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Attachment 1

18 STA. 3 8 NOV 0 7 2001

ENGINEERING DATA TRANSMITTAL

Page 1 of 1

1. EDT 632902

2. To: (Receiving Organization)	3. From: (Originating Organization)	4. Related EDT No.:
S-112 Retrieval Project	Project & Procurement Engineering	N/A
5. Proj./Prog./Dept./Div.: 241-S-112 Saltcake Retrieval Demo	6. Design Authority/Design Agent/Cog. Engr.: RW Reed	7. Purchase Order No.: N/A
8. Originator Remarks:		9. Equip./Component No.: N/A
		10. System/Bldg./Facility: Tank Farms
		12. Major Assm. Dwg. No.: N/A
11. Receiver Remarks: This EDT transmits to the Office of River Protection (ORP) the final S-112 F&R document. This document will be submitted to Washington Department of Ecology (WDOE) to initiate the primary agreement document review process. This document is not a design baseline document while pending approval as a primary agreement between ORP and WDOE.	11A. Design Baseline Document? ☐ Yes ☒ No	13. Permit/Permit Application No.: N/A
		14. Required Response Date: N/A

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15. DATA TRANSMITTED

(A) Item No.	(B) Document/Drawing No.	(C) Sheet No.	(D) Rev. No.	(E) Title or Description of Data Transmitted	(F) Approval Designator	(G) Reason for Transmittal	(H) Originator Disposition	(I) Receiver Disposition
1	RPP-7825, REV. 0			Single-Shell Tank S-112 Full Scale Saltcake Waste Retrieval Technology Demonstration Functions and Requirements	E	1	1	

16. KEY

Approval Designator (F)	Reason for Transmittal (G)		Disposition (H) & (I)	
E, S, Q, D OR N/A (See WHC-CM-3-5, Sec. 12.7)	1. Approval 2. Release 3. Information	4. Review 5. Post-Review 6. Dist. (Receipt Acknow. Required)	1. Approved 2. Approved w/comment 3. Disapproved w/comment	4. Reviewed no/comment 5. Reviewed w/comment 6. Receipt acknowledged

17. SIGNATURE/DISTRIBUTION (See Approval Designator for required signatures)

(G) Reason	(H) Disp.	(J) Name	(K) Signature	(L) Date	(M) MSIN	(G) Reason	(H) Disp.	(J) Name	(K) Signature	(L) Date	(M) MSIN
		Design Authority				1	/	RC Wilson	[signature]	11/5/01	S7-90
		Design Agent				1		WT Thompson	[signature]	11/5/01	S7-90
1	/	Cog. Eng. RW Reed	[signature]	6 Nov 2001		1	/	DW Crass	[signature]	5 Nov 01	S7-90
1	/	Cog. Mgr. MJ Sutey	[signature]	11/7/01		1	/	RD Wojtasek	[signature]	11/05/01	
		QA									
		Safety									
1	/	Env. KS Tollefson	[signature]								

18.	19.	20.	21. DOE APPROVAL (if required)
DW Crass Signature of EDT Originator / Date	RE Bauer [signature] 11/6/01 Authorized Representative for Receiving Organization / Date	[signature] MJ Sutey 11/7/01 Design Authority/ Cognizant Manager / Date	Ctrl No. ____ ☐ Approved ☐ Approved w/comments ☐ Disapproved w/comments

BD-7400-172-2 (10/97)

BD-7400-172-1

Single-Shell Tank S-112 Full Scale Saltcake Waste Retrieval Technology Demonstration Functions and Requirements

DW Crass
CHG
Richland, WA 99352
U.S. Department of Energy Contract DE-AC27-99RL14047

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Key Words: S-112, Functions and Requirements, TPA, Saltcake Dissolution, LDMM, Leak Detection, Monitoring, Mitigation

Abstract: This document establishes the functions and requirements (F&Rs), required by Milestone M-45-03-T03 of the Hanford Federal Facility Agreement and Consent Order, (DOE et al, 1989, as amended), for the retrieval of saltcake waste stored in SST 241-S-112, a designated sound tank located in the 200 East Area of the Hanford Site. The systems proposed to retrieve the tank waste will demonstrate alternate technologies and approaches to retrieving the waste and to LDMM.

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Barbara Wolski 11/7/01

Release Approval Date Release Stamp

Approved For Public Release

RPP-7825, Rev. 0

SINGLE-SHELL TANK S-112 FULL SCALE SALTCAKE WASTE RETRIEVAL TECHNOLOGY DEMONSTRATION FUNCTIONS AND REQUIREMENTS

EXECUTIVE SUMMARY

This document establishes, for the life of the project, the Functions and Requirements required by Milestone M-45-03-T03 of the Hanford Federal Facility Agreement and Consent Order for the retrieval demonstration of mixed waste stored in tank S-112. This document is a primary document as agreed among the U.S. Department of Energy, the Washington State Department of Ecology, and the United States Environmental Protection Agency. Approval of this document allows final design of the retrieval system to commence.

Tank S-112 is a non-leaking saltcake tank located in the 200 West Area of the Hanford Site. The retrieval of tank S-112 will integrate leak detection, monitoring, and mitigation and demonstrate technologies that seek to improve upon past-practice sluicing, improve retrieval efficiency, and minimize the potential for leak loss during retrieval.

The goals of this demonstration are established in the Hanford Federal Facility Agreement and Consent Order Milestone M-45-03C. They include retrieval to safe storage of approximately 99% of the existing tank contents by volume and an estimated 550 curies of mobile, long-lived radioisotopes contained within it. This will leave a residual waste volume of approximately 5,230 gallons (700 cubic feet) or less, depending on the limits of the retrieval technology.

Retrieval of tank S-112 will demonstrate a dissolution process that introduces water in a controlled fashion to dissolve and mobilize solids in the tank. Dissolution water will be added using a set of three sprinkler-type nozzles, which can be rotated and lowered in the tank. An upgraded (increased capacity) saltwell pump will be used to remove the waste. This low volume, density gradient approach minimizes the free liquid in the tank and, thus, minimizes the potential leak loss during retrieval.

Included as an appendix to this document is a scoping-level Retrieval Performance Evaluation (RPE). The RPE includes a human health and environmental risk assessment that establishes the risks from waste remaining in the tank after retrieval and risks posed by leakage during retrieval for several exposure scenarios. The RPE methodology is an iterative process that can be applied before waste retrieval to help develop criteria for the extent of retrieval and leak loss. After retrieval, the RPE can be used to evaluate performance measures using actual retrieval and leak loss data. The results of the pre-retrieval RPE are incorporated into this Functions and Requirements document as requirements applicable to the design of the integrated retrieval and leak detection, monitoring, and mitigation (LDMM) systems.

The RPE indicates that waste remaining in the tank (if not mobilized) will exceed Class C limits (10 CFR 61.55) even after 99% of the waste has been removed. An evaluation was performed to determine the minimum depth of grout that would be required to reduce the radiological constituent concentrations to a level that would not exceed Class C limits. This evaluation indicates that if the retrieval goal was met, the Class C limits could be met by grouting the residual waste to a depth of approximately eleven inches.

This Functions and Requirements document establishes the tank S-112 retrieval demonstration system specifications (including LDMM system specifications) based on a scoping-level RPE to identify environmental and human health risk evaluation data/information associated with the estimated waste volumes to be retrieved, the maximum waste volume that could leak during retrieval, and risk from residual waste. The scoping-level RPE for tank S-112, which includes the known and estimated radionuclide contamination and contaminant migration within the vadose zone as the bases of calculation, is presented in Appendix B.

Because the risk-based retrieval leakage threshold volumes are very small, the LDMM technologies selected for deployment will rely on the Best Available Technology Economically Achievable based on current Environmental Protection Agency reference standards. Alternate technologies, if economically available and developed to a level that adds confidence and increased capability to the Environmental Protection Agency reference methods, will be assessed using the Value Engineering process and incorporated into the tank S-112 retrieval system design, as appropriate.

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FIGURES

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Acronyms

ALARA	as low as reasonably achievable
ASTM	American society for Testing & Materials
BATEA	best available technology that is economically achievable
BBI	Best-Basis Inventory
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act of 1980
CoCs	contaminants of concern
CFR	Code of Federal Regulations
DOE	U.S. Department of Energy
DST	Double-Shell Tank
Ecology	Washington State Department of Ecology
ENRAF™	Enraf-Nonius™ Series 854
EPA	U.S. Environmental Protection Agency
F&R	Functions & Requirements
FY	Fiscal Year
gpm	grams per minute
ILCR	Incremental Lifetime Cancer Risk
in.	inches
LDMM	Leak Detection, Monitoring & Mitigation
MOU	Memorandum of Understanding
NEPA	National Environmental Policy Act of 1969
NRC	Nuclear Regulatory Commission
ORP	Office of River Protection
PCB	Polychlorinated Biphenyl
RCRA	Resource Conservation and Recovery Act of 1976
RPE	Retrieval Performance Evaluation
RPP	River Protection Project
SpG	specific gravity
SST	Single-Shell Tank
TSR	Test Response Spectra
TWINS	Tank Waste Information Network System
WAC	Washington Administrative Code
w.g.	water gauge (unit of measure for pressure or vacuum given as "inches of water gauge")

1.0 INTRODUCTION

The River Protection Project (RPP) mission includes storage, retrieval, immobilization, and disposal of high-level radioactive waste presently stored in 177 underground tanks located in the 200 East and 200 West Areas of the U.S. Department of Energy (DOE) Hanford Site. These tanks consist of 149 single-shell tanks (SSTs - constructed between 1943 and 1964) and 28 newer double-shell tanks (DSTs). The SSTs and DSTs contain a variety of solid and liquid wastes resulting from several decades of nuclear fuel reprocessing and radionuclide recovery processes conducted at the Hanford Site. Immobilization of the retrieved tank wastes for subsequent interim storage and eventual disposal will be performed at a waste treatment facility that is to be constructed at the Hanford Site.

Due to concerns related to the liquid containment integrity of the older SSTs, current plans call for retrieving the SST waste and staging it in the more reliable DSTs to serve as feed material for the waste immobilization process. This interim retrieval step does not constitute closure. However, tank S-112 waste retrieval activities will be conducted, to the extent practical, to meet requirements that allow ultimate closure of the tank and the tank farm. Detailed closure requirements have not been established for the SSTs. Therefore, the steps taken in retrieving waste from tank S-112 will not preclude any future closure decisions.

DOE, the Washington State Department of Ecology (Ecology), and the U.S. Environmental Protection Agency (EPA) have adopted a risk-based approach to SST retrieval. This approach includes:

- Demonstrating alternative retrieval approaches and baseline planning, leak detection, monitoring, and mitigation (LDMM) technologies in tanks containing sludge, saltcake, and mixed saltcake and sludge, and using the results of these demonstrations for future SST retrieval approaches.
- Retrieving tanks that pose the highest long-term risk to minimize the impact of potential releases to the environment.
- Using independently reviewed human health and environmental risk analysis tied to ongoing vadose zone characterization and contaminant transport estimates to establish LDMM and retrieval system performance requirements and operating strategies.

1.1 Background

During the 1950s, 1960s and 1970s, waste from SSTs was retrieved from 58 SSTs using past-practice sluicing. Past-practice sluicing used one or more high volume liquid jets to dislodge and mobilize the tank waste slurry. The slurry was then pumped from the tank. Most recently, waste from 241-C-106 was retrieved using past-practice sluicing to resolve a potential safety problem associated with high amounts of heat generated by the decay of radioactive isotopes in the waste. In this approach, the LDMM methods included a static liquid surface measurement along with ex-tank monthly dry well monitoring. The primary concern with continuing the use of past-practice sluicing is the potential to leak large volumes of waste during retrieval, as the sluicing systems introduce large volumes of liquid into the tank during retrieval operations.

Numerous technologies have been identified for retrieving the various SST waste types to minimize the potential impacts to the environment. In addition to evaluating these technologies for their recovery capability and feasibility, the associated waste retrieval strategies and equipment must also integrate the means to detect, monitor, and mitigate detectable leaks. Viable waste retrieval technologies that have been identified to date are liquid based and rely on the use of water or supernatant to mobilize and transfer the waste. Inherent in the use of liquid based retrieval technologies is the potential for waste to leak to the soil during the retrieval action. Although zero leakage from tank systems is a regulatory requirement, the *Hanford Federal Facility Agreement and Consent Order* signatories have recognized the difficulties in balancing waste retrieval from aging SSTs through the LDMM element of the waste retrieval system. Leak detection, mitigation, and monitoring are capabilities and actions that have been legally agreed to by DOE, Ecology, and EPA in the *Hanford Federal Facility Agreement and Consent Order* (DOE et al. 1989, as amended).

The development of a risk-based retrieval release protection strategy and the retrieval performance evaluation (RPE) process are the basis for establishing functions and requirements (F&Rs). The RPE process is an outgrowth of procedures negotiated in 1994 to evaluate the 99% retrieval goal, including the determination of alternative retrieval goals, as appropriate, if the interim 99% retrieval goal could not be met on a tank-by-tank basis. The RPE methodology was developed in response to a 1996 memorandum of understanding between Ecology and DOE that acknowledged the uncertainty to attain the 99% interim retrieval goal and associated LDMM requirements (Ecology 1996). Under the memorandum of understanding, DOE was tasked to assess retrieval performance criteria for the AX Tank Farm as a means of improving the agency's understanding of the applicability of various performance requirements (e.g., the *Hanford Federal Facility Agreement and Consent Order*, State Dangerous Waste Regulations, and DOE Orders). The design, development, screening, and assessment of alternative technologies according to these F&Rs will result in a preferred LDMM and retrieval system design that is protective of human health and the environment.

The SST Retrieval Program has established a technically defensible program plan that results in deployment of retrieval and LDMM technologies capable of demonstrating waste retrieval from SSTs that contain varied waste forms and pose tank-specific physical constraints. The tank S-112 retrieval demonstration has the following goals:

- Establish the limits and feasibility of a dissolution retrieval system designed to meet the *Hanford Federal Facility Agreement and Consent Order* M-45-03C milestone retrieval goals: retrieve approximately 99% or more of the tank contents by volume from the SST (based on DOE Best Basis Inventory (BBI) data of August 1, 2000), including approximately 550 curies of mobile, long-lived radioisotopes, or the limit of waste retrieval technology capability.

- Establish performance characteristics and limits of technology for an integrated saltcake retrieval and LDMM system designed to minimize leakage risk during retrieval, if it occurs, and to detect leakage within a risk-based performance envelope.

- Upon completion of retrieval activities, provide a basis, along with other SST retrieval projects and demonstration lessons learned, for deploying retrieval and LDMM technologies in the remaining SSTs.

DOE, Ecology, and EPA have not established closure requirements for SSTs. Closure requirements are necessary to establish upper limits for acceptable levels of residual waste in the tanks and ancillary equipment, residual contamination in surrounding soils, and cumulative risks posed to human health and the environment from the 241-S Tank Farm, as well as other tank farms and other waste management sites in the 200 Area. DOE's current planning baseline is to landfill-close the SST farms (DOE/ORP-2001-18). In absence of these requirements however, the results of the RPE are used to determine the risk posed by residual waste (i.e., past leaks, leak losses, and residual tank waste) in the 241-S Tank Farm to establish performance requirements that are protective of human health and the environment. The retrieval demonstration for waste in tank S-112 will not prevent or obstruct implementation of any eventual closure requirements. The RPE process and development of risk-based LDMM and retrieval requirements are discussed in Section 3.0.

In addition to the risk-based requirements established by the RPE, nuclear safety requirements, environmental permits, and existing SST and DST system operational limits imposed on the waste retrieval system design are presented in this F&R (see Section 4.0).

Additions of liquids for retrieval purposes and actions are discussed in the Resource Conservation and Recovery Act of 1976 (RCRA) Part A, Form 3, "Interim Status Permit Application." The permit application addresses treatment in the single-shell tank farms, which is defined as including, but not limited to, mechanical retrieval, sluicing and pumping of waste, and addition of cooling liquids. Discussions are currently underway to modify the Part A permit to clarify the use of liquids for waste retrieval.

1.2 Purpose

The purpose of this document is to establish the (1) functions and requirements, (2) LDMM strategy, and (3) retrieval strategy for the tank S-112 retrieval demonstration specified in the *Hanford Federal Facility Agreement and Consent Order* Milestone M-45-03. Approval of this document allows start of design. Definition of design start, for purposes of the *Hanford Federal Facility Agreement and Consent Order* milestone, is the initiation of a final design (DOE 1999), i.e., beginning of activities to produce the products, engineering design drawings, and written specifications that will be used for procurement and construction.

1.3 Scope

This document provides the functions and requirements necessary to support the design of the demonstration waste retrieval system for tank S-112. This document also provides a preliminary strategy commensurate with the functions and requirements for retrieval and leak detection based on the RPE (Appendix B) and satisfies the requirements established in *Hanford Federal Facility Agreement and Consent Order* Milestone M-45-03-T03 by:

- Establishing the demonstration system requirements including the LDMM requirements (Section 4).
- Including a scoping-level RPE (Appendix B) to provide environmental and human health risk evaluation data/information associated with estimated waste volumes to be retrieved, the maximum volume that could be leaked during retrieval, and risk from residual waste, base on known and estimated radionuclide contamination and contaminant migration within the vadose zone as the bases of calculation.
- Including a design and operating approach that takes into consideration a range of leak losses and residual waste volumes (Appendix B).
- Including lessons learned from previous DOE and industry retrieval projects (Appendix A).
- Including the LDMM and retrieval strategy for the tank S-112 retrieval demonstration, (Section 5).
- Addressing mitigation strategies and decision thresholds for potential leaks during retrieval (Section 3).

The functions and requirements identified in this document provide the foundation for the design criteria and design requirements documented in Level 2 design specifications. Design specifications are used to develop the project engineering concepts, scope, and boundaries. The content of the design specifications will include detailed requirements such as operating pressures, temperatures, materials of construction and control system requirements, confinement boundaries and controls, interface requirements, and similar detailed application requirements. The design specifications for the tank S-112 retrieval system will be developed during preliminary and final design activities consistent with this approved functions and requirements document.

1.4 Tank S-112 Conditions

Tank S-112 was constructed between 1950 and 1951. It is the third in a cascade series of three tanks beginning with tank S-110 and ending with tank S-112. The tank is constructed with a painted grout layer, an asphalt (waterproof) membrane, and an outer reinforced concrete shell to maintain the structural integrity of the steel liner by protecting it from soil loads. The reinforced concrete shell is cylindrical with a domed roof. The interior of the tank contains a steel liner constructed of mild steel. The steel liner extends up the tank wall to a height of 7.6m (25 feet).

The tank contains approximately 523,000 gallons of saltcake and sludge waste, and is classified as non-leaking, per HNF-EP-0182160 (CHG 2001). The tank received waste from REDOX between 1952 and 1973. The tank received evaporator bottoms and recycled waste from the 242-S Evaporator in 1973. The tank was removed from service, i.e., no waste transfers in or out in 1974, and labeled salt-filled and inactive in 1976. The RPE (Appendix B, Section 3.6.1) identifies the radionuclide contaminants of concern as ^{14}C, ^{79}Se, ^{99}Tc, ^{129}I, and the uranium series. Specific volumes and constituents, including the contaminants of concern, are listed in Table 1-1.

Table 1-1. Tank S-112 Selected Inventory

Tank S-112 Constituent	Inventory*
Salt Cake	517,000 gallons
Sludge	6,000 gallons
Total Waste	523,000 gallons
Drainable Interstitial Liquid	81,000 gallons
Sodium	663,000 kg
^{14}C	66.8 Ci
^{79}Se	6.97 Ci
^{90}Sr	77,100 Ci
^{99}Tc	476 Ci
^{129}I	0.92 Ci
^{137}Cs	436,000 Ci
^{241}Am	113 Ci
Uranium (total)	3.31 Ci
Plutonium (total)	304 Ci
Mobile, Long-Lived Isotopes (defined as ^{79}Se, ^{99}Tc, ^{14}C, ^{129}I, Uranium Isotopes per Appendix B, Section 5.1.5.5)	554 Ci
Others not listed above	515,929 Ci
Total Isotopes	1,030,000 Ci

*Data from Task Waste Information Network System (TWINS) Website - Best Basis Inventory Calculation Detail for 241-S-112, downloaded May 22, 2001 (TWINS Website 2001). Decay date is January 1, 1994. Interstitial liquid estimate is from the March 31, 2001 Summary Report data posted on TWINS. These data are consistent with the August 2000 Best Basis Inventory Data.

The above data are taken from the BBI, which has been developed for all Hanford underground tank waste. The BBI estimated inventory is based on sample data, calculations, and estimates based on process modeling and flow sheets (TWINS Website 2001). The RPE provides additional information on tank waste constituents.

Figure 1-1 provides a plan view of the 241-S Tank Farm and nearby existing RCRA groundwater monitoring wells. Groundwater monitoring activities will be consistent with the current RCRA groundwater monitoring plan (PNNL 2000), and any future changes that are implemented. Drywell monitoring will occur prior to, during, and following tank S-112 retrieval. Specific monitoring plans will be developed and documented in a Process Control Plan during retrieval system design.

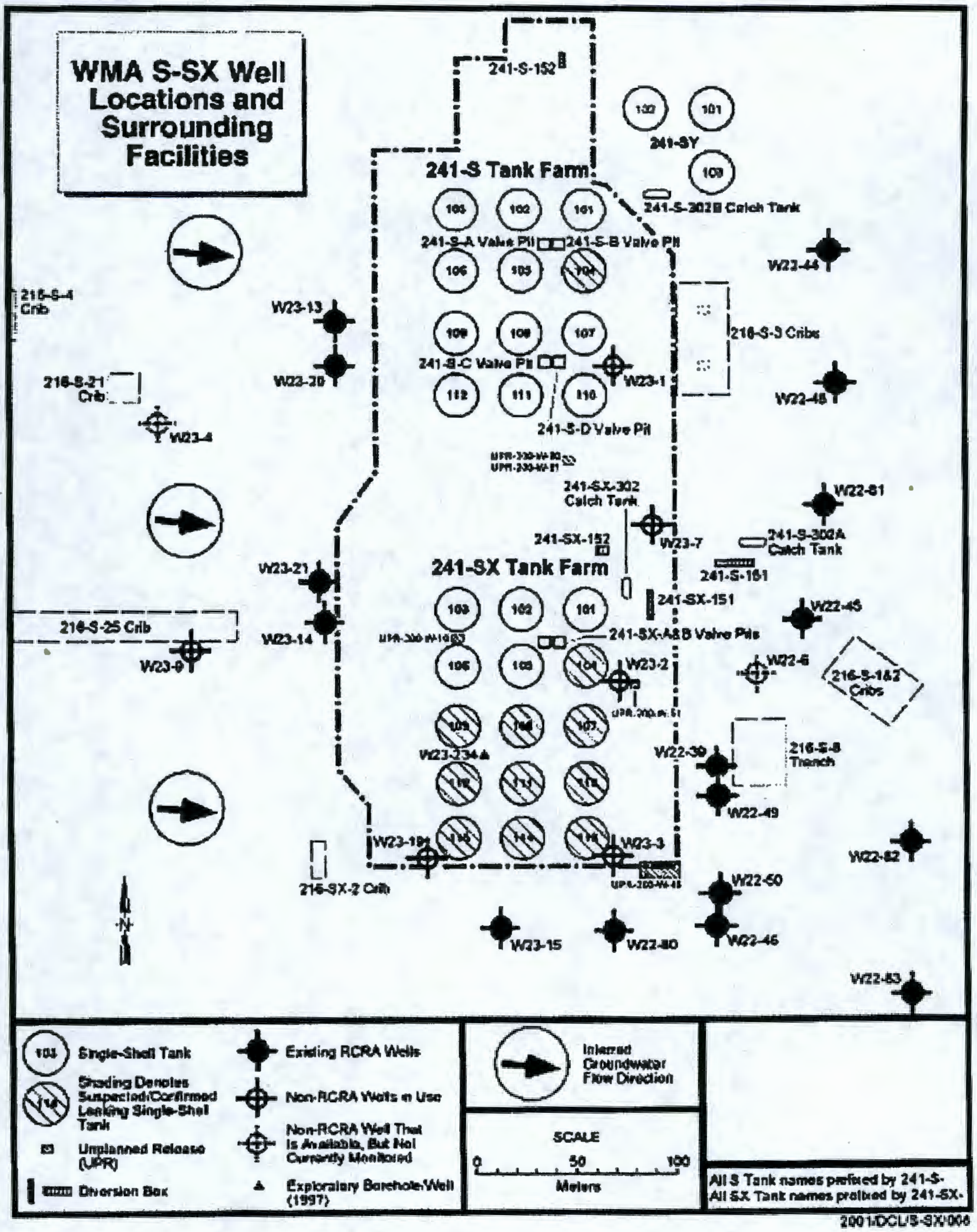


Figure 1-1. 241-S and SX Tank Farms Plan View of RCRA Monitoring Wells

Figure 1-2 shows a plan view of tank farm 241-S with bore-hole (drywell) locations shown inside the tank farm (MACTEC 1998). The dry wells around tank S-112 will be used in addition to other methods (see Section 5) for leak detection and monitoring of possible leaks. Eight dry wells (also called vadose zone monitoring boreholes) were installed around tank S-112 between October 1971 and June 1978 to provide a means of detecting tank leaks. Five boreholes are associated directly with tank S-112. Three boreholes are associated with other tanks but are located sufficiently close to tank S-112 to be useful for detecting radionuclide contaminants in its vicinity. The casings are six inches in diameter. The wells end above the water table and vary in depth. Six wells are approximately 100 feet deep. One is 130 feet deep, and one is 145 feet deep (Vadose 2001). Leak detection is accomplished through periodic geophysical logging of the dry wells (e.g., to detect radiation and moisture increases).

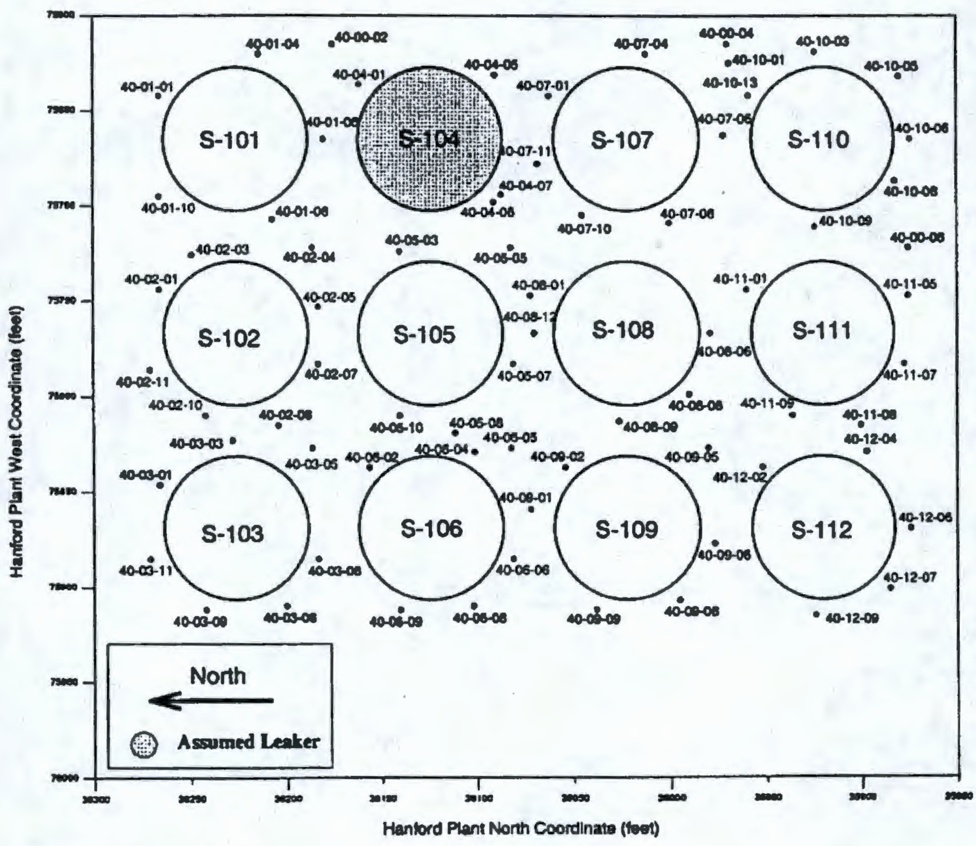


Figure 1-2. 241-S Tank Farm Plan View of Borehole (Dry Well) Locations

1.5 Document Organization

This document is organized as follows:

- Section 1 provides an introduction, background, purpose, and scope to the document, as well as a summary of current tank S-112 conditions.
- Section 2 identifies the regulatory framework and governing requirements documents under which the retrieval demonstration of tank S-112 will be conducted.
- Section 3 presents a description of the technical approach that leads to the development of the risk-based requirements, including the LDMM requirements. The technical approach includes the use of experience from other similar retrieval projects that are captured as lessons learned.
- Section 4 lists the F&Rs, which govern the design of the tank S-112 retrieval demonstration.
- Section 5 defines a retrieval and LDMM strategy, including a description of the retrieval system and LDMM system features, which will guide the design of the demonstration retrieval system for tank S-112.
- Section 6 includes a discussion of the change control procedures that will govern changes to this document.
- Section 7 lists the references cited throughout this document.
- Appendix A is a summary of lessons learned and a bibliography of documented DOE and industry retrieval experience considered in developing the technical approach and F&Rs for retrieving tank S-112.
- Appendix B is the draft scoping-level RPE for 241-S Tank Farm, which supports the technical approach to the development of the retrieval and LDMM strategy for tank S-112. The RPE includes known and estimated radionuclide contamination and contaminate migration within the vadose zone as bases for the risk calculations.

2.0 REQUIREMENTS FRAMEWORK

This section defines the requirements framework under which the tank S-112 retrieval demonstration system will be designed and operated. Sources of requirements include the *Hanford Federal Facility Agreement and Consent Order*, Code of Federal Regulations (CFR) and applicable Washington Administrative Codes (WAC) governing DOE activities. Retrieval and LDMM technologies will be designed and operated in accordance with state and federal requirements as specified in the *Hanford Federal Facility Agreement and Consent Order* and DOE contracts.

The SST system was designed and built before existing standards were promulgated for radiological, environmental, and worker safety. The age and condition of the SSTs limit the extent of the upgrades and corrections that are physically possible. DOE, Ecology, and EPA have approved *Hanford Federal Facility Agreement and Consent Order* Milestone M-45-00. This milestone, and the draft change proposed for it in August 30, 2000 both state the following:

"All parties recognize that the reclassification of previously identified RCRA past practice units to ancillary equipment associated with the Treatment, Storage, and Disposal unit is strictly for application of a consistent closure approach. Upgrades to previously classified RCRA past practice units to achieve compliance with RCRA or dangerous waste interim status technical standards for tank systems (i.e., secondary containment, integrity assessments, etc.) will not be mandated as a result of this action. However, any equipment modified or replaced will meet interim status standards. In evaluating closure options for single-shell tanks, contaminated soil, and ancillary equipment, Ecology and EPA will consider cost, technical practicability, and potential exposure to radiation (DOE/Ecology 2000)." This agreement allows the project to apply appropriate design and construction standards that are relevant to the retrieval and LDMM of tank S-112 and that emphasize protection of human health and the environment. The following subsections identify the requirements framework that will govern the design and operation of the tank S-112 waste retrieval system.

2.1 Hanford Federal Facility Agreement and Consent Order Requirements

Table 2-1 lists the milestones for the tank S-112 waste retrieval demonstration. This document meets the submittal requirements identified by Milestone M-45-03-T03 of the *Hanford Federal Facility Agreement and Consent Order*.

Table 2-1. Hanford Federal Facility Agreement and Consent Order Milestones Applicable to Tank S-112 (per Draft Change Package of August 30,2000)

Milestone	Description	Required Completion
M-45-00 LEAD AGENCY: ECOLOGY	COMPLETE CLOSURE OF ALL SINGLE SHELL TANK FARMS. CLOSURE WILL FOLLOW RETRIEVAL OF AS MUCH TANK WASTE AS TECHNICALLY POSSIBLE, WITH TANK WASTE RESIDUES NOT TO EXCEED 360 CUBIC FEET (CU. FT.) IN EACH OF THE 100 SERIES TANKS, 30 CU. FT. IN EACH OF THE 200 SERIES TANKS, OR THE LIMIT OF WASTE RETRIEVAL TECHNOLOGY CAPABILITY, WHICHEVER IS LESS. IF THE DOE BELIEVES THAT WASTE RETRIEVAL TO THESE LEVELS IS NOT POSSIBLE FOR A TANK, THEN DOE WILL SUBMIT A DETAILED EXPLANATION TO EPA AND ECOLOGY EXPLAINING WHY THESE LEVELS CANNOT BE ACHIEVED, AND SPECIFYING THE QUANTITIES OF WASTE THAT THE DOE PROPOSES TO LEAVE IN THE TANK. THE REQUEST WILL BE APPROVED OR DISAPPROVED BY EPA AND ECOLOGY ON A TANK-BY-TANK BASIS. PROCEDURES FOR MODIFYING THE RETRIEVAL CRITERIA LISTED ABOVE, AND FOR PROCESSING WAIVER REQUESTS ARE OUTLINED IN THE APPENDIX TO THIS CHANGE REQUEST. FOLLOWING COMPLETION OF RETRIEVAL, SIX OPERABLE UNITS (TANK FARMS), AS DESCRIBED IN APPENDIX C (200-BP-7, 200-PO-3, 200-RO-4, 200-TP-5, 200-TP-6, 200-UP-3), WILL BE REMEDIATED IN ACCORDANCE WITH THE APPROVED CLOSURE PLANS. FINAL CLOSURE OF THE OPERABLE UNITS (TANK FARMS) SHALL BE DEFINED AS REGULATORY APPROVAL OF COMPLETION OF CLOSURE ACTIONS AND COMMENCEMENT OF POST-CLOSURE ACTIONS. FOR THE PURPOSES OF THIS AGREEMENT ALL UNITS LOCATED WITHIN THE BOUNDARY OF EACH TANK FARM WILL BE CLOSED IN ACCORDANCE WITH WAC 173-303-610. THIS INCLUDES CONTAMINATED SOIL AND ANCILLARY EQUIPMENT THAT WERE PREVIOUSLY DESIGNATED AS RCRA PAST PRACTICE UNITS. ADOPTING THIS APPROACH WILL ENSURE EFFICIENT USE OF FUNDING AND WILL REDUCE POTENTIAL DUPLICATION OF EFFORT VIA APPLICATION OF DIFFERENT REGULATORY REQUIREMENTS: WAC 173-303-610 FOR CLOSURE OF THE TSD UNITS AND RCRA SECTION 3004(U) FOR REMEDIATION OF RCRA PAST PRACTICE UNITS. ALL PARTIES RECOGNIZE THAT THE RECLASSIFICATION OF PREVIOUSLY IDENTIFIED RCRA PAST PRACTICE UNITS TO ANCILLARY EQUIPMENT ASSOCIATED WITH THE TSD UNIT IS STRICTLY FOR APPLICATION OF A CONSISTENT CLOSURE APPROACH. UPGRADES TO PREVIOUSLY CLASSIFIED RCRA PAST PRACTICE UNITS TO ACHIEVE COMPLIANCE WITH RCRA OR DANGEROUS WASTE INTERIM STATUS TECHNICAL STANDARDS FOR TANK SYSTEMS (I.E., SECONDARY CONTAINMENT, INTEGRITY ASSESSMENTS, ETC.) WILL NOT BE MANDATED AS A RESULT OF THIS ACTION. HOWEVER, ANY EQUIPMENT MODIFIED OR REPLACED WILL MEET INTERIM STATUS STANDARDS. IN EVALUATING CLOSURE OPTIONS FOR SINGLE-SHELL TANKS, CONTAMINATED SOIL, AND ANCILLARY EQUIPMENT, ECOLOGY AND EPA WILL CONSIDER COST, TECHNICAL PRACTICABILITY, AND POTENTIAL EXPOSURE TO RADIATION. CLOSURE OF ALL UNITS WITHIN THE BOUNDARY OF A GIVEN TANK FARM WILL BE ADDRESSED IN A CLOSURE PLAN FOR THE SINGLE-SHELL TANKS. COMPLIANCE WITH THE WORK SCHEDULES SET FORTH IN THIS M-45 SERIES IS DEFINED AS THE PERFORMANCE OF SUFFICIENT WORK TO ASSURE WITH REASONABLE CERTAINTY THAT DOE WILL ACCOMPLISH SERIES M-45 MAJOR AND INTERIM MILESTONE REQUIREMENTS. NOTE:	9/30/2024

Table 2-1. Hanford Federal Facility Agreement and Consent Order Milestones Applicable to Tank S-112 (per Draft Change Package of August 30,2000)

Milestone	Description	Required Completion
	DOE HAS APPEALED THE ISSUE NOTED WITHIN THE PROCEEDING SENTENCE TO THE WASHINGTON POLLUTION CONTROL HEARINGS BOARD. THE OUTCOME OF THIS APPEAL MAY AFFECT THIS M-45-00 LANGUAGE. DOE INTERNAL WORK SCHEDULES (E.G., DOE APPROVED SCHEDULE BASELINES) AND ASSOCIATED WORK DIRECTIVES AND AUTHORIZATIONS SHALL BE CONSISTENT WITH THE REQUIREMENTS OF THIS AGREEMENT. MODIFICATION OF DOE CONTRACTOR BASELINE(S) AND ISSUANCE OF ASSOCIATED DOE WORK DIRECTIVES AND/OR AUTHORIZATIONS THAT ARE NOT CONSISTENT WITH AGREEMENT REQUIREMENTS SHALL NOT BE FINALIZED PRIOR TO APPROVAL OF AN AGREEMENT CHANGE REQUEST SUBMITTED PURSUANT TO AGREEMENT ACTION PLAN SECTION 12.0.	
M-45-03-T03	SUBMIT S-112 SALTCAKE WASTE RETRIEVAL TECHNOLOGY DEMONSTRATION FUNCTIONS AND REQUIREMENTS DOCUMENT. THIS DOCUMENT WILL ESTABLISH DEMONSTRATION SYSTEM SPECIFICATIONS (INCLUDING LDMM SYSTEM SPECIFICATIONS) AND WILL ALSO INCLUDE A SCOPING LEVEL RETRIEVAL PERFORMANCE EVALUATION (RPE). THE FUNCTIONS AND REQUIREMENTS DOCUMENT AND ITS ASSOCIATED RPE SHALL PROVIDE ENVIRONMENTAL AND HUMAN HEALTH RISK EVALUATION DATA/INFORMATION ASSOCIATED WITH ESTIMATED WASTE VOLUMES TO BE RETRIEVED, THE MAXIMUM VOLUME WHICH COULD LEAK DURING RETRIEVAL, AND RISK FROM RESIDUAL WASTE. THIS DOCUMENT WILL DETAIL KNOWN AND ESTIMATED RADIONUCLIDE CONTAMINATION AND CONTAMINANT MIGRATION WITHIN THE VADOSE ZONE AS BASES OF CALCULATION. LDMM AND RPE DOCUMENTATION PROVIDED WILL BE ADEQUATE TO ALLOW ECOLOGY TO ASSESS THE ADEQUACY OF THE DEMONSTRATION SYSTEMS. THIS DOCUMENT WILL INCORPORATE LESSONS LEARNED, INCLUDING LDMM, RETRIEVAL, INSTRUMENTATION, AND OPERATIONAL EXPERIENCE FROM PREVIOUS DOE AND INDUSTRY RELATED RETRIEVAL PROJECTS. DOE WILL SUBMIT ITS S-112 LDMM STRATEGY AS PART OF THE FUNCTIONS AND REQUIREMENTS DOCUMENT, PRIOR TO INITIATION OF DESIGN. THE S-112 FUNCTIONS AND REQUIREMENTS DOCUMENT WILL BE SUBMITTED FOR ECOLOGY APPROVAL AS AN AGREEMENT PRIMARY DOCUMENT. THIS FUNCTIONS AND REQUIREMENTS DOCUMENT WILL BE TIMELY SUBMITTED SO THAT PROJECT CRITICAL PATH IS NOT AFFECTED, AND SO AS TO ALLOW ADEQUATE TIME FOR DOE AND ECOLOGY REVIEW, REVISION AND APPROVAL.	12/30/2001
M-45-03D	COMPLETE S-112 SALTCAKE WASTE RETRIEVAL TECHNOLOGY DEMONSTRATION DESIGN (TO INCLUDE ALL PHYSICAL SYSTEMS INCLUDING DESIGN AND OPERATING STRATEGIES NECESSARY FOR LEAK DETECTION, MONITORING AND MITIGATION (LDMM)). DESIGN WILL BE CONSIDERED COMPLETE WHEN 90% OF THE DESIGN HAS BEEN APPROVED FOR FABRICATION AND/OR CONSTRUCTION.	5/31/2003

Table 2-1. Hanford Federal Facility Agreement and Consent Order Milestones Applicable to Tank S-112 (per Draft Change Package of August 30,2000)

Milestone	Description	Required Completion
M-45-03E	COMPLETE S-112 SALTCAKE WASTE RETRIEVAL TECHNOLOGY DEMONSTRATION CONSTRUCTION (TO INCLUDE ALL PHYSICAL SYSTEMS INCLUDING THOSE NECESSARY FOR LEAK DETECTECTION MONITORING AND MITIGATION) CONSTRUCTION WILL BE CONSIDERED COMPLETE WHEN ALL PROCESS EQUIPMENT IS INSTALLED AND ACCEPTANCE TESTS ARE COMPLETED.	9/30/2004
M-45-03C	COMPLETE FULL SCALE SALTCAKE WASTE RETRIEVAL TECHNOLOGY DEMONSTRATION AT SINGLE SHELL TANK S-112. WASTE SHALL BE RETRIEVED TO THE DST SYSTEM TO THE LIMIT OF TECHNOLOGY (OR TECHNOLOGIES) SELECTED. SELECTED SALTCAKE RETREIVAL TECHNOLOGY (OR TECHNOLOGIES) MUST SEEK TO IMPROVE ON PAST PRACTICE SLUICING BASELINE IN THE AREAS OF EXPECTED RETRIEVAL EFFICIENCY, LEAK LOSS POTENTIAL, AND SUITABILITY FOR USE IN POTENTIALLY LEAKING TANKS. THIS DEMONSTRATION SHALL ALSO INCLUDE THE INSTALLATION AND IMPLEMENTATION OF FULL SCALE LEAK DETECTION, MONITORING, AND MITIGATION (LDMM) TECHNOLOGIES. THE PARTIES RECOGNIZE AND AGREE THAT THIS ACTION IS FOR DEMONSRATION AND INITIAL WASTE RETRIEVAL PURPOSES. COMPLETION OF THIS DEMONSTRATION SHALL BE BY WRITTEN APPROVAL OF DOE AND ECOLOGY. GOALS OF THIS DEMONSTRATION SHALL INCLUDE THE RETRIEVAL TO SAFE STORAGE OF APPROXIMATELY 550 CURIES OF MOBILE, LONG-LIVED RADIOISOTOPES AND 99% OF TANK CONTENTS BY VOLUME (PER DOE BEST-BASIS INVENTORY DATA, 8/01/2000).	9/30/2005

2.2 Regulatory Requirements

Table 2-2 identifies the State and Federal Regulations that apply to the retrieval of tank S-112. These regulatory requirements are imposed on the design of the tank S-112 waste retrieval system via the requirement statements in Section 4 of this document.

Table 2-2. State and Federal Regulations

Document Number	Title
10 CFR 830	"Nuclear Safety," *Code of Federal Regulations*
10 CFR 835	"Occupational Radiation Protection," *Code of Federal Regulations*
29 CFR 1910	"Occupational Safety and Health Standards," *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 280	"Technical Standards and Corrective Action Requirements for Owners and Operators of Underground Storage Tanks," *Code of Federal Regulations*, as amended
40 CFR Subchapter R	"Toxic Substances Control Act," *Code of Federal Regulations*
DOE/RL-2001-25	"Hanford Site Title V, Air Operating Permit 00-05-006"
WAC 173-303-640	"Dangerous Waste Regulations - Tank Systems," *Washington Administrative Code*, as amended. "Hanford Facility RCRA Permit," WA7890008967, Rev. 6, December 2000. (Rev. 7 is under appeal).

3.0 TECHNICAL APPROACH TO DEVELOPING RISK-BASED RETRIEVAL REQUIREMENTS

This section summarizes the current integrated SST waste retrieval and LDMM risk-based requirements development strategy embodied in the *Hanford Federal Facility Agreement and Consent Order* M-45 milestones. It also discusses how the current strategy evolved from the initial strategy embodied in the 1994 *Hanford Federal Facility Agreement and Consent Order* M-45 milestones. In addition, this section describes the approach that DOE-ORP and Ecology have agreed to use to support interim retrieval decisions. The interim retrieval decisions are needed to demonstrate waste retrieval and LDMM technologies for waste retrieval from the 149 SSTs at the Hanford Site. Finally, lessons learned from other projects are presented.

3.1 Integrated SST Waste Retrieval and LDMM Risk-Based Strategy

The *Hanford Federal Facility Agreement and Consent Order* recognizes that waste retrieval from aging SSTs poses technical challenges, including the potential for release of waste to the environment. These challenges require DOE to demonstrate alternative retrieval technologies that seek to improve upon the past-practice sluicing baseline in the areas of expected retrieval efficiency, leak loss potential, and suitability for use in potentially leaking tanks. The demonstration is also required to include the installation and implementation of full scale LDMM technologies. The near-term M-45 series of milestones through 2006 were established to provide a framework for implementation of near-term waste retrieval in an environmentally sound manner within the context of:

- A schedule for retrieval driven by the availability of space in DSTs to support interim storage of SST waste.
- Utilizing available space in DSTs as waste from DSTs is transferred to waste treatment facilities.
- A phased approach to capture lessons learned for vadose zone, retrieval performance, and establishing new milestones.

DOE and Ecology recognized that SST waste retrieval poses risks associated with retrieving waste from aging tanks. There are limited proven retrieval technologies, limited LDMM technologies, and constraints imposed by radiological, chemical, physical, and environmental conditions. To address these uncertainties the *Hanford Federal Facility Agreement and Consent Order* included milestones associated with development and demonstration of retrieval and LDMM technologies. Since 1994, DOE in partnership with Ecology has:

- Reviewed and assessed lessons learned from retrieval and LDMM technologies deployed at other DOE sites (e.g., Oak Ridge and Savannah River sites, see Appendix A).
- Assessed emerging waste retrieval and LDMM technologies (CHG 2000).
- Retrieved waste from tank 241-C-106 to resolve safety issues.

- Modified the *Hanford Federal Facility Agreement and Consent Order* to initiate Corrective Actions for eight of the twelve SST Farms to improve understanding of the nature and extent of soil and groundwater contamination resulting from past tank leaks and spills and to identify, if appropriate, interim actions to mitigate threats to human health and the environment posed by past tank leaks (*Hanford Federal Facility Agreement and Consent Order* Change Control Number M-45-98-03 [Ecology 1999]).
- Refined the strategy for implementation of LDMM to ensure integration of LDMM with retrieval systems and to establish LDMM requirements based on protection of human health and the environment (CHG 2000).
- Developed a methodology for evaluating retrieval options on a tank-specific basis that will support interim decisions on the extent of waste retrieval and retrieval leak loss. The methods/decisions should not restrict final decisions associated with tank farm closure and/or corrective action under WAC 173-303 or DOE Order 435.1 (See Section 3.2).

In 1998, DOE initiated a re-baselining of the SST retrieval project. The basis for the re-baselining, and the strategy adopted to implement the SST retrieval project, were documented in the SST Retrieval Program Mission Analysis Report (LMHC 1998). The focus of the re-baselining was to:

- Provide a technically defensible program plan that will result in deployment of retrieval and LDMM technologies capable of retrieving waste from SSTs containing varied waste forms and posing tank-specific physical constraints,
- Comply with applicable regulatory requirements (e.g., *Hanford Federal Facility Agreement and Consent Order* interim waste retrieval and LDMM requirements, RCRA Permit, Air Operating Permit),
- Accelerate reduction of potential risks to human health and the environment, and
- Enhance integration with the planning and scheduling for waste processing, which will free DST space to support SST waste transfers to DSTs.

In 1999 and 2000, following completion of the SST Mission Analysis Report, DOE initiated revision of its SST LDMM and retrieval strategy. The outcome of this effort is documented in the Single-Shell Tank Retrieval Sequence: Fiscal Year (FY) 2000 Update (CHG 2000a), the FY 2000 Annual Progress Report on the Development of Waste Tank Leak Monitoring /Detection and Mitigation Activities in Support of M-45-08 (CHG 2000), and the change package for the M-45 series milestones (DOE/Ecology 2000). Key features of the revised strategy include:

- Integration of LDMM with retrieval technology and requirements on a tank specific basis,
- Development of risk-based requirements for extent of waste retrieval (i.e., volume of residual waste) and potential retrieval leak loss, based on a screening level assessment of

threats to human health, that serve as minimum performance requirements for design and operation of retrieval and LDMM systems,

- Demonstration technology deployments early in the SST retrieval program to provide a basis for selecting cost-effective, tank-specific retrieval and LDMM technologies, and
- Integration of retrieval activities with tank farm Corrective Action and closure to mitigate potential risks to human health and the environment (see Figure 3-1).

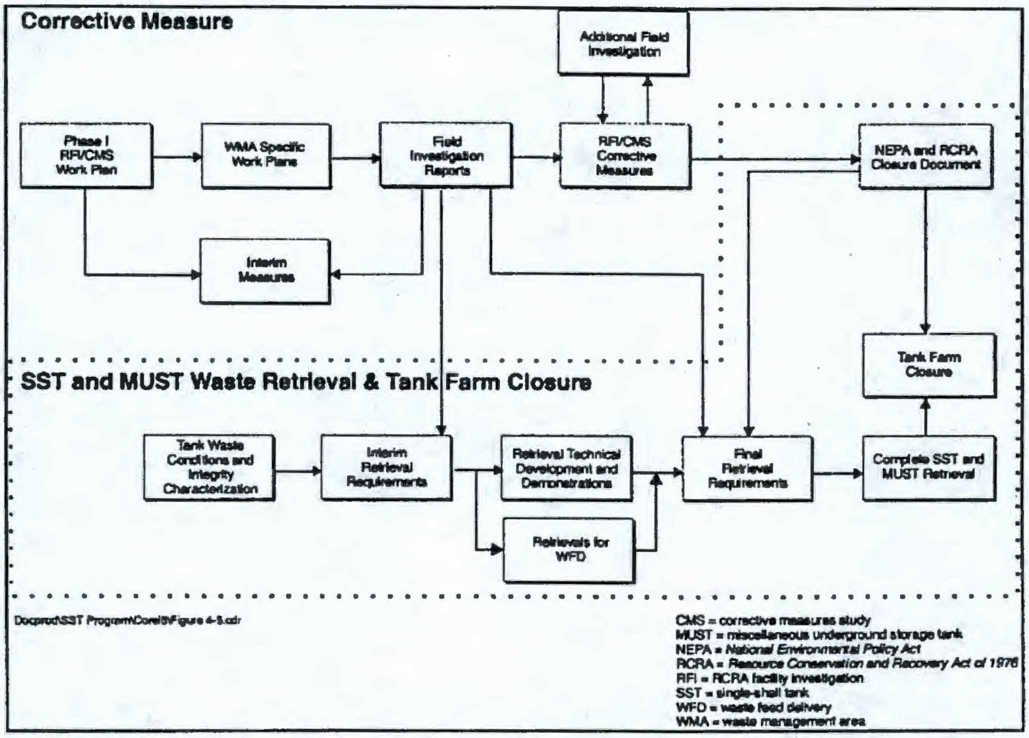


Figure 3-1. Corrective Actions for Tank Farm Closure

In 2000, the *Hanford Federal Facility Agreement and Consent Order* was modified to reflect the revised strategy. The modifications reflect an agreement among the agencies to retrieve waste from fewer SSTs that contain more hazardous long-lived radioactive waste, instead of retrieving waste from 10 relatively empty SSTs, and to establish a risk-based strategy and initial actions necessary for DOE to demonstrate alternative SST waste retrieval technologies. The technologies are targeted to be suitable to use in suspect, leaking, and deteriorating aging SSTs to minimize the potential for leak losses that can impact the environment, and to develop performance and cost data necessary for application to future retrieval actions. These initial retrievals also include development and demonstration of LDMM methods. In addition to demonstrating waste retrieval technologies, the initial actions will focus on single-shell tanks that pose the greatest risk, i.e., highest contaminants of concern, to the environment and on utilizing available DST space.

The retrieval strategy is founded on methods for evaluating retrieval performance that were developed in response to a MOU (Ecology 1996) between DOE and Ecology. The agencies concurred that DOE should demonstrate the analysis necessary to make decisions on a tank-by-tank basis regarding the interim retrieval goal of at least 99 % of the waste volume from SSTs and to establish tank-by-tank retrieval leakage loss limits (Ecology 1996). The RPE of one tank farm (241-AX) was used to identify methods to establish tank-by-tank performance measures associated with short- and long-term human health impacts, closure requirements, technology limitations, and cost (DOE 1999c).

The 241-S Tank Farm RPE establishes three screening level performance measures that are drivers for decisions on leak loss limits and residual waste volume. These measures are used at present in the absence of final closure requirements for the single shell tank farms.

- **Long-Term Risk (Residential Farmer and Industrial Worker) Scenario**. The long-term risk scenario estimates long-term health risks to a human receptor located outside of the tank farm following closure of the tank farms (per *Hanford Federal Facility Agreement and Consent Order* and State Dangerous Waste Regulations). The risks arise from mixed waste (hazardous and radioactive) resulting from past tank leaks, retrieval losses and residual waste, i.e., waste left in the tanks following retrieval migrating through the soil to groundwater. Under this scenario, the receptor uses groundwater for domestic purposes and other uses, depending on the specific exposure scenario. This performance measure is sensitive to changes in the total waste inventory (i.e., past leaks, retrieval losses, and residual waste) and thus drives limits on leak losses and residual waste. Leak losses and residual waste are dependent variables (i.e., as one increases the other must decrease to stay within a total inventory limit). Leaked waste is not contained, whereas the residual waste remains in the tank for 500 years (its release is due to tank deterioration). The contaminants that most influence this performance measure tend to be highly mobile in the environment (e.g., nitrates, technetium-99) (Appendix B, Section 3.6.1). The S-Farm RPE uses the Residential Farmer and Industrial Worker lifestyle scenarios to evaluate the long-term risk. The risks, which change with time, are estimated as the sum of the contributions from the individual source terms past leaks, retrieval losses, and residual waste.
- **Intruder Risk Scenario**. The intruder risk scenario estimates human health risks posed by intrusion into the waste site 100 years after closure. Two aspects of intruder risk are evaluated in the RPE, the DOE Intruder Scenario, and comparison against concentration limits (10 CFR 61). This performance measure is sensitive to changes in the residual waste inventory. The contaminants that most influence this performance measure tend to be less mobile in the environment (e.g., cesium, strontium, plutonium). This is because the intruder comes into direct contact with contaminants that are exhumed by well drilling. The farmer scenario, above, involves only contamination due to use of well water that is down gradient of the tank farm (Appendix B, Section 3.7.1 and Table 3.3).

- **Remediation Worker Risk Scenario.** The worker risk scenario estimates human health risks posed by past tank leaks, retrieval losses, and residual waste to remediation workers, who are required to implement various retrieval and closure strategies. Worker risks evaluated include industrial accidents, routine radiological exposure, and accident conditions. This performance measure is sensitive to waste inventory and duration of retrieval activities and tends to be most influenced by contaminants that are less mobile in the environment (e.g., cesium, strontium, plutonium) (Appendix B). This is because the exposure pathway to workers is primarily through the air and not through the groundwater.

The performance requirements for waste retrieval leak loss and residual waste are intended to limit the Incremental Lifetime Cancer Risk (ILCR) to a level below 10^{-5}. The RPE in Appendix B, Section 5.1.5.3 states that "for carcinogenic risk, the level of protection provided under the regulations ranges from 1 in 10,000 (1×10^{-4}) to 1 in 1,000,000 (1×10^{-6}). For hazardous chemicals under the residential farmer or industrial worker scenarios, Washington State requires the ILCR to be no higher than 1.0×10^{-6} for individual contaminants and 1.0×10^{-5} for cumulative contaminants." This is the case with tank S-112 (WAC-173-340). Because the risk levels at the tank farm fence line are high relative to an ILCR of 10^{-5}, the RPE evaluates retrieval leakage volumes using alternate risk levels and points of compliance to provide information on the performance of different leakage against alternate limits.

3.2 Development and Use of Performance Requirements through the RPE

Risk based goals for SST waste retrieval have been incorporated into the *Hanford Federal Facility Agreement and Consent Order* through the recent change package for the M-45 series milestones (DOE/Ecology 2000). Milestone M-45-03-T03 for tank S-112 (Table 2-1) requires a scoping level RPE as part of this F&R document. Scoping level is interpreted to be the same as a screening level risk assessment that utilizes currently available data and information. The RPE is located in Appendix B.

The RPE process was developed to support waste retrieval and closure decisions using a systems approach that considers contributions from multiple sources (i.e., past leaks, potential retrieval leakage, and residual waste) across a number of performance measures. The RPE methodology is an iterative process that will be applied before waste retrieval to help develop criteria for the extent of retrieval leak losses and residual waste and then after retrieval to evaluate performance measures using actual retrieval leak loss and residual waste data. This iterative process allows for inclusion of additional information and rigor into the assessment as the tank and tank farm move toward final closure decisions. The RPE process for the 241-S SST Tank Farm follows these steps:

1. The scoping level RPE focuses on tank S-112 and evaluates the risks associated with varying assumptions for leak loss and residual waste both in tank S-112 and the other S-Farm tanks. The tank-specific performance requirements are given in terms of the maximum leak loss during retrieval and maximum residual waste after retrieval for tank S-112. Only residual waste below 2,700 gallons and no leakage would meet the risk criterion.

2. After the 241-S-112 waste retrieval demonstration is complete, the tank farm RPE will be updated to reflect the actual residual waste volume and estimated retrieval leak loss, if any. The risk associated with the remainder of the farm tanks will be recalculated.

3. Steps one and two are repeated for each tank to be retrieved in the tank farm with the final RPE amended to include tank farm specific performance data as well as information regarding the cumulative impacts of the post-closure tank farm with other 200 Area waste sites as the tank farm closure RPE.

The current application of the RPE focuses on developing retrieval leak loss and residual waste criteria for 241-S-112 within the 241-S Tank Farm. The impact analysis conducted for each of the retrieval cases includes assessing the screening performance measures from Section 3.1 (used to establish limits), as well as considering additional impacts, as listed below.

- Short-term human health risk – Risks to workers and the public from chemical and radiological exposures that are expected to occur during routine remedial actions (e.g., waste retrieval) or that could result from postulated accidents, and injuries and fatalities resulting from industrial type accidents. The S-Farm RPE (Appendix B, Section 5.1.5.1) shows that short-term human health risks fall within criteria limits for radiological and chemical exposure.
- Long-term human health risk – Human health risks to futuresSite users (assumed to be at the current tank farm boundary) that would occur after completing waste retrieval and implementing closure (post remediation). Long-term human health risk analysis involves evaluating health risks resulting from exposure to contaminated groundwater. Contaminants of concern to long-term human health risks are those that are persistent and mobile in the environment. Long-term human health risks are evaluated over a 10,000-year period of interest based on the lifestyle of a residential farmer and an industrial worker. (DOE performance assessments require use of a 1,000 year time period, however, the RPE uses 10,000 years based on Nuclear Regulatory Commission (NRC) and National Environmental Policy Act of 1969 (NEPA) practices and because impacts from residual waste in the tank are not expected to be seen at receptor locations until after 1,000 years (Appendix B, Section 3.1)). Since this analysis is being conducted to support interim tank farm decisions on the waste retrieval from one tank and not final tank farm closure decisions, the risk assessment is limited to evaluating the incremental risks from 241-S Tank Farm only. The risk assessment does not address risks to down-river future populations or the cumulative risks from other SSTs and waste sites outside the tank

farm. Results from the long-term human health risk evaluation are summarized in Section 3.1.

- Groundwater quality – Impacts on groundwater quality resulting from contaminant release and migration to the groundwater are assessed and compared to regulatory standards. Groundwater quality impacts are evaluated at the tank farm boundary. For tank S-112 retrieval, groundwater quality standards are exceeded for ^{99}Tc for all retrieval leakage volumes analyzed (4,000 gallons and greater) in combination with cases based upon 2,700 gallons of residual waste. When the tanks adjacent to S-112 are considered (i.e., S-110 and S-111) to get a sense of the combined impacts at the fence line, drinking water standards for ^{99}Tc are exceeded by the residual waste alone with no retrieval leakage.
- Compliance assessment – The applicable and appropriate regulatory requirements are identified including areas where open issues and specific quantitative performance measures exist. Regulatory compliance conclusions for S-Farm are located in Section 6.2.5 of Appendix B.

Risk assessments require a number of modeling assumptions to be made and parameter values selected in order to calculate the potential risks to future site users. There is uncertainty associated with these assumptions and in selecting parameter values for use in calculating risks. Uncertainty analysis can be used to support risk-based decision-making because it incorporates system and parameter uncertainties in calculating impacts to human health and the environment. By capturing uncertainties a degree of confidence can be assigned to the estimated risk levels. Additionally, sensitivity analysis of the results can be used to identify the risk drivers. Uncertainties associated with the S-Farm RPE methodology are further discussed in Section 6.4 of Appendix B.

The AX-Tank Farm RPE (DOE/RL-98-72 [DOE 1999c]) included an uncertainty and sensitivity analysis to investigate how variability and uncertainty in model input parameters propagating through the system model translates into uncertainty in long-term human health risk projections. The results of AX-Tank Farm RPE uncertainty analysis indicated that when the exposure parameters were held constant the uncertainty in source term parameters (i.e., inventory and release model) had the greatest influence on the long-term human health risk. These results would be expected to hold at the S-Tank Farm for S-112 since the CoCs and exposure pathways for contaminant release and transport is similar for both farms. The results of the S-112 RPE indicate that technetium-99 is the principal contributor to long-term risk and the risks are sensitive to the solubility and inventory of technetium-99 in the retrieval leakage and residual waste source terms. The solubility of technetium-99 and other key contaminants of concern (CoCs) will be investigated during the S-112 retrieval demonstration, as well as with data obtained during the U-107 saltcake dissolution proof of concept testing, to improve the basis for estimating residual inventories and the concentration of CoCs in potential retrieval leaks. This investigation will involve the collection of waste form specific (i.e., saltcake and sludge) concentrations and release rates. This data will serve to improve risk analyses conducted in support of future retrievals.

The best available data for each component of the tank farm system and the tanks of interest are used to provide a deterministic calculation for each performance measure. Where data were unavailable or highly uncertain, reasonably conservative assumptions were developed to complete the analysis. These assumptions were based on engineering judgment following a review of available data or information from other Hanford Site, DOE complex, or non-DOE remediation programs.

Application of the RPE methodology to the evaluation of tank S-112, and the 241-S Tank Farm included the following:

- Developing a conceptual model of the tank and tank farm system (e.g., the components of the tank farm, sources of contamination, engineered systems, and the natural environment) to analyze the potential implication of SST waste retrieval.
- Identifying retrieval cases that span a reasonable range of residual waste volume and retrieval leakage volumes that will be used to develop risk versus volume relationships for both residual waste and retrieval leakage.
- Performing a risk assessment to assess short- and long-term human health risks to human receptors. Tank-specific impacts are evaluated at the tank farm fence line. Impacts are also evaluated on a tank farm basis at the 200 West Area fence line and at the 200 Area exclusion boundaries. Impacts from the entire tank farm are not evaluated at the tank farm boundary because the contaminant concentrations from different tanks would not all combine at a single location along the tank farm boundary.
- Comparing performance of the total system to requirements established by Federal and State regulations, and the *Hanford Federal Facility Agreement and Consent Order*.
- Evaluating the ability of static (measurements while pumping is shut down) and dynamic (measurements during pumping) in-tank leak detection methods to compare with risk-based limits.

The RPE for the 241-S Tank Farm is provided as Appendix B to this report. The tank S-112 RPE models 10 cases, varying the amounts of leakage and residual waste assumed in tank S-112 and the other tanks in S-Farm. Results of the RPE show that the bounding scenario for risk is the long-term human health risk via the residential farmer scenario.

The RPE extrapolates the data from the case results, and states that, "under the residential farmer scenario, tank S-112 would not meet the Washington State human health risk standards unless the residual waste volume were substantially lower than 2,700 gallons and there was no leakage during retrieval" (Appendix B). When the industrial worker scenario is considered at the tank farm fence line the source terms associated with either a retrieval leak of 1,700 gallons or a residual waste volume of 2,900 gallons would result in an ILCR of 10^{-5}.

The long-term risks from the S Tank Farm, as a whole, were evaluated in the RPE. The results of this analysis indicate that the contribution to the long-term risk from past leaks greatly exceed the risks from retrieval leak and residual waste source terms. On a tank farm level, the impacts associated with retrieval to the *Hanford Federal Facility Agreement and*

Consent Order interim retrieval goal, with no retrieval leakage from any of the S Farm Tanks, results in risk levels that are above 10^{-5} at the 200 West fence for the residential farmer but are below 10^{-5} for the industrial worker. For the 241-S Tank Farm, the long-term risks are not sensitive to a retrieval leak from S-112. A 40,000 gallon leak from S-112 only increases the long-term risk from tank residuals by approximately 9%.

Not retrieving the waste will result in its eventual and certain release, when the tank ultimately fails. The RPE process has determined that the risk from not retrieving the waste in tank S-112 would result in an estimated ILCR of 0.35 to the Residential Farmer at the tank farm fence line (35,000 times over regulatory thresholds). Any inventory reduction from the 241-S Farm by retrieval will reduce the unacceptable long-term risk.

Waste retrieval will use techniques that minimize the amount of waste that could leak. In addition, retrieval activities will commence after the tank has been Interim Stabilized (saltwell pumped). Saltwell pumping of Tank S-112 will result in an immediate degree of risk reduction and will reduce the overall potential risk associated with retrieval.

If there is leakage from this tank, remediation of the soil is not precluded. Since the soils around the tank farms are already contaminated, the area around tank S-112 will be addressed as part of tank farms closure. The RPE risk estimate does not address the short-or-long-term impacts associated with soil remediation.

Figure 3-2 shows four curves, depicting the relationship between the residual waste volumes and waste leakage volumes to a future industrial worker, a residential farmer, and an inadvertent intruder.

As Figure 3-2 illustrates, the intruder scenario risk requirement of <100 mrem/yr is met for the eventual closure volume goal of $\leq$ 360 ft^3 (2,700 gal). However, the ILCR for the residential farmer and industrial worker scenarios exceed 10^{-5} under the following conditions:

- Residual waste of 1,000 gallons, which is not believed to be practical,
- 99% retrieval volume of 5,230 gallons (amount remaining in the tank), and
- The maximum estimated potential retrieval leak of 10,000 gallons (based on a 1.8 gallon leak rate over approximately 194 days).

Developing risk-based retrieval leakage criteria for the S-Tank Farms is complicated by the anticipated impacts from past tank leaks and tank residuals. Peak impacts at the tank farm boundary resulting from past leaks range from and ILCR of 1.4E-03 for the Industrial Worker to 5.5E-02 fro the Residential Worker. The risk from past leaks in the 241-S Tank Farm present ILCR levels that are two to three orders of magnitude above the traditional 10^{-5} risk standards. Therefore, to derive performance criteria for retrieval leak loss thresholds and mitigation strategies at 10^{-5} ILCR is not justified given the existence of substantial past leakage in the 241-S Tank Farm. The peak impacts at the tank farm boundary associated with tank residuals after retrieving 99% of the tank contents range from an ILCR of 2.2E-04 for the Industrial Worker to 4.6E-03 for the Residential Farmer. The impacts from the mobile contaminants associated with past leaks would occur during the time period when impacts from retrieval leakage and these two source terms would be additive. The past leak impacts would not occur during the time period when residual waste impacts would occur and would not be additive.

Given the magnitude of the predictions for past leak impacts at the tank farm fence line, coupled with predictions of future composite impacts in the 200 West Area from Environmental Restoration waste sites and tank farms described in the Composite Analysis (PNNL-11800), the risk basis for developing leak loss criteria is developed based on limiting further impacts rather than meeting traditional risk stands (i.e., 10^{-5}). While the goal of the retrieval demonstration is to retrieve the waste with no leakage from the tank, leakage threshold volumes need to be established to provide requirements for the design process. Establishing retrieval leakage threshold volumes is not intended to imply that this is an "acceptable" event but rather an indication of when substantive impacts from a leak would be anticipated and that corrective and mitigating actions would need to be considered. Establishing retrieval leakage threshold volumes at risk levels of 10^{-3} for the residential farmer and 10^{-4} for the industrial worker scenario translates into a leakage threshold colume of 8,000 to 40,000 gallons for the residential farmer and industrial worker scenario, respectively. Leakage above this range (8,000 to 40,000 gallons) would increase risks from past leaks currently posed to a Residential Farmer and Industrial Worker. Leakage below this range would not measurably affect the risk posed by residual waste under these scenarios. Comparatively, if 10 times drinking water standards were to be used as a performance measure, similar to the 200-UP-1 Interim Record of Decision, then the corresponding 241-S-112 retrieval leakage volume would be 14,000 gallons.

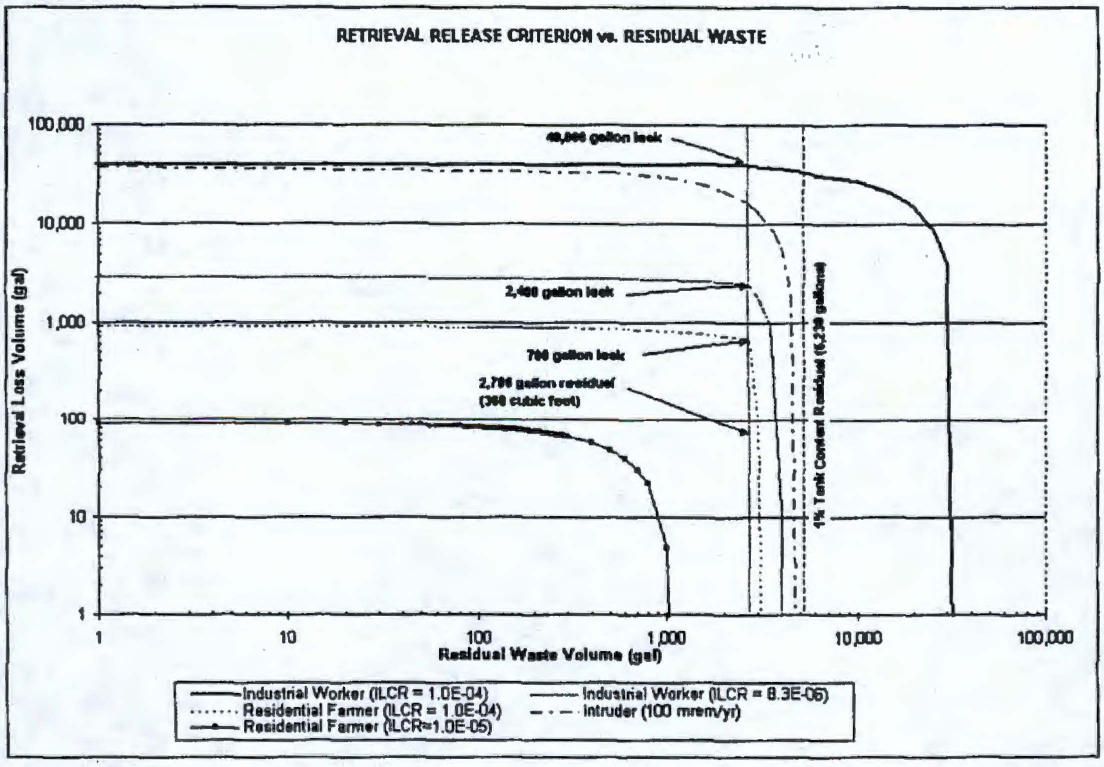


Figure 3-2. *Tank S-112 Preliminary Retrieval Release Criterion vs. Residual Waste*

3.3 Use of Lessons Learned in Supporting Selection and Implementation of Retrieval and LDMM Technologies

DOE and good engineering practice require lessons learned from previous activities to be documented and used in the design considerations for similar activities. This applies to tank waste retrieval and LDMM. Lessons learned from other similar projects provide valuable experience that is incorporated into the design and operation of the retrieval and LDMM system. Lessons learned do not form the functions and requirements for the retrieval and LDMM system design and execution. However they do influence, based on past experience and application, how the functions and requirements are achieved. During the various project phases (i.e., initial engineering development, preliminary design, detailed design, construction, and operations), lessons learned shall be identified and evaluated for application relevant to the tank S-112 retrieval demonstration. This experience will guide the design team in the selection of the best retrieval and LDMM technologies. Lessons learned have shown that waste removal activities have not caused any tank to leak, including tanks in comparable or worse condition than tank S-112.

Appendix A contains a description of the process used to gather lessons learned, the relevant lessons learned that apply to this project, and the bibliography of sources used in gathering the lessons learned information. The lessons learned topics include LDMM, retrieval, instrumentation, and operational experience from previous DOE and industry-related retrieval projects, as required by Milestone M-45-05-T03. DOE will incorporate these lessons learned during the design and operation of the tank S-112 waste retrieval system. The best available and deployable LDMM technology will be used for tank S-112 retrieval.

Lessons learned have already provided some design and operational features that are being given consideration for implementation in the retrieval demonstration system for 241-S-112. These features are highlighted in Appendix A.

4.0 FUNCTIONS & REQUIREMENTS

The functions and requirements included in this document are derived from the need to satisfy the *Hanford Federal Facility Agreement and Consent Order* Milestone requirements to retrieve as much of the current 241-S-112 waste inventory as technically possible with a goal of retrieving to safe storage approximately 550 curies of mobile, long-lived radioisotopes and 99% of the 241-S-112 contents by volume (per the DOE Best Basis Inventory data of 8/1/00) while maintaining a tank and waste retrieval system that safely isolates the waste from the workers, the environment, and the public. Some of these requirements are derived from regulatory documents such as the CFRs, and the resulting certification in the WAC while others are based on the design limitations of tank S-112 and the DST receiver tank. The functions and requirements identified below are focused on appropriately driving the design of the 241-S-112 waste retrieval system so that the aforementioned needs are met.

4.1 Control Tank S-112 Structure and Waste Temperature

The tank S-112 waste retrieval system shall control the tank S-112 structure and waste temperature to within the following specified design limits to prevent structural damage to the tank:

Temperatures:

- Maximum 149°C (300°F) for waste
- Maximum 121°C (250°F) for dome
- Maximum change of 11°C (20°F) per day

[Basis: OSD-T-151-00013, CHG 2000d]

4.2 Control Tank S-112 Waste Level

The tank S-112 waste retrieval system shall control the waste level in tank S-112 to prevent waste overflow and limit the hydrostatic head-induced stresses in the tank. The tank S-112 waste retrieval system shall prevent the waste level in tank S-112 from exceeding 711 cm (275 inches [in.]). The tank S-112 waste retrieval system shall limit the hydrostatic forces on tank S-112 such that the hydrostatic forces do not exceed the force equivalent to 711 cm (275 in.) of waste at a specific gravity (SpG) of 2.0.

[Basis: HNF-4712, LMHC 1999]

4.3 Control Tank S-112 Vapor Space Pressure

The tank S-112 waste retrieval system shall control the vapor space pressure in tank S-112 to within the following specified design limits to prevent structural damage to the tank:

- If the waste level is ≥ 38.1 cm (15 in.),

  Then -38.1 cm (15 in.) w.g. ≤ vapor space pressure ≤ 1.5 m (60 in.) w.g.

- If the waste level is < 38.1 cm (15 in.),

  Then waste level) ≤ vapor space pressure ≤ 1.5 m (60 in.) w.g.

(Note: Operational limits on in-tank vapor space pressure will be established as part of conceptual design. If active ventilation is required for tank S-112 during waste retrieval, a negative vapor space pressure with respect to atmosphere will likely be required at all times during retrieval system operation, as this is the preferred method for verifying that ventilation is operable and ensures confinement.)

[Basis: HNF-4712, LMHC 1999]

4.4 Control Tank S-112 Gaseous Discharges

The tank S-112 waste retrieval system shall control the vapor space pressure in tank S-112 and restrict exhaust air emissions to the environment (DOE 2001a).

[Basis: DOE/RL-2001-25, DOE 2001a]

4.5 Remove Waste from Tank S-112

The tank S-112 waste retrieval system shall be capable of removing (i.e., retrieving and transferring waste to the DST System) as much of the tank S-112 tank contents as technically feasible with a target goal of removing 99% of the tank contents by volume (per DOE Best Basis Inventory data of 8/01/2000), which corresponds to a residual waste volume of 5,230 gallons.

[Basis: DOE/Ecology 2000 (Milestone M-45-03C)]

The S-112 waste retrieval system shall be capable of removing the waste within approximately 194 days.

[Basis: Estimate based on a total pumped waste volume of 1.34 million gallons pumped at a rate of 10 gpm with a 50% efficiency rate (RPP-7087, CHG 2000a)]

4.6 Control and Monitor the Tank S-112 Waste Removal Process

The tank S-112 waste retrieval system shall monitor and control the process parameters for retrieving waste from tank S-112. This includes the detection and monitoring of tank S-112 leaks during waste removal as well as the controlling and monitoring of waste removal process parameters.

[Basis: DOE/Ecology 2000 (Milestone M-45-03C)]

Provisions shall be made to sample waste during retrieval operations.

[Basis: good engineering practice]

4.6.1 Detect Leaks During tank S-112 Waste Removal

The tank S-112 waste retrieval system shall be capable of detecting liquid waste releases from tank S-112 during all waste removal operations.

- The system shall be designed to detect a cumulative leak loss during the retrieval campaign of 8,000 gallons or the system shall be designed using the best available technology that is economically achievable (BATEA) to detect tank leaks during retrieval to as low as reasonably achievable (ALARA).

  [Basis: Section 3.2]

- Probability of Detection Goal: The tank S-112 waste retrieval system shall have a probability of leak detection of greater than 95%.

  [Basis: 40 CFR 280]

- Probability of False Alarm Goal: The tank S-112 waste retrieval system shall have a probability of false alarm less than or equal to 5%.

  [Basis: 40 CFR 280]

4.6.2 Monitor Leaks From Tank S-112 During Waste Removal

The 241-S-112 waste retrieval system shall quantify liquid waste release volumes from tank S-112 if a release is detected during waste retrieval operations. The data shall be collected, in the event of a leak, to support a post-retrieval RPE, which will be used to address retrieval of the next S-Farm tank. Data collected will address estimates of the volume and composition of leaked material, as well as the residual waste in the tank.

[Basis: Section 3.2]

4.6.3 Control And Monitor Tank S-112 Waste Retrieval

The tank S-112 waste retrieval system shall monitor and control the process and equipment parameters for retrieving waste from 241-S-112. Waste removal process parameters (e.g., waste transfer line pressures, flow rates, waste densities) and equipment parameters (e.g., transfer pump speed and motor amperage) shall be monitored for safe and effective operation of the tank S-112 waste retrieval system.

[Basis: good engineering practice]

4.7 Measure and Estimate Residual Waste in Tank S-112

The tank S-112 waste retrieval system shall measure and estimate the residual waste in tank S-112 to verify that the target retrieval goals have been met (see Section 4.5). The tank S-112 waste retrieval system shall be capable of measuring and estimating residual waste on the walls of the tank; on and under the stiffening rings of the tank; on exterior surfaces of in-tank debris, hardware and components; and on the bottom of the tank. Techniques may include video surveillance and topographic mapping.

[Basis: DOE/Ecology 2000 (Milestone M-45-03C and Appendix H, Attachment 1)]

4.8 Waste Minimization

The tank S-112 waste retrieval system shall minimize waste generation to the greatest extent practical, including water introduced into the tanks and solid waste.

4.9 Mitigate Leaks During Tank S-112 Waste Retrieval Process

The integrated retrieval and LDMM system shall be designed and operated to mitigate leak volumes ranging from 8,000 gallons to 40,000 gallons for the duration of the retrieval demonstration. The 241-S-112 waste retrieval system shall mitigate leaks as the primary means of minimizing environmental impact caused by releases during retrieval of SST waste. If a leak occurs, the release shall be evaluated according to the RPE and the appropriate actions implemented (e.g., continue or discontinue retrieval). As the primary mitigation means, the retrieval pump shall be designed to allow continuous pumping for a sufficient amount of time (to be determined during design) to remove all pumpable liquids from 241-S-112. A low volume, density gradient approach shall be employed for waste retrieval, ensuring that the interstitial liquid level remains below its starting level. The current interstitial liquid level is approximately 10.3 feet (124 inches). Mitigation activities will be consistent with the intent of HNF-SD-WM-AP-005, *SST Leak Emergency Pumping Guide*.

[Basis: HNF-SD-WM-AP-005 (CHG 1999).]

4.10 Nuclear Safety

The tank S-112 waste retrieval system shall be designed to protect workers, the public, the environment, and equipment from exposure to tank radioactive waste during retrieval.

[Basis: 10 CFR 830 and 10 CFR 835]

4.11 DST Design Limits

The 241-S-112 waste retrieval system shall not adversely affect the function of the DST System or exceed the DST Design and operational limits. The DST design and operational limits are as follows:

4.11.1 DST Waste Temperature

The DST waste temperature shall not exceed:

- 195°F in all levels of the waste, or
- 195°F in the top 15 feet of waste and 215°F below 15 feet.

[Basis: HNF-SD-WM-TSR-006, Limiting Condition of Operation (LCO) 3.3.2]

4.11.2 DST Pressure Limits

The 241-S-112 waste retrieval system shall not cause the following internal DST pressure limits to be exceeded:

Primary Tanks:

- -15.2 cm (6 in.) water gauge (w.g.) ≤ vapor space pressure ≤ -0.76 cm (0.3 in.) w.g. during normal operating conditions and ≤ 0 during required maintenance or off-normal conditions (AN, AW, AY, AZ, SY Farms)
- -24.1 cm (9.5 in.) w.g. ≤ vapor space pressure ≤ -0.76 cm (0.3 in.) w.g. during normal operating conditions and ≤ 0 during required maintenance or off-normal conditions (AP Farm)

[Basis: HNF-3350, CHG 2000b]

4.11.3 DST Hydrostatic Load Limits

The 241-S-112 waste retrieval system shall not cause the internal DST hydrostatic loads limits specified in Table 4-1 to be exceeded.

Table 4-1. Existing Double-Shell Tank Hydrostatic Load Limits

Tank Farm	Hydrostatic Load
AN, AW	Maximum hydrostatic load as exerted by 4410 m^3 (1.16 Mgal) of fluid @ 1.7 SpG and a depth of 10.7 m (422 in.)
AP	Maximum hydrostatic load as exerted by 4410 m^3 (1.16 Mgal) of fluid @ 2.0 SpG and a depth of 10.7 m (422 in.)
AY, AZ	Maximum hydrostatic load as exerted by 3790 m^3 (0.998 Mgal) of fluid @ 1.22 SpG. and a depth of 9.25 m (364 in.)
SY	Maximum hydrostatic load as exerted by 4330 m^3 (1.14 Mgal) of fluid @ 1.7 SpG and a depth of 10.7 m (422 in.)

[Basis: HNF-3350]

The tank S-112 waste retrieval system new components shall be designed to ensure proper structural strength, compatibility with the waste and protection against corrosion in accordance with requirements of 40 CFR 265.192 and WAC 173-303-640(3).

- The retrieval system design shall be constructed of modular and easily replaceable subsystem components if economically advantageous.

  [Basis DOE Order 430.1A, DOE 1998]

- The retrieval system shall be designed for reuse if economically advantageous.

  [Basis DOE Order 430.1A, DOE 1998]

4.12 Occupational Safety and Health

The 241-S-112 waste retrieval system shall incorporate design features that comply with the applicable requirements of 29 CFR 1910.

[Basis: 20 CFR 1910]

4.13 SST and DST Dome Loading

The tank S-112 waste retrieval system shall not exceed the maximum dome loading on existing SSTs and DSTs specified in HNF-IP-1266, 5.16, Rev. 3a.

[Basis: HNF-SD-WM-SAR-067]

4.14 Prohibited Materials.

Materials that are restricted or prohibited from use in manufacturing, operation, and construction under regulations promulgated pursuant to 40 CFR Subchapter R, shall not be used in the design of the tank S-112 waste retrieval system.

