**This document was too large to scan as a single document. It has been divided into smaller sections.**

**Section 2 OF 2**

| Document Information | | | |
|---|---|---|---|
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**Attachment 3**
**04-TPD-092**

**RPP-19775, Attachment D-12 Single-Shell Tank 241-S-112**
**Component Closure Activity, Revison 1**

(Consisting of 33 pages,
including coversheet)

RPP-19775
Revision 1

# ATTACHMENT D-12
# SINGLE-SHELL TANK 241-S-112 COMPONENT CLOSURE ACTIVITY PLAN

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# PREFACE

This *Single-Shell Tank 241-S-112 Component Closure Activity Plan* is being submitted to the State of Washington, Department of Ecology (Ecology), under the provisions of the *Resource Conservation and Recovery Act of 1976* (RCRA), the *Revised Code of Washington,* Chapter 70.105, "Hazardous Waste Management Act of 1976" (RCW 70.105), and applicable requirements thereunder. Consequently, this plan addresses hazardous and dangerous wastes only (as defined by these statutes and regulations) and does not address waste classification determinations and radioactive waste-specific closure actions that the U.S. Department of Energy (DOE) may take under the *Atomic Energy Act of 1954* (AEA). To the extent that this plan provides data or discussions about materials regulated under the AEA, that information is provided for informational purposes only.

This component closure activity plan is one of a series of closure plan documents that collectively comprise the *Single-Shell Tank System Closure Plan.* Revision 0 of the *Single-Shell Tank System Closure Plan* (RPP-13774a) was initially submitted to Ecology on December 19, 2002, pursuant to the *Hanford Federal Facility Agreement and Consent Order* Milestone M-45-06A (Ecology et al. 1989). After submittal of Revision 0, the United States District Court, District of Idaho, issued a Judgment in *Natural Resources Defense Council, et al., v. Spencer Abraham, et al.*, Civ. No. 01-0413-S-BLW (July 3, 2003) holding invalid certain portions of DOE O 435.1, *Radioactive Waste Management*, relating to waste incidental to reprocessing. On August 27, 2003, DOE appealed this judgment to the U. S. Circuit Court of Appeals for the Ninth Circuit. This component closure activity plan does not address the waste incidental to the reprocessing evaluation process described in DOE O 435.1, and its accompanying Guidance and Manual. Revisions 1 and 2 (RPP-13774b) were later submitted in response to review comments submitted by Ecology and subsequent comment resolution.

The timing of certain actions contemplated in this closure activity plan, such as mixing grout with residual wastes during the closure process, may require decisions that must be made under the AEA and/or in accordance with other applicable requirements. Accordingly, even where apparently mandatory phrases such as "DOE will…" are used in this plan, the actions these phrases refer to are conditional and based on the successful completion of required precursor actions that may be affected by the outcome of the litigation referred to above. No irreversible final closure actions will be taken for the RCRA purposes discussed in this plan unless and until they are shown to be consistent with the radioactive waste management requirements DOE must address under the AEA, DOE orders, and any other applicable requirements. As a specific example, grout will not be added to stabilize tank residual wastes for RCRA purposes unless and until DOE has determined that the waste characteristics of the residuals are suitable for addition of grout in the tank under applicable requirements and Ecology has issued the appropriate permits. In some cases, the paths forward to make the radioactive waste determinations are still under development and may impact schedule dates contemplated in this plan.

RPP-13774b describes the process for closure of 149 single-shell tanks at the Hanford Site, Washington, including the tanks themselves, ancillary equipment, contaminated soil, and contaminated groundwater, in accordance with the requirements of applicable laws and regulations. The *Single-Shell Tank System Closure Plan* consists of three main documents that

are arranged in a hierarchy. The highest-level document (Tier 1) addresses closure topics and issues pertaining to the single-shell tank system. Mid-level documents (Tier 2) address specific groupings of one or more single-shell tank farms known as Waste Management Areas (WMA). The lowest level documents in the hierarchy (Tier 3) address closure activities for specific components within a particular WMA. Tier 2 and 3 level documents will be submitted as separate documents to Ecology. The following summarizes the general content of the Tier 1, 2, and 3 documents that comprise the *Single-Shell Tank System Closure Plan*:

- Tier 1 – *Framework Plan for Single-Shell Tank System Closure:* Referred to as the "Framework Plan," this document is the main body of the text of RPP-13774b. It discusses the general overview of the single-shell tank system, describes the administrative and regulatory framework for single-shell tank closure, describes the process for incorporating Tier 2 and Tier 3 with soil and groundwater corrective actions, and provides single-shell tank closure performance standards, a risk evaluation, an overall closure schedule, and an overall description of the certification and post-closure process.

- Tier 2 – *Waste Management Area Closure Action Plans*: This tier consists of appendices to the Tier 1 Framework Plan, one for each of the seven single-shell tank farm WMAs at the Hanford Site. The seven WMAs include A-AX; B-BX-BY; C; S-SX; T; TX-TY; and U. Each WMA closure action plan will provide a general description of the WMA, a description of the WMA groundwater monitoring effort, a general description of closure activities, a risk evaluation for the WMA, a closure schedule for the WMA, and a description of the certification and post-closure process.

- Tier 3 – *Component Closure Activity Plans* (for specific WMA components): This tier of the *Single-Shell Tank System Closure Plan* consists of attachments to the Tier 2 *WMA Closure Action Plans* for components within a WMA. Each Tier 3 *Component Closure Activity Plan* describes closure activities for one or more components within each WMA, such as for individual single-shell tanks or pieces or groupings of ancillary equipment.

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241-S-112 SEPA Checklist

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# LIST OF TERMS

| | |
|---|---|
| AEA | *Atomic Energy Act of 1954* |
| CFR | *Code of Federal Regulations* |
| DOE | U.S. Department of Energy |
| DST | double-shell tank |
| ECN | engineering change notice |
| Ecology | Washington State Department of Ecology |
| EIS | Environmental Impact Statement |
| EPA | U.S. Environmental Protection Agency |
| HFFACO | *Hanford Federal Facility Agreement and Consent Order* |
| LDR | land disposal restrictions |
| RCRA | *Resource Conservation and Recovery Act of 1976* |
| RCW | *Revised Code of Washington* |
| RDR | retrieval data report |
| REDOX | reduction-oxidation |
| ROD | record of decision |
| RPP | River Protection Program |
| SAP | sampling and analysis plan |
| SEPA | *State Environmental Policy Act* |
| SST | single-shell tank |
| SST S-112 | single-shell tank 241-S-112 |
| TSD | treatment, storage, and disposal |
| WAC | *Washington Administrative Code* |
| WMA | Waste Management Area |

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# 1.0 INTRODUCTION

This document describes component closure activities for single-shell tank (SST) 241-S-112 (hereinafter referred to as SST S-112). SST S-112 is a tank containing mixed waste located in Waste Management Area (WMA) S-SX of the Hanford Site. SST S-112 will be closed as part of the accelerated retrieval and closure of SSTs in accordance with *Hanford Federal Facility Agreement and Consent Order* (HFFACO) Milestone M-45-00 (Ecology et al. 1989). This component closure activity plan will comply with regulatory requirements including, but not limited to, the HFFACO Milestones, *Washington Administrative Code* (WAC) 173-303, "Dangerous Waste Regulations," and the *Dangerous Waste Portion of the Resource Conservation and Recovery Act Permit for the Treatment, Storage, and Disposal of Dangerous Waste,* Rev. 7 (Ecology 2001), hereafter referred to as the "Site-Wide Permit."

"Closure of SST S-112 will follow retrieval of tank waste" and be achieved by the characterization of residual waste, tank isolation, and stabilization of the tank. Closure will comply with SST closure performance standards, including land disposal restrictions (LDR) set forth in WAC 173-303. Characterization of the tank contents will be performed by gathering in-tank measurements and analyses of residual solid waste after retrieval. After characterization, the tanks will be filled and stabilized with grout* or other structural material in layers. Isolation of tanks will be implemented and maintained with administrative controls. Closure performance standards will be implemented to minimize the need for further maintenance, control the post closure escape of tank waste to protect human health and the environment, and return land to appearance of surrounding land area.

The SST S-112 tank component closure activities will supplement knowledge on closure activities, regulatory processes, and provide lessons learned to accelerate future SST component and WMA closure actions. As additional components within WMA S-SX undergo closure activities, corresponding component closure activity plans will be developed as attachments to the *Waste Management Area S-SX Closure Action Plan* (RPP-19773), which is Appendix D to the *Single-Shell Tank System Closure Plan* (RPP-13774b). Each component closure activity plan will require a modification to the Site-Wide Permit. Closure decisions made under corrective actions for past practices (Part IV of the Site-Wide Permit) or a *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (1980) Record of Decision (ROD) will be approved through incorporation into the Site-Wide Permit.

This component activity closure plan summarizes retrieval of tank waste, tank characterization, the post-retrieval risk evaluation, efforts to isolate SST S-112 from the SST system and SST closure performance standards. Background information, conceptual tank stabilization, and general closure information for this tank are provided in RPP-19773.

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* See Preface.

## 1.1 PURPOSE

This plan identifies activities that will accomplish the component closure of SST S-112 conforming to the applicable requirements of WAC 173-303; HFFACO Milestones M-45-00 and M-45-06B; and Section 6 of the HFFACO.

### 1.1.1 Scope of Plan

The scope of this component closure activity plan is SST S-112, including tank risers, in-tank equipment, and debris. This plan does not include closure activities for any equipment or ancillary piping external to the tank, and does not include any corrective measures that may be needed for soil or groundwater contamination. Retrieval activities will have occurred for SST S-112 prior to modification of the Site-Wide Permit and approval of this closure plan. The plan for waste retrieval is described in the *Single Shell Tank S-112 Full Scale Saltcake Waste Retrieval Technology Demonstration Functions and Requirements* (RPP-7825). The *Process Control Plan for Saltcake Dissolution Retrieval Demonstration in Tank 241-S-112* (RPP-15085), describes the process and technical operating controls for waste retrieval and transfer of liquid wastes from the tanks to the double-shell tank (DST) system.

According to HFFACO Appendix I, retrieval and characterization results shall be described in the retrieval data report (RDR) for SST S-112. Upon completion of the work described in RPP-7825 (or the Appendix H request, as appropriate), the U.S. Department of Energy (DOE) will have met the retrieval goals set forth in Milestones M-45-00 and M-45-03C. Subsequent component closure activity plans and RPP-19773 will address the remaining components in the WMA S-SX. The SST S-112 component closure activities will not preclude future closure activities for other components.

Retrieval of SST waste constitutes a key SST system closure action. The SST S-112 retrieval actions have been approved through the HFFACO and scheduled, in advance, through HFFACO Milestone M-45 series. Since retrieval actions are significant closure actions, summaries of those actions will be provided in Section 3.0 when available.

The major component closure activities shall only occur after retrieval of as much waste as technically possible with tank waste residues not to exceed 360 $ft^3$ or the limit of waste retrieval technology capability, whichever is less in accordance with HFFACO Milestone M-45-00. The SST S-112 component closure activities identified will occur in phases pursuant to approval by the Washington State Department of Ecology (Ecology) of the Site-Wide Permit as follows:

- Retrieval of remaining waste to the extent technically possible in accordance with HFFACO Milestone M-45-00.
- Characterization of tank contents. These efforts will be documented in a retrieval data report (i.e., retrieval performance, sampling and analysis of residual waste, post-retrieval evaluation).
- Isolation of the tank.

- Grout* fill to form a monolith consisting of three phases designed to (1) cover the residuals and debris, (2) provide structural stabilization, and (3) fill the tank and risers to the top of the dome and provide a protective layer against inadvertent intrusion. Grout fill will contribute to treatment of the residual waste and debris and will provide the basis for a variance to LDR treatment standards.

HFFACO Milestone M-45-06A required DOE to "submit a certified (Framework) SST System Closure Plan as a Hanford site-wide hazardous waste facility permit modification" to Ecology by December 19, 2002. The milestone also requires DOE to include a characterization approach for residual wastes and a risk assessment methodology in the plan. These submittals were provided to Ecology. HFFACO Milestone M-45-06B required DOE to submit to Ecology "a certified SST S-112 component closure activity plan, by September 30, 2004, as an application for a modification to the Hanford site-wide hazardous waste facility permit...". In addition, a *State Environmental Policy Act* (SEPA) Checklist is being submitted concurrently with the application for modification of the Site-Wide Permit to support the SST S-112 component closure activities (*Revised Code of Washington*, Chapter 43.21C, "Washington State Environmental Policy Act" [RCW 43.21C]).

HFFACO Milestone M-45-03C required DOE to "complete full scale saltcake waste retrieval technology demonstration at SST S-112" by March 30, 2005. According to the milestone, waste is to be retrieved to the DST system to the limits of the technology (or technologies) selected. Additionally, selected saltcake retrieval technology (or technologies) must 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 goal of the demonstration will include the retrieval to safe storage of approximately 550 curies of mobile, long-lived radioisotopes and 99% of tank contents by volume.

HFFACO Milestone M-45-13 required DOE to attain "interim completion of tank S-112 SST waste retrieval and closure demonstration project" by December 31, 2005. The SST S-112 waste retrieval and closure demonstration project is considered interim complete when (1) full scale waste retrieval is completed in accordance with applicable regulatory requirements, including RCW 43.21C, requirements set by the HFFACO, and the approved SST S-112 saltcake waste retrieval technology functions and requirements (DOE is required to document project date and results in a waste retrieval and closure demonstration project report); (2) remaining wastes are adequately characterized and a risk assessment for residuals that remain in the tank is completed and is approved by Ecology; (3) the SST S-112 waste retrieval and closure demonstration plan is submitted by DOE and is approved by Ecology (i.e., incorporated into the Site-Wide Permit); and (4) if appropriate, DOE requests and Ecology approves an exception to waste retrieval criteria pursuant to HFFACO Appendix H.

HFFACO Milestone M-45-13-T01 required DOE to achieve "final completion of tank S-112 SST retrieval and closure demonstration project" by December 30, 2006. The completion of the SST S-112 retrieval and closure demonstration project is defined as the completion of necessary field project actions required by the approved SST S-112 waste retrieval and closure demonstration plan.

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* See Preface.

## 1.2 REGULATIONS AND STANDARDS APPLICABLE TO SST S-112 COMPONENT CLOSURE ACTIVITY

The SST S-112 retrieval and component closure activities are regulated by several requirements. Drivers include a state-federal agreement, federal and state statutes and regulations, and DOE directives and orders. A discussion of these requirements is contained in RPP-13774b.

Ecology regulates the SSTs as dangerous waste storage and treatment units under WAC 173-303, which implements RCRA. SST S-112 contains mixed waste and is included in the RCRA dangerous waste permit application, Part A, Form 3, submitted for the SST system.

### 1.2.1 SST Closure Performance Standards

The HFFACO requires that all treatment, storage, and disposal (TSD) units, regardless of permit status, be closed under WAC 173-303. DOE will close the SST system in compliance with the performance standards set out in WAC 173-303-610(2)(a) and -640(8). The activities described in this component closure activity plan are consistent with closure of the SST system in compliance with these performance standards. However, the SST S-112 component closure activities described in this plan will only partially meet the closure performance standards for the WMA S-SX and SST system (see RPP-13774b, Section 3.0). Full compliance with closure performance standards will occur for the WMA S-SX after all tanks are retrieved and closed, and ancillary equipment, contaminated soil, and groundwater are remediated. Isolation activities and subsequent placement of fill layers into SST S-112 will initiate the process of complying with the closure performance standards for the SST system.

According to HFFACO Milestone M-45-13-T01, "Completion of the tank S-112 retrieval and Closure demonstration project is defined as completion of necessary field project actions required by the approved S-112 waste retrieval and closure demonstration plan. Retrieval shall retrieve as much waste as technically possible, with a remaining residual of no more than 360 cubic feet (cu. ft.)." If the retrieval goal of 360 $ft^3$ is not met, DOE will request an exception to the criteria as specified in Appendix H of the HFFACO. This HFFACO requirement is one of the most significant tank-related performance standards. Retrieval of waste in accordance with these requirements, along with the other closure activities described in this plan, will make significant progress toward meeting closure performance standards at the WMA S-SX and the SST system.

The three general closure performance standards defined in WAC 173-303-610(2)(a) are described in this component closure activity plan in Sections 1.2.1.1 through 1.2.1.3. Removal or decontamination standards defined in WAC 173-303-610(2)(b) and WAC 173-303-640(8) are described in Section 1.2.2. In addition, LDR that pertain to WAC 173-303-140 and Title 40, *Code of Federal Regulations,* Part 268, "Land Disposal Restrictions" (40 CFR 268) are described in RPP-19773, Section 6.0.

**1.2.1.1 Minimize Need for Further Maintenance.** Component closure activities planned for SST S-112 are designed to minimize the maintenance required after the activities are complete. Waste will be retrieved from SST S-112 to meet HFFACO retrieval goals, and the tank will be isolated from the system. If the tank is filled as part of closure field activities, DOE will conduct

annual visual inspections of the tank farm surface in the tank vicinity. If the tank is not filled as part of closure field activities, DOE will conduct annual visual inspections of WMA S-SX surface in the tank vicinity and will continue to operate any existing liquid detection or monitoring device, i.e., Enraf[1]. Other activities, such as capping lines and risers, covering the tank, and providing run-on controls will serve to minimize the need for further maintenance.

**1.2.1.2 Control the Post-closure Escape of Tank Waste to Protect Human Health and the Environment.** SST S-112 will be retrieved to the extent technically possible in accordance with criteria set forth in Milestone M-45-00 and Appendix H of the HFFACO. Component closure activities will include stabilizing any remaining wastes, complete filling of the tank for structural integrity and intrusion prevention, and isolating SST S-112 from the SST system and the environment. Stabilization, filling, and intrusion prevention are described in RPP-19773, Section 6.0. Tank isolation activities will include administrative actions and physical actions sealing off all pipes or other pathways between SST S-112 and the balance of the SST system. All of these activities will serve to control the post-closure escape of remaining dangerous waste constituents. At a later point in the overall closure of the SST system, DOE will undertake final closure of WMA S-SX. Individual actions will be assessed for their impact on long-term cumulative risk (i.e., WMA S-SX together with other adjacent or nearby non-tank risk sources).

**1.2.1.3 Return Land to Appearance of Surrounding Land Areas.** This closure performance standard will be met as part of closure of WMA S-SX and is not a part of this SST S-112 tank component closure activity plan.

### 1.2.2 Removal or Decontamination Standards.

SST S-112 component closure activities will comply with WAC 173-303-610 (closure and post-closure) and WAC 173-303-640(8) (tank system closure and post-closure care) requirements. WAC 173-303-640(8)(a) requires DOE to demonstrate removal or decontamination of tank waste residuals and structures to the extent practicable. Per WAC 173-303-610(2)(b)(ii), such removal or decontamination must assure on a case-by-case basis that levels of dangerous waste or dangerous waste constituents or residues do not exceed those established by Ecology and in accordance with the closure performance standard of WAC 173-303-610(2)(a)(ii) for controlling, minimizing, or eliminating post-closure escape of dangerous waste constituents to the environment. These levels are identified as clean closure standards. F-HTWR-94-144, *Clean Closure Guidance* (Ecology 1994) states that clean closure decontamination levels for metal tanks are generally considered to be met upon meeting the performance treatment standards contained in 40 CFR 268.45, Table 1 (debris rule treatment standards).

WAC 173-303-640(8)(b) requires that, if removal and decontamination of all contaminated soils is not practicable, post-closure care must be performed. The owner or operator must close the tank system and perform post-closure care in accordance with the closure and post-closure care requirements that apply to landfills (WAC 173-303-665(6)).

[1] Enraf - Nonius Series 854 is a trademark of Enraf-Nonius, N.V. Verenigde Instrumentenfabrieken, Enraf-Nonius Corporation Netherlands, Rontegenweg 1, Delft, Netherlands.

WAC 173-303-640(8)(c) requires that the closure plan for any tank system that does not have secondary containment include a contingent closure and post-closure plan. Because SST S-112 closure activities described in this plan do not constitute full closure of the entire tank system (WMA S-SX), a contingent post-closure plan is not included as part of this SST S-112 component closure activity plan. Instead, the contingent post-closure plan will be submitted as part of RPP-19773, to which this plan is attached.

Retrieval and closure activities described in the plan and RPP-7825 will attempt to remove or decontaminate SST S-112 to the extent technically possible in accordance with HFFACO Milestone M-45-00 and to meet clean closure standards. Also, as part of this milestone, an RDR will be submitted to Ecology to demonstrate completion of retrieval in accordance with M-45-00. The tank closure environmental impact statement (EIS) under development will evaluate removal of a tank as a closure alternative.

Land use options available for tank system closure (including landfill and clean closure options) and the evaluation of environmental impacts for closure end-state alternatives will be addressed in the EIS during fiscal year 2005. Ecology, as a cooperating agency, will play a key role in this process.

# 2.0 SST S-112 UNIT DESCRIPTION

SST S-112 is one of twenty-seven 100-series SSTs located in WMA S-SX. SST S-112 is classified as a "sound" tank in the *Waste Tank Summary Report* (HNF-EP-0182). The "sound" tank classification is assigned to a tank when surveillance data indicates no loss of liquid attributed to a breach of integrity (HNF-EP-0182). A description of the 100-series tanks, inclusive of SST S-112, is provided in RPP-19773, Section 2.0. Figures 2-1 and 2-2 show the location of WMA S-SX and SST S-112, respectively. The configuration of SST S-112 (cross-section) is shown in Figure 2-3.

## 2.1 ANCILLARY EQUIPMENT AND SUPPORTING INFRASTRUCTURE

SST S-112 has two associated pipelines: a cascade line from SST S-111, and a transfer line to feed a new tank farm that was never constructed. This transfer line was capped in 1950. SST S-112 pipelines are discussed further in Section 5.1 with respect to isolation from the SST system.

SST S-112 also has risers of varying diameters and lengths of protrusion into the tank. The remaining risers contain various in-tank equipment (Table 2-1). (The risers are shown in Figure 5-1.)

Table 2-1. Riser Use Designation for SST S-112.

| Riser number [a] | Designation of use [a] |
|---|---|
| R1 | Connection nozzle |
| R2 | Camera, grouting, or ventilation |
| R3 | Camera, grouting, or ventilation; remove Enraf[b] |
| R4 | Camera, grouting, or ventilation; remove tank covers. |
| R5 | Saltwell screen and pump |
| R6 | Alternate risers for sampling |
| R7 | Alternate risers for sampling |
| R8 | Multiport adapter installed |
| R11 | Alternate riser |
| R14 | Alternate riser |
| R16 | Alternate riser |

Notes:

[a] Information taken from RPP-16795, 2003, *Engineering Evaluations of Interim Isolation of Hanford Single-Shell Tanks*, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington..

[b] Enraf™ - Nonius Series 854 is a trademark of Enraf-Nonius, N.V. Verenigde Instrumentenfabrieken, Enraf-Nonius Corporation Netherlands, Rontegenweg 1, Delft, Netherlands.

Risers were not numbered sequentially, thus R-9, R-10, R-12, R-13, and R-15 do not exist.

Figure 2-1. Location Map of WMA S-SX and Surrounding Facilities in the 200 West Area.

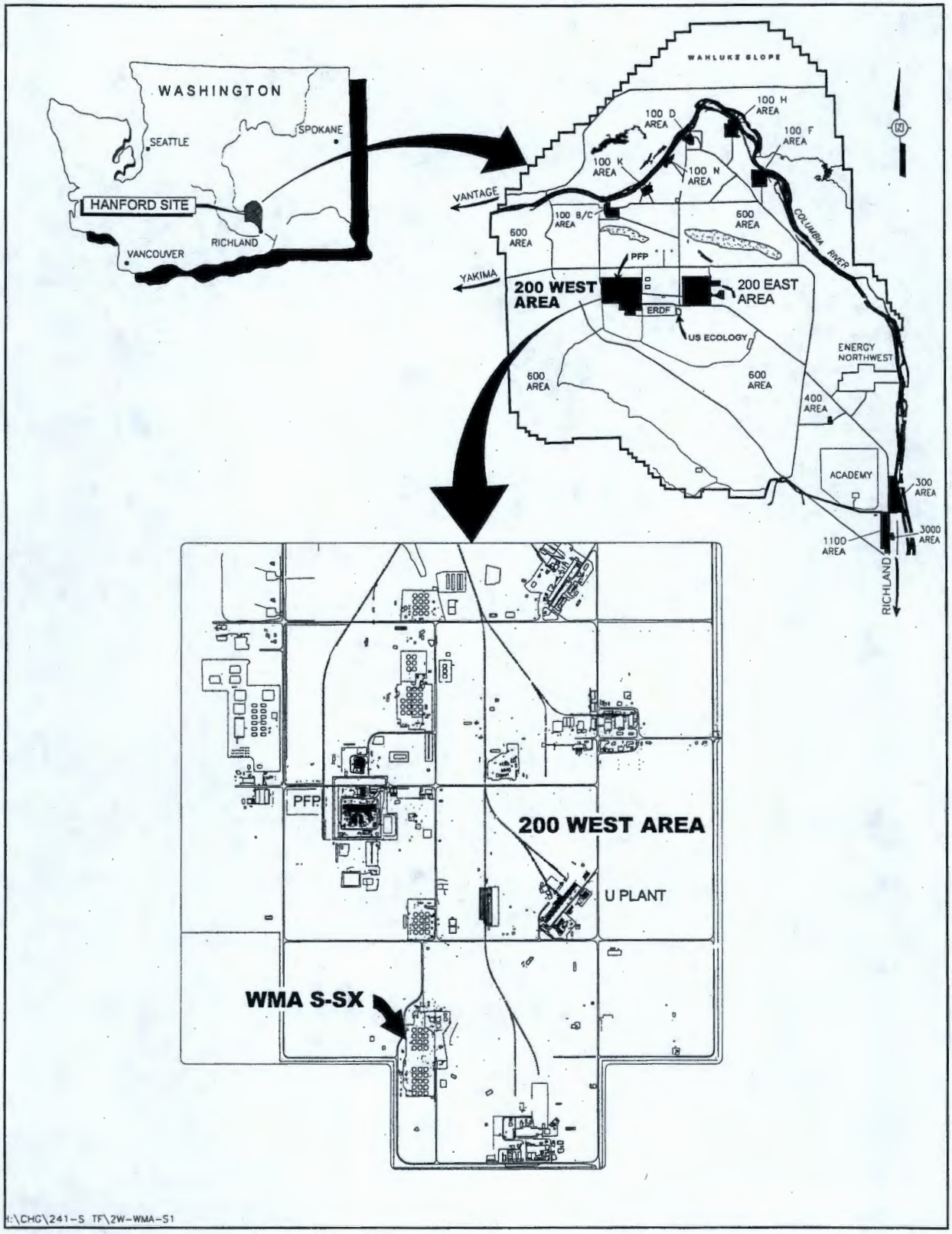


Figure 2-2. Location of SST S-112 within WMA S-SX.

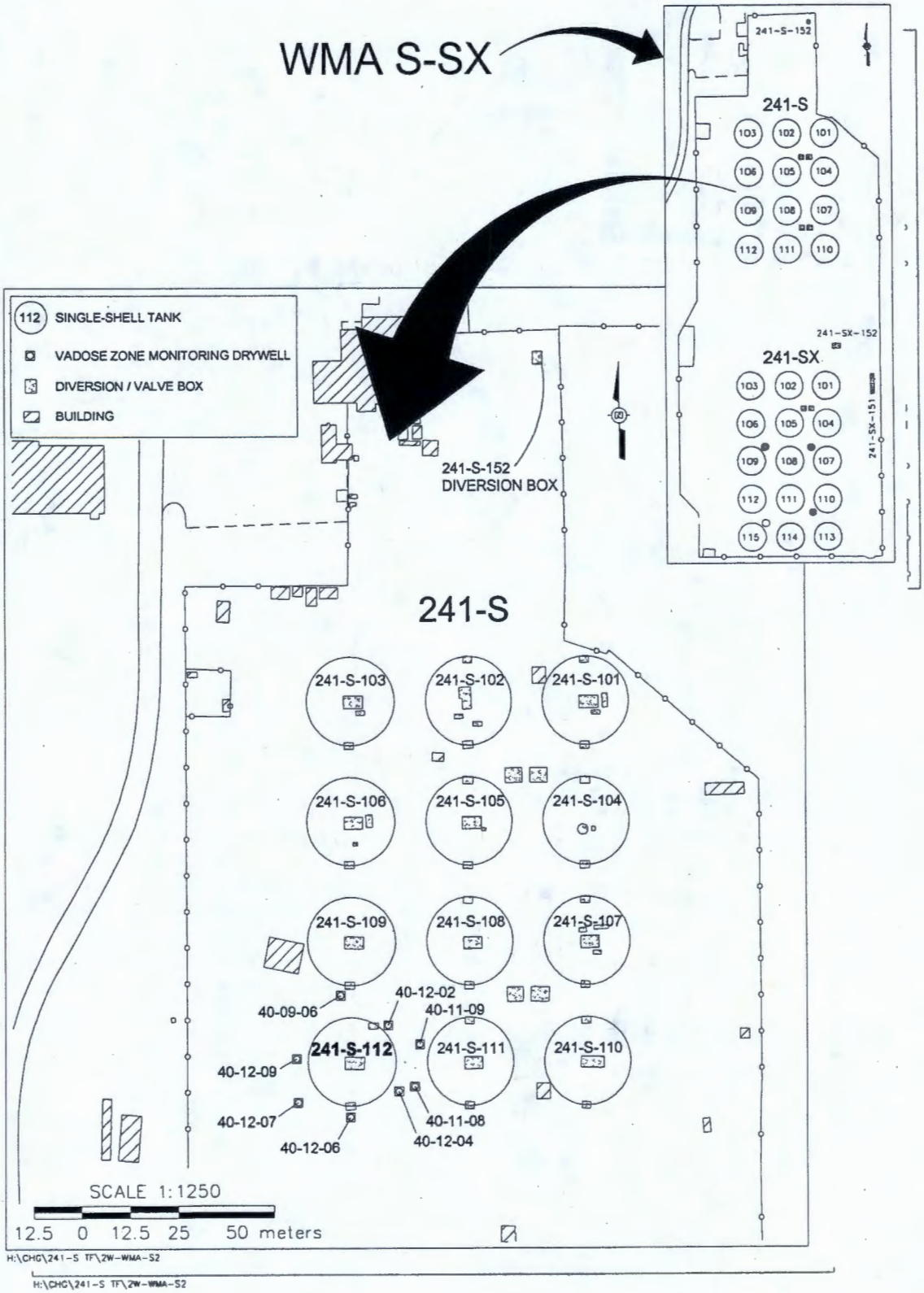
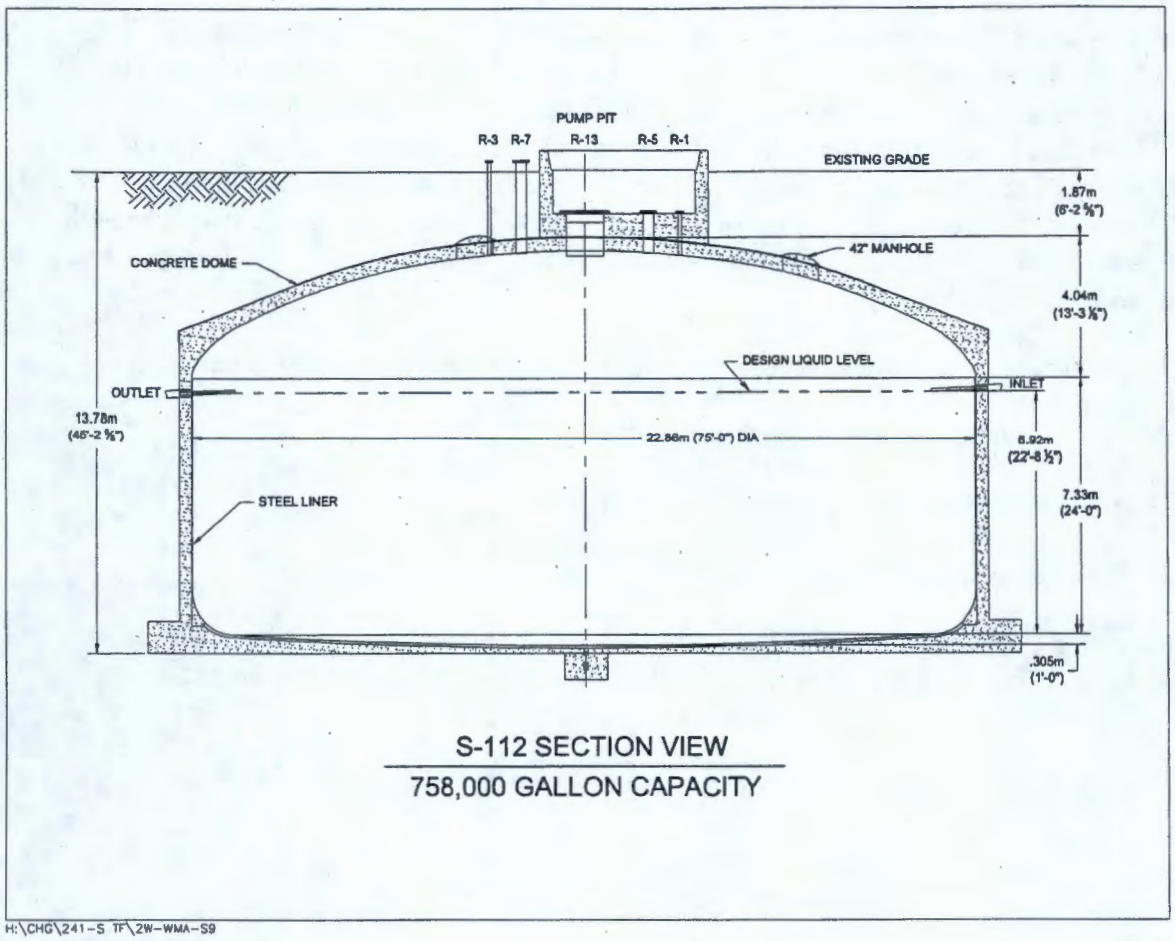


Figure 2-3. Configuration of SST S-112 (cross-section).




## 2.2 SST S-112 OPERATIONS HISTORY

SST S-112 was placed into service in the third quarter of 1952. SST S-112 received reduction-oxidation (REDOX) waste from the third quarter of 1952 until the fourth quarter of 1973. During the first quarter of 1974, the supernatant in SST S-112 was sent to SST S-102 as feed for the 242-S Evaporator. SST S-112 received 242-S Evaporator bottoms from the first quarter of 1974 until the fourth quarter of 1975. SST S-112 was removed from active service in 1976; no subsequent additions were made to the tank inventory (WHC-SD-WM-ER-352, *Historical Tank Content Estimate for the Southwest Quadrant of the Hanford 200 West Area*). SST S-112 was primary stabilized in 1979 and partially isolated in December 1982. Saltwell pumping was initiated in 1978 (GJ-HAN-81, *Vadose Zone Characterization Project at the Hanford Tank Farms, Tank Farm Summary Data Report for Tank S-112*).

# 3.0 SST S-112 RETRIEVAL AND CHARACTERIZATION

This section is a placeholder for a summary of SST S-112 retrieval and characterization efforts. SST S-112 retrieval is scheduled to be complete on October 5, 2005, and will be followed by period of sampling, analysis, and evaluation for compliance with Milestones M-45-00 and M-45-03C. A detailed description of SST S-112 retrieval and characterization (e.g., estimated volume and nature of the waste remaining) will be documented in an RDR according to HFFACO Appendix I, Section 2.1.7, "Retrieval Data Report." Data from the RDR will be used by Ecology and DOE in making WMA-, tank-, and component-specific closure decisions. The RDR will address the following:

- Residual tank waste volume measurement, including associated calculations
- Results of residual tank waste characterization
- Retrieval technology performance documentation
- DOE's updated post-retrieval risk assessment
- Discussion of feasibility/viability of other available retrieval technologies, the feasibility of developing additional retrieval technologies, associated detailed cost estimates, and amount of additional waste that could be removed
- Opportunities and actions being taken to refine or develop tank waste retrieval technologies, based on lessons learned
- Leak detection, monitoring, and mitigation performance results
- DOE's recommendation for further action and proposed schedule(s).

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# 4.0 CLOSURE RISK ASSESSMENT RESULTS

This section is a placeholder for a summary of the SST S-112 risk assessment. Estimates of the post-retrieval long-term risk associated with closure activities for SST S-112 will be prepared following the approach described for tank closure risk assessment described in RPP-19773, Section 7.0. Sampling and analysis conducted for the risk assessment will be performed in accordance with the WMA S-SX sampling and analysis plan (SAP), which will be Addendum D1 of RPP-19773. A detailed description of the risk assessment will be in the RDR.

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# 5.0 COMPONENT CLOSURE ACTIVITIES

The objective of the component closure activities for SST S-112, which is a subunit of the SST system, is to contribute in part to the closure of the dangerous waste management units and SST system closure in accordance with WAC 173-303-610, HFFACO, and the Site-Wide Permit. Retrieval is the initial closure activity that will be performed on SST S-112 followed by residual waste characterization, isolation, and stabilization activities. Because of the timing of retrieval and characterization, Ecology approval of these activities necessarily will occur prior to approval of the remaining closure activities (the latter being approved through incorporation into the Site-Wide Permit). Ecology has already approved RPP-7825, which will direct retrieval activities. Ecology will also approve characterization activities as defined in the WMA S-SX SAP. When prepared the WMA S-SX SAP will be Addendum D1 to RPP-19773. Results of retrieval and characterization activities will be contained in the RDR for SST S-112. Stabilization of tank is described in detail in RPP-19773. The following section describes isolation of tank infrastructure from ancillary/support equipment, permitting for stabilization, LDR compliance, schedule, and reporting.

## 5.1 ISOLATION OF TANK INFRASTRUCTURE FROM ANCILLARY/SUPPORT EQUIPMENT

During the period after retrieval of SST S-112 until the completion of the WMA S-SX closure action, tank isolation will be maintained through both physical and administrative controls. Without the implementation of appropriate controls, there is potential for the inadvertent re-introduction of waste into SST S-112 through various pathways. In addition, without controls, it is possible to prematurely introduce grout into adjacent tanks through interconnecting pathways while grouting SST S-112. SST S-112 has been isolated from the original waste transfer pipeline network installed when the tanks were constructed. Isolation has been documented on the drawings and engineering change notices (ECN).

Nine pathways enter SST S-112 or its associated pits. The pathways include lines, risers, pit drains, and weep holes. Seven pathways into S-112 have already been isolated, as shown on Table 5-1. DOE will take isolation actions on remaining pathways, as shown on Table 5-2, to prevent introduction of new wastes or the intrusion of other liquids into the tank. DOE will use isolation methods based on engineering analysis that do not preclude future remediation. Actions will be implemented via established ECN and work control processes. Figure 5-1 illustrates the line and riser locations into and around SST S-112, along with their current use.

The only direct tank penetrations are the risers and the cascade line from SST S-111, and a cascade line to feed a new tank farm that was never constructed. The associated pipelines to the pits will be capped at the high hydraulic end to prevent accidental waste transfers to the tank. The ends of the cascade lines will be covered/plugged with grout when the tank is filled. The grout will be allowed to set for a short period of time to form a solid cap in the end. This will isolate these pipelines. Water infiltration controls will continue to be maintained following isolation until RPP-19773 is completed in the event of water infiltration through deteriorated pipelines or the tank structure.

Table 5-1. Single-Shell Tank S-112 Previously Isolated Lines.

| Line | Description | Tank waste transfer line? | Isolation technique and status | Verification |
|---|---|---|---|---|
| SN-225 | Waste transfer line | Yes | Isolation blank in 241-S-C valve pit | H-2-73178 |
| SL-125 | Waste transfer line | Yes | Isolated at catch station 244-S | H-2-73209 |
| C1 | Spare nozzle | No | Capped spare, never used | H-2-73191 |
| C2 | Spare nozzle | No | Capped spare, never used | H-2-73191 |
| C3 | Spare nozzle | No | Capped spare, never used | H-2-73191 |
| C4 | Spare nozzle | No | Capped spare, never used | H-2-73191 |
| C6 | Spare nozzle | No | Capped spare, never used | H-2-73191 |

Notes:

H-2-73178, 1985, *Piping Waste Tank Isolation 241-S Farm Plot Plan & Diversion Box Plan*, Rev. 3, Vitro Engineering Corporation, Richland, Washington.

H-2-73209, 1988, *244S Catch Station Isolation Plan*, Rev. 1, Vitro Engineering Corporation, Richland, Washington.

H-2-73191, 2004, *Piping Waste Tank Isolation TK 241-S-112*, Rev. 7, CH2M HILL Hanford Group, Inc., Richland, Washington.

Table 5-2. Single-Shell Tank S-112 Currently Open Lines.

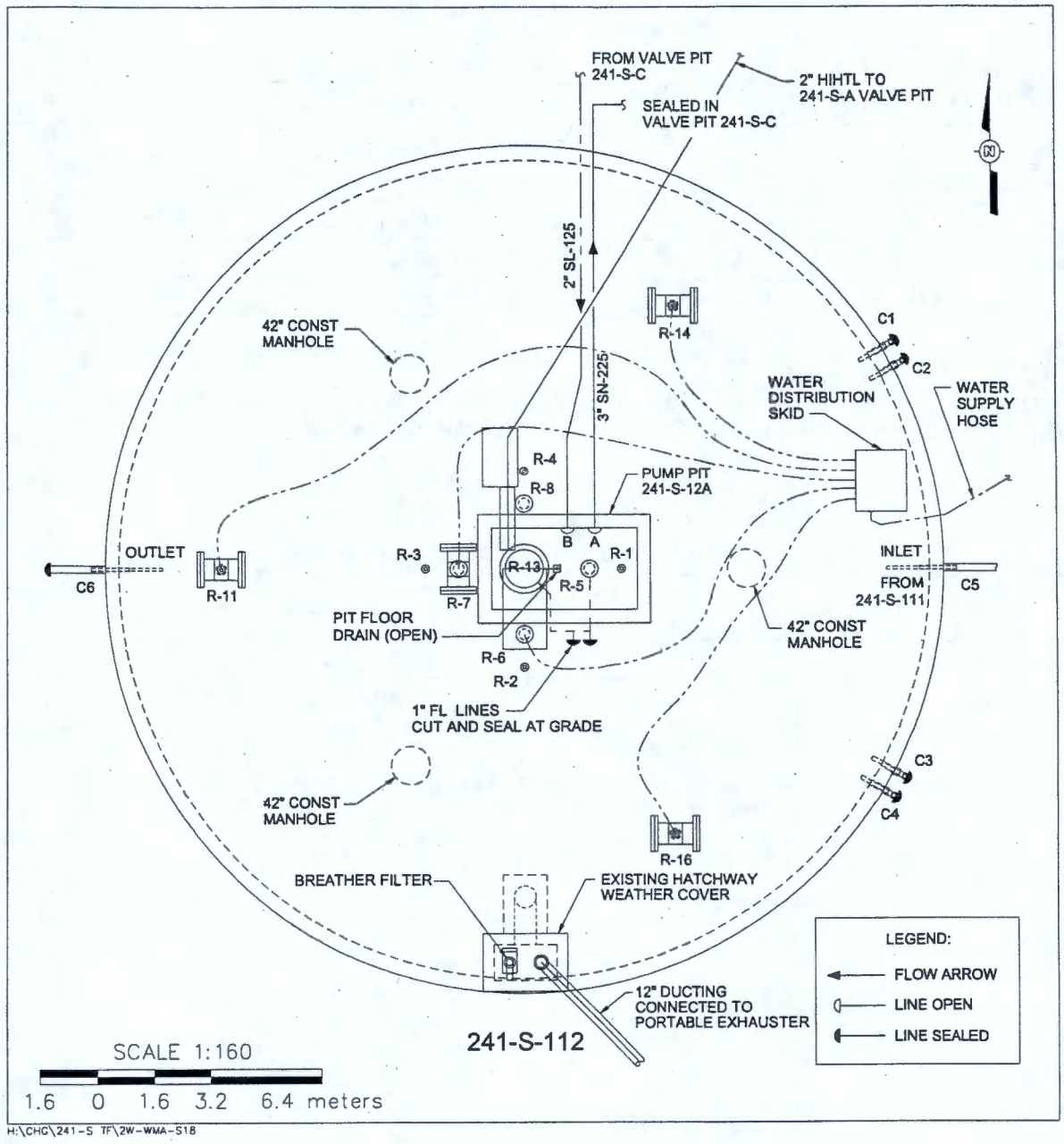
| Line | Description | Tank waste transfer line? | Planned isolation technique |
|---|---|---|---|
| Pit drain | Pump pit drain | No | Weather seal pit cover |
| C-5 | Cascade line from SST S-111 | Yes | Administrative controls on SST S-111. Leave line open until tank fill blocks line |

Notes:

All over ground transfer lines will be removed prior to tank closure. Water, portable exhausters, and other utilities required for retrieval will also be removed prior to tank closure.

SST = single-shell tank.

Figure 5-1. Configuration of Single-Shell Tank S-112 (plan view).



Contaminated equipment removed from the tank will be disposed as mixed waste, and fill equipment may be cleaned using water, which will then be disposed. The contaminated equipment is considered listed waste. It is treated per the alternative treatment standards (40 CFR 268.45, Table 1) and disposed of on the Hanford Site.

Final closure of the WMA will be documented in the WMA S-SX closure process.

## 5.2 TANK STABILIZATION

Tank stabilization occurs after retrieval activities are completed. Tank stabilization involves filling the tank with grout* in order to stabilize any remaining tank waste, in-tank equipment, and debris and to physically stabilize the tank structure. In-tank equipment and debris on the bottom of the tank will likely include thermocouples, manual tapes, piping, and pumps. During characterization, data will be collect with video equipment to better detail equipment and debris remaining in the tank. The Phase I base stabilization layer should cover all of most equipment and debris on the tank floor. Any portion that is not completely covered by the Phase I layer will be completely covered when the Phase II and III fill layers are added to the tanks.

Commencement of tank filling can occur once the waste retrieval criteria are met and risks associated with remaining contaminants are determined acceptable by Ecology. Tank filling activities will not proceed until the closure permit is issued and effective, and the tank closure EIS is completed. Further discussion of the tank fill is contained in RPP-19773, Section 6.2.

Ventilation with a high-efficiency particulate air filtration system will be used during grouting activities to control potential release of emissions to the environment. The following air permits have been obtained for the project to control radiological and toxic emissions: *Notice of Construction Application for Installation and Operation of Waste Retrieval Systems in Single-Shell Tanks 241-U-107, 241-S-102, 241-S-112 for the Department of Energy Richland*, (Ecology 2003), and *Department of Health Radioactive Air Emissions Notice of Construction Approval for Project Title: 241-S-102 Installation and Operation of Waste Retrieval Systems* (DOH 2003). Information will be obtained during the placement of the Phase I layer of grout on how operations are affected, such as impact on high-efficiency particulate air filter change-out.

## 5.3 LAND DISPOSAL RESTRICTIONS COMPLIANCE

Residual waste is expected to remain in place after closure. Therefore, the RCRA LDR treatment standards (WAC 173-303-140 and 40 CFR 268) will apply. A site-specific treatability variance is needed to allow an alternative approach to protecting human health and the environment from the land disposal of dangerous waste for the following reasons:

- Treatment to performance-based treatment levels for other applicable waste codes is likely unachievable.

---

* See Preface.

- 40 CFR 268.48 universal treatment standards are expected to be unachievable in the short-term for the tank and abandoned equipment.

The site-specific LDR treatability variance request for WMA S-SX tanks will be prepared largely based on the SST C-106 treatability variance request when approved by Ecology.

## 5.4 SST S-112 COMPONENT CLOSURE ACTIVITY SCHEDULE

The current schedule for S-112 component closure activities are contained in the HFFACO Milestone M-45 series and will be modified, if needed, according to the HFFACO change process. Table 5-3 lists the HFFACO Milestones associated with the S-112 retrieval and component closure activities.

Following retrieval, characterization and a preliminary evaluation for compliance with Milestones M-45-00 and M-45-03C, DOE will either complete and submit to Ecology its RDR or a request for exception to the retrieval criteria. Ecology and DOE will use information in the RDR to make WMA-, tank-, and component-specific closure decisions. Placement of grout* will commence after the ROD for the tank closure EIS is issued and passed through a 30-day review, and this component closure activity plan is approved and incorporated into the Site-Wide Permit. Figure 5-2 shows the major SST S-112 component closure activities.

## 5.5 FUTURE AMENDMENT OF SST S-112 COMPONENT CLOSURE ACTIVITY PLAN

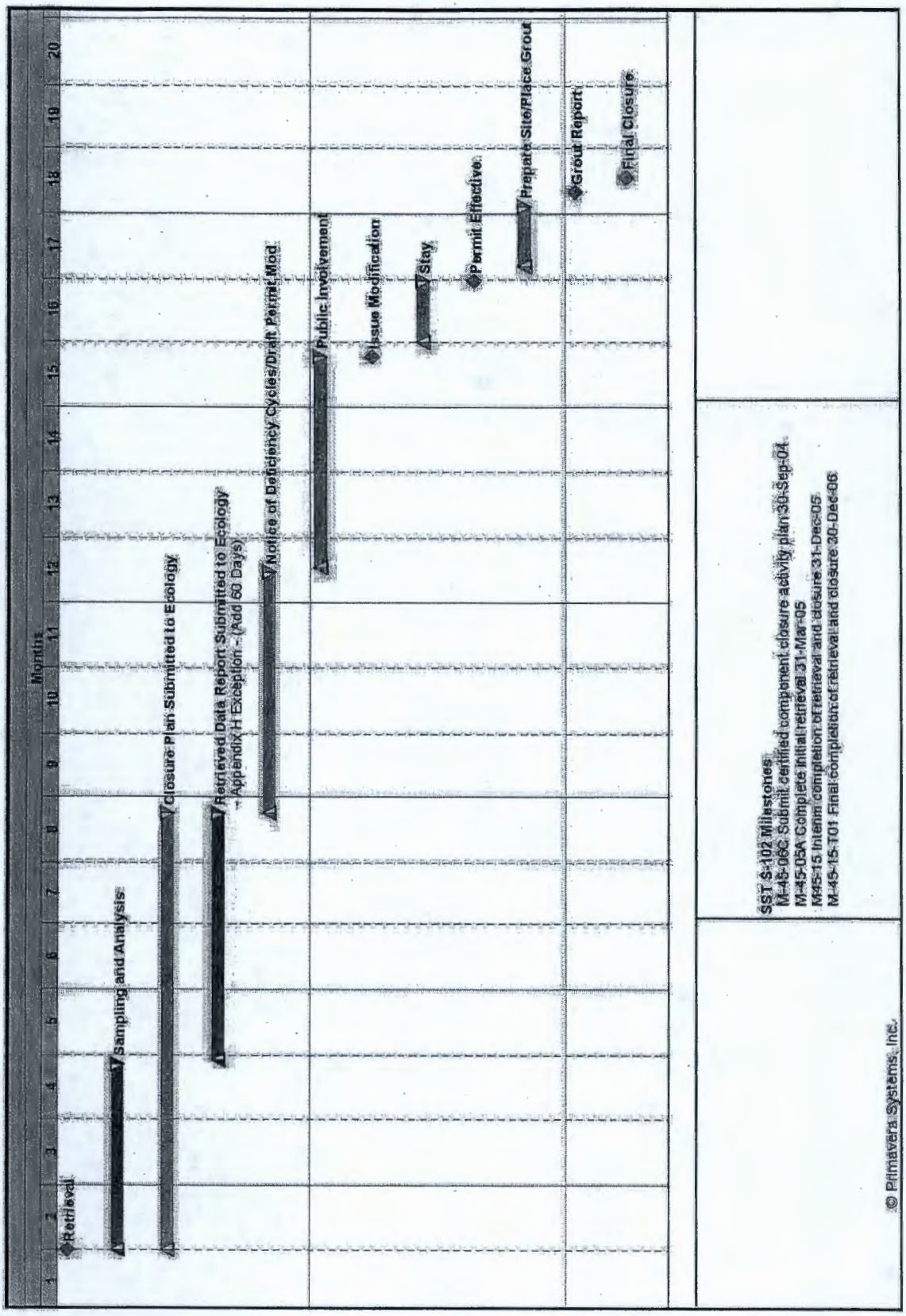
This component closure activity plan will be amended whenever changes in component closure activities occur that would constitute a Class 1, 2, or 3 modification to the permit (WAC 173-303-830).