[Basis: 40 CFR Subchapter R]

4.15 Waste Retrieval System Secondary Containment and Leak Detection

The tank S-112 waste retrieval system shall incorporate in new components secondary containment and leak-detection design features in accordance with 40 CFR 265.193 and WAC 173-303-640 (4).

[Basis: 40 CFR 265 and WAC 173-303-640]

4.16 Waste Retrieval System Deactivation and Decontamination

The tank S-112 waste retrieval system equipment deactivation shall be compatible with decontamination, reuse and/or disposal requirements, e.g., disposal as solid waste.

[Basis: DOE G 430.1-3, DOE 1999a]

5.0 LDMM AND RETRIEVAL STRATEGY

This section describes the LDMM and retrieval strategy for the S-112 demonstration retrieval system. Section 5 includes definitions for LDMM, uncertainties in detecting and monitoring leaks in waste tanks, LDMM and retrieval strategy, preliminary system descriptions, and alternative technologies being evaluated for ex-tank leak detection and monitoring. The functions and requirements established in Section 4 of this document will govern the design and development of the integrated system. However, the progression of design, development, and testing may demonstrate that adequate technologies do not exist to meet all requirements established by this document. Under these circumstances, BATEA will be employed, along with the change control process established in Section 6.0 of this document, to meet the demonstration goals of the *Hanford Federal Facility Agreement and Consent Order* Milestone M-45-03C.

5.1 LDMM Definitions

This section provides definitions for the LDMM terms used in Section 5. Sections 5.2 through 5.7 develop the detailed applications of LDMM for tank S-112 retrieval.

Leak detection, monitoring, and mitigation are defined in RPP-7012 (CHG 2000). These definitions have been accepted by ORP and Ecology and are presented here for reference:

- **Leak Detection:** technologies, methods, or systems used to detect a leak.

- **Leak Monitoring**: technologies, methods, or systems used to quantify liquid waste release volumes from a SST, if a release is detected during waste retrieval operations.

- **Leak Mitigation**: technologies, methods, or systems that can reduce a leak, or reduce the environmental impact of a leak.

5.1.1 Strategy

The integrated LDMM and retrieval strategy for the tank S-112 waste retrieval demonstration system has been developed to meet the requirements specified in the M-45 series of milestones (DOE/Ecology 2000). The purpose of this strategy is to ensure that the demonstration waste retrieval system:

- Minimizes, to the maximum extent possible, hazardous waste releases to the environment.
- Is technically practicable and defensible.
- Complies with all applicable regulations and requirements.
- Meets the programmatic needs of the DOE Office of River Protection.

Figure 5-1 illustrates the three elements necessary for a release of liquid waste from a tank to occur. If there are no leak paths in the tank (i.e., holes, pits or cracks), then by definition there is no possibility of a leak. If, however, there are one or more leak paths in the tank, the volume of liquid released can be reduced by controlling the volume of free liquid or the hydraulic head of the liquid. If any of the legs of the triangle are severed, then no leak can occur. An additional factor in leak minimization is the amount of time available for liquid to leak. The less time that drainable liquid is present in the tank, the smaller the volume of liquid that could leak.

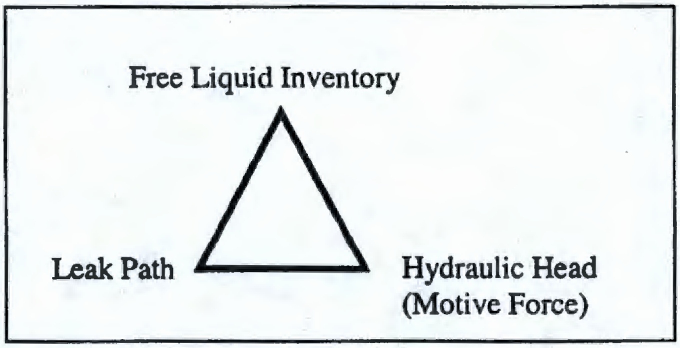


Figure 5-1. Leak Minimization Triangle

5.1.2 Leak Detection

Detecting a leak from a waste tank requires application of suitable technologies, methods, or systems. Work documented over much of the past decade shows that there are many possible methods to detect leaks in underground storage tanks. However, there are a limited number of methods that can be readily implemented for the SSTs. In 1998, a review of previous LDMM investigations and new information regarding technologies applicable to SST retrieval was published (LMHC 1999). This review recommended the use of in-tank volumetric methods similar to the EPA approved methods used on underground petroleum tanks, and external methods for leak detection. In 1999, an update of the SST retrieval LDMM strategy repeated these recommendations (LMHC 1999). These recommendations were based on tanks with a free liquid surface.

A review of recent waste retrieval projects indicates that internal monitoring of liquid inventories is the most commonly used technology applicable to retrieval from tank S-112 (See Appendix A). The approved EPA methods for leak detection, where a free liquid surface exists, are "dynamic" and "static." Dynamic leak detection is monitoring of liquid and waste inventories while waste is actively being retrieved. Static leak detection is performed when operations are temporarily suspended. Each technique is defined further below.

5.1.2.1 Dynamic

Akin to mass balance technology, the dynamic volumetric inventory balance method uses level instruments in the retrieval and receiver tanks along with flow meters to continuously balance the flow in and flow out of the retrieval tank. This method is similar to "Statistical Inventory Reconciliation" employed by the petroleum industry in distribution systems like gas stations. It is important to note that this technique has not been evaluated for SSTs and the complexities of waste solubility and evaporation combined with the scale difference between a local gas station tank and a 75-foot diameter SST are significant. The advantage of this technology is that it provides a continuous on-line measurement. The method does not, however, provide real-time leak detection capability, but can reconcile the pre-retrieval and post-retrieval data to quantify any leaks that may occur. This technique is sensitive to a number of environmental and operational interferences, and requires compensation for those interferences to achieve acceptable performance levels. Based on tank C-106 retrieval experience (HNF-SD-WM-PCP-013 1999), operational influences, such as uncondensed evaporation, may significantly affect the accuracy of available dynamic leak detection technologies.

5.1.2.2 Static

Static volumetric leak detection is used extensively in industry. Volumetric methods measure the liquid surface in a static tank and convert the level data to volume data from the known tank parameters. Leak detection is accomplished by calculating the rate of volume change over time and comparing this rate to a pre-determined "leak detection threshold" to determine whether the tank has an inflow, an outflow, or that the tank is sound (i.e., non-leaking).

Differential pressure measurements are one type of sensor used by the DOE to measure liquid level and conduct leak detection tests [ORNL/ER/Sub/92-SK236/1 1994]. This method measures change in depth by measuring the change in the hydrostatic head above a pressure sensing port. Direct level-sensing instrumentation such as the ENRAF™ and FIC™ gauges are currently used in SSTs that have a continuous free liquid surface. They are well suited for the volumetric method in tanks with a measurable air-liquid interface.

In-tank volumetric technologies that measure the air-liquid interface, which can include adaptation of elements of the mass-based technology, were recommended for leak detection because of the advantages they have over other technologies. These advantages include:

- Deployment readiness
- Technology maturity
- Accuracy
- Ability to evaluate system performance
- Life cycle cost
- Successful application in industry and at other DOE sites

The performance data for leak detection with volumetric systems are based on data obtained in tanks with a free liquid surface. The ability of these methods of leak detection to accurately determine the presence of a sufficiently small leak (on the order of 1.8 gallons per hour) has not been determined in tanks without a liquid surface.

5.1.3 Leak Monitoring

If a release is detected during waste retrieval operations, the leak will be monitored in order to estimate the total volume lost. A leak volume estimate must be performed to quantify the environmental impact resulting from a leak. The estimated leak volume will be incorporated into an updated RPE to recalculate the risk associated with the remainder of the tanks in the farm. Dynamic, static, and ex-tank methods are applied to quantify a potential leak volume during retrieval operations. The limitations associated with leak detection, as discussed above, apply to leak monitoring.

5.1.4 Leak Mitigation

A primary strategy for leak mitigation uses a retrieval technology that limits the liquid hydrostatic head, controls the rate of water addition and waste removal, and minimizes the retrieval time-at-risk during which a leak could occur. Water additions will not exceed the interstitial liquid level of the tank in order to ensure the waste remains below a level at which the tank is known not to leak. In addition, the retrieval system will be designed and deployed to remove all pumpable liquids once the leak has been detected.

5.2 Uncertainties Influencing Leak Detection and Leak Mitigation

Leak detection systems that can be integrated with dissolution retrieval have not undergone system performance testing to determine their performance in terms of probability of detection and probability of false alarm at a given leak threshold in the Hanford SSTs. System performance has been estimated based on the performance of systems in large underground petroleum storage tanks. By extrapolating available SST data and correlating it to the petroleum industry data, it is estimated that a 48-hour static test in a SST, with a free liquid surface, will have a minimum leak detection rate in the range of 2 to 25 gallons per hour with a 95% probability of detection and 5% probability of false alarm. Similarly, based on petroleum industry experience, dynamic leak detection will have a minimum leak detection rate in the range of 20 to 250 gallons per hour with a 95% probability of detection and 5% probability of false alarm. The circumstances and uncertainties that result in less accurate leak detection include:

- Lack of a uniform free liquid surface
- Changes in solution density as the waste dissolves
- Uncertainties associated with the tank physics
- Uncertainty of the waste characterization data and waste chemistry
- Uncertainty of waste pore volume and capillary height
- Uncertainty of soluble to non-soluble waste retrieval rates
- Uncertainty of interstitial liquid movement

Understanding the performance of a leak detection method determines whether risk-based leak detection requirements can be met, as well as how the methodology is applied to meet the requirements (e.g., number of tests to be conducted or combined, number of in-tank parameters measured, and frequency of testing). The performance of each leak detection method or combination of methods will be determined in terms of the Probability of Detection and Probability of False Alarm expressed as a volume or volume rate using methods similar to ASTM and EPA standard test procedures. To compensate for uncertainties in leak detection, the S-112 demonstration retrieval design will minimize the hydraulic head, reduce the free liquid inventory, reduce the available area where a leak could occur, and utilize static, dynamic, and ex-tank leak detection methods.

5.3 Hanford Leak History

The non-catastrophic postulated leak loss (95% confidence) for Hanford SSTs is less than 1.8 gallons per hour (RHO 1981). This analysis was reviewed again in 1998 and found consistent with SST leak data (LMHC 1999). This rate is based on estimated averages of leaks in the 1960s and 1970s from tanks with significant free liquids and includes leaks from catastrophic failures in tanks A-105, BX-102, and T-106. Excluding catastrophic failures, 1.8 gallons/hour postulated leak loss is a much larger leak rate than would be expected today, particularly given the controlled, monitored addition and removal of water to and from the tank.

Based on a worst-case non-catastrophic leak loss of 1.8 gallons per hour for a Hanford SST, the estimated 194-day S-112 retrieval duration could result in a potential undetected leak of approximately 10,000 gallons. If tank S-112 is not retrieved, the amount of liquid that could potentially leak is approximately 81,000 gallons (over a time frame of about five years at 1.8 gal/hr). Over the same five-year period, all of the free interstitial liquid could potentially leak if the tank has not been interim stabilized.

5.4 241-S-112 Integrated Strategy for LDMM and Retrieval

An integrated LDMM and retrieval strategy will be employed for tank S-112 in order to manage the risk posed by potential waste leakage during retrieval. Implementation of this strategy will not preclude or obstruct eventual closure requirements, which have not yet been established for SSTs.

The environmental and programmatic risks posed by different retrieval technologies, tanks, and tank constituents vary significantly. To develop and implement a consistent and reasonable LDMM design concept, a risk-based approach has been used to establish quantitative performance requirements for individual tanks (see Section 3). When integrated with a retrieval technology, the risk-based approach establishes the minimum leak detection limits as a function of potential retrieval leak loss volume and residual waste remaining in the tank following completion of retrieval activities.

The risk associated with continued storage of waste in Tank S-112 is directly proportional to the total contaminants it contains. If the tank waste is not retrieved, the risk is proportional to the curies trapped in the residual waste (523,000 gallons). A worst case leak loss scenario, based on a 1.8 gallon/hour leak loss rate, would be less than 10,000 gallons over the approximately 194-day retrieval campaign. The assured eventual release of all 523,000 gallons if the waste is not retrieved carries a much higher risk (a 100% probability and consequences 35,000 times higher than the residential farmer criterion of 10^{-5} ILCR) than the potential loss of 10,000 gallons (consequences 34 times higher than the residential farmer 10^{-5} ILCR criterion) that might occur during retrieval. The long-term risk of not retrieving the waste is therefore about 1,000 times greater than the risk associated with a 10,000 gallon retrieval leak, if it were to occur.

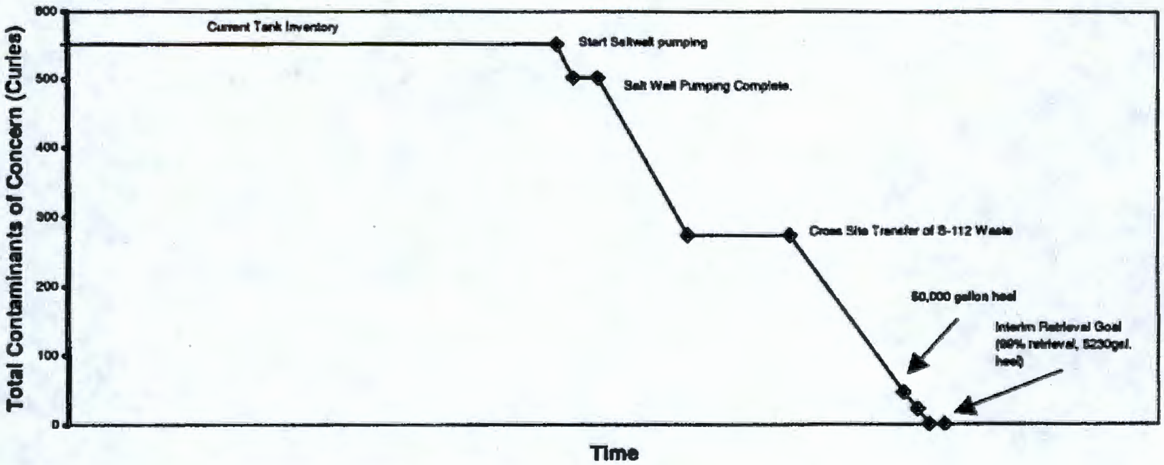


Figure 5.2. Tank S-112 Contaminants of Concern During Retrieval

The LDMM strategy for tank S-112 will use best available leak detection, leak monitoring, and leak mitigation technologies and strategies economically achievable to reduce the risk to human health and the environment from retrieval leak loss. However, leak detection and leak monitoring using the current best available technology require a free liquid surface within the tank to accurately detect and monitor a leak and relies on a free liquid surface to improve precision and reduce false alarms at low volumes.

The retrieval technology selected for the tank S-112 demonstration will not provide a free liquid surface except near the end of retrieval, and relies on the principles that:

- Minimize the amount of liquid required for retrieval,
- Reduce the liquid volume in the tank,
- Incorporate a retrieval strategy that reduces the free liquid surface and hydraulic head, and
- Minimize the time at risk.

During active retrieval operations, the S-112 retrieval and LDMM strategy minimizes the hydraulic head and reduces the wall area in contact with liquid to reduce the leak potential (maintains a liquid level below current the interstitial liquid level) to reduce the overall risk to human health and the environment. Leak detection data for tank S-112 has demonstrated that the tank is not leaking below the liquid level established by the interstitial liquid. Leak mitigation is strengthened by restricting the liquid hydrostatic head in the tank during retrieval operations. This reduces the driving force for leakage, resulting in a slower leak, if one should occur. In addition, as retrieval progresses and the waste level declines, the surface area of the tank walls available to form a leak site is also reduced. This is important because the declining area available to form a leak reduces the probability that a leak will occur.

5.4.1 Strategies for Leak Detection

The tank S-112 scoping-level RPE indicates that the 10^{-5} ILCR criterion is exceeded for the residential farmer scenario when the minimum retrieval residual waste of 5,230 gallons is left in the tank, even with no leak losses during retrieval. However, the risk of not retrieving the waste exceeds that criterion. If the tank is interim stabilized (has the pumpable interstitial liquid removed via saltwell pumping) and the rest of the waste remains in the tank, preliminary analysis shows that the long-term human health risk (to the residential farmer) is about 600 times higher than if the tank is retrieved.

As a result, the best practical and available leak detection methods will be used to minimize the potential for risk to human health and the environment. The LDMM strategy focuses heavily on mitigation of the potential for and consequences of a leak and use of accepted and available methods of leak detection.

Lessons learned from industry and the DOE complex (Appendix A) provide no evidence that retrieval operations have caused a tank leak, and the 95% probability leak rate for a non-catastrophic leak in an SST (1.8 gal/hr) would be undetectable. Therefore, the overall strategy for leak detection is:

- Minimize the amount of liquid in a tank, by maintaining the interstitial liquid level at or below its starting level during active retrieval operations,
- Minimize the liquid hydraulic head during active operations, i.e., the driving force for a leak during active operations,
- Test the tank frequently for the possibility of a catastrophic release while waste is actively being retrieved (dynamic testing),

- Use existing drywell and ground water monitoring wells for detection[1] and monitoring,
- Perform at least two static tests of at least a 48-hour duration during the retrieval campaign,
- Minimize activities that require suspending retrieval operations, and
- Use static leak detection if the dynamic or external tank leak detection system indicates a probable leak.

Logging of drywells will be employed prior to, during, and after retrieval operations. However, radiation detected in a drywell (i.e., due to a leak) may be difficult to interpret for the following reasons:

- Lack of a reading may only mean that a release from the retrieval tank has not migrated to the well, and
- A positive reading may be the result of existing contamination or waste migration from another tank or ancillary equipment.

Due to this uncertainty, ex-tank methods using existing drywells will not be the primary method of leak detection. When used in conjunction with other leak detection systems, they can be helpful in assessing the existence and extent of a leak.

5.4.2 Strategies for Leak Mitigation

The leak mitigation strategy (i.e., reduction of leak loss potential) will use the following techniques for protection of human health and the environment:

- Interim stabilize tank S-112 prior to the retrieval demonstration. Initiating saltwell pumping in advance of retrieval will minimize the potential for leakage prior to and during retrieval operations.
- Control the time required for retrieval. If a leak occurs, the volume leaked will be proportional to the amount of time the leak site is below the interstitial liquid level. Use a modified saltwell pump to increase retrieval capacity and reduce the retrieval duration. The estimated time to retrieve tank S-112 waste using a modified saltwell pump is approximately 194 days.
- Minimize liquid and hydrostatic head in tank S-112 during active retrieval operations. Leak mitigation will be accomplished by minimizing the liquid inventory in S-112 to limit the potential volume of waste that could leak. Minimizing the volume of liquid added to the tank during retrieval reduces the hydrostatic head, which is the driving force for a leak. To do this, waste will be pumped out at a rate greater than or equal to the rate of water addition.
- Maximize the rate of dissolution/collection. Use of three nozzles to deliver water to the tank allows distribution over a larger surface area of waste, making the dissolution more efficient. The ability to lower and aim the nozzles enables the system to move insoluble

[1] The present dry well and groundwater monitoring system is not designed for real time (i.e., instantaneous) detection and response, as time is required for waste to reach the area of influence of the dry well and for radiation data interpretation and analysis. Alternate ex-tank leak detection methods are being evaluated (see section 5.7) and will be considered for use based upon the results of proof-of-concept tests.

solids towards the pump suction. The solvent may also be heated to increase the solubility of the waste in the tank.

- Retrieve from an advantageous location. The system shall be operated in such a way that it can pump from the lowest achievable level in the tank if a leak should occur. This is a mitigation activity allowing removal of the greatest amount of liquid from the tank.

5.5 System Description

The retrieval and LDMM systems described in this section represent a conceptual view of the systems currently planned for deployment in tank S-112. Detailed design will enhance the definition of the system and may change the features described below. However, the final design shall comply with the requirements established in this document. Any subsequent changes will be established through the change control process described in Section 6.

5.5.1 Tank S-112 Retrieval System Description

The tank S-112 demonstration for the dissolution retrieval technology takes advantage of saltwell pumping systems and infrastructure installed prior to retrieval to interim stabilizes the tank. Retrieval operations will commence after completion of the saltwell pumping activities. The subsequent saltcake retrieval by dissolution will use two separate systems; a water distribution system and a solution removal system. Water will be introduced to the tank through three sprinkler mechanisms; one each installed in Risers 11, 14, and 16. The sprinkler nozzles will be designed to allow occasional simple elevation changes and changes in where they are "aimed" in the tank. The three sprinklers will be designed to be operated singly or simultaneously, and the flow rate through the water distribution system will be designed based on the removal rate of the solution removal system such that once equilibrium is reached in the tank, the rate of water introduction will approximately equal the rate of solution removal.

New equipment will replace the existing saltwell pump and some of the associated existing components in the tank. The existing saltwell screen will be reused. Use of the existing saltwell screen will eliminate the need to create a new "well" for pump installation and further limit the water addition. The new pump will be installed as low as possible in the tank. The new saltwell pump is of a type previously approved for tank farm use and will have an approximate 10 gpm capacity.

New dip-tubes installed in the existing saltwell screen will monitor the dissolution process by measuring the specific gravity (SpG) of the solution in the well. The dip-tubes will also be used to measure the accumulation depth of solution in the screen.

Pumping during retrieval operations will maintain a minimum volumetric inventory in the well. Once the waste becomes saturated, the rate of water addition will be balanced to equal the solution removal rate. As the water percolates through the waste it will dissolve and/or erode the saltcake and then flow into the saltwell. Insoluble waste remaining after saltcake dissolution will be directed towards the pump suction by adjusting the height and aim of the sprinkler nozzles. If required, waste samples can be obtained and analyzed periodically to provide data for buffer or corrosion inhibitor feed adjustments. Transfer line flushing will occur as needed and at the end of each operating period.

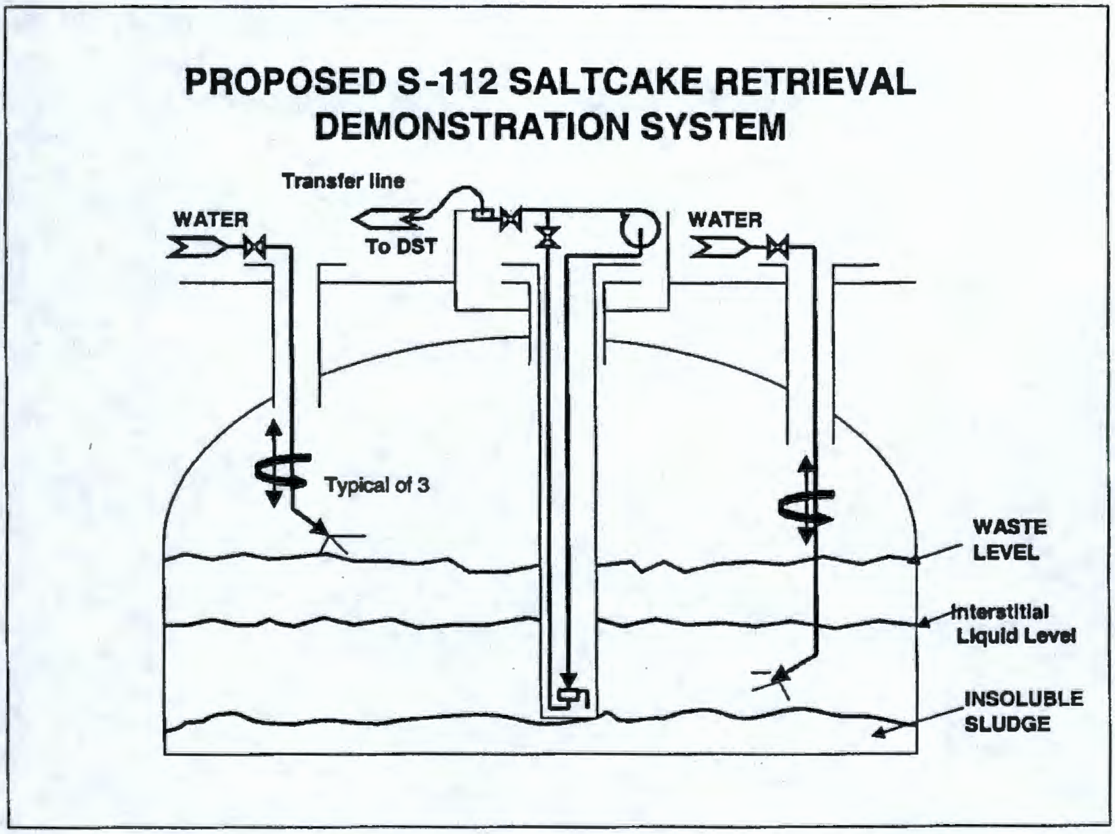


Figure 5-3. Tank S-112 Retrieval System (not to scale)

5.5.2 LDMM System Description

Two methods of in-tank leak detection will be used during the retrieval effort; dynamic and static. Dynamic leak detection uses tank level and transfer flow measurements to measure/calculate waste volume discrepancies between the SST being retrieved and the receiving DST (see Figure 5-4). Static leak detection uses discrepancies between level measurements taken at different points of time in the same tank and requires a halt in the retrieval effort to let the tank level achieve stasis (potentially over a period of days) (see Figure 5-5) and a free liquid surface to measure against. Drywells outside of tank S-112 will be monitored to establish a pre-retrieval baseline for the SST and then periodically monitored to detect variations in radiation levels in the soil column.

The equipment and methods for LDMM will use the BATEA. Use of BATEA has been established by EPA in 40 CFR 415 (*Inorganic Chemicals Manufacturing Point Source Category),* which calls for use of BATEA for controlling effluents from inorganic chemicals point sources. Alternative equipment and methods under development or evaluation (see Section 5.7) will be employed at Hanford if they are available, shown to be an improvement, and found to be economically achievable.

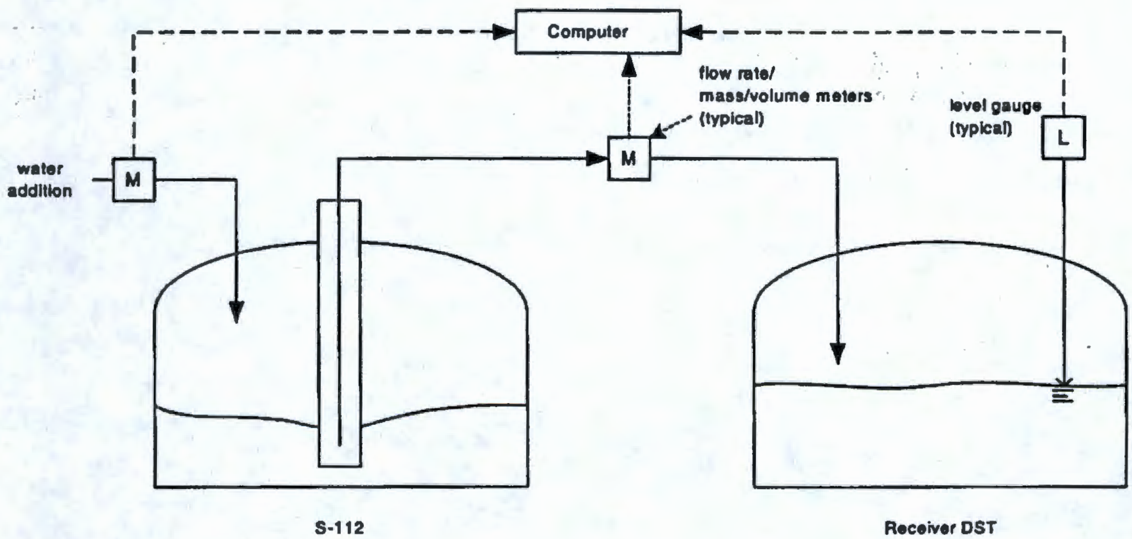


Figure 5-4. 241-S-112 Dynamic Leak Detection
(Based on Mass/Volumetric Flow & Tank Level)

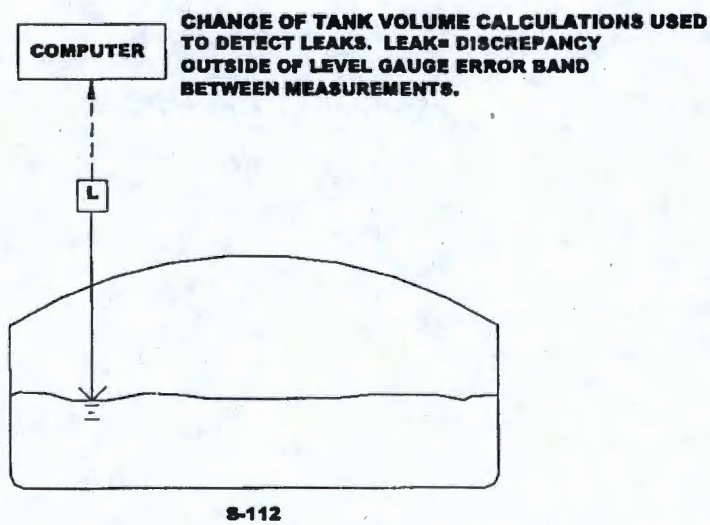


Figure 5-5. Tank S-112 Static Leak Detection
(Based on Changes in Tank Level Only)

Currently, the tank waste level is measured with Enraf-Nonius™ level instruments (ENRAF™). The ENRAF™ instrument is mounted on a dedicated tank riser. The ENRAF™ is remotely controlled by a computer, which causes the instrument to raise and lower a displacer suspended on a stainless-steel or platinum-iridium wire dispensed by a reel.

The displacer is constantly weighed and the weight-sensing circuit can detect the difference between air, supernatant and sludge. The displacer wire dispensed length is measured via a rotary encoder on the reel. Changes in the waste level greater than the uncertainties associated with the measurement error are interpreted as a leak. This is currently defined as ½ inch, equating to a volumetric discrepancy of approximately 1,400 gallons (RHO, 1981)

Transfer flow measurements are done with volumetric/mass-flow instruments, which provide real-time data on volumetric and mass flow. Volumetric flows between tank S-112 and the receiver DST can be compared with tank volumes calculated from tank levels. Differences outside of the instrument error bands and defined uncertainty ranges would indicate a leak. Any flush water additions or volume additions from other sources must also be accounted for in the volumetric balance calculations.

Leak detection is easily employed on the existing transfer lines, new transfer lines, and the receiving DST itself. Leak detection in the receiving DST will be performed primarily with the existing annulus leak detection. Unlike an SST, a DST has redundant protection against leakage (secondary encasement), which allows for using direct forms of leak detection, i.e., conductivity probes. The existing transfer lines and receiving DST are encased and the encasement on each leg of the transfer route will terminate inside of a pit. Leak detectors, such as conductivity probes, will be employed in all interconnected valve and pump pits in the primary transfer system.

Transfer line leak detection may also be performed using volumetric/mass balancing. For example, flow meters placed at the inlet and outlet of the lines can be compared continuously for discrepancies greater than the anticipated measurement error and uncertainty ranges.

5.6 LDMM and Retrieval Operating Strategy

The operating strategy for performing LDMM and retrieval applies before, during, and after retrieval as described below. The strategy is consistent with the current level and maturity of the S-112 retrieval demonstration design, as well as consistent with the functions and requirements established in this document.

5.6.1 Pre-Retrieval Operations

A pre-retrieval LDMM assessment will be undertaken for tank S-112 prior to the start of retrieval operations. Pre-retrieval conditions provide assurance about the integrity of the tank, which contains interstitial liquid, is monitored, and hasn't leaked. The pre-retrieval assessment will be consistent with the *Hanford Federal Facility Agreement and Consent Order* Appendix H – Single Shell Tank Waste Retrieval Criteria Procedure and will:

- Establish an ex-tank baseline condition using gamma monitoring in existing drywells.
- Calculate the volume (liquid, solid, and total) for both tank S-112 and the DST receiver tank.
- Measure/calculate tank S-112 waste inventory via topographical or other mapping and survey techniques.
- Perform an operational history review to look for evidence of releases.

- Perform an operational/functionality review of existing leak detection instrumentation.
- Perform a data review for drywell/borehole and Tank Farm Vadose Zone Project instrumentation and data.
- Perform an initial leak test and/or confirmation of "soundness" using active in-tank and ex-tank instrumentation following existing tank farm surveillance and monitoring programs and the tank leak assessment process (HNF-SD-WM-PROC-021, HNF-3747).

This pre-retrieval LDMM assessment will provide a baseline assessment of tank S-112 conditions prior to retrieval.

5.6.2 Retrieval Operations

The overall retrieval operating strategy will consist of reducing the tank inventory and minimizing liquid hydrostatic head during retrieval operations, monitoring liquid inventories while waste is actively being retrieved (dynamic test), and monitoring liquid inventories when retrieval operations are intermittently suspended (static test). Minimizing the time at risk is also planned, so static leak tests may be coordinated with the time associated with staging waste from the West Area DST receiver tank to an East Area DST. Staging is required in order to have enough DST space to store the retrieved waste. Dynamic testing will be performed throughout the retrieval operations. Static testing will be performed on a periodic basis when the waste configuration and the location of the liquid surface is such that instrumentation can contact the liquid surface, i.e., a free liquid surface exists beneath a riser containing the level instrumentation. The opportunities for conducting static tests, as well as dynamic tests, will be established in a process control plan. Planning for static testing will include taking advantage of opportunities, (such as DST staging described above), that arise when retrieval is shut down for another reason.

To minimize the tank liquid inventory during retrieval operations, water additions will be balanced by liquid waste removal. This strategy is key to leak mitigation since it minimizes the free liquid in the tank and consequently the driving force for a leak. The interstitial liquid level will also be controlled to be below its starting level. The intake for the saltwell pump is located at the bottom of the tank, in the best position to remove drainable liquid in response to a leak. Operations will continue in this fashion until insufficient waste remains to provide a constant source of feed for the saltwell removal mechanism, at which time retrieval operations will end. Operations may be developed further (e.g., a wash cycle of insoluble solids) to increase removal efficiency of soluble long-lived mobile contaminants.

During initial operation of the retrieval system, dynamic leak detection will be the primary means of leak detection. Static leak tests will be performed periodically, using the liquid surface exposed in the salt well or through the addition of liquid to obtain a free liquid surface.

If a leak is indicated during retrieval operations process control procedures will be implemented (see Figure 5-6). The first response to an indication of a potential leak will be to validate the instrumentation. If the validation process concludes that no leak is indicated, retrieval operations would start-up and continue under normal operating procedures. However, if a leak is validated, the operating contractor will notify DOE-ORP, which will in turn notify Ecology. The process control procedures will consider the leak loss limit, leak loss rate, and estimated duration to completion of retrieval operations when determining the appropriate response action. Potential response actions include, 1) modifying leak monitoring (e.g., implementing more frequent in-tank and/or ex-tank testing), 2) modifying operating conditions, 3) discontinuing adding or recycling liquids, 4) implementing emergency retrieval, or 5) stopping all operations (see Figure 5-6). The response actions would then be implemented and, if appropriate, retrieval operations would continue under modified procedures through the completion of the retrieval activities. The requirements for implementation of leak response actions during retrieval operations will be established in the Process Control Plan that will be developed concurrent with the design of the retrieval and LDMM system.

5.6.2.1 Dynamic Leak Detection During Retrieval

Dynamic leak detection will be implemented during waste retrieval operations. It will consist of liquid waste level measurements, including measurements required to compensate for short term variations in the measurement signals, in both tank S-112 and the DST receiver tank. In addition, flow measurements (also including other measurements required to compensate for short term variations) will be made in the transfer piping out of tank S-112 and into the DST.

Based on the leak detection requirements and the capabilities of the instruments, a goal will be established that the analysis result of the dynamic leak detection data being collected during retrieval lags the ongoing operations by no more than 48 to 96 hours, with updates on a 48 to 96 hour basis.

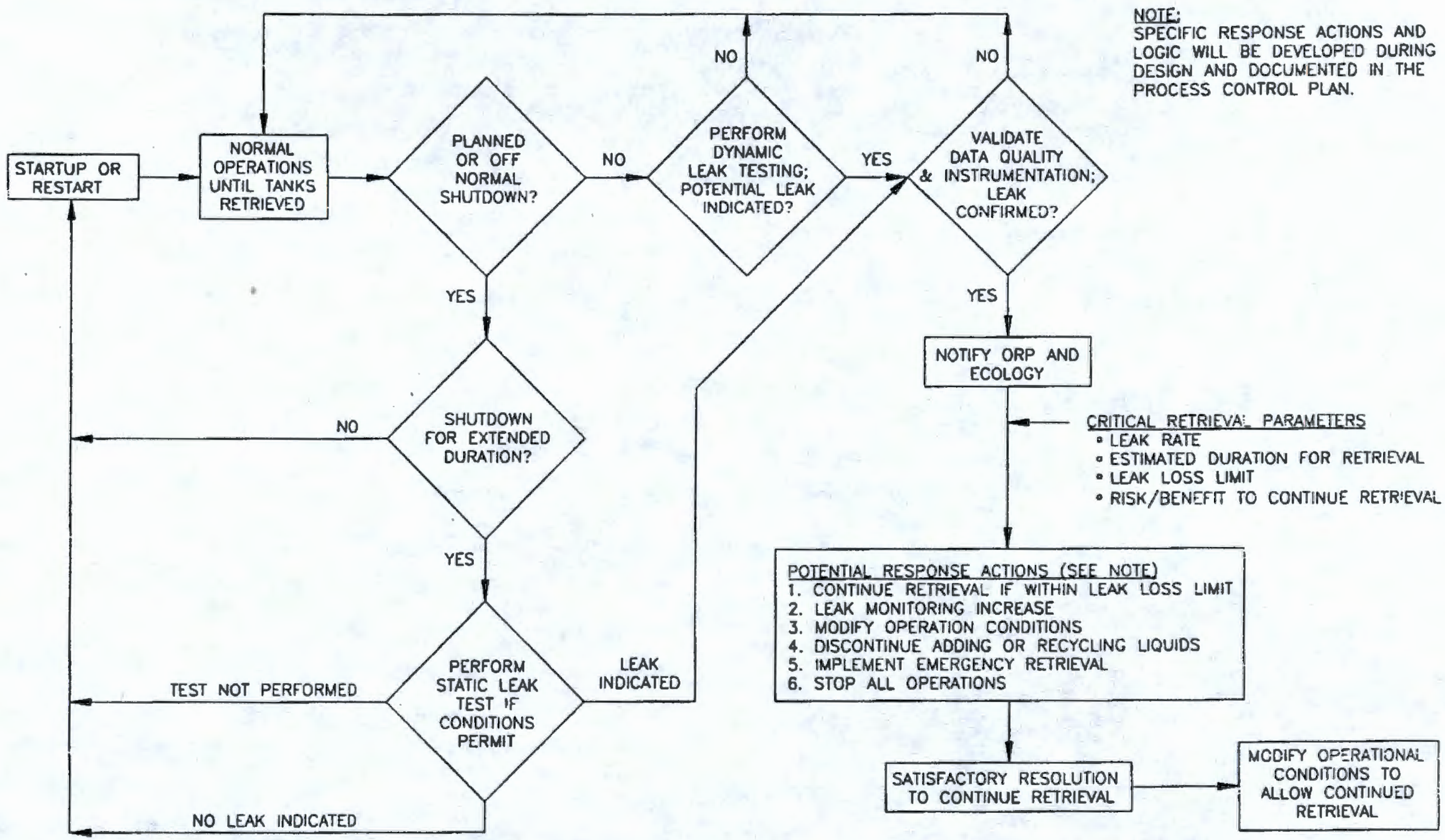


Figure 5-6. Retrieval/LDMM Operational Response Process Diagram

Table 5-2 provides a typical listing of the instrumentation that may be used for dynamic leak testing. The table describes the data and measurement functions for which it may be collected. Some instrumentation is already present. Some may be installed specifically to support retrieval.

Table 5-2. Instrumentation Requirements for Dynamic Leak Detection

Instrument	Measurement Function	Purpose
Level gauge	Free liquid surface level inside SST	Direct measurement
Level gauge	Free liquid surface level inside DST	Direct measurement
Thermocouple	Air temperature inside SST	Instrument error
Thermocouple	Liquid temperature inside SST	Source material compensation
Thermocouple	Air temperature outside SST	Instrument error
Pressure gauge	Barometric pressure	Source material compensation
Pressure gauge	Static pressure inside SST (ventilation system)	Source material compensation
Pressure gauge	Static Pressure Inside DST (ventilation system)	Source material compensation
Pressure gauge	Transfer pipeline pressure	Source material compensation
Flow meter	Volumetric / mass flow out of SST	Direct measurement
Flow meter	Volumetric flow into SST	Direct measurement
Psychrometrics	Evaporation / condensation in SST	External inflow/outflow
Batch sample	Liquid/sludge density inside SST	Source material compensation (if required)
Sensor and switch	Data acquisition and alarm	Record and process data inputs

For dynamic leak detection, the retrieval system will be treated like a closed system consisting of the tank S-112, the receiving DST, and the connecting transfer lines. Specific gravity in the recovery line may be measured and used to compensate/reconcile the recovery volume. The discrepancy between the inflow of water and outflow of waste from tank S-112 will be compared to the volume in the DST (converted from surface level measurements) and the transfer line. Any discrepancy greater than the uncertainties in the volume calculations and estimates of tank S-112 liquid inventory, including the error produced by all compensating measurements (thermal expansion, dissolution, solids loading, etc.), will be considered a leak in tank S-112. This assumes that no leak is detected in the transfer line(s) or the DST. This assumption will be validated by periodic leak testing of the transfer lines and reviewed prior to the actual retrieval operations.

5.6.2.2 Static Leak Testing During Retrieval

A static leak test will require that all water additions and pumping be suspended for a period of time to allow the system to reach equilibrium and to conduct the leak detection test. The liquid level of the tank may be adjusted upward by adding water to the tank to obtain a free liquid surface beneath level measurement instruments if there is not sufficient liquid in the tank to form a stable surface pool.

Once retrieval operations have been suspended, a waiting period will be observed to allow the liquids to gravity drain and reach equilibrium. Static testing will be performed once tank S-112 has reached equilibrium. The frequency and duration of the static test will be determined during the design of the retrieval system. Data will be collected over a period of time (48 hours following equilibrium, for example), and measurements will include tank liquid waste levels and temperatures (to account for thermal expansion.) Table 5-3 provides a listing of the representative instrumentation that can be employed for static leak testing. The table also describes the data and the reason it is collected. Some instrumentation is already present in the tank farms. Other devices may be installed specifically to support retrieval. Once the data collection and analysis are complete and have shown that a leak has not occurred, tank waste retrieval operations are resumed.

Table 5-3. Instrumentation Requirements for Static Leak Detection

Instrument	Measurement Function	Purpose
Level gauge	Free liquid surface level inside SST	Direct measurement
Thermocouple	Air temperature inside SST	Instrument error
Thermocouple	Liquid temperature inside SST	Source material compensation
Thermocouple	Air temperature outside SST	Instrument error
Pressure gauge	Barometric pressure	Source material compensation
Pressure gauge	Static pressure inside SST (ventilation system)	Source material compensation
Psychrometrics	Evaporation / condensation in SST	External inflow/outflow
Batch sample	Liquid/sludge density in SST	Source material compensation
Sensor and switch	Data acquisition and alarm	Data Recording and Processing

The first response to an indication of a potential leak will be to validate the instrumentation. If the validation process concludes that no leak is indicated, retrieval operations would start-up and continue under normal operating procedures. However, if a leak is validated, the operating contractor will notify DOE-ORP, which will in turn notify Ecology and process control procedures will be implemented. The process control procedures will consider the leak loss limit, leak loss rate, and estimated duration to completion of retrieval operations when determining the appropriate response action. Potential response actions include 1) continuing retrieval activities if there is no significant impact to risk, 2) modifying leak monitoring (e.g., implementing more frequent dynamic monitoring or static testing), 3) modifying operating conditions, 4) discontinuing adding or recycling liquids, 5) implementing emergency retrieval, and/or 6) stopping all operations (see Figure 5-6). The response actions would then be implemented and, if appropriate, retrieval operations would continue under modified procedures through completion of the retrieval activities. The requirements for implementation of leak response actions during retrieval operations will be established in the Process Control Plan that will be developed concurrent with the design of the retrieval and LDMM system.

5.6.2.3 Drywell Monitoring During Retrieval

Drywells will be monitored periodically during retrieval operations to provide additional leak detection and monitoring capability. The frequency of drywell monitoring, the types of monitors to be used and the potential response actions to a leak will be established during the design phase of the project.

5.6.3 Post Retrieval

A post-retrieval LDMM assessment will be undertaken for tank S-112 following completion of retrieval operations. This assessment will be consistent with the *Hanford Federal Facility Agreement and Consent Order* Appendix H – Single-Shell Tank Waste Retrieval Criteria Procedure and includes:

- Reevaluate ex-tank conditions using gamma monitoring in existing drywells and compare with the baseline condition.
- Measure/calculate tank S-112 residual waste inventory via proposed topographical or other mapping and survey techniques.
- When the tank S-112 retrieval demonstration has been declared complete, an evaluation of the closure source term will be performed. If leak detection data does not indicate a leak occurred, no post-retrieval LDMM activities are planned. Existing vadose zone contamination is being addressed under a separate program. The SST closure work plan (not part of this project's scope) will specify any specific closure/post closure requirements. If a tank is shown to have leaked during retrieval, the present procedure (see Section 5.1.3) will address any follow-on actions.

5.7 Alternative LDMM Technologies

The S-112 retrieval system will use the best available technology that is economically achievable for leak detection. During FY01, DOE/ORP sponsored screening testing and demonstrations to examine alternate LDMM technologies that provide indirect leak detection outside of the tank. These technologies may have potential to augment the existing drywell ex-tank leak detection system. These ex-tank LDMM technologies evaluated include:

- Electrical Resistance Tomography (ERT) (PNNL 2001)
- Crosshole Radar (PNNL 2001)
- Crosshole Seismic

- Crosshole Electromagnetic Induction (PNNL 2000)
- High-Resolution Resistivity (PNNL 2000)
- Partitioning Interwell Tracer Tests (PITT) (CHG 2000b)

In addition, further in-tank leak detection technologies will be investigated during the tank U-107 proof-of-concept test and during design and development of the tank S-112 retrieval demonstration. These include:

- Liquid Observation Well used with gamma probe, and
- Topographical mapping techniques.

Early in FY 2002, results of these ongoing tests will be evaluated to identify those promising technologies for continued development and testing during FY 2002 and beyond. These technologies will be evaluated and a down-selection process used to identify those technologies with the greatest potential to decrease the uncertainty associated with static and dynamic testing. The parameters that will be evaluated are:

- Maturity, accuracy, and precision of the technology,
- Amount of additional development required to deploy the technology,
- Degree by which LDMM is enhanced versus the cost to deploy the technology,
- Compatibility with retrieval and tank farm operations, and
- Cost and schedule to develop and deploy the technologies.

Additional testing and development of the down-selected technologies is needed to:

- Identify statistical ranges of performance to correlate performance of the system against the EPA standard of 95/5% (probability of detection/probability of false alarm)
- Develop potential performance characteristics of the system during anticipated operations of the retrieval systems and during possible leak scenarios
- Define system configurations and deployment and operational limitations
- Advance the maturity of the technology to a point where it can be integrated with the retrieval system and deployed

The development of an ex-tank leak detection/monitoring technology(s) to support SST retrieval demonstrations follows a technology development approach that is expected to take over two years to assess and proof technologies for potential deployment. The process includes formal evaluation to determine required statistical parameters and performance capabilities. The end result will be a technology(s) that is ready for integration into the retrieval project design process.

The first portion of the technology development and testing approach consists of a five-step process that will be completed within the first quarter of FY02 and includes:

- An industry search for potential ex-tank technologies,
- Short-listing to six ex-tank,

- Preliminary evaluation of technologies under simulated tank farm conditions,
- Down selection and advancement of two to three ex-tank technologies which demonstrate the greatest potential for tank farm and SST retrieval application,
- Conducting formal testing and evaluation of final technologies to develop performance parameters.

If proof-of-concept and follow-on testing demonstrates that any of these technologies significantly decrease uncertainty associated with static and dynamic leak testing, they will be evaluated for inclusion in the S-112 retrieval demonstration.

6.0 HANFORD FEDERAL FACILITY AGREEMENT AND CONSENT ORDER F&R CHANGE CONTROL

This document is a *Hanford Federal Facility Agreement and Consent Order* Primary Document requiring Ecology review and approval. This document will establish the functions and requirements for the tank S-112 retrieval demonstration for the life of the retrieval project. Document revisions will follow the criteria outlined in section 9.3, "Document Revisions" of the *Hanford Federal Facility Agreement and Consent Order*. Modifications to this document will be assessed using existing criteria. Minor field changes (as discussed in section 12.4 of the Agreement) can be made by the person in charge of the particular activity, (i.e., the CHG Project Manager or equivalent). Minor field changes are those that have no adverse effect on the technical adequacy of the job or work schedule (i.e., does not impact completion of milestone commitments). Such field changes will be documented in daily logbooks (or equivalent) that are maintained by the project.

Revisions/Changes not considered minor field changes can be made through use of a change notice in accordance with sections 9.3, "Document Revisions" and 12.0, "Changes to the Agreement." Major changes (those requiring a change notice) or revisions to the plan are further defined by the following criteria:

- Significant change affecting public health or the environment.
- Evaluation of remedial alternatives (i.e., major changes to retrieval technologies and/or programmatic decisions that impact the technical adequacy of the project or impact work schedules).
- Protection of human health or the environment (i.e., exceeding maximum leak loss limits, or major design change to LDMM criteria).

7.0 REFERENCES

10 CFR 61.55, "Waste Classification," Code of Federal Regulations.

10 CFR 830, "Nuclear Safety," Code of Federal Regulations.

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

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

40 CFR 61, "National Emissions Standards for Hazardous Air Pollutants," Code of Federal Regulations.

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

40 CFR 280, "Technical Standards and Corrective Action Requirements for Owners and Operators of Underground Storage Tanks," Code of Federal Regulations.

40 CFR 415, "Inorganic Chemicals Manufacturing Point Source Category," Code of Federal Regulations.

40 CFR Subchapter R, "Toxic Substances Control Act," Code of Federal Regulations.

CHG 1999, *SST Leak Emergency Pumping Guide*, HNF-SD-WM-AP-005, Rev. 8, CH2M Hill Hanford Group, Inc., Richland, Washington.

CHG 2000, *Annual Progress Report on the Development of Waste Tank Leak Monitoring/Detection And Mitigation Activities in Support of M-45-08 (TPA Milestone M-45-09E Fiscal Year 2000 Progress Report)*, RPP-7012, CH2M Hill Hanford Group, Inc., Richland, Washington.

CHG 2000a, *Single-Shell Tank Retrieval Sequence: Fiscal Year 2000 Update*, RPP-7087, CH2M HILL Hanford Group, Inc., Richland, Washington.

CHG 2000b, *Engineering Basis Document Review Supporting Double-Shell System Specification Development*, HNF-3350, 2000, CH2M Hill Hanford Group, Inc., Richland, Washington.

CHG 2000c, *Tank Farms Operations Administrative Controls*, HNF-IP-1266, 2000, CH2M Hill Hanford Group, Inc., Richland, Washington.

CHG 2000d, *Operating Specification for Single-Shell Waste Storage Tanks*, OSD-T-151-00013, November 2000, CH2M Hill Hanford Group, Inc., Richland, Washington.

CHG 2000e, *Project W-523, Tank C-104 Waste Retrieval System Environmental Permits and Approvals Plan*, RPP-6665, 2000, CH2M Hill Hanford Group, Inc., Richland, Washington.

CHG 2001, *Waste Tank Summary Report for Month Ending July 2001*, HNF-EP-0182-160, Hanlon, B.M., CH2M Hill Hanford Group, Inc., Richland, Washington.

CHG 2001a, *Tank Farms Final Safety Analysis Report,* HNF-SD-WM-SAR-067, 2001, CH2M Hill Hanford Group, Inc., Richland, Washington.

CHG 2001b, *Tank Farms Technical Safety Requirements*, HNF-SD-WM-TSR-006, 2001, CH2M Hill Hanford Group, Inc., Richland, Washington.

CHG 2001c, *Project Definition Criteria for 241-S-112 Saltcake Dissolution and Retrieval Demonstration*, RPP-7534, September 2001, CH2M Hill Hanford Group Inc., Richland, Washington.

DOE/Ecology, 2000, *DRAFT Federal Facility Agreement and Consent Order Change, M-45-00-01A, 8/30/2000*, U.S. Department of Energy and Washington Department of Ecology Negotiation Team.

DOE et al. 1989, as amended, DOE, EPA, and Washington Department of Ecology, *Hanford Federal Facility Agreement and Consent Order*, DOE/RL 89-10, as amended, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE 1996, *Dangerous Waste Permit Application - Single-Shell Tank System*, DOE/RL-88-21, U.S. Department of Energy, Richland, Washington.

DOE 1998, *Life Cycle Asset Management*, DOE Order 430.1A, October 14, 1998, U.S. Department of Energy, Washington, D.C.

DOE 1999, *Program and Project Management for the Acquisition of Capital Assets*, DOE Order 413.3, 1999, U.S. Department of Energy, Washington, D.C.

DOE 1999a, *Deactivation Implementation Guide*, DOE Order G 430.1-3, September 29, 1999, U.S. Department of Energy, Washington, D.C.

DOE 1999b, *Radioactive Waste Management*, DOE Order 435.1, July 9, 1999, U.S. Department of Energy, Washington, D.C.

DOE 1999c, *Retrieval Performance Evaluation Methodology for the AX Tank Farm*, DOE/RL-98-72, 1999, U.S. Department of Energy, Richland, Washington.

DOE 2001, *Hanford Tank Farms Vadose Zone Project Web Page*, S Tank Farm Report, Tank Summary Data Report, 2001, website address: http://www.doegjpo.com/programs/hanf/htfvz.html.

DOE 2001a, "Hanford Site Title Air Operating Permit, 00-05-006," June 2001, U.S. Department of Energy, Richland, Washington.

Ecology 1996, Memorandum of Understanding, "Required Percent of Waste Retrieval," August 7, 1996, U.S. Department of Energy and Washington Department of Ecology, Richland, Washington.

Ecology 1999, *Agreement Commitments Regarding Initial Single-Shell Tank Waste Management Area (WMA) Corrective Actions, Vadose Zone and Groundwater Characterization, Assessment, and the Integration of Vadose Zone and Groundwater Activities at Specified Associated Sites*, Change Request M-45-98-03, January 8, 1999, Draft, Washington Department of Ecology.

LMHC 1998, *Single-Shell Tank Retrieval Program Mission Analysis Report*, HNF-2944, 1998, Lockheed Martin Hanford Corporation. Richland, Washington.

LMHC 1999, *Load Requirements for Maintaining Structural Integrity of Hanford Single-Shell Tanks During waste Feed Delivery and Retrieval Activities*, HNF-4712, 1999, Lockheed Martin Hanford Corporation, Richland, Washington.

LMHC 1999a, *Single-Shell Tank Leak History Compilation, Volume 1 of 2*, HNF-4872, 1999, Lockheed Martin Hanford Company, Richland, Washington.

LMHC 2000, *Single-Shell Tank Program Plan*, HNF-5095, 2000, Lockheed Martin Hanford Corporation, Richland Washington.

MACTEC 1998, *Hanford Tank Farms Vadose Zone S Tank Farm Report*, GJO-97-31-QTAR, GJO-HAN-17, MACTEC Corporation, Richland, Washington, Figure 14-13, file located at www.doejpo.com/programs/hanf/Sreport/Report/content.htm.

PNNL 2000, *Vadose Zone Transport Field Study: Detailed Test Plan for Simulated Leak Tests, PNNL-13263*, June 2000, Pacific Northwest National Laboratory, Ward, A.L. and Gee, G.W., Richland, Washington.

PNNL 2001, *RCRA Groundwater Monitoring Plan for Single-Shell Tank Waste Management Areas at the Hanford Site*, PNNL-13024, February 2001, Pacific Northwest National Laboratory, Richland, Washington.

PNNL 2001a, *Vadose Zone Transport Field Study: FY2001 Test Plan*, PNNL-13451, March 2001, Pacific Northwest National Laboratory, Ward, A.L. and Gee, G.W., Richland, Washington.

RHO 1981, *A Scientific Basis for Establishing Dry Well Monitoring Frequencies*, RHO-ST-34, Isaacson, R. E., and Gasper, K. A., Rockwell Hanford Operations Energy Systems Group, Richland, Washington.

TWINS Website 2001, Tank Waste Information Network System, Best Basis Inventory Calculation Detail for 241-S-112, downloaded May 22, 2001, twins.pnl.gov:8001/twins.htm.

Vadose 2001, Hanford Tank Farms Vadose Zone Project Web Page, S Tank Farm Report, Tank Summary Data Report, www.doegjpo.com/programs/hanf/htfvz.html.

WAC 173-303-610, *Dangerous Waste Regulations - Closure and Post-closure*, Washington Administrative Code.

WAC 173-303-640, *Dangerous Waste Regulations – Tank Systems*, Washington Administrative Code, as amended.

APPENDIX A

Lessons Learned for Selection and Implementation of Retrieval and LDMM Technologies

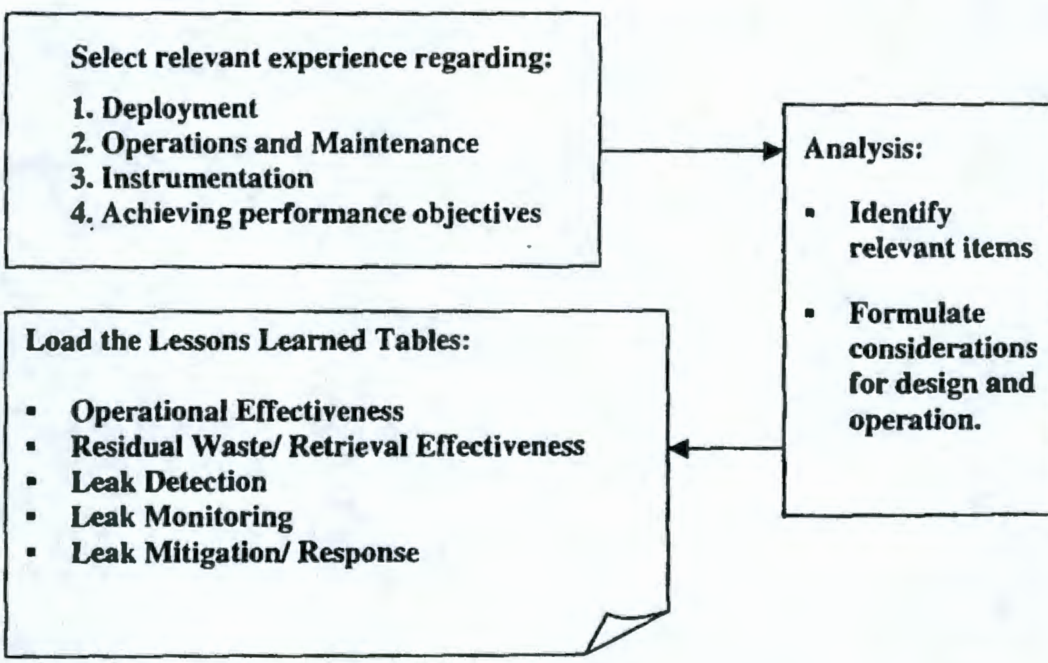
(48 Pages)

APPENDIX A - LESSONS LEARNED BASIS FOR SELECTION AND IMPLEMENTATION OF RETRIEVAL AND LDMM TECHNOLOGIES

A lessons-learned summary was prepared to support the development of the functions and requirements (F&R) for retrieval of wastes from Hanford single-shell tanks (SSTs). A survey of technology application experience was conducted to identify lessons learned relevant to planned applications of retrieval technologies.

A.1 Methodology

Source information was taken from technical documents and communications with key personnel in the technical community from the DOE Complex, other Federal agencies, and the private sector. The information was screened for consideration and applicability to this retrieval activity. Considerations relevant to the 241-S-112 and 241-C-104 retrieval activities were then formulated and presented in tabular format as illustrated below:



Although the selection process was primarily focused on confined sluicing, dissolution, and Leak Detection, Monitoring and Mitigation (LDMM) volumetric/mass balance systems supporting large-scale tank facilities; other applications also offered relevant information.

A.2 Information Sources

Candidate items with relevant technologies were identified. Key documents from these sources were reviewed and personnel contacted to acquire necessary information and to develop a basis to establish lessons learned for Tanks 241-S-112 and 241-C-104 retrieval activities.

A.2.1 Hanford Tank 241-C-106 Retrieval

Project W-320 at the Hanford Site retrieved 187 kgal of sludge from Tank 241-C-106 (Bailey, 2000). The waste retrieval was accomplished using a past-practice sluicing technology in 24-hour batches with 12 hours between batches to perform heat load/transfer calculations. The heat load calculations also provided data for mass balance leak detection.

The mass balance technique employed during Project W-320 (Bailey, 2000 and LMHC, 1999) used both retrieval tank and receiver tank level measurements from sensors such as ENRAFs and FICs (Food Instrument Corporation liquid level monitors). This sensor data was used in combination with in-tank video and with characterization data to convert volume data to mass data. Mass data was run through an algorithm to compare how much sluiced material (by weight) went into the retrieval tank with how much waste material (by weight) came out of the retrieval tank.

This technique required liquid level interface measurements as well as shutdown of the retrieval operation to allow the tank waste level data to be acquired (this has been true for most technologies using in-tank measurements). Because some tanks have solid surface layers, it was necessary to "punch through" the layer for direct measurement of a liquid interface. Alternatively, measurements in the liquid observation wells, where available, could be taken using indirect measurement of the interface through neutron probe or gamma activity to estimate the volume moved between retrieval operations. As in any measurement of fluctuating quantities, "baselines" of level and level trends needed to be established and assessed for any observed change, before the data could be analyzed for "leaks," since normal and routine changes in inferred mass needed to be understood.

Flow rate-augmented mass balancing techniques have the potential to improve accuracy by measuring the rate at which liquids and slurries are transferred. Flow rate measurements were collected during the Tank 241-C-106 retrieval operation, but the data has not been analyzed in terms of mass transfer. When this data is analyzed, the benefits and limitations of flow rate-augmented data will be more evident. In cases where no liquid interface is measurable, such as might be found in tanks containing stabilized sludges, this technique has limited value.

A.2.2 Oak Ridge Gunite and Associated Tanks (GAAT)

The Oak Ridge Gunite and Associated Tanks (GAAT) project successfully completed waste retrieval on eight gunite tanks at the Oak Ridge National Laboratory between 1996 and 2000. The tanks include two 50-kgal gunite tanks in the North Tank Farm and six 140-kgal tanks in the South Tank Farm. Waste retrieval was completed for the last two tanks (W-8 and W-9) in fiscal year 2000.

The GAAT waste retrieval system consisted of the Modified Light-Duty Utility Arm (MLUDA), Confined Sluicing End Effector (CSEE), and the Houdini. The Houdini is a multifunctional, remotely operated crawler. Tank W-9 contained heavy sludge from previous waste consolidation efforts. A heavy-waste retrieval system consisting of an airlift system and heavy-duty pumps was used along with the three other technologies to successfully mobilize and transfer the wastes from the tank.

Leak detection and monitoring for the GAAT project was provided via an external tank monitoring system combined with internal tank volumetric techniques. The gunite tanks were monitored for a large sudden release by using the on-line level measurements that were monitored around the clock at the Waste Operations Control Center. Volumetric precision leak testing was accomplished by analyzing 48-hour data sets of tank level readings that were taken at one-minute intervals. This precision testing was conducted prior to waste retrieval operations to establish baseline conditions. Both the external leak monitoring system and the Waste Operations Control Center monitoring were used during waste retrieval operations.

The external leak monitoring system utilized the drywells adjacent to each tank to monitor the conductivity of the groundwater that naturally flows around the tanks. A significant increase in conductivity would indicate a potential release from a tank. The system worked because the groundwater conductivity was approximately two orders of magnitude (100 times) less than the conductivity of the fluids in the tanks. Field-testing showed that leaks on the order of 0.5 gallons per minute could be detected using the external drywell monitoring method. The method was deployed and used during all GAAT waste retrieval operations. The external drywell monitoring leak detection system has allowed the GAAT project to use several of the inactive tanks (W-8 and W-9) in the South Tank Farm for the temporary storage of sluiced material and supernatant liquids. This use has, in turn, resulted in significant cost avoidance and reduction in schedule by eliminating the need to construct new above-ground tanks and facilitating an efficient transfer of wastes out of the tanks (ORNL, 1998).

A.2.3 Savannah River Tank 19 Heel Removal Project

At the Savannah River Site (SRS), long-shaft mixer pumps are being used for initial waste retrieval from the underground double-shell tanks, in Tank 19. Waste mixing and removal using the slurry pumps has left approximately 40 kgal of residual sludge as a waste heel in Tank 19. In a joint effort between Westinghouse Savannah River Company and the Tanks Focus Area, the use of Flygt® Mixer technology is being demonstrated as a means to remove the waste heel from Tank 19 and other SRS tanks.

Two years of scale up and verification testing of the Flygt® Mixers were conducted at Pacific Northwest National Laboratory and the SRS TNX Test Facility. Following this effort, the third of three Flygt® Mixers was installed in Tank 19 on August 2, 2000. Leak detection in the SRS double-shell tanks is accomplished by monitoring the annular space between the inner and outer tanks with radiation monitors and electrical resistance leak detectors (SRS, 1995). Nine tanks have leaked in the past, and tank liquids were detected in the annular space via radiation monitors and annulus photography (SRS, 1995). The groundwater at the SRS typically ranges from ten to twenty feet below grade, and groundwater sampling is also used as part of the leak detection strategy.

A.2.4 Hanford Tank 241-SY-101 Surface Level Remediation Project

The 241-SY-101 tank contained nearly a million gallons of waste with a history of retained gases that were released during periodic rollover events. This had been remedied with the installation of a mixing pump in 1993. Subsequent to that time, the level of the crust began to grow, retaining ammonia, nitrous oxide, and hydrogen at an increasing rate. This presented critical safety issues requiring transfer and dilution of the waste. This Project deployed a submersible canned rotor transfer pump that was based on technology developed for cooling naval reactors. A temporary at-grade transfer line comprised of a flexible hose within a hose was used for the transfer from 241-SY-101 to 241-SY-102. The transfer line was compliant with established technical and regulatory requirements. With the conclusion of transfers and back dilution, the contents of 241-SY-101 were sufficiently changed to resolve this critical safety issue.

A.2.5 Other Federal Programs and Private Industry Demonstrations

Other commercial nuclear, robotics development, and Federal programs have carried out activities that have provided relevant information for this lessons learned review. Examples include Cybernex (France) development of industrial systems to operate in hazardous environments (Fidani, 2001); Merpro Limited (United Kingdom) products for oil and gas treatment systems (Merpro, 2001a, b, c, and d); DOE/NASA collaborations to develop robotic systems for Chernobyl (Osborn, 2001); and Toshiba (Japan) development of robotic systems to deploy systems to conduct maintenance on nuclear power plant large pressure vessel fuel core support structures (Shimamura et al., 2001). The US-EPA has developed standards for leak detection on large petroleum tanks. Information is available regarding various types of remote or robotic systems operating in hazardous environments (Maresca, et al., 1993). The Salt Institute and Solution Mining Research Institute (and associated solution mining firms) and the National Petroleum Technology Office have information applicable to the dissolution retrieval (Salt Institute, 2001).

There were no specific DOE-observed private industry LDMM demonstrations in fiscal year 2000. The Strategic Environmental Research and Development Program (SERDP) sponsored an applied research project through Pacific Northwest National Laboratory. The applied research project was to perform non-intrusive characterization of dense non-aqueous phase liquids (DNAPLs) in the subsurface (Gauglitz, et al., 1995 and Gauglitz, et al., 2000). The results of the research indicate that short-lived radiotracers in partitioning interwell tests can detect fluid saturation in the subsurface. An adaptation of this approach has been proposed to quantify annual baseline soil moisture changes in the vadose zone immediately surrounding an underground storage tank as a leak detection technique. Previous studies have shown that under the ideal conditions of equilibrium partitioning, gaseous water-soluble tracers can quantify the water content in the vadose zone through an extension of earlier developments in partitioning tracers for delineating DNAPL contamination in aquifers and the vadose zone (Deeds, et al., 1999, Jin, et al., 1995, and Whitley, et al., 1999).

A.3 Tables for Design and Operation Considerations

Lessons learned considerations for design and operation were recorded in one of five "topical" tables consisting of operating effectiveness, residual waste/ retrieval effectiveness, leak detection, leak monitoring, and leak mitigation/response; these are provided as Tables A-1 through A-5 respectively. Each entry is listed in the appropriate table along with the lessons learned, a statement regarding relevancy to Tank 241-C-104 and/or 241-S-112 retrieval activities, and reference documentation, with the associated project. Although this information was drawn from a variety of sources, industries, and applications, the "lessons" to facilitate successful deployment of the retrieval systems typically fell into one of the categories listed below:

a) Careful and complete documentation of applicable *functions and requirements* should be completed before the design activities are initiated. They should be managed to ensure effective flow-down to subcontractors. The Project should prepare a compliance matrix to verify that the deployed system satisfies all (100%) requirements.

b) Establish, communicate, and support a clearly defined *deployment strategy* at all levels of design, safety analysis, construction, test, and operations activities. Assign operations personnel to the design team.

c) Effective *system integration* to control all elements of the Project must be achieved with particular emphasis on *configuration management* of all safety and safety related items.

d) *System availability* analysis should be provided to verify compliance with the functions and requirements using the traditional reliability/availability methodologies. Reliability analysis tools can be used to provide needed maintenance and operational flexibility necessary to avoid the operational problems and performance issues experienced in recent tracked-crawler retrieval operations. Examples of known availability issues to address include: loss of in-tank camera visibility due to fogging, misting, and condensation; insufficient physical access to maintain instrumentation; pump and pipeline plugging; ineffective back flushing or screen clearing features; functional failure of the tracked vehicles; and fouling/failure and excessive contamination of tethered control cables.

e) Place the highest level of importance to the *system/operator interface* and associated operator training.

Table A-1 Operating Effectiveness

Section A.3.1	Lesson Learned from Source/ Reference	Relevancy to 241-C-104 and 241-S-112 Retrieval	Considerations for Design and Operation	Source/ Reference
A.3.1.1	"Batch-wise sluicing" operations resulting from overly restrictive authorization basis control, unreliable LDMM methods, and/or insufficient process control are not cost effective. These require repeated startup and shut down operations with line flushing and system lay-up. This results in extended operating scenarios that are labor-intensive and inefficient.	May adversely impact schedule, operating costs and leak risk.	Design an integrated system to be capable of achieving performance criteria through continuous retrieval operations.	ORP W-320 Bailey, 2000.
A.3.1.2	Overly restrictive controls imposed by authorization basis requirements can result in efficiency losses and extended outages when the need for maintenance or troubleshooting arises.	May adversely impact schedule, operating costs and leak risk.	Design an integrated system to provide sufficient operational flexibility to: a) Operate within safety controls, environmental permits, and operating plans for the retrieval operation, and b) Conduct normal maintenance, calibration, and trouble-shooting as required.	ORP W-320 Bailey, 2000.
A.3.1.3	Waste tank cover gas grab samples were used as a basis to set unreasonably low limits for Volatile Organic Compound (VOC) emissions without consideration for organic compounds in the waste. During start-up operations limits for VOC and ammonia exceeded NOC prescribed limits.	May adversely impact schedule, operating costs and leak risk.	Base environmental permits on credible "disturbed waste" characterization information appropriate for operation so that an overly conservative air permit information does not result in operational delays due to NOC issues.	ORP W-320 Bailey, 2000
A.3.1.4	Sluicer hydraulic drive systems over heated during the summer months due to inadequate cooling.	May adversely impact operational safety, schedule, operating costs and leak risk.	Provide adequate temperature control to ensure that components perform as required in the Hanford environment.	ORP W-320 Bailey, 2000.
A.3.3.4	Hold-up of liquid in the hose loop prevented air trapped in the pump impeller casing from moving up into the transfer line; this prevented priming of the pump.	May adversely impact schedule, operating costs and leak risk.	Design flexible hoses and pipes to be self-draining after post-operation flushing and not prevent priming of the transfer pump.	ORP W-320 Bailey, 2000.

Table A-1 Operating Effectiveness

Section A.3.1	Lesson Learned from Source/ Reference	Relevancy to 241-C-104 and 241-S-112 Retrieval	Considerations for Design and Operation	Source/ Reference
A.3.1.5	Overly flexible hoses together with excessive rotation resistance hose linkage resulted in kinking of slurry and sluice pump discharge lines. This caused the system to be inoperable when the pumps were lowered as the liquid level decreased in the tank. As a remedy, the system was operated at overly high liquid levels, which reduced the effectiveness of the sluicing operation.	May adversely impact schedule, operating costs and leak risk.	Design flexible hoses to be the correct length and reinforced (or fitted with support devices) to ensure that rotary linkage performs effectively and no kinking will occur that would compromise the performance of the system	ORP W-320 Bailey, 2000.
A.3.1.6	Poor pump seal performance resulted in excessive quantities of seal gas in the slurry line flow meter used to monitor aqueous fluid streams in the transfer lines. These gas bubbles were indicated as SpGs below 1.0 (i.e., no flow with no slurry solids loading) and inaccurate estimates of volume transferred from the tank.	May adversely impact schedule, operating costs and leak risk.	Design mass transfer instrumentation systems to mitigate the effects of retrieval system failures (e.g. entrained pump seal gas)	ORP W-320 Bailey, 2000.
A.3.1.7	Poor pump seal (and associated seal gas control system) performance resulted in continuous manual adjustment by operations of seal line pressures to maintain manufacturer's guidance for seal gas.	May adversely impact schedule, operating costs and leak risk.	Make provisions for an appropriate pump seal fluid selection and seal pressure control system to minimize requirement for operator intrusion.	ORP W-320 Bailey, 2000
A.3.1.8	Jumper leaks resulted from misalignment for the sluicer assembly and associated equipment.	May adversely impact operational safety, schedule, operating costs and leak risk.	Use flexible joints on ridgid jumper connections when correct alignment cannot be verified. Test all valves installed on jumpers before putting the jumper in service.	ORP W-320 Bailey, 2000
A.3.1.9	Leaks were discovered in a purchased three-way valve; the blocking function of this valve should have been tested before deployment in C-104	May adversely impact operational safety, schedule, operating costs and leak risk.	Cold test all fluid connections and components prior to deployment in the operating system.	ORP W-320 Bailey, 2000
A.3.1.10	Manual flushing after each sluicing batch required removal of cover blocks and the connection of flush water to a process jumper.	May adversely impact schedule, operating costs and leak risk.	Provide the capability to flush slurry/supernatant piping systems without excessive preparations or system modifications, and operator activity.	ORP W-320 Bailey, 2000.

Table A-1 Operating Effectiveness

Section A.3.1	Lesson Learned from Source/ Reference	Relevancy to 241-C-104 and 241-S-112 Retrieval	Considerations for Design and Operation	Source/ Reference
A.3.1.11	Houdini-II maintenance systems (e.g., TMADS) and supporting equipment did not provide adequate features for effective maintenance. Examples include: ▪ Full-length hinges for access panels that were replaced with doors with positive compressive seals. ▪ No means to illuminate the interior of the robot maintenance compartment in a powered-down (safe) state. ▪ Some items (e.g. power supplies) should not have been located inside containment. ▪ Inadequate sealing of the bag-out port during decontamination spraying operations. ▪ Inadequate glove and reach access for required maintenance activities.	May adversely impact operational safety, schedule, operating costs and leak risk.	Maintenance enclosures, tooling, and access features should: ▪ Design closure panels to provide required containment and confinement features for operating, maintenance, stand-by, and decontamination modes. ▪ Provide a separate power supply for maintenance activities when retrieval system power has been locked out. ▪ Whenever possible, locate support equipment outside containment to facilitate servicing and maintenance. ▪ Provide sufficient access to fully maintain and repair equipment.	ORNL GTRP Burks, et al., 2001, & Falter, 1997
A.3.1.12	Houdini-II system suffered from inadequate planning and preparations to effectively address needed maintenance and repair activities.	May adversely impact operational safety, schedule, operating costs and leak risk.	Develop a reliability/availability – based maintenance strategy utilizing qualitative failure mode effects and criticality analysis (FMECA) methodology. Verify that all required design requirements have been met <u>and</u> anticipated maintenance activities can be achieved in a safe manner consistent with good ALARA principles.	ORNL GTRP Burks, et al., 2001, & Falter, 1997

Table A-1 Operating Effectiveness

Section A.3.1	Lesson Learned from Source/ Reference	Relevancy to 241-C-104 and 241-S-112 Retrieval	Considerations for Design and Operation	Source/ Reference
A.3.1.13	MLUDA/Houdini: A complete understanding of the needed maintenance and support tasks was not established prior to design of the tank riser interface compartment (TRIC). This resulted in the need to retrofit and modify TRIC after the fact.	May adversely impact operational safety, schedule, operating costs and leak risk.	Establish a life-cycle operating profile for the system to be deployed and identify required maintenance and support functions and requirements to be included in the technical basis for the retrieval project.	ORNL GTRP Providence Group, 2001 & Falter, 1997
A.3.1.14	System integration issues with the deployment of the MLUDA/Houdini included: ▪ Failure of the tether cable system moisture protection seal; this limited the operation of the crawler to a maximum of 6-8 inches of sludge depth. ▪ Scarifying operations created aerosol-generated fog that rendered the cameras ineffective. ▪ Repeated hydraulic leaks due to incompatible hydraulic component fit-up. ▪ "Drifting" of the vertical positioning system due to use of hydraulic jacks. ▪ Inadequate strength capability of MLUDA during core sampling operations.	May adversely impact operational safety, schedule, operating costs and leak risk.	Systematically integrate project requirements to ensure performance objectives can be met with the deployed system of individual components and sub-systems. Examples would include: ▪ Adequate ventilation to ensure visual observation capability. ▪ Stable support systems with no excessive drifting during operations. ▪ Adequate hydraulic systems sealing capability. ▪ Reliable tether management process.	ORNL GTRP Providence Group 2001, & Falter, 1997
A.3.1.15	MLUDA maintenance systems (e.g. tank riser interface compartment or TRIC) and supporting equipment did not provide adequate features for effective maintenance. Examples include: ▪ Safety concerns that arose when the TRIC had to be open during testing of the gripper end effector (GEE) systems. This lead to a new design for GEE. ▪ Inadequate means to transfer tools and supplies to be transferred into TRIC.	May adversely impact operational safety, schedule, operating costs and leak risk.	Ensure that safety and ALARA requirements are addressed during design and deployment phases with particular emphasis on maintenance and support activities.	ORNL GTRP Providence Group, 2001 & Falter, 1997

Table A-1 Operating Effectiveness

Section A.3.1	Lesson Learned from Source/ Reference	Relevancy to 241-C-104 and 241-S-112 Retrieval	Considerations for Design and Operation	Source/ Reference
A.3.1.16	Logistics of crawler/deployment system (Houdini/MLUDA) operation in the tank identified important issues to address: ▪ An operational/logistics strategy needed to be established to coordinate crawler and sluicer operations below each riser. ▪ The sluicer typically cleared out an area for the crawler to initially operate from.	May adversely impact schedule, operating costs and leak risk.	Prior to initiation of design activities, establish: ▪ An operations and maintenance strategy for retrieval operations (contact or remote maintenance, etc.) ▪ Establish an operating strategy to coordinate crawler/slucier operations. ▪ Include applicable features as system design requirements.	ORNL GTRP Providence Group, 2001 & Falter, 1997
A.3.1.17	Internal instrumentation should have been accessible without breaking containment.	May adversely impact schedule, operating costs and leak risk.	Where feasible, provide direct access to instrumentation systems without breaking containment.	ORNL GTRP Providence Group, 2001 & Falter, 1997
A.3.1.18	Management and control of hydraulic fluids should have prevented oil from leaking into adjacent systems.	May adversely impact operational safety, schedule, operating costs and leak risk.	Provide engineered systems to safely manage hydraulic fluids under normal (operations and maintenance) and off-normal operations.	ORNL GTRP Providence Group, 2001 & Falter, 1997
A.3.1.19	The multiple control system screens were too complex and busy for efficient/effective operations.	May adversely impact schedule, operating costs and leak risk.	Based on operational planning, integrate the control systems/user interface to provide effective means to conduct safe operations.	ORNL GTRP Providence Group, 2001 & Falter, 1997

Table A-1 Operating Effectiveness

Section A.3.1	Lesson Learned from Source/ Reference	Relevancy to 241-C-104 and 241-S-112 Retrieval	Considerations for Design and Operation	Source/ Reference
A.3.1.20	Air conveyance development testing without water injection resulted in: ▪ " ... *approximately ¼ in. of material coating the hose walls. It was necessary to convey water intermittently to keep material from building up on the hose walls*". In spite of these precautions, the system still plugged up. "*At this point a decision was made to install water injection to the nozzle*". The " *technology is a sound option for waste retrieval with some modification to the basic[commercial] design*." ▪ "*It became obvious during testing that a water injection system is imperative to prevent hose plugging while conveying undiluted sludge....*" A system utilizing a water injection device at the feed nozzle and additional injection units placed along the hose runs will be necessary.	May adversely impact schedule, operating costs and leak risk.	If air conveyance is used, integrate water injection in the nozzle and the line. This is required to prevent sludge from building up on the walls and eventual plugging of the system.	Hanford Developmental Test Thompson, 1990
A.3.1.21	Deployment of a confined sluicing end-effector in the ORNL Tank needed to be carefully managed • to avoid premature submersion and possible plugging of end-effector nozzles. Low-pressure flushing of nozzles was not possible during deployment prior to full deployment of the support system masthead. • to control higher pressure operation (>4,500 psi) which caused end-effector "bouncing" and position alarming and control system faulting. Tank wall scarifying, typically carried out at extremely high pressures, was limited by MLUDA's ability to counteract pneumatic forces above 20,000 psi.	May adversely impact schedule, operating costs and leak risk.	Possible plugging of end-effector nozzles should be addressed by: ▪ Carefully planning the deployment and operating sequence. ▪ Making provisions for in-tank recovery e.g. low-pressure flushing) in the event plugging does occur. High pressure operation should be addressed by ▪ Providing a means to counteract hydraulic loads and stabilize in-tank deployment structure to facilitate all phases of retrieval operations.	ORNL GTRP Lloyd, et al., 2001

Table A-1 Operating Effectiveness

Section A.3.1	Lesson Learned from Source/ Reference	Relevancy to 241-C-104 and 241-S-112 Retrieval	Considerations for Design and Operation	Source/ Reference
A.3.1.22	Successful retrieval operations with MLUDA/Houdini were made possible due to built-in system flexibility. For example, back-drivable joints allowed Houdini to drag the sluicing end-effector to the desired location. Most equipment could be operated in multiple modes (e.g. local versus remote, manual versus automatic). This permitted operations to adapt to varying conditions, maintenance needs, and testing requirements.	May positively impact schedule, operating costs and leak risk.	See item A.3.1.18 where it states: *"Provide engineered systems to safely manage hydraulic fluids under normal (operations and maintenance) and off-normal operations."*	ORNL GTRP Lloyd, et al., 2001
A.3.1.23	The MLUDA/Houdini maintenance systems facilitated ready removal of key support system components to minimize hoisting and rigging, and space for lay-down while controlling contamination. Replacement of the retrieval system hose management assembly could be achieved without breaking tank vapor space containment. Decontamination of components during removal from the tank was achieved with "designed-in" elements integrated into the retrieval system. In addition end-of-shift flushing capability was also provided as part of the system.	May positively impact schedule, operating costs and leak risk.	See item A.3.1.16 where it states: *"Prior to initiation of design activities, establish:* ▪ *An operations and maintenance strategy for retrieval operations (contact or remote maintenance, etc.)* ▪ *Establish an operating strategy to coordinate crawler/slucier operations.* ▪ *Include applicable features as system design requirements."*	ORNL GTRP Lloyd, et al., 2001

Table A-1 Operating Effectiveness

Section A.3.1	Lesson Learned from Source/ Reference	Relevancy to 241-C-104 and 241-S-112 Retrieval	Considerations for Design and Operation	Source/ Reference
A.3.1.24	Various weaknesses were identified during the MLUDA/Houdini deployment consisting of operator ergonomics, maintenance issues, instrumentation deficiencies, and control system faults; these included: ▪ Glove box location and configuration limited tool handling, retraction, and maintenance operations. ▪ Lengthy and demanding process to deploy the main handling system (10 cable and 3 hose connections) ▪ Limited range/rotation of cable and hose management systems required periodic disassemble and reassembly of equipment. ▪ Replacement of a cable was necessary – made possible only because of a spare conduit was included in the design. ▪ "Coriolis" (FE-204) flow meter, was "completely ineffective" due to the highly dynamic 3-phase flow characteristics with significant "slugs" of air. ▪ Debris clogging the screen on the waste inlet. (However, this did prevent pump blockage.) ▪ Contamination traps in confinement box on tank riser. ▪ Inability to replace rupture disks. ▪ Poor seal design in the rotating end-effector. ▪ The control system was not capable of detecting a disconnected control cable; operations needed to de-energize and safely shut down system to conduct trouble shooting activities.	May adversely impact operational safety, schedule, operating costs and leak risk.	See item A.1.1.16 where it states: *"Provide engineered systems to safely manage hydraulic fluids under normal (operations and maintenance) and off-normal operations."* ▪ Provide visual assess for inspections ▪ Provide temporary power for maintenance ▪ Provide a variety of end-effectors to achieve performance objectives ▪ Mount flow instruments in vertical orientation to eliminate air pockets ▪ Provide for signal and control cable disconnection detection alarms.	ORNL GTRP Lloyd, et al., 2001

Table A-1 Operating Effectiveness

Section A.3.1	Lesson Learned from Source/ Reference	Relevancy to 241-C-104 and 241-S-112 Retrieval	Considerations for Design and Operation	Source/ Reference
A.3.1.25	During testing of the EMMA (Manufactured by GreyPilgrim, LLC). GreyPilgrim robotic manipulator, *"barrels used to receive conveyed waste imploded"*. This was the result of an instantaneous seal being made between the end-effector and surfaces of a waste tray *"because of high vacuum created"*. A scalloped hard rubber shroud used to prevent contact between the scarifier and the waste surface did not function well. *"One solution is to redesign the skirt"*. The possibilities include: ▪ Simple passive compliance via springs and contact shoe or caster to affect a compliant motion normal to the waste surface. ▪ A scalloped edge or other skirt design to allow proper airflow while maintaining contact with the waste surface. Other solutions might be: ▪ Active compliance proportional to ultra-sound surface distance feedback or vacuum sensor or tactile or capacitance sensor. ▪ Larger shroud (24"). ▪ Higher power blower. ▪ Hardened closed circuit digital cameras mounted at various points on arm to provide more information to operator." ▪ Use stronger drums. ▪ Use direct computer control of the e-stops to automate response instead of manual response.	May adversely impact schedule, operating costs and leak risk.	Establish (verify) methods to control vacuum suction and prevent loss of control suction cup (end-effector) distance to hard surface. These might include a variety of distance control systems, suction cup configuration, and vacuum rating of the components prone to damage.	Hanford HTI GreyPilgrim, 1997
A.3.1.26	GreyPilgrim: Vacuum hoses "flattened along two locations and split in several others".	May adversely impact schedule, operating costs and leak risk.	Size the retrieval system hoses for the maximum vacuum and better strength to prevent collapse and splitting under vacuum.	Hanford HTI GreyPilgrim, 1997.