## 5.6 REPORT OF SST S-112 COMPONENT CLOSURE ACTIVITIES

Within 60 days of the completion of each phase of activities at SST S-112, DOE will submit to Ecology a letter documenting activities that have been conducted in accordance with the specifications contained within the approved plan, as amended, and as contained in the permit.

* See Preface.

Figure 5-2. Major SST S-102 Component Closure Activities.



1

Table 5-3. HFFACO Milestones for Single-Shell Tank S-112 Component Closure.

| Milestone | Activity | Date |
|---|---|---|
| M-45-00 | Complete closure of all SSTs | 9/30/2024 |
| M-45-06B | Submittal to Washington State Department of Ecology of certified component closure activity plan for SST S-112 | 9/30/2004 |
| M-45-03C | Complete full-scale saltcake waste retrieval technology demonstration | 3/31/2005 |
| M-45-13 | Interim completion of SST S-112 waste retrieval and closure demonstration project | 12/31/2005 |
| M-45-13-T01 | Final completion of SST S-112 waste retrieval and closure demonstration project | 12/30/2006 |

Notes:

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

SST = single-shell tank.

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**Attachment 4**
**04-TPD-092**

**RPP-21596, Risk Assessment for Waste Management Area S-SX Closure Plan, Revision 0**

(Consisting of 164 pages, including coversheet)

RPP-21596
Revision 0

# RISK ASSESSMENT FOR WASTE MANAGEMENT AREA S-SX CLOSURE PLAN

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## LIST OF TERMS

| | |
|---|---|
| BBI | best-basis inventory |
| bgs | below ground surface |
| BTC | breakthrough curve |
| COC | contaminant of concern |
| COPC | contaminant of potential concern |
| DOE | U.S. Department of Energy |
| Ecology | Washington State Department of Ecology |
| EDE | effective dose equivalent |
| EPA | U.S. Environmental Protection Agency |
| HEAST | Health Effects Assessment Summary Table |
| HFFACO | *Hanford Federal Facility Agreement and Consent Order* |
| HI | hazard index |
| HQ | hazard quotient |
| HSRAM | *Hanford Site Risk Assessment Methodology* |
| HTWOS | Hanford Tank Waste Operations Simulator |
| ILCR | incremental lifetime cancer risk |
| $K_d$ | distribution coefficient |
| MCL | maximum contaminant level |
| MTCA | *Model Toxics Control Act* |
| PNNL | Pacific Northwest National Laboratory |
| RCRA | *Resource Conservation and Recovery Act of 1976* |
| SPR | selected phase removal |
| SST | single-shell tank |
| STOMP | *Subsurface Transport Over Multiple Phases* |
| UPR | unplanned release |
| WAC | *Washington Administrative Code* |
| WMA | Waste Management Area |

# 1.0 INTRODUCTION

In accordance with the *Hanford Federal Facility Agreement and Consent Order* (HFFACO) (Ecology et al. 1989), and as regulated through the *Resource Conservation and Recovery Act of 1976* (RCRA), the Hanford Site single-shell tanks (SST) system is administered as a collection of hazardous waste management units that eventually will be closed under *Washington Administrative Code* (WAC) "Dangerous Waste Regulations" (WAC 173-303). Waste Management Area (WMA) S-SX is one of seven WMAs in the SST system for which closure action plans will be developed and submitted to Washington State Department of Ecology (Ecology) for approval. Each WMA is comprised of components including tanks, ancillary equipment, soil, and groundwater for which component closure activity plans must also be submitted to and approved by Ecology.

Prior to closing the SSTs in WMA S-SX, the SSTs will have tank waste retrieved to the extent technically possible and undergo subsequent closure activities for the various components. A risk assessment will be performed to estimate potential health risks from exposure to groundwater and soil impacted by previous leaks, hypothetical retrieval leaks, and residual waste in the tanks and tank farm pipe systems.

This document presents the human-health risk assessment for WMA S-SX. It is written prior to completing retrieval of waste from tanks within WMA S-SX using projected contaminant levels for waste left in SSTs assuming that waste from all tanks in WMA S-SX will be retrieved to the HFFACO goal of 360 $ft^3$. The contents of each chapter of this document are briefly summarized below:

1. Introduction: provides the scope and objectives of the document.

2. Performance Objectives: provides the metrics against which the results of the analysis are compared. For example, WAC 173-340-745 sets a risk level of $1 \times 10^{-5}$ for incremental lifetime cancer risk (ILCR) for the industrial receptor for hazardous waste.

3. Modeling Approach: provides the conceptual model description, computer code description, modeling approach, recharge estimates, listing of modeling cases, contaminants of potential concern (COPC), and estimated mass (hazardous contaminants) or activity of the contaminants of concern (COC).

4. Groundwater Concentrations: provides the groundwater modeling results in terms of long-term predicted groundwater concentrations for each individual source term (past unplanned releases (UPR), ancillary equipment residuals, tank residuals, and hypothetical retrieval leaks) as well as a composite of all sources terms.

5. Exposure Scenarios: provides a summary description of exposure scenarios, exposure pathways, and media (i.e., water, soil, food chain).

6. WMA S-SX Risk and Dose Estimates: applies the risk and dosimetry conversion factors appropriate to the exposure scenarios to estimate dose and risk from modeled

groundwater concentrations and then compares the estimated dose and risk to the performance objectives given in Section 2.0.

7. Limitations and Uncertainties: provides a listing of the limitations and uncertainties in the groundwater model and exposure scenarios.

8. Summary and Conclusions: provides a brief summary and conclusions of the risk assessment.

## 1.1 SCOPE AND OBJECTIVES

The overall objective of this closure risk assessment is to provide quantitative long-term human health risk estimates associated with various retrieval options at various times and varying points of calculation; it will also provide risk estimates when final closure conditions are achieved. Potential risks will also be estimated for SSTs S-112 and S-102 prior to retrieval to determine their contribution to cumulative risk within WMA S-SX.

Four types of contaminant sources will be evaluated within WMA S-SX, which include the following: (1) past leaks from tanks, (2) residual tank waste, (3) potential leaks that occurred during waste retrieval, and (4) residual waste in the WMA S-SX pipe system. Contaminants evaluated in the risk assessment include long-lived radionuclides (such as $^{99}$Tc, $^{129}$I), as well as nonradionuclide mobile contaminants (i.e., chromium). For each contaminant source, breakthrough curves (BTC) are established for each contaminant over the 10,000-year time period. BTCs show peak groundwater concentrations and arrival time at the WMA S-SX fence line. Using peak groundwater concentrations, potential risks will be estimated using a variety of exposure scenarios (industrial, residential, all-pathways farmer, etc.).

Risk estimates obtained from each exposure scenario will be compared to the performance objectives defined in Section 2.0. Comparison of risk estimates to the identified performance objectives is used to determine if the selected cleanup or disposal action protects human health and the environment under the identified exposure conditions.

## 1.2 DATA PACKAGES AND GUIDANCE DOCUMENTS

The methodology for conducting long-term human health risk assessments is given in Figure 1-1. Key to conducting the risk assessments is the development of data packages which describe how the analysis is to be conducted, what inventory data will be used, the dosimetry factors to calculate the human health risk and to what performance objectives the results will be compared. The following data packages were developed in support of the long-term human health risk assessment:

- *Performance Objectives for Tank Farm Closure Performance Assessments* (RPP-14283)
- *Modeling Data Package for an Initial Assessment of Closure for S-SX Tank Farms* (RPP-17209)

- *241-S-SX Waste Management Area Inventory Data Package* (RPP-20420)
- *Exposure Scenarios and Unit Dose Factors for Hanford Tank Waste Performance Assessment* (HNF-SD-WM-TI-707).

This approach of creating data packages to define the risk assessment is the same approach used in the following risk/performance assessments:

- *Field Investigation Report for Waste Management Area S-SX* (RPP-7884)
- *Field Investigation Report for Waste Management Area B-BX-BY* (RPP-10098)
- *Hanford Immobilized Low-Activity Waste Performance Assessment: 2001 Version* (DOE/ORP-2000-24)
- *Performance Assessment for the Disposal of Low-Level Waste in the 200 West Area Burial Grounds* (WHC-EP-0645)
- *Performance Assessment for the Disposal of Low-Level Waste in the 200 East Area Burial Grounds* (WHC-SD-WM-TI-730)
- *Preliminary Performance Assessment for Waste Management Area C at the Hanford Site, Washington* (DOE/ORP-2003-11)
- *Single-Shell Tank System Closure Plan* (RPP-13774).

## 1.3 WMA C MERIT PANEL

During the course of this analysis, a Merit Panel was convened to review the WMA C risk assessment. The panel indicated where additional work should be done to improve the quantification of future risk assessments. Because these comments were supplied during the final stages of production of this work, it was not possible to address all their comments. However, to the extent possible, their comments were addressed. For example, a three-dimensional (3-D) model was developed to address dilution at the fence due to flow spreading in the third dimension, which cannot occur with a two-dimensional (2-D) model and risk assessment results are given total soil pathway and total water pathway, as well as the principal contributors to the pathway.

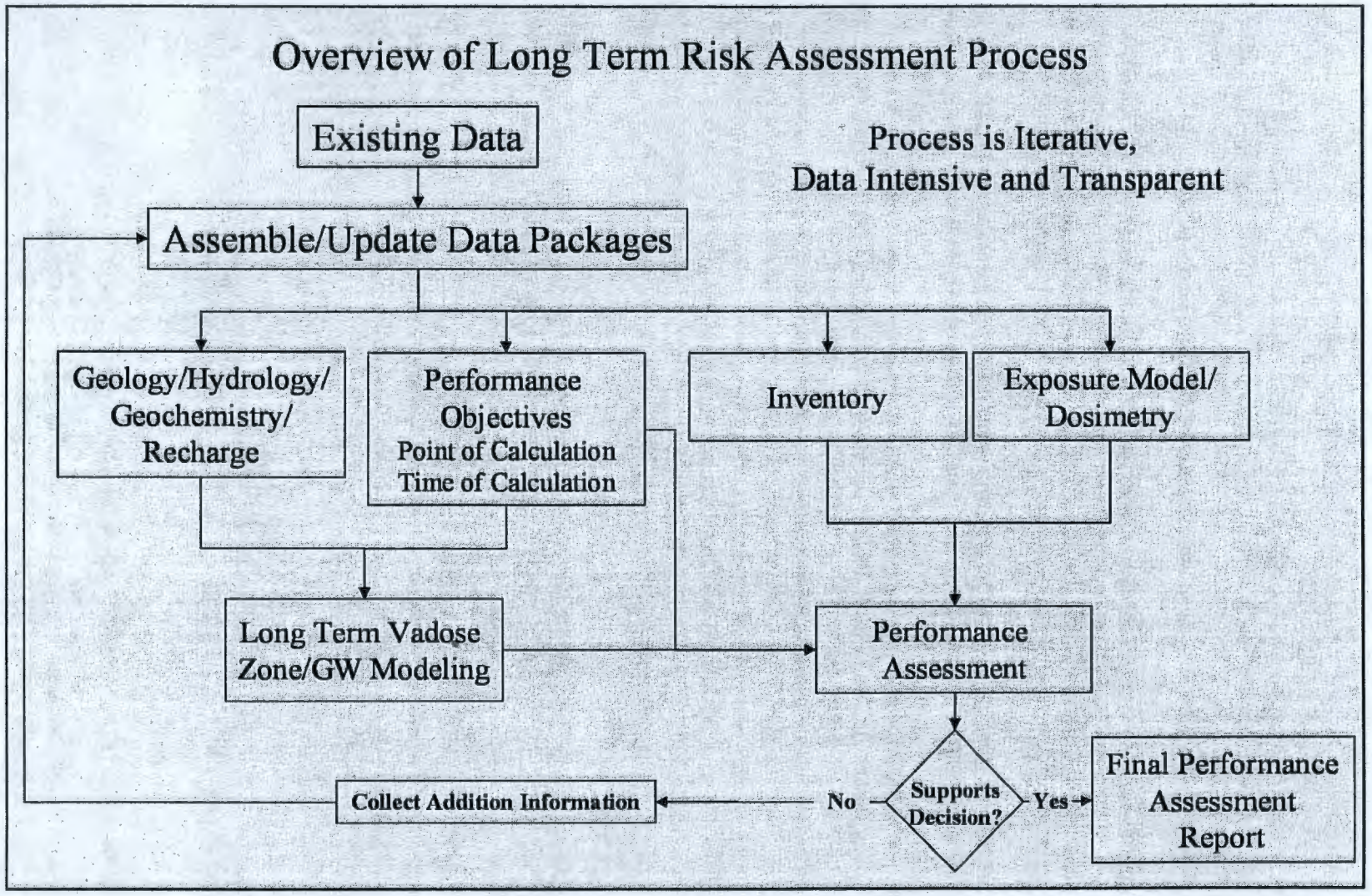


Figure 1-1. Long-Term Human Health Risk Assessment Process for Closure.

# 2.0 PERFORMANCE OBJECTIVES AND METRICS

Tank farm closure risk assessments are studies of the long-term impacts to public health and safety as well as to the environment. They provide information to decision makers on the impacts of baseline activities and other alternatives actively under consideration. The intent is to provide sufficient information so that decision makers dealing with tank farm closure have an adequate understanding of the long-term consequences of closure decisions.

To be meaningful, results from a numeric risk assessment of the consequences of an action must be compared to the standards for such an action. That is, before one disposes of waste or closes a facility with waste, one must show that the disposal or closure action protects the public health and safety and the environment. These standards are called performance objectives.

Regulations that call for risk assessments usually require that the determination of performance objectives be one of the first steps performed. This is true, whether they are federal regulations, such as the U.S. Department of Energy (DOE) order on *Radioactive Waste Management* (DOE O 435.1[1]) and its implementing guides, or those from Washington State such as the regulations implementing the "Model Toxics Control Act – Cleanup" (MTCA) (WAC 173-340). However, it should be noted that the MTCA cleanup standards apply only to the extent that they are incorporated by reference into the dangerous waste regulations. These performance objectives not only set comparison levels for the numeric results, but also define the media, pathways, exposure scenarios (receptors), spatial locations, and times that the risk assessment must consider. Thus, a performance objective consists of a compliance level, place(s) of compliance, and time(s) of compliance. Whenever regulations are cited in this document, the reader is reminded that not all regulations dealing with tank farm closure are included. Rather, only those that are needed for the study of long-term impacts are included.

Performance objectives are not the levels that a regulatory agency will enforce in a permit or authorization. Those levels, often called enforcement levels, will be set in the permit or authorization. Rather, performance objectives are those levels against which the results of the numeric simulation will be compared to judge the success of the proposed cleanup or disposal actions.

This risk assessment is performed using several different exposure scenarios. Each exposure scenario considers a different receptor (industrial worker, resident, all-pathways farmer, or Native American), and evaluates the effect that groundwater beneath the WMA will have on different exposure pathways (ingestion, inhalation, direct radiation exposure, etc.). A more complete description of these exposure scenarios is given in Section 5.1. Ecological risk assessment for native plants and animals will be performed following closure of each WMA

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[1] On July 3, 2003, the United States District Court for the District of Idaho issued a judgment in Natural Resources Defense Council, et al., v. Spencer Abraham, et al., Civ. No. 01-0413-S-BLW holding invalid certain portions of DOE O 435.1 dealing with waste incidental to reprocessing. On August 27, 2003, DOE appealed this judgment to the U.S. Circuit Court of Appeals for the Ninth Circuit. This document does not address the waste incidental to reprocessing described in DOE O 435.1 and its accompanying Guidance and Manual.

(RPP-13774, Section 4.0). Once risk estimates are obtained from each exposure scenario considered, the dose or risk estimates are then compared to the applicable performance objective.

This entire process, along with all the regulations and values considered, is documented in RPP-14283. A summary of the primary performance objectives considered in this risk assessment are listed in Table 2-1. These objectives are the same as those of RPP-14283, except in this risk assessment the air pathway is not calculated.

Table 2-1. Performance Objectives for Tank Closure [a]. (2 sheets)

| | |
|---|---|
| **Protection of General Public and Workers** [b, c, d] | |
| DOE all-pathways dose threshold | 25 mrem/yr [e,k] |
| EPA dose threshold | 15 mrem/yr [l] |
| DOE all-pathways dose including other Hanford Site sources | 100 mrem/yr [e,k] |
| Nonradiological ILCR for industrial land use | $10^{-5}$ [f] |
| Nonradiological ILCR for unrestricted land use | $10^{-6}$ [m] |
| EPA nonradiological ILCR range | $10^{-4}$ to $10^{-6}$ [n] |
| Non-cancer-causing chemicals (hazard index) | 1 [f] |
| **Protection of Groundwater Resources** [b, c, d, g, h, i] | |
| Alpha emitters | |
| $^{226}$Ra plus $^{228}$Ra | 5 pCi/L |
| All others (excluding uranium) | 15 pCi/L |
| Beta and photon emitters | 4 mrem/yr |
| $^{99}$Tc | 900 pCi/L [i] |
| $^{129}$I | 1pCi/L [i] |
| $^{3}$H | 20,000 pCi/L [i] |
| $^{14}$C | 2,000 pCi/L [i] |
| Cr | 0.1 mg/L |
| Total Uranium | 0.03 mg/L |
| Nitrite | 3.3 mg/L |
| Nitrate | 44 mg/L |
| **Protection of an Inadvertent Intruder** [e,j] | |
| Acute exposure | 500 mrem |
| Continuous exposure | 100 mrem/yr |

Notes:

[a] All doses are calculated as effective dose equivalent except for protection of groundwater and surface water, in which case both effective dose equivalent and target organ dose will be given. Values given are in addition to any existing amounts or background. The risk assessment provides calculations of dose based on the results of a review of all pertinent regulations. As noted, regulations vary in how dose is calculated (see RPP-13774, Appendix C, *WMA C Action Closure Plan*, Section 5.2.2 "Drinking Water Dose Calculation Methods," for a comparison between different methodologies for calculating dose).

[b] Evaluated for 1,000 years, but calculated to the time of peak or 10,000 years, whichever is longer.

[c] Groundwater use starts at the time when groundwater contaminated by Hanford Site operations before the year 2000 is estimated to be potable.

[d] Evaluated at the point of maximal exposure, but no closer than the fenceline of the Waste Management Area in which the tank farm belongs. Also calculated at the edge of the 200 Area core zone and just before groundwater enters the Columbia River.

[e] Main driver is DOE O 435.1 (*Implementation Guide for use with DOE M 435.1-1*, July 9, 1999, Chapter IV, Section IV.P.(1) through IV.P.(4)].

[f] Main driver is WAC 173-340-745.

[g] All concentrations are in water taken from a well.

[h] Main drivers are DOE O 5400.5 (II)(d) and 40 CFR 141.

[i] Maximum contaminant level-derived constituent concentration for radionuclides, if that radionuclide is the only radionuclide present in the system, which would give a 4 mrem/yr dose, if more than one beta-photon emitter is in the groundwater, the 4 mrem/yr is the dose calculated for each individual radionuclide, which is then summed to give a

Table 2-1. Performance Objectives for Tank Closure [a]. (2 sheets)

total dose. Technetium-99, iodine-129, carbon-14, and tritium are the radionuclides that are the principal beta-photon emitters at the Hanford Site.

[j] Evaluated for 500 years, but calculated from 100 to 1,000 years.

[k] Dose limits listed are considered absolute and are not distinguished from background levels.

[l] OSWER 9200-4.18, "Establishment of Cleanup Levels for CERCLA Sites with Radioactive Contamination," 1997.

[m] Main driver is WAC 173-340-740.

[n] EPA 1991, *Role of the Baseline Risk Assessment in Superfund Remedy Selection Decisions.*

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

DOE M 435.1-1, 2001, *Radioactive Waste Management Manual*, U.S. Department of Energy, Washington, D.C.

DOE O 435.1, 1999, *Radioactive Waste Management*, U.S. Department of Energy, Washington, D.C.

DOE O 5400.5, 1993, *Radiation Protection of the Public and the Environment*, Change 2, U.S. Department of Energy, Washington, D.C.

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

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

Based on the results of previous risk assessments for the Hanford Site (DOE/ORP-2000-24), risk and dose estimates will be compared to the following performance objectives:

- Comparison to the appropriate performance objectives are made in Section 4.0 for the maximum contaminant level (MCL) and Section 6.0 for the ILCR, hazard index (HI), and radiological dose.

- If the dose from radiological constituents to representative members of the public exceeds 15 mrem/yr total EDE from all exposure pathways (OSWER Directive 9200-4.18).

Groundwater concentrations will be modeled to 10,000 years because of the relatively long travel time in the vadose zone. Groundwater modeling and associated dose and risk estimates will be carried out for at least 10,000 years to demonstrate different groundwater impacts including (1) peak impacts associated with waste forms having relatively short release times compared to vadose zone travel times or (2) the formation of plateaus associated with waste forms having long release times. Several calculation points will be evaluated (WMA S-SX fenceline, 200 Area core zone boundary, shore of the Columbia River). Because of the proximity of the WMA S-SX fenceline to the sources, this calculation point is expected to have the largest groundwater impacts and the results of the risk assessment will primarily focus upon this calculation point.

To evaluate the impact of final closure conditions on groundwater resources, contaminant leaching and migration analyses have been completed for contaminants released from the WMA sources. Modeled groundwater concentrations are compared to groundwater performance objectives (4 mrem/yr from beta and photon emitters or drinking water MCLs) by converting concentrations to dose using radionuclide-specific dose conversion factors.

The following exposure scenarios will be evaluated to determine if groundwater concentrations could potentially result in adverse health effects and include the following:

- Industrial worker who works near the site (ILCR of $1 \times 10^{-5}$ and HI of 1)

- Rural resident who lives near the site (ILCR of $1 \times 10^{-6}$ and HI of 1)

- All pathways farmer who lives 100 m downgradient of WMA S-SX (25 mrem/yr performance objective)

- Native American who lives near the site and at the Columbia River (ILCR of 1 x $10^{-5}$ or HI of 1).

The first three exposure scenarios will be discussed in detail, while the Native American Scenario is given for informational purposes in Appendix A. The rural residential and the industrial exposure scenarios were evaluated in this risk assessment to meet the requirements stated in Appendix I of HFFACO Milestone M-45-04-1 for pre-retrieval risk assessments. Additionally, evaluating the industrial scenario addresses the Hanford Advisory Board, Advice #132. The all pathways farmer scenario was evaluated in accordance with the requirements stated in DOE O 435.1. Additionally, DOE is providing information on the Native American scenario as part of DOE's Federal Native American trust responsibilities. The exposure assumptions used for the Native American scenario used in this risk assessment were obtained from the *Screening Assessment and Requirements for a Comprehensive Assessment: Columbia River Comprehensive Impact Assessment* (DOE/RL-96-16).

Intruder scenarios in which the residual waste[2] left in the SSTs is brought to the surface, thereby exposing an individual (500 mrem [acute exposure] and 100 mrem/yr [chronic exposure]). The results for the intruder scenario are tank specific and will be provided for each component after it has been retrieved.

[2] Contaminant sources include residual tank waste and past leaks; however, residual waste from pipelines and other ancillary equipment are not evaluated because they are not expected to be a primary of contaminants brought to the surface.

# 3.0 MODELING APPROACH: EXISTING DATA AND ASSUMPTIONS

As part of the WMA S-SX closure, an assessment is conducted to evaluate impacts on groundwater resources (the concentration of contaminants in groundwater) and long-term human health risk (associated with groundwater use). The evaluations consider the extent of contamination from residual waste in tanks and tank ancillary equipment; past leaks, spills, and retrieval leaks; contaminant movement through the vadose zone to the saturated zone (groundwater); contaminant movement in the groundwater to various calculation points; and assumed human receptor activities at those calculation points. A plan view of WMA S-SX and associated sources is shown in Figure 3-1. Note that the closure barrier for the tank farms is assumed to be a Modified RCRA Subtitle C Barrier (Figure 3-5) with a design life of 500 years (see Section 3.2.1 for a description of the barrier). The barrier is assumed to be "degraded" beyond 500 years.

The following information is included in this section:

- Modeling approach
- Stratigraphic cross-sectional model for the S and SX tank farms
- Recharge (infiltration) data for S and SX farms under current and post-closure conditions
- Source-term release scenarios and numerical cases considered
- COPC
- Inventory data for various sources.

## 3.1 OVERVIEW OF LONG-TERM HUMAN GROUNDWATER MODELING APPROACH

The modeling approach used in this study at WMA S-SX is documented in RPP-17209. The overall approach relies heavily on earlier work such as the S-SX field investigation report (PNWD-3111, *FY00 Initial Assessment for S-SX Field Investigation Report (FIR): Simulations of Contaminant Migration and Surface Barriers*), B-BX-BY (PNNL-13949, *2002 Initial Assessments for B-BX-BY Field Investigation Report (FIR): Numerical Simulations*), and C tank farm modeling reports (PNNL-14334, *Initial Assessments of Closure for the C Tank Farm*). The specific objectives of the numerical assessment are to quantify the risks posed by tank closure. The assessments of this investigation focus specifically on impacts to groundwater resources (i.e., concentration of contaminants in the groundwater). By providing quantitative comparisons of the different potential contaminant sources, the results from this evaluation may affect current operations or future decisions on retrieval of tank waste and closure of WMA S-SX. The overall groundwater modeling approach is illustrated in Figure 3-2. Although other pathways (e.g., air pathway) are considered, the dominant transport mechanism of contaminants from post-retrieval waste is migration through the vadose zone to groundwater, as indicated by previous Hanford Site performance assessments and environmental impact statements (DOE/ORP-2000-24). A Modified RCRA Subtitle C Barrier (Figure 3-5) will be in place as part of tank farm closure. The barrier design incorporates provisions for biointrusion and human intrusion control.

Figure 3-1. Waste Management Area S-SX and Surrounding Facilities.

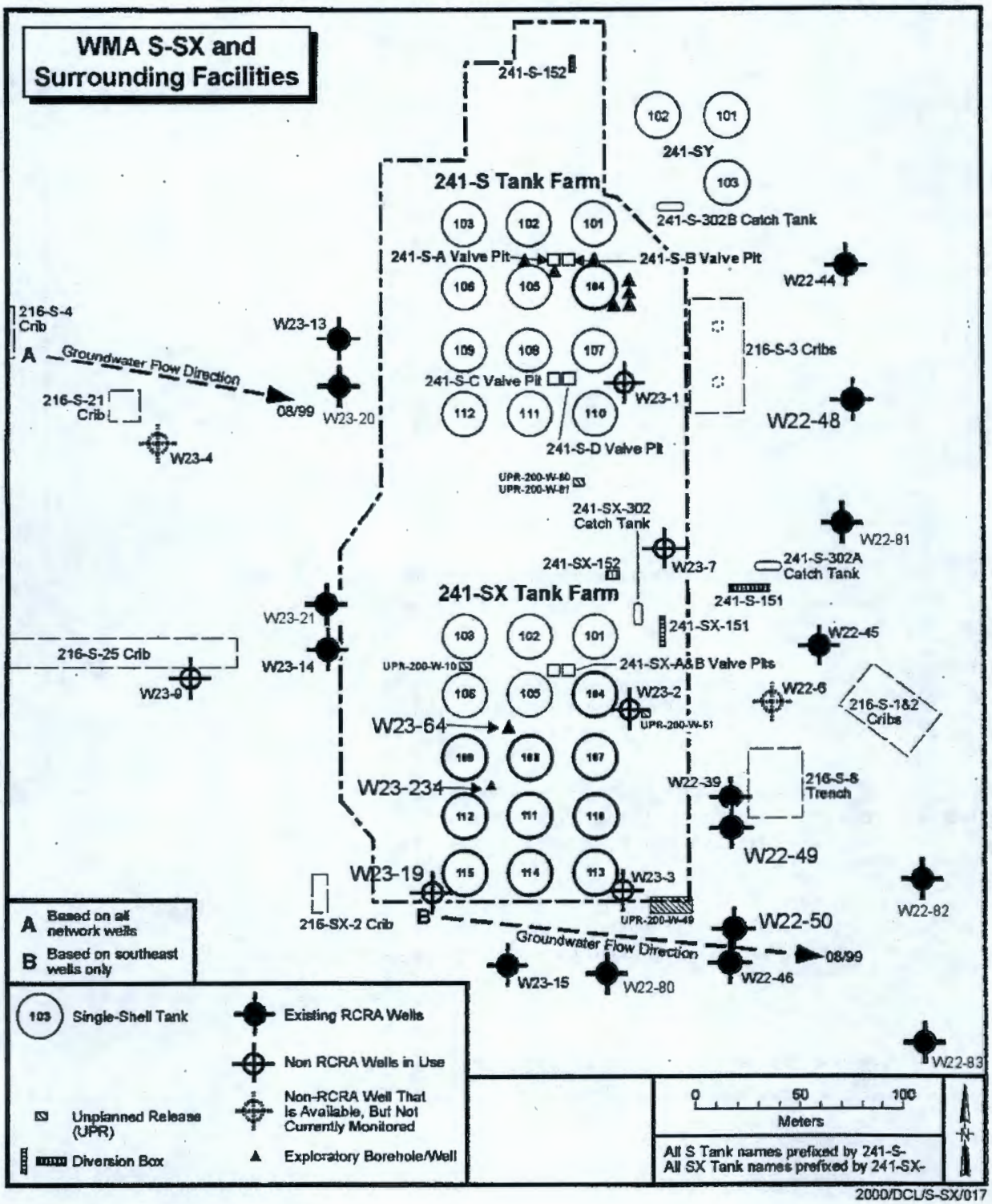
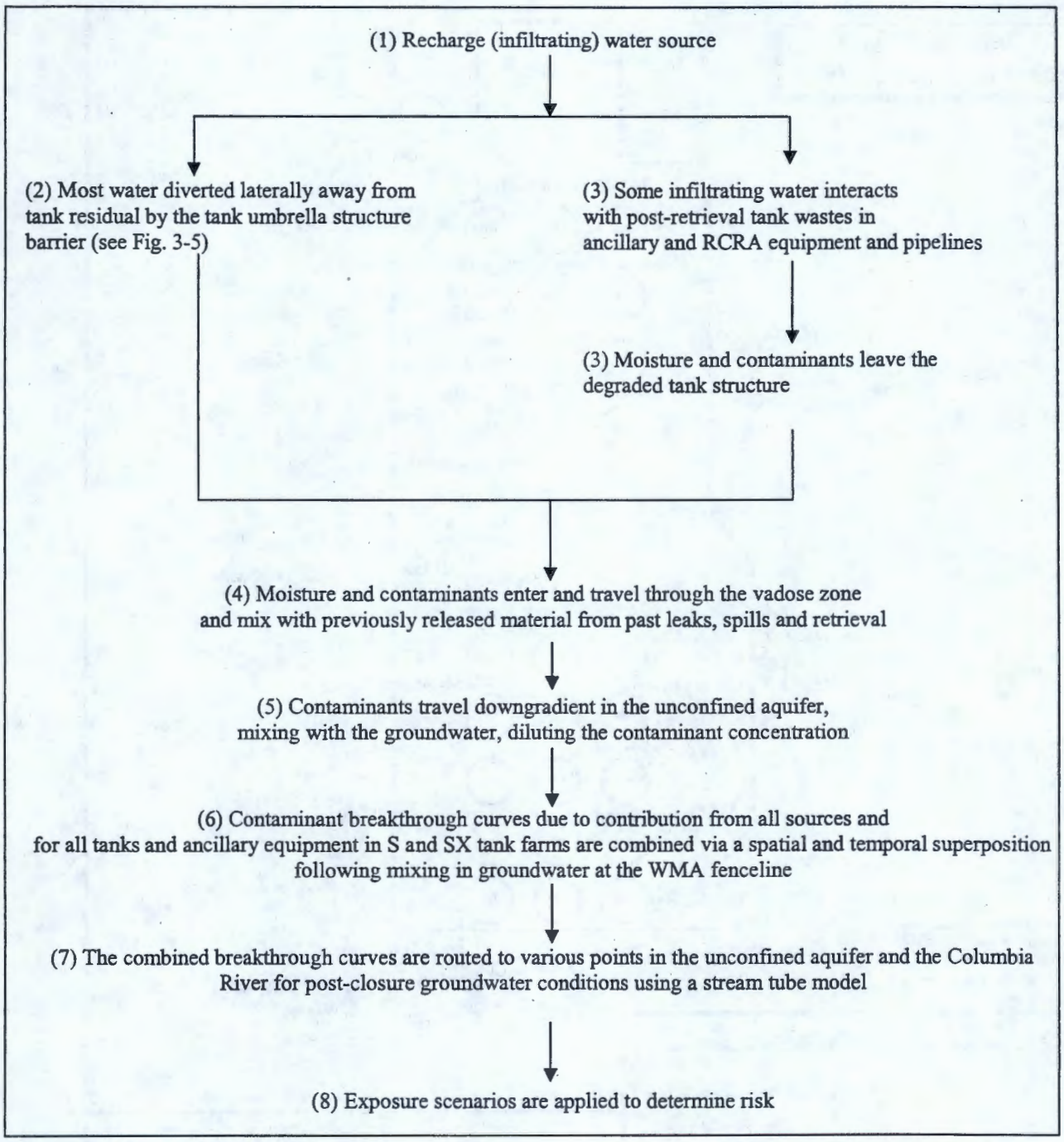


Figure 3-2. Overall Modeling Approach for Risk Assessment.




Notes:

*Contaminant breakthrough curves provide the concentration versus time history.

RCRA = *Resource Conservation and Recovery Act of 1976.*

### 3.1.1 Computer Codes

The numerical simulator *STOMP Subsurface Transport Over Multiple Phases, Version 2.0, Theory Guide* (PNNL-11216) simulated contaminant fluxes and concentrations at the WMA S-SX fenceline using a 2-D, vadose zone-unconfined aquifer conceptualization through SSTs S-101, S-102, and S-103 (Figure 3-3). STOMP was chosen because it met the requirements of *Computer Code Selection Criteria for Flow and Transport Code(s) to be Used in Vadose Zone Calculations for Environmental Analyses in the Hanford Site's Central Plateau* (HNF-5294) and has been used for a number of risk assessments on the Hanford Site (RPP-13774, RPP-7884, RPP-10098).

For downgradient calculation points (core zone boundary and Columbia River), the analytical/stream tube approach was used. The analytical solution in *Physical and Chemical Hydrogeology* (Domenico and Schwartz, 1990) is used to model saturated transport. Flow velocities for the analytical/stream tube approach were derived from the Hanford Sitewide Groundwater Model. The Sitewide Groundwater Model is a 3-D finite element model based on the *Coupled Fluid, Energy, and Solute Transport (CFEST) Model: Formulation and User's Manual* (BMI/ONWI-660) and *Draft User's Manual, CFEST-96 Flow and Solute Transport, Constant/ Variable Density, Computationally Efficient, and Low Disk PC/Unix Version* (Gupta 1996). This model and its conceptual basis are fully described in *Development of a Three-Dimensional Ground-water Model of the Hanford Site Unconfined Aquifer System: FY 1995 Status Report* (PNL-10886) and, *Three-Dimensional Analysis of Future Groundwater Flow Conditions and Contaminant Plume Transport in the Hanford Site Unconfined Aquifer System: FY 1996 and 1997 Status Report* (PNNL-11801). They were most recently used in the Hanford Site Composite Analysis (PNNL-11800, *Composite Analysis for Low-Level Waste Disposal in the 200 Area Plateau of the Hanford Site*; PNNL-11800-Addendum 1, *Addendum to Composite Analysis for Low-Level Waste Disposal in the 200 Area Plateau of the Hanford Site*) and immobilized low-activity waste Performance Assessment (PNNL-13400, *Groundwater Calculations Supporting the 2001 Immobilized Low-Activity Waste Disposal Facility Performance Assessment at the Hanford Site in Southeastern Washington*; DOE/ORP-2000-24). PNNL-11801 contains a complete discussion of the uncertainties in the conceptual model as they are currently understood.

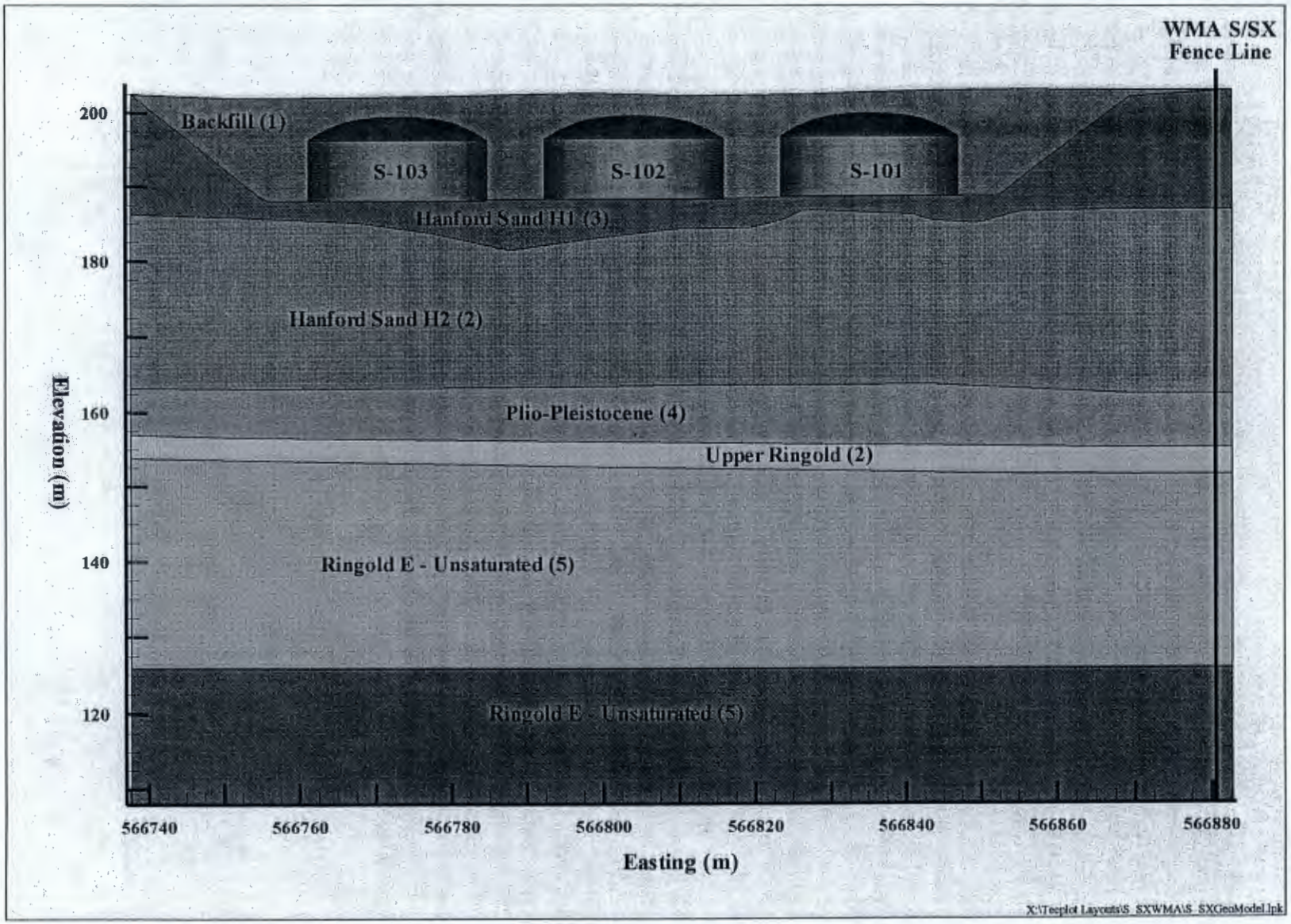



Figure 3-3. West-East Cross-Section through S Tank Farm.

### 3.1.2 Unit Source Inventory and Superposition

Both the STOMP 2-D cross-sectional model and the analytical/stream tube model calculations are performed using one unit curie (or one unit mass [kg]) for the source term (past tank leaks, tank residuals, ancillary equipment residuals, and hypothetical retrieval leaks). Each source is considered separately. The concentration for each contaminant from an individual source can then be calculated by multiplying the unit source results by the actual contaminant inventory. The results for each source and each tank are then summed, using the principle of superposition, to produce a contaminant BTC at the fenceline or downgradient. As shown in Figure 3-3, the distance to the WMA fenceline is approximately 142 m from SST S-103. Superposition can be used for the WMA for the following reasons: (1) the tanks were constructed and placed in a grid-like manner, (2) the geology beneath the WMA appears to be consistent beneath the tanks, and (3) the rows of tanks are aligned parallel to the expected post-Hanford groundwater flow direction. Based on these similarities, any tank in a row may represent any other tank in the groundwater model simply by changing the distance from the tank to the fenceline. Thus, the modeling results for the row of tanks containing SSTs S-101, S-102, and S-103 can be applied to tanks in other rows.

### 3.1.3 Two- and Three-Dimensional Models

Although the simulations in this report are 2-D, in reality, flow and transport from any source type will occur in 3-D. Because of the long simulation times, simulating 3-D processes is not trivial; however, even though 2-D simulations have shorter run times, the absence of flow and transport in the third dimension translates into higher predicted concentration and shorter travel times. Therefore, results from 2-D simulations need to be translated into equivalent values for a 3-D domain to better predict contaminant concentrations in the groundwater. For WMA C (RPP-13774), the 3-D aspects were accounted for by transforming the tank centerline mass flux and BTCs to average values across the WMA fenceline using two translations as described in PNWD-3111. However, for the WMA S-SX, a 3-D model was developed to better ascertain a 2-D to 3-D dilution factor. A complete write-up of the 3-D modeling results is given in *2004 Initial Assessments of Closure for the S-SX Tank Farm: Numerical Simulations* (PNNL-14604), while an abbreviated write-up is given in Section 3.3.4.

## 3.2 RECHARGE ESTIMATES FOR CURRENT AND POST-CLOSURE CONDITIONS

The precise definition of recharge is that flux of water reaching the water table. At the present time, there is no effective way of measuring recharge at the water table for the tank farm conditions. Therefore, shallow unsaturated zone measurements and analyses are used to estimate the deep drainage flux, i.e., the flux leaving the evapotranspiration zone and traveling to the water table. Given sufficient time, the deep drainage flux will eventually manifest itself at the water table. However, when deep drainage fluxes change, the change may not be apparent at the water table for a considerable period of time. The length of time depends on the vadose zone

thickness and hydraulic properties and the initial and final deep drainage rates. Sediment stratification can lengthen that time further.

WMA S-SX ground surfaces are presently covered with gravel to prevent vegetative growth and to prevent the spread of surface contamination. Bare gravel surfaces, however, enhance net infiltration of meteoric water from precipitation, compared to undisturbed naturally vegetated surfaces. Infiltration is further enhanced in tank farms by the effect of percolating water being diverted by the impermeable, sloping surface of the tank domes. This umbrella effect is created by the 23-m diameter buried tank domes. Water shed from the tank domes flows down the tank walls into underlying sediments. Sediments adjacent to the tanks, while remaining unsaturated, can attain elevated moisture contents (WHC-SA-2680-FP, *Effect of Moisture-Dependent Anisotropy and Enhanced Recharge Around Underground Storage Tanks*). Enhanced infiltration from a gravel-covered tank dome can provide potential for faster transport of contaminants to the water table.

Infiltration (recharge) can vary greatly depending on factors such as climate, vegetation, surface condition, and soil texture. For the purpose of this risk assessment, recharge values are based on the data contained in *Recharge Data Package for the Immobilized Low-Activity Waste 2001 Performance Assessment* (PNNL-13033) (available in the DOE reading room). The values used in the S-SX model are given in Table 3-1, along with the recommended values from (PNNL-13033). Timeline estimates for barrier emplacement at WMA S-SX and the corresponding recharge estimates are presented in Table 3-1 and Figure 3-4. The values shown in this table include recharge values used in the WMA S-SX model, as well as the recommended values (PNNL-13033, Table S.1) and reasonable bounding values (PNNL-13033, Table S.1 and Section 5.2). For conservative purposes at all timeline estimates, the WMA S-SX modeling used recharge values that exceeded the recommended values (PNNL-13033) and for the current conditions exceeded the upper limit for the reasonable bounding condition.

Table 3-1. WMA S-SX Infiltration (Recharge) Estimates for Pre-Construction Period, Current Conditions, and Following Emplacement of Closure Barrier. (2 sheets)

| **Condition simulated** | **Recharge estimate (mm/yr)** | | **Duration** | **Comment** |
|---|---|---|---|---|
| | **S-SX model** | **Recommended value* (bounding)** | | |
| Before 1950-1951 (S tank farm construction period) and 1953-54 (SX tank farm construction period) | 3.5 | 0.9 (0.16, 4.0) | Until steady-state moisture conditions are achieved for the year 1952 for S tank farm and the year 1955 for SX tank farm | Vadose zone flow simulated at the recharge rate of 3.5 mm/yr to develop initial moisture conditions for subsequent simulations. |
| Current conditions | 100 | 55.4 (50, 86.4) | 1952 to 2050 for S tank farm and 1955 to 2050 for SX tank farm | Recharge is assumed to increase from the pre-construction period estimate of 3.5 mm/yr to the current value of 100 mm/yr. During this period, the ground cover is gravel with no vegetation. A Modified RCRA Subtitle C Barrier is assumed to be in |

Table 3-1. WMA S-SX Infiltration (Recharge) Estimates for Pre-Construction Period, Current Conditions, and Following Emplacement of Closure Barrier. (2 sheets)

| Condition simulated | Recharge estimate (mm/yr) | | Duration | Comment |
|---|---|---|---|---|
| | S-SX model | Recommended value* (bounding) | | |
| | | | | place by 2050. |
| Transition to conditions of restricted recharge with enhanced RCRA Subtitle C Barrier | 0.5 | 0.1 (0.01, 4.0) | 2050 to 2550 | Recharge is assumed to decrease from a current estimate of 100 mm/yr to the barrier design value of 0.5 mm/yr. The barrier is assumed to function to its design estimate of 500 years. |
| Degraded barrier condition | 3.5 | 0.1 (0.01, 4.0) | 2550 to 12000 | The barrier is degraded and recharge increases from 0.5 mm/yr to 3.5 mm/yr until the end of simulation at 12,000 years. |

Notes:

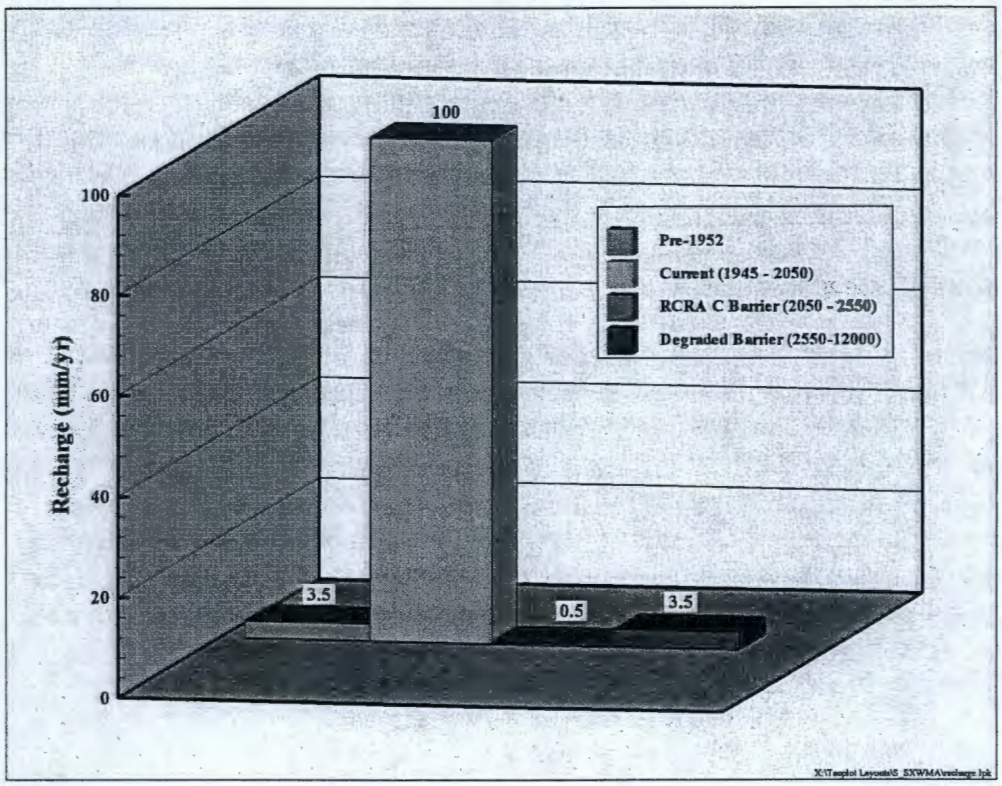
*Based on 8-year lysimeter data for graveled surface (PNNL-13033), lower bound is followed by upper bound.

RCRA = *Resource Conservation and Recovery Act of 1976.*

WMA = Waste Management Area.

PNNL-13033, 1999, *Recharge Data Package for the Immobilized Low-Activity Waste 2001 Performance Assessment,* Pacific Northwest National Laboratory, Richland, Washington.

1 Figure 3-4. Recharge Rates and Timeline Estimates.




2

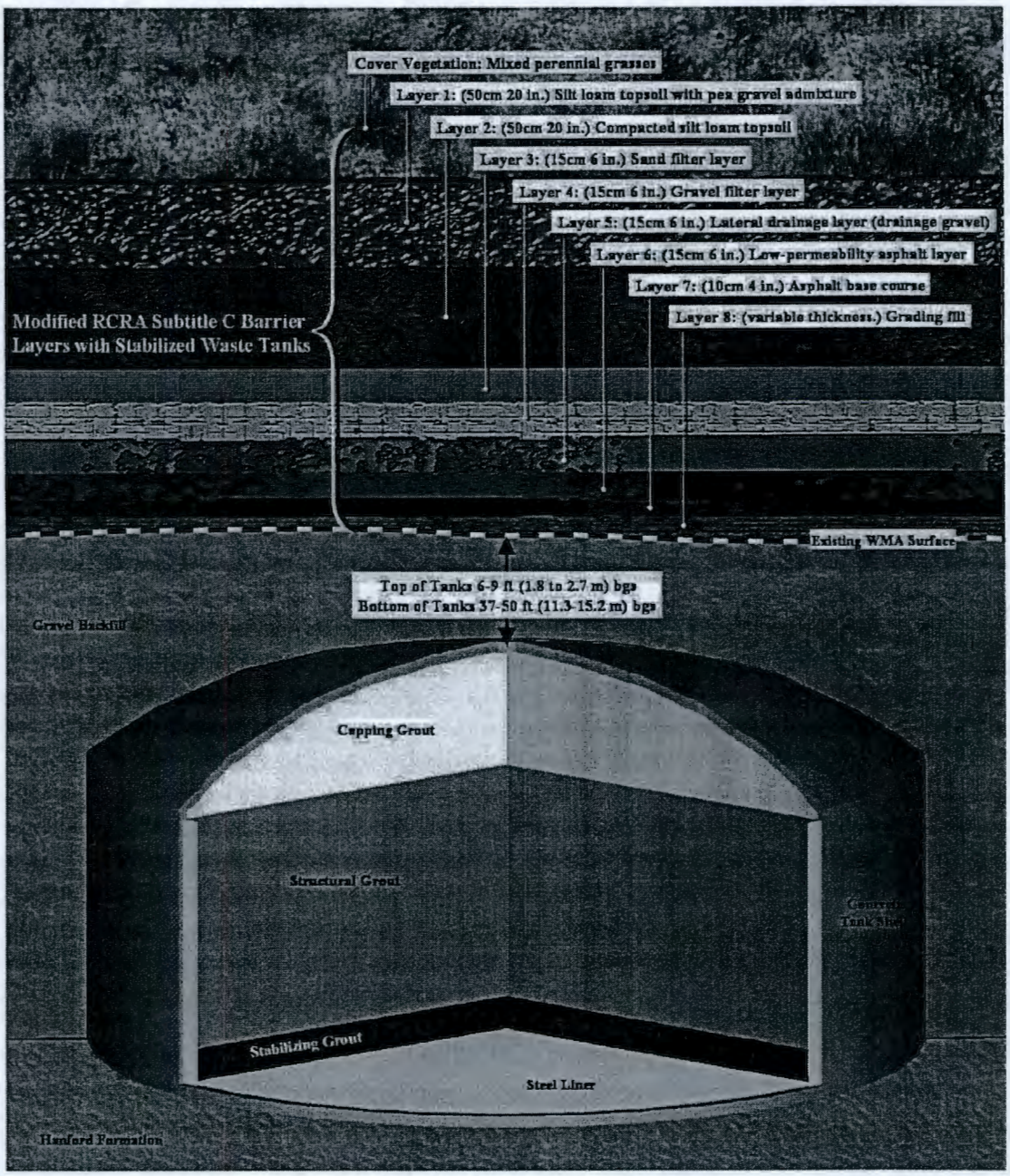
The groundwater modeling started with a pre-Hanford recharge rate of 3.5 mm/yr. After the construction of Hanford tank farms until its closure, a recharge rate of 100 mm/yr was used. The closure barrier for tank farms is assumed to be a Modified RCRA Subtitle C Barrier with a design life of 500 years (see Figure 3-5 and the following section for a description of the barrier). Because of the built-in multiple capillary breaks, nearly all the precipitation is diverted laterally and the recharge through such a barrier is estimated to be as low as 0.1 mm/yr (PNNL-13033). For these simulations, a recharge rate of 0.5 mm/yr is used. This is based on experimental data from a prototype Hanford barrier that was designed and built in 200 Area to limit recharge to $\leq 0.5$ mm/yr ("Quest for the Perfect Cap," Wing and Gee 1994). This is also supported by the numerical simulation results of *Simulations of Infiltration of Meteoric Water and Contaminant Plume Movement in the Vadose Zone at Single-Shell Tank 241-T-106 at the Hanford Site* (WHC-EP-0332), which shows that with a relatively impermeable barrier over the tank farm, the drainage to a 2-m backfill depth decreased to less than 0.5 mm/yr after 8 years for cases of either a backfill or a clean graveled surface. For a degraded closure barrier, recharge rates are expected to return to predevelopment conditions (i.e., shrub-steppe ground cover), with a recharge estimate of 3.5 mm/yr. Such an estimate is within the range of values reported in *Estimated Recharge Rates at the Hanford Site* (PNL-10285).

### 3.2.1 Modified RCRA Subtitle C Barrier

The closure barrier for tank farms is assumed to be a Modified RCRA Subtitle C Barrier. The design of this barrier is given in *Focused Feasibility Study of Engineered Barriers for Waste Management Units in 200 Areas* (DOE/RL-93-33). This barrier is designed to provide long-term containment and hydrologic protection for a period of performance of 500 years. It is composed of eight layers of durable material with a combined minimum thickness of 1.7 m (5.5 ft) (Figure 3-5). A summary description of each of the layers in this barrier is given in PNNL-13033, Table 4.2, including thickness, layer description, specifications, and functions. This design incorporates RCRA minimum technology guidance with modifications for extended performance. The modifications to the RCRA Subtitle C Barrier and the reasoning behind those modifications are given in DOE/RL-93-33. It should be noted that a definitive design for the barrier has not yet been established. The design basis used in this assessment is based on the best information available at this time.

The Modified RCRA Subtitle C Barrier is similar in structure to the Hanford Barrier (DOE/RL-93-33), but layer thicknesses are reduced and there is no fractured basalt. The design incorporates provisions for biointrusion and human intrusion control. The design of this barrier could be enhanced by increasing the thickness of the topsoil layers and by including some type of intrusion layer (similar to the fractured basalt in the fractured basalt layer in the Hanford barrier) so that it would provide additional protection. For the WMA closure, it is assumed that the variable thickness layer (8) will be increased to 2.9 m (9.5 ft) for the purposes of this assessment so that the total thickness of the barrier placed over the WMA will be at least 4.6 m (15 ft) thick.

Figure 3-5. Modified RCRA Subtitle C Barrier Profile from DOE/RL-93-33 with Stabilized Waste Tanks (not to scale).




## 3.3 SOURCE TERM RELEASE SCENARIOS, TRANSPORT MODELING, AND NUMERICAL CASES

This section provides an overview of the source term release scenarios, transport modeling, and numerical cases used in this risk assessment.

### 3.3.1 Source Term Release Scenarios

The source terms for the long-term closure assessment consist of four separate sources, which include: past leaks and spills, leakage during retrieval, residual waste leachate from tanks following closure, and residual waste leachate from tank ancillary equipment following closure. The past leaks represent tank waste that has leaked into the vadose zone and has been migrating through the vadose zone for a number of years. Retrieval leakage refers to leakage to the vadose zone that could occur during waste retrieval operations using water-based sluicing. Releases from the residual wastes (both from tank and tank ancillary equipment) would typically occur over an extended period following closure of the tank farm when infiltrating water would enter the tank or tank ancillary equipment, dissolve contaminants, and migrate into the vadose zone and to the groundwater. For modeling purposes, it is assumed that structural integrity of the tank (i.e., steel tank and concrete) and tank ancillary equipment is lost on January 1, 2050.

As discussed in Section 3.1.2, for each simulation of a particular source (tank residual, past leaks, etc.), the total curie or mass (unit source) is used as the source term inventory for each of the four sources. This is a logical approach when dealing with uncertainty and sensitivity of inventory estimates for various sources. As the best-basis inventory (BBI) and vadose zone inventory data are updated and refined, the contaminant BTCs, on the basis of unit source inventory, can be easily scaled to account for total inventory. The following paragraphs describe the release mechanisms evaluated for WMA S-SX.

**Past Leaks and Retrieval Losses**. The retrieval case simulations assume that leaks occur over a specified area at the base of the tank near the edge, generally considered to be of lower structural integrity (Williams et al. 2001, *Description of Vadose Zone/Groundwater Flow and Transport Numerical Modeling for S Tank Farm Retrieval Performance Evaluation*). The simulations for past leaks and spills do not attempt to model a waste release; instead, they model the potential risk posed by the existing vadose zone contamination footprint from past leaks and spills. Information on contamination footprint (inventory diameter with unit source) is based on recent vadose zone borehole drilling and sampling, as well as spectral gamma data for drywells in WMA S-SX. Only tanks for which there is evidence of contamination in the vadose zone through borehole logs and contaminant sampling, and for which there is a vadose zone inventory are included in the analyses. Results from hypothetical losses are added to the past leaks to determine the cumulative impacts of the releases that occur over a relatively short period of time.

**Residual Waste Release**. In contrast to releases from past leaks and retrieval losses, releases from residual waste generally are expected to occur over a much longer time period. For residual tank waste and residual ancillary equipment waste, actual release mechanisms are unknown at this time. However, post-retrieval samples will be taken to determine a release model for the residual waste. For an accurate determination of the source term, the chemical and physical processes controlling contaminant release from the residual wastes must be explicitly modeled. In the absence of post-retrieval tank waste characterization data and a lack of information of the controlling processes, a series of four different release scenarios were examined for contaminant release from tank wastes and tank ancillary equipment such that the modeling results include the range of potential outcomes. As discussed below and as presented in Table 3-2, releases from tank residual wastes are modeled using advection-, diffusion-, and

solubility-dominated release models, whereas releases from residual wastes in tank ancillary equipment and pipelines are modeled using a diffusion-dominated release model.

**Uniform Residual Waste Release Scenario.** For this scenario, a uniform release rate over specified release periods was assumed, with the source inventory released over the entire release duration. A similar approach was used in various versions of the immobilized low-activity tank waste performance assessment (DOE/ORP-2000-24).

**Advection-dominated Release Scenario.** For this release scenario, an advection-dominated release model is used to simulate contaminant release from unstabilized wastes (a waste form covered with backfill sand and gravel).

**Diffusion-dominated Release Scenario.** For this release scenario, a diffusion-dominated release model is used to simulate contaminant release from stabilized, contained wastes (a waste form mixed with grout or cementitious grout).

**Solubility-dominated Release Scenario.** For this release scenario, a solubility-dominated release model represents a waste form bound in a material that releases risk-driving contaminants congruently with the dissolution of the material.

Details of the tank waste release scenarios are given in the modeling data package (RPP-17209). The release scenarios allow the release duration to vary on the basis of various controlling processes (advection, diffusion, or solubility) that are active during release from residual wastes. The purpose of the different release models is to simulate a wide range of possibilities. For example, a failed grout would be represented by an advection-dominated release. In addition to recharge (infiltration) rates, these models consider the mixing (advection and diffusion) processes occurring within the residual wastes. A similar approach was recommended by the U.S. Nuclear Regulatory Commission for the low-level waste performance assessment (*Background Information for the Development of a Low-Level Waste Performance Assessment Methodology* [NUREG/CR-5453]) and was used for the 200 East and 200 West areas solid waste performance assessment analyses at the Hanford Site (WHC-EP-0645; WHC-SD-WM-TI-730).

### 3.3.2 Vadose Zone Flow and Transport Modeling

Two-dimensional flow and transport models along the row of tanks (Figure 3-3) are used for all vadose zone simulations. The simulations are composed of steady-flow and transient components, where flow fields developed from the steady-flow component are used to initialize the transient simulation. Initial steady-state conditions are developed by simulating from a prescribed unit hydraulic gradient condition to a steady-state condition, dictated by the initial meteoric recharge at the surface, water table elevation, water table gradient, no flux vertical boundaries, variation of hydrologic properties, and location of impermeable tanks.

The steady-flow simulations, representing flow conditions for the year 1952 (completion of S tank farm construction) and the year 1955 (completion of SX tank farm construction), are used as the initial condition for all subsequent flow and transport simulations. From the starting conditions, transient transport simulations are conducted for a 10,000-year period (i.e., years

2000 to 12000) that involve changes in the flow fields in response to current conditions, placement of closure barrier, and effects of degraded barrier. The infiltration (recharge) estimates for various times are described in Section 3.2. All simulations are run assuming isothermal conditions. The vadose zone is modeled as an aqueous-gas porous media system where transport through the gas phase is neglected.

Fluid flow within the vadose zone is described by Richards' equation (Richards 1931, *Capillary Conduction of Liquids through Porous Mediums*), whereas the contaminant transport is described by the conventional advective-dispersive transport equation with an equilibrium linear distribution coefficient ($K_d$) formulation. A series of mobile to moderately retarded contaminant species ($K_d$ = 0, 0.01, 0.03, 0.1, 0.3, 0.6, and 1.0) are considered for each run. The purpose of simulating the system with a suite of $K_d$ with the unit source allows applying inventories to a wide range of COPCs following retrieval.

No site-specific data are available on soil moisture characteristics for the WMA S-SX. Different soil moisture characteristics were assigned to the undisturbed sediments underlying the WMA than to the disturbed sediments of the backfill material. The details of the soil moisture characteristics given to all sediments underlying the WMA are given in RPP-17209. For this work, data on laboratory measurements for moisture retention, particle-size distribution, saturated and unsaturated hydraulic conductivity, and bulk density for individual stratum are based on data for similar soils in 200 East and 200 West areas. Details on modeling inputs are provided in the modeling data package (RPP-17209).

### 3.3.3 Numerical Cases

As discussed in Section 3.3.1, the source terms for the risk assessment consist of four separate sources: hypothetical leakage during retrieval, past leaks and spills, residual waste leakage from the tanks following closure, and residual waste leakage from the tank ancillary equipment following closure. Table 3-2 lists the release scenarios and numerical cases considered. In addition to those listed in Table 3-2, past leaks from ancillary equipment (pipelines) were simulated (see Section 4.0). It was assumed that such a leak occurred with its vadose zone inventory at a depth of about 10.5 m (34.5 ft) below ground surface (bgs) and an inventory diameter of 8 m (25 ft) as of January 1, 2000, with the inventory distributed between SSTs S-102 and S-103. The following provides a rationale selecting the individual cases.

Table 3-2. Release Scenarios and Numerical Cases. (2 sheets)

| |
|---|
| Retrieval Leak<br>• **Case 1: Retrieval leaks; 4,000 gal.** A retrieval leak of 4,000 gal on the tank corner with start of leakage on January 1, 2000 and continuing for 14 days, with the leak occurring at the bottom east corner of SST S-103.<br>• **Case 2: Retrieval leaks; 8,000 gal.** A retrieval leak of 8,000 gal on the tank corner with start of leakage on January 1, 2000, and continuing for 14 days, with the leak occurring at the bottom east corner of SST S-103. |
| Past Leak<br>• **Case 8: Past leaks with inventory well above the Plio-Pleistocene unit.** A past leak with its vadose zone inventory at a depth of about 25.5 m (84 ft) bgs and an inventory diameter of 8 m (25 ft) as of January 1, 2000, with the inventory distributed between SSTs S-102 and S-103. |

Table 3-2. Release Scenarios and Numerical Cases. (2 sheets)

| |
|---|
| • **Case 9: Past leaks with inventory just above the Plio-Pleistocene unit.** A past leak with its vadose zone inventory at a depth of about 39.5 m (130 ft) bgs and an inventory diameter of 8 m (25 ft) as of January 1, 2000, with the inventory distributed between SSTs S-102 and S-103. |
| Release from Residual Tank Waste<br>• **Case 3: Residual tank waste; release rate $R_0$.** Residual tank waste source with a release rate $R_0$ ($10^{-6}$ Ci/yr for 500 yr and $10^{-4}$ Ci/yr for 9,995 yr), a release start date of January 1, 2050 (i.e., date tank integrity is lost) and release over the tank bottom.<br>• **Case 4: Residual tank waste; advection-dominated release.** Residual tank waste source with advection-dominated release, a release start date of January 1, 2050 (i.e., date tank integrity is lost) and release over the tank bottom.<br>• **Case 5: Residual tank waste; diffusion-dominated release.** Residual tank waste source with a diffusion-dominated release rate ($D_d = 6 \times 10^{-7}$ cm$^2$/s; WHC-SD-WM-EE-004), a release start date of January 1, 2050, and release over the tank bottom.<br>• **Case 6: Residual tank waste; solubility-controlled release.** Residual tank waste source with a solubility-dominated release; a release start date of January 1, 2050 (i.e., date tank integrity is lost) and release over the tank bottom. |
| Release from Residual Ancillary Equipment Waste<br>• **Case 7: Residual ancillary equipment waste.** Residual tank ancillary equipment waste source with inventory located at a depth of 20 ft bgs, a release start date of January 1, 2050, and a diffusion-dominated release ($D_d = 6 \times 10^{-7}$ cm$^2$/s;WHC-SD-WM-EE-004) over an inventory diameter of 8 m (25 ft) for the grouted residual waste. |

Notes:

bgs = below ground surface.

SST = single-shell tank.

WHC-SD-WM-EE-004, 1995, *Performance Assessment of Grouted Double-Shell Tank Waste Disposal at Hanford*, Rev. 1, Westinghouse Hanford Company, Richland, Washington.

* To date, no decision has been made on grouting residual wastes in tank ancillary equipment. A corrective measures study (CMS) will be prepared and a decision regarding grouting or otherwise will be made as part of the CMS. The grouting assumption in this assessment is based on the best information available at this time.

**Hypothetical Retrieval Leak Loss.** There is considerable uncertainty regarding the performance of retrieval technologies and the ability to respond to a retrieval leakage event. This initial assessment assumes that hydraulic sluicing will be used to retrieve waste and if a leak were to occur, all tanks would experience an equal leak loss volume of 4,000 gal per tank (Case 1). Such an estimate is based on the best available information at this time (i.e., *EIS for Retrieval, Treatment, and Disposal of Tank Waste and Closure of SSTs at the Hanford Site, Richland, Washington (Waste Retrieval and Storage Data Package)* (DOE/ORP-2003-06). However, a higher leakage loss of 8,000 gal per tank was also used as a sensitivity case (Case 2).

**Past Leaks and Spills.** As stated in Section 3.3.1, the simulated cases for past leaks and spills (Cases 8 and 9) do not attempt to model a waste release, instead they model the potential risk posed by their existing vadose zone contamination footprint (RPP-17209). As mentioned earlier, information on contamination footprint and their location within the vadose zone for past leaks and spills are based on recent vadose zone borehole drilling and sampling as well as spectral gamma data for drywells in WMA S-SX (RPP-7884).

**Residual Waste Release.** Residual waste leakage is considered for both tank (Cases 3 through 6) and tank ancillary equipment (Case 7). As discussed in Section 3.3.1, a series of post-closure scenarios are assumed for contaminant release from tank wastes and tank ancillary equipment such that the modeling results include the range of potential outcomes.

Case 3 assumes uniform release rates over specified release periods, with the unit source inventory released over the entire release duration. Cases 4 through 6 allows the release duration to vary on the basis of various controlling processes (advection, diffusion, or solubility) that are active during release.

Cases 4, 5, and 6 recognize whether the tank wastes are stabilized or unstabilized. The stabilized tank wastes (Cases 5 and 6) correspond to a waste form mixed with grout or cementitious grout (diffusion-dominated release), whereas the unstabilized wastes (Case 4) refer to a waste form covered with backfill sand and gravel (advection-dominated release). Case 6 represents a stabilized waste form bound in a material that releases risk-driving contaminants congruently with the dissolution of the material (solubility-dominated release).

The waste in the tank ancillary equipment, following closure, is assumed to be stabilized (i.e., grouted waste form). Therefore, Case 7 for residual waste release from ancillary equipment considers only a diffusion-dominated release. The residual waste from the ancillary equipment is located closer to present day ground surface. Therefore, contamination takes longer to travel through the vadose zone to the groundwater.

### 3.3.4 Key Modeling Assumptions

The key assumptions invoked in this preliminary risk assessment are summarized below:

- Calculations are performed for unit curie (or unit mass) as a source term for each of the four sources (i.e., past leaks and spills, retrieval leaks, residual tank wastes, and tank ancillary equipment within the WMA).
- Each of the four sources can be modeled separately and not impact the consequences of the others.
- Based on results obtained for a single source in the WMA, the principle of spatial and temporal superposition can be used to extend results for various facilities to the WMA fenceline.
- The inventory for each of the sources is based on the best available information (RPP-20420).
- The fill material in the tanks and tank infrastructure is most likely to be cementitious grout.
- The variety of tank residual waste release models provides the envelope for approximating actual release rate.

- The closure barrier for tanks and facilities in a WMA will be a Modified RCRA Subtitle C Barrier; recharge rates for pre- and post-closure conditions are based on best available data.

Final retrieval of the tanks is just beginning and the inventory in the infrastructure is not known. Thus, inventories for potential retrieval leaks, residual waste in tanks, and residual waste in infrastructure are best available estimates at this time (RPP-20420).

The material that will be used to fill the tanks has not yet been determined. Future assessments will model effects of various materials that will be under consideration as well as the effect that the tank itself has on flow patterns.

It is presently unknown how the contaminants will release from the residual waste. The three models used (advection-dominated, diffusion-dominated, and solubility-controlled dominated) as well as sensitivity cases should bracket the release. However, experimental data from actual residual waste will be used in future work on release scenarios.

Finally, the time and method of final closure for a WMA has not yet been established. The timeline used in this assessment is based on the best estimates available at this time.

### 3.3.5 Relationship Between Two-Dimensional and Three-Dimensional Simulations

As discussed earlier, although the simulations in this report are 2-D, in reality, flow and transport from any source type will occur in 3-D. Because of the long simulation times, simulating 3-D processes is not trivial; however, although 2-D simulations have shorter run times, the absence of flow and transport in the third dimension translates into higher concentration predictions. Therefore, results from 2-D simulations need to be translated into equivalent values for a 3-D domain to better predict contaminant concentrations in the groundwater. However, this conversion relation is not known a priori.

To determine a dilution factor for the 2-D simulations, Case 1 was simulated in 3-D (PNNL-14604). This base case scenario involved a retrieval leak of 4,000 gal at the lower-right corner of SST S-103 that began on the first day of the year 2000. The leak was arbitrarily set to last for 14 days (RPP-17209) and contained a unit release of each of the contaminant species ($^{99}$Tc and $^{238}$U). The main difference between the 2-D and 3-D simulations was the thickness of the simulation domain in the horizontal direction (y direction) perpendicular to the flow direction. In the 2-D simulation, a unit width (1 m) was used. In 3-D, the width was 153 m discretized into 3-m units. Hence, water and solute migration occurred in the y direction for the 3-D simulation, whereas it was absent in 2-D.

To examine the relationship between the concentrations for the two simulations, the fenceline aqueous concentrations of $^{99}$Tc and $^{238}$U with $K_d = 0.03$ mL/g were evaluated along the y direction for the 3-D simulation when the peak concentrations occurred (PNNL-14604). Figure 3-6 shows that the highest concentrations occurred at the center line of SSTs S-101, S-102, and S-103 (y = 125 m), and as the distance from the tank center line increased, the concentrations decreased. The concentration along the y direction was nearly symmetrical along

the centerline of the tank. Approximately 99.4% of $^{99}Tc$ and 98.3% of $^{238}U$ were within 20 m of the centerline of the tank (from 105 to 145 m). Therefore, commingling of plumes between rows is assumed to be negligible because the results of the 3-D simulation indicated that 99% of the contaminants remained within 20 m of the plume centerline.

For both $^{99}Tc$ and $^{238}U$, the shape of the BTCs from the 2-D simulations was very similar to those from the 3-D simulations (PNNL-14604). The ratio of the 2-D ($C_{2d}$) and 3-D ($C_{3d}$) peak $^{99}Tc$ concentrations was 41.1. The $C_{2d}/C_{3d}$ ratio for $^{238}U$ with $K_d = 0.03$ mL/g was 36.6. The arrival time of the of the $^{99}Tc$ peak concentration from the 2-D simulation was 14 years earlier than that from the 3-D simulation. For $^{238}U$ with $K_d = 0.03$ mL/g, the arrival times of the first and second peak concentrations from the 2-D simulation were respectively 36 and 342 years earlier than that from the 3-D simulation.

## 3.4 WASTE MANAGEMENT AREA S-SX GEOLOGY AND SATURATED MEDIA PROPERTIES

A detailed discussion of WMA S-SX geology is provided in *Subsurface Physical Conditions Description of the S-SX Waste Management Areas* (HNF-4936). A geologic cross-section taken through the S tank farm is provided in Figure 3-3. *Subsurface Conditions Description of the C and A-AX Waste Management Area* (RPP-14430) identifies the following sedimentary sequences (from top to bottom) overlying the basalt beneath WMA S-SX:

- Backfill (material type 1, sandy gravel) – backfill materials consist of unstructured, poorly sorted mixtures of gravel, sand, and silt removed during tank excavation, and then later used as fill around the tanks.

- Hanford formation – upper gravelly sequence (H1 unit, material type 3, gravelly sand); Hanford formation H1 unit consists of predominantly loose coarse-grained gravel and sand deposits, with minor beds of sand to silty sand. Coarser beds may contain boulder-sized materials.

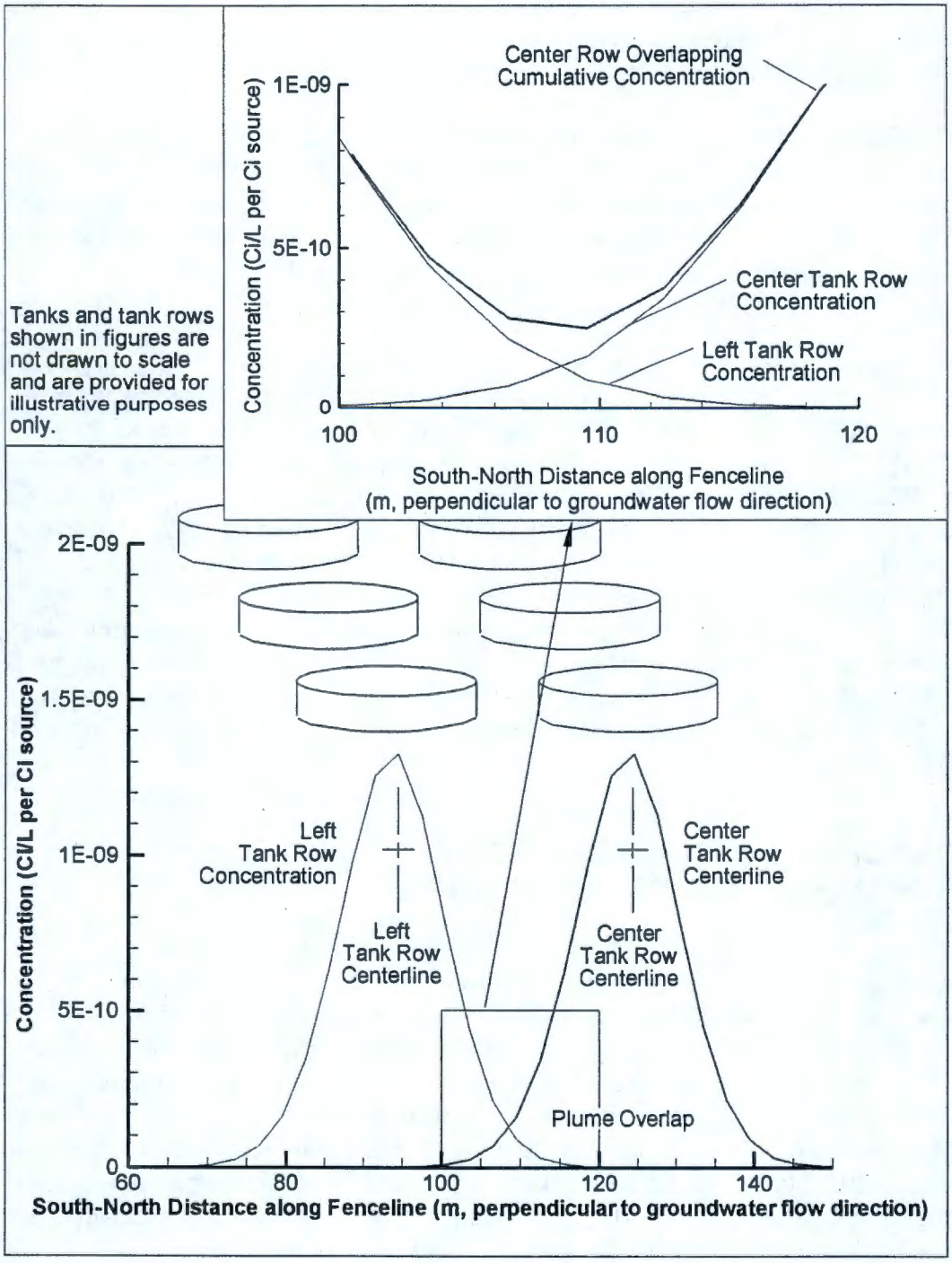
- Hanford formation – sand sequence (H2 unit, material type 2, sand); Hanford formation H2 unit consists of predominantly fine- to coarse-grained sand with lenses of silty-sand to slightly gravelly sand. Minor sandy gravel to gravelly sand beds occur sporadically.

- Cold Creek Unit also known as the Plio-Pleistocene unit – silty very fine sand to sandy silt (material type 4).

- Upper Ringold Formation – Sand-dominated facies consisting of slightly silty coarse to medium sand (material type 5).

- Ringold Unit E – The Ringold Formation comprising the vadose zone (material type 5) and upper part of the unconfined aquifer (material type 6) consists of slightly silty coarse- to medium-grained sandy gravel with intercalated gravelly sand (Ringold Unit E).

Figure 3-6. Results on Commingling of Plumes Based on 3-D Simulations (after PNNL-14604).



The geologic strata (Figure 3-3) are assumed to be continuous but not of constant thickness; the model includes the effect of dipping strata. The water table for WMA S-SX ranges from 136.24 to 136.80 m (446.98 to 448.82 ft) bgs. The hydraulic and transport properties used for these sedimentary sequences in the flow and transport modeling are given in RPP-17209.

**Hydraulic Conductivity of the Unconfined Aquifer**. A saturated hydraulic conductivity of 25 m/d is used for Ringold E formation; the effective porosity of the formation is 21.2%. These values are based on *Transient Inverse Calibration of Hanford Site-Wide Groundwater Model to Hanford Operational Impacts—1943 to 1996* (PNNL-13447) and are consistent with the Pacific Northwest National Laboratory System Assessment Capability model (PNNL-13949, Figure 5.6).

Note the following information was provided in *Waste Management Area S-SX Closure Action Plan* (RPP-19773, Section 3.3). Hydraulic conductivities based on slug tests performed in WMA S-SX wells 299-W22-48, 299-W22-49, and 299-W22-50 range from 1.15 to 8.2 m/day (0.5 to 27 ft/day) (PNNL-13441, *RCRA Groundwater Quality Assessment Report for Waste Management Area S-SX [November 1997 through April 2000]*). The effective porosity of aquifer materials beneath WMA S-SX ranges from 0.068 to 0.257 based on analysis of tracer tests conducted in the area (PNNL-13441). Hydraulic gradient, based on tracer test analysis is about 0.002 whereas the groundwater velocity ranges from 0.013 to 0.374 m/day (0.04 to 1.2 ft/day) (PNNL-13441). Estimates of the rate of groundwater flow, using travel times for tritium between upgradient and downgradient wells in the vicinity of WMA S-SX suggest groundwater flow rates of 25 to 50 m/yr or 0.07 to 0.14 m/day (82 to 164 ft/yr or 0.23 to 0.46 ft/day) (PNNL-12114, *RCRA Assessment Plan for Single-Shell Tank Waste Management Area S-SX at the Hanford Site*).

## 3.5 SELECTION OF CONTAMINANTS OF POTENTIAL CONCERN FOR EVALUATING CLOSURE

As described earlier in this section, the primary transport mechanism of contaminants in WMA S-SX waste is migration through the vadose zone to groundwater. Therefore, all constituents in the WMA S-SX tanks (RPP-20420) were considered in the analysis. However, a process was developed to drop constituents based on the screening approach described in the following subsection. COPCs are defined as those constituents that should be carried forward into the risk assessment process. During the course of the risk assessment, COPCs are evaluated to identify and prioritize those constituents that are estimated to pose an unacceptable risk and are used to support the WAC 173-303-610(2) closure performance standards for human health and the environment to allow component closure activities to continue.

### 3.5.1 COPC Screening Approach

Past leak inventory estimates and inventory estimates of wastes currently stored in the WMA S-SX tanks (RPP-20420) were evaluated. The risk assessment is limited to evaluating only those constituents that are reported in RPP-20420. It is likely that considerably more

constituents are in the tanks but cannot be included in the inventory estimates as a result of limitations in current technology (i.e., inadequate analytical methods and sample collection techniques). Inventory results were then modeled to estimate groundwater concentrations at the fenceline. A tiered approach was used to identify COPCs for the contaminants reported in the WMA S-SX tanks. The first step of the COPC selection process was used to identify those constituents with available U.S. Environmental Protection Agency (EPA) toxicity values (see next section for such sources). The next step of the COPC selection process was used to identify those constituents that would reach groundwater based upon chemical interaction with soils (i.e., mobile constituents having a $K_d$ value of less than 0.6) and with a half-life of greater than 6 years. For those constituents with available toxicity values and also considered mobile and long-lived, ILCR, or HQ values were calculated and compared to a risk screening threshold value ($1.0 \times 10^{-7}$ for ILCR and 0.01 for HQs).

**3.5.1.1 Availability of Toxicity Values.** Any constituent reported in the inventory estimates was included in this step of the selection process. The only criterion in this step is the availability of a reliable toxicity value. If a toxicity value is available from a reliable source, then the constituent was carried forward into the next step of the COPC selection process.

If a constituent does not have a toxicity value from a reliable source, then the constituent was not carried forward into the risk assessment. Sources of toxicity values (cancer slope factors and noncancer reference doses) considered for risk assessment include the following:

- The Health Effects Assessment Summary Tables (HEAST) Radionuclide Table (EPA 1997, *Health Effects Assessment Summary Tables*): Radionuclide Carcinogenity – Slope Factors (EPA 1999, *Cancer Risk Coefficients for Environmental Exposure to Radionuclides*), provided by the EPA Office of Radiation and Indoor Air (April 16, 2001 update), is a compilation of radionuclide slope factors at www.epa.gov/radiation/heast.html

- The Integrated Risk Information System database available through the EPA National Center for Environmental Assessment in Cincinnati, Ohio. The Integrated Risk Information System, prepared and maintained by EPA, is an electronic database containing health risk and EPA regulatory information on specific chemicals http://www.epa.gov/IRIS (EPA 2004, *Integrated Risk Information System*).

- The HEAST, provided by the EPA Office of Solid Waste and Emergency Response (EPA 1997), is a compilation of toxicity values published in various health effects documents issued by EPA.

- The U.S. EPA Region IX Preliminary Remediation Goal Table (October 2002) at www.epa.gov/docs/region09/waste/sfund/prg/index.html

Toxicity values are developed by EPA on an ongoing basis, and they are not available for every constituent reported in the inventory. Exclusion of those constituents without toxicity values may underestimate potential risks within the WMA.

**3.5.1.2 Chemicals Without Toxicity Values.** A total of 68 constituents were reported in the inventory estimates of WMA S-SX tanks. Of the 68 constituents reported, 11 constituents (bismuth, calcium, chloride, lanthanum, phosphate, potassium, silicon, sodium, strontium, sulfate, and zirconium) did not have available toxicity values. Therefore, these 11 constituents were excluded from further consideration in the risk assessment.

**3.5.1.3 Identification of Mobile, Long-Lived Constituents.** The next step of the screening process identifies those constituents that would reach groundwater based on chemical interaction with soils (i.e., mobile constituents having a $K_d$ value of less than 0.6) and did not have a short-half life (greater than 6 years). Of the 57 constituents evaluated, 9 were considered short-lived and 33 were considered immobile. As such, these 39 constituents are not predicted to reach groundwater and were not identified as COPCs. The following 9 constituents are considered short-lived and were not considered further in the risk assessment:

- $^{60}$Co (5.2 yr), $^{90}$Y (64 hr), $^{106}$Ru (1.0 yr), $^{125}$Sb (2.7 yr), $^{134}$Cs (2.1 yr), $^{137m}$Ba (2.5 min), $^{155}$Eu (4.68 yr), $^{228}$Ra (5.7 yr), $^{242}$Cm (0.44 yr).

The following 33 constituents are considered immobile ($K_d$ > 0.6 mL/g) and were not considered further in the risk assessment:

- $^{59}$Ni, $^{63}$Ni, $^{79}$Se, $^{90}$Sr, $^{93}$Nb, $^{93}$Zr, $^{113m}$Cd, $^{126}$Sn, $^{137}$Cs, $^{151}$Sm, $^{152}$Eu, $^{154}$Eu, $^{226}$Ra, $^{227}$Ac, $^{229}$Th, $^{231}$Pa, $^{222}$Th, $^{237}$Np, $^{238}$Pu, $^{239}$Pu, $^{240}$Pu, $^{241}$Pu, $^{242}$Pu, $^{241}$Am, $^{243}$Am, $^{243}$Cm, $^{244}$Cm, aluminum, iron, lead, mercury, manganese, and nickel.

In addition to being relatively immobile in the vadose zone, constituents such as $^{137}$Cs do not appear in BTCs at the WMA fenceline as described in the WMA S-SX field investigation report modeling work (RPP-7884).

**3.5.1.4 Comparison of Risk Estimates to Risk Screening Thresholds.** If a toxicity value was available from a reliable source and the constituent was considered mobile and long-lived, then an ILCR or HQ was calculated for each constituent based on the *Hanford Site Risk Assessment Methodology* (HSRAM) (DOE/RL-91-45) residential exposure scenario and compared to risk screening thresholds to determine their potential for risk contribution. If the ILCR for a carcinogenic constituent was less than $1 \times 10^{-7}$ or the HQ for a noncarcinogenic constituent was less than 0.01, then the constituent was not identified as a COPC and was not considered further in the risk assessment. Of the 16 remaining constituents evaluated, manganese did not exceed its respective risk-screening threshold.

The following 15 constituents are identified as COPCs because they exceeded their respective risk screening threshold values:

- tritium
- $^{14}$C
- $^{99}$Tc
- $^{129}$I
- $^{232}$U
- $^{233}$U
- $^{234}$U
- $^{235}$U
- $^{236}$U
- $^{238}$U
- total chromium
- fluoride
- nitrate
- nitrite
- total uranium.

## 3.6 SOURCE TERMS AND INVENTORY

As discussed earlier, four types of contaminant sources are evaluated within WMA S-SX, which include the following: (1) past leaks from tanks, (2) residual tank waste, (3) potential leaks that occurred during waste retrieval, and (4) residual waste in the WMA S-SX piping system. Although detailed, quantitative inventories are not yet available for many of these sources, the risk assessment has identified them for inclusion when characterization is complete before final closure of the WMA. The sources identified in Table 3-3 have been incorporated into the computational basis for the WMA S-SX risk assessment. These sources include components specifically identified in the RCRA Part A permit application, RCRA past-practice sites associated with the WMA, and other components and systems (such as piping systems) that are geographically associated with the WMA. The discussion following Table 3-3 presents the current state of understanding of the estimated inventory associated with known source terms in WMA S-SX.

Table 3-3. Sources Included in the WMA S-SX Risk Assessment Conceptual Model. (2 sheets)

| Source type | Tank farm | Individual sources | Inventory | Included in risk assessment |
|---|---|---|---|---|
| Past leaks from tanks | S | One confirmed leak from SST S-104 | Yes Table 3-4 | Yes |
| | SX | Five confirmed leakers including SSTs SX-107, -108, -109, -113, -115 | Yes Table 3-4 | Yes |
| Past leaks from tank ancillary equipment[a] | SX | UPR-200-W-49 | No | No, surface contamination, unknown volume. Cleaned up in 1992. |
| | | UPR-200-W-50 | No | No, airborne release in 1958. Cleaned up in 1992. |
| | | UPR-200-W-51 | No | No, release in diversion box, unknown volume. Cleaned up in 1992. |
| | | UPR-200-W-80 | No | No, airborne contamination. |
| | | UPR-200-W-81 | No | No, airborne contamination. |
| | | UPR-200-W-82 | No | No, surface contamination; unknown volume |
| | | UPR-200W-108 | No | No, surface contamination from line leak. Leak volume (30 gal) is significantly smaller than tank leaks. |
| | | UPR-200-W-109 | No | No, surface contamination from line leak. Contaminated site interim stabilized in 1991. Leak volume is unknown; hence inventory for leak is unknown. |

Table 3-3. Sources Included in the WMA S-SX Risk Assessment Conceptual Model. (2 sheets)

| Source type | Tank farm | Individual sources | Inventory | Included in risk assessment |
|---|---|---|---|---|
| | | UPR-200-W-114 | No | No, surface contamination from liquid spill. Contaminated site was stabilized in 1992. Leak volume is unknown. Therefore, inventory for leak is unknown. |
| | | UPR-200-W-127 | No | No, surface contamination from line leak. Leak volume is unknown. Therefore, inventory for leak is unknown. |
| | | UPR-200-W-165 | No | No, surface contamination from line leak. Contaminated site was stabilized in 1997. Leak volume is unknown. Therefore, inventory for leak is unknown. |
| | S | Unknown designation | No | Surface spill, evaporator feed (8,600 gal). |
| Residual waste in tanks and ancillary equipment | S | 12 - 100-series tanks | Yes Table 3-5 & Table 3-7 | Yes |
| | SX | 15 - 100-series tanks | Yes Table 3-6 & Table 3-8 | Yes |
| | S | Pipeline | Yes Table 3-11 | Yes |
| | SX | Pipeline | Yes Table 3-11 | Yes |
| Hypothetical retrieval leaks | S | All tanks will have an hypothetical retrieval leak associated with it | Yes Table 3-9 | Yes |
| | SX | All tanks will have an hypothetical retrieval leak associated with it | Yes Table 3-10 | Yes |

Notes:

[a] HNF-SD-WM-ER-560 and Waste Information Data System report (http://ww.bhi-erc.com/eisdata/wids/).

SST = single-shell tank.

UPR = unplanned release.

WMA = Waste Management Area.

HNF-SD-WM-ER-560, 2001, *Historical Vadose Zone Contamination from S and SX Tank Farm Operations*, Rev. 1, CH2M HILL Hanford Group, Inc., Richland, Washington.

### 3.6.1 Source Term Inventory

The inventories for the data sources listed above are provided in Tables 3-4 through 3-11. However, only the inventories for the identified COPCs for this risk assessment are presented in those tables (see Section 3.5.1 for COPC Selection Process). A complete listing of inventories for all contaminants can be found in RPP-20420. RPP-20420 revised tank leak estimates for inventory given in *Inventory Estimates for Single-Shell Tank Leaks in S and SX Tank Farms* (RPP-6285).

**Tank leak** inventory estimates shown in Table 3-4 were developed as part of the WMA S-SX subsurface description report (HNF-4936).

**Current Tank Inventory** estimates for sludge tanks were developed as part of the *Environmental Impact Statement for Retrieval, Treatment, and Disposal of Tank Waste and Closure of Single-Shell Tanks at the Hanford Site, Richland, WA (Inventory and Source Term Data Package)* (DOE/ORP-2003-02), which supports preparation of the tank closure environmental impact statement. For saltcake tanks, a Hanford Tank Waste Operations Simulator (HTWOS) model was used. The BBI (DOE/ORP-2003-02) estimate for current tank inventories are shown in Tables 3-5 and 3-6 for WMA S and SX, respectfully.

**Residual waste**, as defined in Appendix H of HFFACO, includes all waste remaining in the tank after waste retrieval actions have been completed. Several different methods have been proposed for estimating the composition of the residual waste (DOE/ORP-2003-02). These methods include: (1) the volume ratio method, (2) the selected phase removal (SPR) method, and (3) the HTWOS model. Each of the above methods use a different set of assumptions to derive the post-retrieval inventory. The complete assumptions for the residual inventory are given in DOE/ORP-2003-02 and are briefly summarized here:

- Simple volume ratio method (RPP-20420, Tables 8-4 and 8-5). Residual waste inventory estimates are produced by multiplying the original tank inventory by a ratio of the final tank volume of the residue to the original tank volume (not including retained gas). While this method is simple, it also tends to overestimate the inventory of water-soluble components washed out of the waste during the retrieval process if raw water is used and underestimates the inventory of insoluble components in the saltcake and sludge.

- SPR method (RPP-20420 Tables 8-7 and 8-8). This method is similar to the simple volume ratio, but modified to take into account removal of select phases (sludge, supernatant, etc.) of waste during retrieval. While this method is more complex, it tends to underestimate the inventory of soluble and insoluble components in the saltcake.

- HTWOS method (RPP-20420, Tables 8-9 and 8-10). This method uses the same final volume as the previous two methods. However, this method makes assumptions for water additions and incorporates wash/leach factors. The HTWOS model is preferred model for saltcake-filled tanks because it tracks the fate of all of the soluble and insoluble components in the waste. The residual inventory is generally lower because of leaching of mobile constituents.

The volume ratio, selective phase and HTWOS models provide different sets of estimates for risk assessment analysis. Of these, the volume ratio method produces the least reliable set of estimates. This approach is less reliable because it artificially increases the residual concentration of water-soluble components such as $^{99}$Tc and $^{129}$I, and artificially reduces the concentration of insoluble components from the saltcake. Because of these deficiencies, the volume ratio results were not used in this risk assessment analysis.

The SPR method is substantially better in that it produces more realistic predictions of the composite sludge layer in the sludge-filled tanks. This method is well suited for generating reasonable predictions of the residual waste inventories in SSTs S-107, SX-107, SX-108, SX-113 and SX-115.

The HTWOS model appears to be especially well suited for residual waste inventory predictions in the remaining saltcake-filled tanks in the S and SX tank farms. This model was chosen because it more aptly tracks the fate of the soluble and insoluble components in the waste and thus provides a more complete picture of the liquids and solids remaining in the tanks. These predictions were generated by assuming 35 wt% solids in the residue and 50% dilution of the residual liquid because of the final washing step. These values will be revised as more information becomes available on the residual solids in SST S-112.

Residual inventories for the COPCs are given in Tables 3-7 and 3-8 using the SPR method for predicting residuals in sludge tanks (S-107, SX-107, SX-108, SX-113, and SX-115) and HTWOS method for predicting residuals in saltcake tanks (all other tanks in the WMA S-SX). Note that, following a peer review (RPP-21271, *Justification for Updating the Technetium-99 Wash Factors for the S and SX Tank Farms*), the $^{99}$Tc wash factors used for SSTs S-105, S-109, and SX-106 in the HTWOS model have been revised since the publication of RPP-20420, which resulted in lower residual inventory values for $^{99}$Tc in these tanks. The inventory presented in Tables 3-7 and 3-8 reflect the revised $^{99}$Tc values.

In the future, tank waste will be retrieved for SSTs S-112 and S-102, and the tank waste residuals will be sampled and analyzed. The risk estimates for these tanks will be revised to reflect the actual residual inventory in each tank.

**Hypothetical Retrieval Leak.** Volumes for the 100-series tanks were generated by: (1) assuming a maximum leakage volume of 30,280 L (8,000 gal) of liquid and (2) using HTWOS to estimate the inventory of undiluted, water-soluble components in the leak. The HTWOS estimates are based on the average composition of the liquids retrieved from the tank. Potential leakage inventory estimates for the S and SX tank farms are summarized in Tables 3-9 and 3-10, respectively. Please note, following a peer review (RPP-21271), the $^{99}$Tc wash factors used for SSTs S-105, S-109, and SX-106 in the HTWOS model have been revised since the publication of RPP-20420, which resulted in lower residual inventory values for $^{99}$Tc in these tanks. The inventory presented in Tables 3-9 and 3-10 reflect the revised $^{99}$Tc values.

**Ancillary Equipment Residual Inventory.** Waste transfer piping systems in WMA S-SX are described in *Historical Vadose Zone Contamination from S and SX Tank Farm Operations* (HNF-SD-WM-ER-560). Based on drawings in HNF-SD-WM-ER-560, it is estimated that there are 6,125 ft of waste transfer piping in the S tank farm and 4,675 ft in the SX tank farm.

Assuming a 3-in (inside diameter) piping, there is approximately 301 $ft^3$ of volume in S tank farm piping and 230 $ft^3$ in the SX tank farm piping. For the purpose of this risk assessment, it is assumed that estimated volumes within these two tank farms are 25% filled with wastes (RPP-13774). The wastes in the pipes in each tank farm are assumed to be of the same average composition as that projected to be in the tanks by the BBI numbers for that tank farm. These inventory estimates are shown in Table 3-11. It should be noted that this is likely a very conservative estimate of waste residuals in the piping systems because (1) the systems were designed for liquids to flow back into the tanks and (2) the pipes were flushed with water after each waste transfer.

Table 3-4. WMA S-SX Leak Inventory Estimates as of August 2003
(All radionuclides decayed to January 1, 2001).

| **Tank** | **S-104** | **SX-107** | **SX-108** | **SX-109** | **SX-113** | **SX-115** | **Total** |
|---|---|---|---|---|---|---|---|
| Leak Vol. | 24 Kgal | 15 Kgal | 35 Kgal | 2 Kgal | 15 Kgal | 50 Kgal | -- |
| **Analyte** | **Kg** | **Kg** | **Kg** | **Kg** | **Kg** | **Kg** | **Kg** |
| Cr | 1.44E+01 | 1.11E+03 | 2.60E+03 | 1.48E+02 | 5.08E+02 | 5.03E+02 | 4.88E+03 |
| $NO_3$ | 5.01E+03 | 1.75E+04 | 4.08E+04 | 2.33E+03 | 9.96E+03 | 3.87E+03 | 7.94E+04 |
| $NO_2$ | 1.17E+03 | 1.06E+04 | 2.47E+04 | 1.41E+03 | 3.50E+03 | 9.23E+03 | 5.07E+04 |
| F | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 4.94E-02 | 4.94E-02 |
| U-Total | 3.93E+02 | 1.08E+02 | 2.53E+02 | 1.44E+01 | 5.74E+01 | 1.61E+02 | 9.87E+02 |
| **Radionuclides** | **Ci** | **Ci** | **Ci** | **Ci** | **Ci** | **Ci** | **Ci** |
| $^{3}H$ | 6.59E-01 | 2.13E+01 | 4.97E+01 | 2.84E+00 | 3.11E+00 | 9.65E+00 | 8.73E+01 |
| $^{14}C$ | 1.75E-02 | 1.50E+00 | 3.51E+00 | 2.00E-01 | 3.57E-01 | 6.94E-01 | 6.28E+00 |
| $^{99}Tc$ | 1.53E-01 | 1.19E+01 | 2.77E+01 | 1.59E+00 | 2.50E+00 | 5.52E+00 | 4.94E+01 |
| $^{129}I$ | 2.86E-04 | 2.25E-02 | 5.25E-02 | 3.00E-03 | 4.80E-03 | 1.04E-02 | 9.35E-02 |
| $^{232}U$ | 1.18E-05 | 3.14E-06 | 7.33E-06 | 4.19E-07 | 7.72E-07 | 3.22E-05 | 5.56E-05 |
| $^{233}U$ | 3.70E-07 | 8.93E-08 | 2.08E-07 | 1.19E-08 | 3.15E-08 | 1.13E-04 | 1.14E-04 |
| $^{234}U$ | 1.89E-01 | 4.37E-02 | 1.02E-01 | 5.82E-03 | 1.88E-02 | 7.25E-02 | 4.31E-01 |
| $^{235}U$ | 7.14E-03 | 1.74E-03 | 4.06E-03 | 2.32E-04 | 8.09E-04 | 2.80E-03 | 1.68E-02 |
| $^{236}U$ | 1.24E-02 | 2.05E-03 | 4.79E-03 | 2.74E-04 | 2.97E-04 | 4.29E-03 | 2.41E-02 |
| $^{238}U$ | 1.30E-01 | 3.61E-02 | 8.43E-02 | 4.82E-03 | 1.92E-02 | 5.36E-02 | 3.28E-01 |

Table 3-5. Best-Basis Inventory Estimates for S Tanks.

| Analyte | Standard units of measure | S-101 | S-102 | S-103 | S-104 | S-105 | S-106 | S-107 | S-108 | S-109 | S-110 | S-111 | S-112 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cr | kg | 1.60E+04 | 4.73E+03 | 5.65E+03 | 4.08E+03 | 2.68E+03 | 1.61E+04 | 7.67E+03 | 1.70E+04 | 5.38E+03 | 1.29E+04 | 1.15E+04 | 1.68E+04 |
| F | kg | 5.54E+02 | 6.65E+03 | 1.86E+03 | 5.12E+02 | 1.25E+03 | 6.34E+03 | 4.35E+04 | 8.65E+03 | 8.16E+02 | 1.57E+03 | 2.93E+03 | 5.98E+02 |
| $NO_2$ | kg | 1.39E+05 | 8.84E+04 | 8.52E+04 | 4.61E+04 | 2.53E+04 | 7.75E+04 | 8.08E+04 | 1.68E+05 | 2.33E+04 | 5.39E+04 | 8.40E+04 | 6.39E+04 |
| $NO_3$ | kg | 4.02E+05 | 5.07E+05 | 3.30E+05 | 4.19E+05 | 1.35E+06 | 9.84E+05 | 1.51E+05 | 9.15E+05 | 1.91E+06 | 9.04E+05 | 5.23E+05 | 1.39E+06 |
| U-Total | kg | 9.33E+03 | 4.95E+03 | 8.44E+02 | 7.00E+03 | 5.91E+02 | 6.77E+02 | 1.73E+04 | 2.51E+03 | 5.68E+02 | 6.32E+03 | 4.97E+02 | 1.36E+03 |
| $^{3}H$ | Ci | 1.59E+02 | 2.09E+02 | 1.34E+02 | 2.86E+01 | 2.13E+02 | 1.75E+02 | 2.55E+01 | 1.94E+02 | 1.91E+02 | 1.47E+02 | 1.58E+02 | 3.08E+02 |
| $^{14}C$ | Ci | 2.89E+01 | 4.78E+01 | 3.11E+01 | 3.40E+00 | 7.01E+01 | 5.89E+01 | 4.89E+00 | 6.84E+01 | 6.53E+01 | 4.70E+01 | 4.34E+01 | 3.59E+01 |
| $^{99}Tc$ | Ci | 2.06E+02 | 2.17E+02 | 2.24E+02 | 4.83E+01 | 3.51E+02 | 2.88E+02 | 3.16E+01 | 3.20E+02 | 3.13E+02 | 2.38E+02 | 2.56E+02 | 2.47E+02 |
| $^{129}I$ | Ci | 4.12E-01 | 6.81E-01 | 4.32E-01 | 9.20E-02 | 6.76E-01 | 5.56E-01 | 6.73E-02 | 6.17E-01 | 6.04E-01 | 4.59E-01 | 4.94E-01 | 8.43E-01 |
| $^{232}U$ | Ci | 6.35E-01 | 1.42E+00 | 7.35E-02 | 3.08E-02 | 7.28E-02 | 3.83E-02 | 1.07E-01 | 2.73E-01 | 1.78E-02 | 6.09E-01 | 6.15E-02 | 1.36E-01 |
| $^{233}U$ | Ci | 2.60E+00 | 5.83E+00 | 3.02E-01 | 1.26E-01 | 2.99E-01 | 1.57E-01 | 4.36E-01 | 1.12E+00 | 7.30E-02 | 2.50E+00 | 2.53E-01 | 5.59E-01 |
| $^{234}U$ | Ci | 3.31E+00 | 1.81E+00 | 2.91E-01 | 2.43E+00 | 2.08E-01 | 2.36E-01 | 7.26E+00 | 8.87E-01 | 1.90E-01 | 2.22E+00 | 1.76E-01 | 4.77E-01 |
| $^{235}U$ | Ci | 1.38E-01 | 7.35E-02 | 1.23E-02 | 9.79E-02 | 8.64E-03 | 9.92E-03 | 2.85E-01 | 3.69E-02 | 8.10E-03 | 9.26E-02 | 7.32E-03 | 2.01E-02 |
| $^{236}U$ | Ci | 8.96E-02 | 5.63E-02 | 6.90E-03 | 4.81E-02 | 5.50E-03 | 5.98E-03 | 3.73E-01 | 2.45E-02 | 3.70E-03 | 5.59E-02 | 4.87E-03 | 1.28E-02 |
| $^{238}U$ | Ci | 3.11E+00 | 1.65E+00 | 2.82E-01 | 2.34E+00 | 1.97E-01 | 2.26E-01 | 5.75E+00 | 8.37E-01 | 1.89E-01 | 2.11E+00 | 1.66E-01 | 4.52E-01 |

Notes:

Radionuclides decayed to 1/1/2001.