Table A-1 Operating Effectiveness

Section A.3.1	Lesson Learned from Source/ Reference	Relevancy to 241-C-104 and 241-S-112 Retrieval	Considerations for Design and Operation	Source/ Reference
A.3.1.27	GreyPilgrim: During testing, "... *it was observed that momentary setbacks or sudden stops in arm motion would lead to residual vibrations. These vibrations would generally take the form of free vibration response, a natural frequency of about 0.5 Hz, lightly damped (10 or 20%), and a peak to peak vibration of about 2 inches or so. This residual vibration is unacceptable for service unless it can be controlled. This could be mitigated by special operator action, which requires an extra skill. Another way to control this is through the control algorithm.*"	May adversely impact schedule, operating costs and leak risk.	Design and test the arm for the frequencies in the operation range and also design for proper vibration damping. To mitigate this effect, use experienced and well-trained operators and/or revise the control algorithm.	Hanford HTI GreyPilgrim, 1997
A.3.1.28	GreyPilgrim: Limitations of the Deployment System – Issues regarding actual underground storage tank applications include: ▪ The ceiling above the tank (head space) should allow enough motion for the elevator movements. ▪ Allow adequate space for the actuator and its movements. ▪ Provide adequate space in the actuator room. ▪ Allow enough room so the pivot could be fully utilized.	May adversely impact schedule, operating costs and leak risk.	Design the system for adequate space for the elevator, pivot, and the actuator to be fully utilized.	Hanford HTI GreyPilgrim, 1997.

Table A-1 Operating Effectiveness

Section A.3.1	Lesson Learned from Source/ Reference	Relevancy to 241-C-104 and 241-S-112 Retrieval	Considerations for Design and Operation	Source/ Reference
A.3.1.29	Cybernex (France): ▪ A vital element for safe robotic operations is real-time response for "force-feedback" or tracking system applications. This requires highly responsive, good quality feedback, frequently with fragile components, operating in a very hazardous environment. ▪ ***"An ill-designed cable management system can significantly impair the capabilities to perform tasks efficiently."*** Some systems are being developed with reduced (eliminated) cabling systems. RF spread-spectrum or ultra sound technologies are being used to exchange data between the vehicle and controller.	May adversely impact operational safety, schedule, operating costs and leak risk.	▪ Consider response time as a performance parameter for feedback for tracking or force-feedback applications instrumentation. ▪ Identify and control critical operational requirements. ▪ Effective cable (umbilical, tether) management is critical for successful deployment of a robotic system. Consider alternate technologies to communicate with the robotic (remote system) device.	Non-DOE Cybernetics Fidani, 2001
A.3.1.30	Toshiba (Japan): Low-cost, high reliability robots with fewer degrees of freedom with relatively simple control systems are used to perform dedicated tasks. Collectively, these components accomplish complex tasks normally requiring a robot with many degrees of freedom (DOF) and a complex control system.	May positively impact schedule, operating costs and leak risk.	High reliability performance at relatively low cost robotic systems can be deployed using task-specific sub-systems requiring simpler control systems as an alternative to complex expensive multi-degree of freedom systems. Note – integrate with FMECA activities identified in section A.3.1.12: ***"...Develop a reliability/availability – based maintenance strategy utilizing qualitative failure mode effects and criticality analysis (FMECA) ... "***.	Non-DOE Toshiba FDH, 1999

Table A-1 Operating Effectiveness

Section A.3.1	Lesson Learned from Source/ Reference	Relevancy to 241-C-104 and 241-S-112 Retrieval	Considerations for Design and Operation	Source/ Reference
A.3.1.31	Development of the PIONEER crawler robot for Chornobyl applications identified several lessons learned and recommendations for future applications: ▪ Use of an on-board robot power distribution system would reduce the cross-section, weight, and stiffness of the tether. ▪ Place the highest priority on "operator ease" (e.g. remote viewing system).	May positively impact schedule, operating costs and leak risk.	Assess design trade-offs to enhance operability of remote system: ▪ Reduce tether weight and stiffness through careful selection of power distribution – even at the expense of robot weight and cost. ▪ Identify features early in the design phase to enhance operability of the system; manage these as high-priority objectives.	DOE/ NASA Chernobyl Osborn, 2001
A.3.1.32	Pipeline Unplugging Technologies were tested with the conclusion that several viable alternatives are commercially available. One innovative approach from Atlantic Group's Hydrokinetics used sonic resonance together with high pressure water to clear plugged lines.	May positively impact schedule, operating costs and leak risk.	Integrate available pipe unplugging technology into the retrieval system as a contingency/recovery feature during operation.	DOE/ FL Interna-tional University Sukegawa, et al., 2001
A.3.1.33	PNNL developmental, non-intrusive, ultrasound sensor to measure density in air-entrained waste slurries. Designed to operate in flammable gas environments, this system has completed several laboratory tests and is scheduled to be installed on Tank 241-SY-101 at Hanford.	May positively impact schedule, operating costs and leak risk.	Assess performance applicability of ultrasound density sensor for 241-C-104 retrieval operations. Integrate into design as appropriate.	DOE PNNL Bamberger, et al., 2001

Table A-1 Operating Effectiveness

Section A.3.1	Lesson Learned from Source/ Reference	Relevancy to 241-C-104 and 241-S-112 Retrieval	Considerations for Design and Operation	Source/ Reference
A.3.1.34	Provides an alternative to run-to-failure mentality typical of a "corrective" maintenance philosophy, which is in-appropriate where the consequence of failure is high [i.e. as in in-tank robotic applications such as 241-C-104]. Condition-based operations and maintenance (CBM) offers an approach less costly than preventive or predictive-based methods but more effective than corrective maintenance. Two key characteristics: ▪ Operations ownership in the need to recognize and correct the existence of an abnormal condition. ▪ Pro active identification, through root cause analysis, of the fundamental stressors (parameters outside the design envelope) responsible for off-design conditions.	May positively impact schedule, operating costs and leak risk.	Consider planning to implement condition-based operations and maintenance (CBM) methodologies concurrently with conceptual and definitive design to establish relationships between failure modes, stressors that could lead to system failure. Select and integrate appropriate sensors into the retrieval system design activity. Note – integrate with FMECA activities identified in section A.3.1.12: "*...Develop a reliability/availability – based maintenance strategy utilizing qualitative failure mode effects and criticality analysis (FMECA) ...*".	DOE NERI Jarrel, 2001

Table A-1 Operating Effectiveness

Section A.3.1	Lesson Learned from Source/ Reference	Relevancy to 241-C-104 and 241-S-112 Retrieval	Considerations for Design and Operation	Source/ Reference
A.3.1.35	SRS lessons learned from deployment of a prototype "bagless" transfer system: ▪ Reliability – Schedule pressures resulted a "business decision" not to conduct reliability tests. A "demonstration" unit became the production unit and materials and parts wore out. This resulted in unplanned down time for repairs. ▪ Defense in Depth – insufficient process administrative and engineered controls led to undetected quality problems during operation. ▪ Training – Although a large investment was made during trouble shooting of problems, learning-curve challenges could have been more effective managed if more time had been spent with "…in-depth component specific training …. From….vendors..". In addition, operations and maintenance personnel should have been more involved with development, assembly, testing and troubleshooting. ▪ Resources – Too few engineers that were involved with deployment of the production unit stayed with the project through deployment and operation. This is a critical issue with first-of-a-kind development (or prototype) units.	May adversely impact schedule, operating costs and leak risk.	▪ Develop project and deployment planning with due consideration for reliability testing and process quality assurance. ▪ Address operator and maintenance personnel training and retention of key technical staff through the transition to operations with project "corporate history" to solve problems. Note – integrate with FMECA activities identified in section A.3.1.12: *"…Develop a reliability/availability – based maintenance strategy utilizing qualitative failure mode effects and criticality analysis (FMECA) …".*	SRS Bayer, et al., 2001

Table A-1 Operating Effectiveness

Section A.3.1	Lesson Learned from Source/ Reference	Relevancy to 241-C-104 and 241-S-112 Retrieval	Considerations for Design and Operation	Source/ Reference
A.3.1.36	DNSFB TECH-30 identified several lessons learned which are applicable to any retrieval technology-based project: ▪ A comprehensive Preliminary Safety Analysis Report should be prepared to provide a basis for an integrated review of the facility design. This will avoid overly conservative assumptions, numerous activities to confirm the validity of early assumptions, and potential changes to the safety classification of components late in the project evolution. ▪ Thorough, timely, integrated design reviews during early phases of the project, including PSAR documentation, are necessary to avoid delays and excessive costs in later phases of the project. This should include development of matrices to assess compliance (design verification) with all applicable requirements. ▪ Effective implementation and management of quality assurance requirements for sub-contractors is necessary to avoid deficiencies with procured equipment (e.g. cleanliness requirements for valves, welding quality assurance) ▪ Preoperational test planning must ensure that appropriate rigor is provided to conduct and document tests. Emphasis should be placed on integrated tests rather than relying on tests of individual components and subsystems. Sufficient schedule should be provided to allow for recovery for failures or deficiency identification during testing.	May positively impact operational safety, schedule, operating costs and leak risk.	Develop project design/development construction and deployment planning with due consideration for design reviews (i.e. verification – including testing), quality and technical requirements management, and preliminary safety analysis early in the evolution of the project. Note – integrate with FMECA activities identified in section A.3.1.12: *"...Develop a reliability/availability – based maintenance strategy utilizing qualitative failure mode effects and criticality analysis (FMECA) ...".*	DOE DNSFB Hanford DNFSB, 2001b

Table A-1 Operating Effectiveness

Section A.3.1	Lesson Learned from Source/ Reference	Relevancy to 241-C-104 and 241-S-112 Retrieval	Considerations for Design and Operation	Source/ Reference
A.3.1.37	The Year 2000 DNSFB report to Congress identified a number of lessons learned-type items for DOE implementation based on specific DOE-complex experiences that are applicable to 241-C-104 retrieval: ▪ Project design criteria were not prepared at the outset of the project. ▪ Failure to maintain storage tank chemistry within specified limits. ▪ Failure to assign ***system engineers*** (subject matter experts) to all safety <u>processes</u> and <u>systems</u> with: 1. Requisite knowledge of system safety design basis and operating limits from the safety analysis. 2. Lead responsibility for the configuration management of the design. ▪ Failure to impose appropriate safety requirement through procurement contracts. ▪ Failure to impose industry standards for reliability requirements for safety-related instrumentation and control systems.	May adversely impact operational safety, schedule, operating costs and leak risk.	Develop project and deployment planning with due consideration for: ▪ Project design criteria ▪ Maintain operating safety criteria within limits. ▪ Technical management of system safety requirements and associated configuration management of the design. ▪ Management of flow-down of quality and safety requirement to sub-contractors. ▪ Reliability standards for safety-related instrumentation and control systems. Note – integrate with FMECA activities identified in section A.3.1.11: *"...Develop a reliability/availability – based maintenance strategy utilizing qualitative failure mode effects and criticality analysis (FMECA) ..."*.	DNSFB DOE-Complex DNSFB. 2001a & DNFSB, 2000
A.3.1.38	DNSFB recommendation for DOE criticality safety programs were for: ▪ More formalized and robust reviews to ensure requirements are met. ▪ Formalized surveillance, maintenance, and configuration control management process for those design features should be implemented.	May positively impact operational safety, schedule, operating costs and leak risk.	Develop project and deployment planning with due consideration for: ▪ Criticality safety reviews. ▪ Configuration management, surveillance, and maintenance of criticality safety design features.	DNSFB DOE-Complex DNSFB, 2001

Table A-1 Operating Effectiveness

Section A.3.1	Lesson Learned from Source/ Reference	Relevancy to 241-C-104 and 241-S-112 Retrieval	Considerations for Design and Operation	Source/ Reference
A.3.1.39	Rockwell Tank Farm experience from SST strontium retrieval operations in 1989-1990: ▪ Heavy duty, single-stage, centrifugal pumps built by Barrett Haentjens (Hazleton, PA) generally gave years of service under extreme operating conditions operating at 350 to 400 gallons per minute with SST heavy slurry. Bearings were water lubricated and completely isolated from the process liquids. ▪ Turbine-type pumps were used during final SST cleanout operations involving very low slurry concentrations, but were not suitable for the massive sludge transfers during normal sludge recovery operations. ▪ Pumps that provided long trouble free service in the AR-Vault transfer operation: single-stage, water-lubricated, centrifugal pumps, for sluicing and slurry transfer service; stainless steel, multi-stage, deep-well turbine pumps for clarified sludge. ▪ Standard Hanford deep-well turbine (TX-1) pumps were used to transfer thickened slurry. Service life was very short due to the abrasiveness of the slurry and the constant shaft and bearing stress produced by the powerful agitation in the tank and the resultant pump column flexing. Even heavy bracing of the pump columns could not alleviate the shaft breakage problem; the use of the standard pumps had to be discontinued.	May positively impact schedule, operating costs and leak risk.	▪ Applicable retrieval pump operational experience, which led to successful operations with heavy sludge and low-concentration slurries. Consider need to fully characterize material to be retrieved to ensure successful pump operation.	Hanford Tank Farms Rasmussen, 1980

Table A-1 Operating Effectiveness

Section A.3.1	Lesson Learned from Source/ Reference	Relevancy to 241-C-104 and 241-S-112 Retrieval	Considerations for Design and Operation	Source/ Reference
A.3.1.40	During final SST sludge cleanout it became increasingly difficult to recover the sludge when the level in the tank decreased to a depth of 4 to 6 inches. More elaborate equipment and procedures were then required: ▪ Use of skirted, adjustable length slurry pumps to allow sluicing at the minimum liquid inventory essential for effective sludge recovery. ▪ Frequent in tank photography to chart sludge accumulation. ▪ Radiation monitors on sluice and slurry lines to measure sludge recovery. ▪ Carefully pre-planned sluicing strategies to move sludges toward the pump intake. ▪ Frequent sluicer direction changes to hit sludge concentrations from different angles. ▪ Fitting the intake of the slurry pumps with "funnels" to permit operation at low liquid levels; these funnels were massive enough to support the entire weight of the pump when necessary. High-pressure water nozzles were used to sluice the pumps into the sludge during initial installation. ▪ Aiming the sluicing nozzle precisely by means of a calibrated sluicer control unit calibrated head that provides for both horizontal and vertical adjustments and allows for accurate sluicing of the tank bottom area. The sluicer consisted of (1) high pressure water supply system, and (2) the nozzle aiming mechanism. ▪ The liquid level in the sluiced tank was kept as low as possible to maximize sluice stream penetration power.	May positively impact schedule, operating costs and leak risk.	Applicable retrieval pump operational experience: ▪ Sludge recovery technique for last 4-6 inched of tank bottoms. ▪ Instrumentation and surveillance methods to support retrieval. ▪ Sluicer positioning and operation.	Hanford Tank Farms Rasmussen, 1980

Table A-1 Operating Effectiveness

Section A.3.1	Lesson Learned from Source/ Reference	Relevancy to 241-C-104 and 241-S-112 Retrieval	Considerations for Design and Operation	Source/ Reference
A.3.1.41	SST sludge recovery was closely monitored with a radiation probe on the slurry line. After 1-2 days of sluicing, the tank would be pumped down and photographed to determine progress and the need for further sluicing. In some tanks the tank bottom was cleared to bare metal. In some cases the particles were so large sluicing was required to literally wear particles down. Because of the heat producing strontium present in the tank infrared scanner was used in a system developed by Barnes Engineering Corporation to make temperature profile plots of the tank	May adversely impact schedule, operating costs and leak risk.	Consider instrumentation and surveillance methods to support retrieval.	Hanford Tank Farms Rasmussen, 1980
A.3.1.42	Feature Tests of a pneumatic Needle Scaler were conducted with various simulated waste configurations and on steel and masonry surfaces. These tests indicated that devices of this type could provide effective tools to facilitate retrieval. Deployment of a linear scarifying end-effector was not successful due to deployment difficulties resulting from inadequate integration into the overall retrieval "system".	Inadequate integration may adversely impact performance.	(see item A.3.1.14 regarding integration of required design elements into a system)	Hanford Tank Farms Squires, 1990 & Fitzgerald, 2001
A.3.1.43	Feature tests of Sine pumps indicated that the pump is capable of meeting the required pressure and flow at high viscosities. However, rapid wear with the soft (elastomer) components was experienced. Resolution of this will require additional development work. Feeding the pumps from the inlet hopper was another problem. Residue build-up on the interior hopper walls impeded flow of the product into the pump.	May adversely impact schedule, operating costs and leak risk.	The SINE pumps (positive displacement - used in the food industry) are capable of meeting retrieval flow and pressure requirements including ability to pump very viscous materials, but will require development of improved elastomer components.	Hanford Squires, 1990a

Table A-1 Operating Effectiveness

Section A.3.1	Lesson Learned from Source/ Reference	Relevancy to 241-C-104 and 241-S-112 Retrieval	Considerations for Design and Operation	Source/ Reference
A.3.1.44	The SRS structural integrity program conducted a comprehensive analysis of waste tanks and piping to assess past failures, failure mechanisms, and ageing effects. This resulted in some lessons learned applicable to SST retrieval activities. Many of these offer guidance for path-forward activities to avoid past system integrity issues that resulted on operational impacts and leaks to the environment.	May positively impact operational safety, schedule, operating costs and leak risk.	Develop project and deployment planning with due consideration for: ▪ Chemistry controls to avoid corrosive conditions. ▪ Chemistry monitoring to verify operation within control limits. ▪ Procurement and system operation. ▪ Use inspection processes to ensure structural integrity. ▪ Operational controls to prevent piping failures resulting from typical failure modes such as stagnant water, stress corrosion cracking, pitting, etc.	SRS SRS, 1995

Table A-1 Operating Effectiveness

Section A.3.1	Lesson Learned from Source/ Reference	Relevancy to 241-C-104 and 241-S-112 Retrieval	Considerations for Design and Operation	Source/ Reference
A.3.1.45	ORNL operation of the confined sluicing end effector (CSEE) in GAAT retrieved approximately 7,200 gal of supernatant above the sludge, 5,500 gal of sludge at the bottom of the tank, and 0.1 in of the scale from the tank wall. Less than 0.5% of the tank volume remained as a final residue waste. The retrieval of tank W-3 used 41,800 gal of water, which was added to the waste stream, at a ratio of 3.3:1. This includes water used by the jet pump, flushing operations, and equipment decontamination. Approximately one third of the water was used for scarifying operations and two thirds was from jet pump operations.	Actual volume results in a radioactive waste environment.	Develop project and deployment planning with due consideration for: ▪ Reduced water usage through careful coordination of the activities. ▪ Riser access to accommodate equipment (for this demonstration 24" for Houdini &12" for MLDUA) [see A.3.1.11-15] ▪ Accommodation of in-tank to access all tank locations. ▪ Verification that any additional tank dome loads is within safety allowables. ▪ The addition of a "holster" to provide temporary parking of the CSEE. ▪ Provisions for a means to clear the conveyance inlet screen. (Back flushing with low pressure is not effective and uses a significant amount of water.)	ORNL GATT TFA, 1999

Table A-1 Operating Effectiveness

Section A.3.1	Lesson Learned from Source/ Reference	Relevancy to 241-C-104 and 241-S-112 Retrieval	Considerations for Design and Operation	Source/ Reference
A.3.1.46	The Hanford Tanks Initiative contracted to conduct feature tests designed to establish a better understanding of the technical challenge ahead for deployment of retrieval systems in tanks. ▪ The maneuverability of the tracked vehicle seemed to have an edge over the wheeled vehicle, whereas the wheeled vehicle seemed to have superior ability to get unstuck. The wheeled vehicle was superior to the tracked vehicle in dislodging and breaking up material. ▪ The complex control system in the wheeled vehicle needed to be redesigned to give the operator simpler controls. ▪ The tracked vehicle was jammed repeatedly with small rocks in its tracks; these were successfully un-jammed. A very hard object in a track created a failure mode from which recovery was difficult; the wheeled vehicle mobility and its ability to recover from a failed condition appear to be much better. ▪ A vehicle was weighed before and after decontamination where it was determined that 27 lbs of waste material was removed with 2 lbs remaining. Hold-up of material was worse for the tracked vehicle. ▪ It would be desirable to have multiple tank cameras, all equipped with zoom, pan ,and tilt, so the operator could view the work area no matter where the vehicle was in the tank.	May adversely impact schedule, operating costs and leak risk.	Applicable retrieval pump operational experience: ▪ Ensure that a tracked vehicle if used can be effectively maneuvered in the SST waste material, and decontaminated. ▪ Verify system availability (reliability/maintain-ability) will support deployment objectives; an effective means for recovery from faulted (stuck) conditions needs to be provided. ▪ Lighting and camera systems need to be able support operations throughout the tank and under all operating conditions (mist, fog, - see A.3.1.14 and 48) ▪ Operator training should be provided before deployment to ensure efficient in-tank operations and verify operator/ machine interface needs. (See A.3.1.35) Note – integrate with FMECA activities identified in section A.3.1.11: "*...Develop a reliability/availability – based maintenance strategy utilizing qualitative failure mode effects and criticality analysis (FMECA) ...*".	Hanford HTI Berglin, et al., 1997

Table A-1 Operating Effectiveness

Section A.3.1	Lesson Learned from Source/ Reference	Relevancy to 241-C-104 and 241-S-112 Retrieval	Considerations for Design and Operation	Source/ Reference
A.3.1.47	Hanford Tanks Initiative Vehicle Based Waste Retrieval (non-radioactive) Demonstration Report provided information from feature tests regarding in-SST vehicle operation: ▪ A 100-ft long umbilical was intentionally dragged against the simulated risers to prove the ability a Trac-Pump to negotiate riser obstacles. Minimum bend radius of the umbilical under power of the Trac-Pump was 3 ft. The turn radius of the Trac-Pump assembly was 8 ft. Fifty feet of 5-inch tank-car hose was retrieved and deployed 3 times. ▪ Solids concentration in the waste determined the amount of make-up water required, partial re-circulation of the discharged slurry could be used to minimize the amount of make up water required. A grinder type re-circulation pump could be used to further process the solids. ▪ The back flush system was tested by intentionally blocking the discharge manifold with salt cake; it was unplugged within 1 minute with a 13-gpm 2000psi water jet. The second section was blocked with hardpan and took 3000 psi pressure to unblock it. ▪ Tests were conducted to identify additional features to facilitate assembly, maintenance, and decontamination. The need for a maintenance schedule was identified to verify that all necessary design features have been identified.	May adversely impact schedule, operating costs and leak risk.	Applicable retrieval pump operational experience: ▪ Umbilical system operating characteristics. ▪ Re-circulating water utilization. ▪ Pump inlet back flushing characteristics. ▪ Design for maximum system operational availability.	Hanford HTI ESG, L.L.C., 1997

Table A-1 Operating Effectiveness

Section A.3.1	Lesson Learned from Source/ Reference	Relevancy to 241-C-104 and 241-S-112 Retrieval	Considerations for Design and Operation	Source/ Reference
A.3.1.48	A comprehensive report is available documenting sluicing Hanford operations for 43 tanks from 1952-1957, 10 tanks from 1962-1978 as well as rail cars and several other S-farm tanks. This provides a history of sluicing operations including sludge and heel removal and information regarding equipment (including pumps) failure histories and clean-out time cycles. Of particular interest are the methods used to control fogging and misting to improve the visibility inside the tanks during operations.	May adversely impact schedule, operating costs and leak risk.	Develop project and deployment planning using this operational and equipment performance history as a basis to make key conceptual and definitive design decisions. This would be useful information to support FMECA activities identified in section A.3.1.12: "*...Develop a reliability/availability-based maintenance strategy utilizing qualitative failure mode effects and criticality analysis (FMECA)...*".	Hanford Tank Farms Rodenhizer, 1987
A.3.1.49	The Easily Manipulated Mechanical Arm (EMMA) used FMECA and RAM risk analysis methods as design tools. "*.....The level of analysis and documentation has to commensurate with their relative importance to safety, risk, complexity of the activity, equipment life cycle, and their importance to the key functional goals . The Failure Mode and Effect Analysis (FMEA) and Reliability, Maintainability, and Availability (RMA) have been done systematically. ......, the probability and consequence of failures are evaluated and the risk factors are calculated for the systems, structures and components. Then the risk factors are translated to performance grade. With five grade levels, (PG-1 requiring the highest level of control and management), it has been determined that the deployment tower qualifies for PG-4 and the other systems and structures are PG-5. The system should provide a 10-year operating life with MTBF of 1,000 hr.....*"	May adversely impact operational safety, schedule, operating costs and leak risk.	Use FMECA and RAM as design tools to meet functions and requirements. See also section A.3.1.12 "*.... Develop a reliability/availability-based maintenance strategy utilizing qualitative failure mode effects and criticality analysis (FMECA)...*".	Huang, et al.

Table A-1 Operating Effectiveness

Section A.3.1	Lesson Learned from Source/ Reference	Relevancy to 241-C-104 and 241-S-112 Retrieval	Considerations for Design and Operation	Source/ Reference
A.3.1.50	Resolution of the 241-SY-101 Surface Level Rise issue was achieved using traditional project management methods and tools. These consisted of planning the work, assigning a dedicated team, managing change control, tracking performance measures to closure, and documenting close-out of the work. Specific steps contributing to the success of this effort included: ▪ Assembling a dedicated project team with clear roles and responsibilities, schedule, and objectives. ▪ Measurable performance objectives. ▪ Characterization of interfaced and operational constraints. ▪ Rigorous and timely change control. ▪ Building consensus with client (including operations) , oversight organization, and project team participants. ▪ Effective and frequent communication with team members.	May adversely impact schedule, operating costs and leak risk.	Attributes for a successful project include: ▪ Defined scope managed through change control. ▪ Dedicated team, co-located, participating in frequent (daily) status meeting. ▪ Detailed WBS and resource-loaded schedule with no activity longer than 2 weeks. ▪ Cost estimated based on detail planning. ▪ Defined design process (including design verification). ▪ Pre-deployment testing of equipment and training of operators. ▪ Performance metrics defined and measured. ▪ Strict configuration management of the technical baseline (scope, schedule, technical basis). ▪ End state clearly defined and achieved.	CHG, 2001a and CHG, 2001b

Table A-1 Operating Effectiveness

Section A.3.1	Lesson Learned from Source/ Reference	Relevancy to 241-C-104 and 241-S-112 Retrieval	Considerations for Design and Operation	Source/ Reference
A.3.1.51	The 241-AZ-101 Mixer Pump lessons learned identified items applicable to planned 241-C-104 retrieval: ▪ A realistic, resource-loaded schedule should be developed and staffed accordingly. ▪ Design issues that should have been addressed early impacted the reliability of the mixer test systems and equipment. ▪ Investing more resources (funding) up-front in the project would have resulted in fewer problems during testing.	May adversely impact schedule, operating costs and leak risk.	Efforts need to be made to: ▪ Provide a realistic schedule, resource-loaded to provide realistic support to Project activities. ▪ Develop a cost estimate based on detail planning; provide staff resources accordingly. ▪ Implement a rigorous design process to ensure reliable system performance.	Hanford AZ-101 CHG, 2001b
A.3.1.52	Numerous applications of "Hydrotransport™" technologies based on TORE® systems have been successfully deployed in the petrochemical, mining, nuclear, and water utility industries. Typically these are used for water-oil/sludge separation and entrained solids removal. In some cases the removed solids are also cleaned using the same technology. A family of products is available to perform many functions to clean, trap, separate, and transport fluids or fluidized solids. Typical stream flow rates of 1300 GPM transporting >20 micron solids.	May adversely impact operational safety, schedule, operating costs and leak risk.	Thorough feature testing and process control system characterization is critical to successful operation of these systems. The TORE® principle of operation is based on a phenomenon know as a "precessing" vortex core (PVC). Careful integration of these products into the design application is important to maximize the effectiveness of the chosen system. For example, solids removal may be required upstream of the separators. Liner materials must consider erosion due to fluid velocities.	Industrial Application Merpro Limited, 2001a, b, c, and d.

Table A-1 Operating Effectiveness

Section A.3.1	Lesson Learned from Source/ Reference	Relevancy to 241-C-104 and 241-S-112 Retrieval	Considerations for Design and Operation	Source/ Reference
A.3.1.53	System plugging feature and pilot-scale testing of waste slurry transport equipment configuration was conducted to: ▪ Identify operating parameters and feed conditions that may cause solids formation and transfer line plugging. ▪ Establish correlation of observed data to enable prediction of slurry transport characteristics. ▪ Provide engineering data and technical recommendations.	May adversely impact operational safety, schedule, operating costs and leak risk.	Feature testing of equipment configurations provides necessary verification of key system design attributes. Specific findings established that feed temperatures (50° C and higher) and flow rates (>3 fps) were critical process control parameters to prevent plugging.	US-DOE funded University research Ebadian, 2001, and PNNL TFA, 2001
A.3.1.54	Solution mining information is available from the Salt Institute and Solution Mining Research Institute. These provide a resource for equipment suppliers, operational experience, technical resources, and independent reviews.	May adversely impact operational safety, schedule, operating costs and leak risk.	A large industrial community exists with a great deal of experience with the design, manufacture, and operation of solution mining systems. In addition, resources are available to provide consulting services and informational exchanges with the international salt mining industry.	Industrial Application Salt Institute, 2001
A.3.1.55	Parametric studies were completed and provide design basis information regarding leach times, brine production rates, and specific gravity.	May adversely impact operational safety, schedule, operating costs and leak risk.	Predictive performance models and operational experience is provided from multiple solution mining sites. These analytical tools and operational data may be useful to establish design basis requirements, design solutions, and subsequent operational control methods for SST retrieval.	Industrial Application Bauer, 1998
A.3.1.56	Laboratory tests results were used to assess modeling capability of computer simulations from ESP (Environmental Simulation Program). The results indicate that ESP predictions compare favorably with: ▪ Amounts of water required for dissolution ▪ Concentration of each constituent after it was dissolved.	May adversely impact schedule, operating costs and leak risk.	Laboratory tests results are available to validate the results of dissolution models to establish critical attributes of salt wastes retrieved using dissolution technology.	Hanford Herting, 2000

Table A-1 Operating Effectiveness

Section A.3.1	Lesson Learned from Source/ Reference	Relevancy to 241-C-104 and 241-S-112 Retrieval	Considerations for Design and Operation	Source/ Reference
A.3.1.57	Laboratory tests demonstrate that concentrated salt solutions can be produced and removed from dry salt tanks while maintaining minimum liquid inventory in the tank.	May adversely impact operational safety, schedule, operating costs and leak risk.	Dissolution of dry salt in tanks would be expected to: ▪ Not produce significant channeling if used with a sprinkler system dispersing water uniformly. ▪ Result in very high solution saturation levels, which may cause clogging of pumps and transfer lines. ▪ Cause preferential dissolution of salt species and corresponding depletion of hydroxide and nitride corrosion inhibitors; this may require the addition of additional hydroxide to the dissolution water.	SRS Wiersma, 1997
A.3.1.58	Laboratory tests of simulated waste were conducted to examine impact on in-tank corrosion controls resulting from various methods of dissolution retrieval. Water with and without inhibitors was added to saltcake and relationships established for various density gradient dissolution methods. These included: ▪ Drain-Add-Sit-Remove ▪ Modified Density Gradient ▪ Continuous Salt Mining Determinations were made regarding retrieval attributes and potential impact on tank corrosion controls.	May adversely impact operational safety, schedule, operating costs and leak risk.	There are important relationships between key process parameters for dissolution retrieval. Examples include: ▪ rate of dissolution ▪ degree of channeling or short circuiting ▪ solution temperature ▪ particular method of density gradient dissolution ▪ retrieval rates ▪ elevation of outlet lines ▪ changes in corrosion inhibitor concentration. These should be evaluated and controlled to maintain required corrosion controls during retrieval.	SRS Wiersma, 1996

Table A-2 Residual Waste/ Retrieval Effectiveness

Section A.3.2	Lesson Learned from Source/ Reference	Relevancy to 241-C-104 and 241-S-112 Retrieval	Considerations for Design and Operation	Source/ Reference
A.3.2.1	Sluicer performance in large waste tanks has not met expectations due to inadequate verification of performance prior to deployment. This has been compromised further due to "de-tuning" of the sluicer system in an attempt to: ▪ reduce aerosols/evaporation resulting in gas in the mass flow meter ▪ reduce moisture on the in-tank surveillance cameras Failure to systematically integrate various sub-systems will result in less than adequate performance of the retrieval system.	Adverse impact on retrieval effectiveness and potential for leaving more residual waste than planned.	Verify (through modeling, reliability analysis, feature testing, or other suitable methods) that the design of the sluicer assembly will meet performance and maintenance criteria.	ORP W-320 Bailey, 2000
A.3.2.2	▪ Waste mobilization predictions based on core-sampling information have been determined to be invalid. ▪ Excessive dispersion (ineffective "straightening") of the sluice stream resulted in less than adequate performance.	Adverse impact retrieval effectiveness and potential for residual waste.	Methods to mobilize tank waste need to be verified prior to acceptance of the final design for procurement.	ORP W-320 Bailey, 2000
A.3.2.3	Although crawler system performance was severely limited due to reliability issues such as tether seal leaks, intermittent tether electrical problems and loss of one degree of freedom of MLUDA, the collective system was robust enough to achieve performance goals.	Positive result with confined sluicing/ robotic retrieval technology.	Provide redundant means to achieve performance goals through contingency planning and robust system design. [see associated FMECA recommendations in Table A-1]	ORNL GTRP Providence Group, 2001

Table A-2 Residual Waste/ Retrieval Effectiveness

Section A.3.2	Lesson Learned from Source/ Reference	Relevancy to 241-C-104 and 241-S-112 Retrieval	Considerations for Design and Operation	Source/ Reference
A.3.2.4	Partial submersion of the confined sluicing end-effector offered the best means to avoid 3-phase (solid, liquid, gas) pumping. For the last 1-3 inches of waste retrieval, the Houdini collected and plowed "waves" of waste to the end-effecter.	Adverse impact to retrieval effectiveness and potential for residual waste.	Retrieval pumping performance and confined sluicing operation should be integrated to establish the design-basis operation profile to achieve performance objectives. **(See also A.3.1.40 and A.1.3.41)** *Applicable retrieval pump operational experience:* ▪ *Sludge recovery technique for last 4-6 inched of tank bottoms.* ▪ *Instrumentation and surveillance methods to support retrieval.* ▪ *Sluicer positioning and operation.*	ORNL GTRP Lloyd, et al., 2001

Table A-2 Residual Waste/ Retrieval Effectiveness

Section A.3.2	Lesson Learned from Source/ Reference	Relevancy to 241-C-104 and 241-S-112 Retrieval	Considerations for Design and Operation	Source/ Reference
A.3.2.5	Various weaknesses were identified during the MLUDA/Houdini deployment consisting of ergonomics, maintenance issues, instrumentation deficiencies, and control system faults: ▪ Glove box location and configuration limited tool handling, retraction, and maintenance operations. ▪ Lengthy and demanding process to deploy the main handling system (10 cable and 3 hose connections) ▪ Limited range/rotation of cable and hose management systems required periodic disassemble and reassembly of equipment. ▪ Replacement of a cable was necessary – made possible only because of a spare conduit included in the design. ▪ Coriolos (FE-204) flow meter, was "completely ineffective" due to the highly dynamic 3-phase flow characteristics with significant "slugs" of air. ▪ Debris clogging the screen on the waste inlet. (However this did prevent pump blockage.) ▪ Contamination traps in confinement box on tank riser. ▪ Inability to replace rupture disks. ▪ Poor seal design in the rotating end-effector. ▪ Inability of the control system to detect a disconnected control cable; need to de-energize and safely shut down system.	Adverse impact to retrieval effectiveness and potential for too much residual waste.	See item A.3.1.18: *"Provide engineered systems to safely manage hydraulic fluids under normal (operations and maintenance) and off-normal operations."* Also, provide: ▪ Visual access for inspections ▪ Temporary maintenance power inside and outside glove boxes. ▪ Various end-effectors to achieve performance objectives. ▪ Contamination and corrosion control in high-humidity environments. ▪ "Tune" end-effectors to achieve maximum performance per unit time (e.g. diverging verses converging jets). ▪ Trade off higher jet pressures for control of airborne mist. ▪ Umbilical management optimization (including decontamination and tensioning monitoring systems). ▪ Consider using crawler to position the end-effector. ▪ Establish realistic need to upgrade existing tank farm support systems.	ORNL GTRP Lloyd, et al., 2001

Table A-2 Residual Waste/ Retrieval Effectiveness

Section A.3.2	Lesson Learned from Source/ Reference	Relevancy to 241-C-104 and 241-S-112 Retrieval	Considerations for Design and Operation	Source/ Reference
A.3.2.6	Items from Table A-1 *Operating Effectiveness applicable to Leak Detection*: A.3.1.54	Adverse impact on retrieval effectiveness and potential for leaving more residual waste than planned.	A large industrial community exists with a great deal of experience with the design, manufacture, and operation of solution mining systems. In addition, resources are available to provide consulting services and informational exchange with the international salt mining industry.	Industrial Application Salt Institute, 2001

Table A-3 Leak Detection

Section A.3.3	Lesson Learned from Source/ Reference	Relevancy to 241-C-104 and 241-S-112 Retrieval	Considerations for Design and Operation	Source/ Reference
A.3.3.1	A Gas Pressure Decay (GPD) method was used to test portions of the pressurized transfer piping of a Low Level Liquid Waste System at Oak Ridge National Laboratory (ORNL). This method analyzed the pressure decay rate of a gas introduced into the selected pipeline and expressed results in terms of an equivalent liquid leak rate. This system could measure a leak as small as .1 gal/hour with a probability of detection greater then 95% and a probability of false alarm less than 5%.	Candidate leak detection system for pipe lines between tank 104-C and receiver tank.	Could be a form of leak detection for the transfer lines provided the lines could be pressurized.	ORNL Starr, et al., 1993
A.3.3.2	Liquid integrity test of rusty carbon steel pipelines revealed sufficient integrity to allow GAAT to evaporator transfer. This allowed the project to use the pipeline avoiding the need for a new line resulting in savings in both cost and schedule.	Use existing equipment is qualified to be sound	Verify need for new, replacement lines prior to initiating design and fabrication of new equipment, test to determine if the exciting system is sound.	ORNL Ref. 98

Table A-3 Leak Detection

Section A.3.3	Lesson Learned from Source/ Reference	Relevancy to 241-C-104 and 241-S-112 Retrieval	Considerations for Design and Operation	Source/ Reference
A3.3.3	Items from Table A-1 *Operating Effectiveness* applicable to *Leak Detection*: A.3.1.12 A.3.1.16 A.3.1.17 A.3.1.31 A.3.1.34 A.3.1.35 A.3.1.37	May adversely impact Leak Detection Performance.	▪ *Establish an operation and maintenance strategy and integrate detection system operation.* ▪ *Where feasible, provide direct access to instrumentation systems without breaking containment.* ▪ *Identify features early in the design phase to enhance operability of the system...* ▪ *Implement planning to establish condition-based operations and maintenance (CBM) ...* ▪ *Develop project and deployment planning with due consideration for reliability testing and process quality assurance.* ▪ *Address operator and maintenance personnel training and retention of key technical staff...* ▪ *Management of flow-down of quality and safety requirements...* ▪ *"...Develop a reliability/ availability-based maintenance strategy utilizing FMECAs ...".*	

Table A-3 Leak Detection

Section A.3.3	Lesson Learned from Source/ Reference	Relevancy to 241-C-104 and 241-S-112 Retrieval	Considerations for Design and Operation	Source/ Reference
A.3.3.4	The performance standard for tank tightness testing is established by the U.S. Environmental Protection agency. The standard was developed to address tanks nominally 8,000 to 10,000 gals in capacity or less. To meet regulatory standards for tank tightness testing of petroleum fuel tanks, volumetric leak detection systems must be able to accurately compensate for thermally induced volume changes in the stored fuel. A field study was done to investigate the magnitude of these volume changes with the following results: • Current procedures used to compensate for temperature when testing smaller tanks will not suffice for larger tanks. • The number of temperature sensors must be sufficient that the volume of product in the liquid layer around each sensor is not to great • Duration of testing must be long enough to measure the fluctuation of temperature after additions or subtractions of product and that the precision of the temperature and level instrumentation is sufficient to measure a leak. • An accurate experimental estimate of the constants is necessary for converting level and temperature changes to volume. • A waiting period of approximately 24 hour after addition of product is required to equalize the temperature	Performance criteria for level indication and temperature sensors to be used to monitor the waste level.	Baseline information is required on the physical characteristics of the tank contents. Temperature sensors should be installed 3 inches from top of liquid and bottom of tank and every 6-12 inches through the liquid. Wait at least 24 hours for horizontal gradient in rate of change of temperature to dissipate. Use the most precise temperature and level measurement systems available. Measure the coefficient of thermal expansion experimentally. Determine the height to volume conversion factor level measurements to volume measurements experimentally.	US-EPA Maresca, et al., 1993

Table A-4 Leak Monitoring

Section A.3.4	Lesson Learned from Source/ Reference	Relevancy to 241-C-104 and 241-S-112 Retrieval	Considerations for Design and Operation	Source/ Reference
A.3.4.1	Tank leak monitoring of the GAAT provide the following information • Stratification of waste in tanks caused stratification of conductivity readings used to determine a base line for external monitoring • For external leak monitoring utilizing dry wells, the dry wells should be clear of debris • During baseline activities for external tank leak monitoring utilizing waste conductivity, evaluate and document rainwater impacts.	Dry well would be required and location would have to be evaluated to determine best location	Evaluate the overall conductivity of a tank for baseline and dry well conditions prior to insertion of conductivity instrumentation. Baseline information should be gathered over a period of time that would incorporate changes due to outside conditions (i.e. rain)	ORNL ORNL, 1996, ORNL, 1997, and ORNL, 1997a
A.3.4.2	An un-answered low-level alarm resulted in fines to ORNL. Indications for the liquid level in tank WC-9 dropped from about 1000 gallons to zero gallons within a 24-hour period due to instrumentation error. A low-level alarm sounded and was not addressed for 36 hours because "false alarms are common place". These false alarms tended to be ignored.	Evaluate the instrumentation that will be used on tank 241-C-104 and determine its susceptibility to false alarms	Design the system to operator interface to facilitate immediate response to all alarms; develop instrumentation to minimize false alarms	ORNL Ref. 98
A.3.4.3	A common method for the detection of small leaks in pressurized underground storage tank pipelines containing petroleum is based on monitored pressure in the line. It has been documented that changes in pressure, taking into account temperature variations, can detect a leak of less than one gal/hr. With sufficient information about the physical configuration of the system, the pressure history in the pipeline can be predicted. Establish a baseline prior to initiating retrieval operations. Characterization of the physical properties of the material to be retrieved is crucial to design and operation of a monitoring system.	Leak monitoring system effectiveness.	Verify through analysis and testing that the level of waste characterization is appropriate for the leak monitoring system technology selected.	Industrial Application Maresca, et al., 1990

Table A-4 Leak Monitoring

Section A.3.4	Lesson Learned from Source/ Reference	Relevancy to 241-C-104 and 241-S-112 Retrieval	Considerations for Design and Operation	Source/ Reference
A3.4.4	Items from Table A-1 *Operating Effectiveness* applicable to *Leak Monitoring*: A.3.1.12 A.3.1.16 A.3.1.17 A.3.1.31 A.3.1.34 A.3.1.35 A.3.1.37	May adversely impact Leak Monitoring Performance.	▪ *Establish operation and maintenance strategy and integrate detection system operation.* ▪ *Where feasible, provide direct access to instrumentation systems without breaking containment.* ▪ *Identify features early in the design phase to enhance operability of the system…* ▪ *Implement planning to implement condition-based operations and maintenance (CBM) …* ▪ *Develop project and deployment planning with due consideration for reliability testing and process quality assurance.* ▪ *Address operator and maintenance personnel training and retention of key technical staff…* ▪ *Management of flow-down of quality and safety requirements…* ▪ *"…Develop a reliability/ availability – based maintenance strategy utilizing FMECAs …".*	

Table A-5 Leak Mitigation/ Response

A.3.5	Lesson Learned from Source/ Reference	Relevancy to 241-C-104 Retrieval	Considerations for Design and Operation	Source/ Reference
A.3.5.1	Pipe line (WC-10) at Oak Ridge National Laboratory was shut down due to delays in reporting a potential leak. The Tennessee's TDEC (state environmental agency) ordered ORNL to shut down in order to remediate the leak	Need for an effective working relationship with regulators is essential to maintaining cost and schedule	Conduct regular liquid integrity tests and report results in a timely manner.	ORNL Ref. 98
A.3.5.2	An adversarial relationship between ORNL and TDEC was eased by open dialog regarding leak test program. Long standing mistrust between TDEC and MMES limited interactions. Leak Indication program for ORNL allowed open discussion of data and data collection facilities. This openness smoothed the MMES-TDEC relationship.	Need for effective working relationship with regulators is essential to maintaining cost and schedule	Provide a path for effective communication between regulators and technical staff.	ORNL Ref. 98

Table A-5 Leak Mitigation/ Response

A.3.5	Lesson Learned from Source/ Reference	Relevancy to 241-C-104 Retrieval	Considerations for Design and Operation	Source/ Reference
A3.3.3	Items from Table A-1 *Operating Effectiveness* applicable to *Leak Mitigation/Response*: A.3.1.12 A.3.1.16 A.3.1.17 A.3.1.31 A.3.1.34 A.3.1.35 A.3.1.37	May adversely impact Leak Mitigation/ Response Performance.	▪ *Establish operation and maintenance strategy and integrate detection system operation.* ▪ *Where feasible, provide direct access to instrumentation systems without breaking containment.* ▪ *Identify features early in the design phase to enhance operability of the system...* ▪ *Implement planning to implement condition-based operations and maintenance (CBM) ...* ▪ *Develop project and deployment planning with due consideration for reliability testing and process quality assurance.* ▪ *Address operator and maintenance personnel training and retention of key technical staff...* ▪ *Management of flow-down of quality and safety requirement...* ▪ *"...Develop a reliability/ availability-based maintenance strategy utilizing FMECAs ...".*	

Document Source Bibliography – For Lessons Learned

ALARA Review, *Post Job ALARA Review for Campaign I and II sluicing of C-106 and E-1116.*

Alzheimer, et al., 2001, *Crawler for U-Plant Drain Line Inspection,*

Arnold, 1977, "Scumbuster" Pump Test Series Analysis, ARH-CD-935, Atlantic Richfield Hanford Company, Richland, Washington.

Arnold, 1978, *Fabrication and Testing of an Experimental Slurry Elevator for Use Within Single Shell Hanford Waste Tanks*, RHO-CD-273, Rockwell Hanford Operations, Richland, Washington.

Asercion, et al., 2000, *AZ-101 Mixer Pump Test Project Lessons Learned*, R. Asercion, W. Scott, and R. Kummer.

Bailey, 1999, *Waste Retrieval Sluicing System (WRSS) Jumper Assessment and Lessons Learned LL Document*, HND-4402, Rev. 0, Lockheed Martin Hanford Corp., Richland, Washington.

Bailey, 2000, *Waste Retrieval Sluicing System (WRSS) and Project W-320 Tank 241-C-106 Sluicing Lessons Learned*, RPP-5687, Rev 0, CH2M Hill Hanford Group, Inc. , Richland, Washington

Bamberger, et aL, 2001, *Development of an Ultrasonic Sensor to Measure Density of Radioactive Waste Slurries During Pipeline Transport*, Pacific Northwest National Laboratories, Richland, Washington.

Bauer, et al., 1998, Waste *Disposal in Horizontal Solution Mined Caverns Considerations of Site Location, Cavern Stability, and Development Considerations*, dated August 4, 1998, Underground Storage Technology, Department 6113, Sandia National Laboratories.

Bayer, et. al 2001, *Savannah River Sire Bagless Transfer – What have we learned?*, Westinghouse Savannah River Company, Aiken, South Carolina.

Berglin, et al., 1997, *Hanford Tanks Initiative, Fiscal Year 1997, Retrieval Technology Demonstrations*, HNF-SD-HTI-RPT-001, SGN Eurisys Services Corporation and Pacific Northwest National Laboratory, both of Richland, Washington.

Bogen, 2000, *Site Visitation Notes* ,Holmes & Narver/DMJM, Richland, Washington

Burks, et al., 2001, *Lessons Learned and Final Report for Houdini Vehicle Remote Operations at ORNL*

CHG, 2000, *Annual Progress Report on the Development of Waste Tank Leak Monitoring Activities in Support of M-45-08*, RPP-7012, U.S. Department of Energy, Office of River Protection, Richland, Washington.

CHG, 2001, *F&R for 241-C-014 Waste Retrieval System, W-523*, RPP-6525 Rev 0.

CHG, 2001a, *Lessons Learned Bulletin (CH2M Hill), The disciplined application of effective project management practices will result in project excellence*, #GP-01-02, CH2M Hill Hanford Group, Inc., Richland, Washington.

CHG, 2001b, *Submittal for 2001 Project of the Year, SY-101 Surface Level Rise Remediation Project*, RPP-7657, CH2M Hill Hanford Group, Richland, Washington.

Deeds, et al., 1999, *Difluoromethane as a partitioning tracer to estimate vadose saturations.* L Env Engineer, in press.

Delphinus Engineering, 1997, *Final Test Report – Demonstration Testing in Support of the Track 3 System Waste Dislodging, Retrieval and Conveyance Concepts*, HNF-MR-0543 Rev. O, Lockheed Martin Hanford Corp., Richland, Washington.

DNFSB, 2000, *Defense Nuclear Facilities Safety Board Recommendation 2000-2 to the Secretary of Energy (pursuant to 42 U.S.C. 2286a(a)(5))*, Defense Nuclear Facilities Safety Board, Washington, D.C.

DNSFB, 2001, *Criticality Safety at Department of Energy Defense Nuclear Facilities*, DNSFB/TECH-29, Defense Nuclear Facilities Safety Board, Washington, D.C.

DNSFB, 2001a, *Eleventh Annual Report to Congress*, Defense Nuclear Safety Facilities Board, Washington, D.C.

DNFSB, 2001b, *Safety Review of the Hanford Spent Fuel Project During the Design and Construction Phase*, DNSFB/TECH-30, Defense Nuclear Facilities Safety Board, Washington, D.C.

Ebadian, 2001, *Solids Formation and Feed Stability During Waste Slurry Transfer*, dated January 2001, Hemispheric Center of Environmental Technology, Miami, Florida.

Document Source Bibliography – For Lessons Learned
ESG, L.L.C., 1997, *HTI Vehicle-Based Waste Retrieval Demonstration Report Phase II, Track 2*, HNF-MR-0544 Rev 0, Lockheed Martin Hanford Corporation, Richland, Washington.
Falter, 1997, *Houdini Remotely Operated Vehicle System Performance Assessment for Tank W-3 Waste Removal Operations.*
Farwick, 2001, *Memo- Lessons Learned LDMM*, Visa Engineering Technologies, L.L.C., Richland, Washington.
FDH, 1999, *1999 Leak Detection, Monitoring, and Mitigation Strategy Update*, HND-SD-WM-ES-378, Rev. 2, Fluor Daniel Hanford, Inc., Richland, Washington.
Fidani, 2001, *The Challenges of Industrial Remotely Operated Systems for the 21st Century.*
Fitzgerald, 2001, *Linear Scarifying End-Effector Developed for Wall Cleaning in Underground Storage Tanks*, Oak Ridge National Laboratory, Oak Ridge, Tennessee. .
Foster Wheeler, 1995, *Technology Issues Related to Single-Shell Tank Waste Retrieval Leak Detection, Monitoring, and Mitigation: Final Report*, FWRD-WHC/4344-L95-085, Westinghouse Hanford Company, Richland, Washington.
Gauglitz, et al., 1995, *DNAPL Characterization Using Tracer Test for Detection, Estimation and Remediation Performance Assessment of Subsurface Nonaqueous Phase Liquids*, Water Resources Res. Richland, Washington.
Gauglitz, et al., 2000, *DNAPL Characterization Using Short-Lived Radiotracers in Partitioning Interwell Tracer Tests,* Remediation of Chlorinated and Recalcitrant Compounds, 2nd International Conference, Monterey, California.
Gibbons, 1993, *Review of Prior Single-Schell Tank Waste Retrieval Process Studies*, WHC-SD-WM-ES-252, Westinghouse Hanford Company, Richland, Washington.
Gibbons, 2001, *Overview of the Tanks Focus Area HLW Tank Retrieval activities (Remote Operations)*, Numatec Hanford Corporation, Richland, Washington.
GreyPilgrim, 1997, *Hanford Tanks Initiative Alternative Retrieval System Demonstrations – Final Report of Testing Performed by GreyPilgrim LLC*, HNF-MR-0545 Rev 0, Lockheed Martin Hanford Corporation, Richland, Washington..
Hatchell, et al., 2001, **Russian** *Pulsating Mixed Pump Deployment in the GAAT at ORN.*
Hayden, 1997, *High Performance CLSM Field Mixing and Pumping Test Results*, WSRC-RP-97-272, Westinghouse Savannah River Company, Aiken, South Carolina..
Herting, 2000, *Saltcake Dissolution FY 2000 Status Report*, HNF-7031, Fluor Hanford, Richland, Washington
Hertzel, 1996, *Operational Tank Leak Detection and Minimization During Retrieval*, WHC-SD-WM-377, Westinghouse Hanford Company, Richland, Washington
Hertzel, 1996a, *Trade Study of Leakage Detection, Monitoring, and Mitigation Technologies to Support Hanford Single-Shell Waste Retrieval*, WHC-SD-WM-ES-379, Westinghouse Hanford Company, Richland, Washington.
HND, 2000, *Leak Detection, Monitoring, and Mitigation Design Concepts Evaluation Report for Sluicing-Based Retrieval Technologies*, RPP-6795 Rev 0 DRAFT, Holmes & Narver/DMJM, Richland, Washington.
Huang, et al., *Design of a 52.5 Foot Hyper-Redundant Serpentine Style Manipulator and Its Deployment Tower*, GreyPilgrim Inc., Rockville, MD
Jacobs, 1998, *Hanford Site SST Retrieval Optimization Studies Support to Development of SST Retrieval Strategy, Draft Letter Report #4, Evaluate Relationship Between Retrieval Parametrics and Evaluation Metrics*, Lockheed Martin Hanford Corporation, Richland, Washington.
Janicek, 1981, *Equipment Development Study for Hydraulic Recovery of Single Shell Tank Sludges*, RHO-CD-1533, Rockwell Hanford Operations, Richland, Washington.
Jarrel, 2001, *Remote Prognostics for Nuclear Plant ECCS Systems*, Pacific Northwest National Laboratories, Richland, Washington.
Jin, et al., 1995, *Partitioning Tracer Test for Detection, Estimation and Remediation Performance Assessment of Subsurface Nonaqueous Phase Liquids*, Water Resources Res 31(5): 1201-1211
Krieg, et al., 1990, *SST Waste Retrieval Study*, 1990, WHN-EP-0352-US-721, Westinghouse Hanford Company, Richland, Washington.

Document Source Bibliography – For Lessons Learned
Lloyd, et al., 2001, *Performance Assessment if the Waste Dislodging and Conveyance System During GAAT Remediation Project.*
LMHC, 1999, *Process Control Procedure for W-320*, HNF-SD-WM-PLP-013, Rev 2, Lockheed Martin, Hanford, Company, Richland, Washington.
Maresca, et al., 1993, *Evaluation of Volumetric Leak Detection Systems for Large Underground Tanks*, 34(1993) 335-361, Journal of Hazardous Materials, Amsterdam.
Maresca, et al., 1990, Pressure *and Temperature Fluctuation in Underground Storage Tanks Pipelines Containing Gasoline*, 29-56, Vista Engineering, California and U.S. Environmental Protection Agency, New Jersey
Merpro Limited, 2001a, *Merpro Product Portfolio.* http://www.merpro.com/procprod.htm (2 Aug, 2001)
Merpro Limited, 2001b, *Merpro Product Portfolio, Technical Bulletin No. 5.*, dated August 20, 1999, http://www.merpro.com/acrobat/bulletin05.pdf (2 Aug, 2001)
Merpro Limited, 2001c, *Merpro Product Portfolio, Technical Bulletin No. 3.*, dated March 13, 2001, http://www.merpro.com/acrobat/bulletin03.pdf (2 Aug, 2001)
Merpro Limited, 2001d, *Merpro Product Portfolio,* TORE® *sep "The Crude Separator"*, dated July 7, 1999, http://www.merpro.com/acrobat/bulletin07.pdf (2 Aug, 2001)
Morse, et al., 1996, Simulated *Liquid Release Demonstration on Gunite Tanks W-3 and W-4 in the North Tank Farm*, Technical Report 1060-TR-96-001.
ORNL, 1996. *Preliminary Evaluation of Liquid Integrity Monitoring Methods for Gunite and Associated Tanks at the Oak Ridge National Laboratory, Oak Ridge, Tennessee*, ORNL/ER-349, U.S. Department of Energy, Office of Environmental Management, Washington, D.C.
ORNL, 1997, *Evaluation and Monitoring Plan for Consolidation Tanks: Gunite and Associated Tanks Operable Unit, Waste Area Grouping 1, Oak Ridge National Laboratory, Oak Ridge, Tennessee*, ORNL/ER-396, U.S. Department of Energy, Office of Environmental Management, Washington, D.C.
ORNL, 1997a, *Baseline Monitoring and Simulated Liquid Release Test Report for Tank W-9, Oak Ridge National Laboratory, Oak Ridge, Tennessee*. ORNL/ER-410, U.S. Department of Energy, Office of Environmental Management, Washington, D.C.
ORNL, 1998, *An Assessment of Liquid Integrity and Minimum Detectable Leak Rate for Gunite Tanks W-8, W-9, and W-10 (July 1997 through January 1998)*, Oak Ridge National Laboratory, Oak Ridge, Tennessee.
Osborn, 2001, *Opportunities and Challenges in the Development of Pioneer*, Carnegie Mellon University, et. al.
Pacquet, E. A. 1999, *Project W-320 Tank 241-C-106 Lessons Learned*, Numatec Hanford Company, Richland, Washington.
Providence Group, 2001, *System Review of the MLDUA After the Completion of the ....Waste Removal.... At ORNL*
Rasmussen, 1980, *Hanford Radioactive Tank Cleanout and Sludge Processing*, RHP-ST-30, Rockwell Hanford Operations, Richland, Washington.
Rodenhizer, 1987, *Hanford Waste Tank Sluicing History*, SD-WM-TI-302, Westinghouse Hanford Company, Richland, Washington.
Salt Institute, 2001, *Solution Mining for Salt*, dated August 3, 2001, http://www.saltinstitute.org/12.html, (8 Aug, 2001)
Shimamura, et al., 2001, *Underwater Robotic System for Preventive Maintenance of Core Shroud by Laser Peening*
Squires, 1990, *Feature Test of Sine Pump*, WHC-SD-ER-TRP-003, Westinghouse Hanford Company, Richland, Washington.
Squires, 1990a, *Feature Test of the Pneumatic Needle Scaler*, WHC-SD-ER-TRP-002, Westinghouse Hanford Company, Richland, Washington.
SRS, 1995, *SRS High Level Waste Tank and Piping Systems – Structural Integrity -Program and Topical Report (U)*, WSRC-TR-95-0076, Rev 0, Westinghouse Savannah River Company, Aiken, South Carolina.
Starr, et al., 1993, *Performance Evaluation of a Gas Pressure Decay Test for Detecting Leaks in LLLW Transfer Pipelines*, Technical Report 1040-TR-93-015, Vista Research, Inc., Mountain View, California.

Document Source Bibliography – For Lessons Learned

Sukegawa, et al., 2001, *Equipment Tests of Pipeline Unplugging Technologies on the Full-Size Test Beds*, Hemispheric Center for Environmental Technology, Florida and U.S. Department of Energy Tank Focus Area, Richland, Washington.

TFA, 1999, *Confined Sluicing End Effector*, DOE/EM-0372, U.S. Department of Energy, Office of Environmental Management, Washington, D.C.

TFA, 2001, "*Pipeline Unplugging Tasks Reviewed*", dated January 31, 2001, http://www.pnl.gov/tfa/hilight/back/31jan01.stm#unplugging (8 Aug. 2001)

Thompson, 1990, *Feature Test of Air Conveyance Concept Review*, WHC-SD-ER-TRP-001, Westinghouse Hanford Company, Richland, Washington.

Treat, R., B. Peters, 1996, FWRD-WHC/4344-L-96-038, *Trade Study of LDMM Technologies Available for Support of Hanford SST Waste Retrieval by Sluicing*, Foster Wheeler Environmental Corporation, dated May 1996, (see also WHC-SD-WM-ES-379, Rev. 0).

Virto, 1975, *Evaluation and Adaptation of Standard Mechanical Hydraulic and Pneumatic Devices for Saltcake and Sludge Retrieval at Hanford*, VITRO-R-375, Atlantic Richfield Hanford Company

Vista, 2000, Draft, *2000 Leak Detection, Monitoring, and Mitigation Strategy Update*, HNF-SD-WM-ES-378 Rev 2A, U.S. Department of Energy, Office of River Protection, Richland, Washington

WHC, 1992, *Air/Water Jet Scarifier Feature Test – Final Test Report*, WHC-SD-ER-TRP- 006 Rev 0, Westinghouse Hanford Company, Richland, Washington.

WHC, 1995, *Technology Issues Related to Single-Shell Tank Waste Retrieval Leak Detection, Monitoring, and Mitigation (LDMM)*, dated July, 1995.

Whitley, et al., 1999, *Contaminated Vadose Zone Characterization Using Partitioning Tracers*. J Env Engrg.

Wiersma, 1996, *An Investigation of Density Salt Dissolution Techniques*, WSRC-TR-96-0160, Westinghouse Savannah River Company, Savannah River Technology Center, Aiken, South Carolina.

Wiersma, 1997, *Laboratory Demonstration of Hanford Dissolution Process*, SRT-MTS-96-2003, Westinghouse Savannah River Company, Savanna River Technology Center, Aiken, South Carolina

APPENDIX B

Retrieval Performance Evaluation for Single-Shell Tank S-112
HNF-7644, Rev 0

(179 Pages)

APPENDIX B

RETRIEVAL PERFORMANCE EVALUATION FOR SINGLE-SHELL TANK S-112

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EXECUTIVE SUMMARY

This *Retrieval Performance Evaluation for Single-Shell Tank S-112* is written to document the results of a scoping-level retrieval performance evaluation for waste retrieval from tank S-112 in the Hanford Site 241-S tank farm. The evaluation was performed to satisfy some of the requirements of *Hanford Federal Facility Agreement and Consent Order* Milestones M-45-03-T03[1] to include a scoping-level retrieval performance evaluation in the tank S-112 waste retrieval demonstration functions and requirements documents.

The scoping-level retrieval performance evaluation documented in this report considers human health risk and regulatory performance measures over a range of residual waste volumes and retrieval leakage volumes for tank S-112. Those ranges are intended to provide insight to relationships between risk and volume and provide decision makers with information to support the identification of waste retrieval and leak detection, mitigation, and monitoring system requirements that are protective to human health.

The final extent of retrieval is a tank farm closure issue; however, the extent of retrieval should be considered in the functions and requirements of the initial retrieval system. It is recognized that closure criteria have not been fully defined; however, the criteria as they are currently understood can be used to guide the development of initial retrieval criteria. This approach does not preclude the retrieval of additional waste from the tanks in the future as additional information is gathered during and after waste retrieval activities in the remaining S farm tanks and as closure criteria are established.

Consideration of long-term risks to a future site user at the S tank farm fenceline indicate that volumes as low as 6,400 L (1,700 gal) exceed a regulatory threshold of 10^{-5} incremental lifetime cancer risk for the industrial worker scenario. The projected impacts from residual waste in tank S-112 indicate that the long-term risks to the industrial worker would exceed 10^{-5} incremental lifetime cancer risk at residual volumes greater than 11,000 L (2,900 gal) which is slightly greater than the *Hanford Federal Facility Agreement and Consent Order* interim retrieval goal. The mobile contaminants in retrieval leaks result in two groundwater concentration peaks. The early peak is projected to occur in approximately year 2070 and would be during the post-closure institutional control period. Exposures resulting from consumption of groundwater at the tank farm fenceline during the institutional control period would be prevented. The second peak would occur approximately 1,000 years later and would be after the assumed institutional control period.

The potential long-term risks from the S tank farm were evaluated at the 200 West fence and at the 200 Area exclusion boundary to provide insight on the risk from tank S-112 within the context of the S tank farm. The peak risk levels from past leaks dominated the impacts from retrieval leaks and residual waste source terms. At a tank farm level the long-term risks are not sensitive to changes in tank S-112 retrieval leakage volume. A relatively large leak from

[1] 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.

tank S-112 (151,000 L [40,000 gal]) increases the predicted long-term human health risk across the tank farm less than 10%.

Although retrieval leakage volumes from tank S-112 below current detection limits result in risk levels of concern at the tank farm fence line, these impacts would likely occur during the post-closure institutional control period when the need and options for corrective action could be evaluated.

CONTENTS

ATTACHMENT

FIGURES

TABLES

LIST OF TERMS

BBI	best-basis inventory
CERCLA	*Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
CoC	contaminant of concern
DOE	U.S. Department of Energy
DST	double-shell tank
DWS	drinking water standard
EPA	U.S. Environmental Protection Agency
F&R	functions and requirements
FIR	field investigation report
FY	fiscal year
HFFACO	*Hanford Federal Facility Agreement and Consent Order*
HLW	high-level waste
HWMA	Hazardous Waste Management Act
ILCR	incremental lifetime cancer risk
LCF	latent cancer fatality
LDMM	leak detection, mitigation, and monitoring
LLW	low-level waste
LWC	lost workday case
MCL	maximum contaminant level
MEI	maximally exposed individual
MTCA	Model Toxics Control Act
NRC	U.S. Nuclear Regulatory Commission
RCRA	*Resource Conservation and Recovery Act of 1976*
REDOX	reduction-oxidation
RPE	retrieval performance evaluation
SST	single-shell tank
TRC	total recordable case
TRU	transuranic
TSD	treatment, storage, and/or disposal
URF	unit risk factor
WMA	waste management area

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B.1.0 INTRODUCTION

This *Retrieval Performance Evaluation for Single-Shell Tank S-112* is written to document the results of a scoping-level retrieval performance evaluation (RPE) for waste retrieval from tank S-112 in the Hanford Site 241-S tank farm (S tank farm). The evaluation was performed to partially satisfy the requirements of Milestones M-45-03-T03 of the *Hanford Federal Facility Agreement and Consent Order* (HFFACO; Ecology et al. 1989). Milestone M-45-03-T03 calls for the development of a HFFACO functions and requirements (F&R) document for tank S-112 demonstration systems for waste retrieval and leak detection, mitigation, and monitoring (LDMM). This scoping-level RPE directly supports the tank S-112 F&R document. The HFFACO milestone further identifies that the scoping-level RPE will provide the following:

- Environmental and human health risk evaluation data/information associated with estimated waste volumes to be retrieved
- Environmental and human health risk evaluation data/information associated with the maximum volume that could leak during retrieval and the risk from residual waste
- Detail known and estimated radionuclide contamination and contaminant migration within the vadose zone as a basis of calculation.

The scoping-level RPE documented in this report considers human health risk and regulatory performance measures over a range of residual waste volumes and retrieval leakage volumes selected for tank S-112. Performance measures evaluated include short-term human health risk, impacts to groundwater, long-term human health risk, waste site intruder risk, and regulatory compliance. The results of the RPE analysis will be used to identify performance measures that influence the design and operation of the waste retrieval system. Examples of retrieval system requirements include retrieval leak volume limits considering residual waste remaining in the tank following retrieval and residual waste volume limits based on risk or regulatory performance measures. These performance measures provide one of the inputs to the decision-making process that results in the retrieval system requirements identified in the F&R document. A range of volumes for both residual waste and retrieval leakage are evaluated to investigate the sensitivity of the performance measures to residual waste volumes or leakage volumes. The fundamental goal of the waste retrieval technology demonstration in tank S-112 is to test the limits of technology for a salt cake dissolution retrieval system. The ideal goal of any waste retrieval effort would be to retrieve all of the waste in the tank with no leak loss to the environment. However, achievement of that ideal goal is highly uncertain given the conditions of tanks, physical characteristics of the waste in the tanks, and the limitations of the waste retrieval system. Given this uncertainty it is important to develop a design and operating approach that provides estimates for risk-based performance of the tank at various points along the retrieval path and considers risk and regulatory-based performance measures.

Single-shell tank (SST) waste retrieval decisions and subsequent tank farm closure decisions are interrelated on a tank-by-tank and tank farm-by-tank farm basis. Because tank closure will be completed on a tank farm basis, all potential sources of contamination within the tank farms (past leaks, retrieval losses, and tank residuals) must be considered when evaluating long-term impacts from the tank farm system. Near-term retrieval actions for individual tanks (i.e., inventory remaining in the tank following retrieval and retrieval leakage) could affect future waste retrieval decisions. Tank farm retrieval decisions are also interrelated with remediation and closure decisions of other non-tank sources in the Hanford Site 200 East and 200 West Areas.

This analysis focuses on tank S-112. The general approach involves definition of waste retrieval cases that span a range of retrieval leak loss and residual waste volumes. A range of leak-loss and residual waste volumes is considered to establish risk versus volume relationships for both retrieval leakage and tank residuals. Table B.1.1 lists the areas of analysis considered and provides a crosswalk of those areas to the corresponding section numbers that address technical approach, results of analysis, and conclusions for each tank.

Table B.1.1. Analysis, Approach, Results, and Conclusions Crosswalk

Area of Analysis	Technical Approach/Description	Analysis Results	Conclusions
Retrieval cases	Sections B.3.2 and B.4.0	NA	Section B.6.0
Source terms	Section B.3.3 and the Attachment		
Short-term human health risk	Section B.3.4	Sections B.5.1.1 and B.5.2.1	Sections B.6.2.1 and B.6.3.1
Groundwater impacts	Section B.3.5	Sections B.5.1.2 and B.5.2.2	Sections B.6.2.2 and B.6.3.2
Intruder risk	Section B.3.6	Sections B.5.1.3 and B.5.2.3	Sections B.6.2.3 and B.6.3.3
Long-term human health risk	Section B.3.7	Sections B.5.1.4 and B.5.2.4	Sections B.6.2.4 and B.6.3.4
Regulatory compliance	Section B.3.8	Sections B.5.1.5 and B.5.2.5	Sections B.6.2.5 and B.6.3.5

*Source term results, conclusions, and data needs are identified within each of the areas of analysis as appropriate.

NA = not applicable.

This RPE is not intended to set the minimum performance standard for the retrieval demonstration. The intent of the retrieval demonstration in tank S-112 is to collect performance data and establish a technical basis for the limit of the technology and the performance characteristics (e.g., loss in retrieval efficiency) as a function of waste volume remaining in the tank. Tank and tank farm closure criteria (as they are understood today) are considered in an effort to remove enough waste with minimal leakage providing reasonable assurance that the tanks and the tank farm can be moved toward closure without having to plan for multiple waste retrieval campaigns.

It is recognized that addressing tank farm closure at this stage of the program is preliminary and will be revisited throughout the life of the retrieval program; however, because waste retrieval for tank farm closure is the primary driver for remediating the SSTs it is important to evaluate the relationships between tank waste retrieval and tank farm closure before, during, and after tank waste retrieval.

The RPE methodology will be used to provide risk-based performance data for use in defining retrieval system requirements in the F&R document. The performance measures evaluated will be used to support identification of the requirements for the LDMM systems in terms of required leak detection limits and response actions and the identification of requirements for the waste retrieval systems in terms of the extent of waste retrieval necessary to meet risk- and regulatory-based criteria. The HFFACO F&R document will discuss how the results of this RPE are applied to the waste retrieval systems. Another aspect of the retrieval demonstration involves demonstrating the limit of the retrieval technology (i.e., operational conditions for demonstrating when the technology has reached the practical limit), which will be defined in the HFFACO F&R document and not as part of this RPE report.

B.2.0 BACKGROUND

In 1999 the U.S. Department of Energy (DOE) completed the RPE methodology for the AX tank farm, documented in *Retrieval Performance Evaluation Methodology for the AX Tank Farm* (DOE/RL-98-72), as a demonstration of the methodologies, data, and analysis necessary to support making tank waste retrieval and tank farm closure decisions required under the HFFACO. DOE/RL-98-72 includes an evaluation of a range of residual waste and retrieval leakage volume cases and post-retrieval actions that could be taken to remediate contaminated soil and close the tank farm. The methodology in DOE/RL-98-72 uses a systems approach that considers the entire tank farm when evaluating the cases relative to potential performance criteria. These relationships can then be used to support decisions on the extent of waste retrieval and the limits of retrieval leak loss.

In August of 2000 the HFFACO was modified via Milestone Change Package M-45-00-01A to reflect a revised strategy for SST waste retrieval activities. The revised strategy focuses on maximizing risk reduction by prioritizing the retrieval of waste from tanks with a high contaminants of concern (CoCs) inventory instead of focusing on maximizing the number of tanks entered for waste retrieval. The new strategy is also focused on demonstrating waste retrieval technologies in a variety of waste forms and tank farm locations to establish a basis for future work. To establish overall F&Rs for the waste retrieval demonstration systems, the need for overarching F&R documents has been identified. The F&R documents define the requirements for how the waste retrieval systems will be designed and operated. The major elements of the HFFACO F&R documents for the tank S-112 waste retrieval demonstration along with the HFFACO milestones leading up to completion of that demonstration are shown in Figure B.2.1. HFFACO Milestone M-45-03-T03 specifies how the F&R documents for tank S-112 should include scoping-level RPEs that provide human health risk evaluations associated with waste volumes to be retrieved and the maximum volumes of waste that could leak during waste retrieval operations. Milestone M-45-03C specifies the tank S-112 waste retrieval goal as retrieval of 99% of the August 2000 best-basis inventory (BBI) (BBI 2000) tank contents by volume, with approximately 550 curies of mobile, long-lived radioisotopes retrieved to safe storage.

B.2.1 SETTING

The 200 West Area (Figure B.2.2) is located on a plateau about 8 km (5 mi) south of the Columbia River. The 200 West Area housed facilities called separations plants that received and dissolved irradiated fuel (from the 100 Areas) and then separated out the plutonium. Operations at the Hanford Site resulted in production of liquid, solid, and gaseous wastes. Most wastes resulting from Hanford Site operations have had at least the potential to contain hazardous and radioactive materials. From an operational standpoint, radioactive wastes were originally categorized as high-level waste (HLW) or low-level waste (LLW) depending on the level of radioactivity present. HLW was first stored in large underground SSTs. Portions of the contents of some of these tanks have since leaked into the soil, either directly from the tanks or from associated transfer piping. In later years HLW was stored in double-shell tanks (DSTs), from which waste has not leaked into the soil. However, in a few instances, releases have occurred from the transfer piping within DST farms, contributing to near-surface vadose zone contamination.

Figure B.2.1. Tank S-112 Waste Retrieval Demonstration Milestones

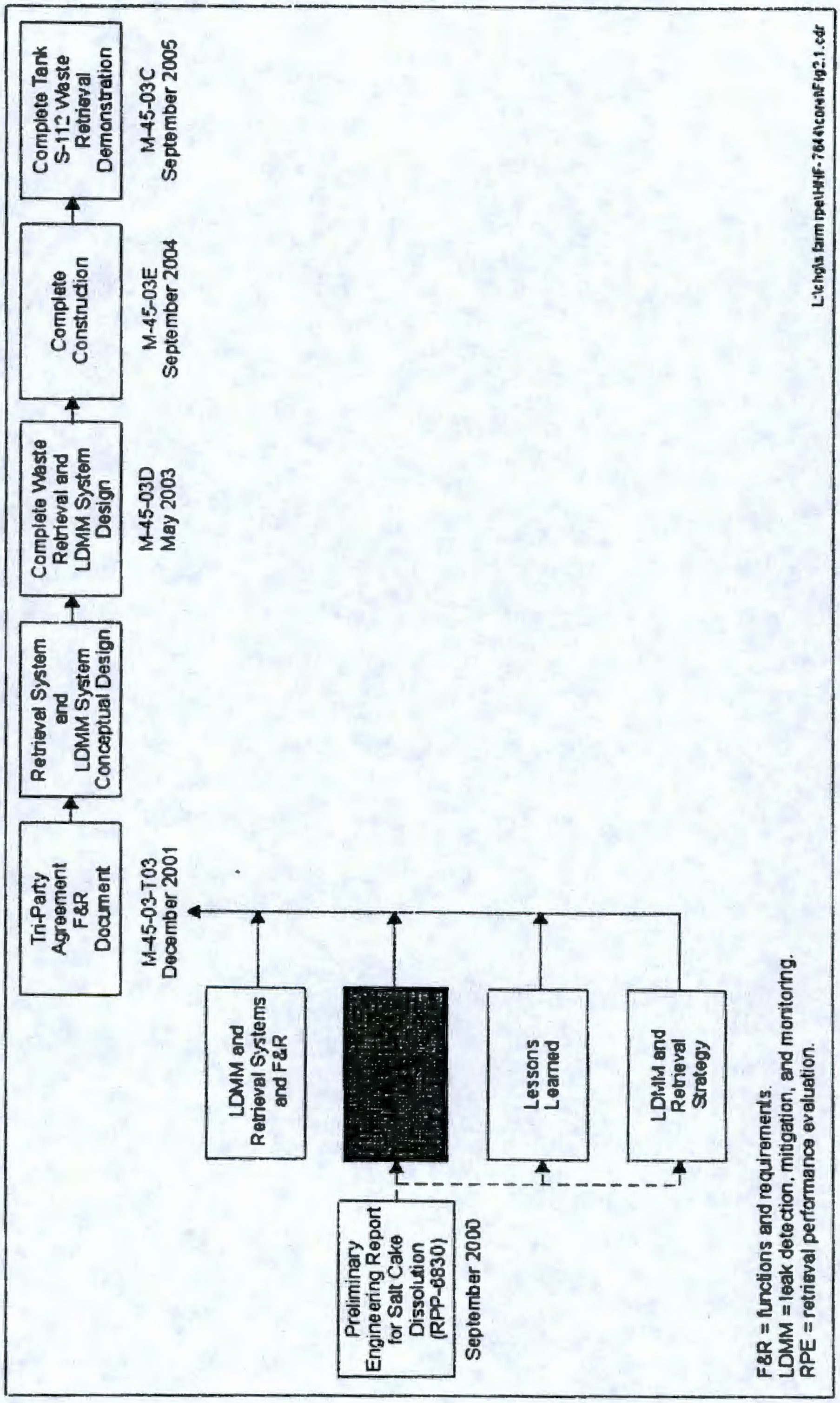
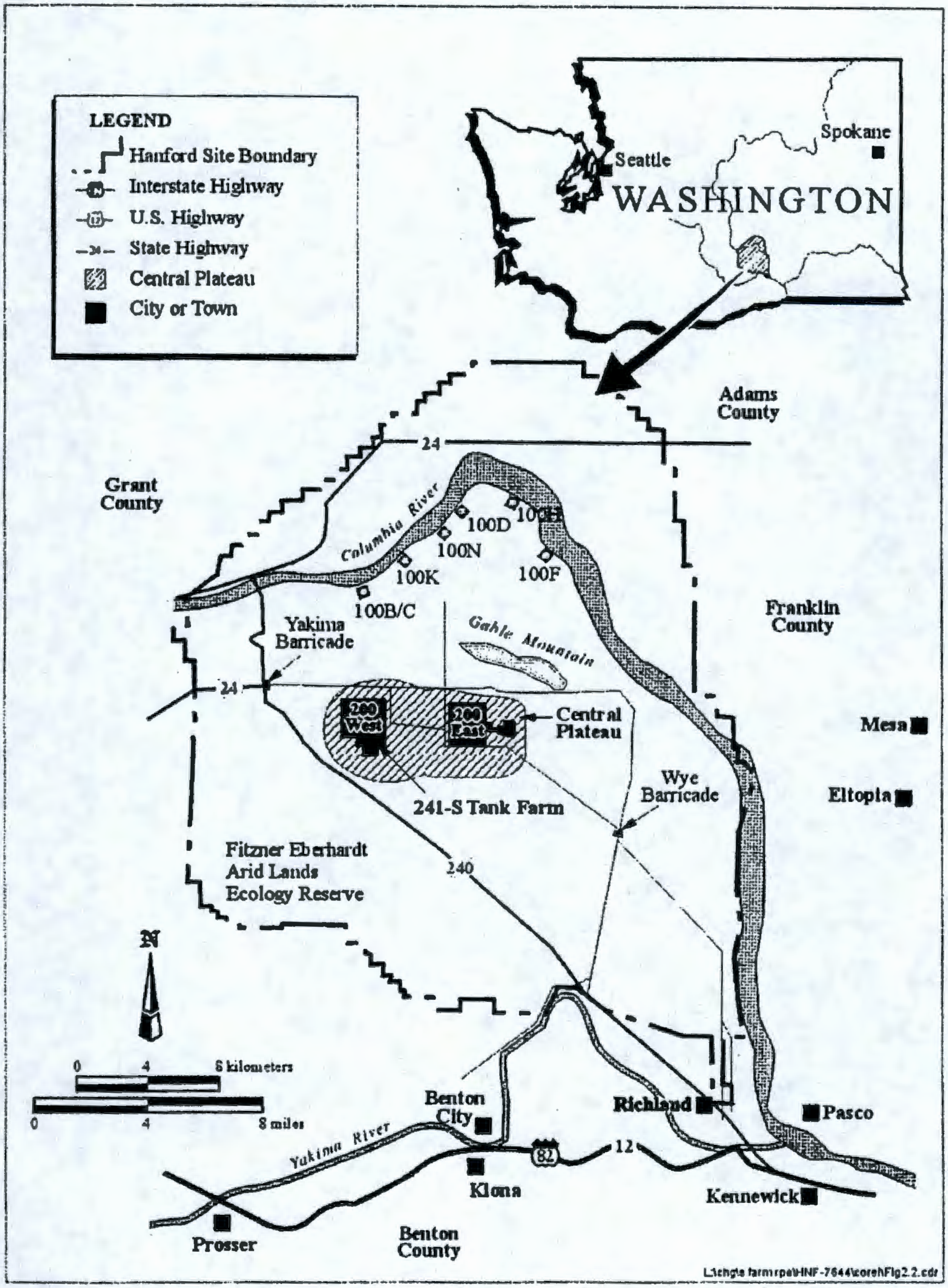


Figure B.2.2. Hanford Site Map and Vicinity



B.2.2 FACILITIES DESCRIPTION

This section contains descriptions of the S tank farm and tank S-112. Definition and description of ancillary equipment are also provided.