Best-basis inventory estimates are dated 12/4/04.

Single-shell tank waste volumes came from HNF-EP-0182.

HNF-EP-0182, 2002, *Waste Tank Summary Report for Month Ending November 30, 2002,* Rev. 176, CH2M HILL Hanford Group, Inc., Richland, Washington.

Table 3-6. Best-Basis Inventory Estimates for SX Tanks.

| Analyte | Standard units of measure | SX-101 | SX-102 | SX-103 | SX-104 | SX-105 | SX-106 | SX-107 | SX-108 | SX-109 | SX-110 | SX-111 | SX-112 | SX-113 | SX-114 | SX-115 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cr | kg | 2.54E+04 | 1.61E+04 | 1.35E+04 | 1.18E+04 | 6.44E+03 | 9.62E+03 | 2.15E+03 | 4.38E+03 | 6.23E+03 | 1.37E+03 | 2.71E+03 | 1.73E+03 | 2.79E+01 | 3.93E+03 | 9.79E+01 |
| F | kg | 6.62E+02 | 8.68E+02 | 9.25E+02 | 5.07E+03 | 6.29E+02 | 1.25E+03 | 6.35E+02 | 2.09E+02 | 6.08E+02 | 2.51E+02 | 6.31E+02 | 4.57E+02 | 7.29E+00 | 4.02E+02 | 3.51E+01 |
| $NO_2$ | kg | 6.91E+04 | 2.45E+05 | 1.75E+05 | 1.30E+05 | 1.44E+05 | 1.69E+05 | 2.43E+04 | 7.56E+03 | 5.50E+04 | 1.33E+04 | 2.99E+04 | 1.93E+04 | 2.34E+02 | 4.16E+04 | 5.15E+01 |
| $NO_3$ | kg | 7.10E+05 | 6.62E+05 | 1.03E+06 | 6.08E+05 | 4.26E+05 | 5.52E+05 | 7.95E+04 | 1.80E+05 | 3.90E+05 | 7.19E+04 | 1.15E+05 | 6.88E+04 | 6.38E+02 | 2.13E+05 | 3.07E+03 |
| U-Total | kg | 3.68E+03 | 1.49E+03 | 1.40E+03 | 5.69E+03 | 1.19E+03 | 8.64E+02 | 2.52E+03 | 2.49E+03 | 4.69E+03 | 1.29E+03 | 2.73E+03 | 1.89E+03 | 4.41E+01 | 2.64E+03 | 1.31E+02 |
| $^{3}H$ | Ci | 1.68E+02 | 2.16E+02 | 2.25E+02 | 1.37E+02 | 1.17E+02 | 2.12E+02 | 1.47E+01 | 7.29E+00 | 9.55E+01 | 1.57E+01 | 2.74E+01 | 1.47E+01 | 7.05E-02 | 6.70E+01 | 3.39E-01 |
| $^{14}C$ | Ci | 2.71E+01 | 5.69E+01 | 5.94E+01 | 3.61E+01 | 3.50E+01 | 5.53E+01 | 1.35E+00 | 8.34E-01 | 7.45E+00 | 1.28E+00 | 2.31E+00 | 1.29E+00 | 8.07E-03 | 5.23E+00 | 3.88E-02 |
| $^{99}Tc$ | Ci | 1.85E+02 | 3.56E+02 | 3.16E+02 | 1.84E+02 | 1.90E+02 | 3.60E+02 | 9.97E+00 | 5.84E+00 | 5.75E+01 | 9.78E+00 | 1.74E+01 | 9.60E+00 | 1.37E+01 | 4.03E+01 | 2.72E-01 |
| $^{129}I$ | Ci | 3.56E-01 | 6.86E-01 | 6.08E-01 | 3.55E-01 | 3.66E-01 | 6.96E-01 | 1.91E-02 | 1.12E-02 | 1.09E-01 | 1.86E-02 | 3.32E-02 | 1.83E-02 | 1.09E-04 | 7.66E-02 | 5.23E-04 |
| $^{232}U$ | Ci | 2.89E-01 | 4.77E-01 | 1.20E-01 | 1.43E-01 | 3.33E-01 | 1.23E-01 | 3.83E-03 | 4.68E-05 | 5.96E-02 | 8.86E-03 | 9.52E-03 | 4.59E-03 | 5.92E-07 | 2.82E-02 | 1.76E-06 |
| $^{233}U$ | Ci | 1.19E+00 | 1.96E+00 | 4.95E-01 | 5.88E-01 | 1.37E+00 | 5.04E-01 | 1.56E-02 | 1.60E-06 | 2.45E-01 | 3.63E-02 | 3.90E-02 | 1.88E-02 | 2.41E-08 | 1.16E-01 | 7.16E-08 |
| $^{234}U$ | Ci | 1.39E+00 | 5.46E-01 | 5.00E-01 | 1.93E+00 | 4.36E-01 | 3.04E-01 | 8.35E-01 | 8.79E-01 | 1.71E+00 | 4.50E-01 | 9.22E-01 | 6.30E-01 | 1.44E-02 | 9.50E-01 | 4.27E-02 |
| $^{235}U$ | Ci | 5.66E-02 | 2.21E-02 | 2.05E-02 | 8.17E-02 | 1.77E-02 | 1.27E-02 | 3.58E-02 | 3.68E-02 | 7.07E-02 | 1.89E-02 | 3.92E-02 | 2.69E-02 | 6.20E-04 | 3.94E-02 | 1.84E-03 |
| $^{236}U$ | Ci | 5.22E-02 | 1.70E-02 | 1.62E-02 | 4.09E-02 | 1.39E-02 | 7.71E-03 | 1.51E-02 | 2.47E-02 | 5.66E-02 | 1.15E-02 | 1.93E-02 | 1.22E-02 | 2.28E-04 | 2.90E-02 | 6.75E-04 |
| $^{238}U$ | Ci | 1.23E+00 | 4.96E-01 | 4.56E-01 | 1.90E+00 | 3.96E-01 | 2.89E-01 | 8.40E-01 | 8.31E-01 | 1.56E+00 | 4.31E-01 | 9.12E-01 | 6.29E-01 | 1.47E-02 | 8.82E-01 | 4.36E-02 |

Notes:

Radionuclides decayed to 1/1/2001.

Best-basis inventory estimates are dated 12/4/04.

Single-shell tank waste volumes came from HNF-EP-0182.

HNF-EP-0182, 2002, *Waste Tank Summary Report for Month Ending November 30, 2002*, Rev. 176, CH2M HILL Hanford Group, Inc., Richland, Washington.

Table 3-7. Summary of S Tank Farm Final Inventory Estimates (Post-Retrieval) Based on the Selective Phase Model for Sludge-Filled Tanks and HTWOS Model for Saltcake-Filled Tanks with 10.2 kL (360 $ft^3$) Remaining.

| Analyte | Standard units of measure | S-101 Saltcake | S-102 Saltcake | S-103 Saltcake | S-104 Saltcake | S-105 Saltcake | S-106 Saltcake | S-107 Sludge | S-108 Saltcake | S-109 Saltcake | S-110 Saltcake | S-111 Saltcake | S-112 Saltcake |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cr | kg | 9.21E+01 | 1.89E+02 | 6.38E+02 | 3.14E+01 | 4.19E+02 | 6.75E+02 | 4.50E+01 | 5.70E+02 | 1.55E+02 | 1.92E+02 | 1.21E+02 | 6.54E+02 |
| F | kg | 2.58E-01 | 1.03E+00 | 1.63E+00 | 2.31E-01 | 6.42E-01 | 3.98E+01 | 3.35E+02 | 4.36E+01 | 5.19E-01 | 4.54E+00 | 2.24E+00 | 4.10E+00 |
| $NO_2$ | kg | 5.48E+01 | 5.14E+01 | 7.42E+01 | 2.07E+01 | 1.30E+01 | 4.19E+01 | 5.85E+02 | 1.28E+02 | 2.02E+01 | 5.50E+01 | 5.48E+01 | 3.87E+01 |
| $NO_3$ | kg | 1.71E+02 | 2.53E+02 | 2.88E+02 | 1.89E+02 | 6.92E+02 | 6.15E+02 | 1.10E+03 | 7.52E+02 | 1.60E+03 | 9.49E+02 | 4.06E+02 | 1.03E+03 |
| U-Total | kg | 1.41E+02 | 3.51E+02 | 1.68E+02 | 9.50E+01 | 3.63E+02 | 7.29E+01 | 1.37E+02 | 2.13E+02 | 8.48E+01 | 2.42E+02 | 8.04E+00 | 1.76E+02 |
| $^{3}H$ | Ci | 4.56E-02 | 9.83E-02 | 1.10E-01 | 1.22E-02 | 1.03E-01 | 7.78E-02 | 7.80E-02 | 1.29E-01 | 1.15E-01 | 1.39E-01 | 8.91E-02 | 1.60E-01 |
| $^{14}C$ | Ci | 5.06E-03 | 3.01E-02 | 8.76E-03 | 5.74E-04 | 1.04E-02 | 8.02E-03 | 1.01E-02 | 1.39E-02 | 1.07E-01 | 1.36E-02 | 1.53E-02 | 5.83E-03 |
| $^{99}Tc$ | Ci | 1.30E-01 | 1.88E+00 | 1.68E-01 | 3.97E-02 | 3.34E+00 | 1.43E+00 | 6.84E-02 | 1.38E+00 | 9.34E-01 | 5.37E-01 | 1.33E+00 | 1.16E+00 |
| $^{129}I$ | Ci | 1.41E-03 | 1.39E-04 | 2.53E-04 | 2.37E-04 | 2.33E-04 | 1.76E-04 | 1.32E-04 | 2.92E-04 | 2.58E-04 | 3.07E-04 | 1.98E-04 | 3.17E-04 |
| $^{232}U$ | Ci | 6.30E-03 | 7.39E-03 | 9.56E-03 | 2.73E-04 | 2.94E-02 | 2.71E-03 | 8.47E-04 | 1.52E-02 | 1.75E-03 | 1.52E-02 | 6.54E-04 | 1.16E-02 |
| $^{233}U$ | Ci | 2.29E-02 | 2.69E-02 | 3.48E-02 | 9.86E-04 | 1.07E-01 | 9.84E-03 | 3.45E-03 | 5.51E-02 | 6.34E-03 | 5.55E-02 | 2.38E-03 | 4.22E-02 |
| $^{234}U$ | Ci | 4.82E-02 | 1.12E-01 | 5.58E-02 | 3.17E-02 | 1.23E-01 | 2.45E-02 | 5.75E-02 | 7.28E-02 | 2.74E-02 | 8.16E-02 | 2.75E-03 | 5.97E-02 |
| $^{235}U$ | Ci | 2.09E-03 | 4.98E-03 | 2.44E-03 | 1.32E-03 | 5.31E-03 | 1.07E-03 | 2.26E-03 | 3.13E-03 | 1.21E-03 | 3.54E-03 | 1.18E-04 | 2.61E-03 |
| $^{236}U$ | Ci | 8.89E-04 | 1.39E-03 | 9.02E-04 | 4.26E-04 | 2.22E-03 | 4.22E-04 | 2.95E-03 | 1.36E-03 | 3.63E-04 | 1.40E-03 | 5.15E-05 | 1.09E-03 |
| $^{238}U$ | Ci | 4.72E-02 | 1.17E-01 | 5.60E-02 | 3.17E-02 | 1.21E-01 | 2.43E-02 | 4.55E-02 | 7.11E-02 | 2.83E-02 | 8.09E-02 | 2.68E-03 | 5.87E-02 |

Notes:

Radionuclides decayed to 1/1/2001.

$^{99}Tc$ inventory in single-shell tanks S-105 and S-109 was updated since the publication of RPP-20420.

HTWOS = Hanford Tank Waste Operations Simulator.

RPP-20420, 2004, *241-S-SX Waste Management Area Inventory Data Package*, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

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Table 3-8. Summary of SX Tank Farm Final Inventory Estimates (Post-Retrieval) Based on the Selective Phase Model for Sludge-Filled Tanks and HTWOS Model for Saltcake-Filled Tanks with 10.2 kL (360 $ft^3$) Remaining.

| Analyte | Standard units of measure | SX-101 Saltcake | SX-102 Saltcake | SX-103 Saltcake | SX-104 Saltcake | SX-105 Saltcake | SX-106 Saltcake | SX-107 Sludge | SX-108 Saltcake | SX-109 Sludge | SX-110 Saltcake | SX-111 Saltcake | SX-112 Saltcake | SX-113 Sludge | SX-114 Saltcake | SX-115 Sludge |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cr | kg | 5.54E+02 | 6.06E+02 | 9.71E+02 | 2.60E+02 | 2.70E+02 | 2.63E+02 | 5.99E+01 | 1.62E+02 | 4.89E+01 | 3.21E+01 | 2.57E+01 | 2.39E+01 | 4.01E+00 | 4.54E+01 | 7.13E+01 |
| F | kg | 2.63E+00 | 6.85E+00 | 7.96E+00 | 1.91E+01 | 4.25E+00 | 1.45E+00 | 2.14E+01 | 7.72E+00 | 3.80E-01 | 6.02E-01 | 6.61E-01 | 6.80E-01 | 1.05E+00 | 4.37E-01 | 2.56E+01 |
| $NO_2$ | kg | 6.54E+01 | 2.09E+02 | 1.53E+02 | 1.40E+02 | 1.93E+02 | 2.12E+02 | 6.88E+02 | 2.79E+02 | 3.44E+01 | 3.19E+01 | 3.13E+01 | 2.88E+01 | 3.36E+01 | 4.48E+01 | 3.75E+01 |
| $NO_3$ | kg | 8.18E+02 | 6.99E+02 | 9.47E+02 | 6.67E+02 | 6.14E+02 | 6.76E+02 | 1.87E+03 | 6.65E+03 | 2.44E+02 | 1.73E+02 | 1.21E+02 | 1.02E+02 | 9.16E+01 | 2.32E+02 | 2.24E+03 |
| U-Total | kg | 2.25E+02 | 2.06E+02 | 2.51E+02 | 3.21E+02 | 1.37E+02 | 4.53E+01 | 7.97E+01 | 9.20E+01 | 8.61E+01 | 9.29E+01 | 8.69E+01 | 8.54E+01 | 6.32E+00 | 8.49E+01 | 9.53E+01 |
| $^{3}H$ | Ci | 1.24E-01 | 1.39E-01 | 1.32E-01 | 1.39E-01 | 1.34E-01 | 2.33E-01 | 2.07E-01 | 2.69E-01 | 5.64E-02 | 3.58E-02 | 2.72E-02 | 2.06E-02 | 1.01E-02 | 6.85E-02 | 2.47E-01 |
| $^{14}C$ | Ci | 6.91E-03 | 1.28E-02 | 1.23E-02 | 1.05E-02 | 1.26E-02 | 4.48E-02 | 2.37E-02 | 3.08E-02 | 2.24E-03 | 1.34E-03 | 1.38E-03 | 1.12E-03 | 1.16E-03 | 2.40E-03 | 1.12E-02 |
| $^{99}Tc$ | Ci | 4.59E-01 | 1.45E+00 | 2.71E-01 | 5.52E-01 | 8.24E-01 | 7.78E-01 | 1.66E-01 | 2.16E-01 | 8.01E-02 | 2.02E-02 | 1.58E-02 | 1.23E-02 | 1.98E+00 | 7.96E-02 | 1.98E-01 |
| $^{129}I$ | Ci | 1.83E-04 | 3.12E-04 | 2.79E-04 | 2.40E-04 | 2.98E-04 | 5.43E-04 | 3.19E-04 | 4.14E-04 | 5.33E-04 | 2.99E-05 | 2.34E-05 | 1.83E-05 | 1.57E-05 | 4.74E-04 | 3.51E-04 |
| $^{232}U$ | Ci | 1.15E-02 | 4.34E-02 | 1.14E-02 | 4.94E-03 | 2.52E-02 | 4.20E-03 | 1.07E-06 | 1.73E-06 | 7.17E-04 | 4.18E-04 | 1.97E-04 | 1.36E-04 | 8.50E-08 | 5.97E-04 | 1.28E-06 |
| $^{233}U$ | Ci | 4.20E-02 | 1.58E-01 | 4.15E-02 | 1.80E-02 | 9.17E-02 | 1.53E-02 | 4.38E-08 | 5.91E-08 | 2.61E-03 | 1.52E-03 | 7.15E-04 | 4.91E-04 | 3.47E-09 | 2.16E-03 | 5.21E-08 |
| $^{234}U$ | Ci | 8.19E-02 | 7.27E-02 | 8.41E-02 | 1.05E-01 | 4.84E-02 | 1.53E-02 | 2.60E-02 | 3.25E-02 | 3.03E-02 | 3.12E-02 | 2.82E-02 | 2.74E-02 | 2.07E-03 | 2.93E-02 | 3.11E-02 |
| $^{235}U$ | Ci | 3.45E-03 | 3.05E-03 | 3.66E-03 | 4.63E-03 | 2.03E-03 | 6.66E-04 | 1.12E-03 | 1.36E-03 | 1.30E-03 | 1.36E-03 | 1.24E-03 | 1.21E-03 | 8.90E-05 | 1.26E-03 | 1.34E-03 |
| $^{236}U$ | Ci | 2.09E-03 | 1.54E-03 | 1.46E-03 | 1.53E-03 | 1.05E-03 | 2.63E-04 | 4.11E-04 | 9.12E-04 | 6.81E-04 | 5.44E-04 | 4.02E-04 | 3.63E-04 | 3.27E-05 | 6.09E-04 | 4.92E-04 |
| $^{238}U$ | Ci | 7.52E-02 | 6.86E-02 | 8.36E-02 | 1.07E-01 | 4.56E-02 | 1.51E-02 | 2.66E-02 | 3.07E-02 | 2.87E-02 | 3.10E-02 | 2.90E-02 | 2.85E-02 | 2.11E-03 | 2.83E-02 | 3.18E-02 |

Notes:

Radionuclides decayed to 1/1/2001.

$^{99}Tc$ inventory in single-shell tanks S-105 and S-109 was updated since the publication of RPP-20420.

HTWOS = Hanford Tank Waste Operations Simulator.

RPP-20420, 2004, *241-S-SX Waste Management Area Inventory Data Package*, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

Table 3-9. Summary of Hypothetical Leakage Inventory (During Retrieval) for S Farm Tanks Based on the HTWOS Model for Undiluted, Water-Soluble Components in 30,280 L (8,000 gal) of Leakage.

| Analyte | Standard units of measure | S-101 Saltcake | S-102 Saltcake | S-103 Saltcake | S-104 Saltcake | S-105 Saltcake | S-106 Saltcake | S-107 Sludge | S-108 Saltcake | S-109 Saltcake | S-110 Saltcake | S-111 Saltcake | S-112 Saltcake |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cr | kg | 2.07E+01 | 1.48E+00 | 4.71E+00 | 1.87E+00 | 6.00E+00 | 2.55E+01 | 5.13E+00 | 3.80E+01 | 1.76E+01 | 4.26E+01 | 1.53E+01 | 3.70E+01 |
| F | kg | 1.83E+00 | 7.27E+00 | 1.15E+01 | 1.63E+00 | 4.55E+00 | 1.96E+01 | 9.97E+01 | 4.03E+01 | 3.72E+00 | 1.03E+01 | 1.59E+01 | 2.22E+00 |
| $NO_2$ | kg | 3.87E+02 | 3.12E+02 | 5.26E+02 | 1.46E+02 | 9.20E+01 | 2.59E+02 | 1.71E+02 | 8.47E+02 | 1.06E+02 | 3.85E+02 | 3.65E+02 | 2.48E+02 |
| $NO_3$ | kg | 1.21E+03 | 1.50E+03 | 2.04E+03 | 1.33E+03 | 4.91E+03 | 3.28E+03 | 3.25E+02 | 4.60E+03 | 8.74E+03 | 6.45E+03 | 2.68E+03 | 5.58E+03 |
| U-Total | kg | 2.36E-04 | 5.03E-01 | 4.26E-03 | 3.84E-02 | 4.05E-02 | 3.66E-01 | 8.40E-24 | 1.26E+00 | 8.51E-02 | 5.98E+00 | 1.13E+00 | 5.49E-01 |
| $^{3}H$ | Ci | 3.22E-01 | 6.93E-01 | 7.80E-01 | 8.60E-02 | 7.33E-01 | 5.52E-01 | 3.40E-02 | 9.24E-01 | 8.22E-01 | 9.90E-01 | 6.32E-01 | 1.15E+00 |
| $^{14}C$ | Ci | 2.10E-02 | 3.10E-02 | 5.60E-02 | 3.00E-03 | 7.40E-02 | 5.70E-02 | 2.00E-03 | 9.90E-02 | 8.20E-02 | 9.70E-02 | 5.70E-02 | 4.20E-02 |
| $^{99}Tc$ | Ci | 3.68E-01 | 5.28E-01 | 1.17E+00 | 1.29E-01 | 1.07E+00 | 8.08E-01 | 3.70E-02 | 1.35E+00 | 1.20E+00 | 1.44E+00 | 9.10E-01 | 8.08E-01 |
| $^{129}I$ | Ci | 7.31E-05 | 9.81E-04 | 2.00E-03 | 1.18E-04 | 2.00E-03 | 1.00E-03 | 2.40E-05 | 2.00E-03 | 2.00E-03 | 2.00E-03 | 1.00E-03 | 2.00E-03 |
| $^{232}U$ | Ci | 1.05E-08 | 1.08E-05 | 8.47E-07 | 5.01E-07 | 3.06E-06 | 1.36E-05 | 4.29E-29 | 9.00E-05 | 1.78E-06 | 2.87E-04 | 9.18E-05 | 3.61E-05 |
| $^{233}U$ | Ci | 3.81E-08 | 3.94E-05 | 3.07E-06 | 1.81E-06 | 1.12E-05 | 4.93E-05 | 1.53E-28 | 3.25E-04 | 6.47E-06 | 1.00E-03 | 3.34E-04 | 1.31E-04 |
| $^{234}U$ | Ci | 8.03E-08 | 1.62E-04 | 1.51E-06 | 1.43E-05 | 1.38E-05 | 1.23E-04 | 3.16E-27 | 4.29E-04 | 2.75E-05 | 2.00E-03 | 3.88E-04 | 1.86E-04 |
| $^{235}U$ | Ci | 3.47E-09 | 7.17E-06 | 6.33E-08 | 5.99E-07 | 5.94E-07 | 5.36E-06 | 1.41E-28 | 1.85E-05 | 1.22E-06 | 6.64E-05 | 1.67E-05 | 8.14E-06 |
| $^{236}U$ | Ci | 1.48E-09 | 2.01E-06 | 3.19E-08 | 4.00E-07 | 2.66E-07 | 2.12E-06 | 1.32E-28 | 8.05E-06 | 3.66E-07 | 2.63E-05 | 7.27E-06 | 3.39E-06 |
| $^{238}U$ | Ci | 7.86E-08 | 1.68E-04 | 1.42E-06 | 1.28E-05 | 1.35E-05 | 1.22E-04 | 2.80E-27 | 4.19E-04 | 2.84E-05 | 2.00E-03 | 3.78E-04 | 1.83E-04 |

Notes:

Radionuclides decayed to 1/1/2001.

$^{99}Tc$ inventory in single-shell tanks S-105 and S-109 was updated since the publication of RPP-20420.

HTWOS = Hanford Tank Waste Operations Simulator.

RPP-20420, 2004, *241-S-SX Waste Management Area Inventory Data Package,* Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington

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Table 3-10. Summary of Hypothetical Leakage Inventory (During Retrieval) for SX Farm Tanks Based on the HTWOS Model for Undiluted, Water-Soluble Components in 30,280 L (8,000 gal) of Leakage.

| Analyte | Standard units of measure | SX-101 Saltcake | SX-102 Saltcake | SX-103 Saltcake | SX-104 Saltcake | SX-105 Saltcake | SX-106 Saltcake | SX-107 Sludge | SX-108 Saltcake | SX-109 Sludge | SX-110 Saltcake | SX-111 Saltcake | SX-112 Saltcake | SX-113 Sludge | SX-114 Saltcake | SX-115 Sludge |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cr | kg | 7.70E+01 | 6.24E+01 | 3.45E+01 | 3.84E+01 | 2.72E+01 | 1.85E+01 | 5.77E+00 | 1.10E+02 | 1.03E+01 | 1.24E+01 | 1.15E+01 | 1.03E+01 | 9.00E-03 | 1.44E+01 | 1.15E+00 |
| F | kg | 4.38E+00 | 5.31E+00 | 4.97E+00 | 3.36E+01 | 5.64E+00 | 1.04E+01 | 4.21E+00 | 7.19E+00 | 2.69E+00 | 4.26E+00 | 4.66E+00 | 4.79E+00 | 1.22E-01 | 3.09E+00 | 7.64E-01 |
| $NO_2$ | kg | 4.03E+02 | 1.37E+03 | 9.82E+02 | 9.68E+02 | 1.32E+03 | 1.40E+03 | 1.61E+02 | 2.60E+02 | 2.43E+02 | 2.26E+02 | 2.21E+02 | 2.03E+02 | 3.90E+00 | 3.17E+02 | 1.12E+00 |
| $NO_3$ | kg | 5.01E+03 | 4.16E+03 | 5.38E+03 | 4.46E+03 | 3.96E+03 | 4.57E+03 | 5.32E+02 | 6.19E+03 | 1.72E+03 | 1.22E+03 | 8.53E+02 | 7.22E+02 | 1.06E+01 | 1.64E+03 | 6.68E+01 |
| U-Total | kg | 1.90E+00 | 1.06E+00 | 9.95E-01 | 5.98E+00 | 1.21E+00 | 2.96E-01 | 2.77E-01 | 0.00E+00 | 3.30E-01 | 7.19E-08 | 2.50E-02 | 1.72E-02 | 3.75E-02 | 3.99E-01 | 2.29E-11 |
| $^{3}H$ | Ci | 8.85E-01 | 9.93E-01 | 9.49E-01 | 9.97E-01 | 9.60E-01 | 1.67E+00 | 9.40E-02 | 2.37E-01 | 3.98E-01 | 2.53E-01 | 1.91E-01 | 1.45E-01 | 1.00E-03 | 4.85E-01 | 6.00E-03 |
| $^{14}C$ | Ci | 4.90E-02 | 9.10E-02 | 8.80E-02 | 7.50E-02 | 9.00E-02 | 1.26E-01 | 2.00E-03 | 7.00E-03 | 9.00E-03 | 6.00E-03 | 5.00E-03 | 4.00E-03 | 1.45E-05 | 1.10E-02 | 0.00E+00 |
| $^{99}Tc$ | Ci | 8.14E-01 | 1.40E+00 | 1.32E+00 | 1.07E+00 | 1.34E+00 | 2.47E+00 | 5.40E-02 | 1.58E-01 | 2.00E-01 | 1.43E-01 | 1.11E-01 | 8.70E-02 | 1.92E-01 | 2.49E-01 | 3.00E-03 |
| $^{129}I$ | Ci | 1.00E-03 | 2.00E-03 | 2.00E-03 | 2.00E-03 | 2.00E-03 | 4.00E-03 | 4.48E-05 | 1.08E-04 | 1.37E-04 | 2.11E-04 | 1.65E-04 | 1.29E-04 | 1.12E-06 | 2.34E-04 | 0.00E+00 |
| $^{232}U$ | Ci | 9.72E-05 | 2.13E-04 | 4.61E-05 | 1.23E-04 | 2.24E-04 | 2.77E-05 | 3.96E-07 | 0.00E+00 | 2.74E-06 | 3.24E-13 | 3.30E-07 | 2.28E-07 | 3.12E-10 | 3.25E-06 | 1.04E-19 |
| $^{233}U$ | Ci | 3.54E-04 | 7.74E-04 | 1.68E-04 | 4.48E-04 | 8.16E-04 | 1.01E-04 | 1.43E-06 | 0.00E+00 | 9.96E-06 | 1.18E-12 | 1.19E-06 | 8.25E-07 | 1.11E-11 | 1.18E-05 | 2.47E-21 |
| $^{234}U$ | Ci | 6.91E-04 | 3.73E-04 | 3.35E-04 | 1.00E-03 | 4.31E-04 | 1.00E-04 | 8.89E-05 | 0.00E+00 | 1.16E-04 | 2.42E-11 | 9.38E-06 | 6.47E-06 | 1.18E-05 | 1.40E-04 | 6.92E-15 |
| $^{235}U$ | Ci | 2.92E-05 | 1.57E-05 | 1.46E-05 | 6.52E-05 | 1.81E-05 | 4.36E-06 | 3.94E-06 | 0.00E+00 | 4.95E-06 | 1.06E-12 | 3.92E-07 | 2.71E-07 | 5.27E-07 | 5.96E-06 | 3.20E-16 |
| $^{236}U$ | Ci | 1.76E-05 | 7.87E-06 | 5.90E-06 | 2.26E-05 | 9.36E-06 | 1.72E-06 | 1.14E-06 | 0.00E+00 | 2.60E-06 | 4.22E-13 | 2.63E-07 | 1.82E-07 | 1.20E-07 | 3.10E-06 | 3.96E-17 |
| $^{238}U$ | Ci | 6.34E-04 | 3.53E-04 | 3.32E-04 | 2.00E-03 | 4.05E-04 | 9.88E-05 | 9.26E-05 | 0.00E+00 | 1.10E-04 | 2.40E-11 | 8.34E-06 | 5.75E-06 | 1.25E-05 | 1.33E-04 | 7.63E-15 |

Notes:

Radionuclides decayed to 1/1/2001.

$^{99}Tc$ inventory in single-shell tank SX-106 was updated since the publication of RPP-20420.

HTWOS = Hanford Tank Waste Operations Simulator.

RPP-20420, 2004, *241-S-SX Waste Management Area Inventory Data Package*, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

Table 3-11. S and SX Pipe Inventory Estimates.

| Analyte | Standard units of measure | S piping inventory estimate | SX piping inventory estimate |
|---|---|---|---|
| | | Kg or Ci | Kg or Ci |
| Cr | kg | 1.32E+01 | 1.33E+01 |
| F | kg | 8.24E+00 | 1.59E+00 |
| $NO_2$ | kg | 1.02E+02 | 1.41E+02 |
| $NO_3$ | kg | 1.07E+03 | 6.42E+02 |
| U-Total | kg | 5.69E+00 | 4.12E+00 |
| $^{3}H$ | Ci | 2.13E-01 | 1.66E-01 |
| $^{14}C$ | Ci | 5.53E-02 | 3.64E-02 |
| $^{99}Tc$ | Ci | 3.00E-01 | 2.21E-01 |
| $^{129}I$ | Ci | 6.50E-04 | 4.22E-04 |
| $^{232}U$ | Ci | 3.81E-04 | 2.01E-04 |
| $^{233}U$ | Ci | 1.56E-03 | 8.27E-04 |
| $^{234}U$ | Ci | 2.14E-03 | 1.45E-03 |
| $^{235}U$ | Ci | 8.66E-05 | 6.05E-05 |
| $^{236}U$ | Ci | 7.53E-05 | 3.99E-05 |
| $^{238}U$ | Ci | 1.90E-03 | 1.37E-03 |

Notes:

Radionuclides decayed to 1/1/2001.

S tank farm estimated to have 6,125 ft of 3 in. (inside diameter) piping or 301 $ft^3$ of pipe volume. For inventory estimate assumed 25% of pipe volume filled with average "S Farm waste."

SX tank farm estimated to have 4,675 ft of 3-in. (inside diameter) piping or 230 $ft^3$ of pipe volume. For inventory estimated 25% of pipe volume filled with average "SX Farm Waste."

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# 4.0 LONG-TERM PREDICTED GROUNDWATER CONCENTRATIONS FOR WASTE MANAGEMENT AREA S-SX

This section presents the results of the long-term groundwater modeling analysis for WMA S-SX and the predicted groundwater concentrations resulting from the four identified contaminant source components (past leaks, tank residual inventory, hypothetical retrieval leaks, and residual waste in the WMA S-SX pipe system). PNNL-14604 presents detailed discussion and description of the modeling approach and methods, model construction, the different modeling scenarios and cases, and the results. The modeling data package (RPP-17209) defines and describes the contaminant source components and model input parameters. Section 3.0 contains a summary of this information.

Eight different simulation cases (using the STOMP vadose zone flow and contaminant transport code) were conducted to provide a basis for evaluating the consequences of various closure decisions and outcomes. The suite of modeling cases is intended to identify and demonstrate the relative importance of the closure decisions and input parameters upon the results (especially those parameters considered manageable), and provides a quantitative estimate of the expected impact of those decisions and parameters. Predicted groundwater concentrations were compared to groundwater concentration performance objectives, the concentrations also converted to dose and risk factors (and compared to those performance objectives) by applying the appropriate dose and risk conversion factor associated with each contaminant and each exposure scenario (Section 5.0).

The release scenario cases considered are presented in Table 4-1. Section 3.0 identified $^{99}$Tc, $^{14}$C, $^{129}$I, tritium, the uranium isotopes, uranium metal, chromium, fluoride, nitrate, and nitrite as COPCs. As discussed in Section 3.0, groundwater concentrations for each of the COPCs are calculated by scaling the BTC of the appropriate surrogate contaminant to the actual inventory of the contaminant. When the analysis includes multiple sources, the results of the individual BTCs are summed according to the principle of superposition. The following specific aspects of the analyses are presented in this section:

- Cumulative source component (base case) results
- Individual source component results
- Base case downgradient concentrations.

In summary, results indicate that the inventory associated with the past leak sources in SX tank farm has the largest impact on the groundwater. Contaminants associated with these sources currently exist in the vadose zone and may have already impacted groundwater. Contaminant transport to the aquifer occurred (and may be occurring) while the gravel surface and the umbrella effect of the tank tops greatly enhance recharge through the vadose zone (RPP-7884). Surface water run-on to WMA S-SX resulting from unusual meteorological events and water line leaks also contribute to the enhanced recharge. Remedial actions to address the leaking water lines and surface run-on have been completed (RPP-7884). The mobile contaminants in the vadose zone included as part of this evaluation peak in concentration in the groundwater around year 2060. These groundwater concentrations may not be greatly influenced by the surface barrier efficacy and longevity (recharge through the barrier is assumed to be 0.1 mm/yr for

500 years after installation and 3.5 mm/yr after the barrier has degraded for the purpose of these analyses) because the concentrations peak so close to the time of barrier installation in 2050. The barrier, even in an eventual degraded state, is expected to inhibit the transport of contaminants that may release into the vadose zone in the future.

The results of the risk assessment modeling are consistent with the results of the modeling contained in RPP-7884, which indicated that waste from past leaks is projected to impact groundwater significantly in the future. Although RPP-7884 contained some differing assumptions with respect to final placement of the surface barrier and location of existing vadose zone contaminant inventory, the conclusions indicated that the tank rows with past leaks may produce groundwater concentrations in excess of the MCL for $^{99}$Tc, chromium, and, nitrate (the only three constituents modeled in RPP-7884).

**Results and Conclusions**

- The primary contributors to groundwater contamination are contaminants contained in past leaks from tanks and, after retrieval of the waste in the tanks to the HFFACO goal of 360 ft$^3$, predicted leaks from tanks during waste retrieval.

- The placement of the surface barrier greatly reduces the recharge rate through vadose zone contamination from 100 mm/yr to 0.1 mm/yr, which results in a decrease in the predicted peak groundwater concentrations until the barrier degrades.

- Key parameters affecting the predicted groundwater contaminant concentrations resulting from tank residual waste releases are release rate (but only if the release extends beyond 3,000 years), contaminant mobility, and inventory.

- During the first 100 years after waste retrieval, the maximum $^{99}$Tc concentration associated with past leaks is 2.1E+05 pCi/L at the WMA S-SX fenceline. The peak concentration of $^{99}$Tc resulting from tank residual diffusion-dominated releases after waste retrieval is 1.7E+02 pCi/L around year 4900.

- During the first 100 years after waste retrieval, peak $^{129}$I concentration associated with past leaks is 4.0E+02 pCi/L and greatly exceeds the MCL of 1 pCi/L at the WMA S-SX fenceline. The peak concentration of $^{129}$I resulting from tank residual diffusion releases after retrieval is 6.6E-02 pCi/L around year 4900.

- Contaminants with a $K_d \geq 1.0$ mL/g do not contribute appreciably to groundwater contamination over the 10,000-year simulation, although contaminants with a $K_d = 1.0$ mL/g do arrive at the fenceline.

- Contaminants with a $K_d \geq 0.3$ mL/g exhibit increasing concentrations at the end of the 10,000-year simulation.

- If retrieved to the HFFACO goal of 1%, all peak concentrations for the COCs downgradient of the WMA S-SX at the 200 Area core zone boundary and Columbia River occur at levels below the contaminant's MCLs.

Table 4-1. Features of Waste Management Area S-SX Base Case (2 sheets).

| | |
|---|---|
| Hydraulic conductivity of unconfined aquifer | 25 m/day |
| Release model for residual waste | Diffusion (coefficient 6.0E-07 $cm^2/s$) |
| COCs and distribution coefficients | $^{99}Tc$, $^{129}I$, $^{14}C$, tritium, chromium, fluoride, nitrate, and nitrate = 0.0 mL/g<br>Uranium metal and uranium isotopes = 0.6 mL/g |

**Inventory and source terms**

| Sources | Assumed retrieval method | Residual volume/ inventory used | Vadose zone contamination associated with past tank leak[a] | Hypothetical retrieval leak | Inventory[b] | | |
|---|---|---|---|---|---|---|---|
| | | | | | Residual[c] | Past tank leak[d] | Retrieval leak[d] |
| S-101 | Sluicing | 360 $ft^3$/HTWOS[e] | No | Yes | Table 3-7 | | Table 3-9 |
| S-102 | Sluicing | 360 $ft^3$/HTWOS | No | Yes | Table 3-7 | | Table 3-9 |
| S-103 | Sluicing | 360 $ft^3$/HTWOS | No | Yes | Table 3-7 | | Table 3-9 |
| S-104 | Sluicing | 360 $ft^3$/HTWOS | Yes | Yes | Table 3-7 | Table 3-4 | Table 3-9 |
| S-105 | Sluicing | 360 $ft^3$/HTWOS | No | Yes | Table 3-7 | | Table 3-9 |
| S-106 | Sluicing | 360 $ft^3$/HTWOS | No | Yes | Table 3-7 | | Table 3-9 |
| S-107 | Sluicing | 360 $ft^3$/SPR[f] | No | Yes | Table 3-7 | | Table 3-9 |
| S-108 | Sluicing | 360 $ft^3$/HTWOS | No | Yes | Table 3-7 | | Table 3-9 |
| S-109 | Sluicing | 360 $ft^3$/HTWOS | No | Yes | Table 3-7 | | Table 3-9 |
| S-110 | Sluicing | 360 $ft^3$/HTWOS | No | Yes | Table 3-7 | | Table 3-9 |
| S-111 | Sluicing | 360 $ft^3$/HTWOS | No | Yes | Table 3-7 | | Table 3-9 |
| S-112 | Sluicing | 360 $ft^3$/HTWOS | No | Yes | Table 3-7 | | Table 3-9 |
| SX-101 | Sluicing | 360 $ft^3$/HTWOS | No | Yes | Table 3-8 | | Table 3-10 |
| SX-102 | Sluicing | 360 $ft^3$/HTWOS | No | Yes | Table 3-8 | | Table 3-10 |
| SX-103 | Sluicing | 360 $ft^3$/HTWOS | No | Yes | Table 3-8 | | Table 3-10 |
| SX-104 | Sluicing | 360 $ft^3$/HTWOS | No | Yes | Table 3-8 | | Table 3-10 |
| SX-105 | Sluicing | 360 $ft^3$/HTWOS | No | Yes | Table 3-8 | | Table 3-10 |

Table 4-1. Features of Waste Management Area S-SX Base Case (2 sheets).

| Sources | Assumed retrieval method | Residual volume/ inventory used | Vadose zone contamination associated with past tank leak[a] | Hypothetical retrieval leak | Inventory[b] | | |
|---|---|---|---|---|---|---|---|
| | | | | | Residual[c] | Past tank leak[d] | Retrieval leak[d] |
| SX-106 | Sluicing | 360 $ft^3$/HTWOS | No | Yes | Table 3-8 | | Table 3-10 |
| SX-107 | Sluicing | 360 $ft^3$/SPR | Yes | Yes | Table 3-8 | Table 3-4 | Table 3-10 |
| SX-108 | Sluicing | 360 $ft^3$/SPR | Yes | Yes | Table 3-8 | Table 3-4 | Table 3-10 |
| SX-109 | Sluicing | 360 $ft^3$/HTWOS | Yes | Yes | Table 3-8 | Table 3-4 | Table 3-10 |
| SX-110 | Sluicing | 360 $ft^3$/HTWOS | No | Yes | Table 3-8 | | Table 3-10 |
| SX-111 | Sluicing | 360 $ft^3$/HTWOS | No | Yes | Table 3-8 | | Table 3-10 |
| SX-112 | Sluicing | 360 $ft^3$/HTWOS | No | Yes | Table 3-8 | | Table 3-10 |
| SX-113 | Sluicing | 360 $ft^3$/SPR | Yes | Yes | Table 3-8 | Table 3-4 | Table 3-10 |
| SX-114 | Sluicing | 360 $ft^3$/HTWOS | No | Yes | Table 3-8 | Table 3-4 | Table 3-10 |
| SX-115 | Sluicing | 360 $ft^3$/SPR | Yes | Yes | Table 3-8 | Table 3-4 | Table 3-10 |
| S-Pipeline Residuals | | | | | Table 3-11 | | |
| SX-Pipeline Residuals | | | | | Table 3-11 | | |

Notes:

[a] Past tank leaks only tanks with verified vadose zone contamination were included in the model. Vadose contamination was either verified by either borehole sampling or geophysical logging.

[b] Inventory Tables are from Section 3.6 of this document.

[c] Residuals used a diffusion release model.

[d] Past leaks and hypothetical retrieval leaks are simulated using advective transport through the vadose zone.

[e] HTWOS = Hanford Tank Waste Operation Simulator Model Output (RPP-8554), modeled inventory after retrieval simulating differential dissolution of waste constituents in high volume retrieval.

[f] SPR = Selected phase removal inventory after the retrieval of tank wastes as reported in DOE/ORP-2003-06.

COC = contaminant of concern.

DOE/ORP-2003-06, 2003, *Environmental Impact Statement for Retrieval, Treatment, and Disposal of Tank Waste and Closure of Single-Shell Tanks at the Hanford Site, Richland, WA [Waste Retrieval and Storage Data Package]*, Rev. 0, U.S. Department of Energy, Office of River Protection, Richland, Washington.

RPP-8554, 2003, *Single-Shell Tank Retrieval Sequence and Double-Shell Tank Space Evaluation*, Rev. 2, CH2M HILL Hanford Group, Inc., Richland, Washington.

## 4.1 SUMMARY SOLUBILITY-CONTROLLED RELEASE OF CUMULATIVE BASE CASE RESULTS EVALUATED AT WASTE MANAGEMENT AREA S-SX

A base case describing the assumed post-retrieval conditions based on current waste retrieval plans is defined for the contaminant inventory. Table 4-1 provides a listing of the selected conditions, constituents, and source terms at WMA S-SX. Base cases are constructed for each row of tanks, or tank row. A tank row contains three tanks and is identified by the tanks contained in that row (e.g., tank row S-104, S-105, and S-106 refers to the row consisting of tanks S-104, S-105, and S-106). Base cases include past leaks where evidence indicates those occurred, hypothetical 8,000-gal leaks occurring during retrieval actions, and the eventual release of residual wastes in the associated tanks and in the WMA S-SX pipe system. Contaminants associated with past leaks and hypothetical retrieval leaks are assumed to be entirely subject to advective transport. The base case included the diffusion-controlled release mechanism because of uncertainty about the solubility and contaminant release characteristics of the waste, especially after sluicing retrieval. Although, saltcake waste releases are often simulated using a solubility-controlled release mechanism, information describing the solubility of the residual waste is not yet available. For the modeling evaluation and comparison of residual waste release models, the solubility of the waste form in the model was assumed to be comparable to the dissolution of a nitrate salt in water (650 g/L, see RPP-17209, Appendix B for a description of the release model). This release model produced groundwater concentration results almost equal to those for the advective-release case, which assumes that the waste form is unstabilized and just covered with backfill sand and gravel. Diffusion-controlled release is a slower release mechanism than the solubility-controlled release mechanism using the current solubility and dissolution rates. Because of the high solubility and dissolution rates used in the solubility-controlled release model, diffusion-controlled release is considered to be much more consistent with the expected state of the residual waste after closure activities have concluded. When data become available regarding the solubility and dissolution rate of the solid material of the tank residual waste, the solubility-controlled release may replace the diffusion-controlled release model.

Base case conditions are used when a cumulative total groundwater concentration is reported for WMA S-SX. In addition to the information provided in Table 4-1, the following information is also important for this analysis:

- Three rows of tanks possess vadose zone contamination attributable to past leaks from the tanks or their associated ancillary equipment. The tanks associated with vadose zone contaminant inventories from past leaks are SSTs S-104, SX-107, SX-108, SX-109, SX 113, and SX-115.

- The retrieval method for the tank residual waste is assumed to be sluicing, thus hypothetical retrieval leaks were modeled for all tanks. All are assumed to leak for the purpose of this analysis. Although retrieval leaks are included in the base case cumulative BTC, it is unlikely that all tanks in a row will leak 8,000 gal.

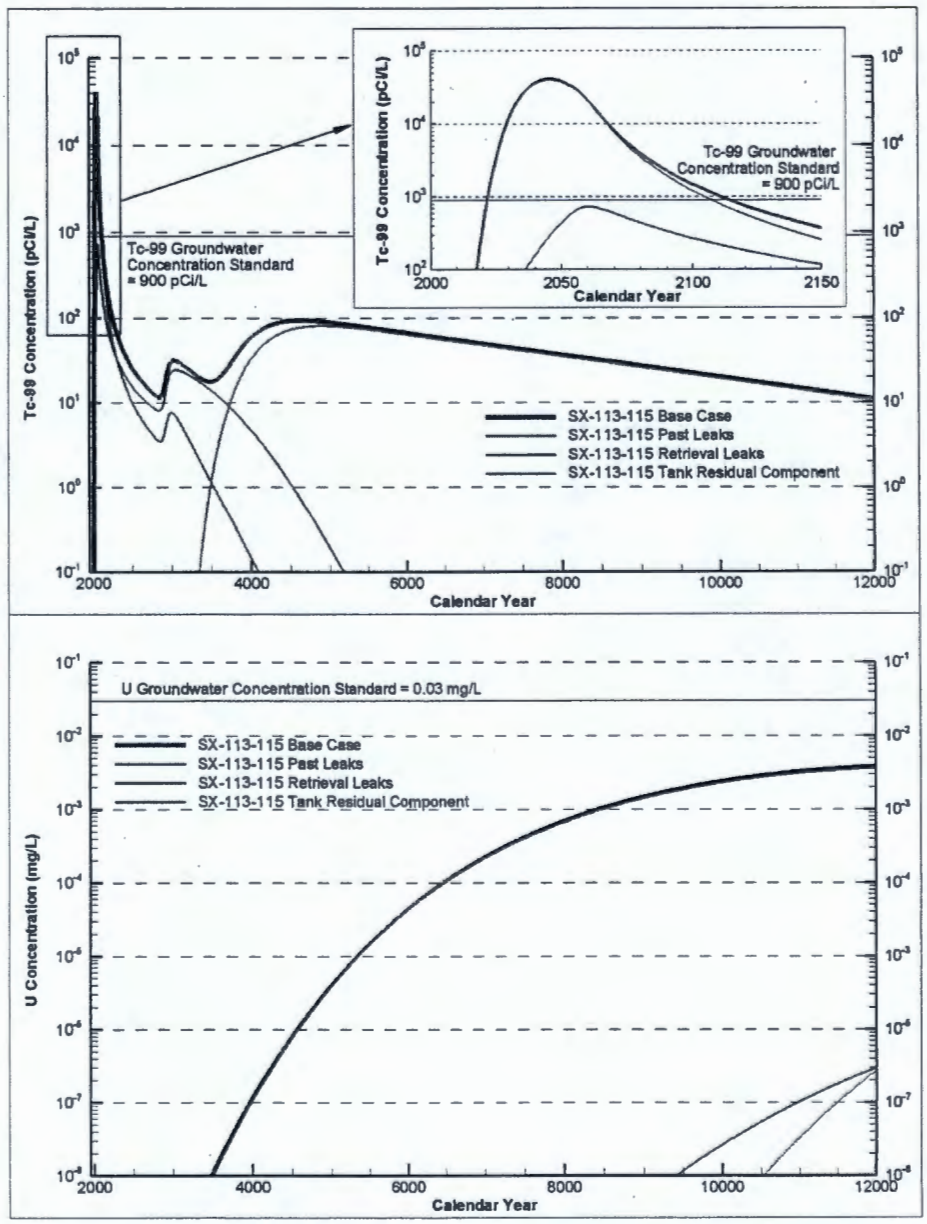
- Tank residual inventories after retrieval are given in Tables 3-7 and 3-8.

- Groundwater flow is assumed to occur in an east-west direction, thus impacts to groundwater are evaluated on a tank row by tank row basis as the tank rows are oriented east to west. Commingling of plumes between rows is assumed to be negligible because the results of the 3-D simulation indicated that 99% of the contaminants at the fenceline remained within 20 m of the plume centerline (PNNL-14334).

- Each simulation for uranium and the uranium isotopes was conducted with a $K_d$ of 0.6 mL/g (PNNL-13895, *Hanford Contaminant Distribution Coefficient Database and Users Guide*). The other COCs that are discussed (tritium, $^{14}C$, $^{99}Tc$, $^{129}I$, chromium, fluoride, nitrate, and nitrite are assumed to be entirely mobile with the vadose and groundwater flow (i.e., $K_d$ of 0 mL/g).

Figure 4-1 shows $^{99}Tc$ and uranium base case BTCs for tank row (SX-107, SX-108, and SX-109) from each individual source term. The $^{99}Tc$ BTCs show that the peak concentration occurs relatively early during the simulation period because of the past leak and hypothetical retrieval leak sources. For tank rows that contain no past leak contaminant inventory, then the early time concentrations result only from the hypothetical retrieval leaks. Beginning around year 3500, the tank residual waste diffusion-limited releases become the dominant source term of the fenceline concentrations and remain as such through the remainder of the simulation period. The uranium BTCs show that only the source contributing substantially to the base case concentration is the inventory associated with the past leak. The uranium concentration continues to increase at the end of the simulation period, but the concentration appears to be close to the peak value.

Figure 4-1. Tank Row SX-107, SX-108, and SX-109 Base Case and Component Breakthrough Curves for $^{99}$Tc and Uranium at the WMA S-SX Fenceline.




### 4.1.1 Tank Rows in S Tank Farm

Maximum groundwater concentrations occur along the row of tanks containing SSTs S-110, S-111, and S-112, which is contributed primarily from hypothetical retrieval leaks. Peak groundwater concentrations for $^{99}$Tc, $^{129}$I, and chromium are 5,100 pCi/L, 8.1 pCi/L, and 0.15 mg/L, respectively. Groundwater concentrations peak at approximately year 2060 and decrease through the end of the simulation period following the emplacement of the surface barrier at year 2050. The base case breakthrough curves associated with tank row S-110, S-111, and S-112 are shown in Figure 4-2. Peak groundwater concentrations for all radiological and

nonradiological COPCs and all tank row at the WMA S-SX fenceline and their arrival times are provided Tables 4-2 and 4-3, respectively.

Inventory from hypothetical retrieval leaks is the primary contributor to elevated groundwater concentrations. When hypothetical retrieval leaks are excluded, maximum groundwater concentrations of $^{99}$Tc, $^{129}$I, and total chromium at the fenceline are considerably reduced (770 pCi/L, 1.5 pCi/L, and 0.073 mg/L, respectively). Groundwater concentrations reported from tank row S-104, S-105, and S-106 are representative of vadose zone contamination that is currently present. None of the other tank rows possess sufficient inventory to produce groundwater concentrations in excess of the MCLs for any COPCs when retrieval losses are excluded from the analysis. These results emphasize the importance of minimizing the losses that occur during retrieval actions at the S tank farm.

### 4.1.2 Tank Rows in SX Tank Farm

Maximum groundwater concentrations occur along the row of tanks containing SSTs SX-107, SX-108, and SX-109, which is contributed from vadose zone contamination that is currently present from all three tanks. Peak groundwater concentrations for $^{99}$Tc, $^{129}$I, tritium, $^{14}$C, chromium, nitrate, and nitrite are 210,000 pCi/L, 400 pCi/L, 37,000 pCi/L, 26,000 pCi/L, 20 mg/L, 310 mg/L, and 190 mg/L, respectively. Groundwater concentrations peak at approximately year 2060 and decrease through the end of the simulation period following the emplacement of the surface barrier at year 2050. The base case breakthrough curves associated with tank row SX-107, SX-108, and SX-109 are shown in Figure 4-3. Peak groundwater concentrations for radiological and nonradiological COPCs at the WMA S-SX fenceline and their arrival times are provided Tables 4-2 and 4-3, respectively.

Inventory from hypothetical retrieval leaks is not the primary contributor to elevated groundwater concentrations as it is at the S tank farm. Inventory from contamination currently existing in the vadose zone at SX tank farm is the primary contributor to elevated groundwater concentrations. When hypothetical retrieval leaks are excluded, predicted groundwater concentrations remain relatively unchanged because of the large inventories from past leaks at tank rows SX-107, SX-108, and SX-109 and SX-113, SX-114, and SX 115. When hypothetical retrieval leaks are excluded from tank rows without existing contamination, then maximum groundwater concentrations at the fenceline are reduced. The emplacement and efficacy of the surface barrier does not impact the results at SX tank farm to the same degree as the S tank farm. Because future groundwater concentrations modeled from past leaks and hypothetical retrieval leaks peak close to the time of barrier installation at year 2050; it does not appear that future concentrations are affected by the emplacement of the surface barrier.

Figure 4-2. Tank Row S-110, S-111, and S-112 Base Case Breakthrough Curves at the WMA S-SX Fenceline for Select Contaminants of Potential Concern.

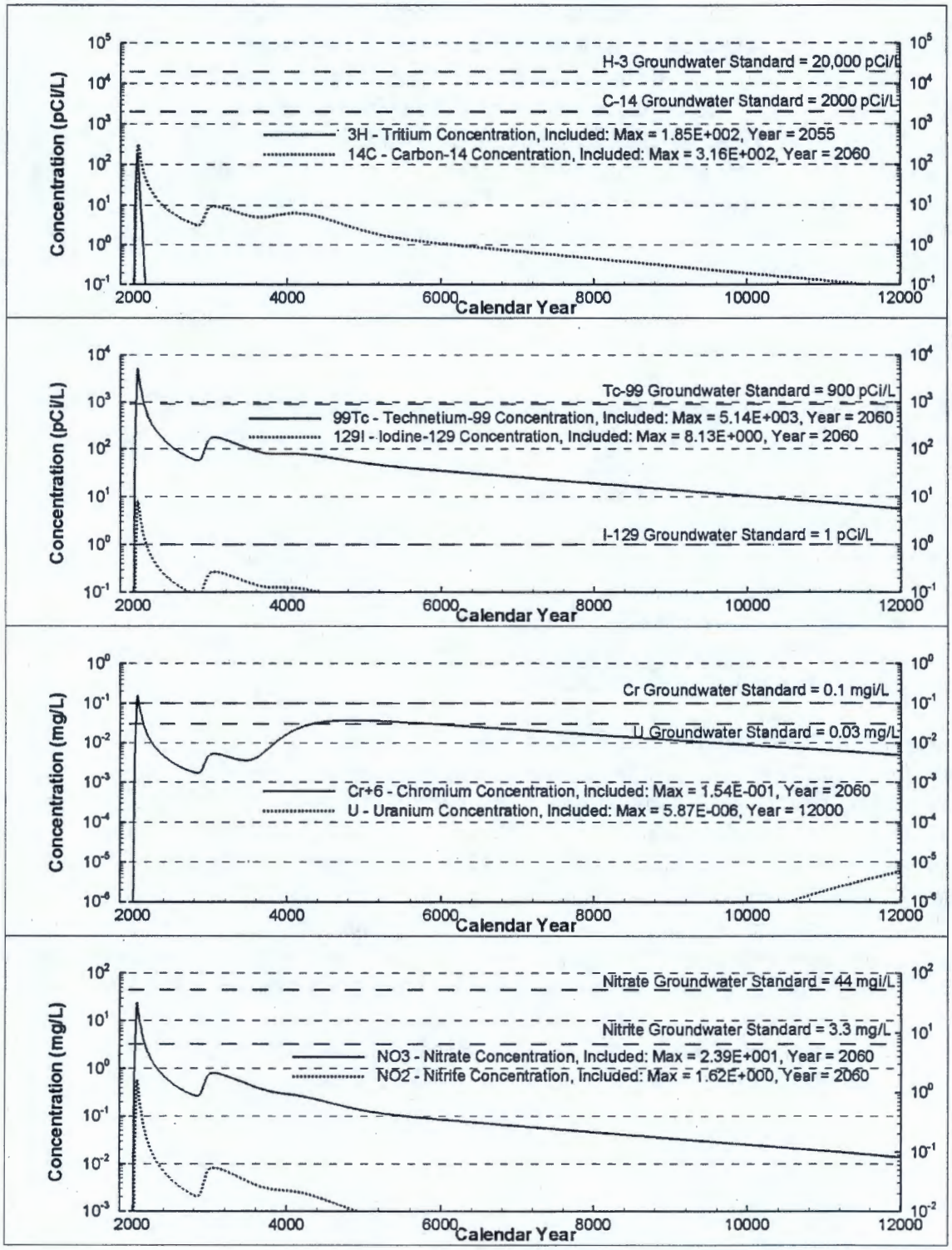


Figure 4-3. Tank Row SX-107, SX-108, and SX-109 Base Case Breakthrough Curves at the WMA S-SX Fenceline for Select Contaminants of Potential Concern.

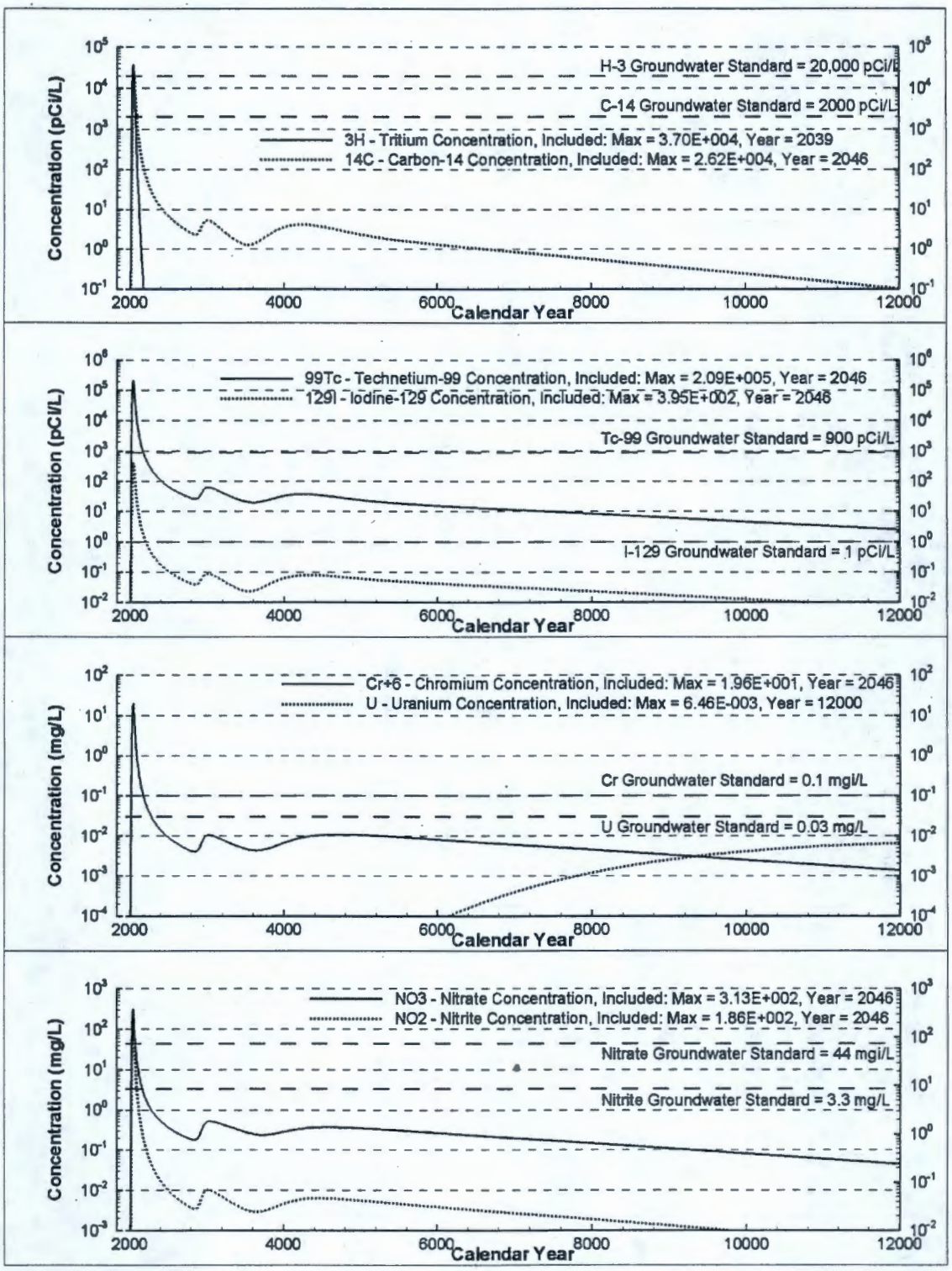


Table 4-2. Simulated Base Case Peak Fenceline Concentrations[a] (pCi/L) and Arrival Times (year) for Radionuclide Contaminants of Potential Concern.

| Tank row | WMA S-SX Fenceline Boundary Concentrations | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Time | $^{99}$Tc peak concentration pCi/L | Time | $^{129}$I peak concentration pCi/L | Time | $^{14}$C peak concentration pCi/L | Time | Tritium peak concentration pCi/L | Time | Maximum U isotope peak concentration pCi/L |
| Row S-101, S-102, S-103 | 2060 | 3.4E+03 | 2060 | 5.0E+00 | 2060 | 1.7E+02 | 2056 | 1.2E+02 | 12000 | 2.2E-01 |
| Row S-104, S-105, S-106 | 2060 | 3.7E+03 | 2060 | 5.8E+00 | 2058 | 2.6E+02 | 2040 | 3.8E+02 | 12000 | 3.8E-01 |
| Row S-107, S-108, S-109 | 2060 | 4.2E+03 | 2060 | 6.5E+00 | 2060 | 3.0E+02 | 2056 | 1.2E+02 | 12000 | 1.6E-01 |
| Row S-110, S-111, S-112 | 2060 | 5.1E+03 | 2060 | 8.1E+00 | 2060 | 3.2E+02 | 2056 | 1.8E+02 | 12000 | 1.5E-01 |
| Row SX-101, SX-102, SX-103 | 2060 | 5.8E+03 | 2060 | 8.1E+00 | 2060 | 3.7E+02 | 2056 | 1.9E+02 | 12000 | 1.3E-03 |
| Row SX-104, SX-105, SX-106 | 2060 | 8.1E+03 | 2060 | 1.3E+01 | 2060 | 4.7E+02 | 2056 | 2.4E+02 | 12000 | 2.0E-03 |
| Row SX-107, SX-108, SX-109 | 2060 | 2.1E+05 | 2058 | 4.0E+02 | 2058 | 2.6E+04 | 2040 | 3.7E+04 | 12000 | 2.6E+00 |
| Row SX-110, SX-111, SX-112 | 2060 | 5.4E+02 | 2060 | 8.2E-01 | 2060 | 2.4E+01 | 2056 | 3.9E+01 | 12000 | 1.5E-04 |
| Row SX-113, SX-114, SX-115 | 2060 | 4.1E+04 | 2058 | 7.7E+01 | 2058 | 5.3E+03 | 2040 | 6.4E+03 | 12000 | 1.6E+00 |

Table 4-3. Simulated Base Case Peak Fenceline Concentrations [a] (mg/L) and Arrival Times (year) for Nonradionuclide Contaminants of Potential Concern.

| Tank row | WMA S-SX Fenceline Boundary Concentrations | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Time | Cr peak concentration mg/L | Time | F peak concentration mg/L | Time | Nitrate peak concentration mg/L | Time | Nitrite peak concentration mg/L | Time | Total uranium peak concentration mg/L |
| Row S-101, S-102, S-103 | 2060 | 4.4E-02 | 2060 | 3.4E-02 | 2060 | 7.7E+00 | 2060 | 2.0E+00 | 12000 | 1.4E-06 |
| Row S-104, S-105, S-106 | 2054 | 1.0E-01 | 2060 | 4.2E-02 | 2050 | 3.3E+01 | 2046 | 6.3E+00 | 12000 | 6.8E-03 |
| Row S-107, S-108, S-109 | 2060 | 9.9E-02 | 2060 | 2.3E-01 | 2060 | 2.2E+01 | 2060 | 1.8E+00 | 12000 | 1.6E-06 |
| Row S-110, S-111, S-112 | 2060 | 1.5E-01 | 2060 | 4.6E-02 | 2060 | 2.4E+01 | 2060 | 1.6E+00 | 12000 | 5.9E-06 |
| Row SX-101, SX-102, SX-103 | 2060 | 2.8E-01 | 2060 | 2.4E-02 | 2060 | 2.4E+01 | 2060 | 4.5E+00 | 12000 | 3.7E-06 |
| Row SX-104, SX-105, SX-106 | 2060 | 1.4E-01 | 2060 | 8.1E-02 | 2060 | 2.1E+01 | 2060 | 6.0E+00 | 12000 | 5.9E-06 |
| Row SX-107, SX-108, SX-109 | 2054 | 2.0E+01 | 2060 | 2.3E-02 | 2050 | 3.1E+02 | 2046 | 1.9E+02 | 12000 | 6.5E-03 |
| Row SX-110, SX-111, SX-112 | 2060 | 5.6E-02 | 2060 | 2.2E-02 | 2060 | 4.5E+00 | 2060 | 1.1E+00 | 12000 | 4.5E-07 |
| Row SX-113, SX-114, SX-115 | 2054 | 5.1E+00 | 2060 | 6.6E-03 | 2050 | 7.1E+01 | 2046 | 6.5E+01 | 12000 | 3.8E-03 |

### 4.1.3 Summary of Cumulative Base Case Results

As shown in Tables 4-2 and 4-3, peak groundwater concentrations from the base case evaluation from eight of the nine rows of tanks in WMA S-SX result in elevated concentrations. The highest concentrations in groundwater at the fenceline is from contamination currently existing in the vadose zone from past leaks in SX tank farm. Concentrations of COPCs currently in groundwater are not likely to be affected by any of the pending closure decisions. Predicted groundwater concentrations of uranium (total or isotopic) or fluoride are relatively low and are not expected to exceed drinking water standards. The following summarize the base case results:

- Hypothetical retrieval leaks and past leaks are the primary contributors to the cumulative groundwater concentrations at S and SX tank farms, respectively.
- The highest groundwater concentrations occur within 100 years of retrieval, and within the time period in which the land use for the core zone is considered industrial.
- The placement of the surface barrier greatly reduces recharge through the vadose zone, which decreases the predicted groundwater concentration until the barrier degrades. Placement and performance of the barrier does not impact the base case results at SX tank farm as much as at S tank farm, because substantial vadose zone contamination currently exists at SX tank farm and likely reaches groundwater before the barrier takes effect.
- Peak groundwater concentrations after the barrier degrades in 2550 are considerably below each contaminant's respective drinking water standard.

## 4.2 SUMMARY OF INDIVIDUAL WASTE SOURCE RESULTS EVALUATED AT WMA S-SX

Impacts to predicted groundwater concentrations were simulated for the following four contaminant sources within WMA S-SX:

- Past leaks from tanks and tank ancillary equipment
- Hypothetical leaks during waste retrieval
- Residual waste in tanks
- Residual waste in WMA S-SX pipe system.

WMA S-SX contains multiple sources within the WMA boundary (Figure 3-2), including the primary waste storage tanks, as well as the WMA S-SX pipe system, and past leaks from those components. Residual waste and retrieval leakage inventories were identified for all of the tanks within WMA S-SX, as well as six past tank leaks. The leaks documented for WMA S-SX may all be attributed to tanks or their immediate ancillary equipment, so no separate past WMA S-SX pipe system leaks were simulated. Other potentially important sources within WMA S-SX (such as waste tanks within the valve pits, catch tanks, and pipelines) currently do not have reliable

inventory estimates. Simple estimates of the inventory associated with these sources were made for the purpose of estimating potential impact to groundwater (Section 3.6). The base case analysis combined the impacts of all of the waste sources; the following sections discuss the impacts of the different waste sources individually.

### 4.2.1 Evaluation of Residual Tank Inventory

Residual tank inventory results indicate that when the wastes are retrieved to the HFFACO goal, none of the tank rows are projected to contain a residual inventory capable of producing a peak contaminant groundwater concentration greater than their respective MCLs for the diffusion-dominated release mechanism. Tank row S-104, S-105, and S-106 produces the highest $^{99}$Tc groundwater concentrations at the fenceline for the S Tank Farm, and tank row SX-113, SX-114, and SX-114 produces the highest $^{99}$Tc groundwater concentrations at the fenceline for SX tank farm. Tank row S-101, S-102, and S-103 produces the highest $^{129}$I groundwater concentrations at the fenceline for the S Tank Farm, and tank row SX-107, SX-108, and SX-109 produces the highest $^{129}$I groundwater concentrations at the fenceline for the SX tank farm. Figures 4-4 and 4-5 show the tank row BTCs resulting from the residual tank waste at the fenceline for SSTs S-104, S-105, and S-106 and SSTs SX-113, SX-114, and SX-115, respectively. Maximum groundwater concentrations for the other COPCs are shown in Tables 4-4 and 4-5.

Figure 4-4. Tank Row S-104, S-105, and S-106 Breakthrough Curves at the WMA S-SX Fenceline for the Select Contaminants of Potential Concern Resulting from Diffusion-Dominated Release.

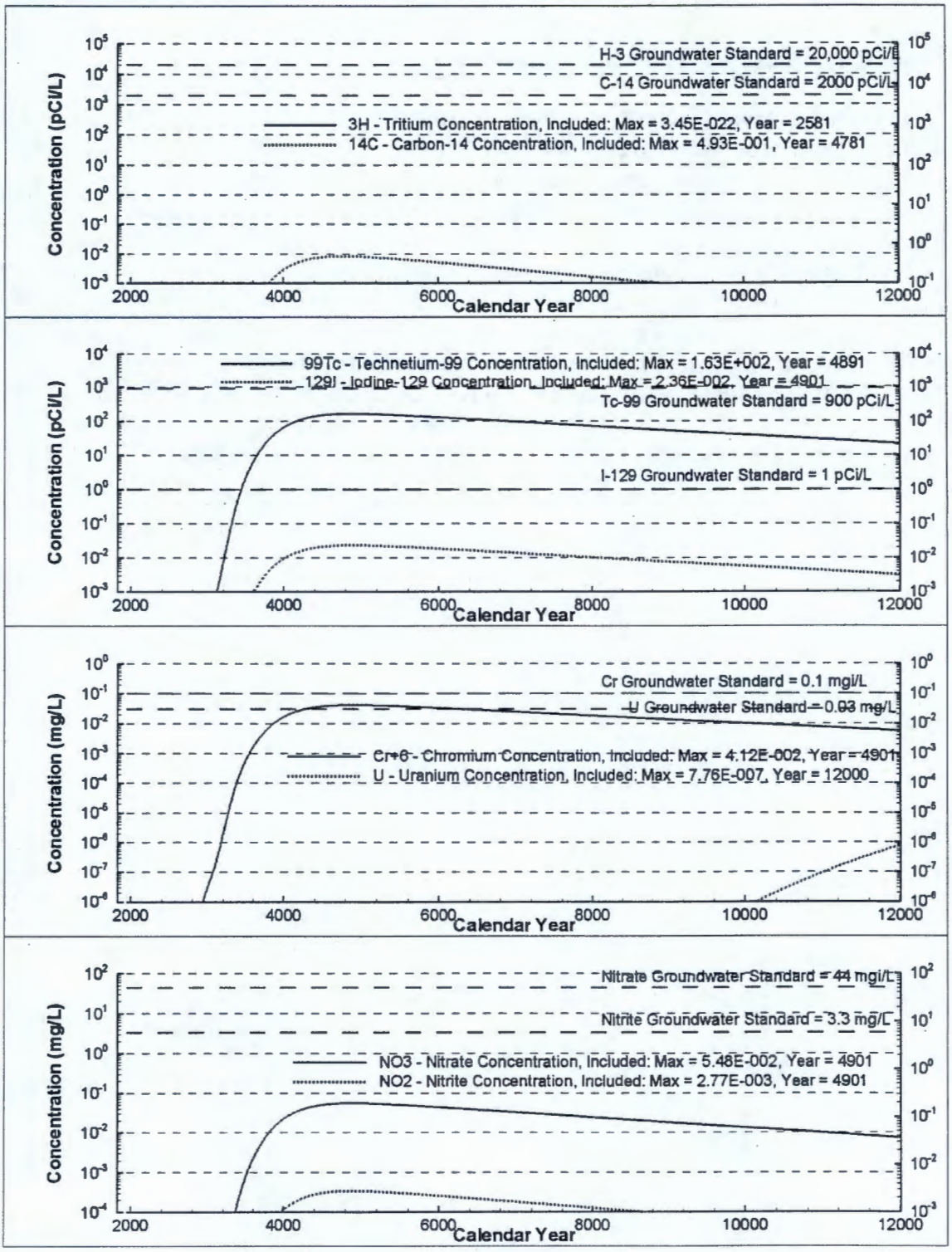


Figure 4-5. Tank Row SX-113, SX-114, and SX-115 Breakthrough Curves at the WMA S-SX Fenceline for the Select Contaminants of Potential Concern Resulting from Diffusion-Dominated Release.

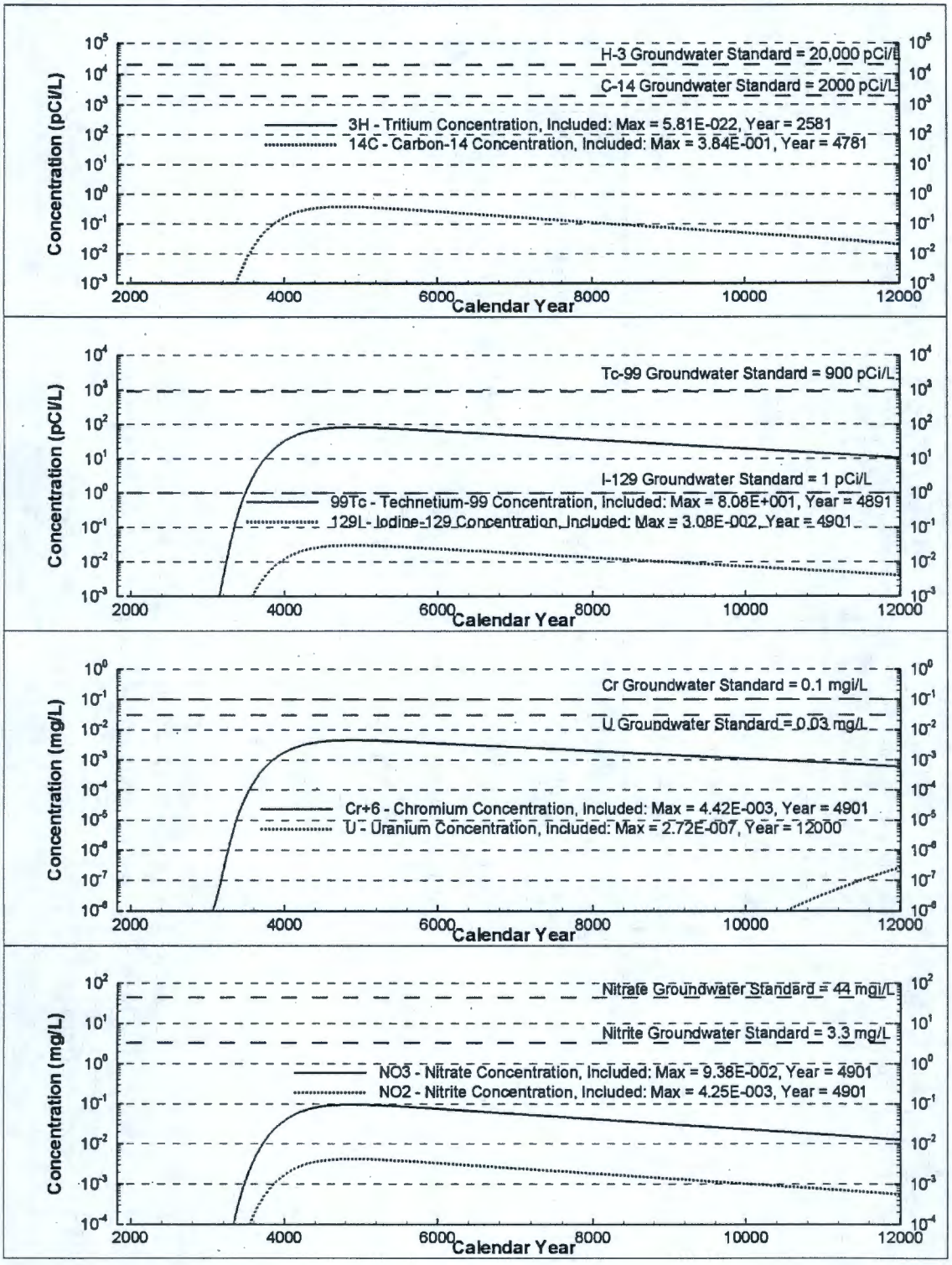


Table 4-4. Simulated Component Peak Fenceline Concentrations (pCi/L) and Arrival Times (year) for Radionuclide Contaminants of Potential Concern. (2 sheets)

| Tank row | WMA S-SX Fenceline Boundary Concentrations | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Time | $^{99}$Tc peak concentration pCi/L | Time | $^{129}$I peak concentration pCi/L | Time | $^{14}$C peak concentration pCi/L | Time | Tritium peak concentration pCi/L | Time | Maximum U isotope peak concentration pCi/L |
| **Past Leaks** | | | | | | | | | | |
| Row S-104, S-105, S-106 | 2046 | 7.7E+02 | 2046 | 1.4E+00 | 2046 | 8.8E+01 | 2040 | 3.3E+02 | 12000 | 3.1E+00 |
| Row SX-107, SX-108, SX-109 | 2046 | 2.1E+05 | 2046 | 4.0E+02 | 2046 | 2.6E+04 | 2040 | 3.7E+04 | 12000 | 2.5E+00 |
| Row SX-113, SX-114, SX-115 | 2046 | 4.1E+04 | 2046 | 7.7E+01 | 2046 | 5.3E+03 | 2040 | 6.4E+03 | 12000 | 1.5E+00 |
| **Hypothetical 8,000-gal retrieval leak** | | | | | | | | | | |
| Row S-101, S-102, S-103 | 2060 | 3.4E+03 | 2060 | 5.0E+00 | 2060 | 1.7E+02 | 2056 | 1.2E+02 | 12000 | 1.2E-04 |
| Row S-104, S-105, S-106 | 2060 | 3.3E+03 | 2060 | 5.1E+00 | 2060 | 2.2E+02 | 2056 | 9.1E+01 | 12000 | 1.0E-04 |
| Row S-107, S-108, S-109 | 2060 | 4.2E+03 | 2060 | 6.5E+00 | 2060 | 2.9E+02 | 2056 | 1.2E+02 | 12000 | 3.0E-04 |
| Row S-110, S-111, S-112 | 2060 | 5.1E+03 | 2060 | 8.1E+00 | 2060 | 3.2E+02 | 2056 | 1.8E+02 | 12000 | 1.7E-03 |
| Row SX-101, SX-102, SX-103 | 2060 | 5.8E+03 | 2060 | 8.1E+00 | 2060 | 3.7E+02 | 2056 | 1.9E+02 | 12000 | 9.0E-04 |
| Row SX-104, SX-105, SX-106 | 2060 | 8.1E+03 | 2060 | 1.3E+01 | 2060 | 4.7E+02 | 2056 | 2.4E+02 | 12000 | 1.7E-03 |
| Row SX-107, SX-108, SX-109 | 2060 | 7.1E+02 | 2060 | 4.7E-01 | 2060 | 2.9E+01 | 2056 | 4.9E+01 | 12000 | 1.4E-04 |
| Row SX-110, SX-111, SX-112 | 2060 | 5.4E+02 | 2060 | 8.2E-01 | 2060 | 2.4E+01 | 2056 | 3.9E+01 | 12000 | 9.6E-06 |
| Row SX-113, SX-114, SX-115 | 2060 | 7.3E+02 | 2060 | 3.8E-01 | 2060 | 1.8E+01 | 2056 | 3.3E+01 | 12000 | 9.9E-05 |

Table 4-4. Simulated Component Peak Fenceline Concentrations (pCi/L) and Arrival Times (year) for Radionuclide Contaminants of Potential Concern. (2 sheets)

| Tank row | WMA S-SX Fenceline Boundary Concentrations | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Time | $^{99}$Tc peak concentration pCi/L | Time | $^{129}$I peak concentration pCi/L | Time | $^{14}$C peak concentration pCi/L | Time | Tritium peak concentration pCi/L | Time | Maximum U isotope peak concentration pCi/L |
| **Tank residuals - diffusion controlled release** | | | | | | | | | | |
| Row S-101, S-102, S-103 | 4902 | 7.9E+01 | 4902 | 6.6E-02 | 4777 | 1.1E+00 | 2577 | <1E-20 | 12000 | 3.2E-04 |
| Row S-104, S-105, S-106 | 4902 | 1.7E+02 | 4902 | 2.4E-02 | 4777 | 4.9E-01 | 2577 | <1E-20 | 12000 | 2.6E-04 |
| Row S-107, S-108, S-109 | 4902 | 8.7E+01 | 4902 | 2.5E-02 | 4777 | 3.4E+00 | 2577 | <1E-20 | 12000 | 2.1E-04 |
| Row S-110, S-111, S-112 | 4902 | 1.1E+02 | 4902 | 3.0E-02 | 4777 | 9.0E-01 | 2577 | <1E-20 | 12000 | 2.1E-04 |
| Row SX-101, SX-102, SX-103 | 4902 | 6.9E+01 | 4902 | 2.8E-02 | 4777 | 8.3E-01 | 2577 | <1E-20 | 12000 | 3.3E-04 |
| Row SX-104, SX-105, SX-106 | 4902 | 5.1E+01 | 4902 | 3.9E-02 | 4777 | 1.8E+00 | 2577 | <1E-20 | 12000 | 2.5E-04 |
| Row SX-107, SX-108, SX-109 | 4902 | 1.6E+01 | 4902 | 4.6E-02 | 4777 | 1.5E+00 | 2577 | <1E-20 | 12000 | 1.3E-04 |
| Row SX-110, SX-111, SX-112 | 4902 | 2.7E+00 | 4902 | 2.6E-03 | 4777 | 1.0E-01 | 2577 | <1E-20 | 12000 | 1.3E-04 |
| Row SX-113, SX-114, SX-115 | 4902 | 8.1E+01 | 4902 | 3.1E-02 | 4777 | 3.8E-01 | 2577 | <1E-20 | 12000 | 9.1E-05 |

Table 4-5. Simulated Component Peak Fenceline Concentrations (mg/L) and Arrival Times (year) for Nonradionuclide Contaminants of Potential Concern. (2 sheets)

| Tank row | WMA S-SX Fenceline Boundary Concentrations | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Time | Cr peak concentration mg/L | Time | F peak concentration mg/L | Time | Nitrate peak concentration mg/L | Time | Nitrite peak concentration mg/L | Time | Total uranium peak concentration mg/L |
| **Past Leaks** | | | | | | | | | | |
| Row S-104, S-105, S-106 | 2046 | 7.3E-02 | 2046 | 0.0E+00 | 2046 | 2.5E+01 | 2046 | 5.9E+00 | 12000 | 6.8E-03 |
| Row SX-107, SX-108, SX-109 | 2046 | 1.9E+01 | 2046 | 0.0E+00 | 2046 | 3.1E+02 | 2046 | 1.9E+02 | 12000 | 6.5E-03 |
| Row SX-113, SX-114, SX-115 | 2046 | 5.1E+00 | 2046 | 2.5E-04 | 2046 | 7.0E+01 | 2046 | 6.4E+01 | 12000 | 3.8E-03 |
| **Hypothetical 8,000-gal retrieval leak** | | | | | | | | | | |
| Row S-101, S-102, S-103 | 2060 | 4.4E-02 | 2060 | 3.4E-02 | 2060 | 7.7E+00 | 2060 | 2.0E+00 | 12000 | 3.5E-07 |
| Row S-104, S-105, S-106 | 2060 | 5.4E-02 | 2060 | 4.2E-02 | 2060 | 1.6E+01 | 2060 | 8.1E-01 | 12000 | 3.0E-07 |
| Row S-107, S-108, S-109 | 2060 | 9.9E-02 | 2060 | 2.3E-01 | 2060 | 2.2E+01 | 2060 | 1.8E+00 | 12000 | 9.1E-07 |
| Row S-110, S-111, S-112 | 2060 | 1.5E-01 | 2060 | 4.6E-02 | 2060 | 2.4E+01 | 2060 | 1.6E+00 | 12000 | 5.2E-06 |
| Row SX-101, SX-102, SX-103 | 2060 | 2.8E-01 | 2060 | 2.4E-02 | 2060 | 2.4E+01 | 2060 | 4.5E+00 | 12000 | 2.7E-06 |
| Row SX-104, SX-105, SX-106 | 2060 | 1.4E-01 | 2060 | 8.1E-02 | 2060 | 2.1E+01 | 2060 | 6.0E+00 | 12000 | 5.1E-06 |
| Row SX-107, SX-108, SX-109 | 2060 | 2.1E-01 | 2060 | 2.3E-02 | 2060 | 1.4E+01 | 2060 | 1.1E+00 | 12000 | 4.1E-07 |
| Row SX-110, SX-111, SX-112 | 2060 | 5.6E-02 | 2060 | 2.2E-02 | 2060 | 4.6E+00 | 2060 | 1.1E+00 | 12000 | 2.9E-08 |
| Row SX-113, SX-114, SX-115 | 2060 | 2.5E-02 | 2060 | 6.5E-03 | 2060 | 2.8E+00 | 2060 | 5.2E-01 | 12000 | 3.0E-07 |

Table 4-5. Simulated Component Peak Fenceline Concentrations (mg/L) and Arrival Times (year) for Nonradionuclide Contaminants of Potential Concern. (2 sheets)

| Tank row | WMA S-SX Fenceline Boundary Concentrations | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Time | Cr peak concentration mg/L | Time | F peak concentration mg/L | Time | Nitrate peak concentration mg/L | Time | Nitrite peak concentration mg/L | Time | Total uranium peak concentration mg/L |
| **Tank residuals - diffusion controlled release** | | | | | | | | | | |
| Row S-101, S-102, S-103 | 4902 | 3.4E-02 | 4902 | 1.1E-04 | 4902 | 2.6E-02 | 4902 | 6.6E-03 | 12000 | 9.6E-07 |
| Row S-104, S-105, S-106 | 4902 | 4.1E-02 | 4902 | 1.5E-03 | 4902 | 5.5E-02 | 4902 | 2.8E-03 | 12000 | 7.7E-07 |
| Row S-107, S-108, S-109 | 4902 | 2.8E-02 | 4902 | 1.4E-02 | 4902 | 1.3E-01 | 4902 | 2.7E-02 | 12000 | 6.3E-07 |
| Row S-110, S-111, S-112 | 4902 | 3.5E-02 | 4902 | 4.0E-04 | 4902 | 8.7E-02 | 4902 | 5.4E-03 | 12000 | 6.2E-07 |
| Row SX-101, SX-102, SX-103 | 4902 | 7.8E-02 | 4902 | 6.4E-04 | 4902 | 9.0E-02 | 4902 | 1.6E-02 | 12000 | 1.0E-06 |
| Row SX-104, SX-105, SX-106 | 4902 | 2.9E-02 | 4902 | 9.1E-04 | 4902 | 7.2E-02 | 4902 | 2.0E-02 | 12000 | 7.3E-07 |
| Row SX-107, SX-108, SX-109 | 4902 | 9.9E-03 | 4902 | 1.1E-03 | 4902 | 3.2E-01 | 4902 | 3.7E-02 | 12000 | 3.8E-07 |
| Row SX-110, SX-111, SX-112 | 4902 | 3.0E-03 | 4902 | 7.1E-05 | 4902 | 1.4E-02 | 4902 | 3.4E-03 | 12000 | 3.9E-07 |
| Row SX-113, SX-114, SX-115 | 4902 | 4.4E-03 | 4902 | 9.9E-04 | 4902 | 9.4E-02 | 4902 | 4.2E-03 | 12000 | 2.7E-07 |

### 4.2.2 Evaluation of Hypothetical Retrieval Leaks

The *Environmental Impact Statement for Retrieval, Treatment, and Disposal of Tank Waste and Closure of Single-Shell Tanks at the Hanford Site, Richland, WA* (DOE/ORP-2003-06) describes in detail the types of retrieval technologies that have been identified for the tank farm WMAs; plans for all of the tanks in WMA S-SX include sluicing. Because sluicing requires the introduction of water into the tank, a waste retrieval leak could potentially occur. Because the tanks contain their entire pre-retrieval inventory at the onset of sluicing, minimizing losses from the tanks during this time is crucial. The results for a hypothetical retrieval leak of 8,000 gal from all tanks in S and SX tank farms is shown in Tables 4-4 and 4-5. Certain rows of tanks in WMA S-SX contain sufficient inventories of $^{99}$Tc, $^{129}$I, chromium, and nitrite to produce peak groundwater concentrations at the fenceline in excess of their respective MCLs. The arrival time for the peak concentration occurs around year 2060, just after installation of the surface barrier. The barrier installation limits the movement of groundwater and the contaminants remain in the vadose zone until the barrier degrades. A second peak arrives after barrier degradation at approximately 1,180 years after the first peak (year 3240), with concentrations below the MCLs for all COPCs and tank rows. Figures 4-6 and 4-7 show the tank row BTCs at the fenceline for SSTs S-110, S-111, and S-112; and SSTs SX-104, SX-105, and SX-106, respectively; these tank rows produce the highest $^{99}$Tc concentrations from each tank farm. No rows contain sufficient inventories of tritium, $^{14}$C, the uranium isotopes, fluoride, nitrate, or total uranium to produce groundwater concentrations at the fenceline in excess of their respective MCLs therefore these COPCs will not be discussed further in this section.

### 4.2.3 Evaluation of Past Leaks

Three rows of tanks (six tanks total) currently possess vadose zone contamination attributable to past leaks from the tanks or their associated ancillary equipment. One row (with one tank identified as a source) is located in S tank farm; two rows (one with two tanks and the other with three tanks identified as sources) are located in SX tank farm. The past leak from SST S-104 results in peak fenceline groundwater concentrations in excess of the MCL for $^{129}$I and nitrite. Other COPCs associated with the past leak from SST S-104 are not expected to produce groundwater concentrations in excess of their respective MCLs. Figure 4-8 shows the tank row BTCs at the fenceline resulting from past leaks for SST S-104.

Past leaks from SSTs SX-107, SX-108, and SX-115 result in peak fenceline groundwater concentrations in excess of the MCL for $^{14}$C; releases from SSTs SX-107, SX-108, and SX-113 result in peak fenceline groundwater concentrations in excess of the MCL for nitrate, and the release from tank SX-108 results in peak fenceline groundwater concentrations in excess of the MCL for tritium. Figure 4-9 shows the tank row BTCs at the fenceline resulting from past leaks for SSTs SX-107, SX-108, and SX-109. The peak concentration of these COPCs occurs around 2060, about 10 years after emplacement of the surface barrier. Similar to waste retrieval leaks, concentrations decrease following the emplacement of a barrier. A second peak arrives approximately 950 years after the first peak (year 3010), with concentrations approximately 5,000 times less than the first peak (tritium has decayed below measurable levels) and below all MCLs.

Figure 4-6. Tank Row S-110, S-111, and S-112 Breakthrough Curves at the WMA S-SX Fenceline for Select Contaminants of Potential Concern Resulting from Hypothetical Retrieval Leaks.

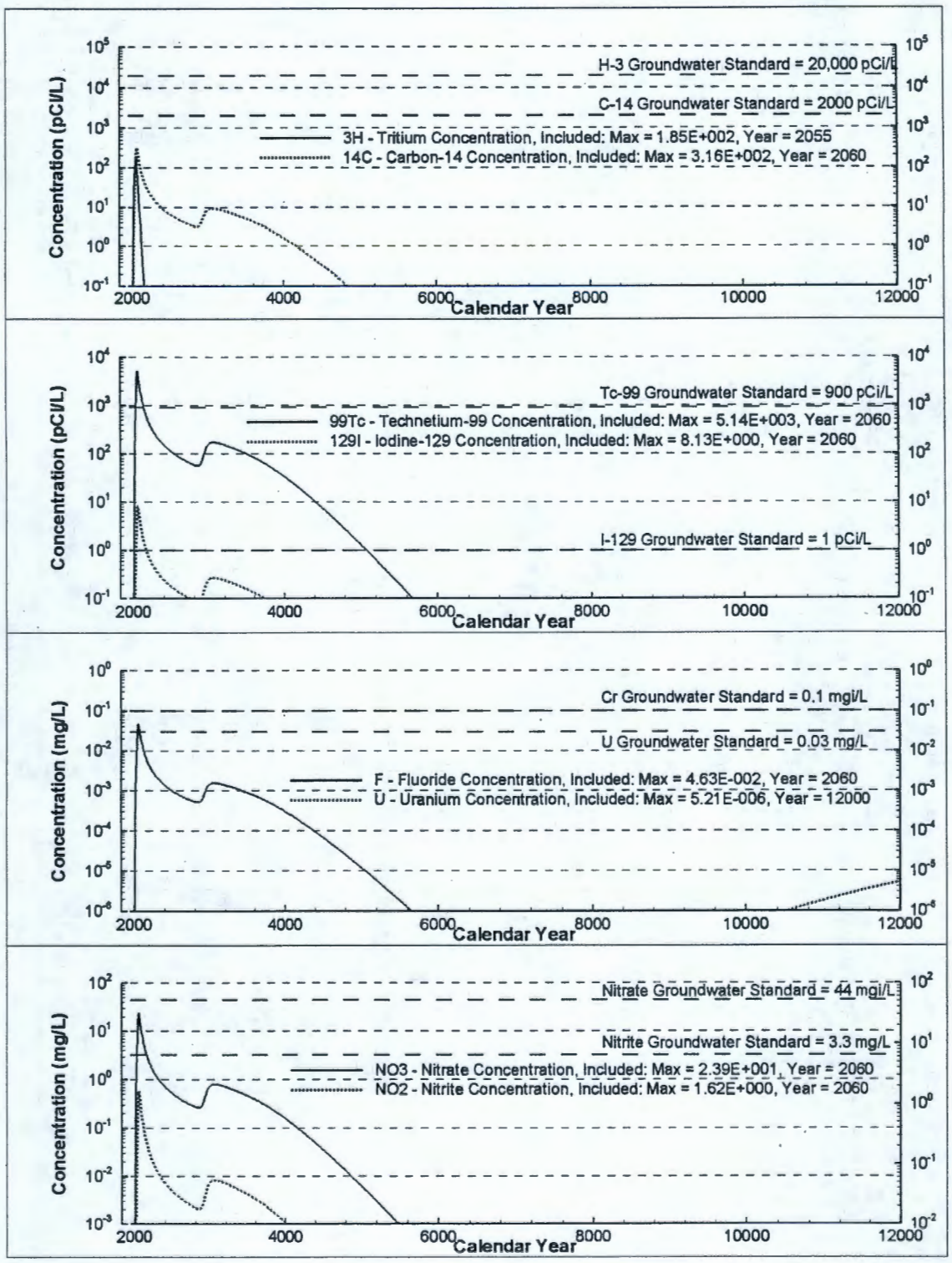


Figure 4-7. Tank Row SX-104, SX-105, and SX-106 Breakthrough Curves at the WMA S-SX Fenceline for Select Contaminants of Potential Concern Resulting from Hypothetical Retrieval Leaks.

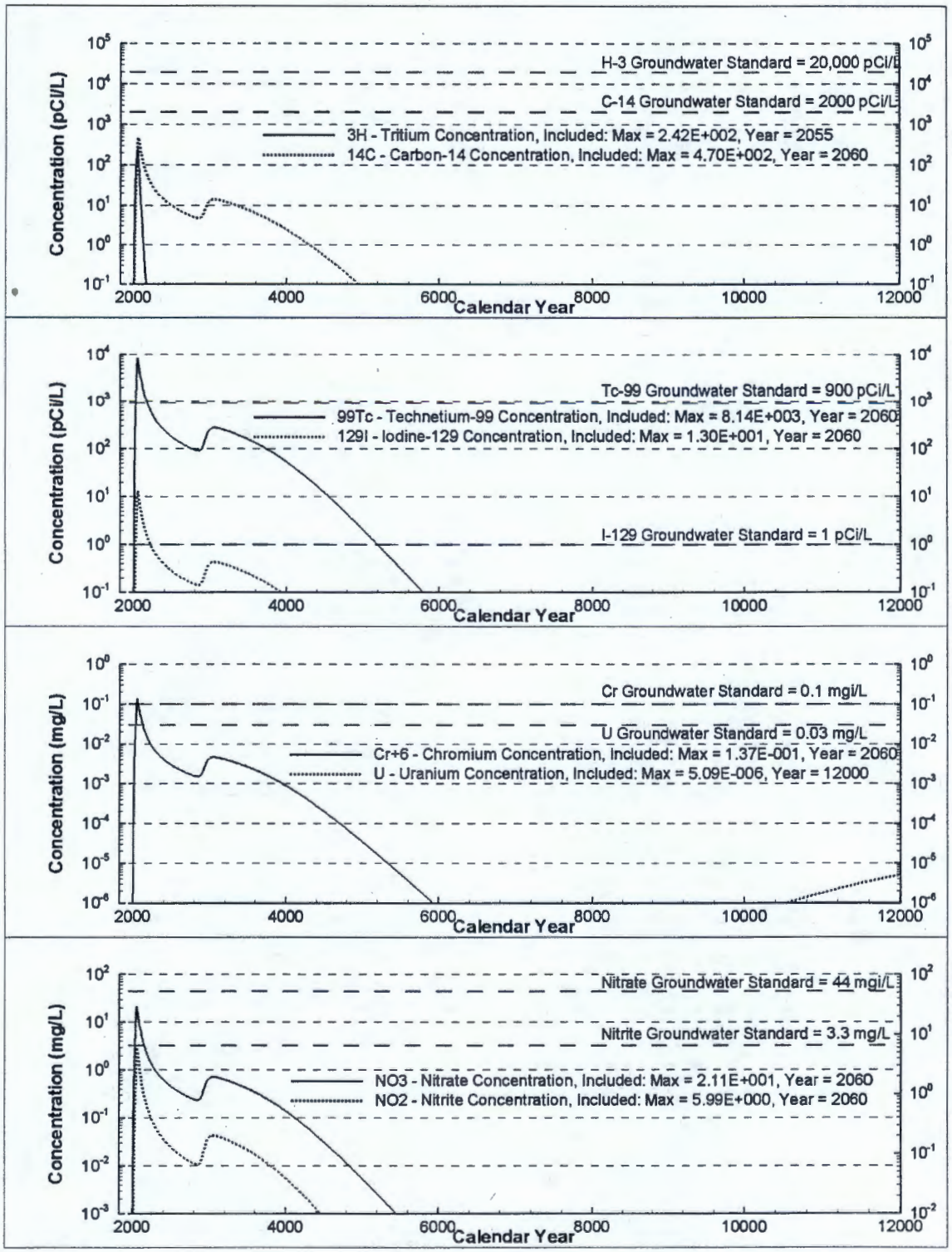


Figure 4-8. Tank Row S-104, S-105, and S-106 Breakthrough Curves at the WMA S-SX Fenceline for Select Contaminants of Potential Concern Resulting from Past Leaks.