B.2.2.1 S Tank Farm

The S tank farm is located in the southern portion of the Hanford Site 200 West Area, near the Reduction-Oxidation (REDOX) Plant (Figure B.2.3). The S tank farm contains 12 SSTs each with a 2,869,000-L (758,000-gal) capacity; waste transfer lines; leak detection systems; and tank ancillary equipment. The SSTs are 23 m (75 ft) in diameter. The S farm SSTs are approximately 11.4-m (37.3-ft) tall from base to dome. The sediment cover from the apex of the dome to ground surface is approximately 2.5 m (8.0 ft) at the S tank farm. All of the tanks have a dish-shaped bottom (Figure B.2.4). Information and data regarding the S tank farm facility description are taken from historical tank content estimate (WHC-SD-WM-ER-352).

The tanks in the S tank farm received REDOX Plant waste, which was allowed to self-boil or self-concentrate through evaporation of liquid. The S tank farm was built between 1950 and 1951. S tank farm operations began in 1951. The tanks were filled with liquids by 1953; however, the waste in the tanks began self-boiling in the summer of 1952 because of the radioactive decay heat load in the REDOX Plant wastes. A surface condenser was installed in 1953 to concentrate the waste and provide more tank space. The vapor condensate was disposed of in nearby cribs. Liquid levels in the tanks fluctuated during the next 20 years and then the tanks filled rapidly with solids. The change can be attributed to the startup of the 242-S Evaporator because the tanks were used as receivers for evaporator waste products. When the tanks were filled with solids, little could be done with technology that had been developed to increase the service lives of the tanks. The tanks were removed from service in the late 1970s and early 1980s (WHC-SD-WM-ER-352). Tank S-104 is the only tank in the S tank farm that is assumed to have leaked.

The S farm SSTs are treatment, storage, and/or disposal (TSD) units operating under interim status pending closure. Following waste retrieval, the S tank farm will be closed in accordance with "Closure and Postclosure" (WAC 173-303-610) under the Washington State "Hazardous Waste Management Act" (HWMA) and HFFACO Milestone M-45-00. Under the *Washington Administrative Code* and HFFACO requirements, individual tanks cannot be closed; an entire tank farm must be closed as a unit.

Figure B.2.3. Location Map of S Tank Farm and Surrounding Facilities in the 200 West Area

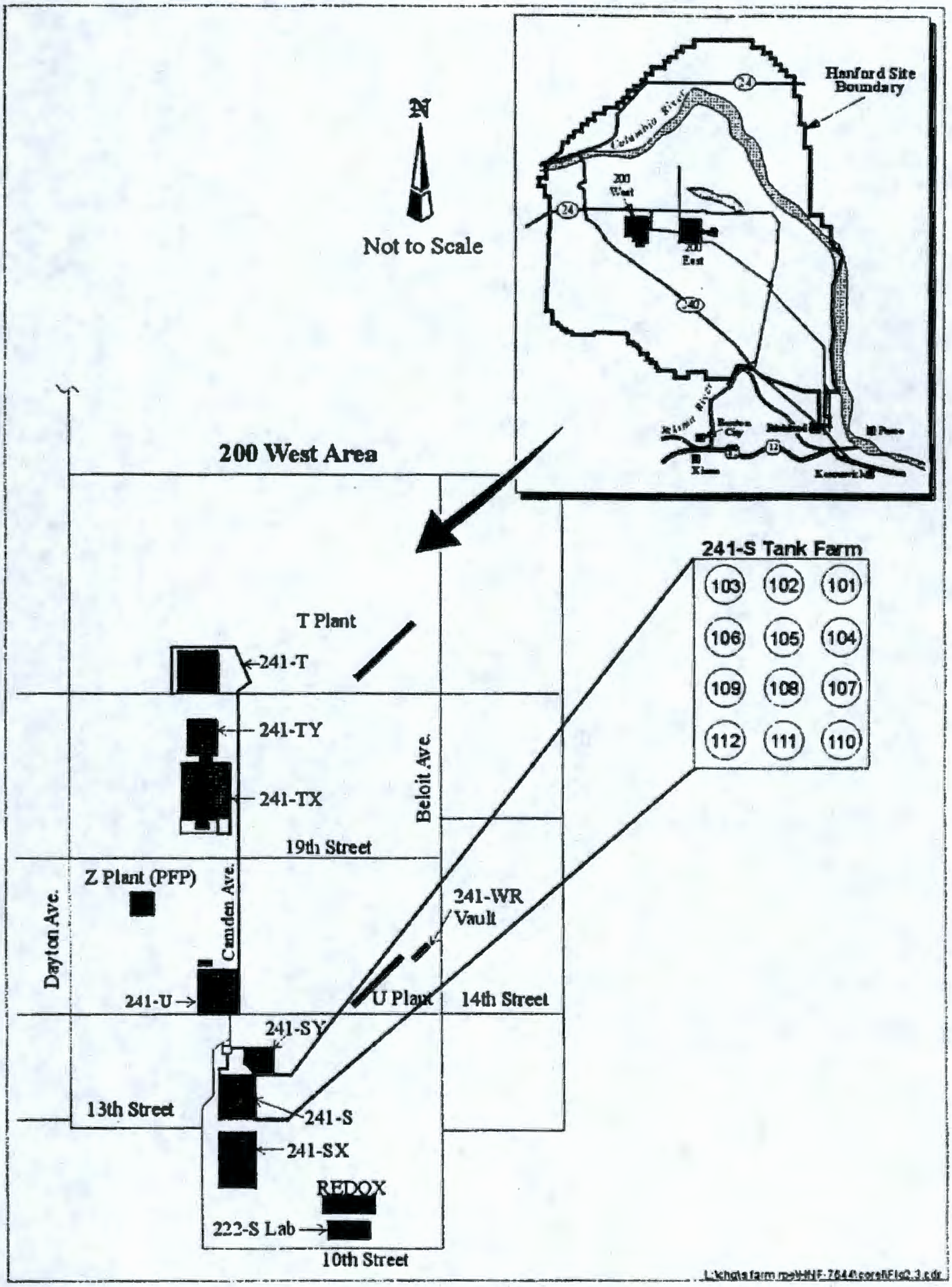
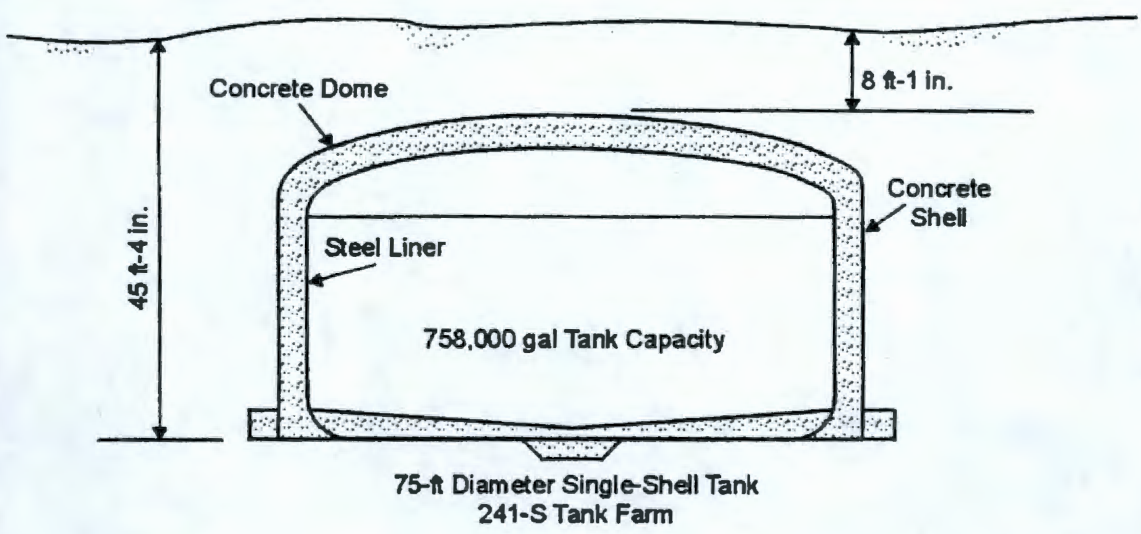


Figure B.2.4. S Farm Tanks



(Adapted from HNF-EP-0182, Rev. 129)

B.2.2.2 Tank S-112

Tank S-112 was used to store REDOX Plant waste beginning in 1952. The tank was removed from service in 1974 and labeled inactive in 1976. Interim stabilization efforts were initiated in 1978 and 473,000 L (125,000 gal) of liquid were removed between 1978 and 1980. Tank S-112 is categorized as a Watch List tank for hydrogen/flammable gas (HNF-EP-0182, Rev. 150). The tank is classified as a sound tank with 2,000,000 L (523,000 gal) of waste, which includes 265,000 L (70,000 gal) of pumpable liquid.

B.2.2.3 Ancillary Equipment

Ancillary equipment is defined as structures, piping, and equipment outside of waste tanks but associated with tank farm operations. Most of the ancillary equipment in the S tank farm was abandoned in place when the S farm tanks were taken out of active service. Evaluating ancillary equipment is an important component of closure strategy evaluations because the equipment represents a potential source term for worker exposures (if the equipment is removed) or long-term human health risk (if the equipment is left in place). S tank farm ancillary equipment includes the following:

- Surplus buildings and other surface facilities
- 72 drywells
- Tank riser penetrations

- Direct-buried piping, encased piping, and ventilation elements
- Pump pits, sluice pits, and valve pits associated with individual tanks
- Other valve pits, jumper pits, diversion boxes, and structures.

Potential sources of contamination include residual waste in the transfer lines, sluicing lines, valve pits, and pump pits. There is currently insufficient data available to assess the contaminant inventory in the ancillary equipment and, therefore, this contamination source was not included in the calculation of long-term risks. This approach is reasonable for this scoping level RPE to support retrieval decisions for tank S-112. Inventory estimates for the ancillary equipment will be needed for future performance evaluations of closure options.

B.3.0 TECHNICAL APPROACH

The value and response of risk and regulatory measures to variations in two main system parameters are the primary focus of this RPE. These two parameters are residual waste volume and retrieval leakage volume. Evaluation of the residual waste volumes supports the definition of the waste retrieval system requirements while evaluation of retrieval leakage volumes supports definition of the LDMM system requirements.

Section B.3.1 provides an overview of the technical approach. Section B.3.2 describes the approach used to identify specific waste retrieval cases for analysis. Section B.3.3 describes the approach used to develop contaminant inventory estimates for past leaks, retrieval leakage, and residual waste for each of the waste retrieval cases. Sections B.3.4 through B.3.8 describe the approach used for the five areas of analysis included in this RPE. Using the technical approach described in this section, performance measures for each case are calculated for four areas of analysis including short-term human health risk, groundwater impacts, long-term human health risk, and inadvertent human intruder risk. The results of these calculations are presented in Section B.5.0. The fifth area of analysis involves comparing the case-specific performance measures against the appropriate regulatory standards and identifying where regulatory uncertainty exists.

The methodology described for establishing waste retrieval and leak loss criteria for tank S-112 involves performing a baseline risk assessment of the S tank farm. In developing the approach for contaminant transport modeling it became apparent that four individual cross-sections were needed to capture the differences in past leaks and tank-specific inventories.

B.3.1 OVERVIEW OF THE TECHNICAL APPROACH

The RPE process was developed as a decision-making tool to support tank waste retrieval and tank farm closure decisions using a systems approach that considers contributions from multiple sources (i.e., past leaks, retrieval leakage, and residual waste) across a number of performance measures. The RPE methodology is an iterative process that can be applied before designing the waste retrieval system to develop criteria for the extent of waste retrieval and leak loss. After retrieval the methodology can be used to evaluate performance measures using actual retrieval and leak loss data. The technical approach includes integration with related site activities (e.g., Tank Farm Vadose Zone Project). The current application of the RPE focuses on developing waste retrieval and leak loss criteria for tank S-112 within the S tank farm. The following tank farm performance measures are assessed.

- **Short-term human health risk** (Section B.3.4) – Health risk to workers and the public from chemical and radiological exposures that is expected to occur during routine remedial actions (e.g., waste retrieval) or that could result from postulated accidents, injuries, and fatalities resulting from industrial accidents.

- **Groundwater impacts** (Section B.3.5) – Impacts resulting from contaminant release and migration to the groundwater are assessed and compared to regulatory standards.

Groundwater quality impacts are evaluated at the tank farm boundary over a 10,000-year period of interest beginning at present.

- **Long-term human health risk** (Section B.3.6) – Human health risk to future Site users that would exist after completion of waste retrieval (post-remediation) and implementation of tank farm closure. Long-term human health risk analysis involves evaluation of health risks resulting from exposure to contaminated groundwater. CoCs to long-term human health risk are those that are persistent and mobile in the environment.

  A 10,000-year period of interest was used for calculating long-term human health risk based on the lifestyle of a residential farmer and an industrial worker. This time period was selected for the following reasons:

  - Classification of the residual waste under *Radioactive Waste Management* (DOE O 435.1). If residuals do not meet the 'waste incidental to processing' criteria a determination from the U.S. Nuclear Regulatory Commission (NRC) will be required, based in part on demonstrating protection of human health and the environment over a 10,000-year period

  - Future requirements for assessing tank closure will consider the 10,000-year period

  - Based on previous analyses, the maximum long-term risk impacts from tank residuals are expected to occur 1,000 to 10,000 years following closure.

- **Inadvertent human intruder risk** (Section B.3.7) – Human health risk to future Site users who could inadvertently drill through the tank following closure and loss of institutional control at 100 years after closure. A comparison of the residual waste inventory to NRC waste classification criteria is also made to support a regulatory evaluation of the planned approach for reclassification of the residuals as incidental waste. CoCs to the inadvertent human intruder include isotopes of cesium, strontium, tin, and transuranics (TRUs) that would remain in the tank.

- **Regulatory compliance** (Section B.3.8) – Applicable and appropriate regulatory requirements have been identified including areas where open issues and specific quantitative performance measures exist.

The best available data for tank S-112 and the S tank farm were used to provide calculations for each performance measure. Where data were unavailable or highly uncertain, assumptions were developed to complete the analysis. The major assumptions are defined in the following methodology sections. Those assumptions were based on engineering judgment following a review of available data or information from other Hanford Site, DOE complex, or non-DOE remediation programs.

Application of the RPE methodology to the evaluation of tank S-112 and the S tank farm includes the following components:

- Conceptual model of the tanks and S tank farm system (e.g., tank farm components, sources of contamination, engineered systems, and the natural environment) to analyze the potential implications of SST waste retrieval
- Waste retrieval cases that span a range of residual waste and retrieval leakage volumes that will be used to develop risk versus volume relationships
- Risk assessment to assess short- and long-term human health risks
- Comparison of the waste retrieval cases to requirements established by federal and state regulations and the HFFACO.

Sections B.3.1.1 through B.3.1.4 outline how each of these components are applied in the tank S-112 evaluation.

B.3.1.1 Conceptual Model of the S Tank Farm

SST waste retrieval decisions and subsequent tank farm closure decisions are interrelated on a tank-by-tank and tank farm-by-tank farm basis. They are also interrelated with other decisions regarding remediation and closure of a number of other waste sites in the 200 Areas.
This analysis focuses on tank S-112 within the context of the S tank farm. Considering the tank farm conceptually as a whole provides a means to evaluate the performance measures at a tank-farm level while also evaluating performance measures changes resulting from variations in residual waste and retrieval leakage parameters for specific tanks of interest. The conceptual model is depicted in Figure B.3.1 and includes the following.

- The S tank farm including tanks and soils within the tank farm boundary and from the surface to the groundwater.
- All waste sources within the S tank farm including:
  - Contamination in the vadose zone from tank leaks
  - Potential releases to the environment during waste retrieval activities
  - Releases to the environment from residual waste potentially remaining in the tank farm following completion of waste retrieval and assumed closure actions.
- Long-term degradation of the tanks and assumed tank closure system.
- Migration of mobile contaminants from the tank farm through the vadose zone and groundwater.
- Residential farmer and industrial worker scenarios and resulting human health impacts from contaminants that have migrated beyond the tank farm boundary.

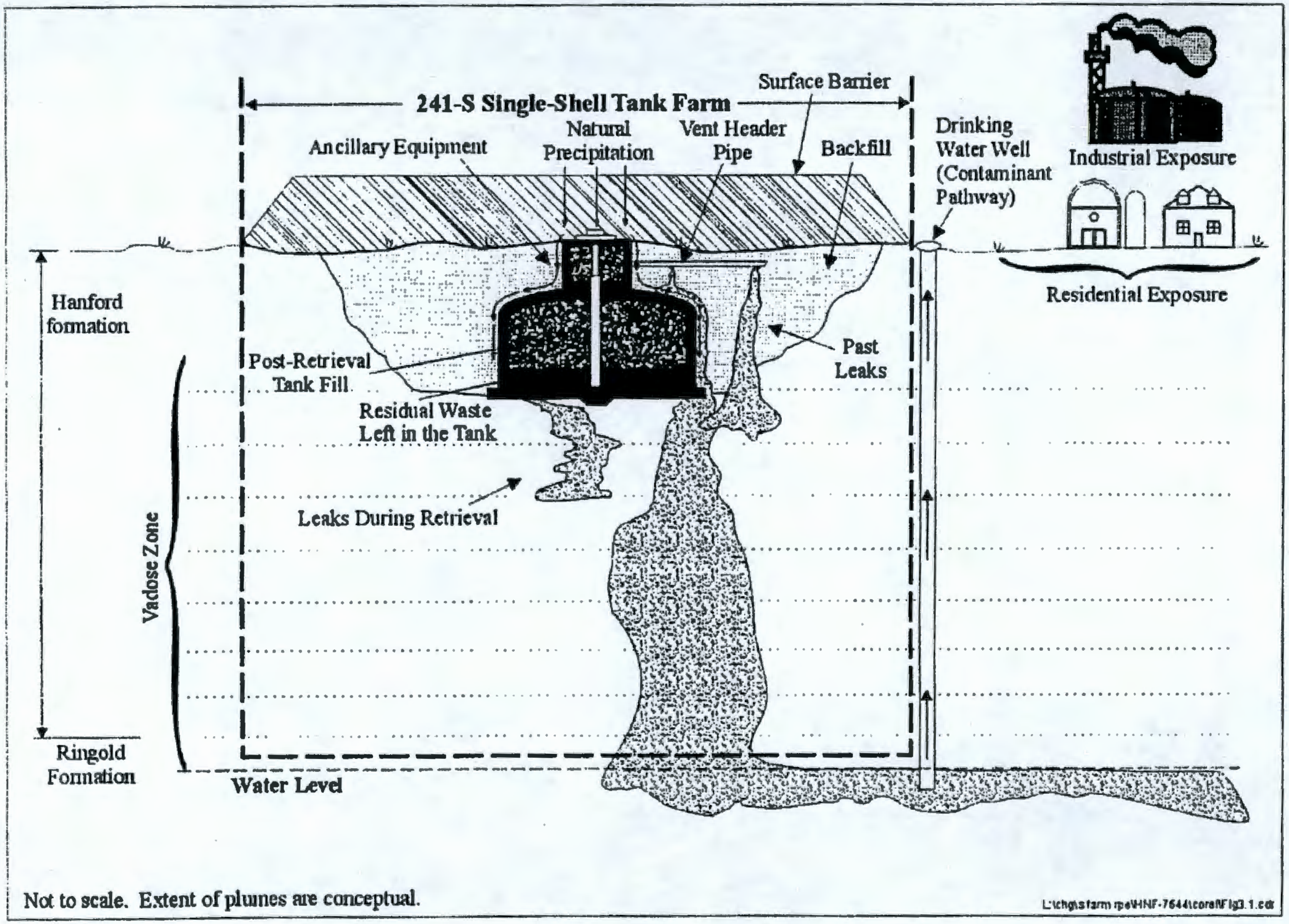


Figure B.3.1. S Tank Farm Conceptual Model for Long-Term Human Health Risk and Groundwater Impacts

The conceptual model shown in Figure B.3.1 identifies source terms, transport pathways, and exposure pathways that could be under investigation by other Site projects (e.g., Tank Farm Vadose Zone, Groundwater/Vadose Zone Integration Project). Efforts to integrate this RPE with other projects were made to provide consistency in approach and methodology. The S tank farm is under the *Resource Conservation and Recovery Act of 1976* (RCRA) Corrective Action so there is a direct integration point at the S tank farm. The past leak inventory for the S tank farm developed by the Groundwater/Vadose Zone Integration Project was adopted for this RPE.

Figure B.3.2 depicts the waste sources, release mechanisms, exposure pathways, and receptors for all impacts analyzed in this RPE. Figures B.3.1 and B.3.2 also serve to illustrate much of the scope of this document, which includes evaluations of impacts associated with all past leak releases, potential future releases from the tanks during retrieval and post-closure, and intrusion into the tanks during post-closure. The scope of this document does not include the impacts associated with immobilization and disposal of the waste once it has been retrieved from the tanks.

B.3.1.2 Use of Waste Retrieval Cases

The approach used to evaluate performance measures for tank S-112 was to identify a number of specific cases that cover a range of retrieval leakage volumes and residual waste volumes. These cases are evaluated against an assumed standard level of retrieval performance in the remaining 10 S farm tanks. Short-term human health risks are evaluated with retrieval activities for the S farm tanks of interest. Groundwater and long-term human health impacts are evaluated on a cross-sectional basis for the farm as well as on an individual tank basis. Inadvertent human intruder risks are evaluated on a tank basis.

B.3.1.3 Performance of a Risk Assessment

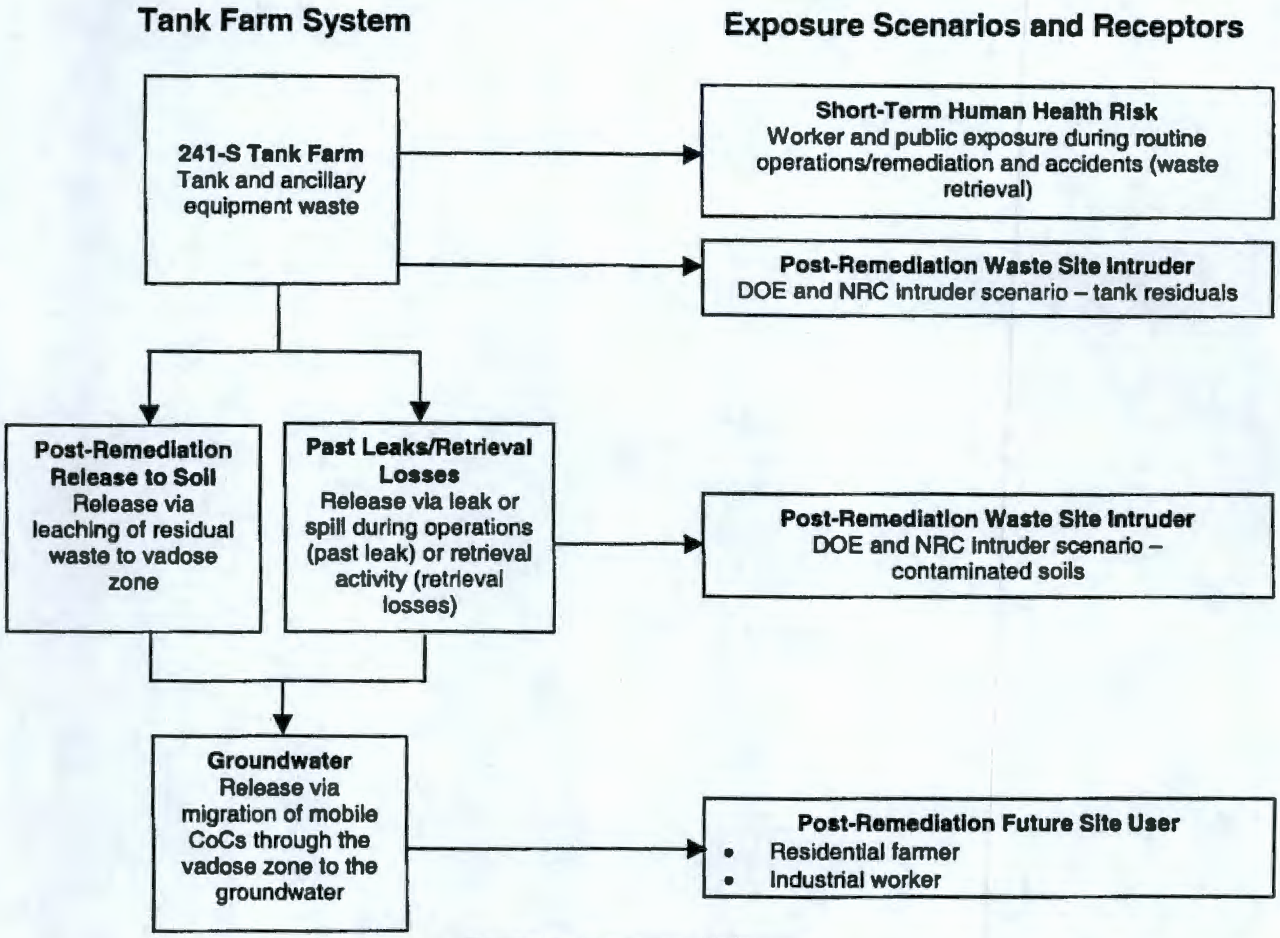
Waste retrieval actions for tank S-112 are evaluated and accident and routine conditions considered. The dominant pathways for short-term exposure include air releases and direct exposure.

Long-term human health risk is calculated based on exposure through the groundwater pathway. Exposure through other pathways (i.e., air and direct contact) would be limited by the tank closure system design and the surface barrier. Thus, contaminant migration through the vadose zone into groundwater and from groundwater to receptors is determined the dominant exposure pathway to future Site users located outside the tank farm boundary.

A numerical model is used to simulate the migration of contaminants through the vadose zone to the groundwater and in the groundwater to the tank farm boundary for each of the major source term components (e.g., past leaks, retrieval leakage, residual waste).

A human intruder into the residual waste following tank farm closure may limit the ability to close some tanks based on the residual waste inventory left in the tanks following waste retrieval. To address this issue, waste site intruder analyses are conducted using both DOE and NRC intruder scenarios.

Figure B.3.2. Evaluated Waste Sources, Release Mechanisms, Exposure Pathways, and Receptors



Receptor Exposure Pathways

Short-Term Human Health Risk				Long-Term Human Health Risk		Long-Term Human Health Risk Future Site User (Post-Remediation)	
				Waste Site Intruder*			
Pathway	Involved Worker	Noninvolved Worker	Public	NRC	DOE	Residential Farmer	Industrial Worker
Inhalation	✓	✓	✓	NA	✓	✓	✓
Direct Exposure	✓			NA	✓		
Groundwater Ingestion				NA		✓	✓
Food Ingestion			✓	NA	✓	✓	
Soil Ingestion				NA	✓	✓	
Dermal (Water)				NA		✓	✓

*The NRC intruder scenario is based on concentration limits of CoCs in the waste.

CoCs = contaminants of concern.
DOE = U.S. Department of Energy.
NA = not applicable.
NRC = U.S. Nuclear Regulatory Commission.

B.3.1.4 Regulatory Compliance

Waste retrieval and future tank farm closure is driven by federal and state regulatory requirements and the values of stakeholders and Tribal Nations. Requirements for waste retrieval and tank farm closure include federal and state regulations associated with management, treatment, and disposal of chemical and radiological wastes.

B.3.2 IDENTIFICATION OF WASTE RETRIEVAL CASES FOR ANALYSIS

Ten waste retrieval cases are identified for this evaluation, as shown in Table B.3.1. Each case assumes specific values for retrieval leakage volume and residual waste volume for tank S-112 and the remaining S farm tanks. The cases were developed by varying one of the system components (i.e., retrieval leakage or residual waste volume) so that results could be compared and risk-versus-volume relationships developed. Because the long-term performance measures associated with closure are evaluated for a tank farm, each waste retrieval case identifies an assumed endstate for tank S-112 and for the remaining S farm tanks. Because the RPEs for tanks S-112 and S-102 are being developed in parallel, the cases identified in Table B.3.1 were developed to address both tanks. The specific retrieval leak and residual waste volumes used to develop the cases are intended to provide impacts over a range of volumes and not to select one of the cases for implementation. It is important to note that to provide results over a range of inputs, some of the cases identify residual waste volumes and retrieval leakage volumes that would not meet the objectives of the tank S-112 retrieval technology demonstration or the HFFACO interim retrieval goal for tank S-112. The purpose of the analysis is to evaluate how the performance measures change as the residual and retrieval leakage volumes change.

Table B.3.1. Summary of Waste Retrieval Cases

Case	Residual Volume Remaining Following Retrieval			Retrieval Leak Loss			Interim Barrier
	Tank S-102 (gal)	Tank S-112 (gal)	Remaining S Farm Tanks (gal)	Tank S-102 (gal)	Tank S-112 (gal)	Remaining S Farm Tanks (gal)	
1	2,700	2,700	2,700	0	0	0	N
2	2,700	2,700	2,700	8,000	8,000	8,000	N
3	1,300	2,700	2,700	8,000	8,000	8,000	N
4	2,700	6,000	2,700	8,000	8,000	8,000	N
5	27,000	27,000	2,700	8,000	8,000	8,000	N
6	2,700	2,700	2,700	0	0	8,000	N
7	2,700	2,700	2,700	4,000	4,000	8,000	N
8	2,700	2,700	2,700	40,000	40,000	8,000	N
9	2,700	2,700	2,700	8,000	80,000	8,000	N
10	2,700	2,700	2,700	0	8,000	0	Y

Note: 2,700 gal represents the HFFACO interim retrieval goal of 360 ft^3 for the 100-series single-shell tanks.
To obtain liters multiply gallons by 3.785.

The two major components identified in Section B.3.1, retrieval leakage and residual waste volume, were combined to form the waste retrieval cases analyzed. Other elements of the cases are assumed fixed. That is, the same past leak inventory estimate is used for each case, and all cases assume an enhanced RCRA Subtitle C barrier is constructed over the tank farm for closure.

The approach used to develop waste retrieval strategies resulting in volume retrieved and leak loss assumptions is based on the fiscal year (FY) 2000 preconceptual engineering studies conducted for tank S-112 (RPP-6830; RPP-7819).

The tank S-112 waste retrieval demonstration is intended to show the capability of a technology to retrieve salt cake waste from a tank. It is anticipated that the effectiveness or efficiency of the retrieval system will drop off as the amount of waste remaining in a tank decreases resulting in greater cost and worker health risk per volume of waste retrieved. The practical limit for when the retrieval system has reached the limit of the technology will be defined in the HFFACO F&R documents. HFFACO Milestone M-45-03C establishes a waste retrieval goal of 99% of the tank contents by volume with approximately 550 curies of mobile, long-lived radioisotopes retrieved to safe storage.

Conservative assumptions are made for the various tank farm case elements so as to not underestimate the long-term human health risk contribution from the remaining S farm tanks. The assumptions made for the remaining S farm tanks are not intended to describe the planned approach but to develop a conservative basis for evaluating long-term human health risk for the S tank farm. For all but one of the waste retrieval cases it is conservatively assumed that each tank leaks during waste retrieval. No retrieval leakage is expected from a sound tank.

B.3.3 SOURCE TERM INVENTORY ESTIMATES

The RPE evaluates three source terms:

- **Past leaks** – Contamination that is currently in the tank farm soil as a result of tank leaks or spills that have occurred in the past
- **Retrieval leakage** – Contamination released to the soil during the waste retrieval operation
- **Residual waste** – Contamination remaining in the tank following waste retrieval operations.

Identification and quantification of source terms are necessary to evaluate both the short-term impacts to human health during routine remediation activities and accidents and the long-term impacts resulting from releases to the tank farm soil. Releases of concern for evaluating long-term impacts include past leaks and spills, potential releases that may occur during waste retrieval, and the eventual release of residual waste remaining in the tanks following closure. Once in the vadose zone contaminants are subject to the influence of fate and transport processes that tend to drive contaminants toward the groundwater, which is the main source of long-term exposure. Source terms of concern for short-term human health risk assessment (both routine and accident) are predominantly in the form of air emissions. Source terms of concern for intruder scenarios are based on inventories of TRU waste and other isotopes of concern from a direct exposure or ingestion pathway caused by an inadvertent intrusion into a waste tank.

The first step in developing source terms involves developing inventory data for the waste retrieval cases. Inventory estimates were developed for each of the major long-term human health risk source term components; past leaks; potential retrieval leakage ranging from 15,000 L (4,000 gal) to 300,000 L (80,000 gal); and residual waste volumes ranging from 4,900 L (1,300 gal) to 100,000 L (27,000 gal). The inventory estimates are provided in the Attachment of this document.

B.3.3.1 Past Leak Estimates

The inventory associated with past leaks at or around tank S-104 (i.e., the only leaking tank at S tank farm) has been evaluated for the S tank farm as a part of the waste management area (WMA) S-SX RCRA facility investigation process (RPP-6285). This inventory comprises a best-estimate of contaminant inventory currently in the vadose zone. The distribution of this inventory as a function of depth was then estimated in the modeling data package for the WMA S-SX field investigation report (FIR) by the Vadose Zone Project (RPP-6296).

In support of the WMA S-SX FIR, the past leak inventories for cesium-137, technetium-99, nitrate, and chromium are presented as soil concentrations as a function of depth. This estimate does not include all of the CoCs used in the contaminant transport and long-term human health risk analyses.

Data from the baseline spectral gamma logging were used in the tank S-112 RPE. The past leak losses were based on the FIR for WMA S-SX (RPP-7884) to be provided to Ecology for approval on January 30, 2002. The FIR for WMA S-SX used the baseline spectral gamma data, gross gamma data, groundwater monitoring data for all RCRA groundwater monitoring wells installed as of FY 2001 (PNNL-12114). A full understanding of past leak releases were evaluated for the highly impacted areas around SSTs SX-107, SX-108, SX-109 and SX-115. Understanding of past releases at tank S-104 was evaluated for the FIR for WMA S-SX and was incorporated into this RPE through the modeling conducted for this RPE. The only difference was the time of compliance was extended to 10,000 years instead of 1,000 years and uranium-238 was included as one of the CoCs for this RPE.

B.3.3.2 Retrieval Leak Loss Estimates

The chemical and radiological inventories associated with the waste retrieval cases were estimated as a part of this task and are presented in the Attachment of this document. A range of potential retrieval leakage volumes are evaluated to support development of LDMM F&Rs. The time and duration of the assumed retrieval leakage events were developed using available retrieval sequence data (RPP-7087). The major assumptions include the following.

- Leak loss rates would be constant throughout the retrieval period.
- Leak loss occurs uniformly around the outer edge of a tank base. It is assumed that the retrieval leakage will be released over a 1.5-m- (5-ft-) wide ring circling the base of the

tank. This corresponds to an area approximately equal to 25% of the tank base area. This assumption is based on engineering judgment and available data on potential leak mechanisms (HNF-4872). If a leak were to occur during waste retrieval the most likely reason for tank failure would be corrosion of the tank steel liner. If corrosion-related failure of the steel liner were to occur it would likely occur at multiple sites throughout the tank. This and the assumption that two probable leak paths out of the concrete tank shell are near the outer edge of the tank base supports the assumption of uniform leakage around the perimeter of the tank base. The two probable leak paths out of the concrete shell are (1) through the construction joint where the tank sidewall meets the base and (2) through cracking in the tank base along the outer edge resulting from vertical loads imposed by the tank sidewall.

Leak loss, if it occurs, will be proportional to retrieval time. The schedule used as a planning basis for waste retrieval has recently been updated to reflect the strategy of using tank S-112 for technology demonstration for salt cake dissolution. The current waste retrieval schedule from the 2000 retrieval sequence update for tank S-112 includes a start date of October 1, 2004 and a duration of 193 days (RPP-7087). The start date and duration indicate the time over which a tank is assumed to leak. The 193 days are assumed for waste retrieval in the short-term human health risk analysis based on the anticipated salt cake dissolution rates identified in *Technology Evaluation for S-103 Saltcake Dissolution Retrieval Demonstration* (RPP-6821).

The concentration of CoCs in leak loss was developed using the BBI (BBI 2000) and tank-specific wash factors (HNF-3157). The amount of water required to retrieve the waste is estimated using waste transfer constraints for both 5 Molar sodium and 10 wt% solids in the retrieved slurry. The larger of the calculated water volumes is then used to calculate the concentration of individual contaminants in the retrieval liquid. The resulting concentrations multiplied by the retrieval leak loss volume provides the retrieval leakage inventory for the individual waste retrieval cases.

B.3.3.3 Residual Waste Estimates

The contaminants that would remain in the tanks after waste retrieval constitute the residual waste inventory. Release of the residual waste is evaluated assuming that the integrity of a tank degrades over a period of 500 years after which recharge water from infiltrating precipitation is assumed to enter the tank, dissolve the residual waste, and drain out into the surrounding vadose zone through cracks in the tank.

The starting point for calculating residual waste inventories is the BBI estimate for each tank (BBI 2000). BBI estimates are derived from the best data sources available. These sources include sample results, model output, historical waste transfer logs, engineering judgments, and calculations.

Two methods were used to develop residual waste inventory estimates for the S farm tanks, based on retrieval assumptions. For tank S-112 the retrieval method is expected to have only localized agitation of the sludge. Consequently, wash factors (HNF-3157) were not applied to the existing sludge before mathematically reducing the heel volume. Other tanks in the S farm were assumed to undergo thorough mixing of the existing sludge with retrieval fluids, and wash factors were applied to the sludge prior to mathematically reducing the sludge heel volume. These methods are similar to calculation methods previously employed and use the same starting data currently employed by the Hanford tank waste operation simulator model to simulate all of the tank farm waste retrieval operations from waste retrieval. Calculation details are found in the Attachment to this document.

B.3.3.4 Ancillary Equipment Inventory

The contaminant inventory currently in the abandoned S tank farm ancillary equipment is of interest in calculating the total long-term impacts from the tank farm under a landfill closure type scenario. This inventory would add to the inventory remaining in the tank farm from tank residuals and contaminated soils and would contribute to the closure source term. There is currently insufficient data available to develop a reasonable estimate basis for the contaminant inventory in the ancillary equipment; therefore, an estimate of this inventory was not developed for this RPE. This is believed to be reasonable for this scoping-level RPE because of the following.

- The ancillary equipment inventory will likely be relatively small in comparison to the residual waste inventory remaining in the tanks following retrieval.

- This RPE is targeted at establishing retrieval requirements for initiating waste retrieval efforts in the S tank farm. Future updates to the RPE will allow additional information to be incorporated as it becomes available (e.g., ancillary equipment inventory, actual residual waste inventories, leak loss estimates).

- The risk allocation methodology provides for balancing the risk from an individual tank within the context of the tank farm and the ancillary equipment inventory can be accommodated as one of the other sources in the tank farm.

B.3.4 SHORT-TERM HUMAN HEALTH RISK

The intent of the short-term human health risk analysis is to estimate the potential health impacts from both accident and normal (nonaccident) conditions resulting from various tank residual scenarios for the S tank farm during waste retrieval activities. The analysis identifies the spectrum of potential accidents associated with construction and operation activities. The hazards associated with these activities include potential occupational hazards resulting in physical trauma, radiological exposure resulting in latent cancer fatalities (LCFs), and toxicological exposure resulting in toxic or corrosive health effects. Initiating events that could result in hazardous health effects may include natural phenomena, human error, component failure, and spontaneous reactions. Health risks during normal conditions include anticipated exposure to radiation fields and radiological and chemical releases to the atmosphere during normal waste retrieval activities.

All waste retrieval cases in this evaluation assume that an enhanced RCRA subtitle C barrier will be constructed over the S tank farm for closure. Because the short-term human health risk associated with closure activities would be common to all the cases it would not be a differentiator and is therefore not evaluated.

Retrieval leak losses are assumed to occur at or near the base of a tank. It is not anticipated that the subsurface leaks at the base of a tank would result in an atmospheric release (in the short-term) nor would the ionizing radiation have an appreciable health risk to the workers. For this reason the short-term human health risk from retrieval leak loss is not evaluated.

B.3.4.1 Occupational Injuries, Illnesses, and Fatalities

The number of injuries, illnesses, and fatalities resulting from waste retrieval activities is calculated based on currently available incidence rates applicable to waste retrieval activities. The number of injuries, illnesses, and fatalities from construction or operations is calculated by multiplying the total person-years required to support the activity by the incidence rates.

B.3.4.2 Radiological Risk from Accidents

Radiological risk is expressed as the number of LCFs resulting from accidents in which people are exposed to radiation fields or radiological constituents released to the atmosphere. The probability of an accident occurring also is evaluated. The methodology used to identify and quantify radiological risk from accidents involves the following steps.

Step 1. Accident identification. Potential hazards associated with retrieval activities were identified from existing preliminary hazard analyses and other safety documents. The hazards are reported in a tabular format showing, for each accident, the barriers within the facility that prevent or mitigate the consequences of the accident, a rough estimate of the magnitude of consequences of the accident assuming that the listed preventive barriers fail, and the estimated likelihood of the accident occurring.

Step 2. Accident strategy selection. The accident with the highest risk is screened for further analysis to determine, as accurately as possible, the consequences and probability of occurrence. The risk of a given accident is the product of the consequences of the accident and the estimated likelihood of the event occurring. Screening for the highest-risk accidents follows the same methodology as outlined in Section B.3.3.2.3.5 of *Preparation Guide for U.S. Department of Energy Nonreactor Nuclear Facility Safety Analysis Reports* (DOE-STD-3009-94).

Step 3. Accident sequence quantification. The frequency of occurrence of the selected accidents is taken from referenced documents where available. Where accident frequencies are not available they are estimated.

Step 4. Source term development. The source term is the respirable fraction of inventory from which the receptor dose is calculated. The source term is developed based on the inventory that could be released to the environment from an accident. The major reduction factors that control the source term are considered in the evaluation. The reduction factors include damage ratios, airborne release fractions, airborne release rates, leak path factors, and respirable fractions. Use of the reduction factors is dependent upon the nature of the accident (i.e., energy of accident at impact, waste form, and effectiveness of mitigating barriers). Exposure resulting from direct exposure to radiation under accident conditions also is evaluated. Direct exposure is the direct gamma radiation dose rate to a receptor.

Step 5. Atmospheric Dispersion Coefficients. The atmospheric dispersion coefficient (χ/Q) values are generated using the GXQ computer code following the methodology outlined in *Atmospheric Dispersion Models for Potential Accident Consequence Assessment at Nuclear Power Plants* (NUREG 1.145). The meteorological data used by the GXQ code is in the form of joint frequency tables. The joint frequency data used are taken from data collected at the Hanford Site meteorology tower in the 200 West Area. The atmospheric dispersion coefficient values are used in equations to calculate the radiological dose experienced by the noninvolved worker and general public receptors as a result of inhaling radioactive materials. Ingestion of radioactive materials is also included for the general public receptor dose.

Step 6. Receptor determination. Potential health effects from radiological exposures are estimated for three subsets of populations and maximally exposed individuals (MEIs) in those populations. The dose to a receptor depends on the location of the receptor relative to the point of release of the radioactive material. The involved workers are those involved in the proposed action and are performing work at the facility. Those workers are assumed to be in the center of a 10-m- (33-ft-) radius hemisphere where the airborne released material has spread instantaneously and uniformly. The noninvolved workers are those that would be on the Hanford Site but not involved in the action. Those workers are assumed to extend from 100 m (330 ft) out to the Hanford Site boundary. The general public is assumed to be located at the Site boundary to a distance of 80 km (50 mi) from the point of release. The Hanford Site boundary used in the analysis is the adjusted Site boundary that excludes areas designated as part of the Hanford Reach National Monument (65 FR 7319). Those areas include the North Slope, the Hanford Reach of the Columbia River, and the Fitzner-Eberhardt Arid Lands Ecology Reserve. The Site boundaries are as follows:

- North: Columbia River, 0.4 km (0.25 mi) south of the south river bank
- East: Columbia River, 0.4 km (0.25 mi) west of the west river bank
- South: A line running west from the Columbia River, just north of the Energy Northwest leased area, through the Wye Barricade to Highway 240
- West: Highway 240 and Highway 24.

Step 7. Radiological dose assessment. The inventory involved in each accident is evaluated to determine the activity concentrations. The activity concentrations are converted to unit liter dose, or gram, factors. The GENII computer code (PNL-6584) is used to generate a single unit liter dose factor for each composite source term for a 70-year dose commitment period.
The receptor doses are given in terms of committed effective dose equivalents. The unit liter dose factors are used with the appropriate atmospheric dispersion coefficient and the source term to determine the radiological dose to the noninvolved worker and general public receptors.

Step 8. LCF risk development. The likelihood that a dose of radiation would result in a fatal cancer at some future time is calculated by multiplying the receptor dose by a dose-to-risk conversion factor. Conversion factors are predictions of health effects from radiation exposure. The dose-to-risk conversion factors used for estimating LCFs from low doses of radiological exposure and from high doses are consistent with those taken from *1990 Recommendation of the International Commission on Radiological Protection* (ICRP 1991). They are summarized as follows.

- **Involved worker and noninvolved worker:** 4.0×10^{-4} LCF/rem for low doses less than 20 rem and 8.0×10^{-4} LCF/rem for doses greater than or equal to 20 rem.
- **General public:** 5.0×10^{-4} LCF/rem for low doses less than 20 rem and 1.0×10^{-3} LCF/rem for doses greater than or equal to 20 rem. The dose-to-risk conversion factors for the general public accounts for the presence of children.

B1.2.1.1 Chemical Exposure from Accidents

Potential acute hazards associated with exposure to concentrations of postulated accidental chemical releases are evaluated using a screening-level approach for the receptors. This involves directly comparing calculated exposure point concentrations of chemicals to a set of Hanford Site-specific air concentration screening criteria known as emergency response planning guidelines (Dentler 1995). The emergency response planning guidelines, as developed by the American Industrial Hygiene Association, are specific levels of chemical contaminants in air designed to be protective of acute adverse health impacts for the general population.
The guidelines are defined as follows.

- **ERPG-1** – The maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to one hour without experiencing other than mild transient adverse effects or perceiving a clearly defined objectionable odor.
- **ERPG-2** – The maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to one hour without experiencing or developing irreversible or other serious health effects or symptoms that could impair their ability to take protective action.
- **ERPG-3** – The maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to one hour without experiencing or developing life-threatening health effects.

Determining the accidents to be used in the analysis, the source term, atmospheric dispersion coefficients, and the receptor location follows the same methodology as applied to radiological risk from accidents.

B.3.4.3 Radiological Latent Cancer Facility Risk from Routine Exposure

Involved worker exposure is a combination of exposure from inhalation and direct radiation. Involved worker dose rates are estimated based on time, distance, and shielding considerations

associated with the various tasks. Noninvolved workers and general public exposure are estimated by determining the expected routine radiological releases during retrieval and closure. Exposure to the noninvolved worker is assumed to be from inhalation and external radiation from the plume continuously throughout the year and from deposition of radionuclides on the ground. The exposure pathways for the general public are assumed to be inhalation, external exposure from submersion in a plume, and ingestion of contaminated farm products.
The involved workers are assumed to be located in the radiation zone. The noninvolved worker population is assumed to be located 100 m (330 ft) from the point of release out to the Hanford Site boundary. The general public population includes people located within 80 km (50 mi) of the Hanford Site boundary.

The GENII computer code (PNL-6584) is used to calculate the dose. The LCF risk is then calculated by multiplying the receptor dose by a dose-to-risk conversion factor (ICRP 1991).

B.3.4.4 Chemical Hazards from Routine Exposure

The nonradiological chemical intake (dose) is estimated for the involved worker, noninvolved worker, and general public according to the U.S. Environmental Protection Agency (EPA) methodology used in DOE/RL-98-72.

To estimate the potential noncarcinogenic effects from exposure to multiple chemicals, the hazard index approach is used consistent with the EPA methodology that was used in DOE/RL-98-72. The hazard index is defined as the summation of the hazard quotient (calculated dose divided by the reference dose) for each chemical and route of exposure. A total hazard index less than or equal to 1.0 is indicative of acceptable levels of exposure.

The potential carcinogenic or incremental lifetime cancer risk (ILCR) (i.e., the cancer risk from fatal and nonfatal cancers) from exposure to carcinogenic chemicals is calculated by multiplying the cancer slope factor for each chemical by the exposure intake of each chemical. Carcinogenic risk is assumed to be additive and is estimated by summing the upper-bound incremental cancer risk for all carcinogenic chemical emissions.

B.3.5 GROUNDWATER IMPACTS

The S tank farm contains four rows of tanks with three tanks in each row that are aligned in an east-west direction (Figure B.2.3). Contaminant releases from the tanks were modeled using a two-dimensional, cross-sectional model of the vadose zone and a portion of the underlying aquifer. The lateral extent of the cross-section(s) was fenceline to fenceline, the east-west boundaries of the S tank farm. The cross-section passes through the centerline of each of the three tanks in a given row. Vertically the cross-section extends from groundsurface downward completely through the vadose zone and includes the upper 5 m (16 ft) of the aquifer.
The groundwater impact assessment approach emphasizes the potential impacts of focus tanks within the S tank farm by evaluating the tank.

- Individually with no other releases assumed from other tanks in the tank farm where the metric is the near-field contaminant concentration at the S tank farm fenceline along the centerline of the S-101 cross-section.

- In the context of the two other tanks in the S-112 cross-section (S-110 and S-111), respectively. Selected contaminant release scenarios were developed and applied to the other tanks in the cross-section. The metric is the near-field contaminant concentration at the S tank farm fenceline along the centerlines of the cross-section.

- In the context of all the tanks within the S tank farm where the metric is far-field contaminant concentration at the eastern sides of the 200 West Area boundary and the exclusion zone boundary.

B.3.5.1 Groundwater Impact Assessment Approach Overview

Each contaminant source term (i.e., past tank release, retrieval losses, and tank residual waste) was modeled separately. The period of interest was from January 1, 2000 to January 1, 12000 for an overall period of 10,000 years.

The deterministic approach taken in this document is based on the approach that was developed for concurrent RCRA facility investigation/corrective measures study investigations at the S tank farm (HNF-5085), which has adopted reasonably conservative best-estimate parameter values. The data on which the deterministic calculations are based are summarized in *Modeling Data Package for S-SX Field Investigation Report (FIR)* (RPP-6296). The means by which contaminants are transported in the vadose zone and groundwater are the same for all of the cases considered. Key to this approach is the use of a two-dimensional cross-section from which a numerical flow and transport model was developed. Assumed recharge rates, geologic stratigraphy, structure, hydrogeologic properties, and contaminant transport properties are as have been developed in RPP-6296. Simulations for all four tank cross-sections were conducted using the geologic cross-section SCC developed in *Geology of the 241-S Tank Farm* (ARH-LD-133). The geologic cross-section SCC contains tanks S-104, S-105, and S-106.

Individual calculations (i.e., numerical model simulations) for this evaluation were performed for the following contaminant source terms:

- Past leaks (tank S-104 is the only tank in the S tank farm that has a documented past leak)
- Future waste retrieval losses
- Tank residual waste.

The contaminant flux through the vadose zone from each of the three sources enters the underlying aquifer and moves in an easterly direction at a prescribed gradient. Contaminant concentrations in the aquifer are then determined at the easterly tank farm boundary (fenceline) as the average concentration in the 5 m (16 ft) aquifer thickness. The concentrations of three contaminants were calculated with the flow and transport model: technetium-99, nitrate, and uranium-238. The concentration of the remaining CoCs (selenium-79; iodine-129; carbon-14;

chromium; nitrite; uranium-234, -235, and -236) were then estimated by scaling from calculated concentrations to the ratio of the inventory of the scaled CoCs to the calculated CoCs.

As described in RPP-6296, the approach to assessing the groundwater impacts for releases from the S tank farm began with developing vadose zone and saturated zone conceptual models and associated assumptions based on best available data and analysis. This conceptual model was then expressed numerically based on the best available data and information. After this step, the migration of contaminants through the vadose zone and the underlying aquifer to the east fenceline of the tank farm were calculated for the various cases.

The STOMP numerical model (PNNL-12030) was used to implement the calculation of flow and transport in the vadose zone and saturated zone. All simulations were comprised of steady-flow and transient components, where flow fields developed from steady-flow components were used to initialize the transient simulations. The characteristics of the three source terms (i.e., past leak from tank S-104, retrieval losses, and residual waste) were made a part of the model inputs. These characteristics include the mass and solubility of the contaminants, their locations within the model domain, and timing of their release. The three source terms were evaluated separately so that the impact of each could be readily determined. Then, based on principle of superpositioning, they were added to form composite time versus concentration curves.

B.3.5.2 Past Leak Simulation

There is only one documented past tank leak in the S tank farm and that release is associated with tank S-104. The past leak simulations for tank S-104 were conducted using the SCC cross-section (Price and Fecht 1976) containing tanks S-106, S-105, and S-104. Inventories for the simulated constituents (uranium-238, technetium-99, nitrate) were based on estimates on the total leak inventory reported in *Inventory Estimates for Single-Shell Tank Leaks in S and SX Tank Farms* (RPP-6285) and relative concentration profiles used in the WMA S-SX FIR (RPP-6296). The inventory estimates were based on concentrations and an assumed leak of 90,800 L (24,000 gal) from tank S-104. Concentration profiles were scaled from measurements on sediment samples from a borehole south of tank SX-115 in the adjacent SX tank farm, because no measurements were available from boreholes in the S tank farm or near tank S-104. The methodology for developing these profiles for the WMA S-SX FIR is described in RPP-6296 and *FY00 Initial Assessments for S-SX Field Investigation Report (FIR): Simulations of Contaminant Migration with Surface Barriers* (PNWD-3111).

The initial profiles representing past leaks for technetium-99 and nitrate were the same as used in the WMA S-SX FIR for what is referred to in RPP-6296 as the uniform case (Table B.3.2). Uranium-238 was not included as a constituent for the WMA S-SX FIR analysis (RPP-6296); therefore, past leak profiles were not available. The RCRA field investigations of WMA S-SX (HNF-5085) did not include deep boreholes and associated sampling in the S tank farm and uranium was not detected in significant quantities in the sediments taken from the borehole south of tank SX-115 in the adjacent SX tank farm. Given that there are no site-specific field data, it was assumed that uranium in the vadose zone from the past leak would be located co-incident with chromium. This enabling assumption is believed to be appropriate given the apparent slight retardation of chromium in the Hanford vadose zone. Using this assumption, the uranium-238 inventory associated with the past leak from tank S-104 (RPP-6285) was distributed over the relative chromium profile used in the WMA S-SX FIR (RPP-6296; PNWD-3111).

Table B.3.2. Summary of Tank S-104 Past Leak Inventory

Solute	Tank Concentration*	Tank S-104 Leak Estimate (24,000 gal loss)*	Mass of Contaminant in WMA S-SX FIR Model Cross-Section	Mass of Contaminant in Tank S-112 RPE Model Cross-Section
Technetium-99	4.25E-05 Ci/L	3.78E+00 Ci	3.25E-02 Ci	3.24E-02 Ci
NO_3^-	186 g/L	1.70E+04 Kg	2.07E+02 Kg	2.07E+02 Kg
Cr^{3+}	8.58 g/L	7.81E+02 Kg	9.77E-01 Kg	NA
Uranium-238	4.34E-07 Ci/L	3.96E-02 Ci	NA	6.12E-04 Ci

*RPP-6285.

FIR = field investigation report.
NA = not applicable.
RPE = retrieval performance evaluation.
WMA = waste management area.

In RPP-6296, the chromium profile was truncated because the calculated radius required to fit both the concentration and inventory estimates at each depth were larger than a predefined limit that was set at the midpoints between the tanks. Because the radial extent of the plume was limited, the chromium inventory in the cross-section was less than the other percentages of inventory for the other solutes. For this RPE, the resulting chromium distribution was multiplied by a constant factor to fit the past leak inventory for uranium-238 in the cross-section (Table B.3.2). One potential reason for the problems with the chromium profile in RPP-6296 modeling data package is that the water-leach data were reported for the core analysis, not the acid-leach data. Chromium concentrations in the water-leach data were significantly less than the acid-leach data. The water-leach tests did not remove all the chromium from the sediment due to sorption or precipitation of chromium on the soil. Using these lower concentrations, the estimated radius of the plume is substantially larger than others to account for estimated inventory lost from the tank.

B.3.5.3 Retrieval Loss Simulation

The potential tank leak during waste retrieval is conceptualized as emanating from a 1.5 m (5 ft) annular ring around the base of the each tank. In cross-section, the leak area is represented as a 0.46 m^2 (5 ft^2) area on each side of the tank. The retrieval start date, end date, and duration are provided in Table B.3.3. These assumed values are important in that they affect the time to peak concentration from the potential retrieval loss. The start times would have a direct effect on the time to peak concentration. The leak durations are proportional to the liquid flux to the vadose zone, which in turn affects contaminant travel time. Table B.3.4 presents the liquid flux, contaminant mass, and contaminant mass flux that would be in an assumed 30,300 L (8,000 gallon) retrieval loss.

Table B.3.3. Retrieval Loss Release Dates and Durations

Tank	Retrieval Start Date	Retrieval End Date	Duration (Days)
S-101	2013.84	2015.10	461
S-102	2006.02	2006.21	69
S-103	2021.15	2021.64	176
S-104	2019.57	2020.21	235
S-105	2008.02	2009.28	459
S-106	2009.28	2011.65	862
S-107	2011.65	2015.03	1232
S-108	2015.10	2019.54	1615
S-109	2025.08	2025.90	298
S-110	2108.48	2019.53	383
S-111	2020.80	2021.97	427
S-112	2004.76	2005.29	193

Table B.3.4. Retrieval Loss Fluxes and Contaminant Mass for a 8,000 Gallon Retrieval Loss

Tank	Liquid Flux ($m^3/[m^2*day]$)	Contaminant Mass			Contaminant Mass Flux		
		Nitrate (grams)	Tc-99 (pCi)	U-238 (pCi)	Nitrate (grams/day)	Tc-99 (pCi/day)	U-238 (pCi/day)
S-101	5.815E-04	1.64E+04	8.00E+09	1.15E+05	3.55E+01	1.74E+07	2.49E+02
S-102	3.885E-03	4.22E+01	2.81E+10	1.77E+08	6.12E-01	4.07E+08	2.57E+06
S-103	1.523E-03	3.73E+04	2.13E+10	1.28E+04	2.12E+02	1.21E+08	7.27E+01
S-104	1.141E-03	1.31E+04	1.52E+09	1.67E+03	5.58E+01	6.46E+06	7.10E+00
S-105	5.841E-04	3.82E+04	1.11E+10	8.36E-04	8.32E+01	2.42E+07	1.82E-06
S-106	3.110E-04	4.96E+04	1.24E+10	1.28E+06	5.75E+01	1.44E+07	1.48E+03
S-107	2.176E-04	8.96E+03	5.40E+09	1.22E+06	7.28E+00	4.39E+06	9.90E+02
S-108	1.660E-04	3.78E+04	1.21E+10	2.29E+06	2.34E+01	7.51E+06	1.42E+03
S-109	8.996E-04	6.09E+04	6.35E+09	1.48E+05	2.04E+02	2.13E+07	4.96E+02
S-110	6.999E-04	4.23E+04	1.58E+10	1.15E+07	1.11E+02	4.13E+07	3.01E+04
S-111	6.278E-04	3.07E+04	1.49E+10	2.46E+06	7.19E+01	3.48E+07	5.76E+03
S-112	1.389E-03	3.77E+04	2.06E+10	3.45E+07	1.95E+02	1.07E+08	1.79E+05

All simulation of retrieval losses, except for sensitivity cases that include an interim barrier over cross-section S-110, assumed that an enhanced RCRA Subtitle C barrier would be installed in the year 2040 and would limit recharge to 0.1 mm/yr (0.004 in./yr) for a 500-year period after which time it would degrade. The assumed recharge rate after the year 2540 is 3.5 mm/yr (0.14 in./yr) which is typical of Hanford arid conditions with a silt shrub-steppe surface condition. Recharge conditions for the current tank farm graveled surface were assumed to be 100 mm/yr (3.9 in./yr).

The potential retrieval loss volumes that were simulated ranged from 7,600 L (2,000 gal) from tank S-102 to 300,000 L (80,000 gal) from tank S-112.

B.3.5.4 Residual Waste Simulation

The release of residual waste is conceptualized as emanating from a layer of waste spread uniformly over the tank base. In cross-section, the leak area is represented as a 25-m- (82.4-ft-) long strip that is 0.305-m (1-ft) wide. The waste is assumed to be distributed over this 7.6 m^2 (82.4 ft^2) area at the same loading as it would be over the entire tank base. The tanks are assumed to remain relatively intact for a 500-year period following the installation of the surface barrier in the year 2040. The surface barrier is assumed to perform with a design infiltration rate of 0.1 mm/yr (0.004 in./yr) also for the 500-year period. The residual waste is assumed to begin release in the year 2540 at the same time the tanks and the surface barrier would be degraded and the recharge rate would increase to 3.5 mm/yr (0.14 in./yr) for the remainder of the period of interest (i.e., until the year 12000).

Table B.3.5 provides an example of the residual waste source term development. The assumed residual waste in the entire tank, the calculated waste in the tank cross-section, and the concentration of the contaminant in the cross-section for the tanks in the S-101 cross-section for an assumed 10,000 L (2,700 gal) residual waste in each of the three tanks are provided in Table B.3.5.

Table B.3.5. Example of Residual Waste Source Term for 2,700 Gallons of Residual Waste in Tanks S-101, S-102, and S-103

Contaminant	Tank S-101			Tank S-102			Tank S-103		
	3D Mass, Ci or kg	2D Mass in Cross-Section, pCi or g	Aqueous Conc., pCi/L or g/L	3D Mass, Ci or kg	2D Mass in Cross-Section, pCi or g	Aqueous Conc., pCi/L or g/L	3D Mass, Ci or kg	2D Mass in Cross-Section, pCi or g	Aqueous Conc., pCi/L or g/L
Nitrate	2.27E+02	3.52E+03	7.19E+01	1.42E+02	2.20E+03	7.19E+01	4.67E+02	7.22E+03	7.19E+01
Technetium-99	1.47E-01	2.266E+09	7.68E+07	2.12E-02	3.282E+08	7.68E+07	2.67E-04	4.126E+06	7.68E+07
Uranium-238	3.01E-02	4.656E+08	2.37E+05	3.16E-02	4.876E+08	2.37E+05	2.04E-02	3.151E+08	2.37E+05

Notes: (1) The "3D Mass" is the mass of residual waste that would remain in the entire tank for a 2,700 gal residual volume. (2) The "2D Mass" is the mass of residual waste that would be in the tank cross-sections and is a model input. (3) The aqueous concentration is the concentration of residual waste that would remain after retrieval and is a model input.

All simulation of residual waste releases assumed that an enhanced RCRA Subtitle C barrier would be installed in 2040 and would limit recharge to 0.1 mm/yr (0.004 in./yr) for a 500-year period after which time it would degrade. The assumed recharge rate after the year 2540 is 3.5 mm/yr (0.14 in./yr) which is typical of Hanford arid conditions with a silt shrub-steppe surface condition.

The potential residual waste volumes that were simulated ranged from 5,000 L (1,300 gal) to 190,000 L (50,000 gal) for tank S-102 and 23,000 L (6,000 gal) to 102,000 L (27,000 gal) for tank S-112.

B.3.5.5 Composite Tank Farm Groundwater Impact Approach

To consider the potential impacts from the entire S tank farm, it is necessary to consider potential compliance points that are sufficiently distant such that the individual contaminant plumes from the individual cross-sections may intermingle. These distant potential compliance points are far-field in contrast to potential near-field compliance points such as the S tank farm fenceline, which is the WMA boundary. Two potential far-field compliance points are considered:

- Eastern boundary of the 200 West Area, located about 1.8 km (1.12 m) from the S tank farm
- Eastern side of the exclusion zone, located about 10.5 km (6.52 m) from the S tank farm.

Four combinations of S tank farm source terms have been assumed for the far-field composite groundwater impacts as described in Table B.3.6.

Table B.3.6. Source Terms Assumed for the Far-Field Composite S Tank Farm Groundwater Impact Calculations

Case	Description of Assumed Source Terms
1	Past leak from tank S-104 with 2,700 gal residual volume in all 12 tanks and 8,000 gal retrieval leak from all 12 tanks.
2	Past leak from tank S-104 with 2,700 gal residual volume in all 12 tanks plus a 40,000 gal retrieval leak from tank S-102. No other retrieval leaks from the other 11 tanks.
3	Past leak from tank S-104 with 2,700 gal residual volume in all 12 tanks plus a 40,000 gal retrieval leak from tank S-112. No other retrieval leaks from the other 11 tanks.
4	Past leak from tank S-104 with 2,700 gal residual volume in all 12 tanks. No retrieval leaks from any of the 12 tanks.

Several approaches to developing far-field contaminant concentrations were considered and the stream tube model was selected to be consistent with and provide comparable results to an ongoing RCRA field investigation of WMA S-SX (PNWD-3111). The stream tube model is an analytical model used to route the simulated composite contaminant concentrations from S tank farm composite source terms to two potential compliance points, the eastern side of the 200 West Area boundary (fenceline) and the eastern side of the exclusion zone. Input to the stream tube model was the time-variant contaminant mass flux from the assumed 5-m- (16-ft-) thick aquifer at the S tank farm boundary. The stream tube model requires an assumption on the aquifer thickness and width. It was assumed that the aquifer would remain a constant 5 m (16 ft) thick and 100 m (330 ft) wide which means the contaminant concentrations would remain uniform over the aquifer cross-sectional area.

The analytical stream tube model, as described in PNWD-3111 is one-dimensional (i.e., constant aquifer thickness and width) and allows for longitudinal dispersion, molecular diffusion, sorption, and first order decay. This approach provides estimated groundwater concentrations of contaminants that are believed to be conservatively high but appropriate for scoping-level analysis.

B.3.6 LONG-TERM HUMAN HEALTH RISK

This section describes the methodology used for assessing long-term human health risk. The approach for this risk assessment is consistent with the overall RPE approach established in DOE/RL-98-72. The primary objectives of the long-term human health risk assessment for this RPE are to:

- Support the development of risk-based retrieval performance criteria for the tank S-112 waste retrieval systems (i.e., retrieval leakage and residual waste volume limits)

- Provide the basis for the design criteria for the tank S-112 LDMM systems.

Long-term human health risk refers to the risk of health effects to a hypothetical future site user from exposure to tank waste contaminants remaining onsite following the completion of waste retrieval and tank farm closure actions. Groundwater is considered the principal pathway (excluding inadvertent intrusion) for post-remediation human exposure to tank waste at compliance points outside of the tank farm boundary. The exposure pathways used in this assessment are therefore based on withdrawal and use of groundwater via wells.

B.3.6.1 Source Term

The waste retrieval cases evaluated for this RPE are similar to the release scenarios evaluated in DOE/RL-98-72 and include a single best-basis past leak release and retrieval leakage and residual waste release variations. A common closure endstate is assumed for all cases (i.e., stabilized tank and an enhanced RCRA Subtitle C barrier).

Multiple release cases are not of interest for the past leak source term because the long-term human health risk from S farm past leaks will not be affected by tank S-112 waste retrieval systems performance. In contrast, multiple release scenarios *are* of interest for the retrieval leakage and residual waste source terms because those variations provide the data needed to develop relationships between risk and volume. The risk-to-volume relationships are the basis for determining risk-based retrieval performance criteria (i.e., volume limits for retrieval leakage and residual waste).

Because the regulatory unit for closure decisions is the tank farm and not the individual tank, tank S-112 impacts need to be understood within the context of S tank farm impacts. Source inventories are therefore developed for all tanks in the S farm. Source inventories are estimated individually for the past leak, retrieval leakage, and residual waste source terms. Source inventories are developed by estimating contaminant-specific source concentrations and then multiplying by the source volumes of interest. Source concentrations are assumed not to vary with variations in release volume. Discussion of source term inventory development is provided in Section B.3.3.

The CoCs for this RPE are largely consistent with those used in DOE/RL-98-72. These CoCs are as follows:

- **Radionuclides**: carbon-14, selenium-79, technetium-99, iodine-129, and the uranium series
- **Chemicals**: nitrite, nitrate, chromium, and uranium.

This CoCs subset was selected for inclusion in DOE/RL-98-72 based on a screening analysis that indicated these constituents would be highly mobile in the vadose zone and groundwater and would contribute approximately 95% of the total groundwater pathway long-term human health risk. Chromium has been identified as a CoC in the RCRA facility investigation/corrective measures study process and is included as a CoC for this analysis.

B.3.6.2 Contaminant Transport

Following release from the source, contaminants would travel through the vadose zone and into the unconfined aquifer. Once in the aquifer, contaminants would travel with the regional groundwater flow toward the Columbia River. A vadose zone and groundwater contaminant transport analysis was performed using the methodology described in Section B.3.5. Results of the analysis provide groundwater CoC concentrations at the S tank farm boundary, 200 West fence, and 200 Area exclusion boundary over a 10,000-year assessment period.

To support the development of tank-specific retrieval performance criteria, a range of waste retrieval cases was analyzed. The cases analyzed were selected in part to ensure that the resulting long-term risk data would be sufficient to bracket a range of regulatory action thresholds (e.g., the 1×10^{-4} federal and 1×10^{-5} state criteria for ILCR).

B.3.6.3 Exposure

The principal receptor scenarios used for this RPE are taken from *Tank Waste Remediation System, Hanford Site, Richland, Washington, Final Environmental Impact Statement* (DOE/EIS-0189) analysis and include the residential farmer and industrial worker scenarios. Both scenarios were adapted for use in DOE/EIS-0189 from scenarios described in *Hanford Site Risk Assessment Methodology* (DOE/RL-91-45). Both scenarios involve multi-pathway groundwater exposures based on hypothetical future land uses and activities.

The residential farmer scenario represents exposures associated with the use of the land for residential and agricultural purposes. This scenario is a slight modification to the residential scenario described in DOE/RL-91-45; it includes all of the exposure pathways for the residential scenario plus most of the food ingestion pathways described in the DOE/RL-91-45 agriculture scenario. The residential farmer scenario includes using groundwater for drinking water (ingestion rate of 2 L/day [0.5 gal/day]) and other domestic uses as well as for irrigation to produce and consume animal, vegetable, and fruit products. The exposures are assumed to be continuous and include occasional shoreline-related recreational activities, which include contact with surface water sediments. A composite adult is used as the receptor for some of the exposure pathways. The composite adult is evaluated using child parameters for 6 years and adult parameters for 24 years, with total exposure duration of 30 years. Body weights of 16 kg (35 lb) for a child and 70 kg (150 lb) for an adult and a lifetime of 70 years are assumed.

The industrial worker scenario represents exposures to workers in a commercial or industrial setting. The receptors are adult employees assumed to work at a location for 20 years. A body weight of 70 kg (150 lb) and a lifetime of 70 years are assumed. The scenario involves mainly indoor activities, although outdoor activities (e.g., soil contact) also are included.
The groundwater exposure pathways for this scenario include drinking water ingestion (1 L/day [0.2 gal/day]), dermal absorption during showering, shower-water ingestion, and inhalation. These exposures would not be continuous because the worker would go home at the end of each work day (i.e., after eight hours). The scenario is intended to represent nonremediation workers who do not wear job-specific personal protective equipment.

Analysis of the state of Washington "Model Toxics Control Act" (MTCA) Method B and Method C exposure scenarios (WAC 173-340-720) is also included in this RPE to allow for comparison to risks being assessed for past tank leaks and releases at SST WMAs under the RCRA Corrective Action Process (DOE/RL-99-36). The MTCA risk assessment criteria apply only to nonradioactive contaminants. Method B and Method C exposure scenarios essentially assume unrestricted and restricted use of groundwater, respectively, and are based on ingestion of drinking water (with an inhalation correction factor for volatile chemicals).

It is important to note the all of the scenarios require an assumption that groundwater wells are drilled at the points of compliance and used as a water supply for the receptors.

B.3.6.4 Risk

Long-term human health risk is calculated for this RPE using a unit risk factor (URF) approach consistent with the approach used for the *Tank Waste Remediation System, Hanford Site, Richland, Washington, Final Environmental Impact Statement* (DOE/EIS-0189) and DOE/RL-98-72 analyses. An URF is the risk associated with exposure to one concentration unit (e.g., risk per pCi/L for radionuclides in groundwater) of a given contaminant in a given exposure medium for a given human exposure scenario. Risk is calculated in the URF approach as the product of the URF and the contaminant concentration at the receptor for the exposure medium of interest. In developing retrieval performance criteria, the contaminant concentration values used are the peak groundwater CoC concentrations at the S tank farm boundary. The URF values used for this analysis are contaminant- and scenario-specific groundwater URFs taken from

Appendix D of DOE/EIS-0189. The URFs for the residential farmer and industrial worker scenarios are listed in Table B.3.7. The human health impact measures given by the URFs are ILCRs for radionuclides and carcinogenic chemicals, and hazard index (sum of hazard quotients) for noncarcinogenic chemicals. ILCRs differ from LCFs in that ILCRs are total cancers (nonfatal and fatal) and LCFs are fatal cancers.

Table B.3.7. Groundwater Pathway Unit Risk Factors

Constituent	Units	Industrial Worker[a]	Residential Farmer[b]
C-14	ILCR per Ci/mL	5.23E+06	6.06E+08
I-129	ILCR per Ci/mL	9.33E+08	1.29E+10
Se-79	ILCR per Ci/mL	3.22E+07	2.87E+08
Tc-99	ILCR per Ci/mL	7.11E+06	2.61E+08
U-233	ILCR per Ci/mL	3.03E+08	1.38E+09
U-234	ILCR per Ci/mL	3.00E+08	1.34E+09
U-235	ILCR per Ci/mL	2.98E+08	1.37E+09
U-236	ILCR per Ci/mL	2.85E+08	1.27E+09
U-238	ILCR per Ci/mL	2.84E+08	1.28E+09
NO2	Hazard quotient per g/mL	9.92E+03	3.73E+04
NO3	Hazard quotient per g/mL	6.20E+03	7.59E+06
Cr	Hazard quotient per g/mL	3.31E+06	1.14E+07
U (Total)	Hazard quotient per g/mL	3.52E+06	1.41E+07

[a]Source = DOE/EIS-0189, Appendix D, Tables D.2.1.21 and D.2.1.23.
[b]Source = DOE/EIS-0189, Appendix D, Tables D.2.1.18 and D.2.1.20.

ILCR = incremental lifetime cancer risk.

The basic expression for risk using an URF approach is:

$$R_{S(x,y,t)} = \sum C^i_{S(x,y,t)} \cdot URF^i_R \qquad \text{Eq. 1}$$

Where:

$R_{S(x,y,t)}$ = risk from source term *S* at point of compliance *x,y,t*

$C^i_{S(x,y,t)}$ = groundwater concentration at point of compliance *x,y,t* for contaminant *i* released from source term *S*

URF^i_R = groundwater URF for contaminant *i* and receptor scenario *R*

x,y = horizontal location coordinates

t = time.

The summation in Equation 1 represents the superposition of the contributions from all CoCs in a given source term. The addition of contributions from the past leak, retrieval leakage, and residual waste source terms gives the composite risk for a given tank. The addition of composite risks for all tanks gives the composite risk for the tank farm.

Equation 1 is used to calculate human health risk for all release cases included in the contaminant transport analysis. Additional cases intermediate to or outside of the range included in the modeling runs are estimated by interpolation using a linear approximation.

Risk-based retrieval performance criteria (i.e., retrieval leakage limits and extent of retrieval requirements) are developed by comparing the peak human health risk values calculated for the various release scenarios against either retrieval leakage volume or residual waste volume. The risk values compared can be either source-term specific or composite values. Comparisons using tank-specific risk and volume data are of interest because they provide the primary basis for determining retrieval performance criteria for tank S-112. Comparisons using risk and volume data for the entire S farm are also of interest because they provide a sense of how quickly the S farm risk performance will change with departure from the baseline retrieval leakage and residual waste assumptions. The overall objective is to provide a range of combinations of residual waste volume and retrieval leak loss volume that would allow the tank S-112 composite risks to maintain compliance with certain risk-based regulatory standards.

B.3.6.5 Risk Allocation

To evaluate retrieval leakage within the context of tank farm risk, a risk allocation method is used. The methodology used involves selection of a risk threshold (i.e., 1×10^{-5}) and developing a risk budget for retrieval leakage. The methodology includes the following steps:

- Calculate the risks on a tank farm basis from past leaks and spills
- Calculate the risk budget for the tank farm by subtracting the risk from past leaks from the risk threshold
- Calculate a risk budget for tank S-112 by apportioning the tank farm risk budget by the fraction of the S tank farm waste volume contained in tank S-112.

Tank S-112 currently contains 14,300 L (3,770 gal) of waste. The S tank farm currently has 12.9 million L (3,403,000 gal) of waste. Therefore, tank S-112 contains 8.4% of the waste in the S tank farm. Using this methodology, the risk budget for tank S-112 is equal to 8.4% of the tank farm risk budget.

B.3.7 INTRUDER RISK

The methodology used for assessing impacts to an inadvertent human intruder is consistent with the approach used in DOE/RL-98-72. The intruder analysis addresses tank S-112 impacts only. The purpose of the intruder risk assessment is to support an analysis of compliance requirements and waste classification issues related to tank S-112 waste retrieval and tank farm closure. Impacts to an intruder are examined based on scenarios and requirements established in DOE regulations (DOE O 435.1; Frei 1996) and NRC regulations (10 CFR 61) related to LLW disposal.

B.3.7.1 U.S. Department of Energy Intruder Scenario

DOE demonstrates protection of an inadvertent human intruder through site-specific performance assessments using a 100 mrem/yr chronic dose standard and a 500 mrem acute dose standard. The scenarios used in this RPE are consistent with those used in DOE/RL-98-72 and are based on the intrusion model in *Performance Assessment for the Disposal of Low-Level Waste in the 200 West Burial Grounds* (WHC-EP-0645). Well driller and post-drilling resident scenarios are used. These scenarios were selected based on their applicability to the deep contamination sources (i.e., soil contaminated by retrieval leak loss and tank residual waste) involved in this analysis.

Contaminant transport is not considered for this analysis. Contaminants are assumed to be exhumed during well drilling and spread over the surface of certain land areas. The intruder receives radiation exposures because of proximity to and use of these contaminated surface areas. Exposures are calculated using unit dose factors. The analysis considers radionuclide contaminants only. The radionuclides used are consistent with those used for the DOE/RL-98-72 analysis. These radionuclides were selected because their half-lives are greater than five years and they have been shown in past performance assessments to dominate intruder doses (DOE/EIS-0189).

The source is calculated as the total activity in curies of each constituent exhumed and made available at the surface. The well is assumed to be drilled through the residual waste in tank S-112 and into the underlying soil column down to the aquifer. The source is calculated based on the tank S-112 residual waste volumes and the contaminated soil from retrieval leakage. The source (Ci_{exh}) from tank S-112 is calculated using the following equation:

$$Ci_{exh} = Ci_{tnk} \cdot [r_{well} \div r_{tnk}]^2 \qquad \text{Eq. 2}$$

Where:

Ci_{tnk} = total activity of each radionuclide of concern in tank S-112
r_{well} = radius of the well or 0.15 m (0.5 ft)
r_{tnk} = radius of tank S-112, or 11.4 m (37.5 ft).

The source activity (Ci) is then multiplied by a unit dose factor (mrem/yr/Ci) for each receptor (well driller and post-drilling resident) to produce the receptor dose (mrem/yr). Unit dose factors are calculated for a unit activity (Ci) for each constituent based on the exposure conditions defined for each receptor. The well driller dose is from 40 hours of external exposure to the exhumed contaminants. The following is assumed of a post-drilling resident:

- Lives on a 2,500-m^2 (0.62-ac) parcel of land over which the exhumed waste has been spread

- Grows a variety of vegetables on the land
- Obtains 25% of total vegetables consumed from this garden.

The post-drilling resident ingests small amounts of contaminated soil each day (100 mg/day [0.004 oz/yr]) and the total ingestion is 37 g/yr (1.3 oz/yr). The annual inhalation and external exposures are based on the post-drilling resident spending 1,800 hours in his garden and 4,380 hours in his house. The remaining 2,580 hours are spent elsewhere away from the intruder site.

Table B.3.8 presents the unit dose factors for each radionuclide of concern in the exhumed waste under the previously listed exposure conditions for the well driller and post-drilling resident scenarios. These dose factors are calculated using the GENII computer code (PNL-6584) and are the same as those used in DOE/EIS-0189. The unit dose factors are calculated for 100 years from tank closure, corresponding to the time of assumed loss of institutional control.

Table B.3.8. Intruder Scenario Unit Dose Factors at 100 Years from 1998

Radionuclide	Dose Factor (mrem per curies exhumed)	
	Well Driller	Post-Drilling Resident
Strontium-90	6.93E-01	8.42E+01
Tin-126	2.13E+03	6.93E+03
Cesium-137	6.13E-01	2.03E+02
Plutonium-238	8.29E+01	2.82E+02
Uranium-238	5.49E+01	2.15E+02
Plutonium-239	2.04E+02	6.96E+02
Plutonium-240	2.00E+02	6.91E+02
Americium-241	1.01E+03	3.27E+03
Plutonium-241	6.42E+00	2.21E+01

B.3.7.2 U.S. Nuclear Regulatory Commission Intruder Scenario

The current Hanford Site planning basis assumes that once HLW has been retrieved from a tank the residual waste would be classified as incidental waste (i.e., non-HLW) and thus not be subject to NRC licensing authority. The residual waste would then be disposed of in place as LLW in accordance with the requirements of DOE O 435.1. The NRC has proposed using several criteria for making incidental waste determinations for DOE HLW tank closure. One of these criteria is that the residual waste be incorporated in a solid form at concentrations that do not exceed Class C LLW limits.

The NRC divides LLW into four classes and sets different disposal requirements for each class (Class A, Class B, Class C, and Greater Than Class C). Class C LLW has the most stringent disposal requirements for near-surface burial. Greater Than Class C waste requires special disposal methods and approval from the NRC on waste form and disposal configuration. The NRC uses the Class C upper concentration limits for individual radionuclides to determine waste classification and demonstrate protection of an inadvertent human intruder. The NRC derived the Class C concentration limits based on calculated doses to an inadvertent human intruder. The Class C upper limits are the waste concentrations that would not exceed either a 500 mrem radiation dose to the whole body or bone or a 1,500 mrem dose to other organs under an intruder construction or agriculture scenario (SAND98-2104). The Class C upper concentration limits are provided in Table B.3.9.

Table B.3.9. Class C Low-Level Waste Upper Concentration Limits

Long-lived Radionuclides	Class C Upper Limits	Short-lived Radionuclides	Class C Upper Limits
Carbon-14	8 Ci/m^3	Nickel-63	700 Ci/m^3
Carbon-14 in activated metal	80 Ci/m^3	Nickel-63 in activated metal	7,000 Ci/m^3
Nickel-59 in activated metal	220 Ci/m^3	Strontium-90	7,000 Ci/m^3
Niobium-94 in activated metal	0.2 Ci/m^3	Cesium-137	4,600 Ci/m^3
Technetium-99	3 Ci/m^3		
Iodine-129	0.08 Ci/m^3		
Alpha emitting transuranic with $t_{1/2} > 5$ yr	100 nCi/g		
Plutonium-241	3,500 nCi/g		
Curium-242	20,000 nCi/g		

Source: 10 CFR 61.

To determine the waste classification for the residual waste in tank S-112 and to demonstrate protection of the inadvertent human intruder, the residual waste concentrations are compared with the concentration limits shown in Table B.3.9. Because the residual waste will contain multiple radionuclides, the sum-of-fractions for the individual radionuclides is used. The NRC is evaluating the application of a grout-averaging concept as a means for meeting the incidental waste criteria for HLW tank closure at the DOE Savannah River Site.