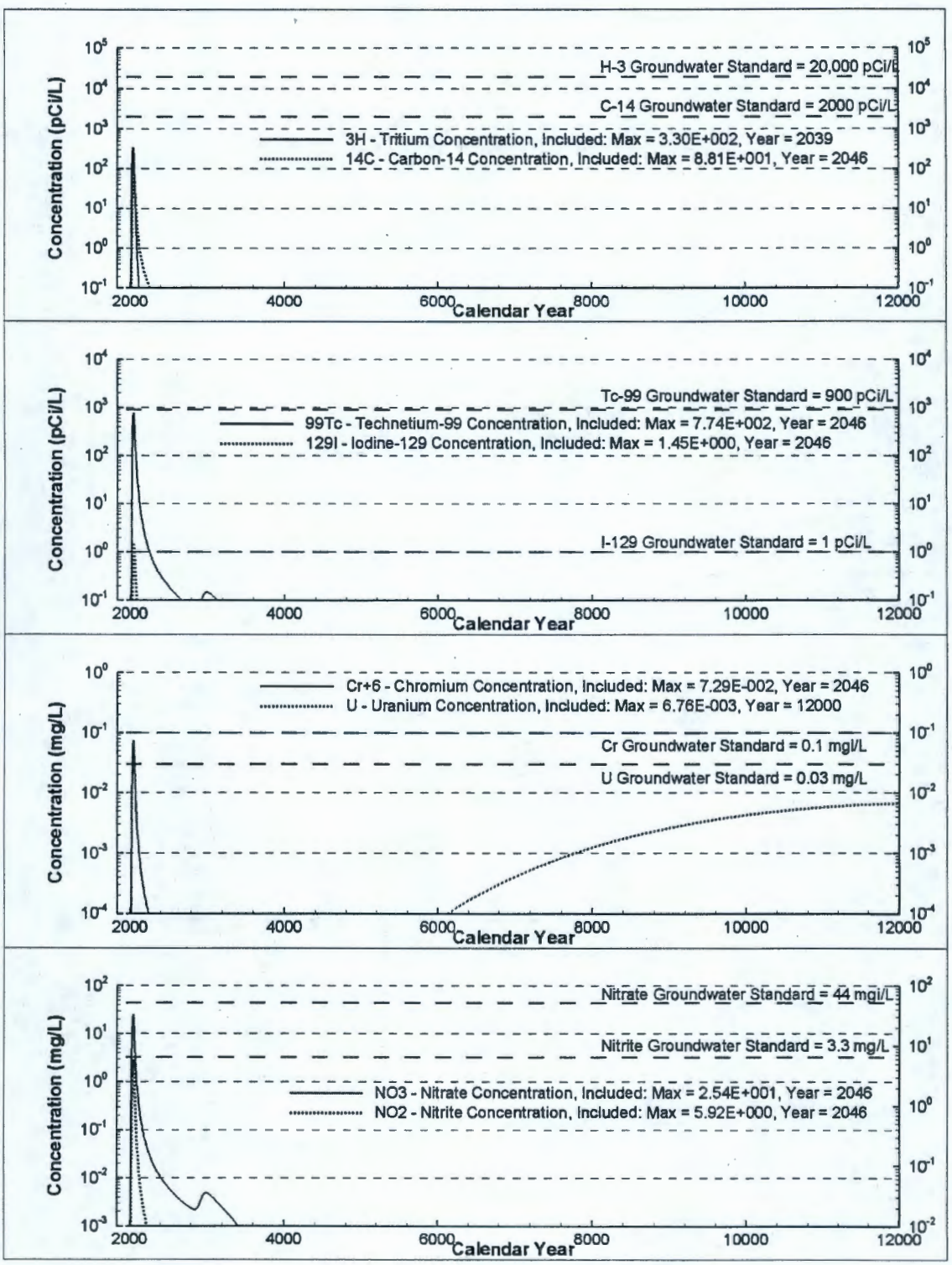
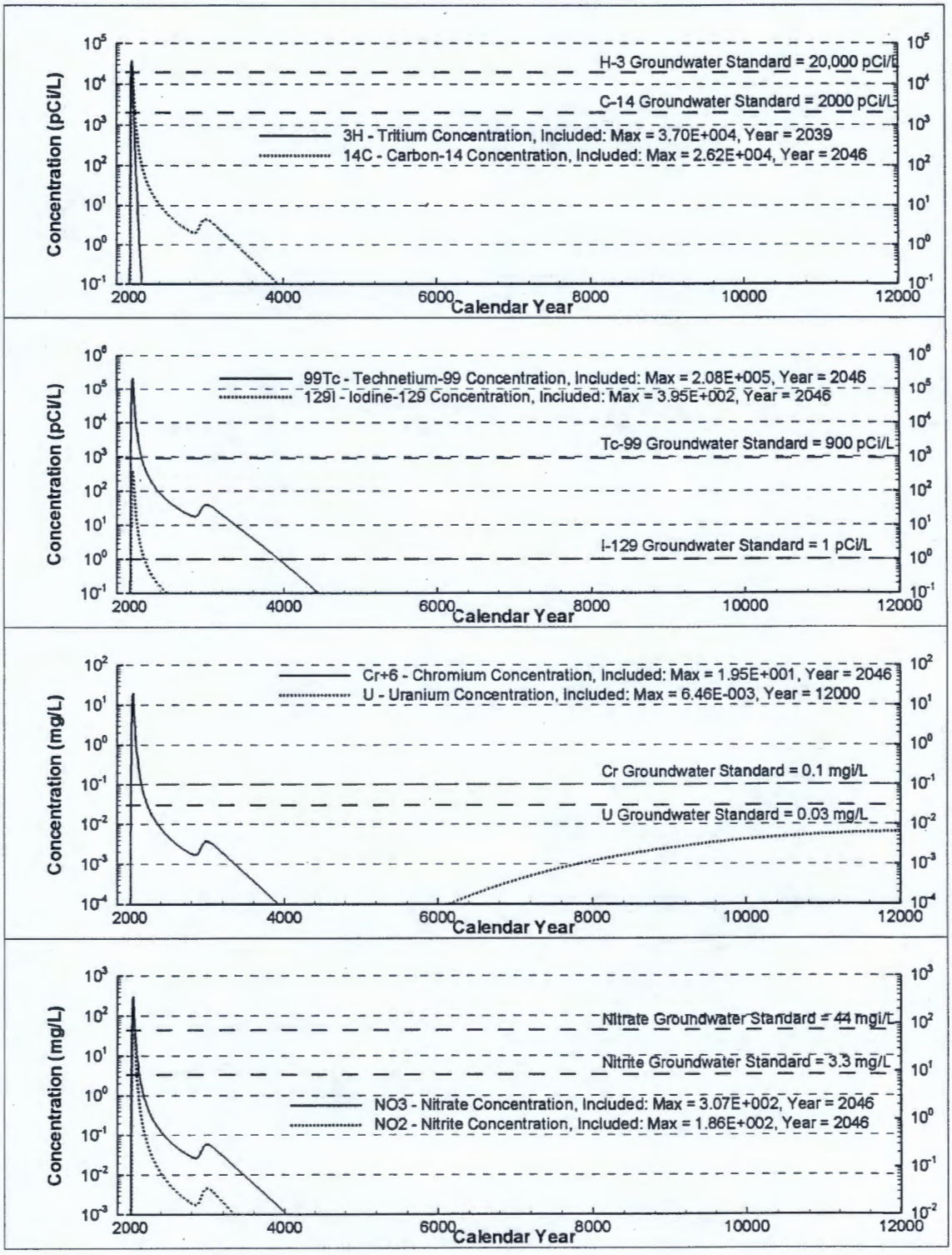


Figure 4-9. Tank Row SX-107, SX-108, and SX-109 Breakthrough Curves at the WMA S-SX Fenceline for Select Contaminants of Potential Concern Resulting from Past Leaks.



### 4.2.4 Evaluation of WMA S-SX Pipe Systems

Detailed inventory data are unavailable for WMA S-SX piping system, and retrieval of waste from the piping system is not yet formally linked to tank waste retrieval and WMA S-SX closure. The WMA S-SX piping system comprises multiple layers of waste transfer piping. New piping was installed within WMA S-SX as older pipes were found to leak, became plugged, or otherwise became unserviceable. Inventory estimates used for the WMA S-SX pipeline system, and the basis for those estimates, are given in Section 3.6.

Peak fenceline groundwater concentrations for the COPCs are below their respective MCLs and are shown in Tables 4-6 and 4-7. Effects on groundwater from the WMA S-SX pipe system are observed approximately 700 years before the residual tank waste impacts groundwater, with the exception of uranium. Uranium concentrations in groundwater peak after 10,000 years.

## 4.3 DOWNGRADIENT GROUNDWATER CONCENTRATIONS

As contaminants from a source move through an aquifer, concentrations are expected to decrease as a result of adsorption, dispersion, and diffusion processes. Contaminant concentrations at locations downgradient from a source were estimated using a 3-D analytical equation developed in Domenico and Schwartz (1990) (i.e., the analytical stream tube solution). Contaminant transport properties required to estimate the concentration of a plume through an aquifer include contaminant-specific $K_d$, soil bulk density, effective porosity, and longitudinal and transverse dispersivity coefficients, which are described in PNNL-14604.

Groundwater concentrations at various points of calculation downgradient from the WMA S-SX fenceline were estimated using the analytical stream tube solution (Domenico and Schwartz 1990). Peak groundwater concentrations and arrival times for each COC predicted by the stream tube model are summarized in Tables 4-8 and 4-9. For each of the source terms, the results indicate that groundwater concentrations for the identified COPCs are not expected to exceed their respective MCL or MCL-derived concentration at the proposed core zone boundary (10.9-km from the WMA S-SX fenceline) or at the Columbia River (32.7 km from the WMA S-SX fenceline).

Table 4-6. Simulated WMA S-SX Piping System Peak Fenceline Concentrations (pCi/L) and Arrival Times (year) for Radionuclide Contaminants of Potential Concern.

| Tank farm | WMA S-SX Fenceline Boundary Concentrations | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Time | $^{99}$Tc peak concentration pCi/L | Time | $^{129}$I peak concentration pCi/L | Time | $^{14}$C peak concentration pCi/L | Time | Tritium peak concentration pCi/L | Time | Maximum U Isotope peak concentration pCi/L |
| S tank farm piping system | 4181 | 3.2E+01 | 4191 | 7.0E-02 | 4181 | 4.6E+00 | 1952 | 2.1E-22 | 12000 | 1.5E-05 |
| SX tank farm piping system | 4181 | 2.3E+01 | 4191 | 4.5E-02 | 4181 | 3.0E+00 | 1952 | 2.1E-22 | 12000 | 1.0E-05 |

Table 4-7. Simulated WMA S-SX Piping System Peak Fenceline Concentrations (mg/L) and Arrival Times (year) for Nonradionuclide Contaminants of Potential Concern.

| Tank row | WMA S-SX Fenceline Boundary Concentrations | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Time | Cr peak concentration mg/L | Time | F peak concentration mg/L | Time | Nitrate peak concentration mg/L | Time | Nitrite peak concentration mg/L | Time | Total uranium peak concentration mg/L |
| S tank farm piping system | 4191 | 1.4E-03 | 4191 | 8.8E-04 | 4191 | 1.1E-01 | 4191 | 1.1E-02 | 12000 | 4.0E-08 |
| SX tank farm piping system | 4191 | 1.4E-03 | 4191 | 1.7E-04 | 4191 | 6.9E-02 | 4191 | 1.5E-02 | 12000 | 2.9E-08 |

Table 4-8. Simulated Component Peak Exclusion Boundary and River Concentrations (pCi/L) and Arrival Times (year) for Select Radionuclide Contaminants of Concern. (2 sheets)

| Tank row | Time | $^{99}$Tc peak concentration pCi/L | Time | $^{129}$I peak concentration pCi/L | Time | $^{14}$C peak concentration pCi/L | Time | Tritium peak concentration pCi/L | Time | Maximum U isotope peak concentration pCi/L |
|---|---|---|---|---|---|---|---|---|---|---|
| **Past Leaks** | | | | | | | | | | |
| *WMA S-SX S exclusion boundary concentrations* | | | | | | | | | | |
| Row S-104, S-105, S-106 | 2323 | 4.8E-02 | 2323 | 9.0E-05 | 2323 | 5.5E-03 | 2323 | 2.4E-09 | 12000 | 5.2E-03 |
| Row SX-107, SX-108, SX-109 | 2323 | 1.3E+01 | 2323 | 2.4E-02 | 2323 | 1.6E+00 | 2323 | 2.7E-07 | 12000 | 4.2E-03 |
| *WMA S-SX river boundary concentrations* | | | | | | | | | | |
| Row S-104, S-105, S-106 | 2406 | 1.5E-02 | 2406 | 2.7E-05 | 2406 | 1.7E-03 | 2406 | 6.9E-12 | 12000 | 1.2E-03 |
| Row SX-107, SX-108, SX-109 | 2406 | 3.9E+00 | 2406 | 7.4E-03 | 2406 | 4.9E-01 | 2406 | 7.7E-10 | 12000 | 9.4E-04 |
| **Hypothetical 8,000-gal retrieval leak** | | | | | | | | | | |
| *WMA S-SX exclusion boundary concentrations* | | | | | | | | | | |
| Row S-110, S-111, S-112 | 2347 | 4.2E-01 | 2347 | 6.7E-04 | 2347 | 2.6E-02 | 2347 | 1.2E-09 | 12000 | 1.1E-07 |
| Row SX-104, SX-105, SX-106 | 2347 | 6.7E-01 | 2347 | 1.1E-03 | 2347 | 3.9E-02 | 2347 | 1.5E-09 | 12000 | 1.1E-07 |
| *WMA S-SX river boundary concentrations* | | | | | | | | | | |
| Row S-110, S-111, S-112 | 2428 | 1.2E-01 | 2428 | 1.9E-04 | 2428 | 7.5E-03 | 2428 | 3.4E-12 | 12000 | 1.5E-08 |
| Row SX-104, SX-105, SX-106 | 2428 | 1.9E-01 | 2428 | 3.1E-04 | 2428 | 1.1E-02 | 2428 | 4.5E-12 | 12000 | 1.4E-08 |
| **Tank residuals - diffusion controlled release** | | | | | | | | | | |
| *WMA S-SX exclusion boundary concentrations* | | | | | | | | | | |
| Row S-104, S-105, S-106 | 5178 | 2.8E-02 | 5178 | 3.7E-06 | 5178 | 7.8E-05 | 5178 | <1E-20 | 12000 | 1.7E-08 |

Table 4-8. Simulated Component Peak Exclusion Boundary and River Concentrations (pCi/L) and Arrival Times (year) for Select Radionuclide Contaminants of Concern. (2 sheets)

| Tank row | Time | $^{99}$Tc peak concentration pCi/L | Time | $^{129}$I peak concentration pCi/L | Time | $^{14}$C peak concentration pCi/L | Time | Tritium peak concentration pCi/L | Time | Maximum U isotope peak concentration pCi/L |
|---|---|---|---|---|---|---|---|---|---|---|
| Row SX-113, SX-114, SX-115 | 5178 | 1.3E-02 | 5178 | 4.8E-06 | 5178 | 6.1E-05 | 5178 | <1E-20 | 12000 | 5.8E-09 |
| *WMA S-SX river boundary concentrations* | | | | | | | | | | |
| Row S-104, S-105, S-106 | 5259 | 7.0E-03 | 5259 | 9.5E-07 | 5259 | 2.0E-05 | 5259 | <1E-20 | 12000 | 1.8E-10 |
| Row SX-113, SX-114, SX-115 | 5259 | 3.2E-03 | 5259 | 1.2E-06 | 5259 | 1.5E-05 | 5259 | <1E-20 | 12000 | 6.5E-11 |

Table 4-9. Simulated Component Peak Exclusion Boundary and River Concentrations (mg/L) and Arrival Times (year) for Nonradionuclide Contaminants of Concern. (2 sheets)

| Tank row | Time | Chromium peak concentration mg/L | Time | Fluorine peak concentration mg/L | Time | Nitrate peak concentration mg/L | Time | Nitrite peak concentration mg/L | Time | Total uranium peak concentration mg/L |
|---|---|---|---|---|---|---|---|---|---|---|
| **Past Leaks** | | | | | | | | | | |
| *WMA S-SX exclusion boundary concentrations* | | | | | | | | | | |
| Row S-104, S-105, S-106 | 2323 | 4.5E-06 | 2323 | 0.0E+00 | 2323 | 1.6E-03 | 2323 | 3.7E-04 | 12000 | 1.1E-05 |
| Row SX-107, SX-108, SX-109 | 2323 | 1.2E-03 | 2323 | 0.0E+00 | 2323 | 1.9E-02 | 2323 | 1.1E-02 | 12000 | 1.1E-05 |
| *WMA S-SX river boundary concentrations* | | | | | | | | | | |
| Row S-104, S-105, S-106 | 2406 | 1.4E-06 | 2406 | 0.0E+00 | 2406 | 4.8E-04 | 2406 | 1.1E-04 | 12000 | 2.5E-06 |
| Row SX-107, SX-108, SX-109 | 2406 | 3.7E-04 | 2406 | 0.0E+00 | 2406 | 5.8E-03 | 2406 | 3.5E-03 | 12000 | 2.4E-06 |

Table 4-9. Simulated Component Peak Exclusion Boundary and River Concentrations (mg/L) and Arrival Times (year) for Nonradionuclide Contaminants of Concern. (2 sheets)

| Tank row | Time | Chromium peak concentration mg/L | Time | Fluorine peak concentration mg/L | Time | Nitrate peak concentration mg/L | Time | Nitrite peak concentration mg/L | Time | Total uranium peak concentration mg/L |
|---|---|---|---|---|---|---|---|---|---|---|
| **Hypothetical 8,000-gal retrieval leak** | | | | | | | | | | |
| *WMA S-SX exclusion boundary concentrations* | | | | | | | | | | |
| Row S-110, S-111, S-112 | 2347 | 1.3E-05 | 2347 | 3.8E-06 | 2347 | 2.0E-03 | 2347 | 1.3E-04 | 12000 | 3.3E-10 |
| Row SX-104, SX-105, SX-106 | 2347 | 2.3E-05 | 2347 | 2.0E-06 | 2347 | 2.0E-03 | 2347 | 3.7E-04 | 12000 | 1.7E-10 |
| *WMA S-SX river boundary concentrations* | | | | | | | | | | |
| Row S-110, S-111, S-112 | 2428 | 3.7E-06 | 2428 | 1.1E-06 | 2428 | 5.7E-04 | 2428 | 3.9E-05 | 12000 | 4.4E-11 |
| Row SX-104, SX-105, SX-106 | 2428 | 6.7E-06 | 2428 | 5.7E-07 | 2428 | 5.6E-04 | 2428 | 1.1E-04 | 12000 | 2.3E-11 |
| **Tank residuals - diffusion controlled release** | | | | | | | | | | |
| *WMA S-SX exclusion boundary concentrations* | | | | | | | | | | |
| Row S-104, S-105, S-106 | 5178 | 6.5E-06 | 5178 | 2.3E-07 | 5178 | 8.6E-06 | 5178 | 4.4E-07 | 12000 | 5.0E-11 |
| Row SX-113, SX-114, SX-115 | 5178 | 4.5E-06 | 5178 | 2.2E-06 | 5178 | 2.0E-05 | 5178 | 4.2E-06 | 12000 | 4.1E-11 |
| *WMA S-SX river boundary concentrations* | | | | | | | | | | |
| Row S-104, S-105, S-106 | 5259 | 1.7E-06 | 5259 | 6.0E-08 | 5259 | 2.2E-06 | 5259 | 1.1E-07 | 12000 | 5.5E-13 |
| Row SX-113, SX-114, SX-115 | 5259 | 1.1E-06 | 5259 | 5.6E-07 | 5259 | 5.1E-06 | 5259 | 1.1E-06 | 12000 | 4.5E-13 |

## 4.4 INPUT PARAMETERS AND SENSITIVITY ANALYSIS

Select input values for system elements were varied to determine the degree of sensitivity in WMA S-SX fenceline groundwater concentration estimates. Sensitivity refers to the relative incremental change in the result of the estimate caused by an incremental change in a given input value for a selected system element. System elements are considered to be sensitive if variations in input values (within the range of realistic possibility) result in substantial variation in the estimated result. System elements that exhibit small changes in results when input values vary over the range of possible inputs are not considered sensitive. Emphasis is placed on testing those elements that retrieval and closure activities and decisions are considered to have the greatest impact on. The following inputs were varied in the sensitivity analysis:

- Post-retrieval waste inventory
- Residual tank waste release models (diffusion-, solubility-, or advection-dominated release)
- Retrieval leak volume (8,000 gal or 4,000 gal)
- $K_d$ of uranium in the vadose zone and aquifer system.

**Post-Retrieval Tank Waste Inventory.** Contaminant inventory in residual tank waste is a highly-sensitive parameter. The reduction or increase in resulting groundwater concentration is a linear function of the reduction or increase in the mass of contaminants remaining in each tank or row of tanks. No specific sensitivity analysis was conducted for post-retrieval tank waste inventory because the results are directly scalable. Tank residual inventories after sluicing retrieval are estimated on the basis of HTWOS modeling completed May 20, 2004. The results may be modified as more information regarding the remaining waste inventories in the tanks becomes available.

**Residual Tank Waste Release Mechanism.** Residual tank waste inventory release mechanisms (advection-dominated, diffusion-dominated, and solubility-limited release models) is also a very sensitive input parameter. The advection dominated (fast) release case represents release from an unstabilized waste form covered with backfill sand and gravel or completely failed grout (RPP-17209). The diffusion release mechanism is considered to be a slow release case. In the diffusion release case, the release duration is much longer than the travel time to groundwater. The diffusion-dominated release case represents a diffusion controlled release process (see RPP-17209 Appendix B for a description of the diffusion-controlled release model) from stabilized, grouted waste for both the residual tank waste and the WMA S-SX piping system. The peak groundwater concentrations of the mobile contaminants (e.g., $^{99}Tc$, $^{129}I$, and chromium) are reduced by a factor of about 4.6 by the diffusion-limited release model when compared to the advection-dominated release model, and the peak groundwater concentrations of the less mobile contaminants (e.g., uranium) are reduced by an approximate factor of 26 (PNNL-14604). These numbers indicate the important function of the final filling material of the tanks, especially with respect to the fenceline concentrations. At the more distant evaluation points, the concentrations

are so far below the MCL values that the added reduction in concentration provided by the filling material and release model becomes less important. The solubility-controlled (fast or slow depending on the solubility of the waste) release model assumed the congruent release of various contaminants with the dissolution of the waste form. As the waste form dissolves, all other constituents within the tank are released proportionately. The solubility of the waste form was assumed to be 650 g/L in the tank solution, comparable to the dissolution of a nitrate salt in water, which is a rapid dissolution rate (see RPP-17209 Appendix B for a description of the solubility-controlled release model). The peak groundwater solubility-controlled releases are essentially the same as the concentrations resulting from the advection-dominated release model, which is a consequence of the high solubility rate used for the waste. Currently, the actual solubility of the post-sluicing waste is unknown and represents a major uncertainty of the solubility-controlled release model. The highly soluble portion of the saltcake is expected to dissolve and be removed during sluicing, leaving only the more insoluble solids in the tanks. Results are likely to vary depending on the actual solubility and release rates. The results may be modified as more information regarding the remaining waste solubility in the tanks becomes available.

**Contaminant Distribution Coefficients**. Peak groundwater concentrations are highly sensitive to the assignment of $K_d$ values to the contaminants. As the contaminants move through the vadose zone or the aquifer, the concentration in the aqueous phase decreases because of adsorption, dispersion, and diffusion processes, as well as environmental and radioactive decay. The $K_d$ is a measure of the characteristic adsorption of the contaminant from the aqueous phase to the geologic materials through which it is moving. The movement of contaminants with a higher $K_d$ value is more highly retarded than contaminants with a lower $K_d$ value. As contaminants sorb to the vadose zone geologic materials, less contamination reaches the water table resulting in lower groundwater concentrations and later arrival times of the peak concentration. Most COCs are highly mobile and exhibit $K_d$ values near zero for the geologic formations in WMA S-SX, meaning that none of the contaminant adsorbs to the soil. Any adsorption of these contaminants that may (in reality) occur would reduce the maximum groundwater concentration. Uranium exhibits some characteristic adsorption and was modeled with a $K_d$ value equal to 0.6 mL/g; PNNL-13895 indicates that the $K_d$ value tends to range between 0.2 and 4.0 mL/g, with the lower value more typical in low and high pH environments.

To evaluate the effect that $K_d$ assignment has on the peak concentration and arrival time, results of the individual base case components for tank row SX-107, SX-108, and SX-109 with the uranium $K_d$ = 0 mL/g, 0.1 mL/g, 0.3 mL/g, and 0.6 mL/g were compared. The peak uranium concentration resulting from past leaks increases from 6.5E-03 mg/L to 1.3E-02 mg/L to 4.8E-02 mg/L to 1.9E+00 mg/L when the $K_d$ decreases from 0.6 mL/g to 0.3 mL/g to 0.1 mL/g to 0.0 mL/g (Table 4-10). The difference between the peak concentration when the $K_d$ = 0 mL/g and the $K_d$ = 0.1 mL/g is almost a factor of 40, so a small change in $K_d$ from zero produces a very large change in the resulting peak concentration. Similar results occur when the $K_d$ for uranium is varied for the hypothetical retrieval leaks; the difference between the peak concentration when the $K_d$ = 0 mL/g and the $K_d$ = 0.1 mL/g is about a factor of 30. There is much less change in the concentration results when the source is the tank residuals with the diffusion release mechanism. The difference between the peak concentration when the $K_d$ = 0 mL/g and the $K_d$ = 0.1 mL/g for that source and release case is less than a factor of 2.

Comparing the $K_d = 0$ mL/g concentration values to the $K_d = 0.6$ mL/g concentration values shown in Table 4-10 indicates that all of these concentrations represent at least a two order of magnitude increase from the same cases when a $K_d = 0.6$ mL/g is applied to uranium. That uranium adsorbs to soils in the tank farms has been observed during several investigative efforts, and the pH of the soil away from the immediate vicinity of the tanks is typically close to neutral, so the $K_d = 0.6$ mL/g value appears to be consistent with available information. It is important to note that constituents with a $K_d$ of $\geq 0.30$ mL/g continue to increase after the 10,000-year simulation period, and that constituents with a Kd of $\geq 1.0$ mL/g do not arrive at the WMA S-SX fenceline within the 10,000-year simulation period.

Table 4-10. Simulated Uranium Metal Fenceline Concentrations[a] (mg/L) and Arrival Times (year) for Different $K_d$ Values.

| Tank row SX-107, SX-108, and SX-109 waste component | WMA S-SX Fenceline Boundary Concentrations | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | $K_d$ = 0 mL/g | | $K_d$ = 0.1 mL/g | | $K_d$ = 0.3 mL/g | | $K_d$ = 0.6 mL/g | |
| | Time | Total uranium peak concentration mg/L | Time | Total uranium peak concentration mg/L | Time | Total uranium peak concentration mg/L | Time | Total uranium peak concentration mg/L |
| Past unplanned releases | 2046 | 1.9E+00 | 2092 | 4.8E-02 | 7251 | 1.3E-02 | 12000 | 6.5E-03 |
| Retrieval leaks | 2060 | 9.9E-04 | 5451 | 3.1E-05 | 11524 | 1.5E-05 | 12000 | 4.1E-07 |
| Tank residuals - diffusion controlled release | 4902 | 9.4E-03 | 9171 | 6.0E-03 | 12000 | 9.0E-04 | 12000 | 3.8E-07 |

# 5.0 CONCEPTUAL EXPOSURE MODEL AND DESCRIPTION OF EXPOSURE SCENARIOS

This section describes the exposure scenarios considered in this risk evaluation. Exposure scenarios considered in this risk assessment are described in detail in HNF-SD-WM-TI-707. The exposure scenarios selected for this evaluation have been used in previous performance and risk assessment activities performed at the Hanford Site and have been extensively reviewed by the Hanford Site regulatory agencies. Quantitative risk and dose estimates for selected exposure scenarios are presented in Section 6.0 using the modeled groundwater concentrations presented in Section 4.0.

## 5.1 SUMMARY OF EXPOSURE SCENARIOS

For the purpose of this risk evaluation, exposure scenarios were selected as a function of the presence or absence of water infiltration and receptor location relative to the WMA. A summary of the exposure pathways evaluated for the standard risk assessment scenarios and the HSRAM and MTCA scenarios are provided in Tables 5-1 and 5-2, respectively.

### 5.1.1 Onsite Exposure Scenarios

The following describes the activities of each onsite receptor (i.e., someone living directly on top of the WMA S-SX and could potentially intrude into the closed facility) and primary exposure pathways considered for each exposure scenario. The evaluation of the onsite scenarios is not considered in this document. The onsite exposure scenario is evaluated in the Tank Waste Retrieval Work Plan, the data report following retrieval, and as part of the system performance assessment due out in 2005. Only a description of the onsite exposure scenarios is provided in this document. The exposure pathways for the post-intrusion scenarios are given in Table 5-1. The primary exposure pathways for the post-intrusion resident scenario includes direct external radiation while working in garden, incidental soil ingestion, ingestion of garden produce, ingestion of well water, dermal contact with soil, and inhalation of vapors and fugitive dust.

**5.1.1.1 Driller Intruder Scenario.** This receptor is primarily exposed to radiological and nonradiological contaminants in exhumed waste while drilling a well through WMA S-SX. The primary exposure pathways include direct external radiation, incidental ingestion, dermal contact, and inhalation of vapors and fugitive dust. This is considered an acute exposure because the driller is in contact with the waste for a relatively short period of time.

**5.1.1.2 Post-Intrusion Resident Scenario.** This receptor is primarily exposed to radiological and nonradiological contaminants from exhumed waste. For this exposure scenario, the drill cuttings are distributed onto land that will be used for food consumption or gardening. This is known as the chronic exposure scenario because the post-intruder resident is exposed over a number of years. Given the present land-use around the Hanford Site, there are three post-intrusion resident scenarios:

1. **Post-Intrusion Suburban Garden:** Assumes that an individual lives near the drill cuttings and manages to spread the drill cuttings in his garden. The individual obtains one-fourth his/her fruit and vegetables (but not grain) in his/her garden.

2. **Post-Intrusion Rural Pasture:** Assumes that an individual lives near the drill cuttings and spreads the well water and tailings in his pasture and hay field. The individual obtains half of his annual intake of milk from the cow.

3. **Post-Intrusion Commercial Farm:** Assumes that an individual lives near the drill cuttings and spreads the well water and tailings in field used for growing a food crop for market.

Table 5-1. Exposure Pathway Summary for Standard Risk Assessment Scenarios. (2 sheets)

| ←Media | Exposure scenarios → | Standard risk assessment exposure scenarios | | | | | |
|---|---|---|---|---|---|---|---|
| | | Waste intruders | | | | All-Pathways farmer | Native American |
| | Exposure pathways ↓ | Driller | Suburban garden | Rural pasture | Commercial farm | | |
| Water | Ingestion | | | | | • | • |
| | Vapor inhalation | | | | | • | • |
| | Shower, dermal | | | | | • | • |
| | Swimming, dermal | | | | | | |
| | Sweat Lodge, inhalation | | | | | | • |
| Soil | Ingestion | • | • | • | • | • | • |
| | Inhalation | • | • | • | • | • | • |
| | Dermal contact | | | | | • | • |
| | External radiation dose | • | • | • | • | • | • |
| | Tritium vapor inhalation | | • | | | • | • |

Table 5-1. Exposure Pathway Summary for Standard Risk Assessment Scenarios. (2 sheets)

| ←Media | Exposure scenarios → | Standard risk assessment exposure scenarios | | | | | |
|---|---|---|---|---|---|---|---|
| | | Waste intruders | | | | All-Pathways farmer | Native American |
| | Exposure pathways ↓ | Driller | Suburban garden | Rural pasture | Commercial farm | | |
| Food Chain | Garden produce | | • | | | • | • |
| | Grains | | | | | | |
| | Beef & Milk | | | Milk only | | • | • |
| | Poultry & Egg | | | | | • | • |
| | Fish | | | | | | |
| | Wild game | | | | | | |

Notes:

The annual total effective dose equivalent (in mrem) is calculated for all of the exposure scenarios shown on this table. Radiological dose is the only risk metric used for the waste intruders. The other exposure scenarios (All Pathways and Native American) also include incremental lifetime cancer risk from a lifetime exposure to both radionuclides and chemicals, and hazard index for nonradioactive chemicals.

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Table 5-2. Exposure Pathway Summary for HSRAM and MTCA Scenarios. (2 sheets)

| ←Media | Exposure scenarios → | HSRAM | | | | WAC 173-340 |
|---|---|---|---|---|---|---|
| | Exposure pathways↓ | Industrial | Recreational | Residential | Agricultural | Ground-water |
| Water | Ingestion | • | • | • | • | • |
| | Vapor inhalation | • | • | • | • | |
| | Shower, dermal | • | • | • | • | |
| | Swimming, dermal | | | | | |
| | Sweat Lodge, inhalation | | | | | |
| Soil | Ingestion | • | • | • | • | |
| | Inhalation | • | • | • | • | |
| | Dermal contact | • | • | • | • | |
| | External radiation dose | • | • | • | • | |
| | Tritium vapor inhalation | • | • | • | • | |

Table 5-2. Exposure Pathway Summary for HSRAM and MTCA Scenarios. (2 sheets)

| ←Media | Exposure scenarios → / Exposure pathways↓ | HSRAM | | | | WAC 173-340 |
|---|---|---|---|---|---|---|
| | | Industrial | Recreational | Residential | Agricultural | Ground-water |
| Food Chain | Garden produce | | | • | • | |
| | Grains | | | | | |
| | Beef & Milk | | | | • | |
| | Poultry & Egg | | | | | |
| | Fish | | | | | |
| | Wild game | | | | | |

Notes:

The annual total effective dose equivalent (in mrem) is not calculated for the exposure scenarios shown on this table. The risk quantifiers for these scenarios are incremental lifetime cancer risk from a lifetime exposure to both radionuclides and chemicals, and hazard index for nonradioactive chemicals.

HSRAM = Hanford Site Risk Assessment Methodology.

MTCA = "Model Toxic Control Act."

### 5.1.2 Offsite Exposure Scenarios

For the evaluation of offsite exposures (outside the boundaries of the WMA), it is assumed that an engineered cover, or cap, is placed over the entire WMA at the time of facility closure. The engineered cover is assumed to retain its effectiveness in controlling infiltration for 500 years, after which infiltration control will degrade. The contribution of contaminants from each source term (past leaks, residual tank waste, hypothetical retrieval leaks, and the pipe system) was evaluated separately because each source term is expected to have a different release mechanism.

The following assumptions are made for each offsite exposure scenario:

- Limited water infiltrates the site
- The receptor is located 100 m downstream of the WMA
- The receptor can enter the WMA anytime after site closure[3]
- Each scenario evaluates well water as a potable water source
- Onsite surface contamination is transported by wind to offsite locations.

[3] Site closure is assumed to happen in 150 years. This assumes that DOE maintains its presence within the core zone for 50 years and institutional controls will be in place for 100 years.

Four offsite exposure scenarios are considered and include:

- All pathways farmer scenario
- Native American scenario
- HSRAM industrial scenario
- HSRAM residential scenario.

The HSRAM recreational and HSRAM agricultural exposure scenarios are not presented in this risk evaluation. The exposure pathways evaluated for the HSRAM recreational scenario are the same as those evaluated for the HSRAM industrial scenario; higher intake rates are considered for the HSRAM industrial receptor, therefore it is considered protective of the HSRAM recreational receptor. The exposure pathways evaluated for the HSRAM agricultural scenario are the same as those evaluated for the all pathways farmer exposure scenario; higher intake rates are considered for the all pathways farmer receptor, therefore it is considered protective of the HSRAM agricultural receptor. The following describes the activities of each receptor and primary exposure pathways considered for each exposure scenario. With the exception of the HSRAM industrial worker scenario, each exposure scenario evaluates the potable water source as a groundwater well downstream from WMA S-SX.

A diagrammatic figure presenting the conceptual exposure model for the HSRAM industrial and residential scenarios and the all pathways farmer and Native American subsistence scenarios is provided in Figure 5-1. The conceptual exposure model describes the sources of contamination, the primary transport mechanisms, exposure points, and exposure routes for each of the receptors evaluated (e.g., industrial worker, resident, all pathways farmer, and Native American). A brief description of each of the exposure scenarios is provided below.

**5.1.2.1 All Pathways Farmer Scenario.** This receptor is primarily exposed to radiological and nonradiological contaminants from well water, soil, and the food chain. The primary exposure pathways for the all pathways farmer includes direct contact with water (ingestion and dermal contact) and inhalation of vapors from showering and other household activities; direct contact with soil (external radiation, incidental ingestion, and dermal contact), inhalation of vapors (including tritium) and fugitive dust; and food chain exposure from ingestion of garden produce, beef, milk, poultry, and eggs.

**5.1.2.2 HSRAM Industrial Worker Scenario.** This receptor is primarily exposed to radiological and nonradiological contaminants from groundwater and soil. The primary exposure pathways for the HSRAM industrial worker scenario includes direct contact with groundwater (ingestion and dermal contact) and inhalation of vapors from showering and direct contact with soil (external radiation, incidental ingestion, and dermal contact), inhalation of vapors, fugitive dust, and tritium vapors.

**5.1.2.3 HSRAM Residential Scenario.** This receptor is primarily exposed to radiological and nonradiological contaminants from well water, soil, and the food chain. The primary exposure pathways for the HSRAM residential scenario includes direct contact with water (ingestion and dermal contact) and inhalation of vapors from showering; direct contact with soil (external radiation, incidental ingestion, and dermal contact), inhalation of vapors (including tritium) and fugitive dust; and food chain exposure from ingestion of garden produce.

**5.1.2.4 Native American Scenario.** This receptor is primarily exposed to radiological and nonradiological contaminants from well water, soil, and the food chain. The primary exposure pathways for the Native American includes direct contact with water (ingestion and dermal contact), inhalation of vapors from showering and other household activities, and inhalation of vapors while in a sweat lodge; direct contact with soil (external radiation, incidental ingestion, and dermal contact), inhalation of vapors (including tritium) and fugitive dust; and food chain exposure from ingestion of garden produce, beef, milk, poultry, and eggs. The results for this exposure scenario are provided for informational purposes only in Appendix A.

## 5.2 POINTS OF CALCULATION

Risk and dose estimates are calculated for modeled groundwater concentrations at select distances downgradient from the WMA S-SX fenceline (i.e., calculation points). Groundwater beneath WMA S-SX is assumed to take a pre-Hanford flow direction that is generally east from the site toward the Columbia River. The following calculation points were selected for the risk evaluation:

- The downgradient WMA S-SX fenceline.
- The proposed core zone boundary surrounding the 200 Areas. At this time, the boundary is not completely defined and is subject to negotiation in terms of its actual location as well as the applicability to select groundwater performance objectives. The boundary location selected for this preliminary analysis is 10.9 km along the stream tube emanating from WMA S-SX.
- At a groundwater well/spring just before the groundwater enters the Columbia River. This location is located 32.7 km along a stream tube emanating from WMA S-SX.

To determine groundwater concentrations at calculation points beyond the WMA S-SX fenceline, an analytical model was applied to the results of the numerical simulations at the WMA S-SX fenceline. These results were used to estimate the reduction in concentration with increasing distance downgradient from WMA S-SX. The estimated downgradient concentrations were then used to calculate risk and dose estimates for each exposure scenario.

1

2

3

| Past or Current Sources of Contamination | eptors | | |
|---|---|---|---|
| | Future Hypothetical HSKAM Resident | Future All Pathways Farmer | Future Native American |
| | C | C | C |
| | C | C | C |
| | N | C | C |
| Past Leaks and Ancillary Equipment from Single-Shell Tanks | N | C | C |
| Residual Waste in Tanks and Ancillary Equipment | C | C | C |
| | C | C | C |
| Potential Retrieval Leaks | C | C | C |
| | C | C | C |
| | C | C | C |
| | C | C | C |

C = Potentially complete pati
N = Incomplete pathway

1. Offsite wells can include d
2. The dermal contact route

# 6.0 WMA S-SX RISK AND DOSE ESTIMATE RESULTS

This section presents the performance objectives (the dose and ILCR thresholds) and the dose and risk estimates for each exposure scenario considered. Risk and dose to offsite receptors were estimated using several different exposure scenarios. Each scenario estimates potential human health impacts from exposure to radiological and nonradiological COPCs at WMA S-SX. The resulting risk and dose estimates are then compared to appropriate performance objectives.

BTCs from each source were developed for COPCs in groundwater and are presented in Section 4.0. The COPC selection process was described in Section 3.5; COPCs that were selected are those considered highly mobile in the vadose zone and are likely to reach the groundwater table. Dose and risk estimates for each waste source and exposure scenario were calculated by multiplying the peak groundwater concentration by the appropriate dose, risk, or HQ conversion factor. A description of the methodology for deriving the conversion factors in addition to a summary of the values is provided in HNF-SD-WM-TI-707.

Radiological dose (in mrem/yr) in terms of effective dose equivalents (EDE) is presented for the all pathways farmer. ILCR is presented for the HSRAM industrial and residential scenarios for radiological constituents and nonradiological constituents. HI results are presented for the HSRAM industrial and residential scenarios for nonradiological constituents only. The Native American subsistence scenario is given for informational purposes in Appendix A.

Groundwater concentrations are also compared to the national primary drinking water standards, as codified in 40 CFR 141.

## 6.1 PERFORMANCE OBJECTIVES

For each exposure scenario considered, ILCR and HI were calculated for evaluating potential carcinogenic and noncarcinogenic health effects from exposure to radiological and nonradiological constituents. Dose (mrem/yr) estimates were calculated for evaluating potential health effects from exposure to radiological constituents for only the all pathways farmer.

For the purposes of this risk evaluation, the potential for unacceptable human health risk is identified using the following risk and dose thresholds:

- If the multi-chemical aggregate risk for nonradiological constituents exceeds an ILCR of $1 \times 10^{-5}$; or a noncancer HI of 1 (WAC 173-340-745) for industrial land use, or if any individual radiological or nonradiological constituents exceeds and ILCR of $1 \times 10^{-5}$, then the major risk-contributing chemicals will be identified as COCs.

- If the multi-chemical aggregate risk for nonradiological constituents exceeds an ILCR of $1 \times 10^{-6}$; or a noncancer HI of 1 (WAC 173-340-740) for unrestricted land use, or if any individual radiological or nonradiological constituents exceeds and ILCR of $1 \times 10^{-6}$, then the major risk-contributing chemicals will be identified as COCs.

- If the multi-chemical aggregate risk for nonradiological constituents is outside the EPA ILCR risk range of $1 \times 10^{-4}$ to $1 \times 10^{-6}$ or a noncancer HI of 1 (EPA 1991, *Role of the Baseline Risk Assessment in Superfund Remedy Selection Decisions*), the major risk-contributing chemicals will be identified as COCs.

- If the dose from radiological constituents to representative members of the public exceeds 25 mrem/yr total EDE from all exposure pathways (DOE G 435.1-1, *Implementation Guide for use with DOE M 435.1-1*), then the major dose contributing constituents will be identified as COCs.

- If the dose from radiological constituents to representative members of the public exceeds 15 mrem/yr total EDE from all exposure pathways (OSWER Directive 9200-4.18), then the major dose contributing constituents will be identified as COCs.

- If groundwater concentrations for alpha emitters, $^{226}$Ra plus $^{228}$Ra exceeds 5 pCi/L or 15 pCi/L for all others (excluding uranium) (40 CFR 141.66), then the radiological constituent will be identified as a COC.

- If groundwater concentrations for beta and photon emitters exceed 4 mrem/yr total body or organ dose (40 CFR 141.66), then the major dose contributing constituents will be identified as a COC.

## 6.2 RISK AND DOSE ESTIMATES FOR WMA S-SX

The results of the HSRAM industrial and residential exposure scenarios and the all pathways farmer at the WMA S-SX fenceline are discussed below for each source term. The results of the Native American subsistence scenario are provided separately in Appendix A. The following briefly describes the assumptions used to conduct the risk evaluation.

For past leaks, the base simulation case (Case 9) evaluates the impacts on groundwater from COPCs currently in the vadose zone at a depth of approximately 39.5 m (130 ft) bgs. For WMA S, one confirmed leak has occurred at SST S-104. Peak groundwater concentrations were obtained from SST S-104 inventory. For SX tank farm, five confirmed leaks have occurred at SSTs SX-107, SX-108, SX-109, SX-113, and SX-115. Peak groundwater concentrations were obtained from tank row SX-107 through SX-109, which reported the highest inventory and constituent concentrations.

For residual tank waste, the base simulation case (Case 5) evaluates the impacts on groundwater from COPCs in residual waste. For all tanks except SSTs S-107, SX-107, SX-108, SX-113, and SX-115 (sludge-filled), the post-retrieval waste volume was estimated using HTWOS (saltcake tanks). The post-retrieval waste volume for SSTs S-107, SX-107, SX-108, SX-113, and SX-115 was estimated using SPR. Case 5 represents a diffusion-controlled release based on the assumption that the waste diffuses through a monolithic waste form (e.g., cement grout). For S tank farm, peak groundwater concentrations were obtained from tank row S-104 through S-106, which reported the highest inventory and constituent concentrations. For SX tank farm, peak groundwater concentrations were obtained from tank rows SX-113 through SX-115

(radiological) and SX-101 through SX-103 (nonradiological), which reported the highest inventory and constituent concentrations.

For potential retrieval leaks, the base simulation case (Case 2) evaluates the impacts on groundwater from COPCs when high-volume water systems are used to retrieve waste (e.g., high-volume sluicing) in tanks with poor structural integrity. This case assumes that an 8,000-gal leak occurs over a period of 14 days. For S tank farm, peak groundwater concentrations were obtained from tank row S-104 through S-106, which reported the highest inventory and constituent concentrations. For SX tank farm, peak groundwater concentrations were obtained from tank rows SX-104 through SX-106 (radiological) and SX-101 through SX-103 (nonradiological), which reported the highest inventory and constituent concentrations.

For the pipe system, the base simulation case (Case 7) evaluates the impacts on groundwater from COPCs in residual waste remaining in the waste transfer piping components. The ancillary piping components were assigned a value of 301 $ft^3$ of volume in S tank farm and 230 $ft^3$ in the SX tank farm based on an arbitrary 25% blockage in 20,000 linear feet of 3-in.-diameter piping. The constituents in the residual ancillary equipment are assumed to release from the pipelines through a diffusion-controlled process. Estimated peak groundwater concentrations were assumed to be the same as the average composition as that projected to be in the tanks by the BBI numbers for that tank farm.

As described in Section 4.0, impacts to groundwater from each source term except the pipe system were evaluated on a tank row by tank row basis. Groundwater flow is assumed to occur in a west to east direction; similarly tank rows are oriented in a west to east direction. It was assumed that commingling of plumes between tank rows does not occur because the results of the 3-D simulation predicted that 99% of the contaminants remained within the 20 m (Section 3.0) on either side of the plume centerline. Peak groundwater concentrations at the fenceline for past tank leaks, residual tank waste, and potential retrieval leaks were selected based on the above assumptions.

### 6.2.1 Risk Estimates for the HSRAM Industrial Scenario

This section provides the risk estimates for the HSRAM industrial exposures scenario at S tank farm and SX tank farm. Risk estimates are provided only for the year that the peak groundwater concentration occurs. Each type of source (residual waste, past tank leaks, hypothetical retrieval leaks and pipeline residuals) is discussed. Summary tables showing radiological ILCR, nonradiological ILCR and the HI, primary COPCs contributing to the risk estimate, and the primary exposure pathway for each source term follow the tank farm discussion.

#### 6.2.1.1 S Tank Farm.

**Past Leaks**. A summary of radiological risk estimates from past leaks is provided in Table 6-1. The radiological ILCR from both soil and water at year 2046 is $1.5 \times 10^{-5}$. The primary contributor to ILCR includes $^{99}Tc$ ($1.1 \times 10^{-5}$, 72% contribution). The ILCR reported for past leaks is within the EPA risk range of $1 \times 10^{-4}$ to $1 \times 10^{-6}$.

A summary of the nonradiological risk estimates and HIs are provided in Tables 6-2 and 6-3, respectively. The nonradiological ILCR from soil at year 2046 is $1.6 \times 10^{-6}$. The ILCR reported for past leaks is within the EPA risk range of $1 \times 10^{-4}$ to $1 \times 10^{-6}$ and does not exceed the threshold value of $1 \times 10^{-5}$ recommended in WAC 173-340-745 for industrial land use. The HI reported from soil and water exposure pathways is 1.1, which is slightly greater than the EPA and WAC recommended threshold value of 1. However, all constituents were reported with an HQ less than 1.0.

**Residual Tank Waste**. A summary of radiological risk estimates from residual tank waste is provided in Table 6-1. The radiological ILCR from both soil and water at year 4902 is $2.3 \times 10^{-6}$. The ILCR reported for residual tank waste is within the EPA risk range of $1 \times 10^{-4}$ to $1 \times 10^{-6}$.

A summary of the nonradiological risk estimates and HIs are provided in Tables 6-2 and 6-3, respectively. The nonradiological ILCR from soil at year 4092 is $6.1 \times 10^{-7}$. The ILCR reported for residual tank waste is less than the EPA lower risk threshold of $1 \times 10^{-6}$ and is less than the threshold value of $1 \times 10^{-5}$ recommended in WAC 173-340-745 for industrial land use. The HI reported from the water and soil exposure pathways is 0.17, which is less than the EPA and WAC recommended threshold value of 1.

**Potential Retrieval Leaks**. A summary of radiological risk estimates from potential retrieval leaks is provided in Table 6-1. The radiological ILCR from both soil and water at year 2060 is $8.0 \times 10^{-5}$. The primary contributor to the ILCR is $^{99}Tc$ ($7.1 \times 10^{-5}$; 89% contribution). The ILCR reported for potential retrieval leaks is within the EPA risk range of $1 \times 10^{-4}$ to $1 \times 10^{-6}$.

A summary of the nonradiological risk estimates and HIs are provided in Tables 6-2 and 6-3, respectively. The nonradiological ILCR from soil at year 2060 is $2.3 \times 10^{-6}$. The ILCR reported for potential retrieval leaks is within the EPA risk range of $1 \times 10^{-4}$ to $1 \times 10^{-6}$ and is less than the threshold value of $1 \times 10^{-5}$ recommended in WAC 173-340 for the industrial exposure scenario. The HI reported from the water and soil exposure pathways is 0.91, which is less than the EPA and WAC recommended threshold value of 1.

It should be noted that the retrieval leaks are a worst case scenario because it assumes that all retrieval leaks happen at the same time. In fact, there would be a number of years between the first retrieval and the last retrieval, which would result in a smaller peak groundwater concentration over a larger number of years.

**S Tank Farm Pipe System**. A summary of radiological risk estimates for the pipe system is provided in Table 6-1. The radiological ILCR from both soil and water at year 4177 is $5.3 \times 10^{-7}$. The ILCR reported for the pipe system is less than the EPA lower risk threshold of $1 \times 10^{-6}$.

A summary of the nonradiological risk estimates and HIs are provided in Tables 6-2 and 6-3, respectively. The nonradiological ILCR from soil at year 4177 is $2.1 \times 10^{-8}$. The ILCR reported for the pipe system is less than the EPA lower risk threshold of $1 \times 10^{-6}$ and is less than the threshold value of $1 \times 10^{-5}$ recommended in WAC 173-340-745 for industrial land use. The HI

reported from water and soil exposure pathways is less than 0.01, which is less than the EPA and WAC recommended threshold value of 1.

Table 6-1. Summary of Radiological Risk Estimates for the HSRAM Industrial Exposure Scenario for S Tank Farm.

| Source | Media | Radiological ILCR | Peak year | Primary radionuclide | Total risk (%) | Primary pathway (%) |
|---|---|---|---|---|---|---|
| Past Leaks[1] | Soil<br>Water<br>Total ILCR | 5.4E-08<br>1.5E-05<br>1.5E-05 | 2046 | $^{99}Tc$ | 72 | Water Ingestion (100) |
| Residuals[2] | Soil<br>Water<br>Total ILCR | 4.2E-09<br>2.3E-06<br>2.3E-06 | 4902 | $^{99}Tc$ | 99 | Water Ingestion (100) |
| Retrieval Leaks[3] | Soil<br>Water<br>Total ILCR | 1.6E-07<br>7.9E-05<br>7.9E-05 | 2060 | $^{99}Tc$<br>$^{129}I$<br>$^{14}C$ | 89<br>7.6<br>3.1 | Water Ingestion (100) |
| Pipe System | Soil<br>Water<br>Total ILCR | 1.1E-09<br>5.3E-07<br>5.3E-07 | 4177 | $^{99}Tc$ | 83.5 | Water Ingestion (100) |

Notes:
[1]Maximum rad-ILCR risk for tank leaks is from single-shell tank S-104.
[2]Maximum rad-ILCR risk for tank residuals is from tank row S-104 to S-106.
[3]Maximum rad-ILCR risk for hypothetical retrieval leak is from tank row S-110 to S-112.
HSRAM = Hanford Site Risk Assessment Methodology.
ILCR = incremental lifetime cancer risk.

Table 6-2. Summary of Nonradiological Risk Estimates for the HSRAM Industrial Exposure Scenario for S Tank Farm. (2 sheets)

| Source | Media | Nonradiological ILCR | Peak year | Primary hazardous constituent | Total risk (%) | Primary pathway (%) |
|---|---|---|---|---|---|---|
| Past Leaks[1] | Soil<br>Water<br>Total ILCR | 1.1E-06<br>--<br>1.1E-06 | 2062 | Chromium | 100 | Soil Inhalation (100) |
| Residuals[2] | Soil<br>Water<br>Total ILCR | 6.1E-07<br>--<br>6.1E-07 | 4902 | Chromium | 100 | Soil Inhalation (100) |
| Retrieval Leaks[3] | Soil<br>Water<br>Total ILCR | 2.3E-06<br>--<br>2.3E-06 | 2060 | Chromium | 100 | Soil Inhalation (100) |
| Pipe System | Soil<br>Water<br>Total ILCR | 2.1E-08<br>--<br>2.1E-08 | 4177 | Chromium | 100 | Soil Inhalation (100) |

Table 6-2. Summary of Nonradiological Risk Estimates for the HSRAM Industrial Exposure Scenario for S Tank Farm. (2 sheets)

| Source | Media | Nonradiological ILCR | Peak year | Primary hazardous constituent | Total risk (%) | Primary pathway (%) |
|---|---|---|---|---|---|---|

Notes:
[1]Maximum nonrad-ILCR risk for tank leaks is from single-shell tank S-104.
[2]Maximum nonrad-ILCR risk for tank residuals is from tank row S-104 to S-106.
[3]Maximum nonrad-ILCR risk for hypothetical retrieval leak is from tank row S-110 to S-112.
HSRAM = Hanford Site Risk Assessment Methodology.
ILCR = incremental lifetime cancer risk.