The grout-averaging approach involves calculating contaminant concentrations assuming the residual tank waste is stabilized using in-tank grouting. The grout is assumed to be uniformly mixed with the residual waste and the concentration of the combined residual waste and grout is used in estimating the solidified waste concentration. Consistent with the approach used for the DOE/RL-98-72 analysis, the amount of grout that would need to be added to tank S-112 to allow the residual waste to meet the Class C limits is estimated using the methods of *Regulatory Closure Options for the Residue in the Hanford Site Single-Shell Tanks* (SAND98-2104) for each of the residual waste cases analyzed.

B.3.8 REGULATORY COMPLIANCE

Hanford Site tank waste and SST and DST facilities are regulated through the federal RCRA, the Washington State HWMA, and their implementing requirements. Ecology is authorized to implement HWMA requirements in lieu of federal program requirements pursuant to RCRA. EPA retains authority for oversight of the state hazardous waste program and for elements of RCRA not yet authorized. Regulatory requirements applicable to Hanford Site tank wastes and tank waste systems include, but are not limited to, those specifying requirements for waste designation, permitting, storage, treatment, disposal, response to releases, and site closure (Fitzsimmons and Clarke 2000).

Regulations that may affect waste retrieval performance issues are addressed in this report. The methodology is to:

- Identify the potentially applicable regulations
- Develop a list of quantitative and qualitative performance measures
- Compare strategy and option performance against the measures
- Develop conclusions regarding ability of strategies to comply
- Refine performance measures based on regulations, analyses, and conclusions
- Identify data needs and uncertainties to support future analysis and decision making.

Statutory, regulatory, and permit requirements relevant to the retrieval and disposal of tank waste, contaminated soils, and tanks and ancillary equipment are described in Section B.3.8.1. The regulatory compliance of the waste retrieval approach for tank S-112 is addressed in Section B.3.8.2.

B.3.8.1 Relevant Regulations and Requirements

Relevant federal and state statutes and regulations are addressed in the following sections.

B.3.8.1.1 Federal Statutes and Regulations. Table B.3.10 summarizes federal requirements that may apply to waste retrieval and endstate analysis associated with establishing waste retrieval performance measures. A more complete discussion of federal regulations is provided in Appendix D of DOE/RL-98-72.

The following summary of federal statutes and regulations that affect tank waste retrieval and closure is excerpted largely from *Regulatory Closure Options for the Residue in the Hanford Site Single-Shell Tanks* (HNF-3428). Three federal entities have the majority of regulatory authority for the disposal of radioactive waste: EPA, DOE, and NRC. Each entity has codified various laws, orders, directives, guidance documents, and branch technical positions that govern the various types of radioactive waste.

Table B.3.10. Relevant Federal Statutes and Regulations

Federal Statutes and Regulations	Relevance
Resource Conservation and Recovery Act	Establishes requirements for the identification, generation, treatment, transportation, storage, and disposal of hazardous waste including mixed waste.
Federal Facility Compliance Act	Requires all federal facilities (e.g., the Hanford Site) to comply with RCRA and establishes requirements for DOE facilities pertaining to mixed waste.
Atomic Energy Act	Establishes the jurisdiction of federal and state agencies to regulate radioactive materials and provides requirements for such regulations.
Nuclear Waste Policy Act	Provides for development of repositories for disposal of HLW and spent nuclear fuel.
Clean Air Act	Regulates emissions of radioactive and nonradioactive pollutants from stationary sources.
Safe Drinking Water Act	Establishes standards for drinking water and groundwater protection.
Toxic Substances Control Act	Regulates toxic chemicals, specifically PCBs and asbestos.
Clean Water Act	Regulates discharges to and quality of surface water bodies (e.g., the Columbia River).
Occupational Safety and Health Act	Regulates safe and healthful working conditions.
Comprehensive Environmental Response, Compensation, and Liability Act	Provides emergency response, reporting, and cleanup requirements for uncontrolled release of contaminants.
National Environmental Policy Act	Requires analysis of potential impacts to human health and the environment of any major federal action.

DOE = U.S. Department of Energy.
HLW = high-level waste.
PCB = polychlorinated biphenyl.
RCRA = *Resource Conservation and Recovery Act of 1976.*

EPA has the authority to write standards, DOE has authority to write and enforce standards for radioactive wastes from atomic energy defense activities, and NRC has the authority to write and enforce regulations for disposal of commercially-generated LLW and for disposal of HLW. However, regulatory authority may depend on whether the radioactive waste has yet to be disposed or the waste has already been released to the environment (e.g., a spill or leak). EPA has the lead role for writing regulations, and DOE and NRC regulations and orders cannot be inconsistent with EPA standards. There are many notable exceptions to these generalizations (HNF-3428).

Nuclear energy became subject to federal regulation with the passing of the *Atomic Energy Act of 1946*. With amendments the act later became the *Atomic Energy Act of 1954*. Through the *Atomic Energy Act of 1954*, Congress gave control of the production and use of fissile materials to the Atomic Energy Commission. The *Atomic Energy Act of 1954* has been amended a significant number of times.

When the EPA was created in 1970 by Reorganization Plan Number 3, President Nixon transferred the functions of the Atomic Energy Commission for establishing generally applicable environmental standards for the protection of the environment from radioactive materials "in the general environment outside the boundaries of locations under the control of persons possessing or using radioactive material." Thus EPA was granted the authority to set release standards but not to implement the release standards. Later, Congress granted EPA authority to address cleanup of radioactive materials under *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) to regulate air emissions of some radionuclides. Congress also asked EPA to certify DOE compliance with "Environmental Radiation Protection Standards for Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes" (40 CFR 191) and "Criteria for the Certification and Re-certification of the Waste Isolation Pilot Plant's Compliance with the 40 CFR 191 Disposal Regulations" (40 CFR 194) for the disposal of TRU wastes in the Waste Isolation Pilot Plant.

In 1974, the *Energy Reorganization Act of 1974* redirected federal energy efforts. The Atomic Energy Commission was abolished and replaced by the NRC and the Energy Research and Development Agency (which was later abolished and became DOE). Section 202 of the *Energy Reorganization Act of 1974* also gave the NRC licensing authority for facilities used primarily for the receipt and storage of HLW. Under this Section 202 authority NRC licenses the disposal of HLW.

The *Nuclear Waste Policy Act of 1982* established federal responsibility for the development of repositories for the disposal of HLW and spent nuclear fuel. The *Low-Level Radioactive Policy Amendments Act* established DOE responsibility for the disposal of commercially generated wastes with radionuclide concentrations exceeding the limits established in "Licensing Requirements for Land Disposal of Radioactive Waste" (10 CFR 61) for Class C LLW (i.e., Greater Than Class C LLW). These amendments require the NRC to license the DOE facility for disposal of commercially-generated Greater Than Class C LLW.

The NRC has regulatory responsibilities under the *Atomic Energy Act of 1954* for establishing standards for the disposal of radioactive waste. NRC has established regulations for low-level radioactive waste that can be disposed of in near-surface disposal sites (10 CFR 61) and for high-level radioactive waste requiring disposal in a geologic repository (10 CFR 60). Under authority of the *Atomic Energy Act of 1954*, EPA has promulgated standards for managing and disposing of spent nuclear fuel, HLW, and TRU waste (40 CFR 191). EPA standards for managing and disposing of LLW are not yet finalized (10 CFR 193).

The *Atomic Energy Act of 1954* authorizes DOE to establish standards to protect health or minimize dangers to life or property for activities under DOE jurisdiction. Through a series of DOE orders, an extensive system of standards and requirements has been established to ensure safe operation of DOE facilities. The most relevant of these is DOE O 435.1, which establishes requirements for managing DOE HLW, TRU waste, LLW, and the radioactive component of mixed waste.

According to definitions in *Radioactive Waste Management Manual* (DOE M 435.1), HLW is the highly radioactive waste material resulting from the reprocessing of spent nuclear fuel and other highly radioactive material that is determined to require permanent isolation. TRU waste is radioactive waste containing more than 100 nanocuries of alpha-emitting TRU isotopes per gram of waste, with half-lives greater than 20 years. Low-level radioactive waste is radioactive material that is not HLW, spent nuclear fuel, TRU waste, byproduct material (as defined in Section 11e[2] of the *Atomic Energy Act of 1954*), or naturally occurring radioactive material. Therefore HLW is defined by source (i.e., spent nuclear fuel); TRU waste is defined by isotope concentration and half-life; and LLW is defined by what it is not (i.e., it is not HLW, spent fuel, TRU waste, or byproduct material).

DOE M 435.1 is organized into four chapters. Chapter I contains requirements and responsibilities applicable to all radioactive waste types and delineates responsibilities for radioactive waste management decision-making at the complex-wide and Field Element levels. Chapter II contains requirements applicable to HLW; Chapter III discusses TRU waste; and Chapter IV discusses LLW.

Chapter II of DOE M 435.1 includes a discussion of general requirements for disposal of HLW. NRC determines whether HLW resulting from reprocessing spent nuclear fuel is considered incidental to reprocessing. If it is incidental it is not HLW and is managed under DOE regulatory authority in accordance with the requirements for TRU waste or LLW, as appropriate. The NRC uses either the citation or evaluation process to determine whether spent nuclear fuel reprocessing plant waste is managed as LLW, TRU waste, or HLW. Waste incidental to reprocessing by citation includes spent nuclear fuel reprocessing plant wastes that meet the description for proposed Appendix D of "Policy Relating to the Siting of Fuel Reprocessing Plants and Related Waste Management Facilities" (10 CFR 50). These radioactive wastes are the result of reprocessing plant operations such as, but not limited to, contaminated job wastes including laboratory items such as clothing, tools, and equipment.

Determinations that any waste is incidental to reprocessing by the evaluation process must be documented. Such wastes may include spent nuclear fuel reprocessing plant wastes that will be managed as LLW and meet the following:

- Have been processed to remove key radionuclides to the maximum extent technically and economically practical
- Will be managed to meet safety requirements comprable to the performance objectives in 10 CFR 61
- Will be incorporated in a solid physical form at a concentration that does not exceed the applicable concentration limits for Class C LLW as set out in 10 CFR 61.55, or will meet alternative requirements for waste classification and characterization as DOE may authorize.

The waste may be managed as TRU waste and meet the following:

- Have been processed to remove key radionuclides to the maximum extent technically and economically practical
- Be incorporated in a solid physical form and meet alternative requirements for waste classification and characteristics as DOE may authorize
- Be managed pursuant to DOE's authority under the *Atomic Energy Act of 1954* in accordance with Chapter III of DOE M 435.1.

A second set of laws and guidance documents is applicable to cleanup of radioactive wastes. Of these laws, the CERCLA and the regulations created to implement the statute are the broadest. CERCLA provides EPA with authority to address releases and threatened release of hazardous substances, including radioactive wastes. The EPA CERCLA Program has created a system to designate the highest priority sites for cleanup, and those sites are National Priorities List sites. The Hanford Site is on the National Priorities List.

RCRA establishes requirements for generators and transporters of hazardous waste and also establishes a specific permit program for TSD of hazardous waste. For purposes of this report, RCRA covers the statute and all amendments including the *Hazardous and Solid Waste Amendments of 1984*, the *Federal Facility Compliance Act of 1992*, and the *Land Disposal Program Flexibility Act of 1996*. RCRA creates cradle-to-grave regulations for the generation, identification, transportation, and TSD of hazardous waste; RCRA imposes requirements on all persons including DOE agents that perform regulated activities. EPA regulations implementing RCRA are found at "Hazardous Waste Management System" (40 CFR 260 through 40 CFR 280).

Most, but not all, of the EPA hazardous waste program at the Hanford Site is delegated to the Washington State Department of Ecology (Rosenthal 1997). EPA delegated the RCRA-based program to Ecology in 1986.

B.3.8.1.2 Washington State Statutes and Regulations. Ecology and the Washington State Department of Health administer Washington State environmental requirements applicable to tank waste retrieval and tank farm closure actions. Those requirements are described in the following sections.

B.3.8.1.2.1 Hazardous Waste Management Act. The HWMA and its implementing regulations, "Dangerous Waste Regulations" (WAC 173-303), implement RCRA in Washington State. The HFFACO provides the framework for applying the state's requirements for dangerous waste TSD units at the Hanford Site. WAC 173-303 specifies requirements for design, permitting, operation, closure, and post-closure of dangerous and mixed waste management sites, including the tank farms. There are some differences between Washington State dangerous waste regulations and federal hazardous waste regulations. The state definition of dangerous waste includes more types of waste than does the federal definition of hazardous waste. For example, the state regulations do not exclude source, special nuclear, and byproduct material from the definition of dangerous waste (Rosenthal 1997). Washington State also designates specific types of state-only dangerous waste, including extremely hazardous waste, that is subject to more stringent regulations (Rosenthal 1997). Other differences exist between the state and federal regulations on contained-in determinations, closure, and corrective actions.

The SSTs are classified as HWMA TSD units that contain hazardous waste as defined by either the characteristics of the waste (e.g., toxicity, corrosivity) or as designated hazardous through listing. In either case, because the SSTs contain dangerous waste, these units are managed as HWMA Subtitle C TSD units. Because the SSTs were in operation on the effective date of the RCRA regulations, they could continue operations without a final status permit. The SSTs were granted interim status (i.e., Part A permit) (WAC 173-303-400) to operate until Ecology determines that a final status permit must be issued (i.e., Part B permit). However, because the SSTs will not be used for continued dangerous waste management, the SSTs must undergo closure in lieu of final status permitting (Ecology et al. 1989).

B.3.8.1.2.2 Water Pollution Control Act. The state "Water Pollution Control Act" and its associated regulations (WAC 173-200) implement provisions of the federal *Clean Water Act* and establish requirements for protecting the quality of all waters of the state for public health and enjoyment.

B.3.8.1.2.3 HFFACO Requirements. The HFFACO establishes an action plan for cleanup that addresses priority actions, methods for resolving problems, and milestones. The HFFACO sets milestones to achieve coordinated cleanup of the Hanford Site and provides for the enforcement of these milestones to keep the program on schedule. In 2000 the HFFACO was amended to adjust near-term milestones, target dates, and associated language governing SST waste retrieval and tank farm closure activities prior to September 30, 2006 (i.e., modifications necessary to achieve compliance with federal and state hazardous waste requirements). DOE has committed to comply with requirements of the HFFACO related to management of Hanford Site tank waste and tank farm closure.

As described in the HFFACO, the agencies determined that the tanks will be closed under WAC 173-303-610 regardless of permit status. These regulations specify closure and post-closure requirements. DOE is required to submit a closure plan for the SST farms (not individual tanks) for approval by Ecology. If all of the dangerous waste cannot be removed or decontaminated, DOE will submit a post-closure work plan and a RCRA Part B permit application for Ecology approval. Upon completing the closure action for each SST TSD unit, the RCRA permit will be amended to indicate that the applicable unit has been closed (Ecology et al. 1989).

According to WAC-173-303-640 the SSTs are deemed unfit-for-use tanks based on lack of secondary containment and/or inability for tank integrity assessment. The tanks must be removed from service immediately, and the owner or operator must take mitigating actions. This regulation further specifies that neither dangerous wastes nor treatment reagents may 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. Therefore, additions of water and waste into SSTs are prohibited under the *Washington Administrative Code* and RCRA. However, a rationale for the addition of liquids to the SSTs can be made under the RCRA Part A permit for SSTs (DOE 1996):

> Treatment of the mixed waste in the SST system occurs when solids and interstitial liquids are separated and/or cooling liquids are added. These treatment processes involve, but are not limited to, mechanical retrieval, sluicing, and saltwell pumping of the mixed waste.

Based on past-practice sluicing operations for tank waste retrieval, water or waste has been added to enable the waste to be pumped out of a tank. DOE, EPA, and Ecology recognize both the need to remove the waste and that addition of liquids will be necessary to facilitate retrieval of SST waste and a modification of the Part A permit is being prepared.

DOE has met some of the requirements for unfit-for-use tanks. After 1980 all SSTs were removed from service. Through the interim stabilization program, pumpable liquids have been removed from almost all of the SSTs, and the remaining tanks will be pumped by FY 2004 (DOE 1996). DOE will need to obtain from Ecology either (1) a waiver for the addition of water or DST supernate for waste retrieval on a tank-by-tank basis or (2) a universal waiver for the entire SST system.

DOE O 435.1 states that unless demonstrated to the contrary, all HLW shall be considered radioactive mixed waste and subject to the requirements of the *Atomic Energy Act of 1954* and RCRA. Hanford Site high-level radioactive tank waste contains hazardous, characteristic, and/or listed wastes under RCRA. To address potential differences between the requirements of RCRA and the *Atomic Energy Act of 1954* DOE, EPA, and Ecology anticipated in the HFFACO that "the TSD units containing mixed waste will normally be closed with consideration of all hazardous substances, which includes radioactive constituents." However, the potential exists for conflict between the regulations for the hazardous and the radioactive components of the waste.

HFFACO Milestone M-45-00 links tank waste retrieval and tank farm closure. According to Milestone M-45-00:

> Closure will follow retrieval of as much tank waste as technically possible, with tank waste residues not to exceed 360 ft^3 in each of the 100 series tanks, 30 ft^3 in each of the 200 series tanks, or the limit of waste retrieval technology capability, whichever is less.

New requirements of the HFFACO through Change Package M-45-00-01A modify the agreement to achieve compliance with federal and state hazardous waste requirements. The near-term strategy for SST waste retrieval activities shifts from focusing on maximizing the number of tanks entered for retrieval (regardless of waste volume or content) to a focus on scheduling the retrieval of wastes from those SSTs with a high volume of CoCs. These contaminants are defined as mobile, long-lived radionuclides that have a potential of reaching the groundwater and Columbia River. The near-term strategy also focuses on the performance of key waste retrieval technology demonstrations in a variety of waste forms and tank farm locations to establish a technical base for future work. The near-term work scope focuses on the performance of risk assessments, incorporating vadose zone characterization data on a tank-by-tank basis, updating tank farm closure/post-closure work plans, and maximizing waste storage space in DSTs for waste retrieved from SSTs.

Appendix H of the HFFACO provides the SST waste retrieval criteria procedure formally agreed upon by DOE, Ecology, and EPA. Modifications to this appendix occurred during negotiations for Change Package M-45-00-01A. The modifications included defining the reference baseline waste retrieval technology as past-practice sluicing that has been conducted on tanks AX-104 and C-106 and earlier past-practice sluicing efforts. The new technology design and deployments are to measure their performance against this reference baseline technology. Appendix H provides for SST demonstration of achievability of the waste retrieval goal during tank S-112 retrieval demonstrations. The second phase evaluates regulatory requirements of HLW disposal from applicable rules, regulations, and DOE orders. In addition, establishment of an interface with the NRC to reach formal agreement on the retrieval and closure actions for SSTs with respect to allowable waste residuals in the tanks and soil column is to be accomplished. Collected data from the demonstration of the waste retrieval technology will assist in the preparation of input in defining the retrieval goal evaluation to accommodate the agreements on allowable residuals.

B.3.8.2 Regulatory Compliance of Waste Retrieval Approach

HFFACO Milestone M-45-03C calls for the completion of a full-scale salt cake waste retrieval technology demonstration from tank S-112 using technology (or technologies) selected based on improving upon the past-practice sluicing baseline in the following areas:

- Expected retrieval efficiency
- Leak loss potential
- Suitability for use in potentially leaking tanks.

The goals of the demonstration waste retrieval project include the retrieval to safe storage of approximately 550 curies of mobile, long-lived radioisotopes and 99% of tank contents by volume per the BBI of August 1, 2000 (BBI 2000).

The HFFACO does not specify which radionuclides are considered mobile and long-lived. For purposes of this evaluation, the following CoCs are considered mobile and long-lived: technetium-99; iodine-129; selenium-79; carbon-14; and uranium-233, -234, -235, -236, and -238.

The HFFACO Milestones M-45-03C and M-45-05A call for retrieval of 99% of tank contents by volume. Because the amount of waste in each tank varies, 99% of the contents of tank S-112 may or may not equal the major HFFACO Milestone M-45-00 requirements, which call for the removal of 360 ft^3 of waste from each 100-series tank. Milestones M-45-00, M-45-03C, and M-45-05A are considered in this evaluation.

For tank S-112, the HFFACO goal is assessed against two major areas. The first is the achievability of the goal during the tank S-112 waste retrieval technology demonstration. In tank S-112 this will demonstrate retrieval of salt cake and sludge wastes in tanks in the 200 West

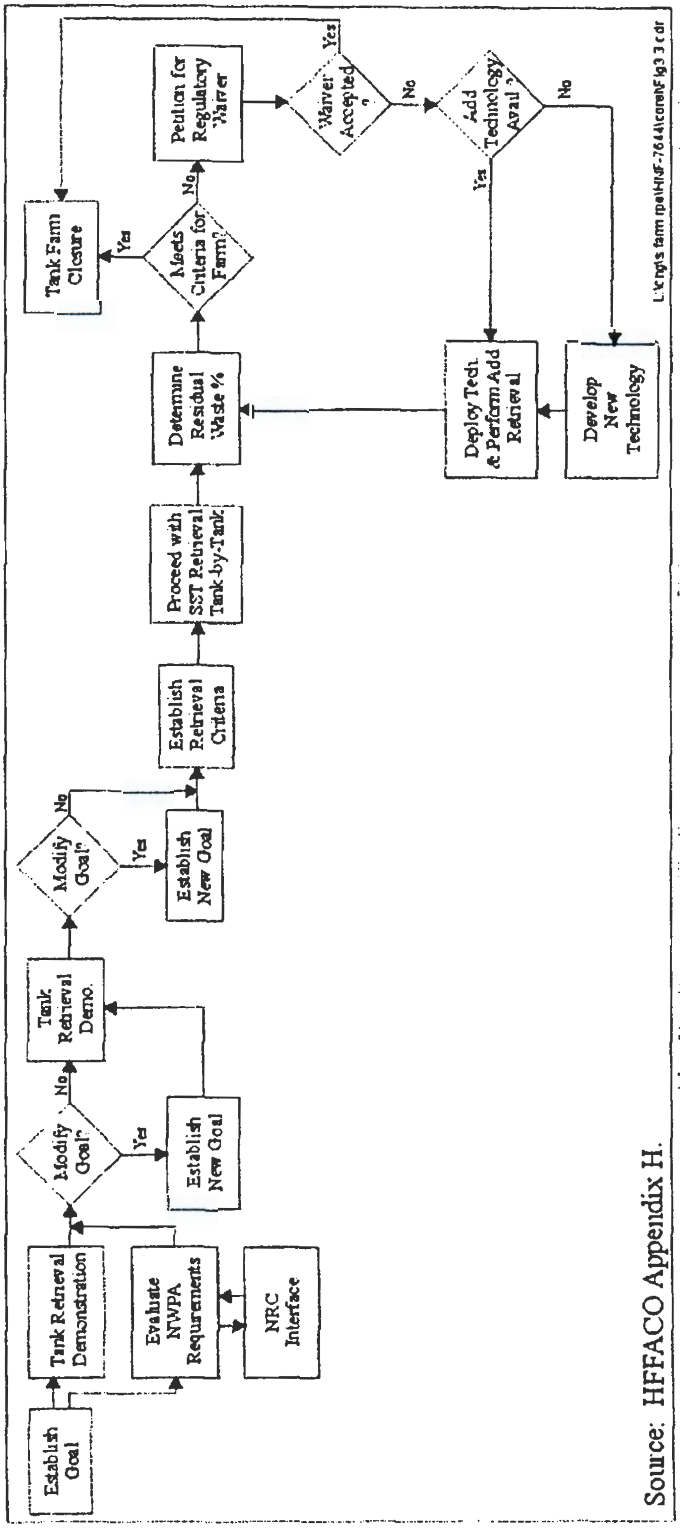
Area. The effectiveness of the waste retrieval operation will be determined with a topographical measurement of remaining waste in the tank and a calculation of waste inventory. The inventory calculation will be based on calculated volume of the tank, waste topography measurements with appropriate surveying techniques, and adjustments for any detectable deformities in the tank structure (e.g., liner bulges). The second area of assessment will be against the evaluation of the regulatory requirements of HLW disposal from applicable rules, regulations, and DOE orders. An interface with the NRC will be established, and formal agreement on the retrieval and closure actions for SSTs with respect to allowable waste residuals in the tank and soil column will be reached.

DOE and Ecology will assess the waste retrieval goal and modify that goal to match the most restrictive case (i.e., the highest retrieval percentage requirement). Tank S-112 waste retrieval efforts will be performed, and the residual waste inventory will be calculated for each tank. DOE and Ecology will then perform an assessment of the waste retrieval goal. Based on the retrieval results the goal may be modified to match capabilities of the best available technology. The agencies will notify NRC as required for compliance with the *Nuclear Waste Policy Act of 1982*. Formal criteria for retrieval of waste from the remaining SSTs will be established, and closure plans for the S tank farm will be finalized with concurrence from regulatory agencies. Waste will be retrieved from the remaining S farm tanks. Retrieval activities may occur on a tank-by-tank basis to allow flexibility to retrieve waste from tanks in various tank farms if desired to support safety issue resolution, pretreatment or disposal feed requirements, or other priorities. Completion of waste retrieval will be in accordance with approved closure plans.

As per HFFACO Appendix H, residual waste will be calculated for each tank following retrieval. Notification to appropriate regulatory authorities will document compliance with criteria. If residual waste volumes comply with criteria, final closure operations will proceed. If residual waste volumes do not comply, a request for waiver will be prepared. If the waiver is accepted, closure operations for the tank farm will begin; if the waiver is not accepted, additional retrieval operations are required. A review of alternate technologies will be performed relative to the need for additional waste removal. If additional technologies are available, they will be used to retrieve additional waste. If additional technologies are not available, new technologies will be developed and deployed. A tank farm will be held in interim status pending completion of the additional tank waste retrieval operations.

When additional waste is retrieved, the residual waste volume will again be calculated and assessed against the criteria. An iterative process will occur. If the goal is met, final tank farm closure will proceed. If the goal is not met, a waiver will be petitioned or additional waste retrieval activities will occur until the appropriate regulatory authorities are satisfied. Figure B.3.3 provides a generic logic diagram of this process.

Figure B.3.3. Process for Assessing Percentage of Waste Retrieved from Waste Retrieval Operations



Source: HFFACO Appendix H.

B.4.0 DESCRIPTION OF WASTE RETRIEVAL CASES

This section summarizes the intent of the waste retrieval cases defined to determine the effects of different volumes of retrieval leak loss and residual waste. These cases are used to determine how sensitive short-term human health risk, impacts to groundwater, long-term human health risk, inadvertent human intrusion, and regulatory impacts are to varying leak loss and residual waste volumes. Section B.4.1 outlines the major enabling assumptions associated with creating and evaluating the cases. Section B.4.2 contains a summary of the case descriptions.

It is important to note that the waste retrieval cases are defined to investigate tradeoffs between risk and volume (both residual waste and retrieval leak loss). As such, evaluation of these cases is not intended to provide a means to relax retrieval requirements, but to provide adequate risk-based analysis to support the HFFACO requirements for waste retrieval.

B.4.1 MAJOR ENABLING ASSUMPTIONS

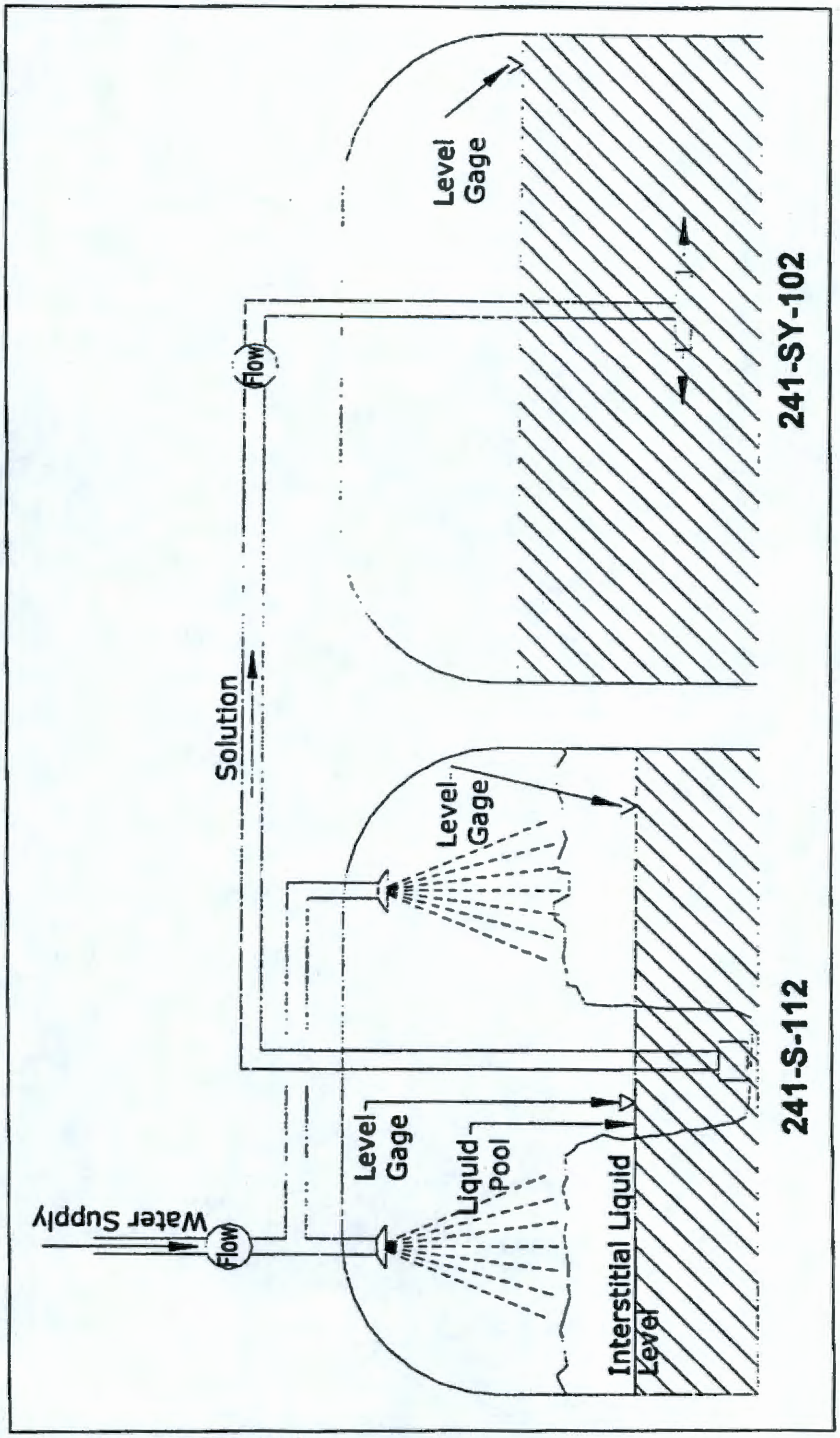
This section summarizes the major enabling assumptions made to support development of the waste retrieval cases. Assumptions were made when available data were insufficient to support this RPE analysis. It is assumed that because a decision has been made to retrieve waste from tank S-112, this evaluation need not include a no action case where the current waste inventories would be left in place. A baseline level of waste retrieval is assumed for all remaining tanks in the S tank farm. This assumption supports an evaluation of the long-term performance of tank S-112 cases combined with the long-term performance of the three-tank cross-section (i.e., of tanks S-110, S-111, S-112).

B.4.1.1 Waste Retrieval Technology Assumptions

Preliminary engineering for the salt cake dissolution retrieval of tank S-112 was completed in FY 2001 (RPP-7526). Subsequently, a decision was made to demonstrate salt cake dissolution in tank S-112. It is acknowledged that, based on current waste volume information, deployment of a salt cake dissolution technology in tank S-112 would not be capable of reaching the HFFACO interim retrieval goal of 360 ft^3. This may require a secondary retrieval deployment after finalization of closure requirements. The need for a secondary waste retrieval deployment in tank S-112 would be evaluated following completion of the technology demonstration. RPP-7526 was completed to develop the technical concepts and support the planning basis for conceptual design of a demonstration salt cake retrieval system.

The salt cake dissolution or low-volume density gradient technology uses two separate systems that would be operated simultaneously (Figure B.4.1). One system would use sprinkler-type mechanisms to introduce water to the waste and the other system would be similar to existing saltwell pumping systems and would serve to remove liquids from the tank. The general approach is to slowly sprinkle water over the salt cake waste to dissolve its soluble constituents while simultaneously removing the waste solution. The water will be introduced at a rate that does not increase the hydraulic head in the tank.

Figure B.4.1. Salt Cake Dissolution Schematic



Adapted from RPP-7526.

The salt cake dissolution technology would not be capable of retrieving the unsoluble sludge from tank S-112 and, based on current waste volume data, would not be able to meet the HFFACO interim retrieval goal of 360 ft^3. If following the deployment of the salt cake dissolution technology it was determined that additional cleanout of the tank was required to meet tank farm closure criteria, then deployment of a second waste retrieval technology would be required. Either the crawler-based retrieval system or the pulse jet fluidic mixing technology could be deployed as a secondary retrieval for heel cleanout. The current cost estimate for deployment of the fluidic mixing technology is approximately $38 million and for deployment of the crawler system is approximately $81 million (Stokes 2001). Both of these costs exclude first-of-a-kind costs associated with the first deployment in the SSTs. For the purpose of the short-term human health risk evaluation, deployment of the crawler was assumed for the waste retrieval cases with a residual volume of 10,000 L (2,700 gal).

B.4.1.2 Leak Detection, Mitigation, and Monitoring System Assumptions

The assumed LDMM strategy for this evaluation is similar to the EPA approach of setting target leak detection rates and leak detection criteria. LDMM information in the following discussion is taken from *LDMM Design Concepts Evaluation Report for Saltcake-Dissolution-Based Retrieval Technologies* (RPP-7627).

Each stage in the LDMM process is governed by specific objectives and requirements as follows.

- Leak detection requirements:
  - Target leak detection rate LDMM requirement will be less than or equal to the risk-based release criterion established by the RPE process divided by the expected duration of the retrieval campaign
  - Performance of the leak detection method or combination of methods will have a probability of detection of 95% against the target leak detection rate and a probability of false alarm less than or equal to 5%
  - Leak detection method or combination of methods shall be functional during all retrieval operations.
- Leak monitoring requirements (assuming a leak occurs):
  - Provide an estimate of the leak volume
  - Provide an accuracy assessment of the leak volume estimate (needed to establish probability that the target leak detection rate has or has not been exceeded).
- Leak mitigation requirements:
  - Tank-specific leak response and mitigation plan shall be developed that minimizes the leak risk potential and reduces the environmental and human health impact of a leak if one occurs during waste retrieval operations.

There have been several leak detection technologies and methods considered for tank S-112 LDMM systems including the following.

- Leak detection in-tank methods:
  - Mass balance
  - Volumetric inventory balance (catastrophic leak detection)
  - Volumetric precision (precision leak detection).
- Leak detection ex-tank methods:
  - Tracers (inoculation, partitioning tracer)
  - Leak detection caissons and borehole technologies (where existing)
  - Electrode development technologies (electrical resistance tomography, high resolution resistively, and time domain reflectrometry).

In recent years the ex-tank methods identified have improved and could be used to detect a leak and to quantify the volume of liquid released from a tank. Preliminary testing indicates that those methods are promising; however, none of these technologies are sufficiently mature to deploy in support of tank S-112 waste retrieval on the schedule outlined in the HFFACO. The current drywell leak detection systems for tank S-112 should be used throughout the tank waste retrieval processes as secondary indication capability to the system chosen for LDMM.

The same technologies used to perform leak detection may also be used to monitor a leak. Leak monitoring involves quantifying the liquid waste release volume from an SST if a release is detected during waste retrieval operations.

Leak mitigation technologies include, but are not limited to, auxiliary pumps, inherent liquid minimization, and limited liquid retrieval. The criteria used to evaluate which LDMM technology would best work for tank S-112 included the following:

- Total life cycle cost
- Past application and performance
- Technical maturity and availability
- Potential performance
- Operational complexity
- Ability to integrate into the waste retrieval operations
- Characteristics of the waste and available data.

According to RPP-7627 the LDMM concept recommended for tank S-112 includes the following:

- Leak detection: In-tank volumetric system and preferred ex-tank method
- Leak monitoring: In-tank volumetric system and preferred ex-tank method
- Leak mitigation: Primary waste mining strategy.

B.4.1.3 Tank Stabilization Assumptions

Following waste retrieval, tank S-112 is assumed to be stabilized to prevent subsidence and provide a structurally sound base for the surface barrier. Closure designs for the SSTs have not been developed in detail; however, most concepts identified to date involve placement of gravel or grout in the tanks. It is likely that grout would be used in the initial step in stabilizing the tanks in an attempt to encapsulate the residual waste. DOE/RL-98-72 includes a conceptual description of the activities necessary to stabilize an SST with grout.

Stabilization of tank residual waste with grout is an element of the tank closure process developed at the Savannah River Site (DOE/EIS-0303D). The grout is used in the tank closure to facilitate NRC classification of the tank residual waste as incidental waste by doing the following:

- Incorporating the residual waste into a stabilized waste form designed to reduce the release of contaminants to the environment

- Producing a waste form with radionuclide concentrations that, on average, meet NRC Class C LLW criteria.

B.4.1.4 Ancillary Equipment Assumptions

Stabilization of ancillary equipment is assumed to include (1) demolishing and removing all surface buildings and equipment that would interfere with constructing the surface barrier and (2) stabilizing the subsurface equipment with grout to prevent long-term subsidence. Concepts for stabilization of ancillary equipment were developed as a part of the AX tank farm RPE (DOE/RL-98-72). These same types of concepts could be used to stabilize the ancillary equipment in the S tank farm. One of the issues identified in developing and evaluating concepts for ancillary equipment stabilization was the worker health and safety issues associated with injecting grout into the abandoned waste transfer lines (HNF-3441). The concept developed for grouting the abandoned waste transfer lines required direct worker contact with equipment to establish grout injection points. If the length of a transfer line was greater than the distance that grout could be pumped, then it was assumed that supplemental pipe penetrations would have to be made along the length of the pipe. One of the conclusions drawn from the AX tank farm RPE was that additional evaluation was required to determine the need for stabilizing the smaller diameter transfer lines.

B.4.1.5 Surface Barrier Assumptions

An enhanced RCRA Subtitle C barrier is assumed to be constructed over the S tank farm. The barrier would be larger than required to cover the tanks and is intended to provide a barrier over the ancillary equipment within the tank farm. The enhanced RCRA Subtitle C barrier design is described in greater detail in *Focused Feasibility Study of Engineered Barriers for Waste Management Units in 200 Areas* (DOE/RL-93-33). This surface barrier is an 8-layer barrier with a combined minimum thickness of 1.7 m (5.6 ft). The barrier is designed to provide long-term contaminant and hydrologic protection for a performance period of 500 years.

An enhanced RCRA Subtitle C barrier is similar in structure to a Hanford barrier, but layer thicknesses are reduced and there is no fractured basalt layer. The design incorporates provisions for biointrusion and human intrusion control. However, the provisions are modest relative to control features incorporated into the Hanford barrier design. The enhanced RCRA Subtitle C barrier is the baseline design for sites containing dangerous waste, Category 3 LLW or Category 3 low-level mixed waste, and Category 1 low-level mixed waste (DOE/RL-93-33). A cross-section of an enhanced RCRA Subtitle C barrier is provided in Figure B.4.2.

B.4.1.6 Cost Assumptions

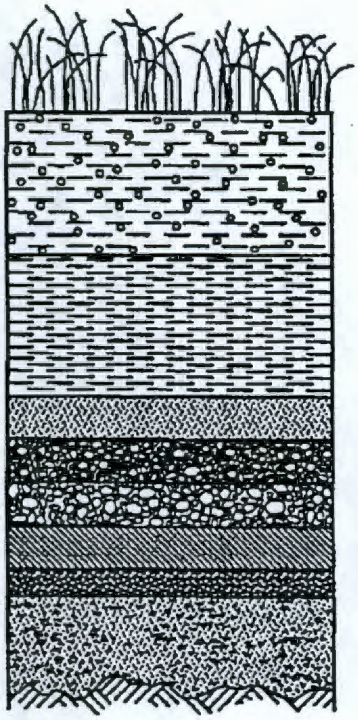
Cost is a performance measure that can be coupled with other measures for use in evaluating different remediation alternatives. For example, when coupled together with risk, cost-versus-risk reduction assessments can be derived and graphed. A total cost estimate, or life cycle cost, for each of the waste retrieval cases has not been developed because (1) the analysis is focused on retrieval decisions for tank S-112 and (2) the variations between the cases are not driven by cost. For example, a number of the cases consider variations in waste retrieval leakage volume for tank S-112. The presence or absence of a retrieval leak does not affect the project cost. However, a leak may result in a stop-work order for waste retrieval operations, therefore resulting in greater residual waste volumes. There also may be added cost for soil characterization and remediation associated with tank farm closure.

B.4.2 SUMMARY OF WASTE RETRIEVAL CASE DESCRIPTIONS

All waste retrieval cases assume a common endpoint that includes the following parameters.

- Vadose zone contamination from past leaks is not remediated.
- Tanks and belowgrade ancillary equipment are stabilized with grout and/or a combination of grout and gravel.
- Aboveground ancillary equipment is removed.
- An enhanced RCRA Subtitle C barrier (Figure B.4.2) is constructed over the tank farm.

Figure B.4.2. Enhanced RCRA Subtitle C Barrier Cross-Section



Cover Vegetation: Mixed perennial grasses

Layer 1: Silt loam topsoil with pea gravel admixture (50 cm [20 in.])

Layer 2: Compacted silt loam topsoil (50 cm [20 in.])

Layer 3: Sand filter layer (15 cm [6 in.])
Layer 4: Gravel filter layer (15 cm [6 in.])
Layer 5: Lateral drainage layer (drainage gravel) (15 cm [6 in.])
Layer 6: Low-permeability asphalt layer (15 cm [6 in.])
Layer 7: Asphalt base course (10 cm [4 in.])

Layer 8: Grading fill (variable thickness)

Adapted from DOE/RL-93-33.

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The waste retrieval cases are designed to illustrate the effects of different waste retrieval performance levels in tanks S-112 as well as for the three-tank cross-section. The following summarize the intent of the different cases.

- Case 1 is designed to illustrate the risks from waste retrieval to the HFFACO interim goal of 360 ft^3 with no leak loss from any tank.
- Case 2 is designed to illustrate the risks associated with retrieving waste to the HFFACO interim retrieval goal but with a 30,000-L (8,000-gal) retrieval leak loss from each tank.
- Cases 3, 8, 9, and 10 are designed to evaluate the effects of varying amounts of retrieval leak loss from tank S-112.
- Case 4 is designed to evaluate the effects of retrieving all S farm tanks to the HFFACO interim retrieval goal with a 30,000-L (8,000-gal) retrieval leak loss, but only retrieving salt cake from tank S-112 (estimated residual heel of 23,000 L [6,000 gal]).
- Cases 4 and 5 are designed to evaluate the effects of varying the volume of the residual waste left in tank S-112.

Table B.3.1 provides a summary of the principal variables associated with each case. Specifics of the variables associated with each case are delineated in *Enabling Assumptions and Calculations to Support the Tanks S-112 and S-102 Retrieval Performance Evaluations* (HNF-7990).

B.5.0 ANALYSIS RESULTS

This section describes the results of the impact assessment for the 10 waste retrieval cases evaluated for this report. Two significant figures are used for presentation of numerical results to show relative differences between the waste retrieval cases. This is not intended to imply a level of confidence in the results, which are generally order-of-magnitude projections.

B.5.1 TANK S-112 ASSESSMENT RESULTS

Impact assessment results specific to the areas of short-term human health risk, groundwater impacts, long-term human health risk, intruder risk, and regulatory compliance specific to tank S-112 are provided in the following sections.

B.5.1.1 Tank S-112 Short-Term Human Health Risk Assessment Results

The short-term human health risk analysis supports a comparison of the short-term human health risks associated with variations in waste retrieval as defined by the waste retrieval cases. This analysis is intended to support risk-based decisions for SST waste retrieval as directed in HFFACO Change Control Package M-45-00-01A. Because of the limited amount of data and because only the differences between the waste retrieval cases are of interest, activities that are common among the cases are not included in the short-term human health risk calculations. For example, activities associated with retrieval of the salt cake from tank S-112 using the low-volume density gradient system (e.g., installation of the low-volume density gradient system and the support systems) would be the same for all the tank S-112 waste retrieval cases with the exception of retrieval operations of the low-volume density gradient system, the installation and operation of a crawler system, and the construction of an interim barrier. The crawler system is the assumed retrieval technology for cases requiring the retrieval of sludge remaining after salt cake retrieval. This assumption provides for a bounding assessment of short-term human health impacts because the crawler system requires a greater number of workers to construct the system compared to alternative technologies. Therefore, only the short-term human health risks associated with salt cake retrieval operations, the installation and operation of a crawler system to retrieve sludge after salt cake retrieval, and the construction of an interim barrier are calculated for comparison. However, it should be noted that adding the risk from activities that are common to all cases would reduce the differences (by percent) between the waste retrieval cases. Therefore, the differences between the waste retrieval cases presented in this document are bounding. Retrieval leak losses are also excluded from this short-term human health risk analysis because they would not result in an appreciable short-term human health risk (the leaks are assumed to occur at the base of the tanks and are assumed to have no associated atmospheric release). Retrieval leak losses do, however, contribute to the long-term human health risk (i.e., post-remediation health impacts) and are evaluated in Sections B.5.1.2 and B.5.1.3.

Short-term human health risk is calculated for both normal (i.e., nonaccident or routine) and accident conditions. Routine conditions include anticipated exposure to radiation fields and radiological and chemical releases to the atmosphere during normal retrieval operation conditions and installation of a crawler system. Accidents are unplanned events or a sequence of events that result in undesirable consequences. The accidents evaluated in this analysis include potential occupational accidents resulting in physical trauma, radiological exposure resulting in LCFs, and toxic or corrosive toxicological exposure resulting in adverse health effects. Initiating events that could result in adverse health effects include natural phenomena, human error, and component failure. The methodology used for the analysis is discussed in Section B.3.4.

B.5.1.1.1 Occupational Accident. The occupational accidents in this analysis are evaluated in terms of the number of total recordable cases (TRCs) and lost workday cases (LWCs) resulting from accidental injuries. The analysis also includes the number of fatalities resulting from accidents. Injuries (i.e., TRCs and LWCs) and fatalities are calculated by multiplying the labor requirements to support the activities of interest by Hanford Site-specific incidence rates.

The parameters of the calculation and the number of incidents to the involved workers for each waste retrieval case are presented in Table B.5.1. Details of the enabling assumptions, data for analysis, and the analysis calculations are provided in HNF-7990.

Table B.5.1. Occupational Accidents

Incident	Labor Requirements (labor-hr)	Incident rate (incident/ labor-hr)	Number of Incidents
Cases 1, 2, 3, 6, 7, 8, and 9[a]			
TRC	7.5E+04	1.9E-05	1.5E+00
LWC	7.5E+04	8.0E-06	6.1E-01
Fatality	7.5E+04	1.4E-08	1.0E-03
Case 4[b]			
TRC	7.0E+04	1.9E-05	1.4E+00
LWC	7.0E+04	8.0E-06	5.7E-01
Fatality	7.0E+04	1.4E-08	9.5E-04
Cases 5[b]			
TRC	6.7E+04	1.9E-05	1.3E+00
LWC	6.7E+04	8.0E-06	5.4E-01
Fatality	6.7E+04	1.4E-08	9.1E-04
Case 10[c]			
TRC	8.3E+04	1.9E-05	1.6E+00
LWC	8.3E+04	8.0E-06	6.7E-01
Fatality	8.3E+04	1.4E-08	1.1E-03

[a]Includes risk from salt cake retrieval, sludge retrieval, and crawler installation to retrieve sludge after salt cake retrieval.
[b]Includes risk from salt cake retrieval.
[c]Includes risk from salt cake retrieval, sludge retrieval, crawler installation to retrieve sludge after salt cake retrieval, and construction of an interim barrier.

LWC = lost workday case.
TRC = total recordable case.

B.5.1.1.2 Routine Radiological Risk. The unit of measure for routine radiological risk in this analysis is the number of LCFs resulting from radiological exposures from routine (nonaccident) conditions for the population receptors. For the MEI receptors it is the probability of an LCF. Exposure to an involved worker would be from ionizing radiation fields in radiation zones. Exposures to an noninvolved worker and the general public would be from abated air emissions. Exposure rates are measured in a dose unit of rem and multiplied by a dose-to-risk conversion factor to calculate the LCF risk.

The parameters of the calculation and the routine radiological risk to the involved workers, noninvolved workers, and general public for each waste retrieval case are presented in Table B.5.2. Details of the enabling assumptions, data for analysis, and analysis calculations are provided in HNF-7990. The dose to the MEI involved worker is assumed to be the Administrative Control Level of 500 mrem/yr for all waste retrieval cases. Exceedance of this dose would require approval from Level 3 line management and the Radiological Control Manager (HSRCM-1).

Table B.5.2. Routine Radiological Risk

Receptor	Dose (rem)[a]	Dose-to-Risk Conversion Factor (LCF/rem)[a]	Risk (LCF)
Cases 1, 2, 3, 6, 7, 8, 9, and 10[b]			
Involved worker MEI	5.0E-01	4.0E-04	2.0E-04
Involved worker population	1.3E+02	4.0E-04	5.0E-02
Noninvolved worker MEI	1.3E-07	4.0E-04	5.2E-11
Noninvolved worker population	9.6E-05	4.0E-04	3.8E-08
General public MEI	5.6E-07	5.0E-04	2.8E-10
General public population	2.2E-02	5.0E-04	1.1E-05
Case 4[c]			
Involved worker MEI	5.0E-01	4.0E-04	2.0E-04
Involved worker population	1.2E+02	4.0E-04	4.9E-02
Noninvolved worker MEI	1.3E-07	4.0E-04	5.2E-11
Noninvolved worker population	9.6E-05	4.0E-04	3.8E-08
General public MEI	5.6E-07	5.0E-04	2.8E-10
General public population	2.2E-02	5.0E-04	1.1E-05
Cases 5[c]			
Involved worker MEI	5.0E-01	4.0E-04	2.0E-04
Involved worker population	1.2E+02	4.0E-04	4.7E-02
Noninvolved worker MEI	1.2E-07	4.0E-04	4.8E-11
Noninvolved worker population	9.1E-05	4.0E-04	3.6E-08
General public MEI	5.6E-07	5.0E-04	2.8E-10
General public population	2.2E-02	5.0E-04	1.1E-05

[a]Person-rem for population receptors.
[b]Includes risk from salt cake retrieval, sludge retrieval, and crawler installation to retrieve sludge after salt cake retrieval. In addition for Case 10 it includes construction of an interim barrier.
[c]Includes risk from salt cake retrieval.

LCF = latent cancer fatality.
MEI = maximally exposed individual.

B.5.1.1.3 Routine Chemical Risk. The routine chemical risk from waste retrieval operations includes toxic health effects measured in exceedance of a hazard index for each toxic chemical and carcinogenic health effects measured in ILCR. The chemical health risk was evaluated for the involved worker MEI, noninvolved worker MEI, and the general public MEI.

The ILCR and the hazard index to the involved worker MEI, noninvolved worker MEI, and general public MEI for each case are presented in Table B.5.3. The enabling assumptions, data for analysis, and analysis calculations are provided in HNF-7990. The chemical concentrations in the residual waste would be the same for all cases and, therefore, the hazard index for all cases would be the same.

Table B.5.3. Routine Chemical Risk to Maximally Exposed Individuals

Receptor	ILCR	HI
Cases 1, 2, 3, 6, 7, 8, 9, and 10		
Involved worker MEI	6.1E-08	2.3E-01
Noninvolved worker MEI	2.7E-08	1.0E-07
General public MEI	7.9E-12	5.3E-05
Case 4		
Involved worker MEI	6.1E-08	2.3E-01
Noninvolved worker MEI	2.7E-08	1.0E-07
General public MEI	7.9E-12	5.3E-05
Case 5		
Involved worker MEI	5.8E-08	2.3E-01
Noninvolved worker MEI	2.5E-08	1.0E-07
General public MEI	7.5E-12	5.3E-05

Note: Ammonia is the major chemical contributor for the hazard index. 1,3-Butadiene is the major chemical contributor for the ILCR.

HI = hazard index.
ILCR = incremental lifetime cancer risk.
MEI = maximally exposed individual.

B.5.1.1.4 Radiological Accident Risk. Only operational accidents are evaluated in this RPE. Additional accidents will be evaluated in a preliminary safety analysis report as part of conceptual design. All waste retrieval cases assume the same low-volume density gradient system technology for salt cake retrieval; therefore, each case is subject to the same type of accidents. Cases that would include the removal of sludge (in addition to the salt cake) are assumed to also require the deployment of crawler technology. Low-volume density gradient system retrieval accidents would be similar to those evaluated in *Preliminary Engineering Report for the 241-C-104 Retrieval System* (RPP-6843) for crawler-based technology. The analysis documented in RPP-6843 was performed to determine if any accidents could be identified at the early preconceptual stage that would exceed the safety envelope of the tank farms authorization basis (HNF-SD-WM-SAR-067). The annual frequency and level of severity of the potential accidents evaluated in the assessment were shown to be bound by that authorization basis. The severity of a given accident and the frequency of the accident are common to all waste retrieval cases evaluated; however, the probability of the accident occurring varies slightly because of the slight variation in duration of operations between the cases. The variation is so slight that there is no change in frequency categories. A table of potential accidents, consequences, and likelihood is provided in HNF-7990.

B.5.1.1.5 Chemical Accident Risk. The same conclusions reached in Section B.5.1.1.4 for radiological accidents also apply to potential chemical accidents. The severity of a given accident and the frequency of the accident are common to all waste retrieval cases; however, the probability of the accident occurring varies slightly because of the slight variation in duration of operations between the cases. The variation is so slight that there is no change in frequency category.

B.5.1.2 Groundwater Impact Assessment Results

The groundwater impact assessment results focus on the potential impacts of tank S-112 as the tank would perform:

- Individually with no other releases assumed from other tanks in the tank farm where the metric is the near-field contaminant concentration at the S tank farm fenceline along the centerline of the S-110 cross-section
- In the context of the two other tanks in the S-110 cross-section, one of which (tank S-111) is adjacent to tank S-112 tanks where the metric is the near-field contaminant concentration at the S tank farm fenceline along the centerline of the S-110 cross-section
- In the context of all the tanks within the S tank farm where the metric is far-field contaminant concentration at the 200 West fence and the 200 Area exclusion boundary.

The near-field groundwater impact results associated with tank S-112 are presented in this section based on simulations of cross-section S-110 which includes tanks S-110, S-111, and S-112. In Section B.5.2.1, the far-field groundwater impact results associated the entire tank farm (i.e., releases from the 12 tanks in S tank farm) are presented.

B.5.1.2.1 Tank Specific Results for Tank S-112. Tank-specific results for tank S-112 are provided individually by source term for the retrieval leakage, residual waste, and composite source terms.

B.5.1.2.1.1 Tank S-112 Groundwater Impacts Associated with Retrieval. Potential groundwater impact results for four assumed retrieval loss volumes from tank S-112 have been derived as described in the technical approach (Section B.3.5). These volumes are 15,000 L (4,000 gal); 30,000 L (8,000 gal); 150,000 L (40,000 gal); and 300,000 L (80,000 gal) from tank S-112 only. Also, for comparison, one simulation was performed where a 30,000 L

(8,000 gal) retrieval loss was assumed for each of the three tanks in the S-110 cross-section. The potential groundwater impacts resulting from these assumed retrieval releases are shown as concentration versus time plots in Figures B.5.1 through B.5.3 for each of the 3 contaminants that were considered directly in the simulations. Figures B.5.1 and B.5.2 illustrate technetium-99 and nitrate impacts. The traces in these two plots are similar as described in the following.

- Both plots exhibit an early peak concentration at about the year 2075 and a late peak concentration between the years 3100 and 3160. The early peak is comparatively sharp. The peak is in response to the relatively larger recharge and shedding of recharge water over the tank domes that is currently occurring and would occur until the surface barrier is installed in the year 2040. The later peak is broader and occurs after the tanks and the surface barrier are assumed to have degraded and after an extended period of relatively low recharge.

- Contaminant concentration in the groundwater would have dissipated to near 0 by about the year 5000 for both technetium-99 and nitrate.

- The maximum technetium-99 concentrations in the early time peaks range from about 2,300 pCi/L for the 15,000 L (4,000 gal) retrieval scenario to 86,000 pCi/L for the 300,000 L (80,000 gal) retrieval scenario (see Figure B.5.1).

- The maximum nitrate concentrations in the early time peak range from about 68 mg/L to 177 mg/L. In the late time peaks, the maximum concentrations range from about 3 mg/L to 55 mg/L.

Figure B.5.1. Technetium-99 Groundwater Concentrations at the S Tank Farm Fenceline versus Time for Cross-Section S-110 Retrieval Source Term

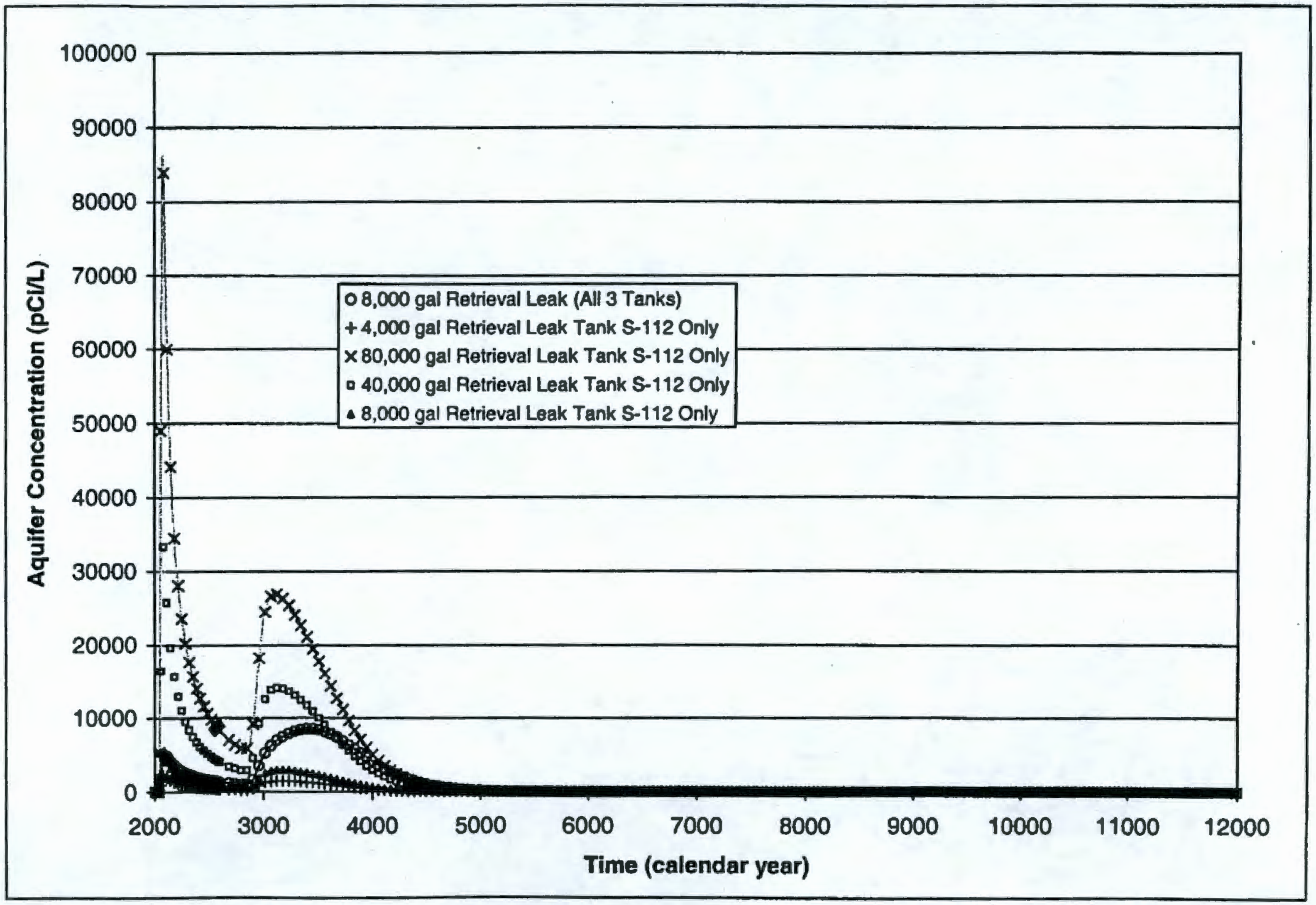


Figure B.5.2. Nitrate Groundwater Concentrations at the S Tank Farm Fenceline versus Time for Cross-Section S-110 Retrieval Source Term

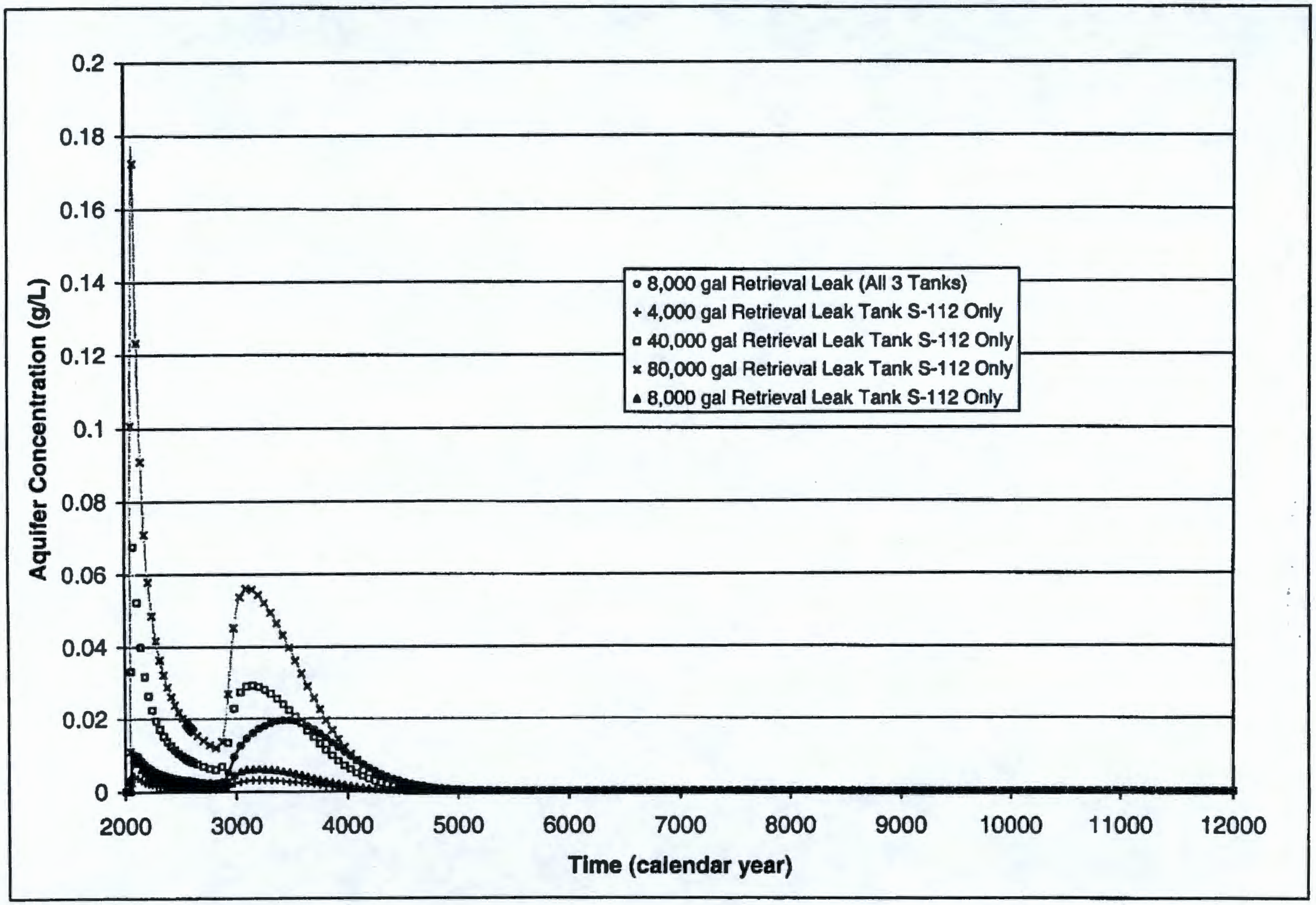
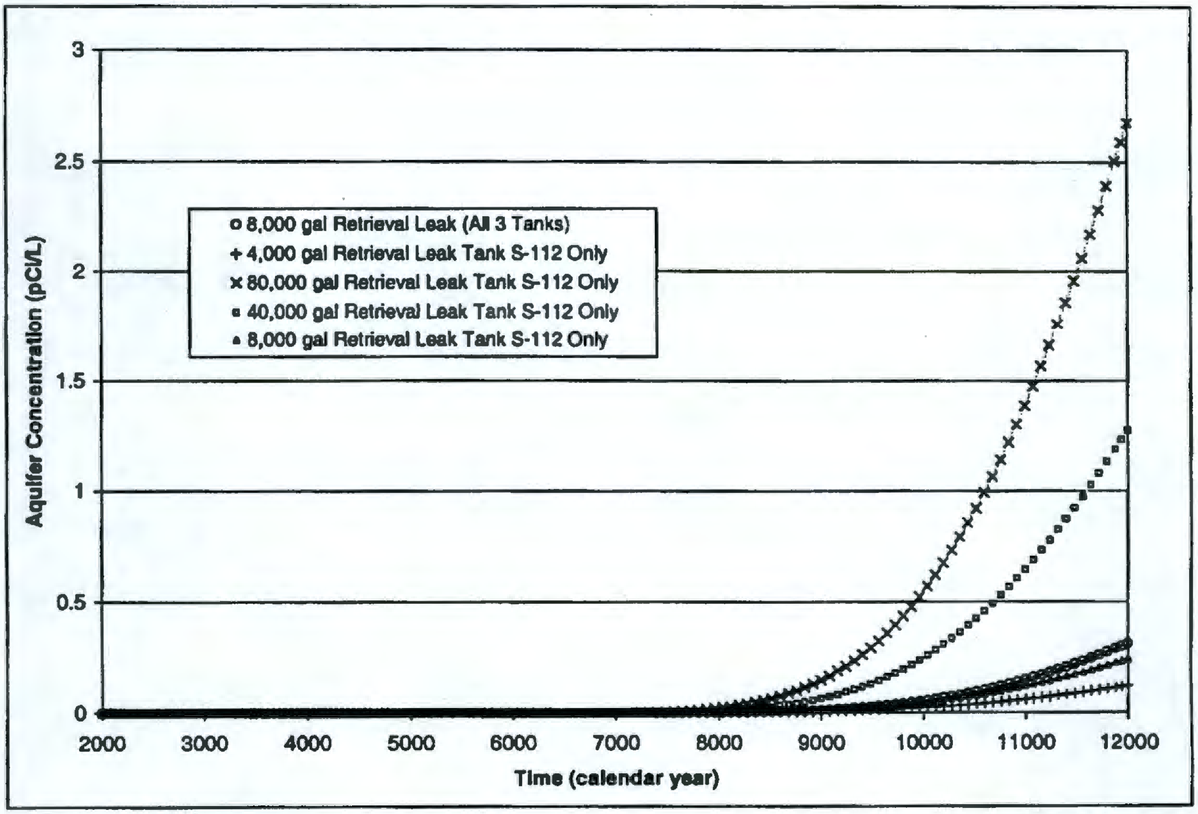


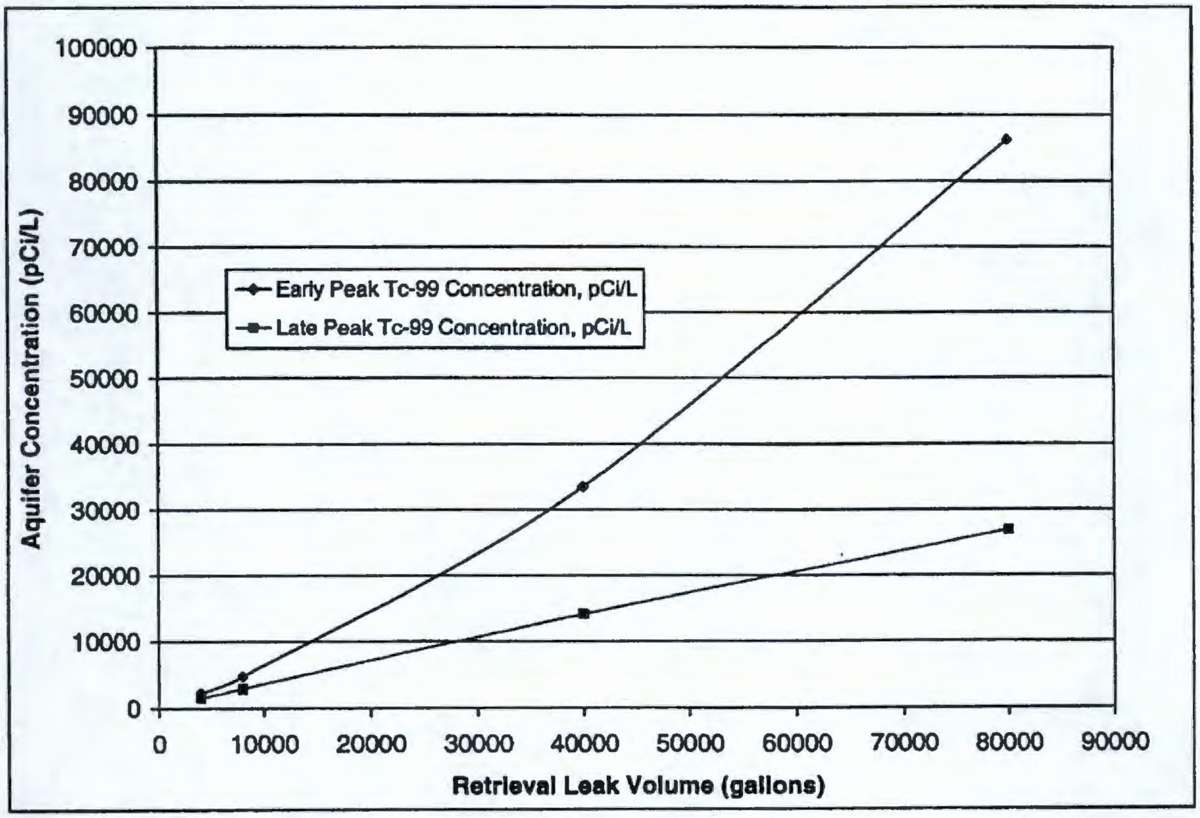
Figure B.5.3. Uranium-238 Groundwater Concentrations at the S Tank Farm Fenceline versus Time for Cross-Section S-110 Retrieval Source Term



The transport of uranium-238 was also simulated from the retrieval releases. Due to the lower mobility of uranium-238 compared to technetium-99 or nitrate, the potential groundwater impacts of uranium-238 remain at a low level, on the order of 10^{-7} pCi/L through the year 7000. By the year 8000, the uranium-238 concentrations would be on the order of 10^{-3} pCi/L and continually increasing until the end of the period of interest at the year 12000. Uranium-238 would not have peaked during the 10,000-year period of interest (Figure B.5.3).

The relationship between volume of retrieval loss and peak contaminant concentration is illustrated in Figure B.5.4 for both the early and late peak techetium-99 concentrations. The late peak technetium-99 concentration versus volume relationship is nearly linear and could be approximated as such. The early peak technetium-99 concentration versus volume relationship is not linear but could be still be approximated. Extrapolations beyond the endpoints would be less uncertain with the late time peak concentration curve because of the apparently strong linear relationship (see Figure B.5.4).

Figure B.5.4. Technetium-99 Peak Groundwater Concentration at the S Tank Farm Fenceline versus Retrieval Volume from Tank S-112



B.5.1.2.1.2 Tank S-112 Groundwater Impacts Associated with Residual Waste. Potential groundwater impact results for two assumed residual waste volumes from tank S-112 have been derived as described in the technical approach (Section B.3.5). These volumes are 23,000 L (6,000 gal) and 102,000 L (27,000 gal) that would remain in tank S-112 only. Also, for comparison, one simulation was performed where a 10,200 L (2,700 gal) residual waste volume was assumed to remain in each of the three tanks in the S-110 cross-section. The potential groundwater impacts resulting from these assumed residual waste releases are shown as concentration versus time plots in Figures B.5.5 through B.5.7 for each of the 3 contaminants that were considered directly in the simulations. Figures B.5.5 and B.5.6 illustrate potential technetium-99 and nitrate impacts. The traces in these two plots are similar as described in the following.

- Initial contaminant concentration becomes evident in the near-field at the S tank farm boundary at about the year 3200 and peaks at about the year 4000.
- There is only 1 peak contaminant concentration over the 10,000 period of interest.
- The peak technetium-99 concentrations range from about 6,200 pCi/L for the scenario with 10,200 L (2,700 gal) residual waste volume in all 3 tanks to 35,000 pCi/L for the

scenario with 102,000 L (27,000 gal) residual waste volume in tank S-112 only (see Figure B.5.5).

- The peak nitrate concentration is about 90 mg/L.

Figure B.5.5. Technetium-99 Groundwater Concentrations at the S Tank Farm Fenceline versus Time for Cross-Section S-110 Residual Source Term

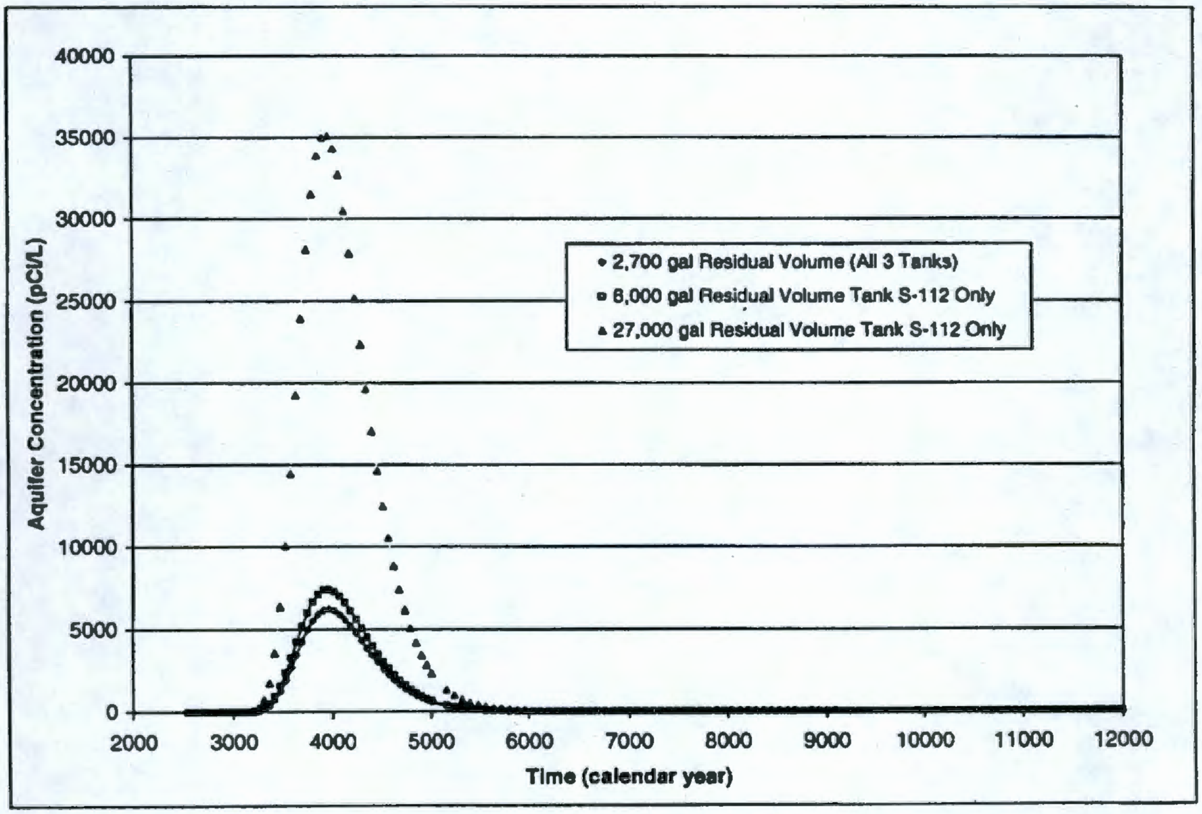


Figure B.5.6. Nitrate Groundwater Concentrations at the S Tank Farm Fenceline versus Time for Cross-Section S-110 Residual Source Term

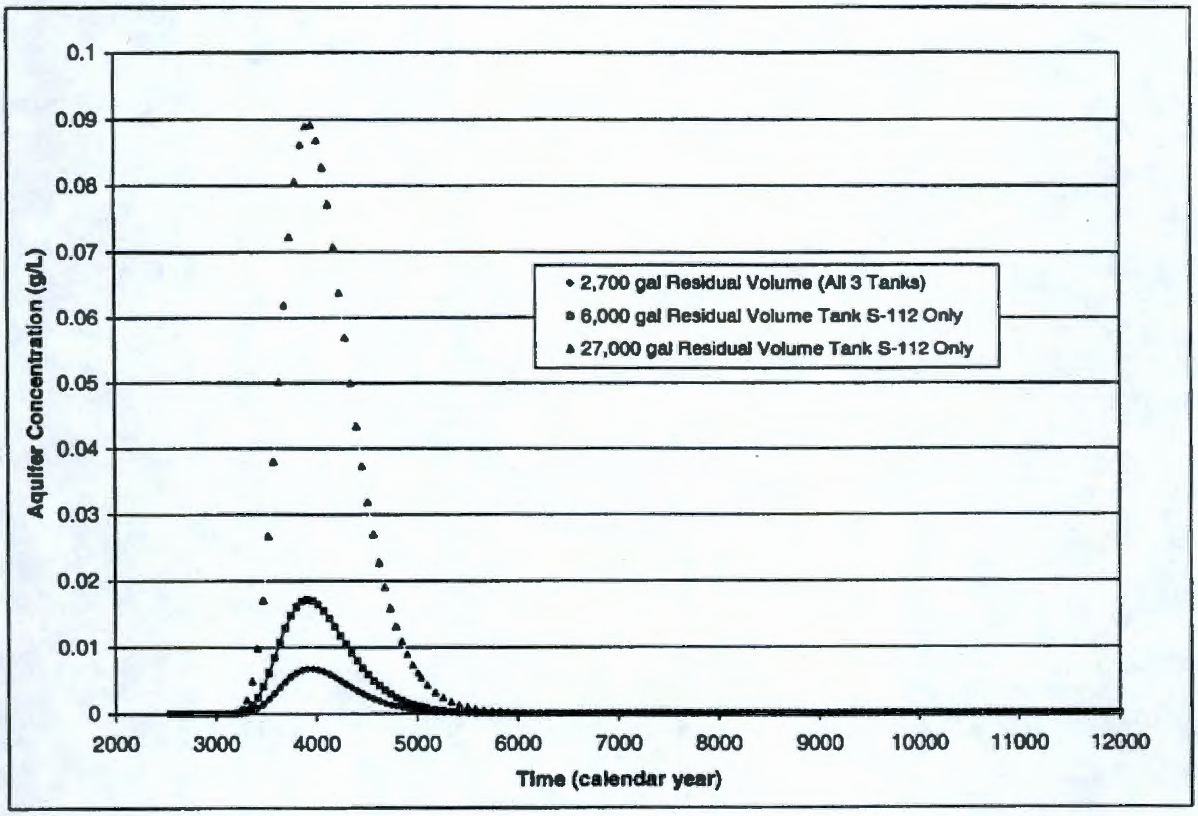
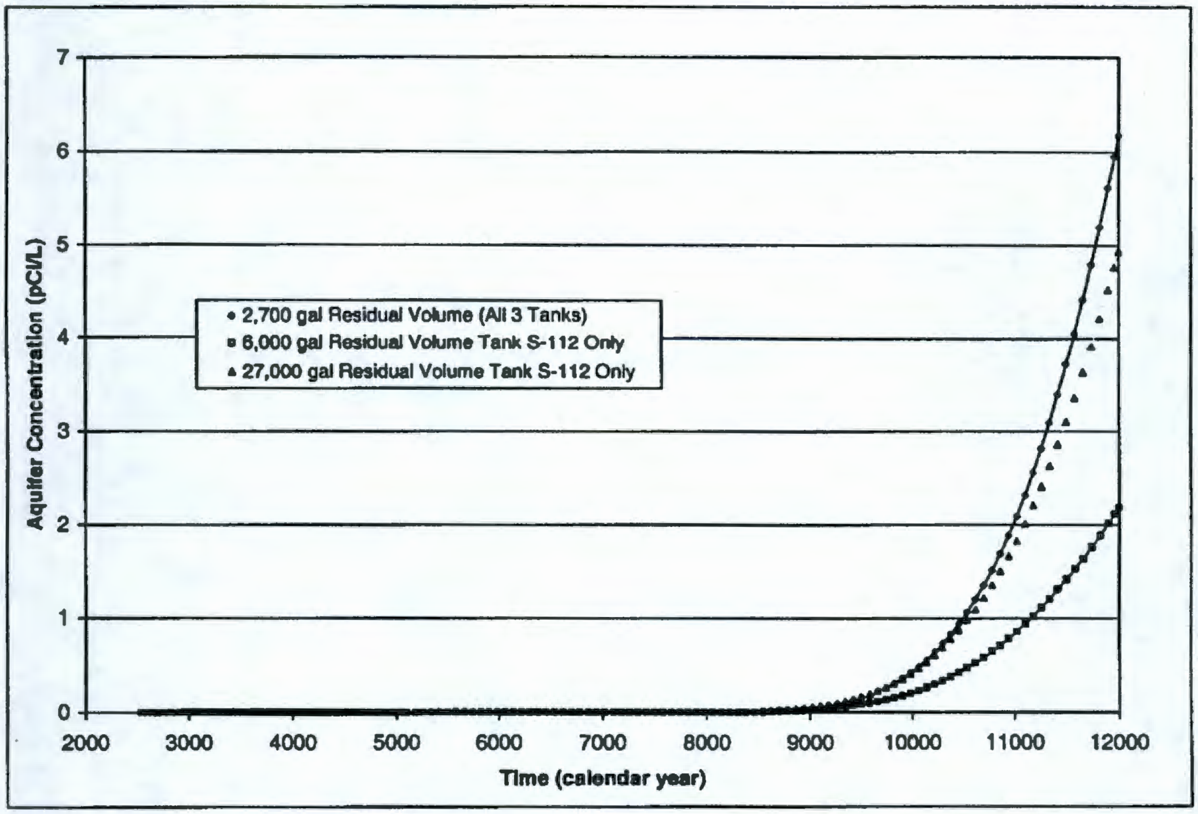


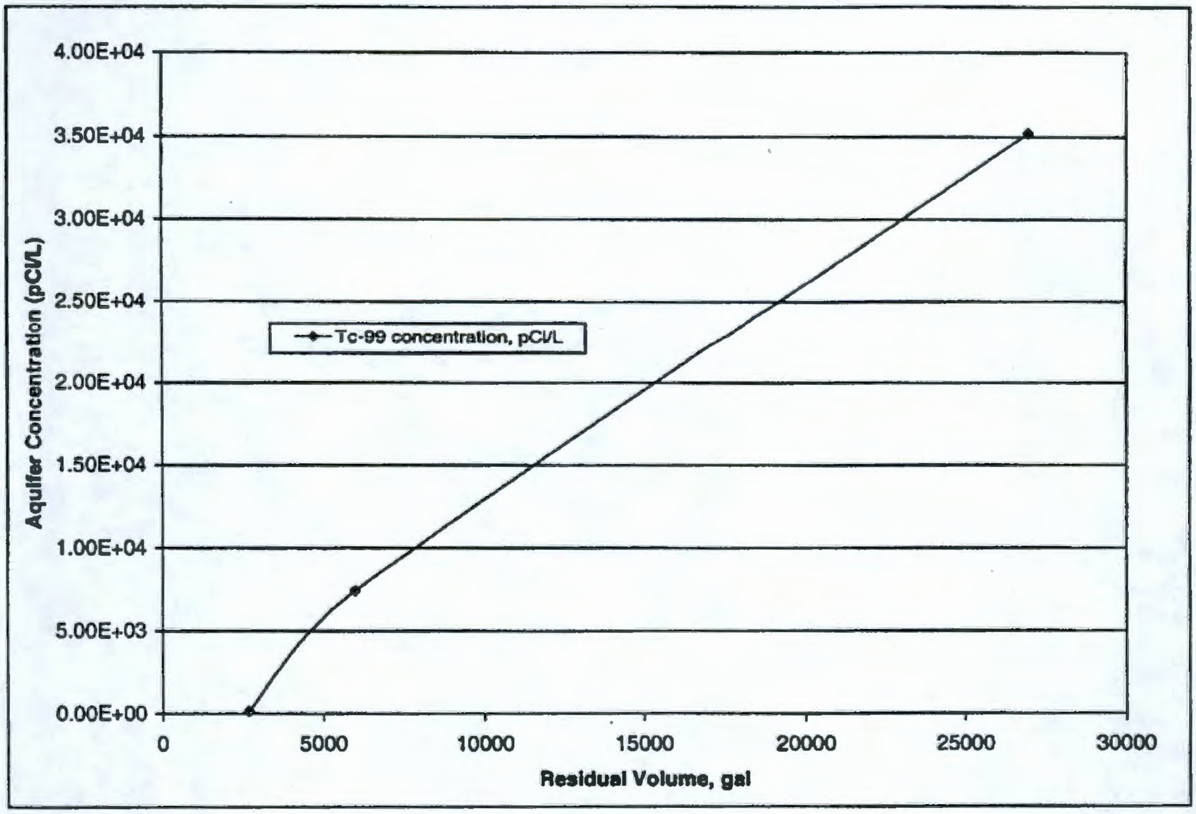
Figure B.5.7. Uranium-238 Groundwater Concentrations at the S Tank Farm Fenceline versus Time for Cross-Section S-110 Residual Source Term



The transport of uranium-238 was also simulated for the assumed residual volumes. The potential groundwater impacts of uranium-238 do not begin until about the year 8500 and would not have peaked during the 10,000 year period of interest (Figure B.5.7). The scenario with 102,000 L (2,700 gal) residual waste in all 3 tanks results in the greatest near-field uranium-238 concentration, which is about 6.2 pCi/L at the year 12000.

The relationship between volume of residual loss and peak contaminant concentration is illustrated in Figure B.5.8 for the near-field peak techetium-99 concentrations in groundwater. The overall relationship is not linear but could be approximated as two separate linear segments. Additional intermediate data points would help define the curve and relationship between residual waste volume and peak technetium-99 concentration.

Figure B.5.8. Technetium-99 Peak Groundwater Concentration at the S Tank Farm Fenceline versus Residual Volume in Tank S-112



B.5.1.2.1.3 Tank S-112 Results. To investigate the groundwater impacts associated with the tank S-112 combination of retrieval losses and residual waste source terms for the composite source term is analyzed for the waste retrieval cases identified in Section B.3.2. Results are summarized in Table B.5.4. The highest concentrations are associated with the largest retrieval losses.

Table B.5.4. Summary of Peak Contaminant Concentrations and the Calendar Year in Which They Occur for Releases from Tank S-112 Only

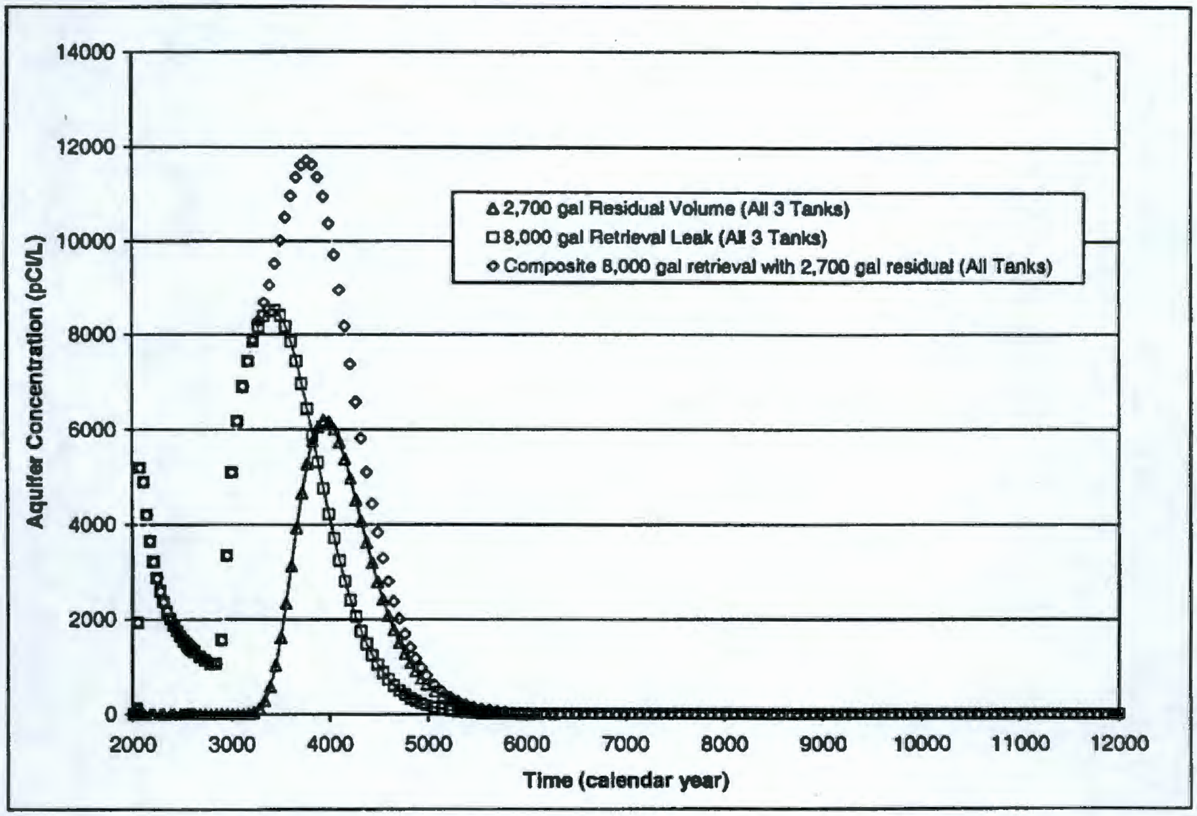
Description of Release Associated with Tank S-112	Result	U-238 (pCi/L)	Tc-99 (pCi/L)	Nitrate (g/L)
Cases 1 and 6: 2,700 gal residual waste volume in tank S-112 only.	Peak Conc.	4.40E+00	1.51E+02	3.65E-03
	Year Peak Occurs	12000	3915	3915
Cases 2 and 3: 8,000 gal retrieval leak with 2,700 gal residual only from tank S-112 only.	Peak Conc.	4.65E+00	4.75E+03	9.21E-03
	Year Peak Occurs	12000	2080	2080
Case 4: 8,000 gal retrieval leak with 6,000 gal residual only from tank S-112 only.	Peak Conc.	2.42E+00	8.28E+03	1.94E-02
	Year Peak Occurs	12000	3910	3875
Case 5: 8,000 gal retrieval leak with 27,000 gal residual from tank S-112 only.	Peak Conc.	5.18E+00	3.60E+04	9.14E-02
	Year Peak Occurs	12000	3935	3935
Case 7: 4,000 gal retrieval leak with 2,700 gal residual only from tank S-112 only.	Peak Conc.	4.52E+00	2.30E+03	4.91E-03
	Year Peak Occurs	12000	2080	3815
Case 8: 40,000 gal retrieval leak with 2,700 gal residual only from tank S-112 only.	Peak Conc.	5.68E+00	3.35E+04	6.80E-02
	Year Peak Occurs	12000	2075	2075
Case 9: 80,000 gal retrieval leak with 2,700 gal residual only from tank S-112 only.	Peak Conc.	7.08E+00	8.63E+04	1.77E-01
	Year Peak Occurs	12000	2070	2070

Note: Case 10 groundwater impacts are discussed separately.

B.5.1.2.2 Cross-Section Composite Retrieval and Residual Groundwater Impacts. The previous sections provided details on the potential impacts of the two individual source terms. In this section, the composite groundwater impacts that would occur for the 3 tanks in the S-110 cross-section are provided for selected combinations of the two source terms. The three traces in Figure B.5.9 illustrate near-field concentration of technetium-99 in groundwater versus time for the following:

- 30,000 L (8,000 gal) retrieval loss from all 3 tanks
- 10,200 L (2,700 gal) residual volume in all 3 tanks
- The composite of these 2 source terms that would result from the commingling of the 2 technetium-99 contaminant plumes.

Figure B.5.9. Technetium-99 Groundwater Concentrations at the S Tank Farm Fenceline versus Time for Composite 8,000 gal Retrieval Loss (All Tanks) and 2,700 gal Residual (All Tanks) for Cross-Section S-110



Eight variations of the potential composite groundwater impacts of the 2 source terms have been constructed in a fashion similar to that illustrated in Figure B.5.9. These selected composite scenarios have assumed retrieval losses that range from 15,000 L (4,000 gal) to 300,000 L (80,000 gal) from tank S-112 and residual waste volumes that range from 23,000 L (6,000 gal) to 102,000 L (27,000 gal) from tank S-112. Figures B.5.10 through B.5.12 provide a graphical comparison of the selected composite results of the near-field groundwater contaminant concentrations. The mobile contaminants, techetium-99 and nitrate, exhibit a bimodal peak response. Groundwater impacts from the residual source term do not begin to occur until about the year 3200 which is well after the early peak, thus the early peak for the composite impacts is the same as shown for the retrieval impacts in the previous section. The late-time peaks are affected by both the residual waste and retrieval loss source terms. The year of peak contaminant concentration and the contaminant concentration at the peak for technetium-99, uranium-238, and nitrate are summarized in Table B.5.5 for each of the 8 potential cross-section S-110 composite cases.

Figure B.5.10. Comparison Groundwater Concentrations of Technetium-99 versus Time at the Waste Management Area Fenceline for Composite Retrieval and Residual Source Terms for Cross-Section S-110

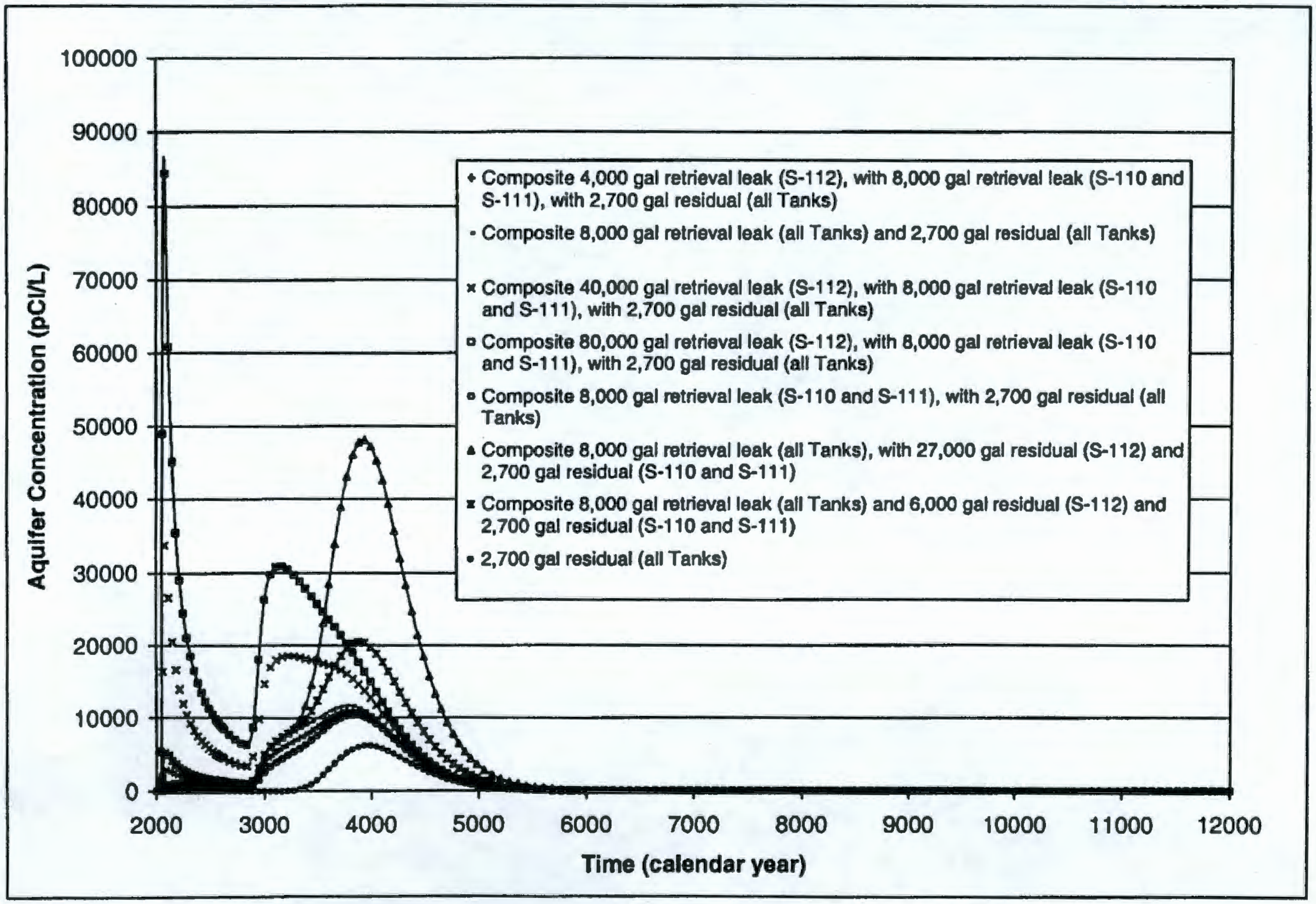


Figure B.5.11. Comparison Groundwater Concentrations of Nitrate versus Time at the Waste Management Area Fenceline for Composite Retrieval and Residual Source Terms for Cross-Section S-110

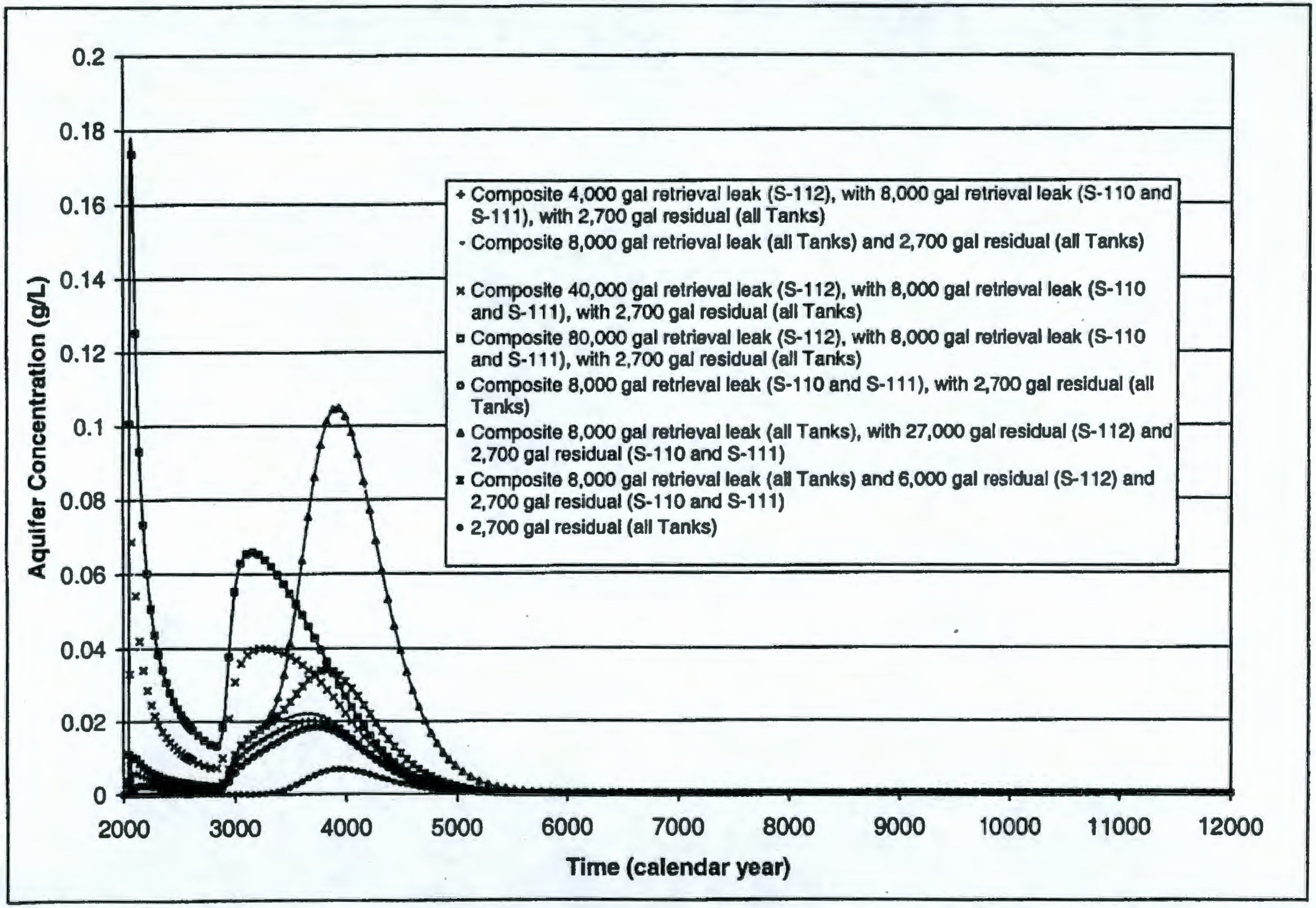


Figure B.5.12. Comparison Groundwater Concentrations of Uranium-238 versus Time at the Waste Management Area Fenceline for Composite Retrieval and Residual Source Terms for Cross-Section S-110

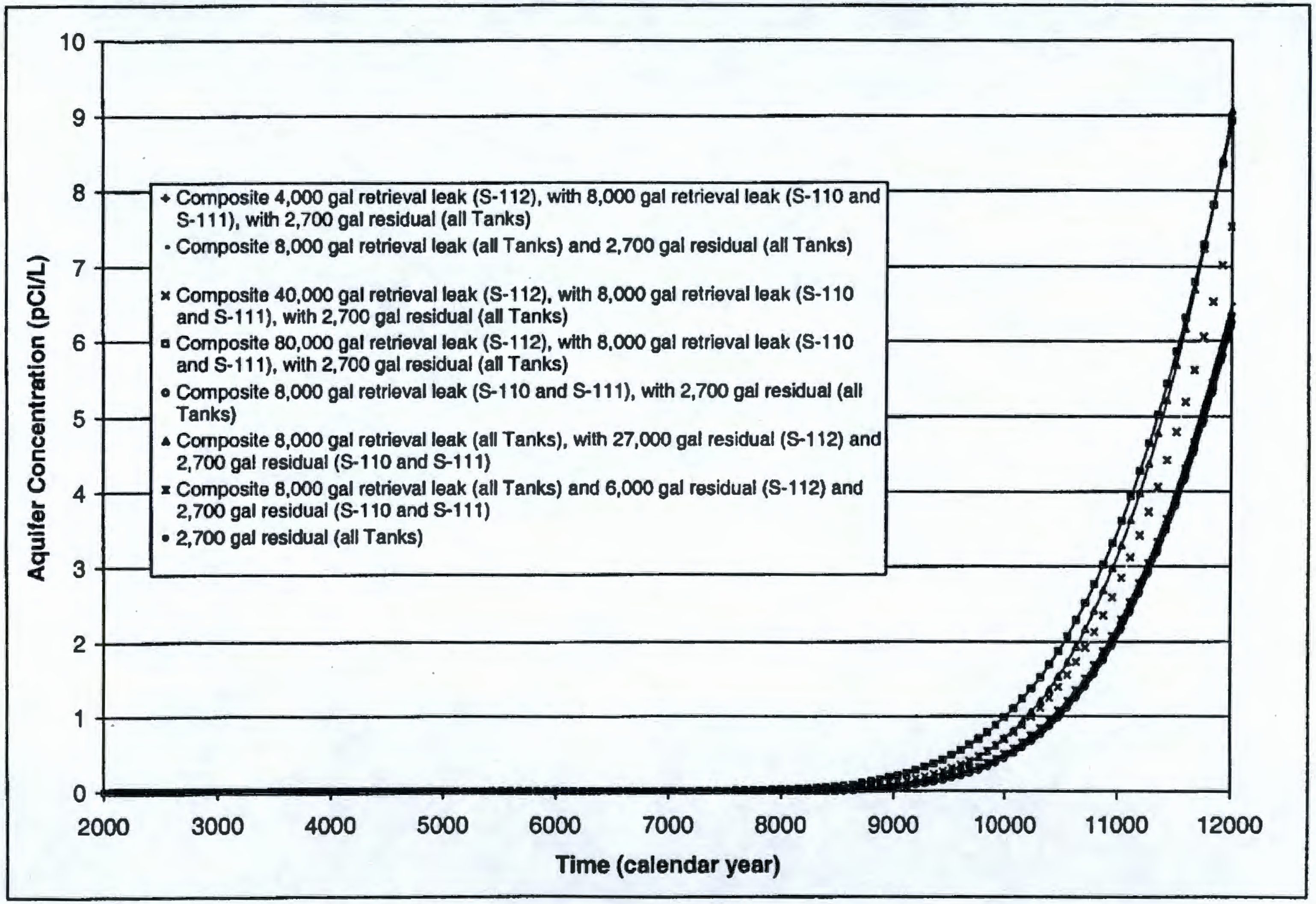


Table B.5.5. Summary of Peak Contaminant Concentrations for Selected Composite Terms for Cross-Section S-110

Description of Composite Retrieval and Residual Simulation	Result	U-238, pCi/L	Tc-99, pCi/L	Nitrate, g/L
Case 1: 2,700 gal residual waste volume in all three tanks, no retrieval losses	Peak Conc.	6.18E+00	6.20E+03	6.78E-03
	Year Peak Occurs	12000	3960	3940
Cases 2 and 3: Composite 8,000 gal retrieval leak (all tanks) and 2,700 gal residual waste (all tanks)	Peak Conc.	6.49E+00	1.17E+04	2.20E-02
	Year Peak Occurs	12000	3780	3645
Case 4: Composite 8,000 gal retrieval leak (all tanks); with 6,000 gal residual waste (S-112); and 2,700 gal residual waste (S-110 and S-111)	Peak Conc.	6.31E+00	2.06E+04	3.42E-02
	Year Peak Occurs	12000	3880	3815
Case 5: Composite 8,000 gal retrieval (all tanks); with 27,000 gal residual waste (S-112); with 2,700 gal residual waste (S-110 and S-111)	Peak Conc.	9.06E+00	4.81E+04	1.05E-01
	Year Peak Occurs	12000	3920	3915
Case 6: Composite 8,000 gal retrieval leak (S-110 and S-111) and 2,700 gal residual waste (all tanks)	Peak Conc.	6.25E+00	1.05E+04	1.83E-02
	Year Peak Occurs	12000	3830	3730
Case 7: Composite 4,000 gal retrieval leak (S-112); with 8,000 gal retrieval leak (S-110 and S-111); with 2,700 gal residual waste (all tanks)	Peak Conc.	6.37E+00	1.11E+04	2.01E-02
	Year Peak Occurs	12000	3805	3690
Case 8: Composite 40,000 gal retrieval leak (S-112), with 8,000 gal retrieval leak (S-110 and S-111), with 2,700 gal residual waste (all tanks)	Peak Conc.	7.52E+00	3.39E+04	6.89E-02
	Year Peak Occurs	12000	2075	2075
Case 9: Composite 80,000 gal retrieval leak (S-112), with 8,000 gal retrieval leak (S-110 and S-111), with 2,700 gal residual waste (all tanks)	Peak Conc.	8.93E+00	8.66E+04	1.78E-01
	Year Peak Occurs	12000	2070	2070

Notes: Peak concentration values for technetium-99 and uranium-238 are decayed from the year 2000.
"All tanks" refers to all tanks in the cross-section (S-110, S-111, and S-112).

B.5.1.2.3 Potential Groundwater Impacts with Interim Barrier. The potential benefit, in terms of reduced groundwater contaminant concentration, of adopting an interim barrier is investigated with selected simulations and the results are reported in this section. The potential benefit is only applicable to retrieval losses and past leaks. One simulation of 10,200 L (2,700 gal) residual waste from all three tanks in the S-110 cross-section was performed to verify this contention. The times to peak technetium-99 groundwater concentration and magnitude of the peaks for cases with and without an interim barrier were indistinguishable when plotted. The impact on the one past leak, which was from tank S-104, was not investigated herein but was the subject of investigation in the WMA S-SX FIR (RPP-7884).

Application of an interim barrier would not change the overall mass of contaminant that would reach the aquifer for a non-decaying contaminant such as nitrate. For the long-lived contaminants techentium-99 and uranium-238, the reduction due to radioactive decay is too small to be noticeable. Thus, for the three simulated contaminants, technetium-99, nitrate, and uranium-238, the interim barrier serves to shift the impacts from an earlier time to a later time. This is illustrated in Figure B.5.13 for techetium-99. Note that in Figure B.5.13, the simulation with no interim barrier and a 30,000 L (8,000 gal) retrieval loss from tank S-112 results in a early peak concentration of about 4,800 pCi/L. Installation of an interim barrier either in the year 2005 or year 2025 serves to mute the early peak concentration to less than 600 pCi/L; however, the overall mass of contaminant to the aquifer would not change. Therefore, the late time peaks would increase for either interim barrier scenario. The late time peaks for the interim barrier simulations are higher and occur later in time that those for the simulation without an interim barrier. The early application of an interim barrier in the year 2005 eliminates the early technetium-99 peak concentration. The resulting technetium-99 versus time trace is similar to that for a residual waste source term discussed in previous sections. The late time peak for the early application of an interim barrier is nearly the same magnitude as the early peak would be in the simulation without an interim barrier but occurs at about the year 4000 which is nearly coincident with the residual waste time of peak concentration for mobile contaminants. Similar results for technetium-99 are realized when a 150,000 L (40,000 gal) retrieval loss is assumed (Figure B.5.14). The higher late-time technetium-99 concentration peaks for retrieval source term simulations with the interim barrier would be additive to the impacts from the other source terms, most notably the residual source term which also reaches peak concentration in about the year 4000 (see Figure B.5.5).

Figure B.5.13. Comparison of Groundwater Concentrations of Technetium-99 versus Time at the S Tank Farm Fenceline for a 8,000 gal Retrieval Source Term and Alternative Interim Barrier Installations for Cross-Section S-110

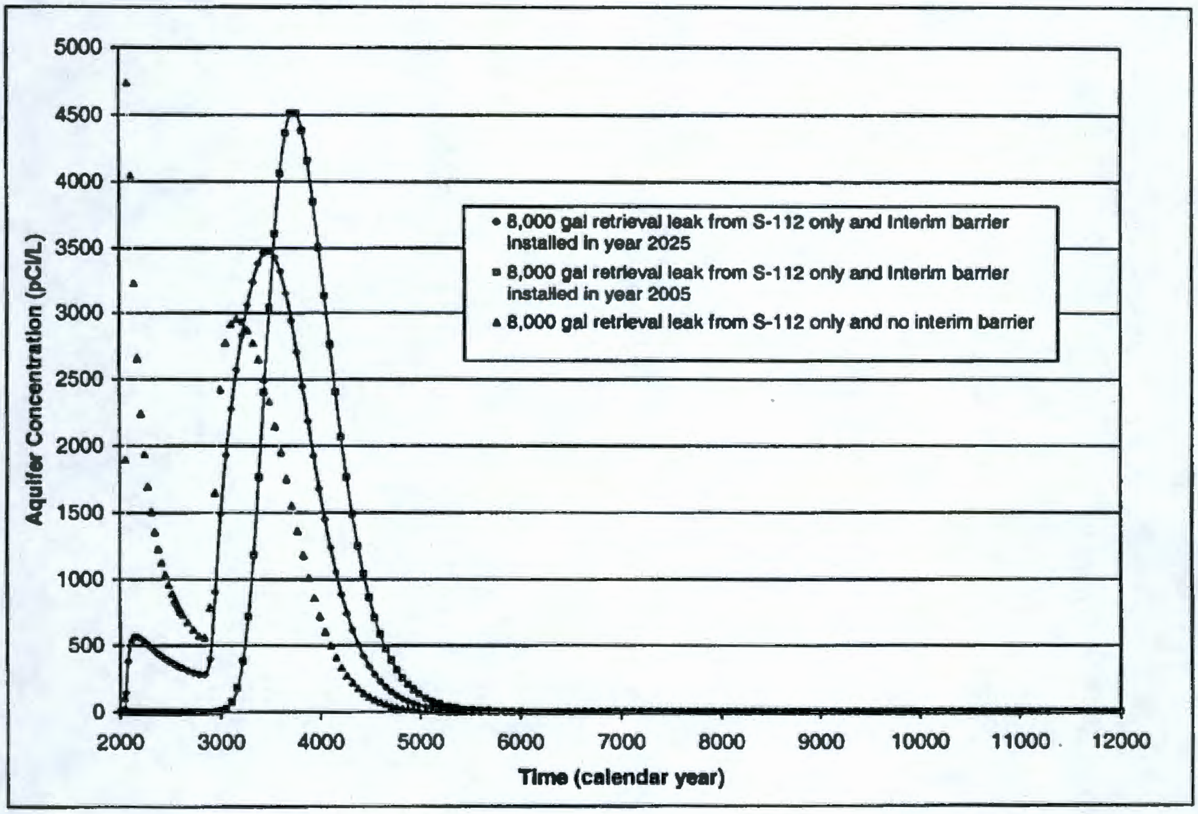
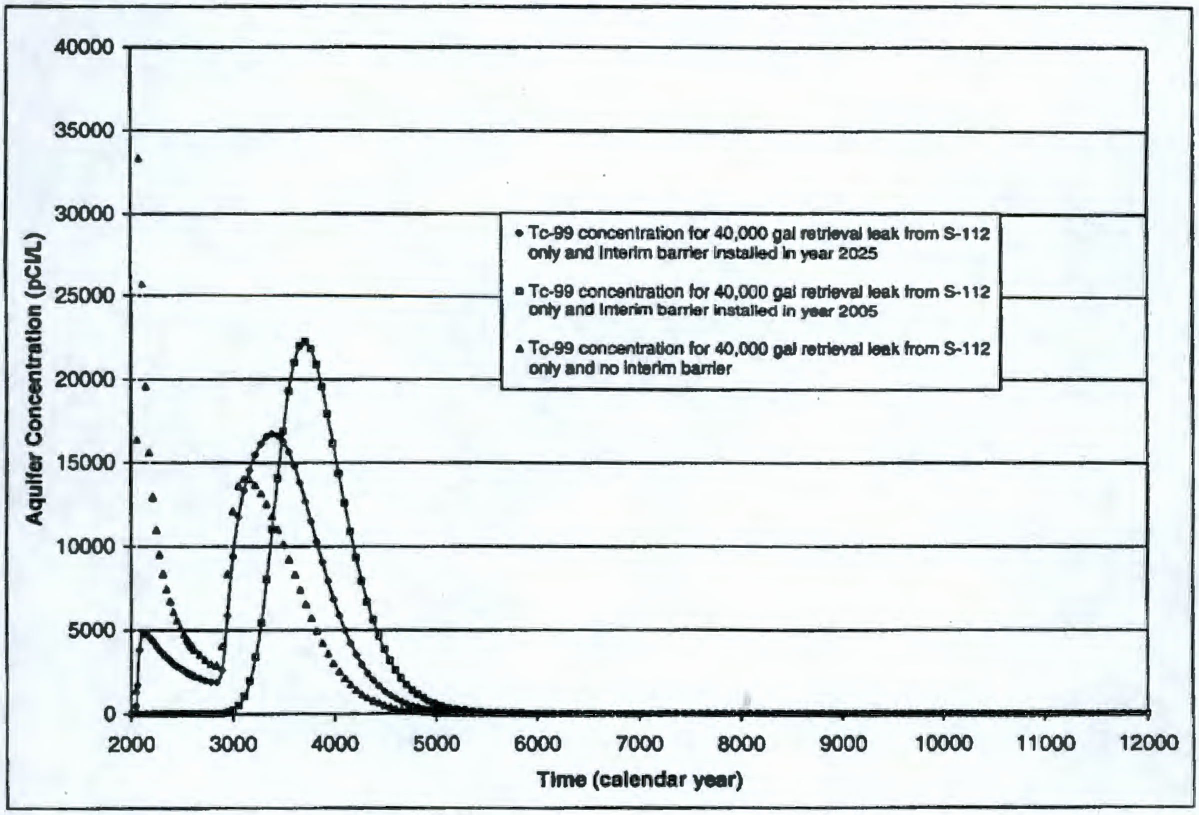


Figure B.5.14. Comparison of Groundwater Concentrations of Technetium-99 versus Time at the S Tank Farm Fenceline for a 40,000 gal Retrieval Source Term and Alternative Interim Barrier Installations for Cross-Section S-110



B.5.1.3 Tank S-112 Long-Term Human Health Risk Assessment Results

Results of the tank S-112 long-term human health risk assessment are provided in this section based on predicted contaminant concentrations in groundwater at the east fenceline of the S tank farm (Section B.5.1.2). Results are provided on both a tank-specific (Section B.5.1.3.1) and cross-section (Section B.5.1.3.2) basis. A comparison of the results for the different receptor scenarios evaluated is also provided (Section B.5.1.3.3). Assessment results for the S tank farm as a whole, including changes in S tank farm impacts resulting from changes in tank S-112 retrieval leakage, are provided in Section B.5.2.2.

The Washington State Department of Health has issued guidance that the dose limit for release of a site is 15 mrem/year total effective dose equivalent (WDOH/320-015). The DOE dose limit defined in DOE O 435.1 for LLW facility closure is 25 mrem/year total effective dose equivalent from all exposure pathways. To provide a comparison of these dose rates with the long-term risks presented, the 25 mrem/year dose limit can be converted to long-term human health risk by using a conversion factor of 6×10^{-4} cancer incidences per rem. This dose can be converted to an annual dose by taking the scenario-specific exposure durations into account. Using the conversion an annual dose of 15 mrem/yr converts to a risk of 9×10^{-6} on an annual basis. When the exposure durations for the industrial worker (20 years) and residential farmer (30 years) are taken into account the 15 mrem/yr dose corresponds to an ILCR of 1.8×10^{-4} and 2.7×10^{-4} for the industrial worker and residential farmer scenarios, respectively.

B.5.1.3.1 Tank-Specific Results for Tank S-112. Tank-specific results for tank S-112 are provided individually by source term for the retrieval leakage, residual waste, and composite source terms.

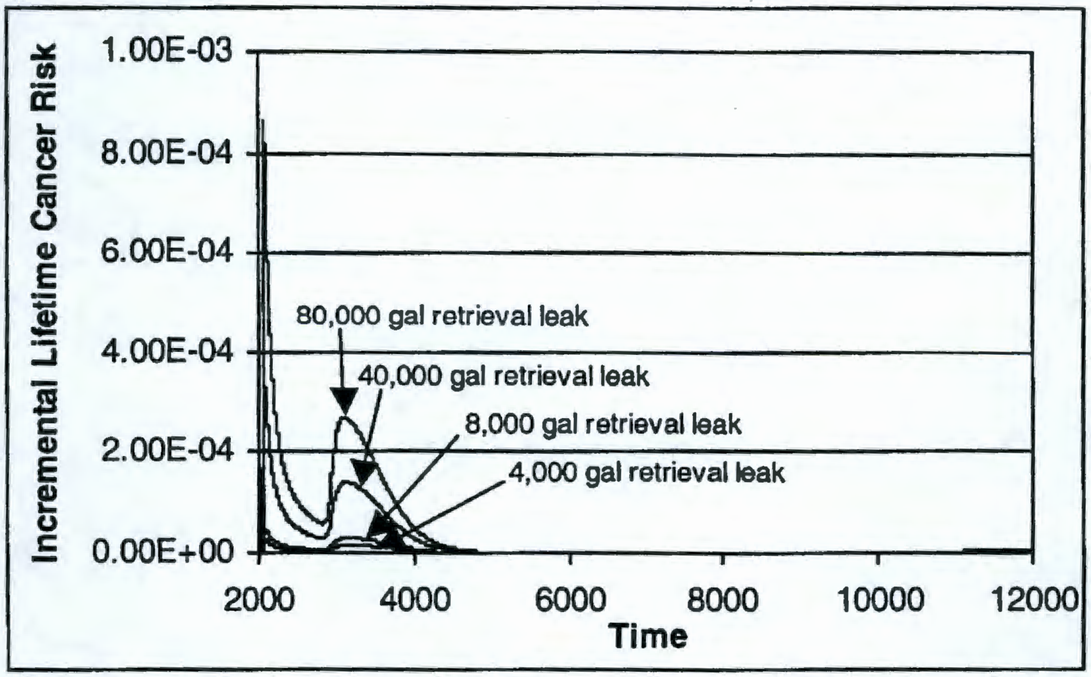
B.5.1.3.1.1 Retrieval Leakage. To develop a risk-to-volume relationship for retrieval leakage from tank S-112, retrieval leaks of 15,000; 30,000; 150,000; and 300,000 L (4,000; 8,000; 40,000; and 80,000 gal) are analyzed. Results are summarized in Table B.5.6 and Figure B.5.15. Table B.5.6 shows the peak ILCR and hazard index at the tank farm fenceline for each leak volume; Figure B.5.15 illustrates variations in ILCR from retrieval leakage over time for each leak volume. The peak industrial worker ILCR ranges between 2.31×10^{-5} and 8.66×10^{-4} and the peak hazard index ranges between 1.12×10^{-1} and 4.55×10^{0}. The peak residential farmer ILCR ranges between 8.96×10^{-4} and 3.37×10^{-2} and the peak hazard index ranges between 3.35×10^{1} and 1.36×10^{3}.

Table B.5.6. Tank S-112 Peak Incremental Lifetime Cancer Risk and Hazard Index at Tank Farm Boundary from Retrieval Leakage

Volume (gal)	ILCR		HI	
	Residential Farmer	Industrial Worker	Residential Farmer	Industrial Worker
4,000	8.96E-04	2.31E-05	3.35E+01	1.12E-01
8,000	1.85E-03	4.77E-05	7.05E+01	2.36E-01
40,000	1.31E-02	3.36E-04	5.21E+02	1.75E+00
80,000	3.37E-02	8.66E-04	1.36E+03	4.55E+00

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

Figure B.5.15. Tank S-112 Industrial Worker Incremental Lifetime Cancer Risk versus Time at Tank Farm Boundary from Retrieval Leakage



To investigate the effect of interim barrier use on the impacts from tank S-112 retrieval leakage, a barrier versus no barrier sensitivity comparison is made for a 30,000 L (8,000 gal) retrieval leak from tank S-112. Results are summarized in Table B.5.7. As shown in Table B.5.7, use of an interim barrier has negligible effect on peak impact values. However, use of an interim barrier delays the arrival of the peak by approximately 1,600 years (from the year 2100 to the year 3700).

Table B.5.7. Tank S-112 Effect of Interim Barrier on Peak Incremental Lifetime Cancer Risk and Hazard Index at Tank Farm Boundary from 8,000 Gallon Retrieval Leak

Source Term	ILCR		HI	
	Residential Farmer	Industrial Worker	Residential Farmer	Industrial Worker
8,000 gallon retrieval leak with interim barrier	1.69E-03	4.48E-05	7.25E+01	2.43E-01
8,000 gallon retrieval leak without interim barrier	1.85E-03	4.77E-05	7.05E+01	2.36E-01

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

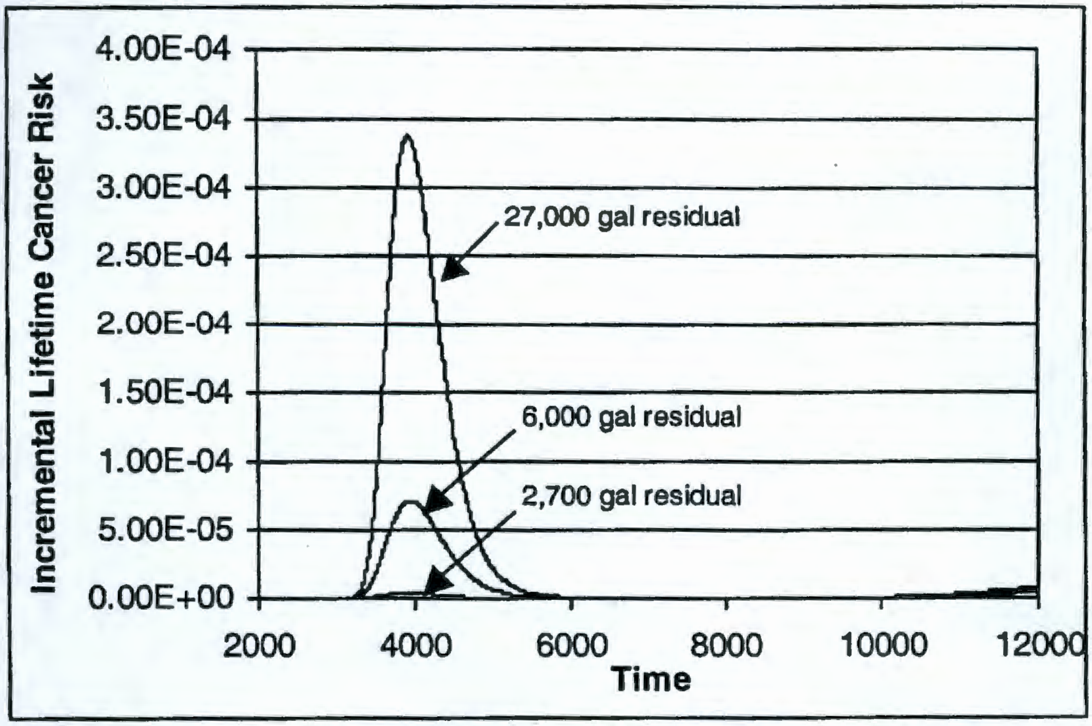
B.5.1.3.1.2 Residual Waste. To develop a risk-to-volume relationship for residual waste in tank S-112, residual waste volumes of 10,200; 23,000; and 102,000 L (2,700; 6,000; and 27,000 gal) are analyzed. Results are summarized in Table B.5.8 and Figure B.5.16. Table B.5.8 shows the peak ILCR and hazard index at the tank farm fenceline for each residual waste volume; Figure B.5.16 illustrates variations in ILCR from residual waste over time for each residual waste volume. The peak industrial worker ILCR ranges between 6.05×10^{-6} and 3.38×10^{-4} and the peak hazard index ranges between 4.62×10^{-2} and 5.61×10^{-1}. The peak residential farmer ILCR ranges between 8.38×10^{-5} and 1.25×10^{-2} and the peak hazard index ranges between 2.78×10^{1} and 6.78×10^{2}.

Table B.5.8. Tank S-112 Peak Incremental Lifetime Cancer Risk and Hazard Index at Tank Farm Boundary From Residual Waste

Volume (gal)	ILCR		HI	
	Residential Farmer	Industrial Worker	Residential Farmer	Industrial Worker
2,700	8.38E-05	6.05E-06	2.78E+01	4.62E-02
6,000	2.64E-03	7.12E-05	1.30E+02	1.08E-01
27,000	1.25E-02	3.38E-04	6.78E+02	5.61E-01

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

Figure B.5.16. Tank S-112 Industrial Worker Incremental Lifetime Cancer Risk versus Time at Tank Farm Boundary from Residual Waste



B.5.1.3.1.3 Composite Source Term. To illustrate the effects of variation in the 2 primary system components for tank S-112 (i.e., retrieval leakage and residual waste volume), analysis results are provided for 2 sets of composite source term combinations. The first set illustrates the effects of retrieval leakage variation by combining each of the 4 retrieval leak volumes analyzed with a residual waste volume of 10,200 L (2,700 gal). The second set illustrates the effects of residual waste variation by combining each of the 3 residual waste volumes analyzed with a 30,000 L (8,000 gal) retrieval leak. Results for the retrieval leakage set are summarized in Table B.5.9 and Figure B.5.17. Results in Table B.5.9 are almost identical to the results for the retrieval leakage source term cases (Table B.5.6), indicating retrieval leakage dominates a residual waste volume of 10,200 L (2,700 gal) even at small retrieval leak volumes. Results for the residual waste set are summarized in Table B.5.10 and Figure B.5.18. Results in Table B.5.10 diverge at low volumes from the results for the residual waste source term cases (Table B.5.8), indicating residual waste dominates a 30,000 L (8,000 gal) retrieval leak at moderate to high residual waste volumes but not at low residual waste volumes. Table B.5.11 summarizes the tank S-112 composite source term results for the 10 waste retrieval cases identified in Section B.3.2.

Table B.5.9. Tank S-112 Peak Incremental Lifetime Cancer Risk and Hazard Index at Tank Farm Boundary from Composite of Varying Retrieval Leakage Volumes and 2,700 Gallons of Residual Waste

Retrieval Leakage Volume (gal)	ILCR		HI	
	Residential Farmer	Industrial Worker	Residential Farmer	Industrial Worker
0	8.38E-05	6.05E-06	2.78E+01	4.62E-02
4,000	8.96E-04	2.31E-05	3.74E+01	1.12E-01
8,000	1.85E-03	4.77E-05	7.05E+01	2.36E-01
40,000	1.31E-02	3.36E-04	5.21E+02	1.75E+00
80,000	3.37E-02	8.66E-04	1.36E+03	4.55E+00

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

Figure B.5.17. Tank S-112 Industrial Worker Incremental Lifetime Cancer Risk versus Time at Tank Farm Boundary from Varying Retrieval Leakage Volume and 2,700 Gallons of Residual Waste

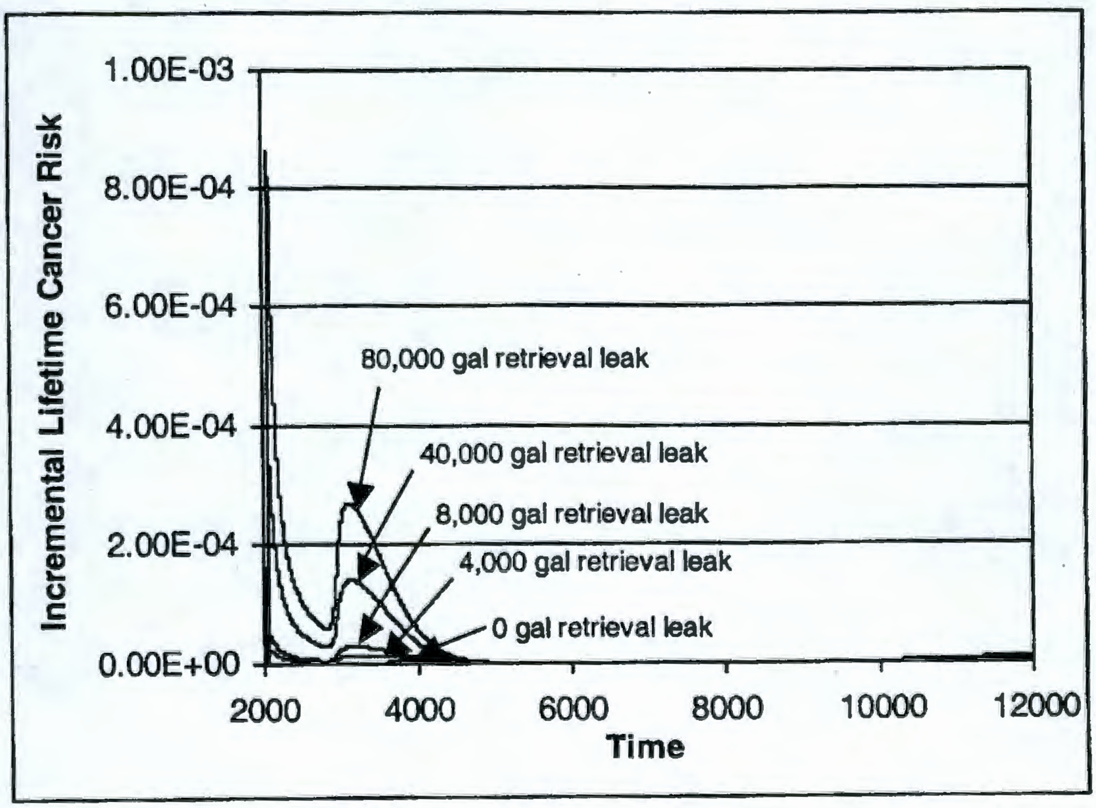


Table B.5.10. Tank S-112 Peak Incremental Lifetime Cancer Risk and Hazard Index at Tank Farm Boundary from Composite of Varying Residual Waste Volumes and 8,000 Gallons of Retrieval Leakage

Residual Waste Volume (gal)	ILCR		HI	
	Residential Farmer	Industrial Worker	Residential Farmer	Industrial Worker
0	1.85E-03	4.77E-05	7.05E+01	2.36E-01
2,700	1.85E-03	4.77E-05	7.05E+01	2.36E-01
6,000	2.96E-03	7.99E-05	1.47E+02	2.36E-01
27,000	1.28E-02	3.46E-04	6.94E+02	6.14E-01

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

Figure B.5.18. Tank S-112 Industrial Worker Incremental Lifetime Cancer Risk versus Time at Tank Farm Boundary from Varying Residual Waste Volumes and 8,000 Gallons of Retrieval Leakage

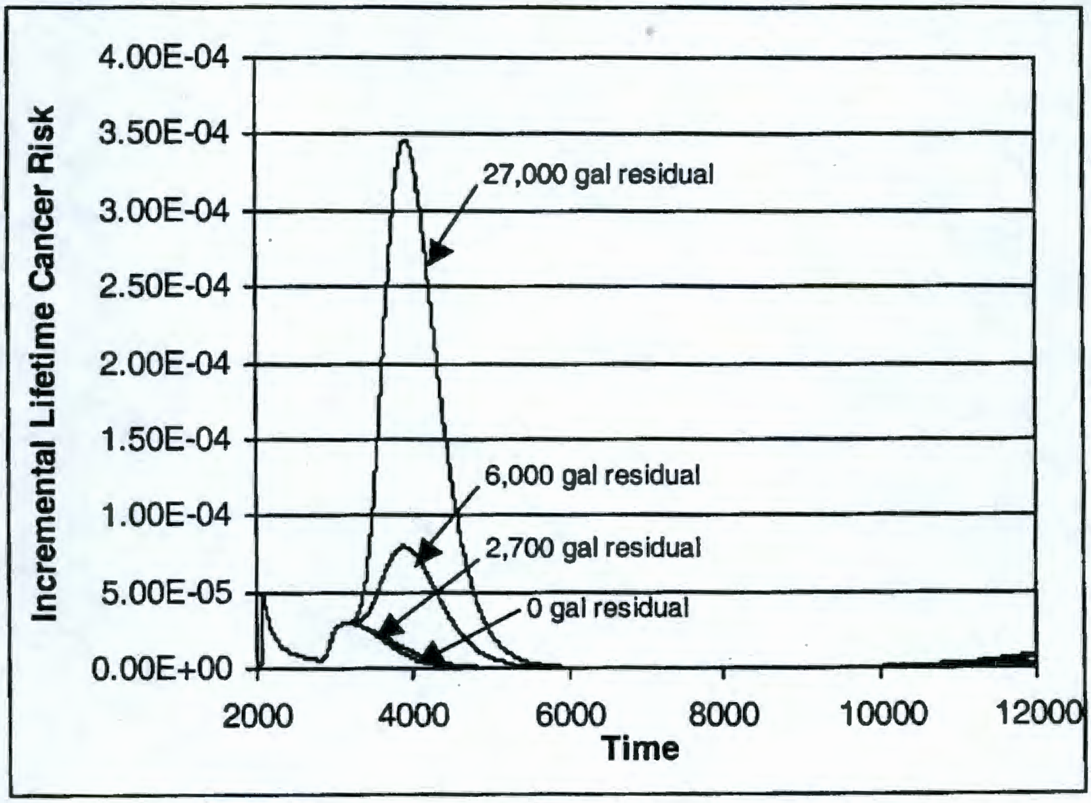


Table B.5.11. Tank S-112 Peak Incremental Lifetime Cancer Risk and Hazard Index at Tank Farm Boundary From Composite Source Term

Case	Retrieval Leakage Volume (gal)	Residual Waste Volume (gal)	ILCR		HI	
			Residential Farmer	Industrial Worker	Residential Farmer	Industrial Worker
1	0	2,700	8.38E-05	6.05E-06	2.78E+01	4.62E-02
2	8,000	2,700	1.85E-03	4.77E-05	7.05E+01	2.36E-01
3	8,000	2,700	1.85E-03	4.77E-05	7.05E+01	2.36E-01
4	8,000	6,000	2.96E-03	7.99E-05	1.47E+02	2.36E-01
5	8,000	27,000	1.28E-02	3.46E-04	6.94E+02	6.14E-01
6	0	2,700	8.38E-05	6.05E-06	2.78E+01	4.62E-02
7	4,000	2,700	8.96E-04	2.31E-05	3.74E+01	1.12E-01
8	40,000	2,700	1.31E-02	3.36E-04	5.21E+02	1.75E+00
9	80,000	2,700	3.37E-02	8.66E-04	1.36E+03	4.55E+00
10	8000	2700	4.90E-03	2.01E-04	1.19E+02	3.04E-01

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

B.5.1.3.2 Tank S-112 Cross-Section Results. To investigate the human health impacts associated with the tank S-112 cross-section, the composite source term for the 3 tanks in combination is analyzed for the 10 waste retrieval cases identified in Section B.3.2. Results are summarized in Table B.5.12. The highest impacts are associated with Cases 8 and 9, which represent scenarios with large retrieval leaks from tank S-112, small retrieval leaks from the other 2 cross-section tanks, and small residual waste volumes in each of the 3 cross-section tanks. Impacts are also high for Case 5, which represents a scenario with small retrieval leaks from each of the 3 cross-section tanks, large residual waste volume in tank S-112, and low residual waste volumes in the other 2 cross-section tanks. The lowest impacts are associated with Case 1, which represents a scenario with no retrieval leaks from any of the 3 cross-section tanks and small residual waste volumes in each of the 3 tanks.

Table B.5.12. Tank S-112 Cross-Section Peak Incremental Lifetime Cancer Risk and Hazard Index at Tank Farm Boundary from Composite Source Term

Case	Retrieval Leakage Volume (gal)		Residual Waste Volume (gal)		ILCR		HI	
	Tank S-112	Tanks S-110, S-111	Tank S-112	Tanks S-110, S-111	Residential Farmer	Industrial Worker	Residential Farmer	Industrial Worker
1	0	0	2,700	2,700	4.63E-03	2.18E-04	5.75E+01	8.62E-02
2, 3	8,000	8,000	2,700	2,700	6.50E-03	2.66E-04	1.71E+02	5.19E-01
4	8,000	8,000	6,000	2,700	9.00E-03	3.33E-04	2.60E+02	5.51E-01
5	8,000	8,000	27,000	2,700	1.88E-02	5.99E-04	7.99E+02	9.27E-01
6	0	8,000	2,700	2,700	6.12E-03	2.57E-04	1.44E+02	4.03E-01
7	4,000	8,000	2,700	2,700	6.31E-03	2.61E-04	1.57E+02	4.60E-01
8	40,000	8,000	2,700	2,700	1.32E-02	3.40E-04	5.28E+02	1.77E+00
9	80,000	8,000	2,700	2,700	3.38E-02	8.69E-04	1.36E+03	4.57E+00
10	8,000	0	2,700	2,700	9.41E-03	4.14E-04	1.46E+02	3.39E-01

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

B.5.1.3.3 Receptor Scenario Comparison. Table B.5.13 provides a comparison of the composite source term results for the receptor scenarios based on *Hanford Site Risk Assessment Methodology* (DOE/RL-91-45) (industrial worker and residential farmer) with the results for the MTCA scenarios (Method B and Method C). Because the MTCA risk criteria (WAC 173-340) are applicable only to nonradioactive contaminants, Table B.5.13 compares only hazard index values. Table B.5.13 indicates that the residential farmer scenario is consistently the most conservative (i.e., produces the highest hazard index values), followed by MTCA Method B and MTCA Method C. The industrial worker scenario is the least conservative (i.e., produces the lowest hazard index values) of the four exposure scenarios.

Table B.5.13. Tank S-112 and Cross-Section Comparison of Peak Hazard Index at Tank Farm Boundary from Composite Source Term for Different Receptor Scenarios

Case	Tank S-112				Cross-Section			
	Residential Farmer	Industrial Worker	MTCA Method B	MTCA Method C	Residential Farmer	Industrial Worker	MTCA Method B	MTCA Method C
1	2.78E+01	4.62E-02	8.91E-01	4.07E-01	5.75E+01	8.62E-02	1.84E+00	8.42E-01
2	7.05E+01	2.36E-01	2.39E+00	1.09E+00	1.71E+02	5.19E-01	5.72E+00	2.62E+00
3	7.05E+01	2.36E-01	2.39E+00	1.09E+00	1.71E+02	5.19E-01	5.72E+00	2.62E+00
4	1.47E+02	2.36E-01	2.39E+00	1.09E+00	2.60E+02	5.51E-01	5.64E+00	2.58E+00
5	6.94E+02	6.14E-01	4.49E+00	2.05E+00	7.99E+02	9.27E-01	8.23E+00	3.76E+00
6	2.78E+01	4.62E-02	8.91E-01	4.07E-01	1.44E+02	4.03E-01	4.79E+00	2.19E+00
7	3.74E+01	1.12E-01	1.22E+00	5.58E-01	1.57E+02	4.60E-01	5.25E+00	2.40E+00
8	5.21E+02	1.75E+00	1.77E+01	8.08E+00	5.28E+02	1.77E+00	1.79E+01	8.19E+00
9	1.36E+03	4.55E+00	4.61E+01	2.11E+01	1.36E+03	4.57E+00	4.63E+01	2.12E+01
10	1.19E+02	3.04E-01	3.93E+00	1.80E+00	1.46E+02	3.39E-01	4.80E+00	2.20E+00

MTCA = Model Toxics Control Act.

B.5.1.4 Tank S-112 Intruder Risk Assessment Results

This section presents the results of the risk analyses for the inadvertent human intruder based on the DOE and NRC methodologies described in Section B.3.7. The DOE inadvertent human intruder analysis involves a well driller scenario and post-driller resident scenario. The NRC inadvertent human intruder analysis is based on a scenario of the tank waste meeting the concentration limits established for Class C for the inadvertent human intruder at 500 years.

B.5.1.4.1 U.S. Department of Energy Intruder Scenario. The doses to the well driller and post-driller resident for each of the waste retrieval cases are presented in Table B.5.14. The source or the total activity in curies of each constituent exhumed and made available at the surface for all the cases includes a fraction of waste from the residual waste in tank S-112 and soil contaminated by tank S-112 retrieval leak losses. The radiological activity in the retrieval leak losses and residual waste is obtained from calculations presented the Attachment of this document.

Table B.5.14. Well Driller and Post-Driller Resident Dose in 2100 for Tank S-112

Case	Well Driller (mrem/incident)	Post-Driller Resident (mrem/yr)
1	5.4E+00	4.6E+01
2	1.1E+01	6.6E+01
3	1.1E+01	6.6E+01
4	1.8E+01	1.2E+02
5	6.3E+01	2.7E+02
6	5.4E+00	4.6E+01
7	8.4E+00	5.6E+01
8	3.5E+01	1.5E+02
9	6.5E+01	2.5E+02
10	1.1E+01	6.6E+01

Note: U.S. Department of Energy regulations limit exposures to an inadvertent human intruder to no greater than 100 mrem/yr for chronic exposure (post-driller resident) and 500 mrem for an acute or single event (well driller) at a point in time 100 years after closure (DOE O 435.1).

B.5.1.4.2 U.S. Nuclear Regulatory Commission Requirements. A comparison of the radionuclide concentrations in the residual waste in tank S-112 to the Class C upper limit concentration values is presented in Table B.5.15. The tank S-112 residual waste inventories are discussed in more detail in the Attachment of this document. The comparison shows the long-lived radionuclides (specifically, alpha-emitting TRU with $t_{1/2} > 5$ yr) can exceed the Class C upper limits. Table B.5.15 also shows the long-lived radionuclide sum-of-fractions is greater than 1 or an exceedance of 8 times for Cases 1, 2, 3, 4, 6, 7, 8, 9, and 10 and 3 times for Case 5.

Table B.5.15. Tank S-112 Residual Waste Concentrations Compared to the Class C Upper Limits

Radionuclides	Class C Upper Limits	Cases 1, 2, 3, 4, 6, 7, 8, 9, and 10	Case 5
Long-Lived Radionuclides			
Carbon-14	8 Ci/m^3	0.009 Ci/m^3	0.03 Ci/m^3
Carbon-14 in activated metal	80 Ci/m^3	0 Ci/m^3	0 Ci/m^3
Nickel-59 in activated metal	220 Ci/m^3	0 Ci/m^3	0 Ci/m^3
Niobium-94 in activated metal	0.2 Ci/m^3	0 Ci/m^3	0 Ci/m^3
Technetium-99	3 Ci/m^3	0.08 Ci/m^3	0.17 Ci/m^3
Iodine-129	0.08 Ci/m^3	0.0002 Ci/m^3	0.0003 Ci/m^3
Alpha emitting transuranic with $t_{1/2} > 5$ yr			
Neptunium-237	100 nCi/g	0.2 nCi/g	0.35 nCi/g
Plutonium-238,239,240	100 nCi/g	776 nCi/g	298 nCi/g
Americium-241,243	100 nCi/g	26 nCi/g	61 nCi/g
Curium-243 to 247	100 nCi/g	0.007 Ci/g	0.002 nCi/g
Berkelium-247	100 nCi/g	0 nCi/g	0 nCi/g
Californium-249 to 251	100 nCi/g	0 nCi/g	0 nCi/g
Plutonium-241	3,500 nCi/g	405 nCi/g	231 nCi/g
Curium-242	20,000 nCi/g	0.2 nCi/g	0.05 nCi/g
Short-Lived Radionuclides			
Nickel-63	700 Ci/m^3	1.1 Ci/m^3	0.49 Ci/m^3
Nickel-63 in activated metal	7,000 Ci/m^3	0 Ci/m^3	0 Ci/m^3
Strontium-90	7,000 Ci/m^3	1,558 Ci/m^3	383 Ci/m^3
Cesium-137	4,600 Ci/m^3	341 Ci/m^3	391 Ci/m^3
Sum-of-fractions for long-lived radionuclides	1.0	8	3.7
Sum-of-fractions for short-lived radionuclides	1.0	0.30	0.14

The residual waste inventory estimates in tank S-112 were further evaluated for each of the waste retrieval cases (HNF-7990 using the Shyr and Bustard 1997 methodology) to determine the minimum volume of grout that would be required to stabilize the residual waste and at the same time reduce the radiological constituent concentrations to a level that would not exceed Class C upper limits. This evaluation was performed to determine the feasibility of attaining Class C concentrations through mixing the residual waste with grout. The minimum depth of grout that would be required in each waste retrieval case is summarized in Table B.5.16. It should be noted that the amount of grout required to stabilize 100,000 L (27,000 gal) and 190,000 L (50,000 gal) of residual waste would be considerably more than 20 cm (8 in.) and 16.5 cm (6.5 in.), respectively (shown in Table B.5.11). These amounts are based strictly on achieving Class C concentrations.

Table B.5.16. Minimum Level of Grout Required to Reduce Concentrations to Class C Upper Limits for Tank S-112

Case	Residual Waste Volume (gal)	Minimum Level of Grout* (in.)
1, 2, 3, 6, 7, 8, 9, 10	2,700	5
4	6,000	11
5	27,000	19

*Cases 4 and 5 would require more than 8 and 6.5 in. of grout, respectively, to stabilize the waste in an adequate grout form.

To obtain liters multiply gallons by 3.785.
To obtain centimeters multiply inches by 2.54.

B.5.1.5 Tank S-112 Regulatory Compliance Assessment Results

This section describes the regulatory compliance assessment results for the analyses presented in Sections B.5.1.1 to B.5.1.4 for Cases 1 through 10. Each of the following items is evaluated against the regulatory standards:

- Short-term human health risk to the worker MEI and the general public MEI from radiological and hazardous constituents
- Groundwater protection
- Long-term human health risk to the residential farmer and industrial worker from radiological and hazardous constituents for the peak time periods over a 10,000-year period
- Risk to DOE and NRC inadvertent human intruder
- HFFACO milestones.

B.5.1.5.1 Tank S-112 Short-Term Human Health Risk Compliance. Short-term human health risk was evaluated based on operating the waste retrieval system to different endpoints in terms of residual waste volumes. Short-term human health risk is affected by variance in the duration of the waste retrieval operations; that is, the more waste retrieved, the longer the duration for waste retrieval and the more exposure to workers and the public. If it is necessary to employ more than one retrieval technology, workers and the public will experience slightly more risk.

B.5.1.5.1.1 Routine Radiological Exposure During Retrieval Operations. The regulatory requirement for worker exposure based on annual whole body dose is 5.0 rem/yr (10 CFR 20; DOE Order 5480.11). Hanford Site Administrative Controls limit a worker's annual whole body dose to 0.5 rem/yr (HSRCM-1). Worker radiological dose during routine waste retrieval operations will be carefully monitored to ensure levels do not exceed recommended standards. The functional requirement or standard of practicality in this instance is to demonstrate with worker dose estimates that waste from tank S-112 can be retrieved with appropriate time, distance, and shielding provisions in a manner that maintains worker doses within acceptable limits. The general public radiological dose from normal operations does not exceed the regulatory requirement standard of 100 mrem/yr in any of the waste retrieval cases based on the assumptions and data in this report. Based on the results, no LCFs are reported for the general public or offsite receptor.

B.5.1.5.1.2 Routine Chemical Exposure During Retrieval Operations. Short-term chemical health impacts from normal operations would be below the regulatory standard for noncarcinogenics in all waste retrieval cases, based on available data and assumptions documented in this report. For carcinogenic risks from exposure, the ILCR for the noninvolved worker and public would be below the regulatory standard of 1.0×10^{-6}. The involved worker ILCR would be below the Washington State standard of 1.0×10^{-5} for multiple constituents (WAC 173-340) and below the federal standard of 1.0×10^{-4} (55 FR 8666).

B.5.1.5.2 Tank S-112 Groundwater Protection Compliance. Groundwater quality requirements include compliance with EPA maximum contaminant levels (MCLs) (40 CFR 141), the DOE derived concentration guide (DOE Order 5400.5), and concentration limits under WAC 173-303-645. The most restrictive of these groundwater quality requirements is the EPA MCLs.

Three CoCs were evaluated for compliance with regulatory requirements. The CoC with the highest predicted concentration level for the radionuclides in the groundwater is technetium-99. Technetium-99 is used as an indicator because of its mobility in the environment (distribution coefficient of 0) and its long half-life. Uranium-238 is also of interest because of its moderate mobility in the environment (distribution coefficient of 0.6) and its long half-life. The third contaminant evaluated is nitrate, a chemical of concern for potential groundwater impact.

Results of groundwater protection compliance evaluation are presented first for groundwater impacts associated with retrieval, then for impacts associated with residual waste, third for impacts for tank S-112 composite source term, and finally for the cross-section of tanks S-110, S-111, and S-112.

B.5.1.5.2.1 Retrieval. As described in Section B.5.1.2.1.1, technetium-99 exceeds the EPA regulatory MCL (900 pCi/L) in all retrieval loss scenarios considered. Uranium-238 does not exceed the EPA regulatory MCL (6.7 pCi/L) in any scenario. Nitrate exceeds drinking water standards (DWSs) (45 mg/L) in the 150,000 L (40,000 gal) and 300,000 L (80,000 gal) retrieval loss scenarios.

B.5.1.5.2.2 Residual. As described in Section B.5.1.2.1.2, technetium-99 exceeds the EPA regulatory MCL (900 pCi/L) in all residual waste scenarios considered. Uranium-238 does not exceed the EPA regulatory MCL (6.7 pCi/L) in any scenario. Nitrate exceeds DWSs (45 mg/L) only in the 102,000 L (27,000 gal) residual waste scenario.

B.5.1.5.2.3 Tank S-112 Composite Retrieval Loss and Residual Waste. As shown in Table B.5.4, technetium-99 exceeds the EPA regulatory MCL (900 pCi/L) in all cases except Cases 1 and 6. Uranium-238 exceeds the EPA regulatory MCL (6.7 pCi/L) only in Case 9. Nitrate exceeds DWSs (45 mg/L) in Cases 5, 8, and 9.

B.5.1.5.2.4 Cross-Section. As shown in Table B.5.5, in the cross-section for tank S-112 technetium-99 exceeds the EPA regulatory MCL (900 pCi/L) in all cases. Uranium-238 exceeds the EPA regulatory MCL (6.7 pCi/L) in all cases except Case 4. Nitrate exceeds DWSs (45 mg/L) in Cases 5, 8, and 9.

B.5.1.5.3 Tank S-112 Long-Term Human Health Risk Compliance. Long-term human health risk is evaluated based on maximum groundwater concentration and exposure scenarios as expressed in human health risk resulting from exposure to nine radiological contaminants (technetium-99; selenium-79; iodine-129; carbon-14; and uranium-233, -234, -235, -236, and -238) and four chemical contaminants (total uranium, chromate, nitrate, and nitrite). These contaminants were chosen to evaluate long-term human health risk.

For carcinogenic risk the level of protection required under the regulations ranges from 1 in 10,000 (1.0×10^{-4}) to 1 in 1,000,000 (1.0×10^{-6}). Washington State requires the ILCR be no higher than 1.0×10^{-6} for individual contaminants and 1.0×10^{-5} for multiple contaminants (WAC 173-340), while the EPA requires the ILCR be no higher than 1.0×10^{-4} (55 FR 8666). For noncarcinogenic risk a hazard index equal to or greater than one exceeds state and federal standards.

Regulatory standards may be exceeded for long-term human health risk and not for DWSs (40 CFR 141; EPA/822-B-96-002) as a result of water being used for bathing, washing food, irrigation, as well as drinking for the residential farmer exposure scenario; the DWS only assumes consumption. For example, the DWS for technetium-99 is 900 pCi/L; exposure to groundwater concentrations at this level would result in an ILCR of 2.3×10^{-4} for a residential farmer.

Results of long-term human health risk protection compliance (ILCR and hazard index) evaluation are presented in both industrial worker and residential farmer scenarios first for long-term impacts associated with retrieval; then for impacts associated with residual waste; third for impacts for tank S-112 composite source term; and finally for the cross-section of tanks S-110, S-111, and S-112.

B.5.1.5.3.1 Retrieval. As shown in Table B.5.6, the ILCR risk exceeds the Washington State long-term human health cancer risk standard (1.0×10^{-5}) in all retrieval loss scenarios considered for both the industrial worker and the residential farmer. The hazard index standard of 1.0 is exceeded for the industrial worker in all except the 15,000 L (4,000 gal) and 30,000 L (8,000 gal) retrieval loss scenarios; it is exceeded in all of the scenarios for the residential farmer.

B.5.1.5.3.2 Residual. As shown in Table B.5.8, the ILCR risk exceeds the Washington State long-term human health cancer risk standard (1.0×10^{-5}) in all residual scenarios considered except the 10,200 L (2,700 gal) retrieval loss scenario for the industrial worker. The hazard index standard of 1.0 is not exceeded for the industrial worker for any of the residual scenarios; it is exceeded in all scenarios for the residential farmer.

B.5.1.5.3.3 Tank S-112 Composite Retrieval Loss and Residual Waste. As shown in Table B.5.11 of Section B.5.1.3.1.3, the ILCR risk exceeds the Washington State long-term human health cancer risk standard (1.0×10^{-5}) for composite source term for tank S-112 for the industrial worker in all cases except Cases 1 and 6; exceedance occurs in all cases for the residential farmer. The hazard index standard of 1.0 is exceeded for the industrial worker only in Cases 8 and 9; it is exceeded in all cases for the residential farmer.

B.5.1.5.3.4 Cross-Section. As shown in Table B.5.12 of Section B.5.1.3.2, the ILCR risk exceeds the Washington State long-term human health cancer risk standard (1.0×10^{-5}) for the cross-section analysis in all cases for both the industrial worker and the residential farmer. The hazard index standard of 1.0 is exceeded for the industrial worker only in Cases 8 and 9; it is exceeded in all cases for the residential farmer.

B.5.1.5.4 Tank S-112 Inadvertent Human Intrusion Compliance. DOE regulations limit exposures to an inadvertent human intruder to no greater than 100 mrem/yr for chronic exposure and 500 mrem for an acute or single event at a point in time 100 years after closure (DOE O 435.1). A post-driller resident scenario is used to provide the bounding analysis for chronic exposure; a well-driller scenario is used to provide the bounding analysis for acute exposure. Results of the analysis (Table B.5.14) indicate that tank S-112 would meet the 500 mrem dose limit under all waste retrieval cases and would meet the 100 mrem/yr chronic dose limit in all cases except Cases 4, 5, 8, and 9.

According to the results presented in Section B.5.1.4.2, the NRC Class C limits would be exceeded for all waste retrieval cases if no additional actions were implemented. However, in all cases those limits could be met with stabilization of the residual waste with grout, assuming credit for mixing of the grout and the residual waste. The technological feasibility of credit for mixing the required amount of grout with the residual waste is uncertain. Section B.6.0 addresses this uncertainty with respect to current NRC determinations at the DOE Savannah River Site.

B.5.1.5.5 Tank S-112 HFFACO Milestone Compliance. HFFACO Milestone M-45-03C states:

> Goals of this demonstration shall include the retrieval to safe storage of approximately 550 Curies of mobile long-lived radioisotopes and 99% of tank contents by volume (per DOE Best-Basis Inventory data, 8/01/2000).

The contaminants considered mobile and long-lived in this evaluation are technetium-99; iodine-129; selenium-79; carbon-14; and uranium-233, -234, -235, -236, and -238. Per the August 2000 BBI these radioisotopes contained a total of 554 curies. Using this inventory, all the waste retrieval cases except Case 5 meet the Milestone M-45-03C demonstration goal of retrieving approximately 550 curies of mobile, long-lived radioisotopes from tank S-112. That is, leaving a residual of 22,700 L (6,000 gal) or less will retrieve approximately 554 curies and will be in compliance with HFFACO Milestone M-45-03C.

With the revised baseline inventory used in risk analyses for this RPE, the contaminants of interest contain a total of 323 curies so it is impossible to meet the HFFACO milestone of removing 550 curies. However, leaving a residual of 22,700 L (6,000 gal) or less, all cases except Case 5 will retrieve 320 of the curies.

The second part of Milestone M-45-03C has the goal of retrieving 99% of tank contents by volume. Given the volume of waste in tank S-112, the retrieval of 99% of tank content is achieved by leaving a residual of 19,700 L (5,200 gal). The HFFACO Milestone M-45-00 interim retrieval goal of 360 ft^3 is 10,200 L (2,700 gal). The 9,500 L (2,500 gal) difference between 99% of volume and 360 ft^3 may be a matter for consideration and is discussed in Section B.6.0.

B.5.2 S TANK FARM ASSESSMENT RESULTS

Impact assessment results for the S tank farm are provided in the following sections. Impacts evaluated for the S tank farm include impacts to groundwater, long-term human health risk, and regulatory compliance.

B.5.2.1 S Tank Farm Groundwater Impact Assessment Results

The previous sections provide the results that are specific to tank S-112 or the cross-section containing tanks S-110, S-111, and S-112. It is also necessary to discuss the potential impacts from tank S-112 in the context of the potential release from all the tanks in S tank farm. This is accomplished by considering 'base case' retrieval loss and residual waste releases from the remaining tanks in combination with the past leak associated with tank S-104. These releases were simulated with 3 cross-sections:

- Cross-section S-101 with 3 tanks and residual and retrieval losses
- Cross-section S-104 with 3 tanks and 3 source terms (i.e., past leak from tank S-104, retrieval losses from all tanks, and residual losses from all tanks)
- Cross-section S-107 with 3 tanks and retrieval and residual losses from all tanks in the cross-section.

Selected retrieval loss and residual waste scenarios were then identified for the entire tank farm and the composite releases were developed with the principle of superposition as described in Section B.3.5. Then, using a simple stream tube analytical solution consistent with the approach used for the WMA S-SX FIR (RPP-7884) contaminant concentrations were calculated at two potential far-field compliance points:

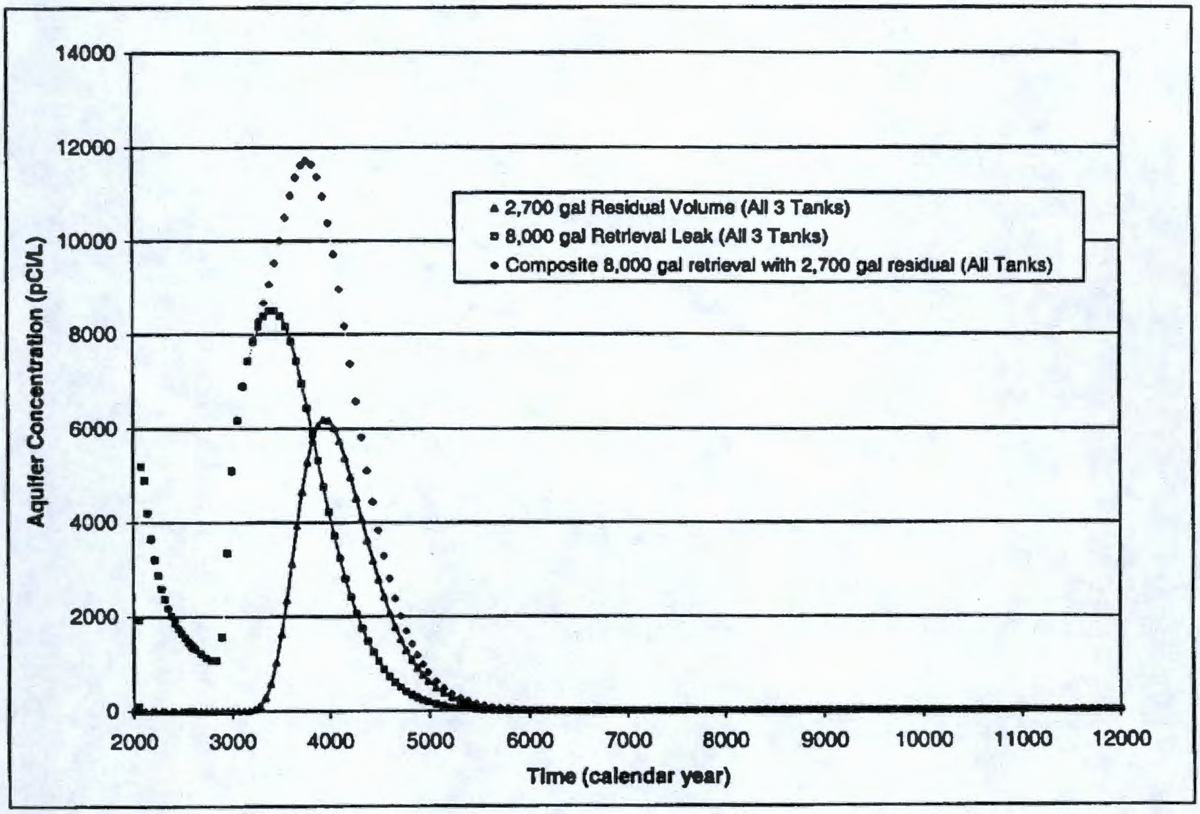
- 200 West fence, located about 1.8 km (1.12 mi) east of the S tank farm
- 200 Area exclusion boundary, located about 10.5 km (6.52 mi) east of the S tank farm.

The potential near-field groundwater impacts at the S tank farm boundary associated with releases from cross-sections S-101, S-104, and S-107 are presented in the following sections followed by a discussion of potential groundwater impacts associated with the composite releases from all 12 tanks in S tank farm.

B.5.2.1.1 Groundwater Impacts Associated with Retrieval Losses and Residual Waste from Cross-Section S-101. Potential groundwater impact results associated with the 'base case' retrieval scenario of 30,000 L (8,000 gal) from each of the 3 tanks and the 'base case' residual waste volume of 10,200 L (2,700 gal) in each of the three tanks in cross-section S-101 are presented in this section. The potential groundwater impacts resulting from these two source terms are shown as technetium-99 concentration versus time plots in Figure B.5.19.
The approximate near-field peak technetium-99 groundwater concentrations for the individual source terms and the year in which the peak would occur are as follows:

- Retrieval: year 2078 and 7,060 pCi/L
- Residual: year 4045 and 640 pCi/L.