Table 6-3. Summary of Hazard Index Estimates for the HSRAM Industrial Exposure Scenario for S Tank Farm.

| Source | Media | Hazard index | Peak year | Primary hazardous constituent | HI (%) | Primary pathway (%) |
|---|---|---|---|---|---|---|
| Past Leaks[1] | Soil<br>Water<br>Total HI | 0.0087<br>1.1<br>1.1 | 2046 | -- | -- | -- |
| Residuals[2] | Soil<br>Water<br>Total HI | 0.0028<br>0.16<br>0.17 | 4902 | -- | -- | -- |
| Retrieval Leaks[3] | Soil<br>Water<br>Total HI | 0.012<br>0.90<br>0.91 | 2060 | -- | -- | -- |
| Pipe System | Soil<br>Water<br>Total HI | 0.00010<br>0.0073<br>0.0074 | 4177 | -- | -- | -- |

Notes:
[1]Maximum HI for tank leaks is from single-shell tank S-104.
[2]Maximum HI for tank residuals is from tank row S-107 to S-109.
[3]Maximum HI for hypothetical retrieval leaks is from tank row S-110 to S-112.
HI = hazard index.
HSRAM = Hanford Site Risk Assessment Methodology.
ILCR = incremental lifetime cancer risk

### 6.2.1.2 SX Tank Farm.

**Past Leaks**. A summary of radiological risk estimates from past leaks is provided in Table 6-4. The radiological ILCR from both soil and water at year 2046 is $3.4 \times 10^{-3}$. The primary contributors to ILCR include $^{99}Tc$ ($2.9 \times 10^{-3}$, 85% contribution), $^{129}I$ ($2.9 \times 10^{-4}$; 8.6% contribution), and $^{14}C$ ($2.0 \times 10^{-4}$; 6% contribution). The ILCR reported for past leaks is greater than the EPA upper risk threshold of $1 \times 10^{-4}$.

A summary of the nonradiological risk estimates and HIs are provided in Tables 6-5 and 6-6, respectively. The nonradiological ILCR from soil at year 2046 is $2.9 \times 10^{-4}$ (chromium 100% contribution). The ILCR reported for past leaks is greater than the EPA upper risk threshold of $1 \times 10^{-4}$and exceeds the threshold value of $1 \times 10^{-5}$ recommended in WAC 173-340-745 for industrial land use. The HI reported from soil and water exposure pathways is 96, which is greater than the EPA and WAC recommended threshold value of 1. The primary contributors to the HI of 96 are chromium$^{+6}$ (HQ=76, 78.7% contribution), nitrite (HQ=18; 19% contribution), and nitrate (HQ=1.9; 2% contribution).

**Residual Tank Waste**. A summary of radiological risk estimates from residual tank waste is provided in Table 6-4. The radiological ILCR from both soil and water at year 4902 is $1.1 \times 10^{-6}$. The ILCR reported for residual tank waste is slightly greater than the EPA lower risk threshold of $1 \times 10^{-6}$.

A summary of the nonradiological risk estimates and HIs are provided in Tables 6-5 and 6-6, respectively. The nonradiological ILCR from soil at year 4092 is $1.1 \times 10^{-6}$ (hexavalent chromium 100% contribution). The ILCR reported for residual tank waste is slightly above the lower risk threshold of $1 \times 10^{-6}$ and is less than the threshold value of $1 \times 10^{-5}$ recommended in WAC 173-340-745 for industrial land use. The HI reported from the water and soil exposure pathways is 0.30, which is less than the EPA and WAC recommended threshold value of 1.

**Potential Retrieval Leaks**. A summary of radiological risk estimates from potential retrieval leaks is provided in Table 6-4. The radiological ILCR from both soil and water at year 2060 is $1.3 \times 10^{-4}$. The primary contributors to risk include $^{99}$Tc ($1.1 \times 10^{-4}$; 89% contribution) and $^{129}$I ($9.6 \times 10^{-6}$;8% contribution). The ILCR reported for potential retrieval leaks is slightly above the EPA upper risk threshold of $1 \times 10^{-4}$.

A summary of the nonradiological risk estimates and HIs are provided in Tables 6-5 and 6-6, respectively. The nonradiological ILCR from soil at year 2060 is $4.2 \times 10^{-6}$ (hexavalent chromium 100% contribution). The ILCR reported for potential retrieval leaks is within the EPA risk range of $1 \times 10^{-4}$ to $1 \times 10^{-6}$ and is less than the threshold value of $1 \times 10^{-5}$ recommended in WAC 173-340-745 for industrial land use. The HI reported from the water and soil exposure pathways is 1.7, which is above the EPA and WAC recommended threshold value of 1. The primary contributor to the HI of 1.7 is hexavalent chromium (HQ=1.1). No other constituents were reported with an HQ greater than 1.

It should be noted that the retrieval leaks are a worst case scenario, because it assumes that all retrieval leaks happen at the same time. In fact, there would be a number of years between the first retrieval and the last retrieval, which would result in a smaller peak groundwater concentration over a larger number of years.

**SX Tank Farm Pipe System**. A summary of radiological risk estimates for the pipe system is provided in Table 6-4. The radiological ILCR from both soil and water at year 4177 is $3.8 \times 10^{-7}$. The ILCR reported for the pipe system is less than the EPA lower risk threshold of $1 \times 10^{-6}$.

A summary of the nonradiological risk estimates and HIs are provided in Tables 6-5 and 6-6, respectively. The nonradiological ILCR from soil at year 4177 is 2.1 x $10^{-8}$. The ILCR reported for the pipe system is less than the EPA lower risk threshold of 1 x $10^{-6}$ and is less than the threshold value of 1 x $10^{-5}$ recommended in WAC 173-340-745 for industrial land use. The HI reported from water and soil exposure pathways is less than 0.074, which is less than the EPA and WAC recommended threshold value of 1.

Table 6-4. Summary of Radiological Risk Estimates for the HSRAM Industrial Exposure Scenario for SX Tank Farm.

| Source | Media | Radiological ILCR | Peak year | Primary radionuclide | Total risk (%) | Primary pathway (%) |
|---|---|---|---|---|---|---|
| Past Leaks[1] | Soil<br>Water<br>Total ILCR | 7.0E-06<br>3.4E-03<br>3.4E-03 | 2062 | $^{99}$Tc<br>$^{129}$I<br>$^{14}$C | 85<br>8.6<br>6.0 | Water Ingestion (100) |
| Residuals[2] | Soil<br>Water<br>Total ILCR | 2.3E-09<br>1.1E-06<br>1.1E-06 | 4902 | $^{99}$Tc<br>$^{129}$I<br>$^{14}$C | 98<br>2.0<br>0.3 | Water Ingestion (100) |
| Retrieval Leaks[3] | Soil<br>Water<br>Total ILCR | 2.6E-07<br>1.3E-04<br>1.3E-04 | 2060 | $^{99}$Tc<br>$^{129}$I | 89<br>7.7 | Water Ingestion (100) |
| Pipe System | Soil<br>Water<br>Total ILCR | 7.9E-10<br>3.8E-07<br>3.8E-07 | 4177 | $^{99}$Tc<br>$^{129}$I<br>$^{14}$C | 85<br>8.8<br>6.1 | Water Ingestion (100) |

Notes:
[1]Maximum rad-ILCR risk for tank leaks is from tank row SX-107 to SX-109.
[2]Maximum rad-ILCR risk for tank residuals is from tank row SX-113 to SX-115.
[3]Maximum rad-ILCR risk for hypothetical retrieval leaks is from tank row SX-104 to SX-106.
HSRAM = Hanford Site Risk Assessment Methodology.
ILCR = incremental lifetime cancer risk.

Table 6-5. Summary of Nonradiological Risk Estimates for the HSRAM Industrial Exposure Scenario for SX Tank Farm. (2 sheets)

| Source | Media | Nonradiological ILCR | Peak year | Primary hazardous constituent | Total risk (%) | Primary pathway (%) |
|---|---|---|---|---|---|---|
| Past Leaks[1] | Soil<br>Water<br>Total ILCR | 2.9E-04<br>--<br>2.9E-04 | 2046 | Chromium | 100 | Soil Inhalation (100) |
| Residuals[2] | Soil<br>Water<br>Total ILCR | 1.1E-06<br>--<br>1.1E-06 | 4902 | Chromium | 100 | Soil Inhalation (100) |

Table 6-5. Summary of Nonradiological Risk Estimates for the HSRAM Industrial Exposure Scenario for SX Tank Farm. (2 sheets)

| Source | Media | Nonradiological ILCR | Peak year | Primary hazardous constituent | Total risk (%) | Primary pathway (%) |
|---|---|---|---|---|---|---|
| Retrieval Leaks[3] | Soil<br>Water<br>Total ILCR | 4.2E-06<br>--<br>4.2E-06 | 2060 | Chromium | 100 | Soil Inhalation (100) |
| Pipe System | Soil<br>Water<br>Total ILCR | 2.1E-08<br>--<br>2.1E-08 | 4177 | Chromium | 100 | Soil Inhalation (100) |

Notes:
[1]Maximum nonrad-ILCR risk for tank leaks is from tank row SX-107 to SX-109.
[2]Maximum nonrad-ILCR risk for tank residuals is from tank row SX-101 to SX-103.
[3]Maximum nonrad-ILCR risk for hypothetical retrieval leaks is from tank row SX-101 to SX-103.
HSRAM = Hanford Site Risk Assessment Methodology.
ILCR = incremental lifetime cancer risk.

Table 6-6. Summary of Hazard Index Estimates for the HSRAM Industrial Exposure Scenario for SX Tank Farm.

| Source | Media | Hazard index | Peak year | Primary hazardous constituent | HI (%) | Primary pathway (%) |
|---|---|---|---|---|---|---|
| Past Leaks[1] | Soil<br>Water<br>Total HI | 1.4<br>95<br>96 | 2062 | Chromium<br>Nitrate<br>Nitrite | 78.7<br>2.0<br>19.2 | Water Ingestion (100) |
| Residuals[2] | Soil<br>Water<br>Total HI | 0.01<br>0.30<br>0.30 | 4902 | -- | -- | -- |
| Retrieval Leaks[3] | Soil<br>Water<br>Total HI | 0.02<br>1.7<br>1.7 | 2060 | Chromium<br>Nitrate<br>Nitrite | 64.9<br>8.6<br>26.2 | Water Ingestion (100) |
| Pipe System | Soil<br>Water<br>Total HI | 1.0E-04<br>7.3E-03<br>7.4E-03 | 4177 | -- | -- | -- |

Notes:
[1]Maximum HI for tank leaks is from tank row SX-107 to SX-109.
[2]Maximum HI for tank residuals is from tank row SX-101 to SX-103.
[3]Maximum HI for hypothetical retrieval leaks is from tank row SX-101 to SX-103.
HI = hazard index.
HSRAM = Hanford Site Risk Assessment Methodology.
ILCR = incremental lifetime cancer risk.

### 6.2.2 Risk Estimates for the HSRAM Residential Scenario

This section provides the risk estimates for the HSRAM residential exposure scenario at S tank farm and SX tank farm. Risk estimates are provided only for the year that the peak groundwater concentration occurs. Summary tables showing radiological ILCR, nonradiological ILCR and the HI, primary COPCs contributing to the risk estimate, and primary exposure pathway for each source term follow the tank farm discussion.

#### 6.2.2.1 S Tank Farm.

**Past Leaks**. A summary of radiological risk estimates from past leaks is provided in Table 6-7. The radiological ILCR from both soil and water at year 2046 is $2.8 \times 10^{-4}$. The primary contributors to ILCR include $^{99}$Tc ($2.6 \times 10^{-4}$; 92% contribution), $^{129}$I ($5.6 \times 10^{-6}$; 2% contribution), and $^{14}$C ($5.0 \times 10^{-6}$; 2% contribution). The ILCR for past leaks is greater than the EPA upper risk threshold of $5.0 \times 10^{-4}$.

A summary of the nonradiological risk estimates and HIs are provided in Tables 6-8 and 6-9, respectively. The nonradiological ILCR from soil at year 2046 is $2.5 \times 10^{-6}$. The ILCR reported for past leaks is within the EPA risk range of $1 \times 10^{-4}$ to $1 \times 10^{-6}$. The HI reported from the soil and water exposure pathways is 7.3, which is greater than the EPA and WAC recommended threshold value of 1. The primary contributor to the HI is nitrite (HQ=1.7), chromium (HQ=1.6), and nitrate (HQ-1.0) from the water ingestion pathway.

**Residual Tank Waste**. A summary of radiological risk estimates from residual tank waste is provided in Table 6-7. The radiological ILCR from both soil and water at year 4902 is $5.5 \times 10^{-5}$. The primary contributor to ILCR includes $^{99}$Tc ($5.5 \times 10^{-5}$; > 99% contribution). The ILCR residual tank waste is slightly greater than the EPA upper risk threshold of $1 \times 10^{-4}$.

A summary of the nonradiological risk estimates and HIs are provided in Tables 6-8 and 6-9, respectively. The nonradiological ILCR from soil at year 4092 is $1.4 \times 10^{-6}$. The ILCR reported for past leaks is slightly greater than the EPA lower risk threshold of $1 \times 10^{-6}$ and is approximately equal to the threshold value of $1 \times 10^{-6}$ recommended in WAC 173-340-740 for unrestricted land use. The HI reported from the water and soil exposure pathways is 1.0, which is equal to the EPA and WAC recommended threshold value of 1. No individual constituents are reported with an HQ greater than the threshold value of 1.

**Potential Retrieval Leaks**. A summary of radiological risk estimates from potential retrieval leaks is provided in Table 6-7. The radiological ILCR from both soil and water at year 2060 is $1.8 \times 10^{-3}$. The primary contributors to ILCR include $^{99}$Tc ($1.7 \times 10^{-3}$, 97% contribution), $^{129}$I ($3.1 \times 10^{-5}$; 2% contribution), and $^{14}$C ($1.8 \times 10^{-5}$; 1% contribution). The ILCR reported for potential retrieval leaks is greater than the EPA upper risk threshold of $1 \times 10^{-4}$.

A summary of the nonradiological risk estimates and HIs are provided in Tables 6-8 and 6-9, respectively. The nonradiological ILCR from soil at year 2060 is $3.5 \times 10^{-5}$ (chromium 100% contribution). The ILCR reported for potential retrieval leaks is within the EPA risk range of $1 \times 10^{-4}$ to $1 \times 10^{-6}$ and is greater than the threshold value of $1 \times 10^{-6}$ recommended in

WAC 173-340-740 for unrestricted land use. The HI reported from the water and soil exposure pathways is 5.7, which is greater than the EPA and WAC recommended threshold value of 1. The primary contributors to the HI include chromium (HQ=3.4) and nitrite (HQ=1.0) from the water ingestion pathway. No other constituents are reported with an HQ greater than the threshold value of 1.

**S Tank Farm Pipe System.** A summary of radiological risk estimates for the pipe system is provided in Table 6-7. The radiological ILCR from both soil and water at year 4177 is $1.1 \times 10^{-5}$. The primary contributor to ILCR is $^{99}Tc$ ($1.1 \times 10^{-5}$, 95% contribution). The ILCR reported for potential retrieval leaks is within the EPA risk range of $1 \times 10^{-4}$ to $1 \times 10^{-6}$.

A summary of the nonradiological risk estimates and HIs are provided in Tables 6-8 and 6-9, respectively. The nonradiological ILCR from soil at year 4177 is $4.9 \times 10^{-8}$. The ILCR reported for the pipe system is less than the EPA lower risk threshold of $1 \times 10^{-6}$ and is less than the threshold value of $1 \times 10^{-6}$ recommended in WAC 173-340-740 for unrestricted land use. The HI reported from the water and soil exposure pathways is less than 0.048, which is less than the EPA and WAC recommended threshold value of 1.

Table 6-7. Summary of Radiological Risk Estimates for the HSRAM Residential Exposure Scenario for S Tank Farm.

| Source | Media | Radiological ILCR | Peak year | Primary radionuclide | Total risk (%) | Primary pathway (%) |
|---|---|---|---|---|---|---|
| Past Leaks[1] | Soil<br>Water<br>Total ILCR | 2.2E-04<br>6.5E-05<br>2.8E-04 | 2046 | $^{99}Tc$<br>$^{129}I$<br>$^{14}C$ | 92<br>2.0<br>1.8 | Garden Produce (82)<br>Water Ingestion (18) |
| Residuals[2] | Soil<br>Water<br>Total ILCR | 4.5E-05<br>9.9E-06<br>5.5E-05 | 4902 | $^{99}Tc$ | 100 | Garden Produce (82)<br>Water Ingestion (18) |
| Retrieval Leaks[3] | Soil<br>Water<br>Total ILCR | 1.4E-03<br>3.5E-04<br>1.8E-03 | 2060 | $^{99}Tc$<br>$^{129}I$<br>$^{14}C$ | 97<br>1.8<br>1.0 | Garden Produce (80)<br>Water Ingestion (20) |
| Pipe System | Soil<br>Water<br>Total ILCR | 8.9E-06<br>2.3E-06<br>1.1E-05 | 4177 | $^{99}Tc$ | 95 | Garden Produce (79)<br>Water Ingestion (20) |

Notes:
[1]Maximum rad-ILCR risk for tank leaks is from single-shell tank S-104.
[2]Maximum rad-ILCR risk for tank residuals is from tank row S-104 to S-106.
[3]Maximum rad-ILCR risk for tank residuals is from tank row S-110 to S-112.
HSRAM = Hanford Site Risk Assessment Methodology.
ILCR = incremental lifetime cancer risk.

Table 6-8. Summary of Nonradiological Risk Estimates for the HSRAM Residential Exposure Scenario for S Tank Farm.

| Source | Media | Nonradiological ILCR | Peak year | Primary hazardous constituent | Total risk (%) | Primary pathway (%) |
|---|---|---|---|---|---|---|
| Past Leaks[1] | Soil<br>Water<br>Total ILCR | 2.5E-06<br>--<br>2.5E-06 | 2046 | Chromium | 100 | Soil Inhalation (100) |
| Residuals[2] | Soil<br>Water<br>Total ILCR | 1.4E-06<br>--<br>1.4E-06 | 4902 | Chromium | 100 | Soil Inhalation (100) |
| Retrieval Leaks[3] | Soil<br>Water<br>Total ILCR | 5.3E-06<br>--<br>5.3E-06 | 2060 | Chromium | 100 | Soil Inhalation (100) |
| Pipe System | Soil<br>Water<br>Total ILCR | 4.9E-08<br>--<br>4.9E-08 | 4177 | Chromium | 100 | Soil Inhalation (100) |

Notes:
[1]Maximum nonrad-ILCR risk for tank leaks is from single-shell tank S-104.
[2]Maximum nonrad-ILCR risk for tank residuals is from tank row S-104 to S-106.
[3]Maximum nonrad-ILCR risk for tank residuals is from tank row S-110 to S-112.
HSRAM = Hanford Site Risk Assessment Methodology.
ILCR = incremental lifetime cancer risk.

Table 6-9. Summary of Hazard Index Estimates for the HSRAM Residential Exposure Scenario for S Tank Farm.

| Source | Media | Hazard index | Peak year | Primary hazardous constituent | HI (%) | Primary pathway (%) |
|---|---|---|---|---|---|---|
| Past Leaks[1] | Soil<br>Water<br>Total HI | 0.28<br>7.0<br>7.3 | 2046 | Nitrite (HQ = 1.7)<br>Chromium (HQ=1.6)<br>Nitrate (HQ=1.0) | 51<br>22<br>14 | Water Ingestion (100) |
| Residuals[2] | Soil<br>Water<br>Total HI | 0.073<br>0.93<br>1.0 | 4902 | --[4] | --[4] | --[4] |
| Retrieval Leaks[3] | Soil<br>Water<br>Total HI | 0.30<br>5.4<br>5.7 | 2060 | Chromium (HQ=3.4)<br>Nitrite (HQ=1.0) | 60<br>18 | Water Ingestion (100) |
| Pipe System | Soil<br>Water<br>Total HI | 0.0049<br>0.042<br>0.047 | 4177 | --[4] | --[4] | --[4] |

Notes:
[1]Maximum HI for tank leaks is from single-shell tank S-104.
[2]Maximum HI for tank residuals is from tank row S-107 to S-109.
[2]Maximum HI for tank residuals is from tank row S-110 to S-112.
[4]No individual constituents were reported with a HQ greater than 1.0.
HI = hazard index.
HQ = hazard quotient.
HSRAM = Hanford Site Risk Assessment Methodology.

#### 6.2.2.2 SX Tank Farm.

**Past Leaks**. A summary of radiological risk estimates from past leaks is provided in Table 6-10. The radiological ILCR from both soil and water at year 2046 is $7.3 \times 10^{-2}$. The primary contributors to risk include $^{99}Tc$ ($7.0 \times 10^{-2}$; 96% contribution), $^{129}I$ ($1.5 \times 10^{-3}$; 2.1% contribution), and $^{14}C$ ($1.5 \times 10^{-3}$; 2.0% contribution). The ILCR reported for past leaks is greater than the EPA upper risk threshold of $1 \times 10^{-4}$.

A summary of the nonradiological risk estimates and HIs are provided in Tables 6-11 and 6-12, respectively. The nonradiological ILCR from soil at year 2046 is $6.7 \times 10^{-4}$ (hexavalent chromium; 100% contribution). The ILCR reported for past leaks is greater than the EPA upper risk threshold of $1 \times 10^{-4}$ and is greater than the threshold value of $1 \times 10^{-6}$ recommended in WAC 173-340-740 unrestricted land use. The HI reported from soil and water exposure pathways is 587, which is greater than the EPA and WAC recommended threshold value of 1. The primary contributors to the HI of 587 are hexavalent chromium (HQ=456), nitrite (HQ=118), and nitrate (HQ=12).

**Residual Tank Waste**. A summary of radiological risk estimates from residual tank waste is provided in Table 6-10. The radiological ILCR from both soil and water at year 4902 is $2.7 \times 10^{-5}$. The primary contributor to ILCR is $^{99}Tc$ at $2.2 \times 10^{-5}$, which represents greater than 99% of the ILCR. The ILCR reported for residual tank waste is within the EPA risk range of $1 \times 10^{-4}$ to $1 \times 10^{-6}$.

A summary of the nonradiological risk estimates and HIs are provided in Tables 6-11 and 6-12, respectively. The nonradiological ILCR from soil at year 4092 is $2.7 \times 10^{-6}$ (hexavalent chromium; 100% contribution). The ILCR reported for residual tank waste is slightly above than the EPA lower risk threshold of $1 \times 10^{-6}$ and is slightly greater than the threshold value of $1 \times 10^{-6}$ recommended in WAC 173-340-740 for unrestricted land use. The HI reported from the water and soil exposure pathways is 1.8, which is greater than the EPA and WAC recommended threshold value of 1. The primary contributor to the HI of 1.8 is chromium (HQ=1.8). No other constituents are reported with an HQ greater than the threshold value of 1.

**Potential Retrieval Leaks**. A summary of radiological risk estimates from potential retrieval leaks is provided in Table 6-10. The radiological ILCR from both soil and water at year 2060 is $2.8 \times 10^{-3}$. The primary contributors to risk include $^{99}Tc$ ($2.7 \times 10^{-3}$; 97% contribution), $^{129}I$ ($5.0 \times 10^{-5}$; 1.8% contribution), and $^{14}C$ ($2.6 \times 10^{-5}$; 0.9% contribution). The ILCR reported for potential retrieval leaks is above the EPA upper risk threshold of $1 \times 10^{-4}$.

A summary of the nonradiological risk estimates and HIs are provided in Tables 6-11 and 6-12, respectively. The nonradiological ILCR from soil at year 2060 is $9.8 \times 10^{-6}$ (hexavalent chromium; 100% contribution). The ILCR reported for potential retrieval leaks is within the EPA risk range of $1 \times 10^{-4}$ to $1 \times 10^{-6}$ and is greater than the threshold value of $1 \times 10^{-6}$ recommended in WAC 173-340-740 for unrestricted land use. The HI reported from the water and soil exposure pathways is 10, which is greater than EPA and WAC recommended threshold value of 1. The primary contributors to HI of 10 are hexavalent chromium (HQ=6.6) and nitrite (HQ=2.8).

**SX Tank Farm Pipe System**. A summary of radiological risk estimates for the pipe system is provided in Table 6-10. The radiological ILCR from both soil and water at year 4177 is $8.2 \times 10^{-6}$. The primary contributor to risk is $^{99}Tc$ ($7.9 \times 10^{-6}$; 96% contribution). The ILCR reported for the pipe system is within the EPA risk range of $1 \times 10^{-4}$ to $1 \times 10^{-6}$.

A summary of the nonradiological risk estimates and HIs are provided in Tables 6-11 and 6-12, respectively. The nonradiological ILCR from soil at year 4177 is $4.9 \times 10^{-8}$. The ILCR reported for the pipe system is less than the lower risk threshold of $1 \times 10^{-6}$ and is less than the threshold value of $1 \times 10^{-6}$ recommended in WAC 173-340-740 for unrestricted land use. The HI reported from water and soil exposure pathways is less than 0.046, which is less than the EPA and WAC recommended threshold value of 1.

Table 6-10. Summary of Radiological Risk Estimates for the HSRAM Residential Exposure Scenario for SX Tank Farm.

| Source | Media | Radiological ILCR | Peak year | Primary radionuclide | Total risk (%) | Primary pathway |
|---|---|---|---|---|---|---|
| Past Leaks[1] | Soil<br>Water<br>Total ILCR | 5.8E-02<br>1.5E-02<br>7.3E-02 | 2062 | $^{99}Tc$<br>$^{129}I$<br>$^{14}C$ | 96<br>2.1<br>2.0 | Garden Produce |
| Residuals[2] | Soil<br>Water<br>Total ILCR | 2.2E-05<br>5.0E-06<br>2.7E-05 | 4902 | $^{99}Tc$ | 99.5 | Garden Produce |
| Retrieval Leaks[3] | Soil<br>Water<br>Total ILCR | 2.3E-03<br>5.5E-04<br>2.8E-03 | 2060 | $^{99}Tc$<br>$^{129}I$<br>$^{14}C$ | 97<br>1.8<br>0.9 | Garden Produce |
| Pipe System | Soil<br>Water<br>Total ILCR | 6.6E-06<br>1.7E-06<br>8.2E-06 | 4177 | $^{99}Tc$ | 96 | Garden Produce |

Notes:
[1]Maximum rad-ILCR risk for tank leaks is from tank row SX-107 to SX-109.
[2]Maximum rad-ILCR risk for tank residuals is from tank row SX-113 to SX-115.
[3]Maximum rad-ILCR risk for hypothetical retrieval leaks is from tank row SX-104 to SX-106.
HSRAM = Hanford Site Risk Assessment Methodology.
ILCR = incremental lifetime cancer risk.

Table 6-11. Summary of Nonradiological Risk Estimates for the HSRAM Residential Exposure Scenario for SX Tank Farm.

| Source | Media | Nonradiological ILCR | Peak year | Primary hazardous constituent | Total risk (%) | Primary pathway (%) |
|---|---|---|---|---|---|---|
| Past Leaks[1] | Soil<br>Water<br>Total ILCR | 6.7E-04<br>--<br>6.7E-04 | 2062 | Chromium | 100 | Soil Inhalation (100) |
| Residuals[2] | Soil<br>Water<br>Total ILCR | 2.7E-06<br>--<br>2.7E-06 | 4902 | Chromium | 100 | Soil Inhalation (100) |
| Retrieval Leaks[3] | Soil<br>Water<br>Total ILCR | 9.8E-06<br>--<br>9.8E-06 | 2060 | Chromium | 100 | Soil Inhalation (100) |
| Pipe System | Soil<br>Water<br>Total ILCR | 4.9E-08<br>--<br>4.9E-08 | 4177 | Chromium | 100 | Soil Inhalation (100) |

Notes:
[1]Maximum nonrad-ILCR risk for tank leak s is from tank row SX-107 to SX-109.
[2]Maximum nonrad-ILCR risk for tank residuals is from tank row SX-101 to SX-103.
[3]Maximum nonrad-ILCR risk for hypothetical retrieval leaks is from tank row SX-101 to SX-103.
HSRAM = Hanford Site Risk Assessment Methodology.
ILCR = incremental lifetime cancer risk.

Table 6-12. Summary of Hazard Index Estimates for the HSRAM Residential Exposure Scenario for SX Tank Farm.

| Source | Media | Hazard index | Peak year | Primary hazardous constituent | HI (%) | Primary pathway (%) |
|---|---|---|---|---|---|---|
| Past Leaks[1] | Soil<br>Water<br>Total HI | 36<br>551<br>587 | 2062 | Chromium<br>Nitrate<br>Nitrite | 78<br>2.1<br>20 | Water Ingestion (100) |
| Residuals[2] | Soil<br>Water<br>Total HI | 0.14<br>1.7<br>1.8 | 4902 | Chromium | 99 | Water Ingestion (100) |
| Retrieval Leaks[3] | Soil<br>Water<br>Total HI | 0.55<br>9.9<br>10 | 2060 | Chromium<br>Nitrate<br>Nitrite | 63<br>9.0<br>27 | Water Ingestion (100) |
| Pipe System | Soil<br>Water<br>Total HI | 0.0027<br>0.043<br>0.046 | 4177 | -- | -- | -- |

Notes:
[1]Maximum HI for tank leaks is from tank row SX-107 to SX-109.
[2]Maximum HI for tank residuals is from tank row SX-101 to SX-103.
[3]Maximum HI for hypothetical retrieval leaks is from tank row SX-101 to SX-103.
HI = hazard index.
HSRAM = Hanford Site Risk Assessment Methodology.

### 6.2.3 Dose Estimates for the All Pathways Farmer Scenario

This section provides the dose estimates for the all pathways farmer exposure scenario at S tank farm and SX tank farm. Risk estimates are provided only for the year that the peak groundwater concentration occurs. Summary tables showing radiological dose, primary COPCs contributing to the dose estimates, and primary exposure pathways for each source term follow the tank farm discussion.

#### 6.2.3.1 S Tank Farm.

**Past Leaks**. A summary of soil and water dose estimates from past leaks is provided in Table 6-13. The EDE dose from soil at year 2046 is 1.9 mrem/yr and the EDE dose from water at year 2046 is 1.8 mrem/yr. The total EDE dose (3.7 mrem/yr) from both soil and water is less than the threshold value of 25 mrem/yr for representative members of the public.

**Residual Waste**. A summary of soil and water dose estimates from residual waste is provided in Table 6-13. The EDE dose from soil at year 4902 is 0.17 mrem/yr and the EDE dose from water at year 4902 is 0.13 mrem/yr. The total EDE dose from both soil and water (0.30 mrem/yr) is less than the DOE recommended threshold value of 25 mrem/yr for representative members of the public and is also less than the EPA dose threshold of 15 mrem/yr.

**Potential Retrieval Leaks**. A summary of soil and water dose estimates from retrieval leaks is provided in Table 6-13. The EDE dose from soil at year 2060 is 9.1 mrem/yr and the EDE dose from water at year 2060 is 5.7 mrem/yr. The total EDE dose from both soil and water (14.8 mrem/yr) is less than the DOE recommended threshold value of 25 mrem/yr for representative members of the public and is slightly less than the EPA dose threshold of 15 mrem/yr.

**S Tank Farm Pipe System**. A summary of soil and water dose estimates from the pipe system is provided in Table 6-13. The EDE dose from soil at year 4177 is 0.074 mrem/yr and the EDE dose from water at year 4177 is 0.041 mrem/yr. The total EDE dose from both soil and water (0.11 mrem/yr) is less than the DOE recommended threshold value of 25 mrem/yr for representative members of the public and is also less than the EPA dose threshold of 15 mrem/yr.

Table 6-13. Summary of Radiological Dose (EDE) for the All-Pathways Farmer at S Tank Farm. (2 sheets)

| Source | Media | Radiological dose (mrem/yr) | Peak year | Primary radionuclide(s) | Total dose (%) | Primary pathway (%) |
|---|---|---|---|---|---|---|
| Past Leaks[1] | Soil | 1.9 | 2046 | $^{99}Tc$ | 40 | Water Ingestion (37) |
| | Water | 1.8 | | $^{129}I$ | 29 | Beef (17) |
| | Total Dose | 3.7 | | $^{14}C$ | 18 | Milk (17) |
| Residuals[2] | Soil | 0.17 | 4902 | $^{99}Tc$ | 95 | Water Ingestion (37) |
| | Water | 0.13 | | $^{129}I$ | 4.1 | Egg (20) |
| | Total Dose | 0.30 | | $^{14}C$ | 0.8 | Vegetable Garden (25) |

Table 6-13. Summary of Radiological Dose (EDE) for the All-Pathways Farmer at S Tank Farm. (2 sheets)

| Source | Media | Radiological dose (mrem/yr) | Peak year | Primary radionuclide(s) | Total dose (%) | Primary pathway (%) |
|---|---|---|---|---|---|---|
| Retrieval Leaks[3] | Soil<br>Water<br>Total Dose | 9.1<br>5.7<br>15 | 2060 | $^{99}Tc$<br>$^{129}I$<br>$^{14}C$ | 61<br>29<br>10 | Water Ingestion (38)<br>Egg (17)<br>Milk (15) |
| Pipe System | Soil<br>Water<br>Total Dose | 0.074<br>0.041<br>0.11 | 4177 | $^{99}Tc$<br>$^{129}I$<br>$^{14}C$ | 49<br>32<br>19 | Water Ingestion (36)<br>Beef (19)<br>Milk (18) |

Notes:
[1]Maximum radiological dose (EDE) for tank leaks is from single shell tank S-104.
[2]Maximum radiological dose (EDE) for tank residuals is from tank row S-104 to S-106.
[3]Maximum radiological dose (EDE) for hypothetical retrieval leaks is from tank row S-110 to S-112.
EDE = effective dose equivalent.

### 6.2.3.2 SX Tank Farm.

**Past Leaks**. A summary of soil and water dose estimates from past leaks is provided in Table 6-14. The EDE dose from soil at year 2062 is 445 mrem/yr and the EDE dose from water at year 2062 is 257 mrem/yr. The total EDE dose (702 mrem/yr) from both soil and water is greater than the DOE recommended threshold value of 25 mrem/yr for representative members of the public and is also greater than the EPA dose threshold of 15 mrem/yr. The primary contributors to dose are $^{99}Tc$ (364 mrem/yr; 52% contribution), $^{129}I$ (208 mrem/yr; 30% contribution), and $^{14}C$ (127 mrem/yr; 18% contribution).

**Residual Waste**. A summary of soil and water dose estimates from residual waste is provided in Table 6-14. The EDE dose from soil at year 4902 is 0.09 mrem/yr and the EDE dose from water at year 4902 is 0.07 mrem/yr. The total EDE dose from both soil and water (0.16 mrem/yr) is less than the DOE recommended threshold value of 25 mrem/yr for representative members of the public and is also less than the EPA dose threshold of 15 mrem/yr.

**Potential Retrieval Leaks**. A summary of soil and water dose estimates from retrieval leaks is provided in Table 6-14. The EDE dose from soil at year 2060 is 14 mrem/yr and the EDE dose from water at year 2060 is 9.0 mrem/yr. The total EDE dose from both soil and water (23 mrem/yr) is slightly less than the DOE recommended threshold value of 25 mrem/yr for representative members of the public; however, the total EDE dose is greater than the EPA dose threshold of 15 mrem/yr.

**SX Tank Farm Pipe System**. A summary of soil and water dose estimates from the pipe system is provided in Table 6-14. The EDE dose from soil at year 4177 is 0.051 mrem/yr and the EDE dose from water at year 4177 is 0.029 mrem/yr. The total EDE dose from both soil and water (0.079 mrem/yr) is less than the DOE recommended threshold value of 25 mrem/yr for representative members of the public and is also less than the EPA dose threshold of 15 mrem/yr.

Table 6-14. Summary of Radiological Dose (EDE) for the All Pathways Farmer at SX Tank Farm.

| Source | Media | Radiological dose (mrem/yr) | Peak year | Primary radionuclide(s) | Total dose (%) | Primary pathway (%) |
|---|---|---|---|---|---|---|
| Past Leaks[1] | Soil<br>Water<br>Total Dose | 445<br>257<br>702 | 2046 | $^{99}Tc$<br>$^{129}I$<br>$^{14}C$ | 52<br>30<br>18 | Water Ingestion (37)<br>Beef (17)<br>Milk (17) |
| Residuals[2] | Soil<br>Water<br>Total Dose | 0.090<br>0.069<br>0.16 | 4902 | $^{99}Tc$<br>$^{129}I$<br>$^{14}C$ | 89<br>10<br>1.2 | Water Ingestion (44 )<br>Egg (23)<br>Vegetable Garden (19) |
| Retrieval Leaks[3] | Soil<br>Water<br>Total Dose | 14<br>9.0<br>23 | 2060 | $^{99}Tc$<br>$^{129}I$<br>$^{14}C$ | 61<br>29<br>9.7 | Water Ingestion (38)<br>Egg (17)<br>Milk (15) |
| Pipe System | Soil<br>Water<br>Total Dose | 0.051<br>0.029<br>0.079 | 4177 | $^{99}Tc$<br>$^{129}I$<br>$^{14}C$ | 52<br>30<br>18 | Water Ingestion (36)<br>Beef (18)<br>Milk (17) |

Notes:
[1]Maximum radiological dose (EDE) for tank leak s is from tank row SX-107 to SX-109.
[2]Maximum radiological dose (EDE) for tank residuals is from tank row SX-113 to SX-115.
[3]Maximum radiological dose (EDE) for hypothetical retrieval leaks is from tank row SX-104 to SX-106.
EDE = effective dose equivalent.

### 6.2.4 Maximum Contaminant Level

This section provides a comparison of the model derived contaminant concentration against the MCL. Nonradionuclide groundwater concentrations are compared directly against the federal drinking water MCL. Radionuclide groundwater concentrations are compared to total dose in addition to the MCL-derived constituent concentration given in *Radionuclides Notice of Data Availability Technical Support Document*, Table III-3 (EPA 2000). In this section, total dose is calculated using two different methodologies that are described in the following section.

**6.2.4.1 Drinking Water Dose Calculation Methods.** The radiological dose resulting from the presence of radionuclides in drinking water may be calculated by either of the following two methods:

- Target organ
- EDE.

The derivation and application of these two methods are described in the following subsections.

**Target Organ Method:** The target organ method, as presented in this discussion, is the method prescribed by EPA for determination of compliance of drinking water supply systems with the MCL requirements of the "National Primary Drinking Water Regulations" (40 CFR 141.66, Final Rule 7, December 2000). The MCL for beta/photon emitters in drinking water is 4 mrem/yr. This method is derived from dose calculations described in *National Bureau of Standards Handbook 69* (NBS 1963, *Maximum Permissible Body Burdens and Maximum Permissible Concentrations of Radionuclides in Air and in Water for Occupational Exposure*).

The Radionuclide Rule is implemented according to procedures described by EPA in the *Implementation Guidance for Radionuclides* (EPA 2002) utilizing a sum-of-fractions calculation based on observed radionuclide concentrations in water and predetermined derived concentrations for each radionuclide that would result in a 4 mrem/yr dose if the nuclide was the only nuclide present. The 4 mrem/yr MCL, based on the target organ calculation, has been in place as the drinking water standard since 1976. The derived concentrations for selected radionuclides of interest to tank closure are shown in Table 6-15.

Table 6-15. Comparison of Derived Concentrations for Selected Beta and Photon Emitting Radionuclides.

| Nuclide | Concentration resulting in 4 mrem/yr MCL to critical organs (pCi/L) | Risk at MCL | 1991 proposed concentration resulting in 4 mrem/yr EDE (pCi/L) | Risk at EDE |
|---|---|---|---|---|
| Tritium | 20,000 | 3.57 E-05 | 60,900 | 1.09 E-04 |
| $^{14}C$ | 2,000 | 1.09 E-04 | 3,200 | 1.75 E-04 |
| $^{99}Tc$ | 900 | 7.28 E-05 | 3,790 | 3.07 E-04 |
| $^{129}I$ | 1 | 4.22 E-06 | 21 | 8.87 E-05 |

Notes:
Source: EPA, 2000, *Radionuclides Notice of Data Availability Technical Support Document*, U.S. Environmental Protection Agency, Washington, D.C., Table III-3.
EDE = effective dose equivalent.
MCL = maximum contaminant level.

**Effective Dose Equivalent Method.** The EDE method of calculating radiological dose from drinking water was proposed for use in determining compliance with the radionuclide MCL in 1991. This method was proposed because it would result in a more consistent risk level within EPA's target risk range, and would be more consistent with similar dose calculations used by other agencies (such as DOE). In codifying the final rule in December 2000, however, EPA decided to retain the existing target organ calculation method on the basis that it is protective of public health. The EDE dose calculation method is prescribed by DOE in DOE O 5400.5. The EDE dose is implemented in the same manner as the target organ dose method utilizing a sum-of-fractions calculation. The derived concentrations for individual nuclides that result in 4 mrem/yr EDE drinking water dose are different from those established for the target organ method. The EDE-derived concentrations for selected radionuclides are shown in Table 6-15.

**Comparison of Dose Calculation Methods**. Both calculation methods are included for the WMA S-SX closure risk evaluation because of the apparent direct applicability of DOE O 5400.5 to the Hanford Site. For the selected nuclides shown in Table 6-15, the difference between derived concentrations for EDE and target organ methods ranges from a low of about 1.5 times higher for the EDE method for $^{14}C$ to as much as 21 times higher for the EDE method for $^{129}I$. This difference means that for a specific concentration of a particular nuclide present in drinking water, the dose resulting from that nuclide will be lower using the EDE calculation method than for the target organ method. For drinking water containing a mixture of nuclides, the difference between the two methods is greater when a nuclide such as $^{129}I$ is present because of the greater difference in the derived concentration for these nuclides between the two methods. Because $^{129}I$ and $^{99}Tc$ account for the majority of calculated dose in the preliminary

WMA S-SX dose estimates, there is a substantial difference between the two methods. There remains substantial uncertainty in the actual $^{129}I$ and $^{99}Tc$ content of the wastes contained in WMA S-SX tanks. The $^{129}I$ concentration may actually be substantially lower than current estimates. Sampling and analysis of residual waste is planned and should result in reduced uncertainty and more accurate dose estimates. This was actually the case with the post-retrieval sampling of SST C-106, where $^{129}I$ was not detected and was dropped from the risk assessment following a screening for analytes that were below the detection limits (RPP-20577, *Stage II Retrieval Data Report for Single-Shell Tank 241-C-106*).

**6.2.4.2 S Tank Farm.** Table 6-16 presents a summary of the model-predicted peak groundwater concentrations for COPCs from each source at the WMA fenceline. Included in this table are the following: year of peak arrival, peak groundwater concentration, peak dose estimate (EDE) and peak dose estimate (target organ) (radionuclides), the MCL (nonradionuclides), the derived MCL, if only that radionuclide was present), if the COPC was above the MCL, the year the concentration would fall below the MCL. Also, included is the total dose estimate for all beta/photon emitters. The year predicted for the total dose estimate to fall below the MCL uses the target organ dose estimate.

**Radionuclides.** Only $^{129}I$ for past leaks (1.5 pCi/L) and $^{99}Tc$ (3,260 pCi/L) and $^{129}I$ (5.1 pCi/L) for potential retrieval leaks are above the MCL-derived concentration. The total drinking water dose for past leaks is 1.2 mrem/yr (EDE) and 9.5 mrem/yr (total organ). The total organ dose will fall below the MCL of 4 mrem/yr by the year 2061. The total drinking water dose for potential retrieval leaks is 4.7 mrem/yr (EDE), and 35.3 mrem/yr (total organ). The total organ dose will fall below the MCL of 4 mrem/yr by the year 2177.

**Nonradionuclides.** None of the nonradionuclide groundwater concentrations exceeded their respective MCLs for any of the sources (past leaks, tank residuals, potential retrieval leaks or pipeline residuals).

Table 6-16. Residential Drinking Water Dose and MCLs at S Tank Farm Fenceline. (2 sheets)

| | Contaminant | Peak arrives at year | Peak concentration | Drinking water dose (mrem/yr) [EDE] | Drinking water dose (mrem/yr) [target organ] | MCL-derived concentration | Year drinking water MCL achieved |
|---|---|---|---|---|---|---|---|
| **Past Leaks (S-106)** | | | | | | | |
| Rad | Tritium | 2046 | 329 pCi/L | 0.022 | 0.066 | 20000 pCi/L | --[a] |
| Rad | $^{14}C$ | 2046 | 88 pCi/L | 0.11 | 0.18 | 2000 pCi/L | --[a] |
| Rad | $^{99}Tc$ | 2046 | 774 pCi/L | 0.82 | 3.4 | 900 pCi/L | --[a] |
| Rad | $^{129}I$ | 2046 | 1.5 pCi/L | 0.28 | 5.8 | 1 pCi/L | 2058 |
| Rad | Total Dose | -- | -- | 1.2 | 9.5 | 4 mrem/yr | 2061 |
| Non-Rad | Chromium | 2046 | 0.073 mg/L | N/A | N/A | 0.10 mg/L | --[a] |
| Non-Rad | Nitrate | 2046 | 25 mg/L | N/A | N/A | 44 mg/L | --[a] |
| Non-Rad | Nitrite | 2046 | 5.9 mg/L | N/A | N/A | 3.3 mg/L | --[a] |
| Non-Rad | Uranium | 12000 | 0.0068 mg/L | N/A | N/A | 0.030 mg/L | --[a] |

Table 6-16. Residential Drinking Water Dose and MCLs at S Tank Farm Fenceline. (2 sheets)

| | Contaminant | Peak arrives at year | Peak concentration | Drinking water dose (mrem/yr) [EDE] | Drinking water dose (mrem/yr) [target organ] | MCL-derived concentration | Year drinking water MCL achieved |
|---|---|---|---|---|---|---|---|
| **Tank Residuals (S-104 to S-106)** | | | | | | | |
| Rad | $^{14}C$ | 4902 | 0.5 pCi/L | 0.00062 | 0.0010 pCi/L | 2000 | --[a] |
| Rad | $^{99}Tc$ | 4902 | 163 pCi/L | 0.17 | 0.72 pCi/L | 900 | --[a] |
| Rad | $^{129}I$ | 4902 | 0.024 pCi/L | 0.0045 | 0.095 pCi/L | 1 | --[a] |
| Rad | Total Dose | -- | -- | 0.18 | 0.82 pCi/L | 4 mrem/yr | --[a] |
| Non-Rad | Chromium | 4902 | 0.041 mg/L | N/A | N/A | 0.10 mg/L | --[a] |
| Non-Rad | Fluoride | 4177 | 0.014 mg/L | N/A | N/A | 4.0 mg/L | --[a] |
| Non-Rad | Nitrate | 4177 | 0.13 mg/L | N/A | N/A | 44 mg/L | --[a] |
| Non-Rad | Nitrite | 4177 | 0.027 mg/L | N/A | N/A | 3.3 mg/L | --[a] |
| Non-Rad | Uranium | 12000 | 6.35E-07 mg/L | N/A | N/A | 0.030 mg/L | --[a] |
| **Retrieval Leaks (S-104 to S-106)** | | | | | | | |
| Rad | Tritium | 2056 | 91 pCi/L | 0.0060 | 0.018 pCi/L | 20000 | --[a] |
| Rad | $^{14}C$ | 2060 | 216 pCi/L | 0.27 | 0.43 pCi/L | 2000 | --[a] |
| Rad | $^{99}Tc$ | 2060 | 3260 pCi/L | 3.4 | 15 pCi/L | 900 | 2114 |
| Rad | $^{129}I$ | 2060 | 5.1 pCi/L | 0.97 | 20 pCi/L | 1 | 2134 |
| Rad | Total Dose | -- | -- | 4.7 | 35.3 pCi/L | 4 mrem/yr | 2177 |
| Non-Rad | Chromium | 2060 | 0.054 mg/L | N/A | N/A | 0.10 mg/L | --[a] |
| Non-Rad | Fluoride | 2060 | 0.042 mg/L | N/A | N/A | 4.0 mg/L | --[a] |
| Non-Rad | Nitrate | 2060 | 16 mg/L | N/A | N/A | 44 mg/L | --[a] |
| Non-Rad | Nitrite | 2060 | 0.81 mg/L | N/A | N/A | 3.3 mg/L | --[a] |
| Non-Rad | Uranium | 12000 | 3.02E-07 mg/L | N/A | N/A | 0.030 mg/L | --[a] |
| **Pipeline Residuals** | | | | | | | |
| Rad | Tritium | 4177 | 5.88E-12 pCi/L | 3.86E-16 | 1.18E-15 | 20000 pCi/L | --[a] |
| Rad | $^{14}C$ | 4177 | 4.6 pCi/L | 0.0057 | 0.0091 | 2000 pCi/L | --[a] |
| Rad | $^{99}Tc$ | 4177 | 32 pCi/L | 0.034 | 0.14 | 900 pCi/L | --[a] |
| Rad | $^{129}I$ | 4177 | 0.070 pCi/L | 0.013 | 0.28 | 1 pCi/L | --[a] |
| Rad | Total Dose | | | 0.053 | 0.43 | | --[a] |
| Non-Rad | Chromium | 4177 | 0.0014 mg/L | N/A | N/A | 0.10 mg/L | --[a] |
| Non-Rad | Fluoride | 4177 | 0.00088 mg/L | N/A | N/A | 4.0 mg/L | --[a] |
| Non-Rad | Nitrate | 4177 | 0.12 mg/L | N/A | N/A | 44 mg/L | --[a] |
| Non-Rad | Nitrite | 4177 | 0.011 mg/L | N/A | N/A | 3.3 mg/L | --[a] |
| Non-Rad | Uranium | 12000 | 4.01E-08 mg/L | N/A | N/A | 0.030 mg/L | --[a] |

Notes:

[a]Indicates that groundwater concentration does not exceed MCL at any year.

EDE = effective dose equivalent.

MCL = maximum contaminant level.

Non-Rad = nonradionuclide.

Rad = radionuclide.

#### 6.2.4.3 SX Tank Farm

Table 6-17 presents a summary of the model-predicted peak groundwater concentrations for COPCs from each source at WMA fenceline. The information provided in Table 6-17 is in the same format as that provided in Table 6-16.

**Radionuclides**

**Past Tank Leaks.** For the given inventories, all radionuclide groundwater concentrations exceed their respective MCL-derived concentration. The predicted peak tritium concentration is 36,800 pCi/L resulting in a drinking water dose of 2 mrem/yr (EDE) and 7 mrem/yr (target organ). Tritium is predicted to be below the MCL-derived concentration of 20,000 pCi/L by the year 2051. The predicted peak $^{14}C$ concentration is 26,200 pCi/L resulting in a drinking water dose of 33 mrem/yr (EDE) and 53 mrem/yr (target organ). $^{14}C$ is predicted to be below the MCL-derived concentration of 2,000 pCi/L by the year 2081. The predicted peak $^{99}Tc$ concentration is 208,000 pCi/L resulting in a drinking water dose of 220 mrem/yr (EDE) and 926 mrem/yr (target organ). $^{99}Tc$ is predicted to be below the MCL-derived concentration of 900 pCi/L by the year 2165. The predicted peak $^{129}I$ concentration is 395 pCi/L resulting in a drinking water dose of 75 mrem/yr (EDE) and 1,580 mrem/yr (target organ). $^{129}I$ is predicted to be below the MCL-derived concentration of 1 pCi/L by the year 2197. The total drinking water dose is 330 mrem/yr [EDE] and 2,566 mrem/yr (target organ). The total drinking water dose is predicted to be below the MCL of 4 mrem/yr by the year 2234.

**Tank Residuals.** For the given residual inventories, no predicted peak groundwater concentrations exceed their respective MCL-derived concentrations nor does the predicted total drinking water dose of 0.092 mrem/yr (EDE) or 0.48 mrem/yr (target organ).

**Potential Retrieval Leaks:** For the given residual inventories, only the predicted peak groundwater concentration for $^{99}Tc$ (8,140 pCi/L) and $^{129}I$ (13 pCi/L) exceed their respective MCL-derived concentration. These concentrations result in a drinking water dose of 8.6 mrem/yr (EDE) and 36 mrem/yr (target organ) for $^{99}Tc$ and 2.5 mrem/yr (EDE) and 52 mrem/yr (target organ) for $^{129}I$. $^{99}Tc$ is predicted to be below the MCL-derived concentration of 900 pCi/L by the year 2180 and $^{129}I$ is predicted to be below the MCL-derived concentration of 1 pCi/L by the year 2221. The total drinking water dose is 12 mrem/yr (EDE) and 89 mrem/yr (target organ). The total drinking water dose is predicted to be below the MCL of 4 mrem/yr by year 2308.

**SX Tank Farm Pipe System.** For the given residual inventories, no predicted peak groundwater concentrations exceed their respective MCL-derived concentrations nor does the predicted total drinking water dose of 0.037 mrem/yr (EDE) or 0.29 mrem/yr (target organ).