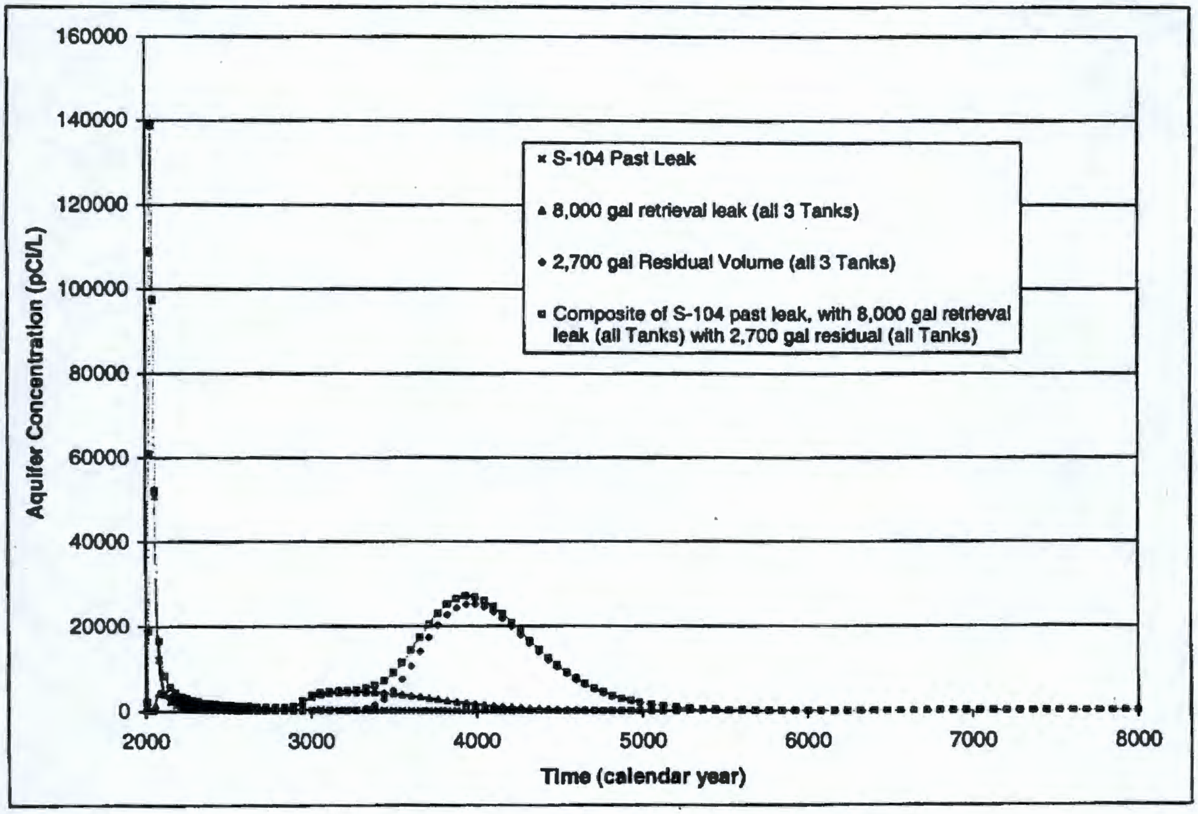
Figure B.5.19. Technetium-99 Groundwater Concentrations at the S Tank Farm Fenceline versus Time for 8,000 gal Retrieval Loss (All Tanks) and 2,700 gal Residual (All Tanks) for Cross-Section S-101



B.5.2.1.2 Groundwater Impacts Associated with Past Leaks, Retrieval Losses, and Residual Waste from Cross-Section S-104. Potential groundwater impact results associated with the past leak from S-104, the 'base case' retrieval scenario of 30,000 L (8,000 gal) from each of the 3 tanks, and the 'base case' residual volume of 10,200 L (2,700 gal) in each of the 3 tanks are presented in this section. The potential groundwater impacts resulting from these three source terms are shown as technetium-99 concentration versus time plots in Figure B.5.20. The approximate near-field peak technetium-99 concentrations at the S tank farm boundary for the individual source terms and the year in which the peak would occur are as follows:

- Past leak: year 2032 and 140,000 pCi/L
- Retrieval: year 3300 and peak of 4,600 pCi/L
- Residual: year 4000 and 25,000 pCi/L

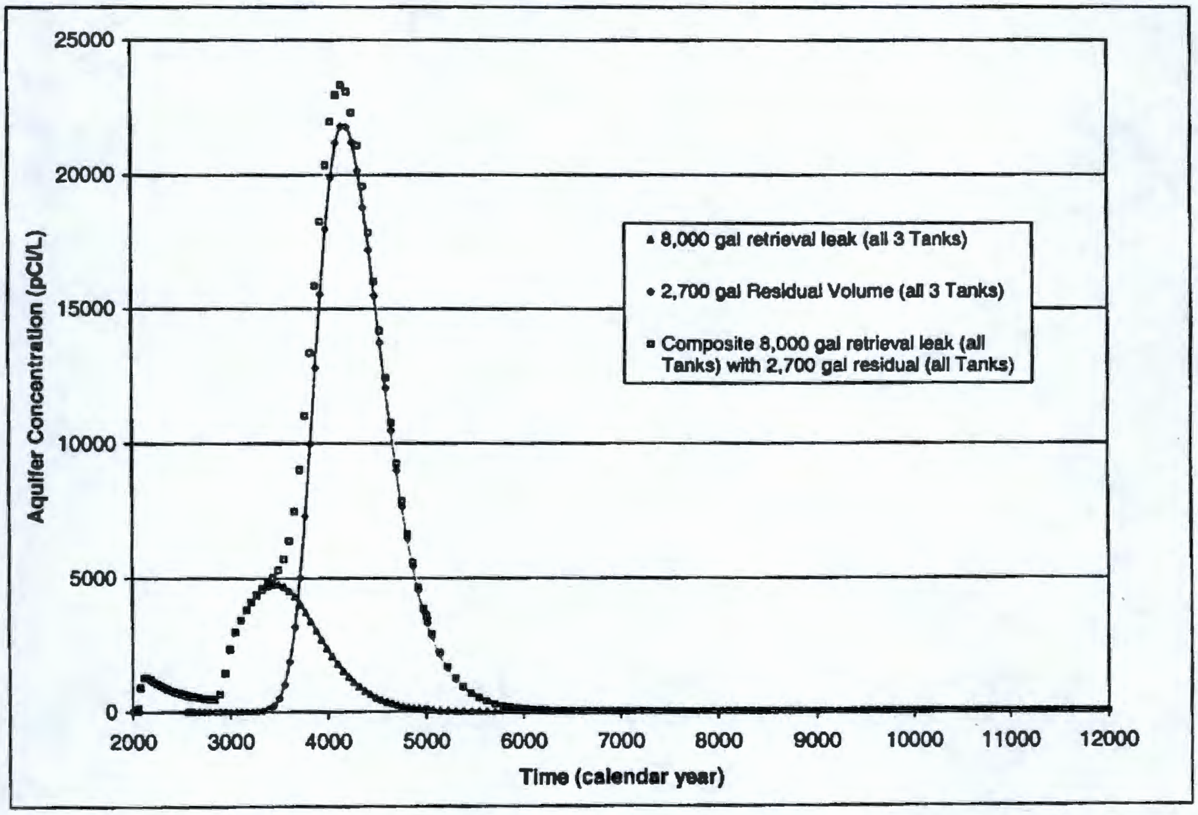
Figure B.5.20. Technetium-99 Groundwater Concentrations at the S Tank Farm Fence Line versus Time for Past Leak, 8,000 gal Retrieval Loss (All Tanks) and 2,700 gal Residual (All Tanks) for Cross-Section S-104



B.5.2.1.3 Groundwater Impacts Associated with Retrieval Losses and Residual Waste from Cross-Section S-107. Potential groundwater impact results associated with the 'base case' retrieval scenario of 30,000 L (8,000 gal) from each of the 3 tanks and the 'base case' residual waste volume of 10,200 L (2,700 gal) in each of the 3 tanks in cross-section S-107 are presented in this section. The potential groundwater impacts resulting from these 2 source terms are shown as technetium-99 concentration versus time plots in Figure B.5.21. The approximate near-field peak technetium-99 groundwater concentrations for the individual source terms and the year in which the peak would occur are as follows:

- Retrieval: year 3450 and peak of 4,800 pCi/L
- Residual: year 4200 and 21,900 pCi/L.

Figure B.5.21. Technetium-99 Groundwater Concentrations at the S Tank Farm Fenceline versus Time for 8,000 gal Retrieval Loss (All Tanks) and 2,700 gal Residual (All Tanks) for Cross-Section S-107



B.5.2.1.4 Composite Tank Farm Groundwater Impacts. The far-field composite groundwater impact results associated the entire tank farm (i.e., releases from 12 tanks in S tank farm) are provided in this section. Four combinations of source terms have been assumed from which the potential far-field groundwater impacts for techetium-99 and uranium-238 are described. These two contaminants were selected based on their range of mobility in the Hanford subsurface. Technetium-99 is mobile and would move with groundwater. The mobility of uranium-238 is somewhat less than that of technetium-99 but much more mobile than contaminants such as cesium-137. The impacts of the past leak from tank S-104 are included in each of the tank farm cases. Two potential far-field compliance points are considered:

- Eastern fenceline of the 200 West Area
- Eastern side of the 200 Area exclusion boundary.

The three source term combinations that are considered are described in Table B.5.17.

Table B.5.17. Source Terms Assumed for the Far-Field Composite S Tank Farm Groundwater Impact Calculations

Case	Description of Assumed Source Terms
1	Past leak from tank S-104 with 2,700 gal residual volume in all 12 tanks and 8,000 gal retrieval leak from all 12 tanks.
2	Past leak from tank S-104 with 2,700 gal residual volume in all 12 tanks plus a 40,000 gal retrieval leak from tank S-112. There would be no other retrieval leaks from the other 11 tanks.
3	Past leak from tank S-104 with 2,700 gal residual volume in all 12 tanks. There would be no retrieval leaks from any of the 12 tanks.

Figures B.5.22 and B.5.23 illustrate the groundwater concentration versus time for technetium-99 and uranium-238, respectively, at the two potential compliance points for Case 1 which, involves the past leak from tanks S-104; a 30,000 L (8,000 gal) retrieval loss from all 12 tanks; and a 10,200 L (2,700 gal) residual waste volume in all 12 tanks. The peak technetium-99 groundwater concentrations and associated time at the peak would be about 7,950 pCi/L in the year 2200 and 1,720 pCi/L in the year 2350 at the 200 West fence and the 200 Area exclusion boundary, respectively. Uranium-238 would still be increasing in the year 12000.
The uranium-238 groundwater concentration at the 200 West fence would be about 1.6 pCi/L. At the 200 Area exclusion boundary, uranium-238 groundwater concentrations would have dropped to about 0.36 pCi/L, approximately a 4.4-fold reduction.

Figure B.5.22. Technetium-99 Concentrations at Selected Compliance Points for Whole Farm Past Leak from Tank S-104 with 2,700 gal Residual Volume in All 12 Tanks and 8,000 gal Retrieval Leak from All 12 Tanks

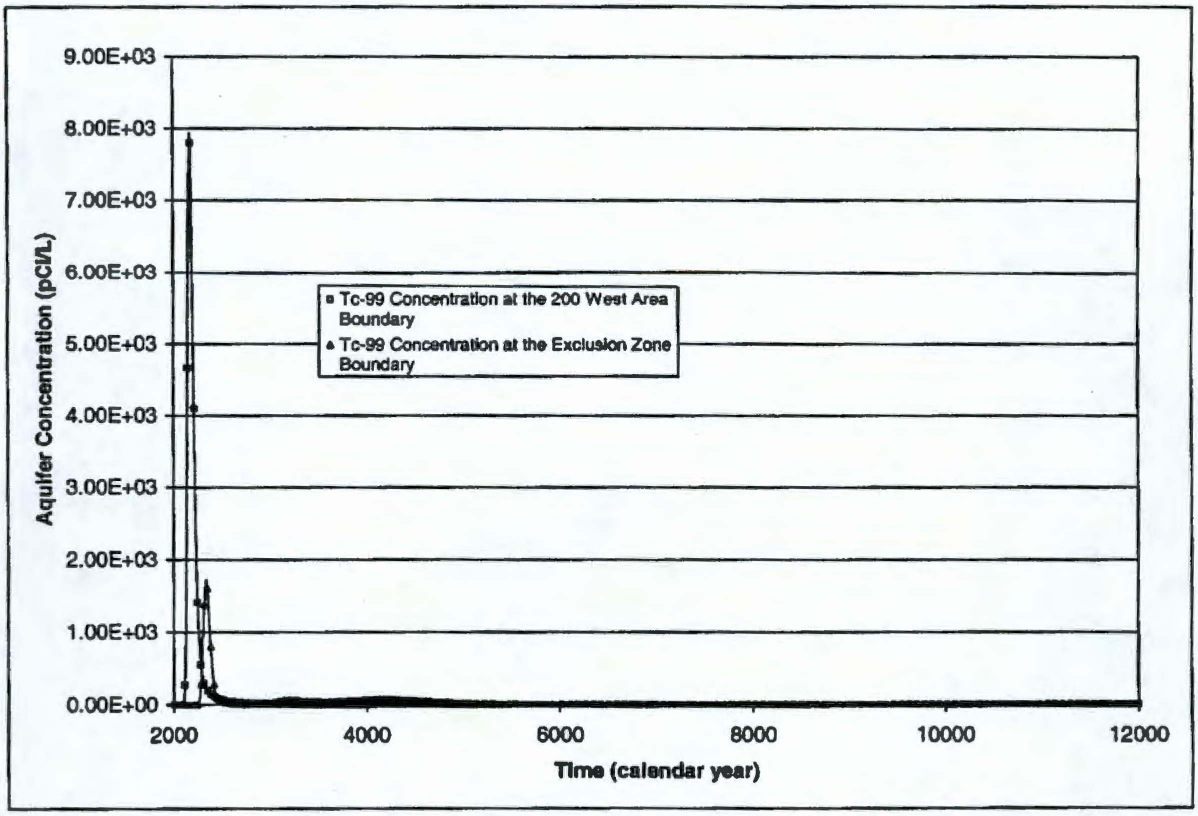
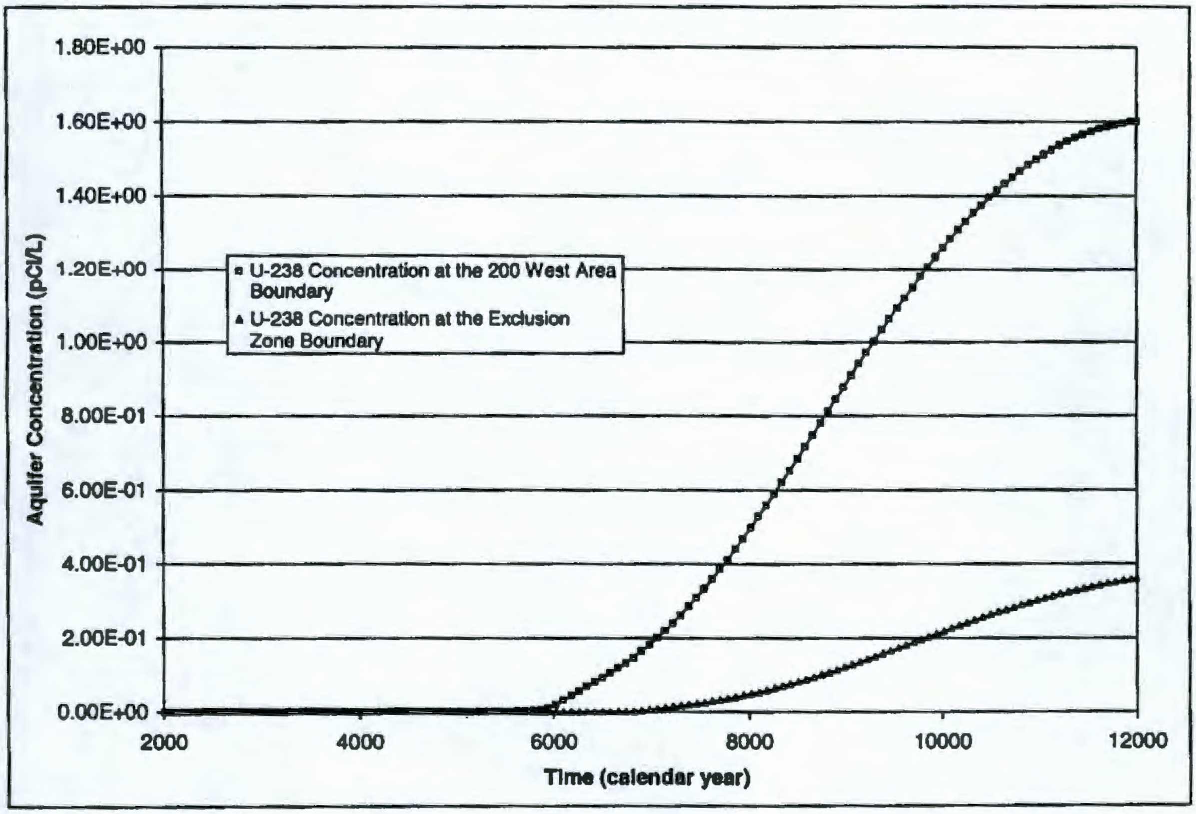


Figure B.5.23. Uranium-238 Concentrations at Selected Compliance Points for Whole Farm Past Leak from Tank S-104 with 2,700 gal Residual Volume in All 12 Tanks and 8,000 gal Retrieval Leak from All 12 Tanks



Figures B.5.24 and B.5.25 illustrate the groundwater concentration versus time for technetium-99 and uranium-238, respectively, at the two potential compliance points for Case 2 (i.e., consists of past leak from tank S-104; 10,200 L [2,700 gal] residual in all 12 tanks; plus a single 150,000 L [40,000 gal] retrieval loss from tank S-112 and no other losses). The year the peak technetium-99 concentration occurs and the concentration at the peak would be the same of from Cases 1 and 2 because of the overwhelming impacts associated the past leak source term. The uranium-238 concentrations at the year 12000 remain as they are calculated for Case 1.

Figure B.5.24. Technetium-99 Concentrations at Selected Compliance Points for Whole Farm Past Leak from Tank S-104 with 2,700 gal Residual Volume in All 12 Tanks Plus a 40,000 gal Retrieval Leak from Tank S-112

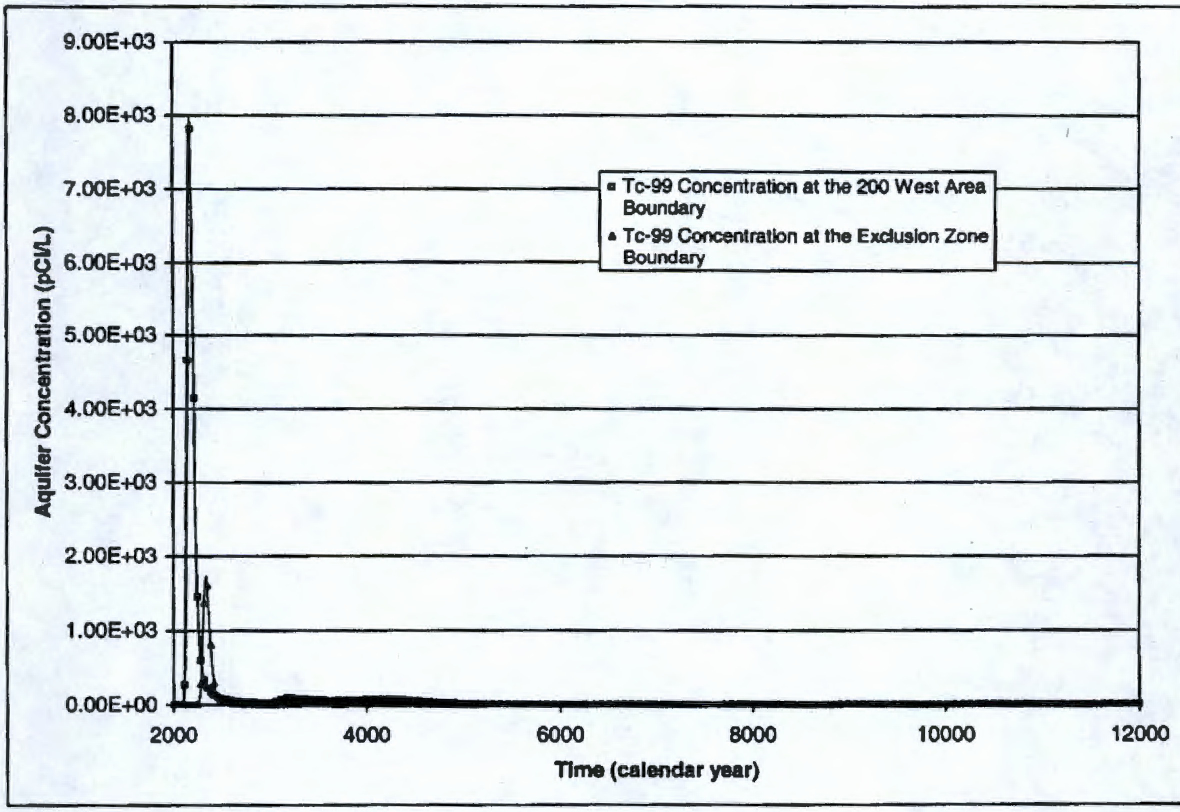
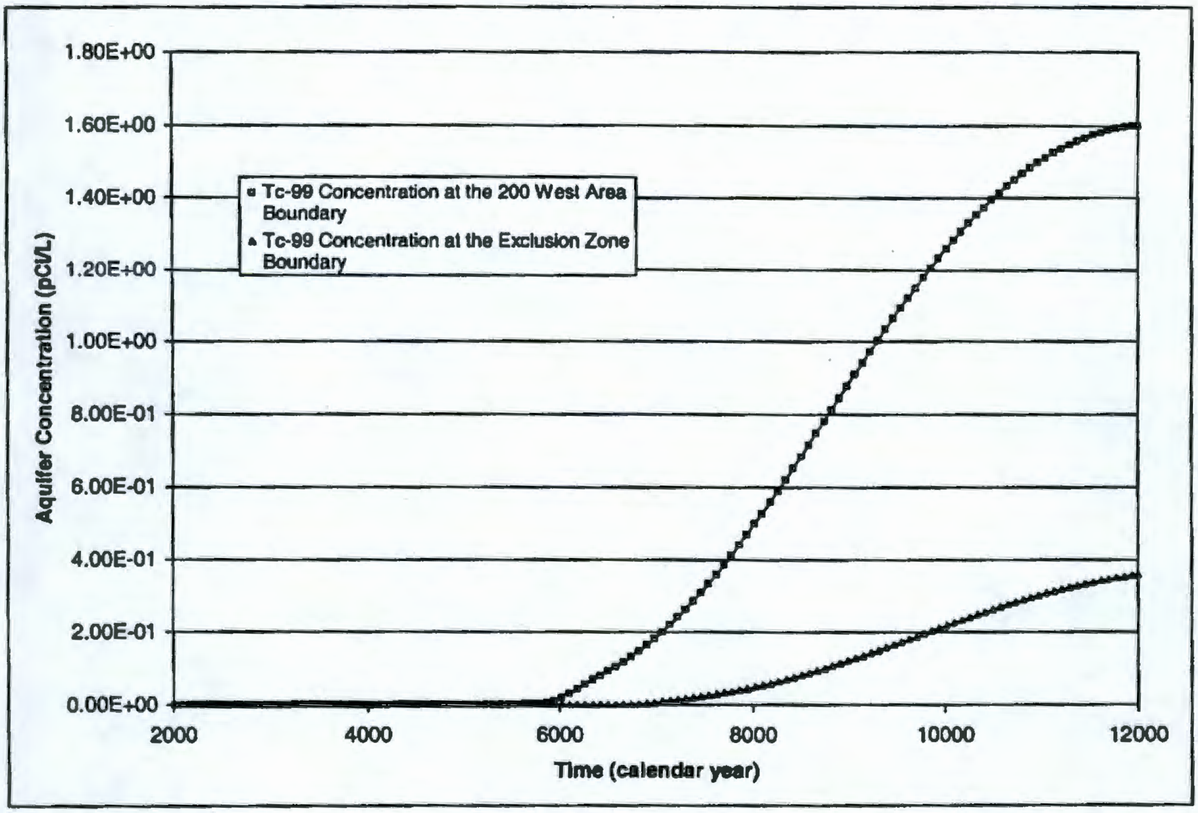


Figure B.5.25. Uranium-238 Concentrations at Selected Compliance Points for Whole Farm Past Leak from Tank S-104 with 2,700 gal Residual Volume in All 12 Tanks Plus a 40,000 gal Retrieval Leak from Tank S-112



The results of Case 3 are illustrated in Figures B.5.26 and B.5.27. Case 3 includes the past leak from tank S-104 and a 10,200 L (2,700 gal) residual volume in each of the 12 tanks. There would be no other losses. The time of peak concentration and concentration at the peak would be as with the other 3 cases, except at the 200 Area exclusion boundary where the peak technetium-99 concentration would be about 1,600 pCi/L in the year 2350. The uranium-238 concentrations at the year 12000 remain as they were calculated for Cases 1 and 2.

Figure B.5.26. Technetium-99 Concentrations at Selected Compliance Points for Whole Farm Past Leak from Tank S-104 with 2,700 gal Residual Volume in All 12 Tanks

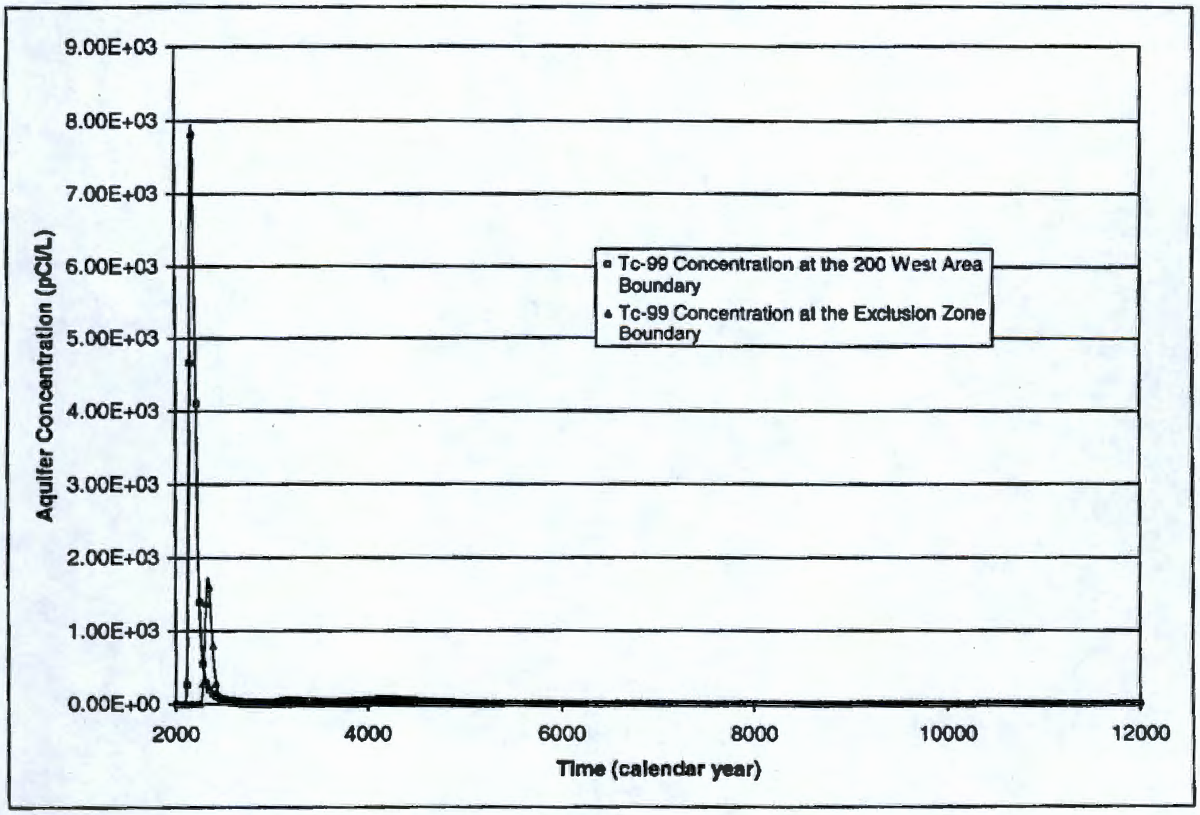
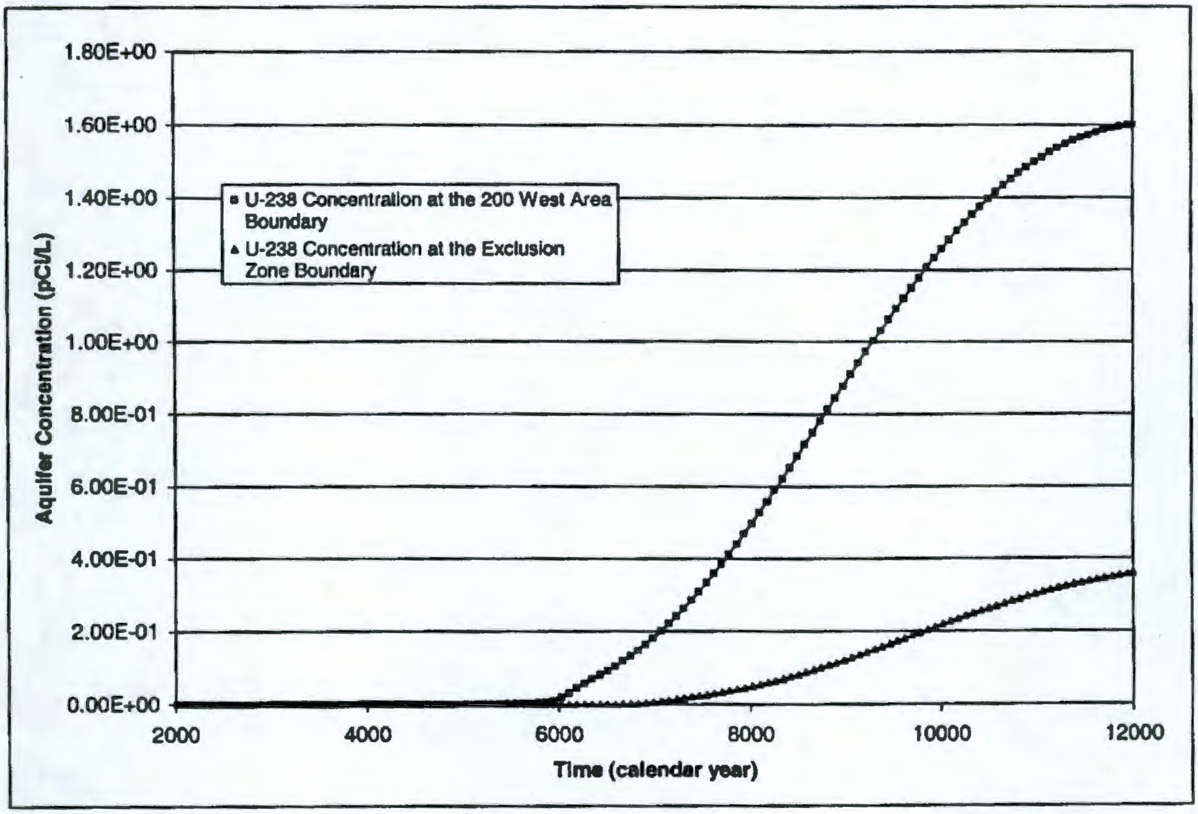


Figure B.5.27. Uranium-238 Concentrations at Selected Compliance Points for Whole Farm Past Leak from Tank S-104 with 2,700 gal Residual Volume in All 12 Tanks



The results of the far-field composite groundwater impacts discussed about indicate that the past leak component dominates all other impacts and makes it difficult to assess impact changes associated with the other source terms (i.e., the retrieval loss and residual waste). The same cases as described in Table B.5.17 were recompiled without the past leak source term component to observe the effects of variations in retrieval loss and residual waste in the far-field. Figures B.5.28 and B.5.29 illustrate the groundwater concentration versus time for technetium-99 and uranium-238, respectively, at the two potential compliance points for Case 1, without the past leak source term. There is still a bimodal response for technetium-99 but the early peak now occurs at a lower concentration than the late peak without the past leak source term.

The contaminant concentration in groundwater is reduced as a function of distance from the source (i.e., the S tank farm). The peak technetium-99 concentrations are reduced between the 200 West boundary and the exclusion zone boundary by about a factor of 4.5 and 4.2 for the early and late peaks, respectively. The peak technetium-99 groundwater concentrations and time when they would occur for the 3 cases without the past leak source term are summarized in Table B.5.18. Without the past leak contribution, the uranium-238 groundwater concentration at the year 12000 would be about 7.7×10^{-3} pCi/L at the 200 West fence and 5.7×10^{-4} at the 200 Area exclusion boundary (see Figure B.5.29).

Figure B.5.28. Technetium-99 Concentrations at Selected Compliance Points for Whole Farm 2,700 gal Residual Volume in All 12 Tanks and 8,000 gal Retrieval Leak from All 12 Tanks (Without Past Leak)

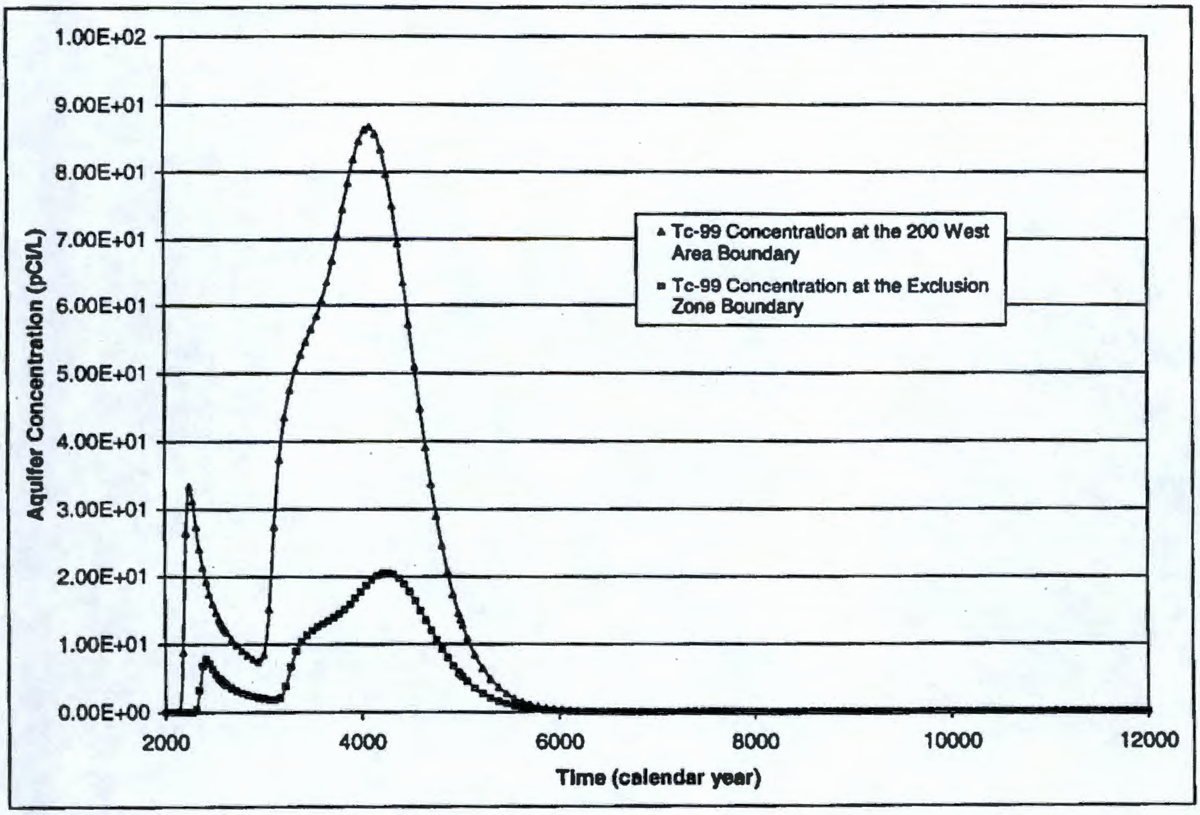


Figure B.5.29. Uranium-238 Concentrations at Selected Compliance Points for Whole Farm 2,700 gal Residual Volume in All 12 Tanks and 8,000 gal Retrieval Leak from All 12 Tanks (Without Past Leak)

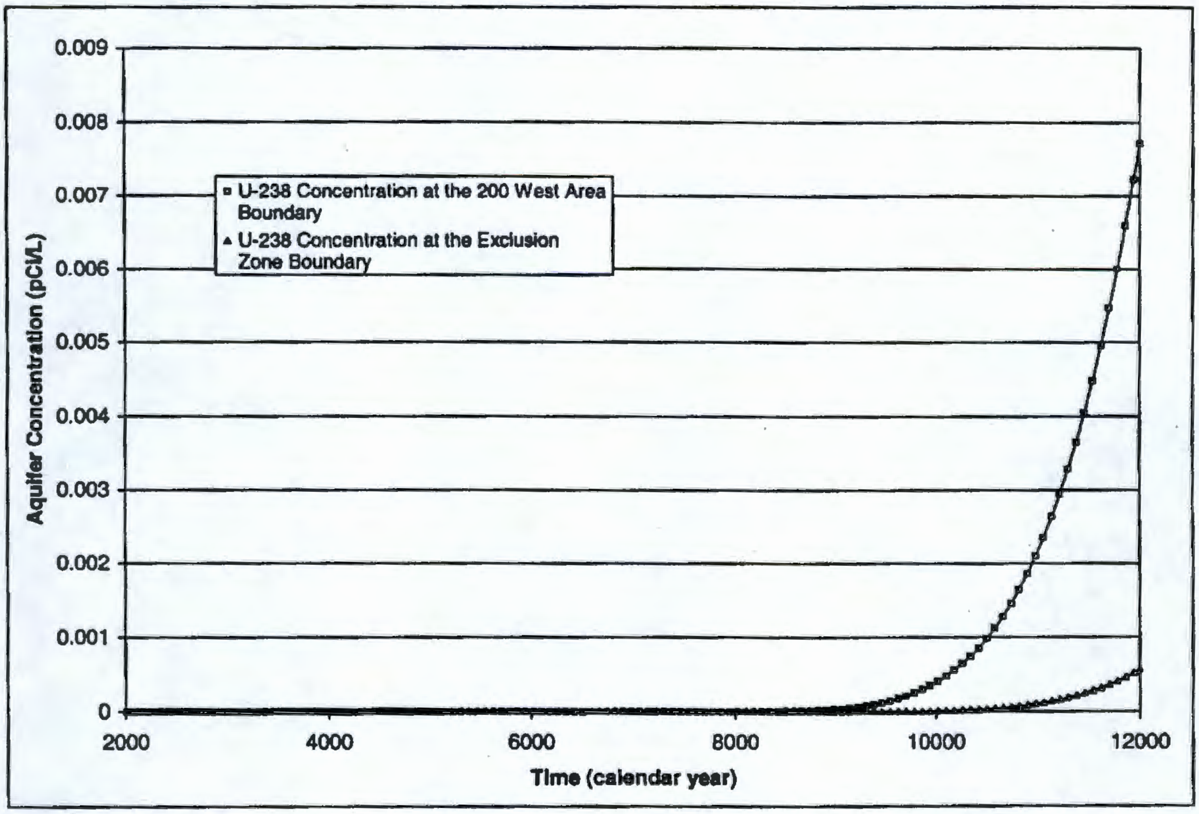


Table B.5.18. Summary of Peak Technetium-99 Concentrations and Time When Peak Would Occur for the Potential Compliance Points for Four Whole Farm Cases Without the Past Leak Source Term

Case	200 West Boundary		Exclusion Zone Boundary	
	Year in which Peak Concentration Occurs	Tc-99 Concentration at Peak (pCi/L)	Time to Peak (Year)	Tc-99 Concentration at Peak (pCi/L)
1	4100	87	4275	21
2	4180	68	4350	16
3	4210	63	4380	15

Figures B.5.30 and B.5.31 illustrate the groundwater concentration versus time for technetium-99 and uranium-238, respectively, at the 2 potential compliance points for Case 2 without the past leak source term (i.e., consists of 10,200 L [2,700 gal] residual in all 12 tanks plus a single 150,000 L [40,000 gal] retrieval loss from tank S-112 and no other losses). The time to peak technetium-99 concentration is about the same as for Case 1. The peak technetium-99 concentrations for Case 2 are both reduced by about 22 and 24% at the 200 West fence and the 200 Area exclusion boundary, respectively (see Table B.5.18) compared to Case 1. The uranium-238 groundwater concentration at the year 12000 would be about 7.8×10^{-3} pCi/L at the 200 West fence and 5.8×10^{-4} at the 200 Area exclusion boundary (see Figure B.5.31).

Figure B.5.30. Technetium-99 Concentrations at Selected Compliance Points for Whole Farm 2,700 gal Residual Volume in All 12 Tanks Plus a 40,000 gal Retrieval Leak from Tank S-112 (Without Past Leak)

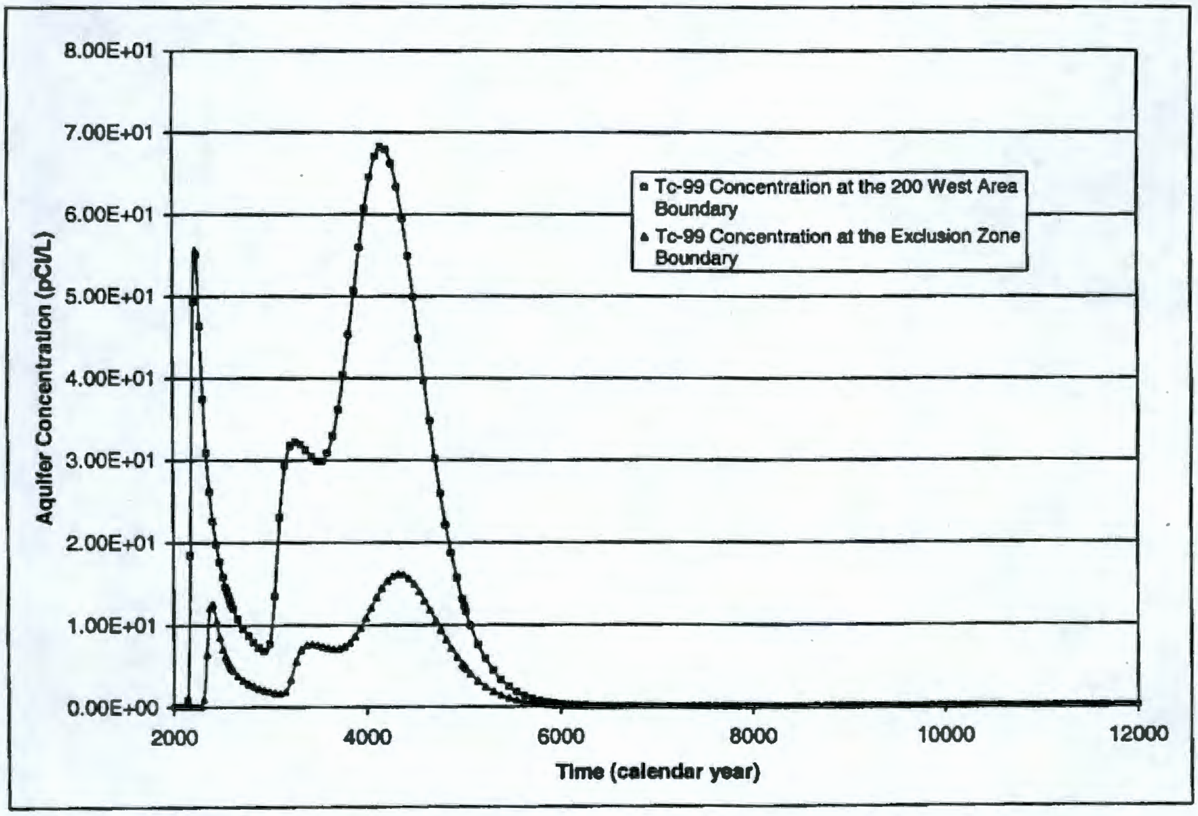
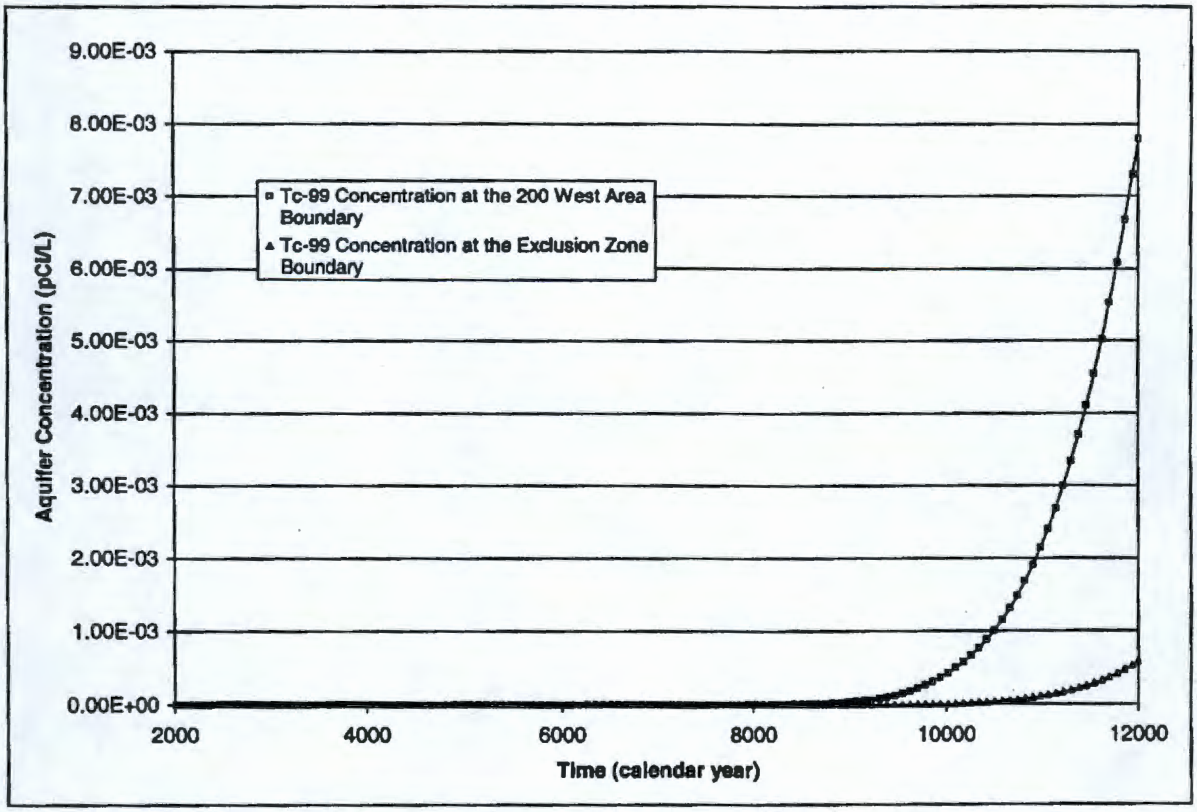


Figure B.5.31. Uranium-238 Concentrations at Selected Compliance Points for Whole Farm 2,700 gal Residual Volume in All 12 Tanks Plus a 40,000 gal Retrieval Leak from Tank S-112 (Without Past Leak)



The results of Case 3 without the past leak source term are illustrated in Figures B.5.32 and B.5.33. Case 3 includes a 10,200 L (2,700 gal) residual volume in each of the 12 tanks. There would be no other losses. There is only one peak in the traces for this case and it occurs at about the year 4210 at the 200 West fence and the year 4380 at the 200 Area exclusion boundary (see Table B.5.18). The peak technetium-99 concentrations for Case 3 are reduced by about 27 and 29% at the 200 West fence and the 200 Area exclusion boundary, respectively (see Table B.5.18) compared to Case 1. The uranium-238 groundwater concentration at the year 12000 would be about 6×10^{-3} pCi/L at the 200 West fence and 4×10^{-4} at the 200 Area exclusion boundary (see Figure B.5.33).

Figure B.5.32. Technetium-99 Concentrations at Selected Compliance Points for Whole Farm 2,700 gal Residual Volume in All 12 Tanks (Without Past Leak)

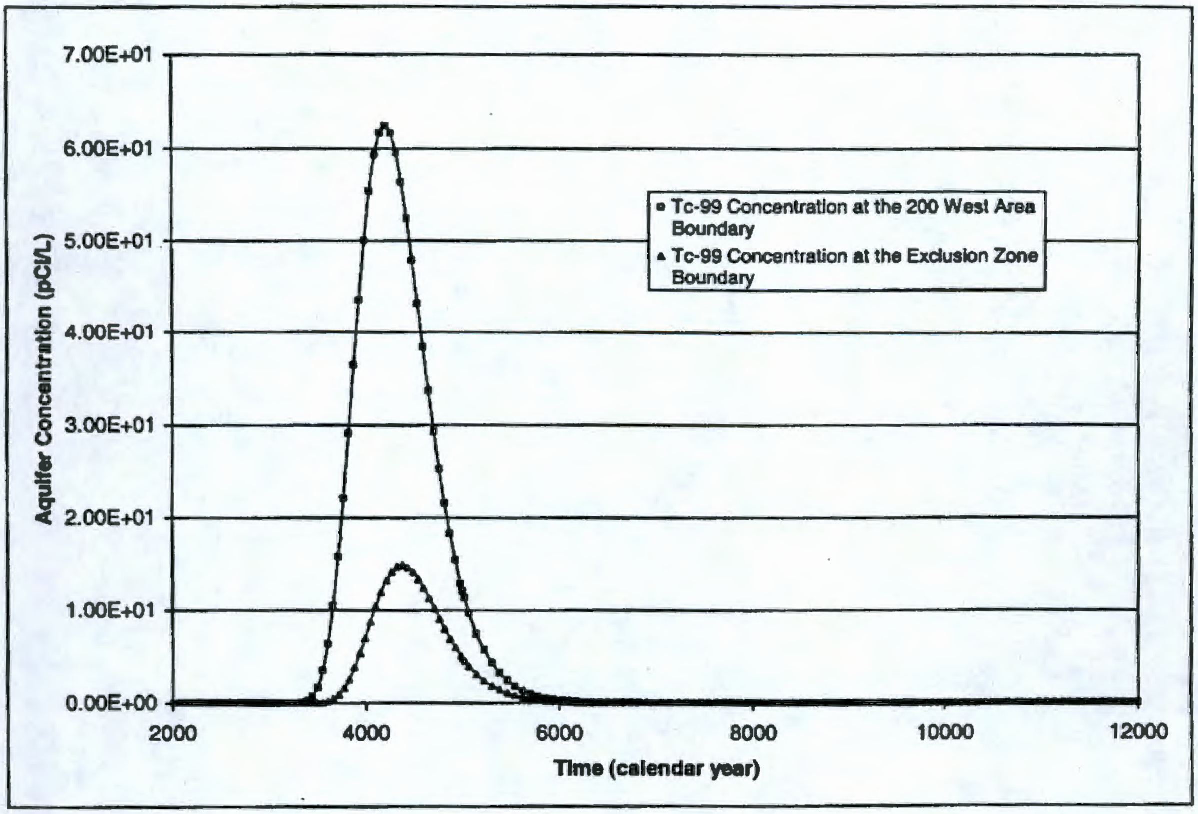
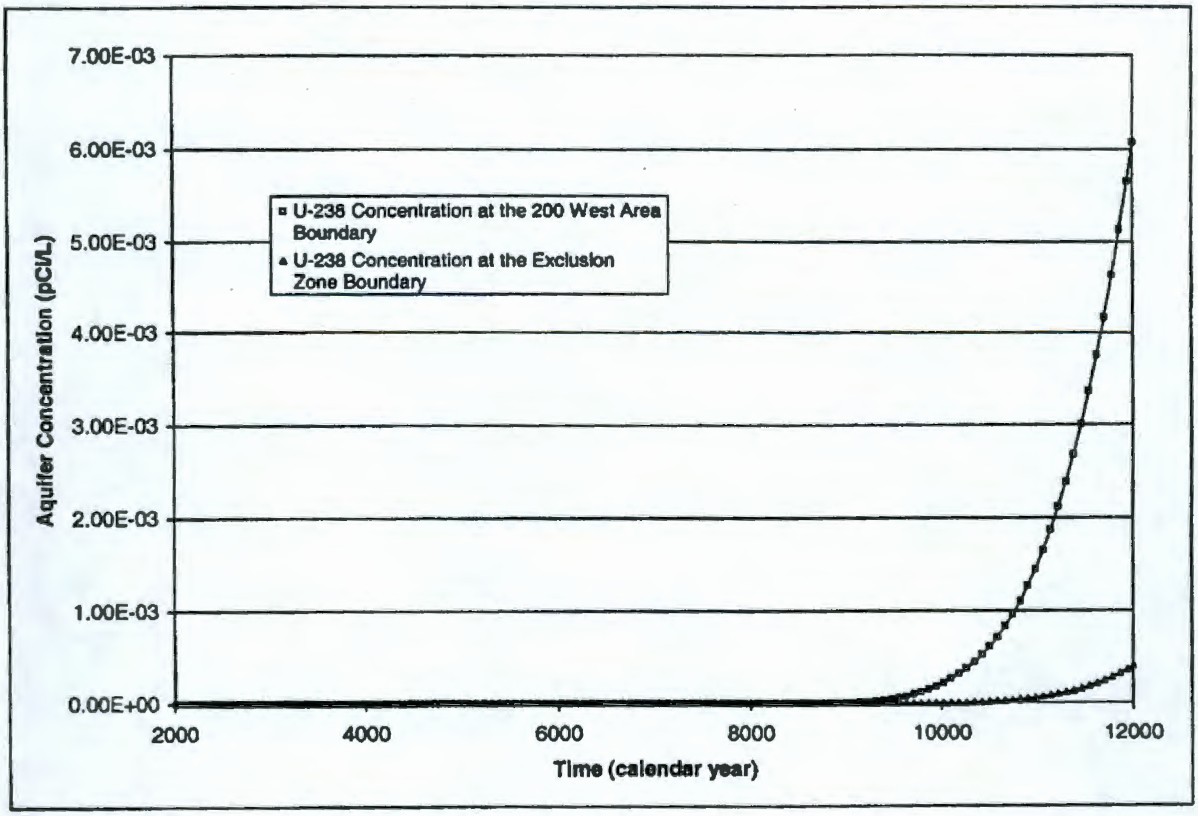


Figure B.5.33. Uranium-238 Concentrations at Selected Compliance Points for Whole Farm 2,700 gal Residual Volume in All 12 Tanks (Without Past Leak)



B.5.2.2 S Tank Farm Long-Term Human Health Risk Assessment Results

Results of the long-term human health risk assessment for the S tank farm as a whole are provided in this section based on predicted contaminant concentrations in groundwater at the east fenceline of the 200 West Area and the east side of the 200 Area exclusion boundary (Section B.5.2.1). Results are summarized in Table B.5.19, which shows the peak composite source term impacts for the 3 whole-farm waste retrieval cases evaluated. Note that these 3 cases involve contributions from retrieval leakage and residual waste only and do not include the contribution from the tank S-104 past leak. The assessment results revealed that the tank S-104 past leak drives the peak impacts for all 3 cases, rendering them indistinguishable. To illustrate the effects of variation in the primary system components (i.e., retrieval leakage and residual waste), the tank S-104 past leak contribution has been removed from the results shown in Table B.5.19.

Table B.5.19. Peak Incremental Lifetime Cancer Risk and Hazard Index for S Tank Farm as a Whole

Case	S Tank Farm Source Term		200 West Fence		200 Area Exclusion Boundary	
			Residential Farmer	Industrial Worker	Residential Farmer	Industrial Worker
1	2,700 gal residual waste and 8,000 gal retrieval leak for all tanks	ILCR	3.17E-05	8.49E-07	7.51E-06	2.01E-07
		HI	1.70E+00	5.70E-03	4.04E-01	1.35E-03
2	2,700 gal residual waste in all tanks and 40,000 gal retrieval leak from tank S-112 (no leak from other tanks)	ILCR	2.49E-05	6.68E-07	5.89E-06	1.58E-07
		HI	8.73E-01	2.93E-03	2.01E-01	6.72E-04
3	2,700 gal residual waste in all tanks	ILCR	2.28E-05	6.11E-07	5.38E-06	1.45E-07
		HI	6.85E-01	2.29E-03	1.62E-01	5.44E-04

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

Results for Case 3 illustrate the farm-wide impacts of closing the tank farm with all tanks retrieved to the HFFACO interim retrieval goal of 10,200 L (2,700 gal) of residual waste and without incurring retrieval leakage from any of the tanks. Comparing results for Case 3 with Case 1 illustrates the incremental increase in farm-wide impacts from incurring a retrieval leak of 30,000 L (8,000 gal) from all tanks while retrieving all tanks to the HFFACO interim retrieval goal. The increase in impacts would be small, a factor of three increase at most.

Comparing results for Case 3 with Case 2 illustrates the incremental increase in farm-wide impacts from incurring a large retrieval leak (150,000 L [40,000 gal]) from tank S-112 (Case 2) while retrieving all tanks to the HFFACO interim retrieval goal. The increase in impacts would once again be small, a factor of two increase at most.

B.5.2.3 S Tank Farm Regulatory Compliance Assessment Results

This section describes the regulatory compliance assessment results for the analyses presented in Sections B.5.2.1 and B.5.2.2. Three specific analysis cases, which differ from the cases presented in Section B.3.2, are analyzed for the S tank farm as a whole. The three cases are evaluated with and without the contributions from past leaks associated with tank S-104. Two potential far-field compliance points are considered: the west side of the 200 West Area boundary which is the fenceline, and the west side of the 200 Area exclusion boundary.

It is not possible to evaluate short-term human health risk or inadvertent human intrusion risk for the tank farm system, so there are no regulatory compliance assessment results. The HFFACO milestone compliance is tank-specific and therefore not appropriately considered for the entire tank farm system.

B.5.2.3.1 S Tank Farm Short-Term Human Health Risk Compliance. Not applicable.

B.5.2.3.2 S Tank Farm Groundwater Protection Compliance. Groundwater quality requirements include compliance with EPA MCLs (40 CFR 141), the DOE derived concentration guide (DOE Order 5400.5), and concentration limits under WAC 173-303-645. The most restrictive of these groundwater quality requirements are the EPA MCLs.

Three CoCs were evaluated for compliance with regulatory requirements. The CoC with the highest predicted concentration level for the radionuclides in the groundwater is technetium-99. Technetium-99 is used as an indicator because of its mobility in the environment (distribution coefficient of 0) and its long half-life. Uranium-238 is also of interest because of its moderate mobility in the environment (distribution coefficient of 0.6) and its long half-life. The third contaminant evaluated is nitrate, a CoC for groundwater impacts.

As shown in Figure B.5.22, technetium-99 exceeds the EPA regulatory MCL (900 pCi/L) in all 3 cases at both points of compliance. Uranium-238 does not exceed the EPA regulatory MCL (6.7 pCi/L) in any case at either point of compliance. Nitrate does not exceed DWSs (45 mg/L) in any case at either point of compliance. When the past leak contributions are removed from the evaluation as shown in Table B.5.18 the technetium-99 concentrations are all well below the MCL (900 pCi/L) for all 3 cases at both points of compliance.

B.5.2.3.3 S Tank Farm Long-Term Human Health Risk Compliance. Long-term human health risk is evaluated based on maximum groundwater concentration and health effects (i.e., ILCR and hazard index) as expressed in human health risk resulting from exposure to 9 radiological contaminants (technetium-99; selenium-79; iodine-129; carbon-14; and uranium-233, -234, -235, -236, and -238) and four chemical contaminants (total uranium, chromate, nitrate, and nitrite). These contaminants were chosen to evaluate long-term human health risk.

As shown in Table B.5.19 of Section B.5.3.3, the ILCR exceeds the Washington State long-term human health cancer risk standard (1.0×10^{-5}) for composite source term for the S tank farm for the residential farmer located at the 200 West fence in all cases. The ILCR does not exceed 1×10^{-5} for the industrial worker under any case at either point of compliance. The hazard index standard of 1.0 is not exceeded for the industrial worker in any case at either point of compliance. The hazard index standard of 1.0 is exceeded for the residential farmer for Case 1.

B.5.2.3.4 S Tank Farm Inadvertent Human Intrusion Compliance. Not Applicable.

B.5.2.3.5 S Tank Farm HFFACO Milestone Compliance. Not Applicable.

B.6.0 CONCLUSIONS

This section provides the conclusions and observations relative to tank waste retrieval for tank S-112 based on the analysis results presented in Section B.5.0. Section B.6.1 provides a summary of the conclusions as they relate to near-term waste retrieval efforts. Section B.6.2 provides summaries of the conclusions specific to the different areas of analysis for tank S-112.

B.6.1 SUMMARY CONCLUSIONS

The summary conclusions in the following sections are RPE findings that would influence waste retrieval and LDMM system criteria for tank S-112. Risk-based threshold leakage volumes are dependent on the performance measure and the location where it will be measured (e.g., point of compliance). Threshold leakage volumes are essentially zero at the tank farm fenceline unless higher risk levels or alternative performance measures are considered. Consideration of the long-term rimpacts from S-112 retrieval leakge within the context of the S tank farm provide a means to establish risk-based threshold leakage volumes for S-112.

B.6.1.1 Tank S-112 Summary Conclusions

The goal of the technology demonstration in tank S-112 is to demonstrate the limits of technology for the waste retrieval system and application and demonstration of the LDMM system to waste retrieval. The HFFACO F&R document will identify the proposed methodology for demonstrating limits of the technologies. Because of the potential for leakage to occur during tank waste retrieval and the interrelationship between retrieval leakage and residual waste from a tank farm closure standpoint, it is important to understand how the variations in residual waste and retrieval leakage volumes influence the risk- and regulatory-based performance measures.

The final extent of tank waste retrieval is a tank farm closure issue; however, because one of the goals of the waste retrieval function is to enter a tank one time, the extent of waste retrieval should be considered in the F&R of the initial retrieval system. It is recognized that closure criteria have not been fully defined; however, the criteria as they are currently understood can be used to guide the development of initial waste retrieval criteria. This approach does not preclude the retrieval of additional waste from a tank in the future as additional information is gathered during and after waste retrieval activities in the remaining S farm tanks and as closure criteria are established.

Long-term risks from retrieval leak losses are a constraint for defining tank S-112 LDMM system criteria. The performance measures that influence F&Rs for defining retrieval leak loss limits and the extent of retrieval (i.e., how much waste needs to be retrieved) for tank S-112 are driven by the long-term risk to a future site user. The point-of-compliance assumed for the evaluation of tank specific impacts is the S tank farm fenceline. The long-term human health risk results indicate that impacts from tank S-112 retrieval leakage volumes, when considered by themselves, exceed an ILCR of 10^{-5} for the industrial worker scenario at the tank farm fenceline at volumes as low as 6,400 L (1,700 gal). The long-term human health risk results indicate that impacts from tank S-112 residual waste, when considered by themselves, are below an ILCR of 10^{-5} for the industrial worker for residual volumes below approximately 11,000 L (2,900 gal). When the residential farmer scenario is considered the long-term risks from a residual volume equal to 10,200 L (2,700 gal) from tank S-112 are above an ILCR of 10^{-5}, which means that under this scenario there would be no retrieval leakage allowance.

The influence of waste retrieval leakage to long-term human health risk is not unexpected at tank S-112. Tank S-112 is specifically targeted in the SST retrieval strategy as a sound salt cake tank with elevated levels of technetium-99 (RPP-7087). Tank S-112 has the eighth highest technetium-99 inventory in all of the SSTs.

A number of conservative assumptions are made in this assessment and are discussed further in Section B.6.4. This conservatism, in combination with consideration of alternative points of compliance and/or higher acceptable risk levels (e.g., 10^{-4} under EPA guidance), could provide a means for identifying an acceptable leakage envelope for moving forward with waste retrieval from tank S-112. An uncertainty and sensitivity analysis is currently being conducted to evaluate the range and distribution of estimated risks. The uncertainty analysis results will be incorporated into future revisions of this RPE.

For the waste retrieval leakage impacts, the time that the peak impacts are projected to occur for leak volumes greater than 30,000 L (8,000 gal) from tank S-112 is during the time when the tank farm would be under post-closure care and it is unlikely that the groundwater exposure pathway would be accessible for industrial or residential use at the tank farm fenceline. At points of compliance beyond the tank farm fenceline those concentrations would be attenuated.

For tank S-112 the inadvertent human intruder analysis results indicate that a residual waste volume of approximately 18,000 L (4,700 gal) or less with no waste retrieval leakage would be required to meet the post-drilling resident DOE inadvertent intruder performance criteria of 100 mrem/yr. Therefore, for defining risk-based residual waste volumes, the inadvertent human intrusion performance measure is not as restrictive as the long-term human health risk industrial worker scenario.

As noted in Section B.4.0 the salt cake dissolution retrieval technology is for retrieving soluble components from the waste and is not capable of retrieving insoluble sludge. The current volume estimate of sludge in tank S-112 is approximately 23,000 L (6,000 gal). If, following deployment of the salt cake dissolution, retrieval technology it was determined that additional waste retrieval were required, a second waste retrieval technology would be required.

B.6.1.2 S Tank Farm Summary Conclusions

The potential groundwater impacts and long-term human health risks for the S tank farm were evaluated in Section B.5.0 with and without the contribution from past leaks. The results of this analysis indicate that the contribution from past leaks dominate the impacts from the retrieval leak and residual source terms. On a tank farm level the impacts associated with retrieval to the HFFACO interim retrieval goal with no retrieval leakage from any of the S farm tanks results in risk levels that are above 10^{-5} at the 200 West fence for the residential farmer but are below 10^{-5} for the industrial worker. When the long-term human health risks are evaluated at the 200 Area exclusion boundary the risks estimated for retrieval to the HFFACO interim retrieval goal with no retrieval leakage are below 10^{-5} for both the residential farmer and the industrial worker.

At the tank farm level the long-term human health risks are not sensitive to changes in the retrieval leakage volume. A 151,000 L (40,000 gal) leak from tank S-112 only increases the long-term human health risk by approximately 9% above the risk from the tank residuals.

Alternative performance measures could be used in the evaluation of retrieval leak loss criteria. If an approach similar to that taken for the remedial action objectives for the 200-UP-1 Operable Unit were used where 10 times DWSs were established as the performance objective the corresponding leak loss volume for tank S-112 would be considerably higher than the risk based number. As shown in Section B.5.2.1.4 the technetium-99 groundwater concentrations for a leak volume of 150,000 L (40,000 gal) would not exceed 9,000 pCi/L (10 times DWS) for technetium-99 at the 200 West fenceline or at the 200 Area exclusion boundary.

B.6.2 TANK S-112 CONCLUSIONS BY AREA OF ANALYSIS

Conclusions specific to the areas of short-term human health risk, groundwater impacts, long-term human health risk, intruder risk, and regulatory compliance specific to tank S-112 are provided in the following sections.

B.6.2.1 Tank S-112 Short-Term Human Health Risk Conclusions

This section provides the conclusions reached in the tank S-112 short-term human health risk analysis for occupational risk, routine radiological risk, routine chemical risk, radiological accident risk, and chemical accident risk. Only the human health risk associated with salt cake retrieval operations, the installation and operation of a crawler system to retrieve sludge after salt cake retrieval, and the construction of an interim barrier are calculated for comparison.
The results of the analysis indicate that, overall, short-term human health risk is not a driver for establishing tank S-112 waste retrieval and LDMM system criteria. The differences are not significant in light of the inherent uncertainties in the analysis and assumptions. The analysis results are presented in Section B.5.1.1.

B.6.2.1.1 Occupational Accident Conclusions. A comparison of the occupational risks (i.e., TRCs, LWCs, and fatalities) associated with the waste retrieval cases results in the following conclusions.

- None of the cases result in a lost work day or fatality. Therefore, the analysis results indicate that this performance measure is not a driver for establishing waste retrieval and LDMM system criteria for tank S-112.

- As less sludge is retrieved from tank S-112 in comparison to the cases with 10,000 L (2,700 gal) residual waste (Cases 1, 2, 3, 6, 7, 8, 9) the occupational risk from retrieval operations is reduced by 7% for Case 4 and 10% for Case 5.

- Adding the occupational risk from constructing an interim barrier for Case 10 increases the TRC, LWC, and fatality incidences by 10% as compared to the cases that assume 10,000 L (2,700 gal) residual waste without an interim barrier (Cases 1, 2, 3, 6, 7, 8, 9).

B.6.2.1.2 Routine Radiological Risk Conclusions. A comparison of the routine radiological risks (LCF) to the involved worker, noninvolved worker, and general public associated with the waste retrieval cases results in the following conclusions.

- There is no LCF among the worker population, noninvolved worker population, or general public population resulting from waste retrieval operations. The LCF risk to the involved worker MEI, noninvolved worker MEI, and general public MEI is small (2.0×10^{-4}, 5.2×10^{-11}, 2.8×10^{-10}, respectively). Therefore, the analysis results indicate that this performance measure is not a driver for establishing waste retrieval and LDMM system criteria for tank S-112.

- As less sludge is retrieved from tank S-112 in comparison to that assumed in the cases with 10,000 L (2,700 gal) residual waste (Cases 1, 2, 3, 6, 7, 8, 9, 10) the LCF risk from waste retrieval operations is reduced by as much as 10%.

B.6.2.1.3 Routine Chemical Risk Conclusions. A comparison of the routine carcinogenic health risks (ILCR) to the involved worker MEI, noninvolved worker MEI, and general public MEI during retrieval operations associated with the 10 waste retrieval cases results in the following conclusions.

- The ILCR for all the cases is small (i.e., less than 1.0×10^{-7}). Therefore, the analysis results indicate that this performance measure is not a driver for establishing waste retrieval and LDMM system criteria for tank S-112.

- As less sludge is retrieved from tank S-112 in comparison to that assumed in the cases with 10,000 L (2,700 gal) residual waste (Cases 1, 2, 3, 6, 7, 8, 9, 10) the ILCR risk from waste retrieval operations is reduced by 0.3% for Case 4 and 5% for Case 5.

It should be noted that depending on the level of organic compounds contained in the sludge, operating plans should include a phased startup of the waste retrieval system to limit the potential release of volatile organic compounds and/or ammonia emissions to within the prescribed limits. Such safeguards would help prevent a potential release that occurred in the C tank farm with tank C-106 retrieval operations when the air permit limit was immediately exceeded when waste retrieval began (RPP-5687).

B.6.2.1.4 Radiological Accident Risk Conclusions. The severity of a given accident and the frequency of the accident are common to all waste retrieval cases; however, the probability of the accident occurring varies slightly because of the slight variation in duration of operations between the cases. The variation is so slight that there is no change in frequency categories. Therefore, this performance measure is not a driver for establishing waste retrieval and LDMM system criteria for tank S-112.

B.6.2.1.5 Chemical Accident Risk Conclusions. The severity of a given accident and the frequency of the accident are common to all waste retrieval cases; however, the probability of the accident occurring varies slightly because of the slight variation in duration of operations between the cases. The variation is so slight that there is no change in frequency category.

Therefore, this performance measure is not a driver for establishing waste retrieval and LDMM system criteria for tank S-112.

B.6.2.2 Tank S-112 Groundwater Impact Conclusions

The groundwater impact evaluations presented in Section B.5.0 result in several observations and conclusions relative to waste retrieval from tank S-112. The conclusions associated with the near-field groundwater impacts of the S-112 focus tank are provided in this section. Conclusions associated with the far-field impacts of the composite sources from the entire S tank farm, including those from focus tank S-112, are provided in Section B.6.4.2. For tank S-112, conclusions are discussed in the following.

- Mobile contaminants such as technetium-99 and nitrate associated with retrieval losses exhibit 2 concentration pulses or a bimodal peak (see Figures B.5.1 and B.5.2) in the groundwater at the S tank farm fenceline. The larger leak loss volumes evaluated resulted in an early time peak that dominated the later peak. The first peak, or early time peak, typically occurs in about the year 2070 (within the institutional control period) and the second in about the years 3100 to 3450. The early time peak is in the form of a sharp peak. The second peak is broader and of lower maximum concentration compared to the early time peak.

- The relationship between mobile contaminant near-field concentration and retrieval loss volume (from the focus tanks only) is relatively linear and predictable as illustrated in Section B.5.0 (see Figure B.5.4). Based on the trend line for the early peak concentration versus volume in Figure B.5.4 it would be necessary to limit retrieval volume to about 5,700 L (1,500 gal) to not exceed the technetium-99 DWS of 900 pCi/L. If the action levels identified in the 200-UP-1 interim Record of Decision of 10 times DWSs were used then the leak volume would be limited to approximately 53,000 L (14,000 gal). The trend line slope for the late time peak concentration versus volume is not as steep resulting in a retrieval volume limit of about 8,000 L (2,100 gal) to meet the 900 pCi/L DWS.

- Significant groundwater impacts from uranium-238 associated with both the retrieval and residual source terms do not begin to appear until the year 7000 or later and would not overlap with the mobile contaminant peaks associated with retrieval leakage or residual waste. The uranium-238 groundwater impacts associated with the residual waste volume (see Figure B.5.7) source term are similar to that of the retrieval loss (see Figure B.5.3) source term except that their increase occurs over 500 years later due to the later release of the residual waste. Uranium-238 from retrieval and residual source terms would be present at extremely low concentrations (i.e., on the order of 10^{-17} pCi/L) beginning in the year 4850 and still be low (i.e., on the order of 10^{-7} pCi/L) until about the years 7000 to 8000 and would not have peaked over the 10,000-year period of interest.

- Mobile contaminants such as technetium-99 and nitrate (see Figures B.5.5 and B.5.6) associated with residual waste will exhibit one concentration peak typically at about the year 4000. The concentration peak is in the form of a relatively broad peak compared to the early time retrieval loss concentration peak.

- The relationship between mobile contaminant near-field concentration and residual waste volume (from tank S-112 only) is relatively linear and predictable as illustrated in Section B.5.0 (see Figure B.5.8). For tank S-112, it would be necessary to limit residual waste volume to some value less than 11,000 L (3,000 gal) to not exceed the technetium-99 DWS of 900 pCi/L or less than approximately 28,000 L (7,500 gal) to not exceed 10 times the DWS.

- The mobile contaminants such as technetium-99 and nitrate will exhibit 2 concentration pulses or a bimodal peak for the composite of retrieval loss and residual waste source terms. The first peak typically occurs in about the year 2070 and is due only to the retrieval loss source term. The second peak typically occurs in about the years 3600 to 4000 for all the scenarios except those involving the 150,000 L (40,000 gal) and 300,000 L (80,000 gal) retrieval losses. These large retrieval loss volumes skew the second peak to an earlier time, at about the year 3200. The late time concentration peaks are due to a combination of the retrieval and residual source terms and as such, are higher and broader than either the retrieval or residual late time peak taken separately.

- The uranium-238 groundwater impacts associated with the composite of the retrieval loss and residual waste source terms have similar concentration versus time trends. Uranium-238 from the composite of the retrieval and residual source terms would be present at extremely low concentrations (i.e., on the order of 10^{-7} pCi/L) until about the years 7000 to 8000 and would not have peaked over the 10,000-year period of interest. The large retrieval loss scenarios (i.e., 150,000 L [40,000 gal] and 300,000 L [80,000 gal]) and large residual loss scenario (i.e., 102,000 L [27,000 gal]) would result in uranium-238 concentrations ranging from about 7.5 pCi/L to 27 pCi/L at 12,000 years, which are above the DWS of 6.7 pCi/L. None of the other scenarios would exceed the DWS for uranium-238 over the 10,000-year period of interest.

- An interim barrier would not change the groundwater impacts associated with the residual waste but would effectively shift the impacts from retrieval losses by reducing the early time peak and increasing the later peak groundwater concentrations from mobile contaminants.

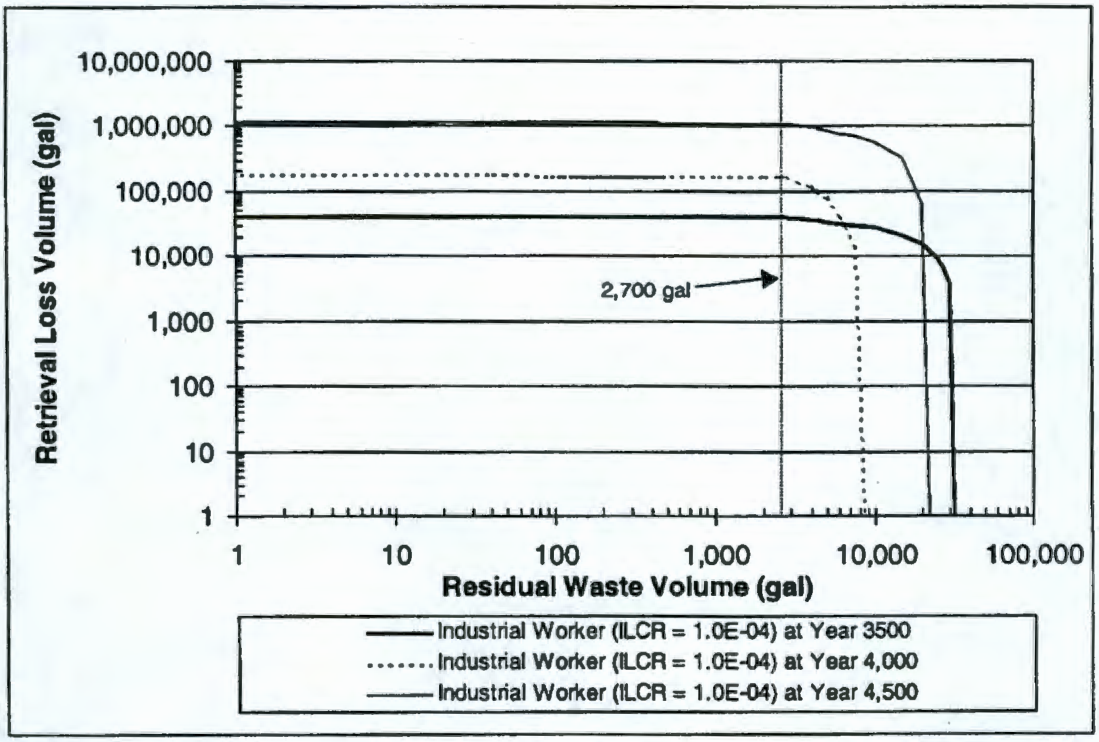
B.6.2.3 Tank S-112 Long-Term Human Health Risk Conclusions

This section identifies tank S-112 retrieval performance requirements based on the results of the long-term human health risk analysis presented in Section B.5.1.3. Risk-based retrieval requirements are specified in terms of the volume limits on the two primary system components for the tank S-112 retrieval demonstration (i.e., retrieval leakage and residual waste). Residual waste volume targets for the tank S-112 retrieval demonstration have been established in the HFFACO. The emphasis in this section is therefore on establishing limits on tank S-112 retrieval leakage. Such limits could provide a means for identifying an acceptable leakage envelope for moving forward with waste retrieval of tank S-112.

Based on extrapolation of the analysis results, the impacts from tank S-112 retrieval leakage losses, when considered by themselves, exceed an ILCR of 1.0×10^{-5} for the industrial worker scenario at the S tank farm fenceline at volumes greater than approximately 6,400 L (1,700 gal). Similarly, the impacts from tank S-112 residual waste, when considered by themselves, exceed an ILCR of 1.0×10^{-5} for the industrial worker at the S tank farm fenceline at volumes greater than approximately 11,000 L (2,900 gal). It is important to note that the peak impacts from tank S-112 retrieval leakage are projected to occur during the time period when the tank farm would be under active post-closure care and access to the groundwater exposure pathway at the tank farm fenceline for industrial or residential use would be restricted. Use of an interim barrier, although of negligible benefit in reducing the peak risk from tank S-112 retrieval leakage, is projected to shift the retrieval leakage peak arrival time at the tank farm fenceline until well beyond the end of the active post-closure care period. Peak impacts from tank S-112 residual waste are also projected to occur well beyond the end of the active post-closure care period.

The compliance status of tank S-112 relative to the risk-based regulatory standards will be based not on the impacts from any one source term alone but on the impacts from all source terms combined. Determining risk-based retrieval requirements for tank S-112 therefore necessitates considering the source terms in composite rather than individually. Considering the composite source term necessitates selecting a discrete point in time at which the risks from the individual source terms are to be combined. Simply adding the peak risk values from the individual source terms is not meaningful because these peaks arrive at the S tank farm fenceline at different points in time and a receptor would in reality never see these peaks in combination. To identify an appropriate point in time for considering the composite source term, a set of curves showing the relationship between tank S-112 retrieval leakage volume and residual waste volume was generated by extrapolation of the analysis results at different points in time. Curves for the years 3500, 4000, and 4500 are shown in Figure B.6.1. All three curves are based on a risk threshold of 1.0×10^{-4} at the tank farm fenceline for the industrial worker scenario. Curves for these and several additional time periods were evaluated to identify the time period that yielded the most restrictive (i.e., lowest and most conservative) retrieval leakage volume for a residual waste volume equal to the interim retrieval goal of 10,200 L (2,700 gal) of residual waste. As can be seen in Figure B.6.1, the year 3500 is more restrictive than either the year 4000 or the year 4500 and is therefore used as the basis for the conclusions that follow.

Figure B.6.1. Industrial Worker 1×10^{-4} Incremental Lifetime Cancer Risk at Tank Farm Boundary at Different Points in Time for Tank S-112 Retrieval Leakage Volume and Residual Waste Volume



The primary method for determining the tank S-112 risk-based retrieval requirements is shown in Figure B.6.2. Like Figure B.6.1, Figure B.6.2 was generated by extrapolation of the analysis results and shows the relationship between tank S-112 retrieval leakage volume and residual waste volume at the S tank farm fenceline. Unlike Figure B.6.1, Figure B.6.2 shows curves representing different risk thresholds at one point in time (year 3500) rather than one risk threshold at different points in time. Using Figure B.6.2, the tank S-112 retrieval leakage volume that could occur in combination with a given residual waste volume without exceeding a specified risk threshold can be readily determined. The risk thresholds illustrated on Figure B.6.2 are based on the federal and state cancer risk standards of 1.0×10^{-4} and 1.0×10^{-5}, respectively. Tank S-112 retrieval leakage limits are identified in the following discussion by applying these 2 risk standards at the S tank farm fenceline and assuming waste is retrieved from tank S-112 to the HFFACO interim retrieval goal of 10,200 L (2,700 gal) of residual waste (shown on Figure B.6.2 with a dashed vertical line).

Figure B.6.2. Industrial Worker and Residential Farmer Incremental Lifetime Cancer Risk Levels at Tank Farm Boundary at Year 3500 for Tank S-112 Retrieval Leakage Volume and Residual Waste Volume

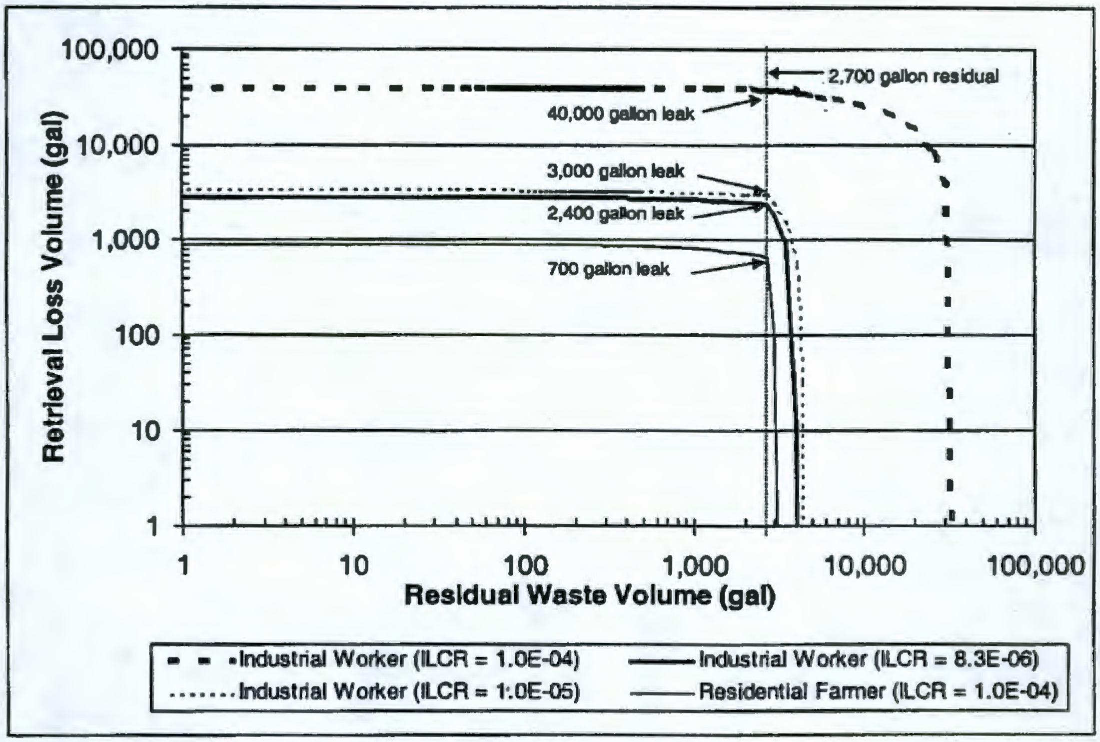


Figure B.6.2 indicates that retrieving waste to the HFFACO interim retrieval goal would allow up to 150,000 L (40,000 gal) of retrieval leakage from tank S-112 without exceeding a risk threshold of 1.0×10^{-4} for the industrial worker scenario at the S tank farm fenceline. However, avoiding exceedance of a 1.0×10^{-5} risk threshold for the industrial worker scenario at the tank farm fenceline would require limiting retrieval leakage to 11,000 L (3,000 gal) or less (Figure B.6.2).

For a given risk threshold, retrieval requirements are significantly more restrictive for the residential farmer scenario than the industrial worker scenario. For example, Figure B.6.2 indicates that for a 1.0×10^{-4} risk threshold, using a residential farmer scenario instead of an industrial worker scenario lowers the tank S-112 retrieval leakage limit from 150,000 L (40,000 gal) to 3,000 L (700 gal), assuming retrieval to the interim retrieval goal. In addition, the analysis results indicate that avoiding exceedance of a 1.0×10^{-5} risk threshold for the residential farmer scenario (not shown on Figure B.6.2) would not be possible unless waste were retrieved from tank S-112 to considerably lower residual waste levels than specified in the HFFACO interim retrieval goal (approximately 4,000 L [1,000 gal]) and no leakage occurred during waste retrieval.

Retrieval requirements identified in the preceding paragraphs assume the specified risk threshold is apportioned entirely to tank S-112. When the risk threshold is applied to the S tank farm as a whole and apportioned across all of the tanks using the risk allocation methodology discussed in Section B.3.6.5, the retrieval requirements on tank S-112 are significantly more restrictive. For example, a tank farm risk threshold of 1.0×10^{-4} for the industrial worker scenario allocates to a tank S-112 risk budget of 8.3×10^{-6}. Using this apportioned risk budget lowers the tank S-112 retrieval leakage limit from 150,000 L (40,000 gal) to 9,000 L (2,400 gal), assuming retrieval to the HFFACO interim retrieval goal (Figure B.6.2).

Tank farm risk thresholds of 1.0×10^{-5} for the industrial worker scenario and 1.0×10^{-4} for the residential farmer scenario allocate to tank S-112 risk budgets of 7.4×10^{-7} and 4.6×10^{-6}, respectively (neither shown in Figure B.6.2). Analysis results indicate that avoiding exceedance of both of these apportioned risk budgets would not be possible unless waste were retrieved to lower residual waste levels than specified in the HFFACO interim retrieval goal and no leakage occurred during retrieval.

It is not possible to allocate a tank farm risk threshold of 1.0×10^{-5} for the residential farmer scenario using the methodology discussed in Section B.3.6.5 because at the year 3500 the risk to the residential farmer from the tank S-104 past leak alone exceeds 1.0×10^{-5}, leaving no risk to allocate to the other tanks or source terms. Although impacts from the tank S-104 past leak are projected to peak within the time period when the tank farm would be under active post-closure care, risk levels would exceed 1.0×10^{-5} for the residential farmer at the S tank farm fenceline until approximately the year 4000.

B.6.2.4 Tank S-112 Intruder Risk Conclusions

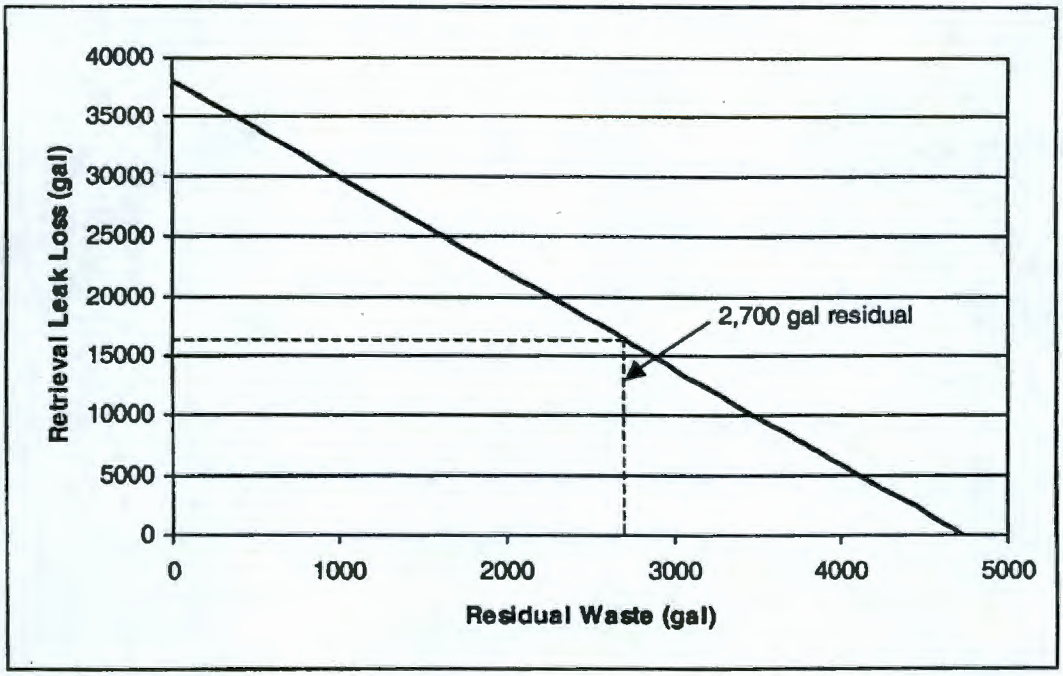
This section provides the conclusions based on the tank S-112 inadvertent human intruder analysis for the DOE intruder scenario and the NRC requirements. The analysis results are presented in Section B.5.1.4.

B.6.2.4.1 U.S. Department of Energy Intruder Scenario Conclusions. DOE regulations require that exposure to an inadvertent human intruder do not exceed 500 mrem for an acute or single event (well driller) and 100 mrem/yr from chronic exposure (post-driller resident) (DOE O 435.1). The relationship between retrieval leak loss and residual waste is shown in Figure B.6.3. Figure B.6.3 shows that retrieving waste to the HFFACO interim retrieval goal of 10,000 L (2,700 gal) of residual waste would allow up to 61,000 L (16,000 gal) of retrieval leakage loss without exceeding the 100 mrem/yr dose to the post-driller receptor. Figure B.6.3 also shows if retrieval leakage losses are minimized to 30,000 L (8,000 gal) (base case) the 100 mrem/yr dose to the post-driller receptor would not be exceeded if the residual waste is kept under 14,000 L (3,700 gal). A comparison of the well driller and post-driller resident doses to the DOE regulations for the waste retrieval cases results in the following conclusions.

- None of the well driller cases exceed the 500 mrem acute dose limit set in DOE O 435.1. Case 9 has the greatest radiological impact (65 mrem) to the well driller.
- Cases 4, 5, 8, and 9 exceed the 100 mrem chronic dose limit set in DOE O 435.1 for the post-driller resident; Cases 1, 2, 3, 6, 7, and 10 do not.

- Tank S-112 exceeds the 100 mrem/yr chronic dose limit except for those cases where the HFFACO-compliant residual waste volume of 10,000 L (2,700 gal) is coupled with the assumed retrieval leakage volume of 30,000 L (8,000 gal) or less (Cases 1, 2, 3, 6, 7, and 10).

Figure B.6.3. U.S. Department of Energy Inadvertent Human Intruder Post-Driller Threshold Dose (100 mrem/yr) for Tank S-112



B.6.2.4.2 U.S. Nuclear Regulatory Commission Requirement Conclusions. The analysis results indicate that this performance measure is not a significant driver for establishing tank S-112 waste retrieval and LDMM system criteria. Mixing the residual waste with grout to achieve NRC Class C concentrations is possible for all waste retrieval cases.

B.6.2.5 Tank S-112 Regulatory Compliance Conclusions

This section presents regulatory compliance conclusions relative to the analysis results for tank S-112. The analysis results are presented in Section B.5.1.5.

The tank S-112 retrieval demonstration goals as specified in HFFACO Milestone M-45-03C are to remove to safe storage approximately 550 curies of mobile, long-lived radionuclides and 99% of the tank S-112 contents by volume. The more restrictive of these 2 goals from a retrieval performance perspective is the removal of 99% of the volume of the tank. Removing approximately 550 curies would require retrieving all but a residual waste volume of approximately 22,700 L (6,000 gal). These calculations are dependent on the post-retrieval inventory estimates for the CoCs in the residual waste; the uncertainty this introduces is discussed in Section B.6.4.

Removing 99% of the tank contents by volume would require retrieving at least 1,950,0000 L (515,000 gal) of waste from tank S-112, equating to a maximum residual waste volume of 19,000 L (5,000 gal). A residual waste volume of 19,000 L (5,000 gal) would be less restrictive (i.e., require less waste to be retrieved) than the Milestone M-45-00 interim retrieval goal of 360 ft^3 (10,000 L [2,700 gal]) of residual waste. This could become an important distinction as decisions are made about employing a second retrieval technology in tank S-112; the low-volume density gradient demonstration technology is expected to be effective in retrieving the salt cake portion of the waste but could leave approximately 22,700 L (6,000 gal) of residual sludge in the tank.

B.6.2.5.1 Tank S-112 Short-Term Human Health Risk Compliance Conclusions. The short-term human health risks associated with routine retrieval operations assumed in each of the waste retrieval cases do not exceed standards for the general public MEI. The incremental annual dose for the MEI at the Site boundary from tank S-112 retrieval operations is 5.6×10^{-7} rem; therefore, the total is below the International Commission on Radiological Protection standard of 0.1 rem/yr.

B.6.2.5.2 Tank S-112 Groundwater Protection Compliance Conclusions. Analysis results of the maximum groundwater concentration value for each CoC in tank S-112 were compared to the EPA MCLs and DWSs for nitrates. Technetium-99 exceeds the EPA regulatory MCL (900 pCi/L) for all cases; greatest exceedance is Case 9 with 86,300 pCi/L, and least exceedance is Cases 1 and 6 with 1,510 pCi/L. In Cases 2, 3, 7, 8, 9, and 10 the technetium-99 peak concentration occurs between 2070 and 2080, within the timeframe of institutional controls. Uranium-238 exceeds the EPA regulatory MCL (6.7 pCi/L) only in Case 9. Uranium groundwater impacts would not peak over the 10,000-year period of interest. Nitrate concentrations exceed the regulatory standard of 45 mg/L in Cases 5, 8, 9, and 10. In Cases 8 and 9 the exceedance occurs within the timeframe of institutional controls.

B.6.2.5.3 Tank S-112 Long-Term Human Health Risk Compliance Conclusions. Long-term human health risk standards may be exceeded even though groundwater quality standards (i.e., MCLs, derived concentration guide) are not exceeded because the groundwater quality standards are strictly based on drinking water ingestion, whereas the long-term human health risk calculations for future land use scenarios are based on multiple exposure pathways (e.g., drinking water ingestion, milk and meat ingestion, leafy vegetable ingestion). Long-term human health risk exceedance for tank S-112 occurs for the industrial worker scenario in all cases except Cases 1 and 6; exceedance occurs for all cases for the cross-section in the industrial worker scenario. Exceedance of the hazard index standard occurs for both tank S-112 and the cross-section in the industrial worker scenario in Cases 8 and 9. The long-term human health risk associated with the residential farmer scenario exceeds risk standards and the hazard index for both tank S-112 and the cross-section. The driver for long-term human health risk is retrieval leakage; cases with the least leakage have lower long-term human health risk values than cases with higher leakage volumes.

B.6.2.5.4 Tank S-112 Inadvertent Human Intrusion Compliance Conclusions. The analysis results indicate that for tank S-112, Cases 4, 5, 8, and 9 exceed the exposure performance objective for the post-driller resident (100 mrem/yr). Only cases with the minimal amount of residual waste (10,000 L [2,700 gal]) and no more than 30,000 L (8,000 gal) of retrieval leakage (Cases 1, 2, 3, 6, 7, and 10) do not exceed the chronic dose limit of 100 mrem/yr. The analysis results for the well driller indicate that the performance objective for the acute dose (500 mrem/yr) is not exceeded in any case.

Under the NRC intruder scenario, used to establish Class C concentration limits for CoCs, none of the waste retrieval cases achieve satisfaction of the criteria. However, all waste retrieval cases could meet the standards with the addition of up to 48 cm (19 in.) of grout (HNF-3428). Additionally, all waste retrieval cases could meet the Savannah River Site-specific Class C LLW standard based on the criteria for incidental waste established by the NRC staff for Savannah River Site tank closure (Travers 1999).

B.6.2.5.5 Additional Tank S-112 Regulatory Issues. Tank S-112 regulatory issues beyond the four performance measure drivers are addressed in the following sections.

B.6.2.5.5.1 Residual Waste Issues. The NRC incidental waste criterion one specifies that:

> ...wastes have been processed (or will be processed) to remove key radionuclides to the maximum extent that is technically and economically practicable.

The first step in evaluating removal of radionuclides is establishing initial waste volumes and concentrations. Mechanical removal technologies remove bulk quantities of waste, but do not preferentially remove key radionuclides. Therefore, reduction of volume by waste removal may not change concentrations. Chemical treatment, which removes key radionuclides, could be considered to supplement the retrieval technology employed for tank S-112.

B.6.2.5.5.2 Inadvertent Intruder Scenario Issues. The NRC regulatory requirements for the classification of Class C LLW are analyzed for tank S-112. The analysis reveals that 10 m^3 (360 ft^3) of residual waste will meet Class C standards when the residual waste is mixed with 13 cm (5 in.) of grout per the methodology established for the Savannah River Site. The NRC incidental waste Criterion 2 states that:

> ...wastes will be incorporated in a solid physical form at a concentration that does not exceed the applicable concentration limits for Class C low-level waste as set out in 10 CFR 61.

Using grout will ensure the waste will be in a solid physical form, but uniformly mixing the residual grout may not be technically feasible. Adding only 13 cm (5 in.) of grout to approximately 3 cm (1 in.) of waste remaining in the tank may not adequately stabilize the waste.

NRC staff recommend the following alternative waste classification be administered at the Savannah River Site for HLW tank residuals similar to that provided for in 10 CFR 61.58. The reclassification redefines the maximum allowable radionuclide concentration as follows: no radionuclide concentration shall exceed 10 times the value specified in Table 1 of 10 CFR 61.55, at 500 years following the proposed closure for each tank grouping, and no radionuclide concentration shall exceed the value specified in Table 2 Column 3 in 10 CFR 61.55.

The procedure established in 10 CFR 61.55(a)(7) shall be followed such that the sum-of-fractions for all Table 1 radionuclides shall not exceed 10, and the sum-of-fractions for all Table 2 radionuclides shall not exceed 1. This standard is attainable with tank S-112 in all waste retrieval cases; the sum-of-fractions ranges from a low of 3.7 in Case 5 to a high of 8 in all cases assuming a residual waste volume of 10,000 L (2,700 gal).

B.6.2.5.5.3 Long-Term Human Health Risk Issues. None of the waste retrieval cases considered for tank S-112 satisfy both scenarios for evaluating acceptable risk to long-term human health. This is an issue because, although leak loss is the driver for long-term human health risk, even with no leakage and the minimum residual waste both the risk standards and the hazard index are exceeded in the residential farmer scenario.

B.6.3 S TANK FARM CONCLUSIONS

Conclusions specific to the groundwater impacts, long-term human health risk, and regulatory compliance for the S tank farm are provided in this section. The short-term health risks and intruder risks are tank-specific and are not addressed for the tank farm as a whole.

B.6.3.1 S Tank Farm Groundwater Impact Conclusions

Conclusions associated with the far-field composite groundwater impacts from the entire tank farm (i.e., releases from 12 tanks in the S farm) are provided in this section. Three combinations of source terms have been assumed for potential far-field groundwater impacts. As noted in Section B.5.0, 2 contaminants, technetium-99 and uranium-238, were selected as representative of the range of far-field groundwater impacts based on their mobility in the Hanford subsurface. Technetium-99 is mobile and would move with groundwater. The mobility of uranium-238 is somewhat less than that of technetium-99 but much more mobile than contaminants such as cesium-137. Each of the three combinations were considered with and without the past leak from tank S-104. Two potential far-field compliance points that were considered are as follows:

- 200 West fence located about 1.8 km (1.12 mi) east of the S tank farm
- 200 Area exclusion boundary located about 10.5 km (6.52 mi) east of the S tank farm.

The three source term combinations that are considered are described in Table B.5.17

The peak concentration from the past leak component dominates all other far-field impacts considered and makes it difficult to assess impact changes associated with the other source terms (i.e., the retrieval loss and residual waste). With the impacts from the past leaks included, the peak technetium-99 groundwater concentration from all 3 cases would be in the years 2200 and 2350 at the 200 West fence and 200 Area exclusion boundary, respectively. Technetium-99 peak groundwater concentrations corresponding to the 200 West fence and 200 Area exclusion boundary potential compliance points would be within 1 and 10 times the DWS of 900 pCi/L.

The 3 cases described in Table B.5.17 were re-evaluated without the contribution from the tank S-104 past leak, because of the dominance of the past leak source term on the far-field groundwater impacts. Conclusions from this evaluation are as follows.

- Technetium-99 groundwater concentrations at the 2 potential far-field compliance points did not exceed the DWS of 900 pCi/L when the same 3 cases were considered without the past leak source term.

- A bimodal peak is observed for the technetium-99 groundwater concentration versus time traces for Cases 1 and 2 which each include a retrieval loss and residual volume (see Figures B.5.28 and B.5.30). The late time peak concentration is always greater than the early time peak for these 2 cases.

- The time from peak technetium-99 groundwater concentration at the 200 West fence to the peak technetium-99 groundwater concentration at the 200 Area exclusion boundary is about 170 years (see Figure B.5.28). The peak technetium-99 concentrations are reduced by a factor of about 4.25 from the 200 West fence to the 200 Area exclusion boundary.

- The impacts of large retrieval losses (i.e., 150,000 L [40,000 gal]) from tank S-112 are manifest primarily in the early time peaks and would have comparatively little impact on the late time technetium-99 groundwater concentration peaks. From the S tank farm perspective the impacts in terms of peak concentration are not sensitive to a relatively large leak loss from S-112.

- Peak uranium-238 groundwater concentrations, within the 10,000-year period of interest, are dominated by the residual waste volume source term and are not sensitive to retrieval leakage. The far-field uranium-238 concentrations from the 10,200 L (2,700 gal) residual volume in each of the 12 tanks (Case 4) reach maximum concentrations of 6.1×10^{-3} pCi/L and 4.0×10^{-4} pCi/L at the 200 West fence and 200 Area exclusion boundary, respectively. The maximum uranium-238 concentrations only increase by factors of from 1.2 (200 West fence) to 1.4 (200 Area exclusion boundary), with the addition of a 30,000 L (8,000 gal) retrieval loss from each of the 12 tanks (Case 1).

B.6.3.2 S Tank Farm Long-Term Human Health Risk Conclusions

Based on the results of S tank farm long-term human health risk analysis presented in Section B.5.2.2, long-term human health risk on a tank farm level appears to have a low sensitivity to changes in retrieval leakage, either from tank S-112 or from the S tank farm as a whole. A limited set of whole-farm analysis cases is evaluated for the S tank farm in this RPE. A common assumption for these cases is that waste is retrieved from all S farm tanks to the HFFACO interim retrieval goal of 10,200 L (2,700 gal) of residual waste. Results of the analysis suggest that if the S tank farm were closed with 10,200 L (2,700 gal) of residual waste remaining in all tanks, the residual waste contribution would dominate the retrieval leakage contribution at the time of peak farm wide human health impacts. Analysis results indicate that a large retrieval leak from tank S-112 would have a negligible effect on peak farm-wide impacts at the two far-field compliance points evaluated. Additionally, a nominal retrieval leak from all of the tanks would have only a minor effect. These results suggest that a retrieval leak from tank S-112 is unlikely by itself to trigger a need for mitigative action when considered from the perspective of the peak human health impacts projected for the S tank farm as whole.

Results of the S tank farm analysis can also be used to make several higher-level observations regarding alternative points of compliance. At compliance points beyond the tank farm fenceline, peak human health impacts will decrease as a result of natural attenuation of contaminant concentrations in the unconfined aquifer. A sense of the magnitude of this decrease in peak impacts can be gained by comparing the analysis results at the tank farm fenceline with the analysis results at the two far-field points of compliance. Because it was determined not to be credible to analyze the impacts for the whole tank farm at the tank farm fenceline, a direct comparison between the near- and far-field analysis results is not possible (i.e., near-field impacts are evaluated only for tank S-112 and its cross-section whereas far-field impacts are evaluated only for the whole tank farm). Nevertheless, comparing near-field cross-section impacts with far-field tank farm impacts provides an informative perspective on the potential implications of selecting alternative compliance points. The comparison is made between analysis results from like waste retrieval scenarios as follows. For the cross-section, analysis Case 2 represents a scenario where waste is retrieved to the interim retrieval goal with a 30,000 L (8,000) retrieval leak from each tank (Section B.5.1.3). For the S tank farm, analysis Case 1 represents this same waste retrieval scenario applied to all tanks in the S tank farm (Section B.5.2.2). The peak residential farmer ILCR for Case 2 at the tank farm fenceline is projected to exceed 1.0×10^{-3} for the tank S-112 cross-section (Table B.5.12). The peak residential farmer ILCR for Case 1 at the 200 West fence is projected to be between 1.0×10^{-4} and 1.0×10^{-5}; the peak at the 200 Area exclusion boundary is projected to be between 1.0×10^{-5} and 1.0×10^{-6} (Table B.5.19). This comparison suggests that the potential decrease in peak human health impacts resulting from natural attenuation between the tank farm fenceline and compliance points on the east side of the Central Plateau could range from one to over two orders of magnitude.

B.6.3.3 S Tank Farm Regulatory Compliance Issues

This section presents regulatory compliance conclusions relative to the analysis results presented in Section B.5.3. The analysis was performed by constructing 3 new cases with composite source terms, calculating groundwater concentrations and long-term human health risk at 2 points of compliance, the west side of the 200 West fence, and the west side of the 200 Area exclusion boundary. Because the past leak from tank S-104 dominates all other impacts making it difficult to assess impact changes associated with the other source terms, the analysis was also performed excluding the past leak.

B.6.3.3.1 S Tank Farm, Including Past Leak From Tank S-104. Groundwater concentrations for technetium-99 exceed the regulatory MCLs (900 pCi/L) in all 3 cases, both at the 200 West fence and at the 200 Area exclusion boundary. Uranium-238 and nitrate do not exceed regulatory limits in any case at either boundary. The technetium-99 peaks are early, about the year 2173, because of the dominance of the past leak. Long-term human health risk regulatory standards are exceeded in both ILCR and hazard index at both boundary points for the residential farmer scenario. In the industrial worker scenario, ILCR standards are exceeded in all cases at both boundaries, but hazard index is not exceeded.

B.6.3.3.2 S Tank Farm, Excluding Past Leak From Tank S-104. Groundwater concentrations for technetium-99 do not exceed the regulatory MCLs (900 pCi/L) in any of the 3 cases, at either of the boundaries. Peak concentrations occur late, between the years 4070 and

4335. Uranium-238 and nitrate standards are not exceeded. Long-term human health risk regulatory standards are exceeded at the 200 West fence in the 3 cases using the residential farmer scenario. The hazard index standard is exceeded in Case 1, with 10,000 L (2,700 gal) residual waste in all tanks and assuming 30,000 L (8,000 gal) for the residential farmer scenario at the 200 West fence. In the industrial worker scenario, neither ILCR nor hazard index standards are exceeded in any case at either boundary.

B.6.4 UNCERTAINTIES

The long-term human health risk analysis presented in this RPE is based on the following:

- Inventory projection for what is currently in the vadose zone as a result of past leaks and spills
- Inventory projections for what would remain in the tanks following waste retrieval
- Leakage that could occur during waste retrieval.

The inventory estimates for tank residuals and retrieval leakage have been developed using tank-specific wash factors; there is some uncertainty associated with those wash factors because the basis for the wash factors is approximate. Tank-specific chemical modeling could provide a better basis for calculating residual waste and retrieval leakage inventories and should be considered in future RPE analyses.

The risk assessment performed for this RPE is based on best available information and data. The inventory estimates for retrieval leakage and residual waste are based on the current BBI (BBI 2000) and a methodology designed to provide a best estimate for retrieval leakage concentrations and residual waste concentrations that consider tank-specific wash factors. Source terms or release rates from the residual waste volumes are conservative in that no credit is taken for stabilization of the residual wastes (e.g., grouting). Additionally, the tanks are assumed to completely degrade at the same time providing a conservative estimate of residual waste impacts across the cross-section. The groundwater concentrations calculated through the numerical transport model are based on a unit width at the tank farm. This approach does not account for the lateral dispersion of contaminants as they migrate toward the tank farm fenceline. Taking this into account would tend to spread the contaminant plume out and reduce the peak concentration. Taking lateral dispersion into account would not be expected to significantly reduce the groundwater concentrations because the tanks are relatively close to the tank farm fenceline. There is emerging information that selenium-79 is not as mobile as assumed in this RPE; recent laboratory tests conducted for the immobilized low-activity waste program indicate that selenium has an average distribution coefficient of 6.7 mL/g (PNNL-13037). This indicates that selenium-79 would not reach the groundwater in the timeframe evaluated and would not contribute to the long-term human health risk.

B.6.4.1 Uncertainties Associated with Risk Assessment

Risk assessments are inherently uncertain in that a number of enabling assumptions and estimates have to be made to assess potential risks to a future site user. For a point estimate risk assessment the inputs used are typically conservative point estimates and those conservative estimates combine to produce a conservative or bounding result. A stochastic uncertainty and sensitivity analysis was performed for the AX tank farm RPE (DOE/RL-98-72) to evaluate how variation and uncertainty in model input parameters translates into uncertainty in long-term human health risk projections. Both uncertainty (lack of knowledge about a parameter) and variability (naturally occurring variations such as receptor bodyweight) contribute to the overall risk uncertainty. Based on the sensitivity analysis results from DOE/RL-98-72 the input parameters (ranked in order from highest to lowest influence) were exposure, source term, and transport parameters. Based on the AX tank farm uncertainty analysis results it was observed that variation and uncertainty in the exposure parameters (e.g., milk consumption, water consumption, exposure duration) resulted in 2.5 orders of magnitude overall uncertainty. The results of the DOE/RL-98-72 uncertainty analysis are generally applicable to this RPE in that the parameters that tended to dominate the uncertainty at the AX tank farm would be expected to drive the uncertainty at the S tank farm. Additionally, an uncertainty analysis is being developed for the S tank farm and will be incorporated into a future revision of this RPE.

One of the conclusions drawn from the DOE/RL-98-72 uncertainty analysis was that additional data collection would provide limited reduction in the overall uncertainty and that the uncertainty should not be used as an argument for delaying interim decisions to move forward with waste retrieval.

DOE/RL-98-72 evaluates tank closure options that include demolition and removal of the tanks and contaminated soils from the tank farm. That study concludes that the retrieval leakage beneath the base of a tank would significantly add to worker doses from tank and soil excavation. The engineering approach developed for tank and soil excavation involves radiation workers operating shielded equipment. Remote operations are evaluated but would require substantial research and development efforts prior to deployment. Based on the analysis in DOE/RL-98-72 it can be concluded that large retrieval leakage volumes could preclude options for pursuing clean closure due to the increased risk to workers.

B.6.4.2 Uncertainties Associated with the Groundwater Impact Analyses

For the groundwater impact analysis, there are four areas of uncertainty that could have measurable effect on the resulting calculation of groundwater contaminant concentration. These areas are as follows:

- Vadose zone geometry and hydrostratigraphy
- Aquifer properties and viability
- Far-field calculation of groundwater contaminant concentration
- Past leak inventory.

An overview of each of these uncertainties is provided in the following sections.

B.6.4.2.1 Vadose Zone Geometry and Hydrostratigraphy. The vadose zone is nominally 64 m (210 ft) thick at the S tank farm. Information on sediment layering and thickness are limited to the evaluation of disturbed drill cutting samples that were collected during the installation of the drywells. These data are limited to the depth of the drilling, which varies, but was generally

30 m (100 ft) below ground surface. There are no site-specific data below the nominal 30 m (100 ft) below ground surface level. The S tank farm vadose zone hydraulic parameter values assumed values and are all based on test results of similar materials taken at other locations.

B.6.4.2.2 Aquifer Properties and Viability. The near-field aquifer properties (i.e., thickness, hydraulic conductivity, and total and effective porosity) are all assumed values based on generalized descriptions of the aquifer in the vicinity. There are no known irrigation wells in the uppermost aquifer in the vicinity of Hanford and the viability (i.e., the ability of the aquifer to produce a quantity of water sufficient to support irrigation or domestic use as would be required for both of the long-term human health risk exposure scenarios) from the Ringold Formation at S tank farm location is speculative. Groundwater levels are declining in the area of the S tank farm due to cessation of wastewater disposal to the ground. As the decline continues, the vadose zone will become thicker and the uppermost aquifer currently in the Ringold Formation will become thinner. This trend further reduces the potential viability of the uppermost aquifer and increases the contaminant travel time in the vadose zone.

B.6.4.2.3 Far-Field Calculation of Groundwater Contaminant Concentration. The stream tube approach that was used to estimate the far-field groundwater contaminant concentrations does not take into consideration a number of variables of groundwater flow and contaminant transport inherent with a site as large and variable as the Hanford Site. The results may be relatively small reductions of contaminant concentrations as a function of contaminant travel distance. For instance, over a distance of about 8.7 km (5.4 mi) between the 200 West fence and the 200 Area exclusion boundary, technetium-99 groundwater concentration was reduced by a factor of about 4.25.

B.6.4.2.4 Past Leak Inventory. The information on past leak volume and inventory has been reconstructed for various records. Uncertainties exist due to the nature of Site operations and the lack of complete documentation. The areas of the tank from which the leak occurred are also not available in the records. As noted in DOE/RL-98-72, the tank leak area combined with the leak duration and leak volume can affect the flux to the vadose zone, which can affect contaminant transport time and location of contaminants in the vadose zone.

B.7.0 REFERENCES

10 CFR 20, "NRC Standards for Protection Against Radiation," *Code of Federal Regulations*, as amended.

10 CFR 50, "Policy Relating to the Siting of Fuel Reprocessing Plants and Related Waste Management Facilities," *Code of Federal Regulations*, as amended.

10 CFR 60, "Disposal of Radioactive Waste in Geological Repositories," *Code of Federal Regulations*, as amended.

10 CFR 61, "Licensing Requirements for Land Disposal of Radioactive Waste," *Code of Federal Regulations*, as amended.

10 CFR 193, "Environmental Standards for the Management, Storage, and Land Disposal of Low-Level Radioactive Waste Land Naturally Occurring Accelerator-Produced Radioactive Waste," *Code of Federal Regulations*, Draft.

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

40 CFR 191, "Environmental Radiation Protection Standards for Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes," *Code of Federal Regulations*, as amended.

40 CFR 194, "Criteria for the Certification and Re-certification of the Waste Isolation Pilot Plant's Compliance with the 40 CFR 191 Disposal Regulations," *Code of Federal Regulations*, as amended.

40 CFR 260, "Hazardous Waste Management System: General," *Code of Federal Regulations*, as amended.

40 CFR 261, "Identification and Listing of Hazardous Waste," *Code of Federal Regulations*, as amended.

40 CFR 262, "Standards Applicable to Generators of Hazardous Waste," *Code of Federal Regulations*, as amended.

40 CFR 263, "Standards Applicable to Transporters of Hazardous Waste," *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 266, "Standards for the Management of Specific Hazardous Wastes and Specific Types of Hazardous Waste Management Facilities," *Code of Federal Regulations*, as amended.

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

40 CFR 270, "EPA Administered Permit Programs: The Hazardous Waste Permit Program," *Code of Federal Regulations*, as amended.

40 CFR 271, " Requirements for Authorization of State Hazardous Waste Programs," *Code of Federal Regulations*, as amended.

40 CFR 272, "Approved State Hazardous Waste Management Programs," *Code of Federal Regulations*, as amended.

40 CFR 273, "Standards for Universal Waste Management," *Code of Federal Regulations*, as amended.

40 CFR 279, "Standards for the Management of Used Oil," *Code of Federal Regulations*, as amended.

40 CFR 280, "Technical Standards and Corrective Action Requirements for Owners and Operators of Underground Storage Tanks (UST)," *Code of Federal Regulations*, as amended.

55 FR 8666, 1990, "National Oil and Hazardous Substances Pollution Contingency Plan," *Federal Register*, March 8.

65 FR 7319, 2000, "Establishment of the Hanford Reach National Monument," *Federal Register*, June 13.

ARH-LD-133, 1976, *Geology of the 241-S Tank Farm*, Atlantic Richfield Hanford Company, Richland, Washington.

Atomic Energy Act of 1954, 42 USC 2011 et seq., as amended.

BBI, 2000, *Best Basis Inventory*, August 1, 2000 revision accessed at http://www.hanford.gov/twrs/char.pub/ in December 2000.

Clean Air Act, Public Law 88-206, 42 USC 7401 et seq., as amended.

Clean Water Act, Public Law 95-217, 91 Stat. 1566 and Public Law 96-148, (December 1977).

Comprehensive Environmental Response, Compensation, and Liability Act of 1980, Public Law 96-150, 94 Stat. 2767, 42 USC 9601 et seq.

Dentler, M. E., 1995, "Toxicological Evaluation of Tank Waste Chemicals," Hanford Environmental Health Foundation Industrial Hygiene Assessments, Richland, Washington, January 13.

DOE, 1996, *Dangerous Waste Permit Application – Single-Shell Tank System*, Rev. 4, U.S. Department of Energy, Washington, D.C.

DOE/EIS-0189, 1996, *Tank Waste Remediation System, Hanford Site, Richland, Washington, Final Environmental Impact Statement*, U.S. Department of Energy and Washington State Department of Ecology, Washington, D.C.

DOE/EIS-0303D, 2000, *High-Level Waste Tank Closure Draft Environmental Impact Statement*, Department of Energy, Savannah River Operations Office, Aiken, South Carolina.

DOE M 435.1, 1997, *Radioactive Waste Management Manual*, U.S. Department of Energy, Washington, D.C.

DOE O 435.1, 1997, *Radioactive Waste Management*, U.S. Department of Energy, Washington, D.C.

DOE Order 5400.5, 1990, *Radiation Protection of the Public and the Environment*, U.S. Department of Energy, Washington, D.C.

DOE Order 5480.11, 1991, *Radiation Protection for Occupational Workers*, U.S. Department of Energy, Washington, D.C.

DOE/RL-89-16, 1996, *Single-Shell Tank Closure Work Plan*, Rev. 1, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-91-45, 1995, *Hanford Site Risk Assessment Methodology*, Rev. 3, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-93-33, 1996, *Focused Feasibility Study of Engineered Barriers for Waste Management Units in 200 Areas*, Rev. 0, U.S. Department of Energy, Office of Environmental Restoration and Waste Management, Richland, Washington

DOE/RL-98-72, 1999, *Retrieval Performance Evaluation Methodology for the AX Tank Farm*, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-99-36, 1999, *Phase 1 RCRA Facility Investigation/Corrective Measures Study Work Plan for Single-Shell Tank Waste Management Areas*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE-STD-3009-94, 1994, *Preparation Guide for U.S. Department of Energy Nonreactor Nuclear Facility Safety Analysis Reports*, U.S. Department of Energy, Washington, D.C.

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.

Energy Reorganization Act of 1974, 42 USC 5842, as amended.

EPA-822-B-96-002, 1996, *Drinking Water Regulations and Health Advisories*, U.S. Environmental Protection Agency, Office of Water, Washington, D.C.

Federal Facility Compliance Act of 1992, Public Law 102-386, 42 USC 6921 et seq.

Fitzsimmons, T. and C. Clarke, 2000, "Final Determination Pursuant to the Hanford Federal Facility Agreement and Consent Order in the Matter of Hanford Site High-Level Radioactive Tank Waste Treatment Capacity Acquisition, Tank Waste Treatment and Associated Tank Waste Work Requirements" (letter to C. Huntoon, Assistant Secretary of EM; R. T. French, Manager of ORP; and K. Klein, Manager of RL, March 29), Office of Director of Washington State Department of Ecology and Office of Administrator of Region 10 U.S. Environmental Protection Agency, U.S. Department of Energy, Olympia, Washington.

Frei, M. W., 1996, *Issuance of Low-Level Waste Performance Assessment Guidance* (Memorandum to Distribution Issuing the Interim Format and Content Guide and Standard Review Plan for U.S. Department of Energy Low-Level Waste Disposal Facility Performance Assessments), U.S. Department of Energy, Washington, D.C.

Hazardous and Solid Waste Amendments of 1984, Public Law 98-616, 42 USC 6979 et seq.

"Hazardous Waste Management Act," RCW 70.105, *Revised Code of Washington*, as amended.

HNF-3157, 1999, *Best-Basis Wash and Leach Factor Analysis*, Rev. 0A, COGEMA Engineering Corporation, Richland, Washington.

HNF-3428, 1998, *Regulatory Closure Options for the Residue in the Hanford Site Single-Shell Tanks*, Rev. 0, Lockheed Martin Hanford Corporation, Richland, Washington.

HNF-3441, 1998, *AX Tank Farm Ancillary Equipment Study*, Rev. 0, COGEMA Engineering Corporation, Richland, Washington.

HNF-4872, 1999, *Single-Shell Tank Leak History Compilation*, Rev. 0, Lockheed Martin Hanford Corporation, Richland, Washington.

HNF-5085, 2000, *Site-Specific Single-Shell Tank (SST) Phase 1 Resource Conservation and Recovery Act of 1976 (RCRA) Facility Investigation/Corrective Measures Study (RFI/CMS) Work Plan Addendum for Waste Management Area (WMA) S-SX*, Rev. 1, CH2M HILL Hanford Group, Inc., Richland, Washington.

HNF-7990, 2001, *Enabling Assumptions and Calculations to Support the Tanks S-112 and S-102 Retrieval Performance Evaluations*, Draft, CH2M HILL Hanford Group, Inc., Richland, Washington.

HNF-EP-0182, 1999, *Waste Tank Summary Report for Month Ending December 30, 1998*, Fluor Hanford, Inc., Richland, Washington.

HNF-EP-0182, 2000, *Waste Tank Summary Report for Month Ending September 30, 2000*, Rev. 150, CH2M HILL Hanford Group, Inc., Richland, Washington.

HNF-SD-WM-SAR-067, 1999, *Tank Waste Remediation System Final Safety Analysis Report*, Rev. 1, Fluor Hanford, Inc., Richland, Washington.

HSRCM-1, 1994, *Hanford Site Radiological Control Manual*, Westinghouse Hanford Company, Richland, Washington.

ICRP, 1991, *1990 Recommendation of the International Commission on Radiological Protection*, ICRP Publication 60, International Commission on Radiological Protection, Pergamon Press, New York, New York.

Land Disposal Program Flexibility Act of 1996, Public Law 104-119, 42 USC 6924 et seq.

Low-Level Waste Policy Amendments Act, Public Law 99-240, as amended.

"Model Toxics Control Act," RCW 70.105D, *Revised Code of Washington*, as amended.

National Environmental Policy Act of 1969, 42 USC 4321 et seq.

Nuclear Waste Policy Act of 1982, 42 USC 10101 et seq.

NUREG 1.145, 1982, *Atmospheric Dispersion Models for Potential Accident Consequences Assessment at Nuclear Power Plants*, U.S. Nuclear Regulatory Commission, Washington D.C.

Occupational Safety and Health Act of 1970, 29 USC 651 et seq.

PNL-6584, 1988, *GENII – The Hanford Environmental Radiation Dosimetry Software System*, Pacific Northwest Laboratory, Richland, Washington.

PNNL-12030, 2000, *STOMP Subsurface Transport Over Multiple Phases: Theory Guide, Version 2.0*, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-12114, 1999, *RCRA Assessment Plan for Single-Shell Tank Waste Management Area S-SX at the Hanford Site*, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-13037, 1999, *Geochemical Data Package for the Hanford Immobilized Low-Activity Tank Waste Performance Assessment (ILAW-PA)*, Rev. 0, Pacific Northwest National Laboratory, Richland, Washington.

PNWD-3111, 2001, *FY00 Initial Assessments for S-SX Field Investigation Report (FIR): Simulations of Contaminant Migration with Surface Barriers*, Battelle, Pacific Northwest Division, Richland, Washington.

Resource Conservation and Recovery Act of 1976, 42 USC 6901 et seq.

Rosenthal, 1997, *Approaches to Closure of High-Level Mixed Waste Tanks Considering the Hazardous Waste Component of the Waste*, Colorado Center for Environmental Management, Denver, Colorado.

RPP-5687, 2000, *Waste Retrieval Sluicing System (WRSS) and Project W-320, Tank 241-C-106 Sluicing, Lessons Learned*, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-6285, 2000, *Inventory Estimates for Single-Shell Tank Leaks in S and SX Tank Farms*, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-6296, 2000, *Modeling Data Package for S-SX Field Investigation Report (FIR)*, U.S. Department of Energy, Office of River Protection, Richland, Washington.

RPP-6821, 2000, *Technology Evaluation Report for S-103 Saltcake Dissolution Retrieval Demonstration*, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-6830, 2000, *Preliminary Engineering Report for the 241-S-103 Saltcake Dissolution Retrieval System*, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-6843, 2000, *Preliminary Engineering Report for the 241-C-104 Retrieval System*, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-7087, 2000, *Single-Shell Tank Retrieval Sequence: Fiscal Year 2000 Update*, Rev. 0, Numatec Hanford Company, Richland, Washington.

RPP-7526, 2001, *Preliminary Engineering Report for the 241-S-112 Retrieval System*, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-7627, 2001, *LDMM Design Concepts Evaluation Report for Saltcake-Dissolution-Based Retrieval Technologies*, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-7819, 2001, *An Evaluation of Power Fluidics™ Mixing and Pumping for Application in the Single Shell Tank Retrieval Program*, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-7884, 2001, *Field Investigation Report for Waste Management Area S-SX*, Draft, CH2M HILL Hanford Group, Inc., Richland, Washington.

Safe Drinking Water Act, Public Law 93-523, December 16, 1974, 88 Stat. 1660.

SAND98-2104, 1998, *Regulatory Closure Options for the Residue in the Hanford Site Single-Shell Tanks (SSTs)*, Sandia National Laboratory, Albuquerque, New Mexico.

Shyr, L. J. and L. D. Bustard, 1997, *Summary of Communication with DOE Tank Sites on Tank Closure Issues*, Sandia National Laboratories, Albuquerque, New Mexico.

Stokes, W. J., "outlining current SST outyear planning cost estimates" (e-mail to C. H. Henderson, Jacobs Engineering Group Inc., March 23), CH2M HILL Hanford Group, Inc., Richland, Washington.

Toxic Substances Control Act of 1976, 15 USC 2601, et seq.

Travers, W. D., 1999, "Classification of Savannah River Residual Tank Waste as Incidental" (Letter SECY-99-294 to The Commissioners, NRC, December 15), Office of Executive Director for Operations, U.S. Nuclear Regulatory Commission, Washington, D.C.

WAC 173-200, "Water Pollution Control Act," *Washington Administrative Code*, as amended.

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

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

"Water Pollution Control Act," RCW 90.48, *Revised Code of Washington*, as amended.

WDOH/320-015, 1997, *Hanford Guidance for Radiological Cleanup*, Rev. 1, Washington State Department of Health, Olympia, Washington.

WHC-EP-0645, 1995, *Performance Assessment for the Disposal of Low-Level Waste in the 200 West Burial Grounds*, Westinghouse Hanford Company, Richland, Washington.

WHC-SD-WM-ER-352, 1994, *Historical Tank Content Estimate for the Southwest Quadrant of the Hanford 200 West Area*, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

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ATTACHMENT

RETRIEVAL AND RESIDUAL INVENTORY CALCULATIONS

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CONTENTS

TABLES

LIST OF TERMS

BBI	best-basis inventory
HFFACO	*Hanford Federal Facility Agreement and Consent Order*

B1.1.0 INTRODUCTION

Waste composition calculations were made for each of the S farm tanks, estimating waste tank contents after retrieval to 10 m^3 (360 ft^3), the maximum residual waste heel allowed by the *Hanford Federal Facility Agreement and Consent Order* (HFFACO; Ecology et al. 1989). Calculations also include inventory estimates for a 30,300 L (8,000 gal) leak to ground. Additional residual waste heel amounts and leak loss inventories were calculated for tanks S-112 and S-102 because they have been assigned alternate retrieval technologies and are the focus of retrieval performance evaluations. Tank S-102 is treated separately from the other S farm tanks because it is being evaluated in parallel in a separate retrieval performance evaluation. These calculations support the evaluation of the various cases evaluated in this retrieval performance evaluation. The source of all starting inventory information for these calculations is the best-basis inventory (BBI) data (BBI 2000).

New retrieval methods have been proposed for tanks S-112 and S-102. Differences between the previous baseline retrieval method (sluicing) and the demonstration retrieval methods caused the development of two different calculation methods: one for tanks S-112 and S-102, and one for the remainder of the S farm tanks. The calculation differences are driven by the amount of agitation assumed to take place in the tanks during retrieval, and the assumption that the new retrieval methods will preferentially dissolve salt cake leaving the sludge essentially untouched.

The following are the basic assumptions used in making the waste inventory estimates.

1. Retrieval liquid requirement for each tank is based on the amount required to ensure the concentration of sodium is less than 5 Molar and the concentration of undissolved solids is less than 10 wt% in the waste solution transferred out of the tank.

2. Water is used for retrieval of all S farm tank wastes.

3. The baseline retrieval endpoint of 99% retrieval is as defined in the HFFACO; specifically a wet sludge heel of 360 ft^3 (10,000 L [2,700 gal]) is assumed.

4. The initial conditions in the tanks are as defined in the BBI (BBI 2000).

5. Each component in the waste solids currently in all the tanks except tanks S-112 and S-102 will be dissolved according to the BBI wash factors upon addition of the waste retrieval liquid. The methodology for tanks S-112 and S-102 is to preferentially dissolve salt cake prior to any sludge retrieval.

6. Post-retrieval residual waste will have the same physical characteristics (e.g., interstitial volume) as the dry waste heels left in the 200-series tanks of the farm. Final heel porosity was calculated for the 200-series tanks to be 58.5%, which is comparable to *Chemical Engineers' Handbook* (Perry 1963) values for similar solids (e.g., sand, dirt).

7. Tanks not yet interim stabilized will be interim stabilized prior to waste retrieval. Interim stabilization is defined for single-shell tanks as (HNF-EP-0182, Rev. 150):

A tank which contains less than 50,000 gal of drainable interstitial liquid and less than 5,000 gal of supernate liquid. If the tank is jet pumped to achieve interim stabilization, then the jet pump flow or saltwell screen inflow must also have been at or below 0.05 gpm before interim stabilization criteria is met.

B1.2.0 INVENTORY FROM TANK S-104 PAST LEAK

In the S tank farm, tank S-104 has leaked waste to the ground. The total inventory leaked from tank S-104 is estimated in BHI-01496, *Groundwater/Vadose Zone Integration Project – Hanford Soil Inventory*, published in March 2001. The values in Table B1.1 are from BHI-01496.

Table B1.1. Tank S-104 Past Leak Inventory

Contaminant of Concern	Units	Inventory
Cr	kg	7.73E+02
Na	kg	1.80E+04
NO_2	kg	6.79E+03
NO_3	kg	1.68E+04
Total U	kg	1.18E+02
^{14}C	Ci	5.46E-01
^{60}Co	Ci	2.18E-01
^{63}Ni	Ci	6.45E+00
^{79}Se	Ci	1.16E-01
^{90}Sr	Ci	4.46E+03
^{90}Y	Ci	4.46E+03
^{99}Tc	Ci	3.83E+00
^{126}Sn	Ci	1.78E-01
^{129}I	Ci	7.35E-03
^{137}Cs	Ci	1.12E+04
^{137}mBa	Ci	1.07E+04
^{233}U	Ci	7.28E-06
^{234}U	Ci	4.05E-02
^{235}U	Ci	1.72E-03
^{236}U	Ci	9.61E-04
^{238}U	Ci	3.92E-02
^{238}Pu	Ci	2.25E-02
^{239}Pu	Ci	1.42E+00
^{240}Pu	Ci	2.05E-01
^{241}Pu	Ci	1.27E+00
^{242}Pu	Ci	5.44E-06
^{241}Am	Ci	1.95E+00
^{243}Am	Ci	1.84E-05
^{243}Am	Ci	2.13E-05
^{244}Am	Ci	6.50E-04

B1.3.0 RETRIEVAL AND RESIDUAL INVENTORY CALCULATION METHOD FOR RETRIEVAL OF TANKS S-112 AND S-102

Residual waste estimates for tank S-112 were calculated using a different methodology than that used to calculate residual estimates for other S farm tanks. The methodology used for tank S-112 was also applied to tank S-102. This difference is designed to respect the mechanical differences between the proposed retrieval technologies for these tanks and the traditional sluicing technology assumed to be used for the other S farm tanks.

The residual waste inventory estimate for tanks S-112 and S-102 were calculated using the same methodology as was used to generate the inventory estimates for the AX tank farm (DOE/RL-98-72). Like the AX farm tanks, tanks S-112 and S-102 contain both sludge and salt cake waste. To calculate the residual waste inventory, it was assumed that the use of salt cake dissolution technology as the retrieval mechanism would preferentially remove salt cake from the tank. Retrieval of the sludge waste would require a second retrieval effort using a different technology.

The BBIs for tanks S-112 and S-102 were used as the starting point for these calculations, and the inventory associated with the salt cake and sludge waste types was apportioned from the total tank waste inventory identified (BBI 2000). The inventory estimate was then reduced to account for the tanks being interim stabilized before waste retrieval from that tank. The salt cake and sludge waste volumes remaining after interim stabilization were obtained by calculating and removing enough liquid inventory to bring the tank into compliance with the definition of interim stabilization.

It was assumed that the inventory associated with each waste type (i.e., salt cake and sludge) was uniformly distributed within the waste type and that the waste types were segregated.
The residual waste inventory for the tanks were calculated by determining what volume of each waste type would remain after waste retrieval (dependent upon the case being evaluated) and then scaling down each waste type inventory.

For example, total tank S-112 waste retrieval of 80% would remove 87.3% of the salt cake and none of the sludge in the tank. The residual waste inventory was then determined by adding the remaining inventory of the salt cake (12.7% of the original salt cake inventory) to the sludge inventory (100% of the original). The estimates represent the following:

- Tank post-retrieval inventory estimates are based on the best-estimate inventory methodology and reported in BBI
- The waste retrieval process preferentially removes salt cake and then sludge (not a factor in tank S-102 because it has such a large amount of sludge)
- Residual inventory estimates are proportional to the volume of sludge and salt cake remaining after waste retrieval that do not account for preferential removal of water-soluble contaminants.

Beginning inventory for tank S-112 is contained in Table B1.2. Tables B1.3 and B1.4 contain calculated residual waste and retrieval leak loss inventory for tank S-112. Tank S-102 estimates are reported with the balance of the S farm tanks for clarity.

Table B1.2. Pre- and Post-Interim Stabilized Inventories for Tank S-112

Constituent of Concern	Units	Pre-Stabilization Inventory	Post-Stabilization Inventory
Cr	kg	1.49E+04	1.09E+04
Na	kg	6.54E+05	4.78E+05
NO_2	kg	1.71E+05	1.25E+05
NO_3	kg	7.77E+05	5.68E+05
Total U	kg	2.05E+03	1.53E+03
^{14}C	Ci	6.68E+01	4.88E+01
^{60}Co	Ci	3.42E+01	2.50E+01
^{63}Ni	Ci	6.17E+02	4.57E+02
^{79}Se	Ci	8.12E-01	5.92E-01
^{90}Sr	Ci	6.27E+04	5.05E+04
^{90}Y	Ci	6.27E+04	5.05E+04
^{99}Tc	Ci	3.71E+02	2.71E+02
^{126}Sn	Ci	4.92E+00	3.59E+00
^{129}I	Ci	7.14E-01	5.21E-01
^{137}Cs	Ci	4.11E+05	3.01E+05
^{137}mBa	Ci	3.90E+05	2.85E+05
^{151}Sm	Ci	2.72E+04	1.98E+04
^{233}U	Ci	1.06E+00	7.90E-01
^{234}U	Ci	7.26E-01	5.43E-01
^{235}U	Ci	3.02E-02	2.26E-02
^{236}U	Ci	2.02E-02	1.51E-02
^{238}Pu	Ci	1.25E+01	9.17E+00
^{238}U	Ci	6.84E-01	5.12E-01
^{239}Pu	Ci	4.90E+02	3.64E+02
^{240}Pu	Ci	8.08E+01	5.99E+01
^{241}Am	Ci	2.45E+02	1.79E+02
^{241}Pu	Ci	6.36E+02	4.68E+02
^{242}Pu	Ci	4.81E-03	3.54E-03
^{243}Am	Ci	7.79E-03	5.68E-03
^{243}Cm	Ci	2.20E-04	2.08E-04
^{244}Cm	Ci	1.31E-03	9.83E-04

Table B1.3. Tank S-112 Residual Waste Inventory Summary

Constituent of Concern	Units	2,700 gal Heel	6,000 gal heel	27,000 gal heel
Cr	kg	5.84E+01	1.30E+02	7.29E+02
Na	kg	2.19E+03	4.87E+03	3.12E+04
NO_2	kg	7.99E+02	1.78E+03	8.62E+03
NO_3	kg	1.86E+03	4.14E+03	3.54E+04
Total U	kg	6.69E+01	1.49E+02	2.26E+02
^{14}C	Ci	9.56E-02	2.13E-01	2.91E+00
^{60}Co	Ci	2.21E-02	4.94E-02	1.43E+00
^{63}Ni	Ci	1.16E+01	2.59E+01	4.98E+01
^{79}Se	Ci	8.71E-04	1.94E-03	3.47E-02
^{90}Sr	Ci	7.95E+03	1.77E+04	1.95E+04
^{90}Y	Ci	7.95E+03	1.77E+04	1.95E+04
^{99}Tc	Ci	8.53E-01	1.90E+00	1.68E+01
^{126}Sn	Ci	5.30E-03	1.18E-02	2.11E-01
^{129}I	Ci	1.65E-03	3.67E-03	3.24E-02
^{137}Cs	Ci	1.79E+03	3.98E+03	2.05E+04
^{137}mBa	Ci	1.69E+03	3.77E+03	1.94E+04
^{233}U	Ci	3.44E-02	7.67E-02	1.16E-01
^{234}U	Ci	2.37E-02	5.28E-02	8.01E-02
^{235}U	Ci	9.83E-04	2.19E-03	3.32E-03
^{236}U	Ci	6.55E-04	1.46E-03	2.22E-03
^{238}Pu	Ci	1.59E-01	3.54E-01	8.44E-01
^{238}U	Ci	2.23E-02	4.97E-02	7.54E-02
^{239}Pu	Ci	1.20E+01	2.67E+01	4.54E+01
^{240}Pu	Ci	1.71E+00	3.80E+00	6.92E+00
^{241}Am	Ci	4.71E-01	1.05E+00	1.09E+01
^{241}Pu	Ci	7.23E+00	1.61E+01	4.12E+01
^{242}Pu	Ci	4.62E-05	1.03E-04	2.94E-04
^{243}Am	Ci	7.41E-06	1.65E-05	3.31E-04
^{243}Cm	Ci	7.86E-05	1.75E-04	1.77E-04
^{244}Cm	Ci	5.21E-05	1.16E-04	1.64E-04

Table B1.4. Tank S-112 Retrieval Leak Loss Inventory Summary

Constituent of Concern	Units	4 kgal Retrieval Leak	8 kgal Retrieval Leak	40 kgal Retrieval Leak	80 kgal Retrieval Leak
Cr	Kg	3.97E+01	7.95E+01	3.97E+02	7.95E+02
Na	Kg	1.74E+03	3.48E+03	1.74E+04	3.48E+04
NO_2	Kg	4.54E+02	9.09E+02	4.54E+03	9.09E+03
NO_3	Kg	2.07E+03	4.14E+03	2.07E+04	4.14E+04
Total U	Kg	5.37E+00	1.07E+01	5.37E+01	1.07E+02
^{14}C	Ci	1.78E-01	3.56E-01	1.78E+00	3.56E+00
^{60}Co	Ci	9.13E-02	1.83E-01	9.13E-01	1.83E+00
^{63}Ni	Ci	1.63E+00	3.26E+00	1.63E+01	3.26E+01
^{79}Se	Ci	2.16E-03	4.33E-03	2.16E-02	4.33E-02
^{90}Sr	Ci	1.56E+02	3.11E+02	1.56E+03	3.11E+03
^{90}Y	Ci	1.56E+02	3.11E+02	1.56E+03	3.11E+03
^{99}Tc	Ci	9.88E-01	1.98E+00	9.88E+00	1.98E+01
^{126}Sn	Ci	1.31E-02	2.62E-02	1.31E-01	2.62E-01
^{129}I	Ci	1.90E-03	3.80E-03	1.90E-02	3.80E-02
^{137}Cs	Ci	1.09E+03	2.19E+03	1.09E+04	2.19E+04
^{137}mBa	Ci	1.04E+03	2.07E+03	1.04E+04	2.07E+04
^{233}U	Ci	2.77E-03	5.53E-03	2.77E-02	5.53E-02
^{234}U	Ci	1.90E-03	3.80E-03	1.90E-02	3.80E-02
^{235}U	Ci	7.91E-05	1.58E-04	7.91E-04	1.58E-03
^{236}U	Ci	5.28E-05	1.06E-04	5.28E-04	1.06E-03
^{238}Pu	Ci	3.30E-02	6.60E-02	3.30E-01	6.60E-01
^{238}U	Ci	1.79E-03	3.58E-03	1.79E-02	3.58E-02
^{239}Pu	Ci	1.29E+00	2.58E+00	1.29E+01	2.58E+01
^{240}Pu	Ci	2.13E-01	4.26E-01	2.13E+00	4.26E+00
^{241}Am	Ci	6.53E-01	1.31E+00	6.53E+00	1.31E+01
^{241}Pu	Ci	1.69E+00	3.37E+00	1.69E+01	3.37E+01
^{242}Pu	Ci	1.28E-05	2.55E-05	1.28E-04	2.55E-04
^{243}Am	Ci	2.08E-05	4.15E-05	2.08E-04	4.15E-04
^{243}Cm	Ci	4.73E-07	9.46E-07	4.73E-06	9.46E-06
^{244}Cm	Ci	3.41E-06	6.81E-06	3.41E-05	6.81E-05

B1.4.0 RETRIEVAL AND RESIDUAL INVENTORY CALCULATION METHOD FOR RETRIEVAL OF REMAINING S FARM TANKS

Water was used in the calculations as the retrieval liquid for all the S farm tanks because most of the tanks contain significant quantities of salt cake in addition to sludge. The amount of water calculated for retrieval was the amount required to result in both (1) a concentration of less than 5 M sodium and (2) 10 wt% solids or less in the retrieved waste. These limits were established to minimize the possible crystallization of sodium-rich salts in the waste transfer lines and to minimize problems transferring slurries.

Tank-specific water wash factors have been developed for each component in the waste and are documented in the *Best-Basis Wash and Leach Factor Analysis* (HNF-3157). These estimates were derived from a variety of sources, including analytical data; large-scale sludge washing experiments; thermodynamic solubility models; comparison of similar wastes; and the use of chemical analogs for certain chemicals and for most radionuclides. Separate wash factors do not exist for the salt cake and sludge portions of the solids currently in the tanks. The wash factors apply to the total solids. Therefore, the solids remaining after retrieval water is added to the S farm tanks will be the sum of each component times one minus the wash factor.

This method for determining residual waste inventories was chosen because it relies on the same data currently being used in the Hanford tank waste operations simulator model to simulate all of the tank farm retrieval operations. The Hanford tank waste operations simulator model is not only being used to model various retrieval scenarios, but to estimate the volume and composition of waste derived from each tank and the amount of high-level and low-activity waste glass produced from each batch of tank waste.

Residual sludge heels were assumed to be physically similar to the dry heels left in the C tank farm 200-series tanks, with a similar porosity. The average calculated heel porosity for the C tank farm 200-series tanks is 58.5%, meaning that the final heel will be 58.5% interstitial liquid and 41.5% washed solids. The 58.5% volume was calculated to be filled with retrieval liquid, contributing the final retrieval liquid concentrations of chemical and radionuclide constituents for the estimated volume.

Residual tank waste volumes evaluated included 10 m^3 (360 ft^3). This tank residual waste volume represent retrieval performance equal to the HFFACO interim retrieval goal of 360 ft^3. The residual waste solids were calculated for the 10 waste retrieval cases.

The conceptual model for final waste composition is similar to sand left in a bucket. Even with the bucket full of sand, it can still contain a certain additional volume of liquid. This is because there is space (interstitial volume) between the particles of sand. The calculation is designed to leave a sludge heel of some volume, saturated with either retrieval fluid or the final rinse fluid.

The estimating calculation method follows the following process.

1. Calculate the amount of liquid needed to make a 10 wt% solids slurry or a 5 M sodium solution with the amount of waste presently in the tanks.

2. Use the best-basis wash factor (a tank-specific value) to estimate the amount of solids that would dissolve into the total volume of retrieval fluid.

3. Calculate the retrieval fluid concentration. This is done by adding the three inventories (average supernate inventory [which is equal to the average supernate concentration times the amount of supernate introduced into the tank], the solids inventory fraction dissolved into the supernate [using best-basis wash factors], and inventory from liquid already in the tank [retrieved directly from BBI]) and dividing the sum by the total amount of liquid required to retrieve the tank.

4. Reduce (by ratio) the new calculated volume of solids (diminished by dissolution into the retrieval fluid) to the desired residual waste heel volume.

5. Using an assumed average porosity calculated from dry sludge in C farm 200-series tanks (assumed to be 58.5%) calculate the heel interstitial volume.

6. Using the final retrieval fluid concentration (calculated in step 3), calculate the heel inventory contribution of the final retrieval fluid filling the interstitial volume of the reduced heel volume (calculated in step 4).

7. If the final heel volume is calculated to be the HFFACO maximum allowable volume (which would leave approximately 2.54 cm [1 in.] of waste at the bottom of the tank) or less it is assumed that the heel would be washed to reduce inventory addition from the retrieval fluid (1:3 dilution). If the final heel volume calculated for is greater than that allowed by the HFFACO, the retrieval fluid filling the interstitial volume of the heel is left at full strength on the assumption that something would have gone wrong for the retrieval effort to be terminated early.

8. Final heel inventory is estimated as the sum of waste constituents calculated in step 4 plus the waste constituents from either step 6 or 7, depending on the final heel volume calculated for.

9. Retrieval leak loss inventory is found by multiplying the concentration of the retrieval fluid (calculated in step 3) times the volume leaked during retrieval.

This calculation method assumes that all the waste in the tank will be aggressively agitated to fully contact with the retrieval fluid during retrieval operations.

Table B1.5 presents the BBI inventories for the S farm tanks (except tanks S-112 and S-102). Table B1.6 presents estimated inventory in a 10,200 L (2,700 gal) wet sludge residual heel for S farm tanks (except tanks S-112 and S-102). Table B1.7 presents the estimated inventory loss to ground that would result from a 30,300 L (8,000 gal) leak during retrieval. Table B1.8 presents tank S-102 pre- and post-stabilization inventories. Tank S-102 residual waste inventory and retrieval leak inventories are presented separately due to the different methodology. Table B1.9 presents tank S-102 inventory estimates associated with a 10,200 L (2,700 gal) residual waste heel. Table B1.10 presents estimated inventory loss to ground of a 30,300 L (8,000 gal) leak loss volume for tank S-102.

Table B1.5. S Farm Non-Focus Tank Beginning Inventories

Analyte	S-101	S-103	S-104	S-105	S-106	S-107	S-108	S-109	S-110	S-111
Cr (kg)	1.9E+04	6.0E+03	4.3E+03	1.4E+04	1.3E+04	8.6E+03	1.3E+04	7.7E+03	1.7E+04	1.2E+04
Na (kg)	4.0E+05	2.7E+05	2.2E+05	5.8E+05	5.0E+05	2.1E+05	5.5E+05	7.0E+05	4.7E+05	4.4E+05
NO_2 (kg)	1.3E+05	8.3E+04	4.7E+04	1.4E+05	6.2E+04	7.5E+04	1.3E+05	5.3E+04	6.6E+04	9.0E+04
NO_3 (kg)	4.3E+05	3.4E+05	3.5E+05	7.6E+05	8.6E+05	1.4E+05	7.2E+05	1.5E+06	7.0E+05	5.1E+05
U(total) (kg)	1.2E+04	8.1E+02	1.2E+04	2.0E+03	7.8E+02	1.7E+04	2.0E+03	4.6E+02	8.2E+03	4.5E+02
^{14}C (Ci)	3.2E+01	3.3E+01	1.6E+00	4.2E+01	4.8E+01	1.3E+01	5.4E+01	6.2E+01	3.9E+01	5.0E+01
^{60}Co (Ci)	3.4E+01	1.7E+02	6.7E+00	4.2E+01	8.1E+01	3.2E+02	6.5E+02	7.1E+01	4.2E+01	5.0E+01
^{63}Ni (Ci)	8.8E+02	2.0E+02	9.7E+02	3.0E+02	5.2E+02	5.9E+02	6.3E+02	6.0E+02	7.0E+02	8.9E+02
^{79}Se (Ci)	5.2E+00	2.8E+00	4.4E+00	4.6E+00	6.4E+00	1.7E+00	7.3.E+00	7.2E+00	3.9E+00	5.2E+00
^{90}Sr (Ci)	6.9E+05	4.0E+04	5.5E+05	2.7E+05	4.0E+04	4.0E+05	6.4E+04	5.9E+04	3.7E+05	4.4E+05
^{90}Y (Ci)	6.9E+05	4.0E+04	5.5E+05	2.7E+05	4.0E+04	4.0E+05	6.4E+04	5.9E+04	3.7E+05	4.4E+05
^{99}Tc (Ci)	2.3E+02	1.9E+02	4.4E+01	3.0E+02	2.3E+02	9.3E+01	2.5E+02	3.6E+02	2.8E+02	3.3E+02
^{126}Sn (Ci)	7.9E+00	4.3E+00	6.8E+00	7.0E+00	9.7E+00	2.7E+00	1.1E+01	1.1E+01	5.9E+00	7.9E+00
^{129}I (Ci)	4.4E-01	3.7E-01	1.2E-01	5.8E-01	4.5E-01	1.8E-01	4.8E-01	6.9E-01	5.4E-01	6.4E-01
^{137}Cs (Ci)	3.6E+05	2.5E+05	1.1E+05	4.5E+05	2.7E+05	2.1E+05	3.6E+05	1.9E+05	2.8E+05	3.7E+05
^{137}mBa (Ci)	3.4E+05	2.4E+05	1.0E+05	4.3E+05	2.6E+05	2.0E+05	3.4E+05	3.3E+05	2.6E+05	3.5E+05
^{233}U (Ci)	3.4E+00	1.0E+00	3.3E-01	1.2E+00	1.8E-01	4.2E-01	1.1E+00	1.8E-01	3.3E+00	2.3E-01
^{234}U (Ci)	4.3E+00	3.0E-01	4.2E+00	7.2E-01	2.7E-01	7.0E+00	7.2E-01	1.6E-01	2.9E+00	1.6E-01
^{235}U (Ci)	1.8E-01	1.2E-02	1.7E-01	3.0E-02	1.1E-02	2.8E-01	3.0E-02	6.8E-03	1.2E-01	6.6E-03
^{236}U (Ci)	1.2E-01	9.3E-03	7.5E-02	2.0E-02	6.9E-03	3.6E-01	2.0E-02	4.3E-03	7.3E-02	4.3E-03
^{238}U (Ci)	4.1E+00	2.7E-01	4.1E+00	6.8E-01	2.6E-01	5.6E+00	6.7E-01	1.6E-01	2.7E+00	1.5E-01
^{238}Pu (Ci)	1.1E+01	4.5E+00	1.1E+01	1.5E+00	8.3E-01	7.4E+01	1.2E+01	1.5E+00	1.0E+01	5.2E-01
^{239}Pu (Ci)	6.6E+02	1.8E+02	4.2E+02	6.1E+01	4.4E+01	1.8E+03	4.8E+02	6.8E+01	6.0E+02	2.7E+01
^{240}Pu (Ci)	9.7E+01	2.9E+01	8.3E+01	9.8E+00	6.5E+00	3.2E+02	7.9E+01	1.0E+01	8.8E+01	4.1E+00
^{241}Pu (Ci)	6.7E+02	3.0E+02	4.6E+02	1.0E+02	5.0E+01	4.0E+03	8.0E+02	9.1E+01	6.1E+02	3.2E+01
^{242}Pu (Ci)	3.1E-03	1.6E-03	6.6E-03	5.3E-04	2.4E-04	2.3E-02	4.3E-03	4.6E-04	2.9E-03	1.6E-04
^{241}Am (Ci)	1.4E+02	1.3E+02	7.5E+01	7.5E+01	1.6E+01	3.2E+01	2.2E+02	6.9E+00	1.1E+02	1.2E+01
^{243}Am (Ci)	4.7E-03	4.6E-03	2.3E-03	2.0E-03	4.9E-04	1.2E-03	6.0E-03	2.0E-04	3.6E-03	3.6E-04
^{243}Cm (Ci)	2.0E-02	3.2E-02	1.5E-03	1.2E-02	2.8E-03	1.1E-02	3.7E-02	1.2E-03	2.5E-02	2.3E-03
^{244}Cm (Ci)	1.8E-01	3.1E-01	1.2E-03	1.3E-01	3.1E-02	1.6E-01	4.0E-01	1.4E-02	2.4E-01	2.4E-02

Table B1.6. S Farm Non-Focus Tank Inventories for 2,700 gal Residual Waste Heel

Analyte	S-101	S-103	S-104	S-105	S-106	S-107	S-108	S-109	S-110	S-111
Cr (kg)	9.0E+01	3.9E+02	3.5E+01	1.1E+03	7.3E+02	1.0E+02	6.4E+02	1.8E+02	4.1E+02	1.1E+02
Na (kg)	7.6E+02	3.9E+02	6.0E+02	8.7E+01	6.4E+02	3.5E+02	6.1E+02	1.6E+03	3.8E+02	7.5E+02
NO_2 (kg)	7.0E+00	1.1E+02	2.3E+01	4.8E+02	5.4E+01	5.7E+01	1.0E+02	3.7E+01	5.6E+01	7.5E+01
NO_3 (kg)	2.3E+02	4.7E+02	1.7E+02	3.2E+02	8.5E+02	1.1E+02	6.2E+02	1.3E+03	6.3E+02	4.3E+02
U(total) (kg)	9.0E+01	9.1E+01	1.0E+02	1.0E+02	7.4E+01	2.8E+02	1.6E+02	7.0E+01	3.3E+02	4.6E+00
^{14}C (Ci)	8.5E-03	2.1E-03	5.0E-04	2.7E-05	3.8E-05	7.8E-03	3.7E-05	3.7E-01	3.2E-05	2.1E-02
^{60}Co (Ci)	2.5E-01	1.3E+01	5.7E-02	6.6E+00	8.3E+00	5.2E+00	5.5E+01	1.0E+01	1.8E+00	6.5E-01
^{63}Ni (Ci)	6.5E+00	1.5E+01	8.2E+00	4.8E+01	5.4E+01	9.6E+00	5.3E+01	7.2E+01	3.0E+01	1.2E+01
^{79}Se (Ci)	4.9E-03	3.9E-06	2.2E-06	2.9E-06	4.7E-02	2.6E-04	2.5E-02	6.9E-03	6.9E-03	2.9E-03
^{90}Sr (Ci)	5.1E+03	1.7E+03	4.7E+03	2.1E+04	3.1E+03	6.7E+03	4.1E+03	9.1E+03	1.2E+04	6.1E+03
^{90}Y (Ci)	5.1E+03	1.7E+03	4.7E+03	2.1E+04	3.1E+03	6.7E+03	4.1E+03	9.1E+03	1.2E+04	6.1E+03
^{99}Tc (Ci)	1.5E-01	2.7E-04	3.2E-02	1.3E+01	1.7E+00	1.3E-01	1.6E+00	3.2E+01	9.0E-01	1.2E+00
^{126}Sn (Ci)	5.4E-02	2.8E-01	5.8E-02	1.1E+00	9.9E-01	4.0E-02	9.3E-01	1.5E+00	2.5E-01	8.2E-02
^{129}I (Ci)	3.3E-03	5.1E-07	5.7E-04	3.6E-07	3.5E-07	1.7E-03	3.3E-07	4.0E-07	4.4E-07	5.1E-07
^{137}Cs (Ci)	8.0E+01	3.5E-01	1.1E+02	1.5E+04	1.0E+03	8.1E+02	1.2E+03	4.0E+00	2.3E-01	1.6E+03
^{137}mBa (Ci)	7.6E+01	3.3E-01	1.1E+02	1.4E+04	9.6E+02	7.7E+02	1.1E+03	2.7E+01	2.1E-01	1.5E+03
^{233}U (Ci)	2.5E-02	7.6E-02	2.8E-03	1.8E-01	1.7E-02	7.0E-03	8.9E-02	2.8E-02	1.3E-01	2.3E-03
^{234}U (Ci)	3.2E-02	2.2E-02	3.6E-02	1.1E-01	2.6E-02	1.2E-01	5.7E-02	2.5E-02	1.2E-01	1.6E-03
^{235}U (Ci)	9.1E-04	9.1E-04	1.5E-03	4.7E-03	1.1E-03	4.6E-03	2.3E-03	1.0E-03	4.9E-03	6.6E-05
^{236}U (Ci)	1.3E-03	7.0E-04	6.4E-04	3.1E-03	6.5E-04	6.0E-03	1.6E-03	6.6E-04	2.9E-03	4.4E-05
^{238}U (Ci)	3.0E-02	2.0E-02	3.5E-02	1.1E-01	2.5E-02	9.2E-02	5.3E-02	2.3E-02	1.1E-01	1.5E-03
^{238}Pu (Ci)	8.5E-02	3.4E-01	9.6E-02	2.4E-01	8.5E-02	1.2E+00	1.0E+00	2.2E-01	4.3E-01	6.7E-03
^{239}Pu (Ci)	4.9E+00	1.3E+01	3.7E+00	9.5E+00	4.5E+00	2.9E+01	4.0E+01	1.0E+01	2.6E+01	3.5E-01
^{240}Pu (Ci)	7.2E-01	2.2E+00	7.1E-01	1.5E+00	6.7E-01	5.2E+00	6.6E+00	1.6E+00	3.7E+00	5.3E-02
^{241}Pu (Ci)	4.9E+00	2.2E+01	3.9E+00	1.5E+01	5.1E+00	6.6E+01	6.7E+01	1.4E+01	2.6E+01	4.2E-01
^{242}Pu (Ci)	2.3E-05	1.2E-04	5.6E-05	8.3E-05	2.4E-05	3.8E-04	3.6E-04	6.9E-05	1.2E-04	2.1E-06
^{241}Am (Ci)	1.1E+00	1.0E+01	6.3E-01	1.2E+01	1.7E+00	5.3E-01	1.8E+01	1.0E+00	4.7E+00	1.6E-01
^{243}Am (Ci)	3.5E-05	3.5E-04	2.0E-05	3.1E-04	5.0E-05	2.0E-05	5.0E-04	3.0E-05	1.5E-04	4.9E-06
^{243}Cm (Ci)	1.3E-04	2.1E-03	1.2E-05	4.2E-05	1.4E-04	1.7E-04	1.5E-03	3.9E-05	5.3E-04	2.3E-05
^{244}Cm (Ci)	1.1E-03	2.1E-02	9.9E-06	4.7E-04	1.6E-03	2.3E-03	1.7E-02	4.3E-04	5.1E-03	2.4E-04

Table B1.7. S Farm Non-Focus Tank 8,000 gal Retrieval Leak Loss Inventories

Analyte	S-101	S-103	S-104	S-105	S-106	S-107	S-108	S-109	S-110	S-111
Cr (kg)	3.4E+01	1.1E+01	6.2E-01	4.4E+01	4.2E+01	1.9E+01	3.8E+01	3.3E+01	5.8E+01	3.2E+01
Na (kg)	1.5E+03	3.6E+02	7.3E+02	3.5E+03	3.5E+03	1.5E+03	3.5E+03	3.5E+03	3.5E+03	3.1E+03
NO_2 (kg)	6.1E+02	1.1E+03	2.2E+02	8.4E+02	4.3E+02	5.8E+02	8.4E+02	2.7E+02	4.9E+02	6.7E+02
NO_3 (kg)	2.0E+03	4.5E+03	1.6E+03	4.6E+03	6.0E+03	1.1E+03	4.6E+03	7.4E+03	5.1E+03	3.8E+03
U(total) (kg)	4.2E-02	4.7E-03	6.1E-04	3.0E-10	4.7E-01	0.0E+00	8.4E-01	5.4E-02	4.2E+00	9.0E-01
^{14}C (Ci)	1.4E-01	4.3E-01	7.2E-03	2.6E-01	3.4E-01	9.8E-02	3.4E-01	3.0E-01	2.9E-01	3.6E-01
^{60}Co (Ci)	0.0E+00	6.7E-02	1.0E-05	9.2E-04	8.4E-03	3.3E-02	4.4E-03	2.4E-02	3.3E-04	2.1E-02
^{63}Ni (Ci)	3.9E-02	9.5E-02	1.5E-03	6.7E-03	4.7E-02	6.1E-02	3.8E-02	6.8E-01	4.9E-02	1.6E-01
^{79}Se (Ci)	2.1E-02	3.7E-02	2.0E-02	2.8E-02	4.2E-02	1.3E-02	4.5E-02	3.6E-02	2.8E-02	3.7E-02
^{90}Sr (Ci)	0.0E+00	2.3E+02	1.9E+00	8.2E+02	7.2E+01	0.0E+00	9.5E+01	2.3E+00	6.3E+02	8.6E-01
^{90}Y (Ci)	0.0E+00	2.3E+02	1.9E+00	8.2E+02	7.2E+01	0.0E+00	9.5E+01	2.3E+00	6.3E+02	8.6E-01
^{99}Tc (Ci)	9.7E-01	2.6E+00	1.8E-01	1.3E+00	1.5E+00	6.6E-01	1.5E+00	7.7E-01	1.9E+00	1.8E+00
^{126}Sn (Ci)	2.8E-03	7.1E-03	6.3E-06	1.0E-04	1.4E-03	1.6E-03	3.3E-04	7.5E-03	2.1E-04	1.5E-02
^{129}I (Ci)	0.0E+00	5.0E-03	2.2E-04	3.5E-03	3.1E-03	5.9E-04	3.1E-03	3.5E-03	4.0E-03	4.8E-03
^{137}Cs (Ci)	1.6E+03	3.4E+03	4.4E+02	2.2E+03	1.8E+03	1.3E+03	2.2E+03	9.7E+02	2.0E+03	1.9E+03
^{137}mBa (Ci)	1.5E+03	3.2E+03	4.2E+02	2.0E+03	1.7E+03	1.2E+03	2.1E+03	1.7E+03	1.9E+03	1.8E+03
^{233}U (Ci)	1.2E-05	5.8E-06	1.6E-08	1.7E-13	1.1E-04	0.0E+00	4.7E-04	2.1E-05	1.7E-03	4.6E-04
^{234}U (Ci)	1.5E-05	1.7E-06	2.1E-07	1.1E-13	1.6E-04	0.0E+00	3.0E-04	1.9E-05	1.5E-03	3.2E-04
^{235}U (Ci)	6.2E-07	6.9E-08	8.5E-09	4.5E-15	6.8E-06	0.0E+00	1.2E-05	7.9E-07	6.2E-05	1.3E-05
^{236}U (Ci)	4.0E-07	5.3E-08	3.7E-09	3.0E-15	4.1E-06	0.0E+00	8.4E-06	5.0E-07	3.7E-05	8.8E-06
^{238}U (Ci)	1.4E-05	1.6E-06	2.0E-07	1.0E-13	1.6E-04	0.0E+00	2.8E-04	1.8E-05	1.4E-03	3.0E-04
^{238}Pu (Ci)	2.1E-05	3.8E-04	2.9E-05	1.1E-04	1.2E-04	3.2E-04	1.2E-03	2.5E-04	1.2E-03	2.2E-04
^{239}Pu (Ci)	1.2E-03	1.5E-02	1.1E-03	4.3E-03	6.2E-03	7.7E-03	4.7E-02	1.2E-02	7.3E-02	1.1E-02
^{240}Pu (Ci)	1.7E-04	2.4E-03	2.2E-04	6.9E-04	9.1E-04	1.4E-03	7.8E-03	1.8E-03	1.1E-02	1.7E-03
^{241}Pu (Ci)	1.2E-03	2.5E-02	1.2E-03	7.1E-03	6.9E-03	1.8E-02	7.8E-02	1.6E-02	7.3E-02	1.4E-02
^{242}Pu (Ci)	5.6E-09	1.4E-07	1.7E-08	3.8E-08	3.3E-08	1.0E-07	4.2E-07	8.0E-08	3.4E-07	6.7E-08
^{241}Am (Ci)	2.6E-04	2.8E-03	3.7E-06	1.1E-11	1.9E-03	0.0E+00	1.7E-02	1.0E-03	1.1E-02	1.8E-03
^{243}Am (Ci)	8.4E-09	9.5E-08	1.1E-10	3.0E-16	5.8E-08	0.0E+00	4.7E-07	2.9E-08	3.5E-07	5.7E-08
^{243}Cm (Ci)	1.2E-05	5.2E-05	4.0E-07	6.9E-05	9.8E-06	8.5E-06	1.2E-04	5.0E-06	9.3E-05	4.6E-06
^{244}Cm (Ci)	1.1E-04	5.1E-04	3.2E-07	7.7E-04	1.1E-04	1.2E-04	1.3E-03	5.5E-05	8.9E-04	4.8E-05

Table B1.8. Pre- and Post-Stabilization Inventories for Tank S-102

Constituent of Concern	Units	Pre-Stabilization Inventory	Post-Stabilization Inventory
Cr	kg	4.73E+03	2.53E+03
Na	kg	3.64E+05	1.88E+05
NO_2	kg	8.84E+04	4.62E+04
NO_3	kg	1.00E+06	7.43E+05
Total U	kg	4.95E+03	4.24E+03
^{14}C	Ci	4.78E+01	2.40E+01
^{60}Co	Ci	1.76E+01	8.82E+00
^{63}Ni	Ci	2.75E+02	1.81E+02
^{79}Se	Ci	3.88E-01	1.96E-01
^{90}Sr	Ci	9.29E+04	7.66E+04
^{90}Y	Ci	9.29E+04	7.66E+04
^{99}Tc	Ci	2.18E+02	1.10E+02
^{126}Sn	Ci	2.35E+00	1.19E+00
^{129}I	Ci	6.81E-01	3.42E-01
^{137}Cs	Ci	2.55E+05	1.32E+05
^{137m}Ba	Ci	2.41E+05	1.25E+05
^{233}U	Ci	5.80E+00	4.98E+00
^{234}U	Ci	1.81E+00	1.55E+00
^{235}U	Ci	7.36E-02	6.31E-02
^{236}U	Ci	5.64E-02	4.83E-02
^{238}Pu	Ci	2.97E+00	1.52E+00
^{238}U	Ci	1.65E+00	1.42E+00
^{239}Pu	Ci	1.15E+02	5.89E+01
^{240}Pu	Ci	1.91E+01	9.78E+00
^{241}Am	Ci	1.50E+01	8.99E+00
^{241}Pu	Ci	1.50E+02	7.67E+01
^{242}Pu	Ci	1.14E-03	5.83E-04
^{243}Am	Ci	4.20E-03	2.15E-03
^{243}Cm	Ci	2.42E-02	1.24E-02
^{244}Cm	Ci	2.18E-01	1.11E-01

Table B1.9. Tank S-102 Case Residual Waste Inventory Summary

Constituent	2,700 gal heel
Cr (kg)	8.67E+00
Na (kg)	3.13E+02
NO2 (kg)	1.05E+02
NO3 (kg)	1.29E+04
Total U (kg)	9.44E+01
14C (Ci)	4.03E-03
60Co (Ci)	6.34E-04
63Ni (Ci)	2.35E+00
79Se (Ci)	8.57E-05
90Sr (Ci)	1.61E+03
90Y (Ci)	1.61E+03
99Tc (Ci)	2.82E-02
126Sn (Ci)	5.26E-04
129I (Ci)	5.44E-05
137Cs (Ci)	2.39E+02
137mBa (Ci)	2.27E+02
233U (Ci)	1.11E-01
234U (Ci)	3.46E-02
235U (Ci)	1.40E-03
236U (Ci)	1.07E-03
238Pu (Ci)	1.92E-03
238U (Ci)	3.16E-02
239Pu (Ci)	7.49E-02
240Pu (Ci)	1.24E-02
241Am (Ci)	7.95E-02
241Pu (Ci)	9.72E-02
242Pu (Ci)	7.41E-07
243Am (Ci)	2.72E-06
243Cm (Ci)	1.57E-05
244Cm (Ci)	1.41E-04

Table B1.10. Tank S-102 Case Retrieval Leak Loss Inventory Summary

Constituent	8,000 gal Retrieval Leak
Cr (kg)	1.76E+01
Na (kg)	1.31E+03
NO_2 (kg)	3.23E+02
NO_3 (kg)	5.12E+03
Total U (kg)	2.91E+01
^{14}C (Ci)	1.68E-01
^{60}Co (Ci)	6.18E-02
^{63}Ni (Ci)	1.25E+00
^{79}Se (Ci)	1.37E-03
^{90}Sr (Ci)	5.25E+02
^{90}Y (Ci)	5.25E+02
^{99}Tc (Ci)	7.67E-01
^{126}Sn (Ci)	8.30E-03
^{129}I (Ci)	2.39E-03
^{137}Cs (Ci)	9.24E+02
^{137}mBa (Ci)	8.72E+02
^{233}U (Ci)	3.41E-02
^{234}U (Ci)	1.06E-02
^{235}U (Ci)	4.32E-04
^{236}U (Ci)	3.31E-04
^{238}Pu (Ci)	1.06E-02
^{238}U (Ci)	9.70E-03
^{239}Pu (Ci)	4.12E-01
^{240}Pu (Ci)	6.84E-02
^{241}Am (Ci)	6.24E-02
^{241}Pu (Ci)	5.37E-01
^{242}Pu (Ci)	4.08E-06
^{243}Am (Ci)	1.50E-05
^{243}Cm (Ci)	8.68E-05
^{244}Cm (Ci)	7.79E-04

B1.5.0 REFERENCES

BBI, 2000, *Best Basis Inventory*, August 1, 2000 inventory access at http://twins.pnl.gov:8001/data/datamenu.htm in December 2000.

BHI-01496, 2001, *Groundwater/Vadose Zone Integration Project – Hanford Soil Inventory*, Rev. 0, Bechtel Hanford, Inc., Richland, Washington.

DOE/RL-98-72, 1999, *Retrieval Performance Evaluation Methodology for the AX Tank Farm*, U.S. Department of Energy, Richland Operations Office, 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.

HNF-3157, 1999, *Best-Basis Wash and Leach Factor Analysis*, Rev. 0A, COGEMA Engineering Corporation, Richland, Washington.

HNF-EP-0182, 2000, *Waste Tank Summary Report for Month Ending September 30, 2000*, Rev. 150, CH2M HILL Hanford Group, Inc., Richland, Washington.

Perry, J.H., 1963, *Chemical Engineers' Handbook*, Fourth Edition, McGraw-Hill Book Company, New York, New York.