**Nonradionuclides**

**Past Tank Leaks.** For the given inventories, chromium, nitrate, and nitrite exceed their respective MCLs. The predicted peak groundwater concentration for chromium is 20 mg/L, which is greater than the MCL of 0.1 mg/L. Chromium is predicted to be below the MCL of 0.1 mg/L by the year 2160. The predicted peak groundwater concentration for nitrate is

307 mg/L, which is greater than the MCL of 44 mg/L. Nitrate is predicted to be below the MCL of 44 mg/L by the year 2074. The predicted peak groundwater concentration for nitrite is 186 mg/L, which is greater than the MCL of 3.3 mg/L. Nitrite is predicted to be below the MCL of 3.3 mg/L by the year 2116.

**Tank Residuals.** For the given inventories, no peak groundwater concentrations exceed their respective MCL.

**Potential Retrieval Leaks:** For the given inventories, only peak groundwater concentrations for chromium and nitrite exceed their respective MCLs. The predicted peak groundwater concentration for chromium is 0.28 mg/L, which is greater than the MCL of 0.1. Chromium is predicted to be below the MCL of 0.1 mg/L by the year 2101. The predicted peak groundwater concentration for nitrite is 4.5 mg/L, which is greater than the MCL of 3.3 mg/L. Nitrate is predicted to be below the MCL of 3.3 by the year 2084.

**Pipeline Residuals.** For the given inventories, no peak groundwater concentrations exceed their respective MCL.

Table 6-17. Residential Drinking Water Dose and MCLs at S-SX WMA Fenceline. (2 sheets)

| Contaminant | | Peak arrives at year | Peak concentration (pCi/L) | Drinking water dose (mrem/yr) [EDE] | Drinking water dose (mrem/yr) [target organ] | MCL-derived concentration (pCi/L) | Year drinking water MCL achieved |
|---|---|---|---|---|---|---|---|
| **Past Leaks** | | | | | | | |
| Rad | Tritium | 2040 | 36,800 pCi/L | 2 | 7 | 20,000 pCi/L | 2051 |
| | $^{14}C$ | 2046 | 26,200 pCi/L | 33 | 53 | 2,000 pCi/L | 2081 |
| | $^{99}Tc$ | 2046 | 208,000 pCi/L | 220 | 926 | 900 pCi/L | 2165 |
| | $^{129}I$ | 2046 | 395 pCi/L | 75 | 1580 | 1 pCi/L | 2197 |
| | Total Dose | -- | -- | 330.4 | 2566 | 4 mrem/yr | 2234 |
| Non-Rad | Chromium | 2046 | 20 mg/L | N/A | N/A | 0.1 mg/L | 2160 |
| | Nitrate | 2046 | 307 mg/L | N/A | N/A | 44 mg/L | 2074 |
| | Nitrite | 2046 | 186 mg/L | N/A | N/A | 3.3 mg/L | 2116 |
| | Uranium | 12000 | 0.006 mg/L | N/A | N/A | 0.03 mg/L | --[a] |
| **Tank Residuals (SX-113 to SX-115 [rad], SX-101 to SX-103 [non-rad])** | | | | | | | |
| Rad | $^{14}C$ | 4777 | 0.38 pCi/L | 4.8E-04 | 7.7E-04 | 2000 pCi/L | --[a] |
| | $^{99}Tc$ | 4902 | 80.8 pCi/L | 8.5E-02 | 3.6E-01 | 900 pCi/L | --[a] |
| | $^{129}I$ | 4902 | 3.1E-02 pCi/L | 5.9E-03 | 1.2E-01 | 1 pCi/L | --[a] |
| | Total Dose | -- | -- | 9.2E-02 | 4.8E-01 | 4 mrem/yr | --[a] |
| Non-Rad | Chromium | 4902 | 0.078 mg/L | N/A | N/A | 0.1 mg/L | --[a] |
| | Fluoride | 4902 | 6.4E-04 mg/L | N/A | N/A | 4 mg/L | --[a] |
| | Nitrate | 4902 | 0.090 mg/L | N/A | N/A | 44 mg/L | --[a] |
| | Nitrite | 4902 | 0.016 mg/L | N/A | N/A | 3.3 mg/L | --[a] |
| | Uranium | 12000 | 2.7E-07 mg/L | N/A | N/A | 0.03 mg/L | --[a] |

Table 6-17. Residential Drinking Water Dose and MCLs at S-SX WMA Fenceline. (2 sheets)

| Contaminant | | Peak arrives at year | Peak concentration (pCi/L) | Drinking water dose (mrem/yr) [EDE] | Drinking water dose (mrem/yr) [target organ] | MCL-derived concentration (pCi/L) | Year drinking water MCL achieved |
|---|---|---|---|---|---|---|---|
| **Retrieval Leaks (SX-104 to SX-106 [rad], SX-101 to SX-103 [non-rad])** | | | | | | | |
| Rad | Tritium | 2056 | 241 pCi/L | 1.6E-02 | 4.8E-02 | 20000 pCi/L | --[a] |
| | $^{14}C$ | 2060 | 470 pCi/L | 5.9E-01 | 9.4E-01 | 2000 pCi/L | --[a] |
| | $^{99}Tc$ | 2060 | 8140 pCi/L | 8.6 | 36.2 | 900 pCi/L | 2180 |
| | $^{129}I$ | 2060 | 13 pCi/L | 2.5 | 52.0 | 1 pCi/L | 2221 |
| | Total Dose | -- | -- | 11.7 | 89.2 | 4 mrem/yr | 2308 |
| Non-Rad | Chromium | 2060 | 2.8E-01 mg/L | N/A | N/A | 0.1 mg/L | --[a] |
| | Fluoride | 2060 | 2.4E-02 mg/L | N/A | N/A | 4 mg/L | --[a] |
| | Nitrate | 2060 | 23.6 mg/L | N/A | N/A | 44 mg/L | --[a] |
| | Nitrite | 2060 | 4.5 mg/L | N/A | N/A | 3.3 mg/L | 2084 |
| | Uranium | 12000 | 5.1E-06 mg/L | N/A | N/A | 0.03 mg/L | --[a] |
| **Pipeline Residuals** | | | | | | | |
| Rad | Tritium | -- | 0 pCi/L | 3.0E-16 | 9.2E-16 | 20000 pCi/L | --[a] |
| | $^{14}C$ | 4177 | 3.0 pCi/L | 3.7E-03 | 6.0E-03 | 2000 pCi/L | --[a] |
| | $^{99}Tc$ | 4177 | 23.5 pCi/L | 2.5E-02 | 1.0E-01 | 900 pCi/L | --[a] |
| | $^{129}I$ | 4177 | 4.5E-02 pCi/L | 8.6E-03 | 1.8E-01 | 1 pCi/L | --[a] |
| | Total Dose | -- | -- | 3.7E-02 | 2.9E-01 | 4 mrem/yr | --[a] |
| Non-Rad | Chromium | 4177 | 1.4E-03 mg/L | N/A | N/A | 0.1 mg/L | --[a] |
| | Fluoride | 4177 | 1.7E-04 mg/L | N/A | N/A | 4 mg/L | --[a] |
| | Nitrate | 4177 | 6.9E-02 mg/L | N/A | N/A | 44 mg/L | --[a] |
| | Nitrite | 4177 | 1.5E-02 mg/L | N/A | N/A | 3.3 mg/L | --[a] |
| | Uranium | 12000 | 2.9E-08 mg/L | N/A | N/A | 0.03 mg/L | --[a] |

Notes:
[a]Indicates that groundwater concentration does not exceed MCL at any year.
EDE = effective dose equivalent.
MCL = maximum contaminant level.
N/A = not applicable.
Non-Rad = nonradionuclide.
Rad = radionuclide.
WMA = Waste Management Area.

### 6.2.5 Risk and Dose Estimates at Downgradient Locations

This section provides the risk estimates for the HSRAM industrial and HSRAM residential exposure scenarios and dose estimates for the all pathways farmer scenario contributed from the S tank farm and SX tank farm at downgradient locations. Two downgradient locations were evaluated for the risk evaluation and include (1) the proposed core zone boundary surrounding

the 200 Areas, which is located approximately 10,900 m east of WMA S-SX and (2) the Columbia River, which is located approximately 32,700 m from WMA S-SX.

To estimate the risk contributed from each of the sources at downgradient locations, one set of dilution factors were calculated for the S tank farm and SX tank farm and applied to the risk estimates obtained at the fenceline. Dilution factors were calculated for each source using a unit inventory (or simulation case) by determining a ratio between the predicted peak $^{99}$Tc concentrations at the fenceline and predicted peak $^{99}$Tc concentrations at each downgradient location. With the exception of past leaks, $^{99}$Tc groundwater concentrations for each source term and each location were obtained from PNNL-14604. $^{99}$Tc groundwater concentrations for past leaks were obtained from STOMP modeling results (Section 4.0). Peak groundwater concentrations, peak years, and dilution factors from each source and each location are provided in Table 6-18. Except for past leaks the values in Table 6-18 were taken from PNNL-14604, Table 4-9. The values have been adjusted from Ci/L to pCi/L and adjusted to take into account the 3-D aspects of the modeling.

Table 6-18. Summary of Peak Groundwater Concentrations, Peak Year, and Dilution Factors at Downgradient Locations

| Source | Peak GW concentration at fenceline (pCi/L) | Peak year at fenceline | Peak GW concentration at core zone boundary (pCi/L) | Peak year at core zone boundary | Core zone boundary dilution factor | Peak GW concentration at Columbia River (pCi/L) | Peak year at Columbia River boundary | Columbia River dilution factor |
|---|---|---|---|---|---|---|---|---|
| Past Leaks | 5050 | 2062 | 0.31 | 2323 | 1.62E+04 | 0.095 | 2406 | 5.30E+04 |
| Residuals | 37 | 4902 | 0.0058 | 5178 | 6.34E+03 | 0.0015 | 5259 | 2.49E+04 |
| Retrieval Leaks | 1625 | 2060 | 0.13 | 2347 | 1.21E+04 | 0.039 | 2428 | 4.22E+04 |
| Pipe System | 107 | 4177 | 0.017 | 4465 | 6.33E+03 | 0.0043 | 4546 | 2.49E+04 |

Note:
GW = groundwater.

Risk and dose estimates are provided only for the year that the peak groundwater concentration occurs. Summary tables showing total radiological ILCR, total nonradiological ILCR, and HI for the HSRAM industrial and residential exposure scenarios from each source term, each downgradient location, and each tank farm follow the tank farm discussions. A summary table showing total radiological dose for the all pathways farmer scenario from each source term, each downgradient location, and each tank farm is also provided after the tank farm discussions. The discussions provided below are limited to the risk and dose estimate results at the core zone boundary and the Columbia River.

**6.2.5.1 S Tank Farm.** A summary of downgradient risk and dose estimates from each source within S tank farm is provided in Tables 6-19 through 6-21. The following summarizes the risk and dose estimates contributed from the S tank farm at the core zone boundary and the Columbia River:

- The radiological and nonradiological ILCR for the HSRAM industrial scenario is less than the EPA lower risk threshold of $1 \times 10^{-6}$ and is less that the threshold value of $1 \times 10^{-5}$ recommended in WAC 173-340-745 for industrial land use for each source term and downgradient point evaluated (Table 6-19).
- The radiological and nonradiological ILCR for the HSRAM residential scenario is less than the EPA lower risk threshold of $1 \times 10^{-6}$ and is less that the threshold value of $1 \times 10^{-6}$ recommended in WAC 173-340-740 for unrestricted land use for each source term and downgradient point evaluated (Table 6-20).
- The HI for the HSRAM industrial and HSRAM residential exposure scenarios are less than the EPA and WAC recommended threshold value of 1 for each source term and each downgradient point evaluated (Tables 6-19 and 6-20).
- The total EDE dose is less than the threshold value of 25 mrem/yr for representative members of the public for each source term and downgradient point evaluated (Table 6-21).

**6.2.5.2 SX Tank Farm.** A summary of downgradient risk and dose estimates from each source within SX tank farm is provided in Tables 6-19 through 6-21. The following summarizes the risk and dose estimates contributed from the SX tank farm at the core zone boundary and the Columbia River:

- The radiological and nonradiological ILCR for the HSRAM industrial scenario is less than the EPA lower risk threshold of $1 \times 10^{-6}$ and is less that the threshold value of $1 \times 10^{-5}$ recommended in WAC 173-340-745 for industrial land use for each source term and downgradient point evaluated (Table 6-19).
- With the exception of radiological risk from past leaks at the core zone boundary and the Columbia River, the radiological and nonradiological ILCR for the HSRAM residential scenario is less than the EPA lower risk threshold of $1 \times 10^{-6}$ and is less that the threshold value of $1 \times 10^{-6}$ recommended in WAC 173-340-740 for unrestricted land use for each source term and downgradient point evaluated (Table 6-20).
- Radiological risk from past leaks at the core zone boundary ($4.5 \times 10^{-6}$) and the Columbia River ($1.4 \times 10^{-6}$) are within the EPA risk range of $1 \times 10^{-4}$ to $1 \times 10^{-6}$ and are greater than the threshold value of $1 \times 10^{-6}$ recommended in WAC 173-340-740 for unrestricted land use.
- The HI for the HSRAM industrial and HSRAM residential exposure scenarios are less than the EPA and WAC recommended threshold value of 1 for each source term and downgradient point evaluated (Tables 6-19 and 6-20).
- The total EDE dose is less than the threshold value of 25 mrem/yr for representative members of the public for each source term and downgradient point evaluated (Table 6-21).

Table 6-19. Summary of HSRAM Industrial Scenario ILCR Results for WMA S-SX at Downgradient Locations

| Source | Tank farm | Peak year at fenceline | ILCR or HI at fenceline | Peak year at proposed core zone boundary | ILCR or HI at proposed core zone boundary | Peak year at Columbia River | ILCR or HI at Columbia River |
|---|---|---|---|---|---|---|---|
| Past Leaks | WMA S – Rad-ILCR | 2062 | 6.2E-06 | 2323 | 3.9E-10 | 2406 | 1.2E-10 |
| | Non-Rad ILCR | | 4.9E-07 | | 3.0E-11 | | 9.2E-12 |
| | HI | | 0.49 | | 3.0E-05 | | 9.2E-06 |
| | WMA SX – Rad-ILCR | | 3.4E-03 | | 2.1E-07 | | 6.4E-08 |
| | Non-Rad ILCR | | 2.9E-04 | | 1.8E-08 | | 5.5E-09 |
| | HI | | 96 | | 5.9E-03 | | 1.8E-03 |
| Residuals | WMA S – Rad-ILCR | 4902 | 2.3E-06 | 5178 | 3.6E-10 | 5259 | 9.2E-11 |
| | Non-Rad ILCR | | 6.1E-07 | | 9.6E-11 | | 2.4E-11 |
| | HI | | 0.17 | | 2.7E-05 | | 6.8E-06 |
| | WMA SX – Rad-ILCR | | 1.1E-06 | | 1.7E-10 | | 4.4E-11 |
| | Non-Rad ILCR | | 1.1E-06 | | 1.7E-10 | | 4.4E-11 |
| | HI | | 0.30 | | 4.7E-05 | | 1.2E-05 |
| Retrieval Leaks | WMA S – Rad-ILCR | 2060 | 7.9E-05 | 2347 | 6.5E-09 | 2428 | 1.9E-09 |
| | Non-Rad ILCR | | 2.3E-06 | | 1.9E-10 | | 5.4E-11 |
| | HI | | 0.91 | | 7.5E-05 | | 2.2E-05 |
| | WMA SX – Rad-ILCR | | 1.3E-04 | | 1.1E-08 | | 3.1E-09 |
| | Non-Rad ILCR | | 4.2E-06 | | 3.5E-10 | | 1.0E-10 |
| | HI | | 1.7 | | 1.4E-04 | | 4.0E-05 |
| Pipe System | WMA S – Rad-ILCR | 4177 | 5.3E-07 | 4465 | 8.4E-11 | 4546 | 2.1E-11 |
| | Non-Rad ILCR | | 2.1E-06 | | 3.3E-10 | | 8.4E-11 |
| | HI | | 0.0074 | | 1.2E-06 | | 3.0E-07 |
| | WMA SX – Rad-ILCR | | 3.8E-07 | | 6.0E-11 | | 1.5E-11 |
| | Non-Rad ILCR | | 2.1E-08 | | 3.3E-12 | | 8.4E-13 |
| | HI | | 0.0074 | | 1.2E-06 | | 3.0E-07 |

Notes:

HI = hazard index.
HSRAM = Hanford Site Risk Assessment Methodology.
ILCR = incremental lifetime cancer risk.
WMA = Waste Management Area.

Table 6-20. Summary of HSRAM Residential Scenario ILCR Results for WMA S-SX at Downgradient Locations.

| Source | Tank farm | Peak year at fenceline | ILCR or HI at fenceline | Peak year at proposed core zone boundary | ILCR or HI at proposed core zone boundary | Peak year at Columbia River | ILCR or HI at Columbia River |
|---|---|---|---|---|---|---|---|
| Past Leaks | WMA S – Rad-ILCR | 2062 | 1.3E-04 | 2323 | 8.0E-09 | 2406 | 2.5E-09 |
| | Non-Rad ILCR | | 1.2E-06 | | 7.4E-11 | | 2.3E-11 |
| | HI | | 3.1 | | 1.9E-04 | | 5.8E-05 |
| | WMA SX – Rad-ILCR | | 7.3E-02 | | 4.5E-06 | | 1.4E-06 |
| | Non-Rad ILCR | | 6.7E-04 | | 4.1E-08 | | 1.3E-08 |
| | HI | | 587 | | 0.036 | | 6.9E-07 |
| Residuals | WMA S – Rad-ILCR | 4902 | 5.5E-05 | 5178 | 8.7E-09 | 5259 | 2.2E-09 |
| | Non-Rad ILCR | | 1.4E-06 | | 2.2E-10 | | 5.6E-11 |
| | HI | | 1.0 | | 1.6E-04 | | 4.0E-05 |
| | WMA SX – Rad-ILCR | | 2.7E-05 | | 4.3E-09 | | 1.1E-09 |
| | Non-Rad ILCR | | 2.7E-06 | | 4.3E-10 | | 1.1E-10 |
| | HI | | 1.8 | | 2.8E-04 | | 7.2E-05 |
| Retrieval Leaks | WMA S – Rad-ILCR | 2060 | 1.8E-03 | 2347 | 1.5E-07 | 2428 | 4.3E-08 |
| | Non-Rad ILCR | | 3.5E-05 | | 2.9E-09 | | 8.3E-10 |
| | HI | | 5.7 | | 4.7E-04 | | 1.4E-04 |
| | WMA SX – Rad-ILCR | | 2.8E-03 | | 2.3E-07 | | 6.6E-08 |
| | Non-Rad ILCR | | 9.8E-06 | | 8.1E-10 | | 2.3E-10 |
| | HI | | 10 | | 8.2E-04 | | 2.4E-04 |
| Pipe System | WMA S – Rad-ILCR | 4177 | 1.1E-05 | 4465 | 1.7E-09 | 4546 | 4.4E-10 |
| | Non-Rad ILCR | | 4.9E-08 | | 7.7E-12 | | 2.0E-12 |
| | HI | | 0.048 | | 7.6E-06 | | 1.9E-06 |
| | WMA SX – Rad-ILCR | | 8.2E-06 | | 1.3E-09 | | 3.3E-10 |
| | Non-Rad ILCR | | 4.9E-08 | | 7.7E-12 | | 2.0E-12 |
| | HI | | 0.046 | | 7.3E-06 | | 1.8E-06 |

Notes:

HI = hazard index.
HSRAM = Hanford Site Risk Assessment Methodology.
ILCR = incremental lifetime cancer risk.
WMA = Waste Management Area.

Table 6-21. Summary of All Pathways Farmer Dose Results for WMA S-SX at Downgradient Locations.

| Source | Tank farm | Peak year at fenceline | Radiological dose at fenceline (mrem/yr EDE) | Peak year at proposed core zone boundary | Radiological dose at proposed core zone boundary (mrem/yr EDE) | Peak year at Columbia River | Radiological dose at Columbia River (mrem/yr EDE) |
|---|---|---|---|---|---|---|---|
| Past Leaks | WMA S | 2062 | 2.5 | 2323 | 1.5E-04 | 2406 | 4.7E-05 |
| | WMA SX | | 702 | | 0.043 | | 0.013 |
| Residuals | WMA S | 4902 | 0.30 | 5178 | 4.7E-05 | 5259 | 1.2E-05 |
| | WMA SX | | 0.16 | | 2.5E-05 | | 6.4E-06 |
| Retrieval Leaks | WMA S | 2060 | 15 | 2347 | 0.0012 | 2428 | 3.5E-04 |
| | WMA SX | | 23 | | 0.0019 | | 5.5E-04 |
| Pipe System | WMA S | 4177 | 0.11 | 4465 | 1.7E-05 | 4546 | 4.4E-06 |
| | WMA SX | | 0.079 | | 1.2E-05 | | 3.2E-06 |

Notes:
EDE = effective dose equivalent.
WMA = Waste Management Area.

## 6.3 CUMULATIVE EFFECTS OF ALL SOURCE TERMS

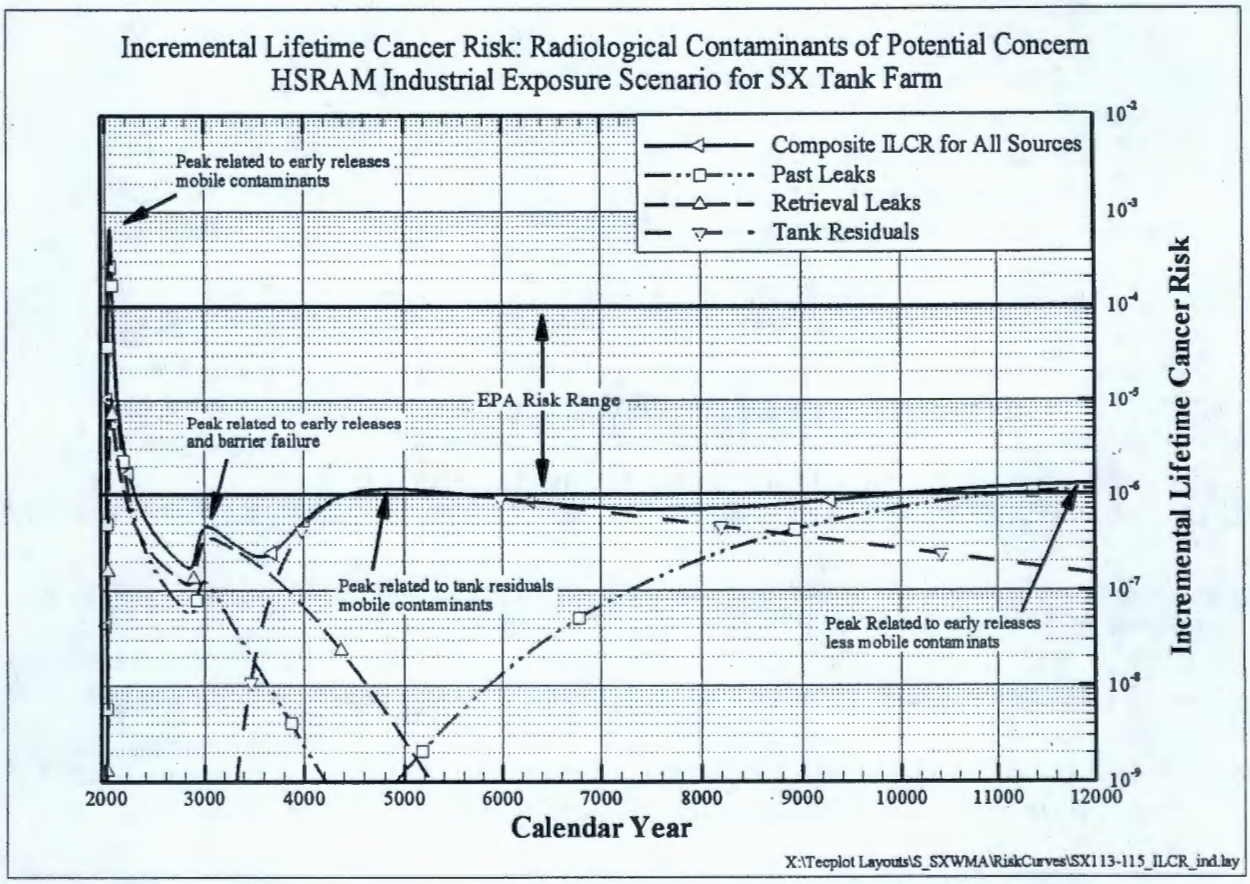
In the previous subsections, the exposure scenarios were presented for row of tanks that provided the maximum contribution at the WMA S-SX fenceline for each individual tank farm. This was done on tank row basis, since the plumes from each tank row do not mix minimally (Section 3.3) at the WMA S-SX fenceline. Therefore, each tank row will contribute separately to the exposure scenario at the WMA S-SX fenceline and the tank row with the maximum contribution was used to analyze the impact of past leaks, tank residuals, and potential retrieval leaks. In this section all sources along each individual row of tanks is analyzed to determine the cumulative impact of each tank farm within the WMA S/SX.

For example, the ILCR for the industrial exposure scenario is given as a function of time for tank row SX-113 to SX-115 in Figure 6-1. This tank row had the maximum impact for tank residuals (dashed line) at the WMA S-SX fenceline. The impacts of the individual tank residuals for tanks SX-113, SX-114, and SX-115 were summed to create a cumulative curve for this row. The same methodology was used to calculate the impacts from potential retrieval leaks (long dash line) and past leaks (dashdotdot line). Finally, all sources (tank residuals, potential retrieval leaks, and past leaks) were summed to provide a composite curve (solid line) from tank row SX-113 to SX-115 at the fenceline.

The curves for past tank leaks and potential retrieval leaks (i.e., early release from WMA), show a distinctive three-hump curve. The first peak arrives before (past leaks) or shortly after (potential retrieval leaks) the barrier is emplaced. The second peak arrives approximately 1,000 years into the future after the barrier has decayed, with the ILCR being 1 to 3 orders of magnitude less than the first peak. This indicates the placing of a barrier over the tank farm at closure will have a minimal impact at controlling the early releases. When there is a contaminant inventory with a higher $K_d$ associated with early releases (such as uranium), a third peak will appear as part of the early releases. The peak associated with uranium arrives at approximately 10,000 years into the future. The ILCR associated with tank residuals does not appear until approximately 1,500 years into the future and reaches a peak ILCR at approximately 3,000 years into the future, before slowly tapering off.

A composite curve (solid line) shows the total cumulative ILCR from all sources within a tank row and has four distinct peaks. The first peak is associated with the early release of mobile contaminants, the second smaller peak is associated with contaminants released after the barrier has degraded (approximately 1,000 years into the future), the third peak is associated tank residuals (approximately 3,000 years into the future), and the fourth peak is associated with the early release of less mobile contaminants (approximately 10,000 years in the future). Composite curves for each row of sources within the WMA have been prepared for each exposures scenario evaluated and include cumulative radiological ILCR for the HSRAM industrial and residential scenarios (Figures 6-2 and 6-3), cumulative HI for the HSRAM industrial and residential scenarios (Figures 6-4 and 6-5), and cumulative all pathways farmer radiological dose (EDE) (Figure 6-6).

Figure 6-1. ILCR over Time for Different Sources at Tank Row SX-113-SX-115.




The cumulative radiological HSRAM industrial ILCR contributed from all sources within the WMA is provided in Figure 6-2. The upper plot of Figure 6-2 is for S tank farm and the lower plot is for the SX tank farm. For S tank farm, the cumulative ILCR from all early releases (i.e., past leaks and potential retrieval leaks) are within the EPA risk range ($1.0 \times 10^{-6}$ to $1.0 \times 10^{-4}$). The ILCR from late releases (i.e., tank residuals) are slightly above lower EPA risk threshold of $1 \times 10^{-6}$. For SX tank farm, the cumulative ILCR from all early releases are above the EPA upper risk threshold of $1 \times 10^{-4}$. The cumulative ILCR from late releases are above the EPA lower risk threshold of $1 \times 10^{-6}$.

The cumulative radiological HSRAM residential ILCR contributed from all sources within the WMA is provided in Figure 6-3. The upper plot of Figure 6-2 is for S tank farm and the lower plot is for the SX tank farm. For S tank farm, the cumulative ILCR from all early releases are above the upper EPA risk threshold of $1 \times 10^{-4}$and several orders of magnitude above the WAC 173-340-740 risk threshold of $1 \times 10^{-6}$ for unrestricted land use. The cumulative ILCR from late releases are within EPA's risk range of $1 \times 10^{-4}$ to $1 \times 10^{-6}$. For SX tank farm, the cumulative ILCR from early releases are approximately 3 orders of magnitude above the EPA's upper risk threshold of $1 \times 10^{-4}$. The cumulative ILCR from late releases (i.e., tank residuals) are within EPA's risk range for all sources.

The cumulative HSRAM industrial HI contributed from all sources within the WMA is provided in Figure 6-4. The upper plot of Figure 6-4 is for S tank farm and the lower plot is for the SX tank farm. For S tank farm, the cumulative HI from early releases are approximately equal to the EPA and WAC 173-340-745 threshold value of 1.0. The cumulative HI from late releases are less than the EPA and WAC 173-340-745 threshold value of 1.0. For SX tank farm, the cumulative HI from all early releases are approximately 2 orders of magnitude above the EPA and WAC 173-340-745 threshold value of 1.0. The cumulative HI from late releases are below the EPA and WAC 173-340-745 threshold value of 1.0.

The cumulative HSRAM residential HI from all sources within the WMA is provided in Figure 6-5. The upper plot of Figure 6-5 is for S tank farm and the lower plot is for the SX tank farm. For S tank farm, the cumulative HI from early releases are an order of magnitude above the EPA and WAC 173-340-740 threshold value of 1.0. The cumulative HI from late releases are slightly below the EPA and WAC 173-340-745 threshold value of 1.0. For SX tank farm, the cumulative HI from all early releases are approximately 3 orders of magnitude above the EPA and WAC 173-340-745 threshold value of 1.0.

The cumulative total radiological dose (EDE) for the all pathways farmer contributed from all sources within the WMA are provided in Figure 6-6. The upper plot of Figure 6-6 is for S tank farm and the lower plot is for the SX tank farm. For S tank farm, the cumulative total dose from early and late releases is below the performance objective of 25 mrem/yr required by DOE O 435.1. For SX tank farm, the cumulative total dose from early releases is above the performance objective of 25 mrem/yr by approximately a factor of 30. The cumulative total dose from late releases are below the performance objective of 25 mrem/yr.

Figure 6-2. WMA S-SX Radioactive Incremental Lifetime Cancer Risk Composite Curves for the HSRAM Industrial Scenario on a Tank Row Basis.

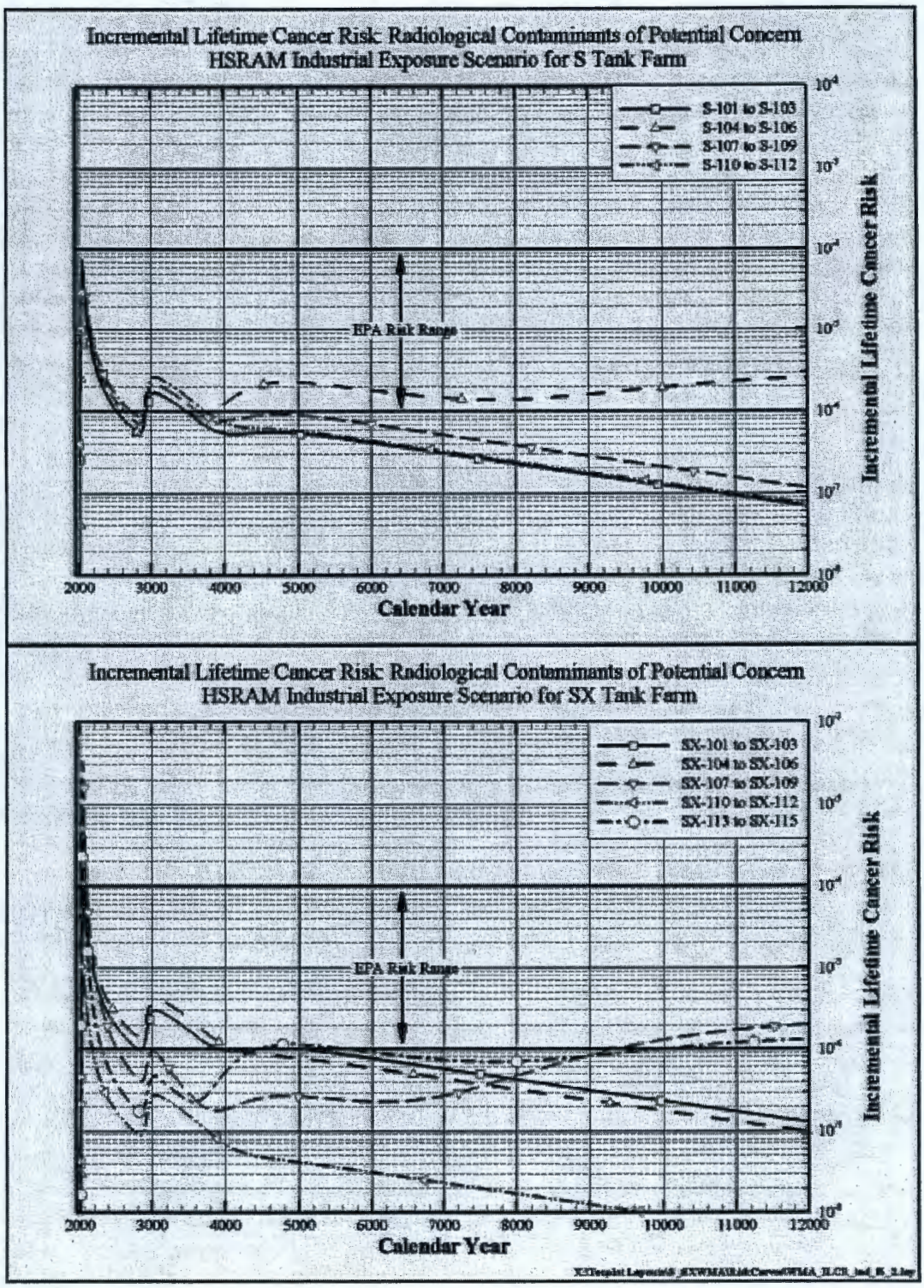
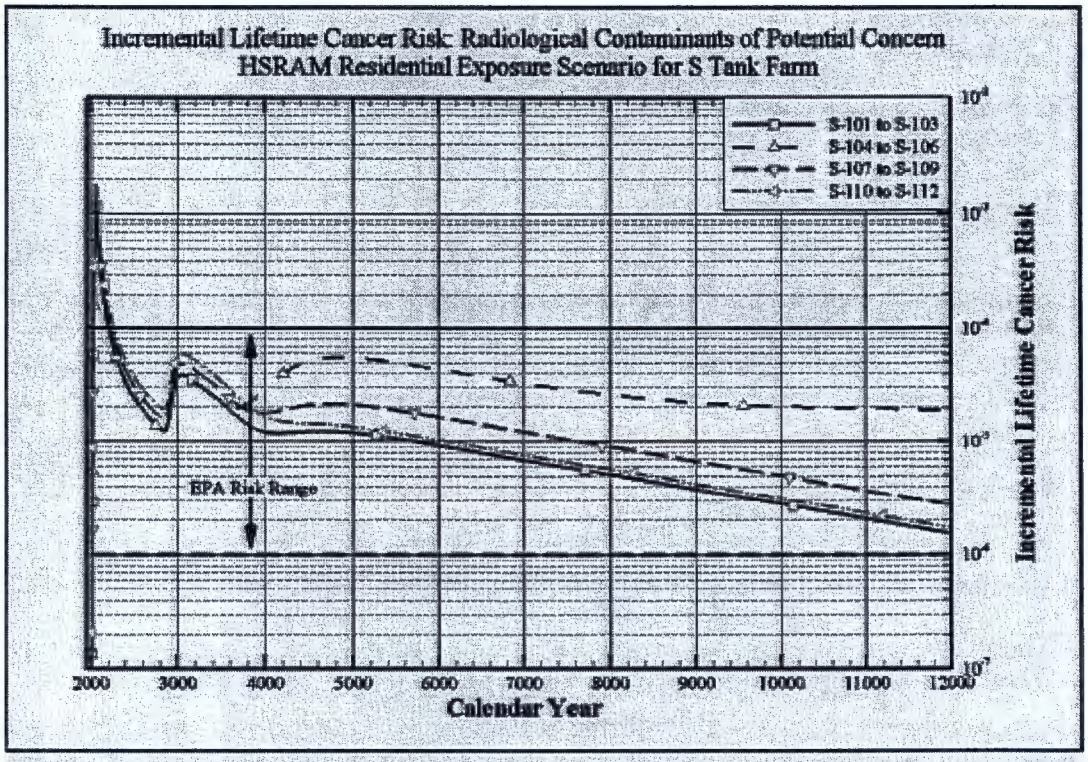


Figure 6-3. WMA S-SX Radioactive Incremental Lifetime Cancer Risk Composite Curves for the HSRAM Residential Scenario on a Tank Row Basis.



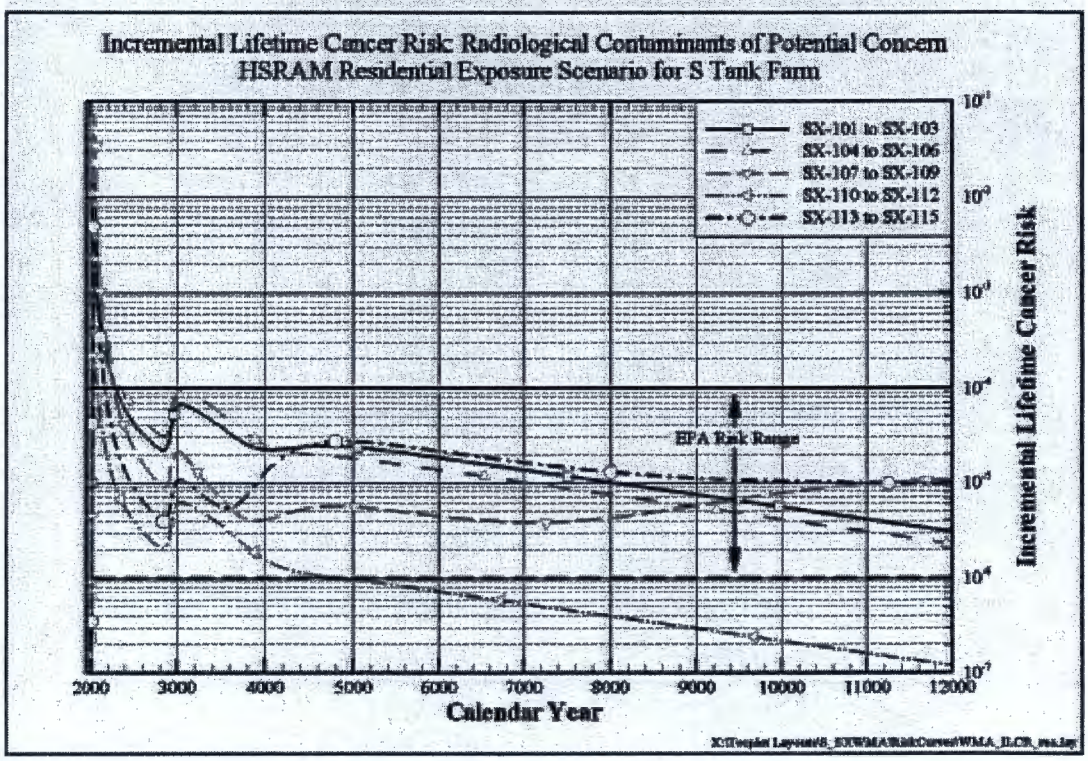



Figure 6-4. WMA S-SX Hazard Index Composite Curves for the HSRAM Industrial Scenario on a Tank Row Basis.

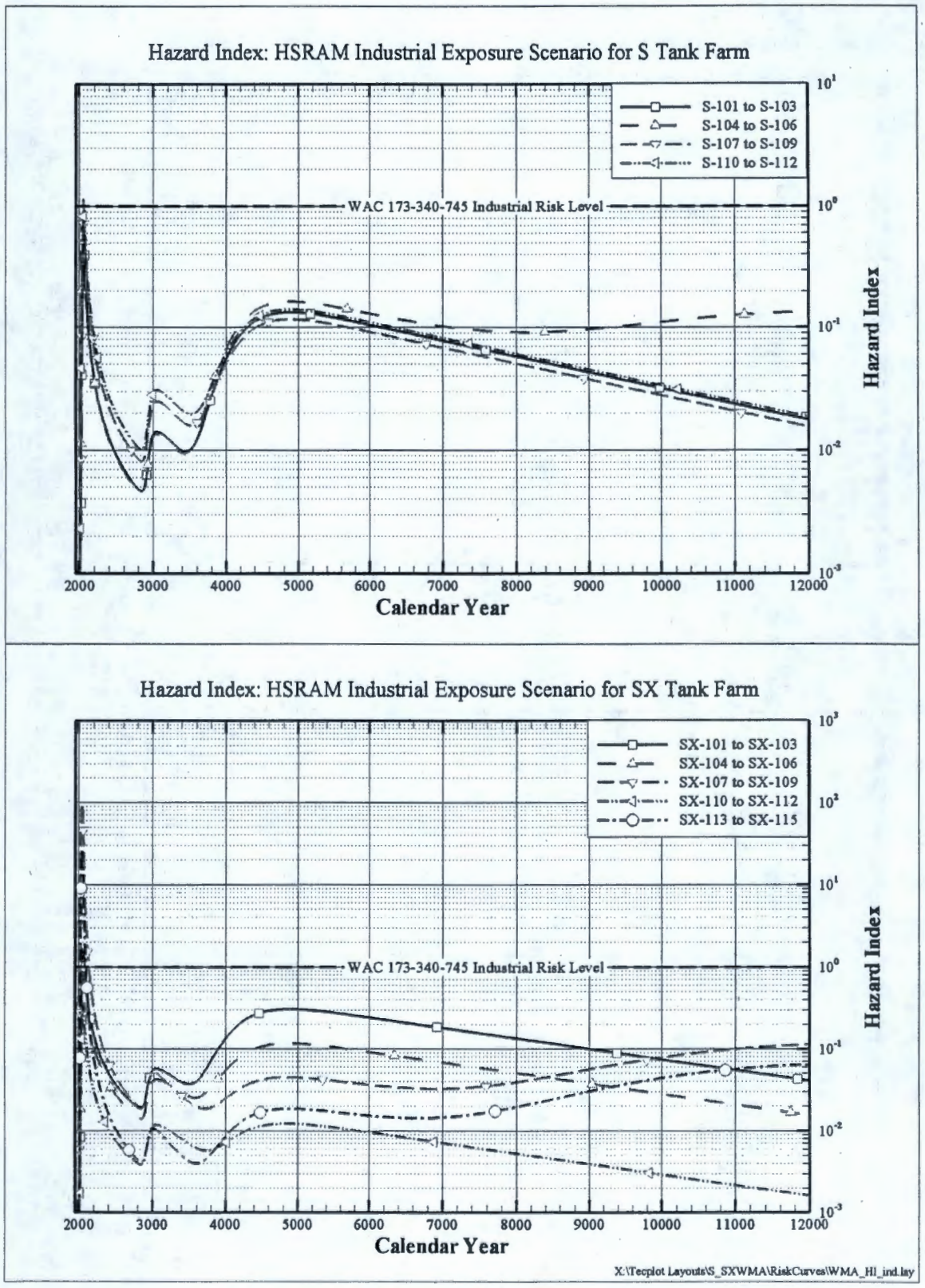


Figure 6-5. WMA S-SX Hazard Index Composite Curves for the HSRAM Residential Scenario on a Tank Row Basis.

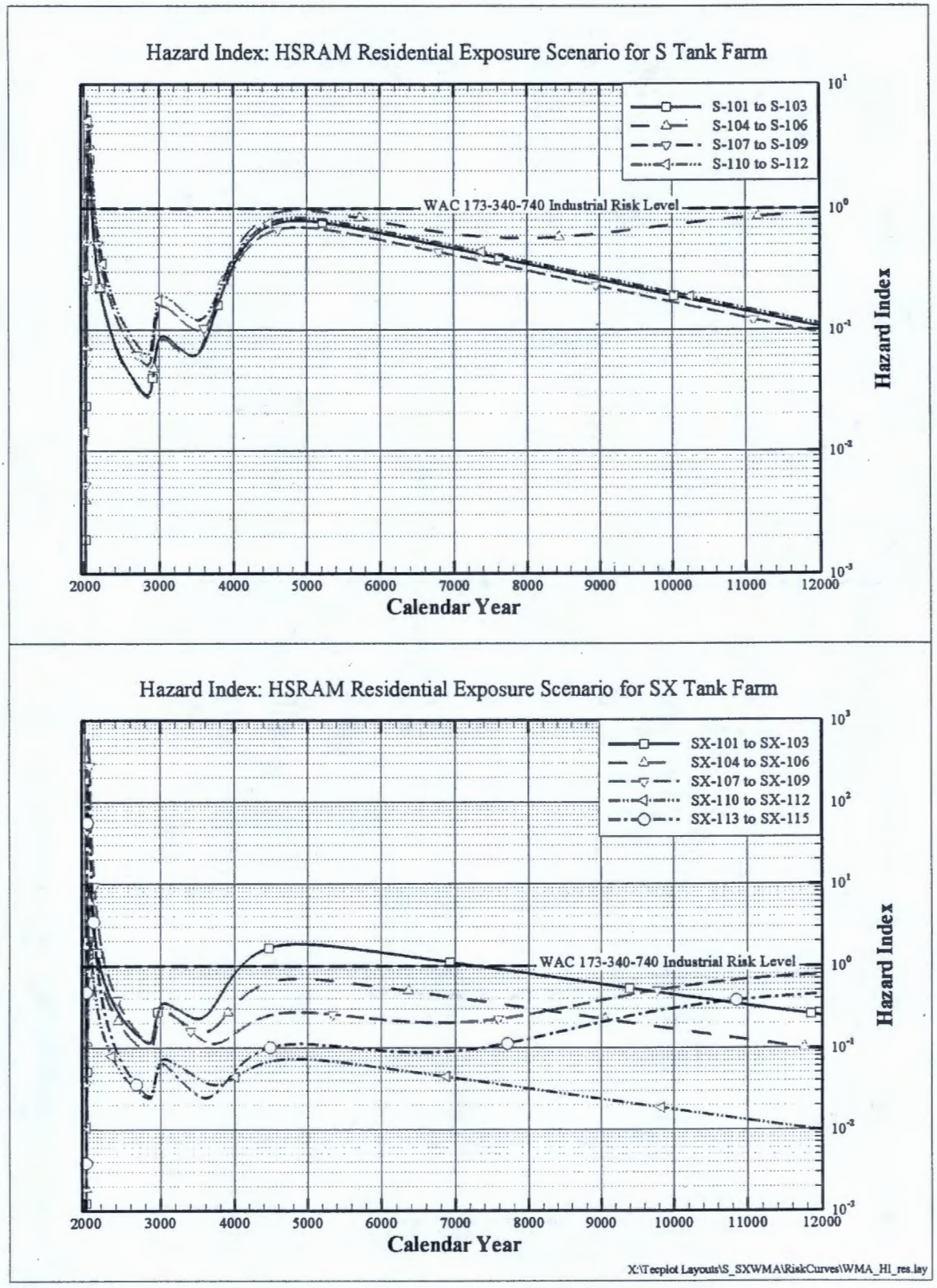
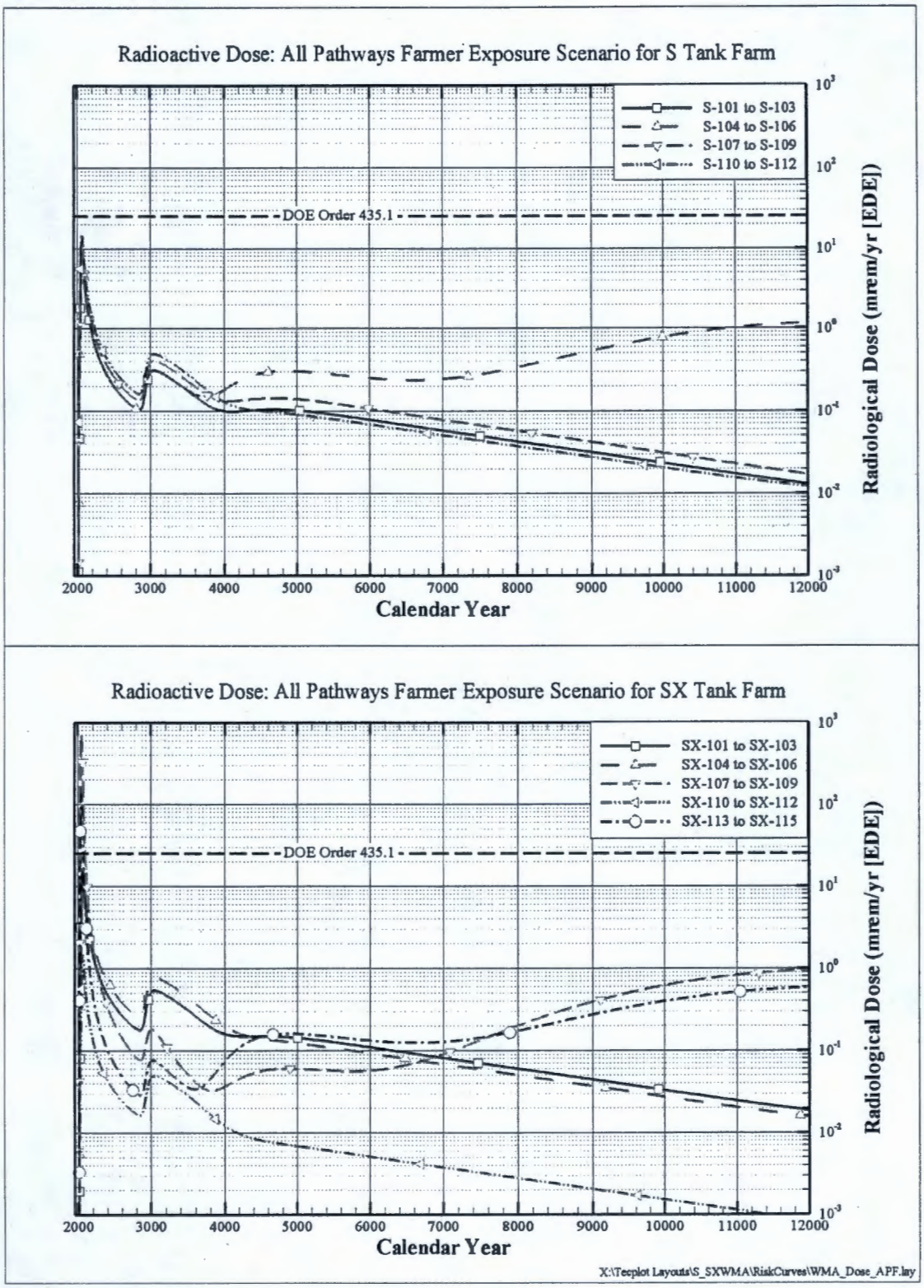


Figure 6-6. WMA S-SX Radiological Dose (EDE) Composite Curves for the All Pathways Farmer on a Tank Row Basis.



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# 7.0 LIMITATIONS AND UNCERTAINTIES

This risk assessment was developed to show the present understanding of the risks associated with closure of WMA S-SX as a landfill. However, significant limitations and uncertainties exist in this preliminary risk assessment of WMA S-SX. RPP-13774, Figure 4-2 conceptually shows how this uncertainty is addressed through a series of circles that represent uncertainty with the circles becoming smaller as more data is collected and the uncertainty about a parameter is reduced. Because this is a preliminary risk assessment, an understanding of this uncertainty is necessary when comparing the results of the risk assessment to the performance objectives. To address the uncertainty associated with the first iteration of the risk assessment, the parameters, for the most part, have been biased to yield higher risk and dose estimates. It is expected, that as retrieval progresses, new information will become available that will reduce the uncertainty associated with retrieval leaks. Table 7-1 lists the uncertainties associated with this risk assessment and how this uncertainty could impact the results.

Table 7-1. Uncertainties Associated with the Preliminary Risk Assessment Results. (6 sheets)

| Uncertainty | Uncertainty description | Impact on results (if known) |
|---|---|---|
| Best-Basis Inventory | All results are based on some derivation of the BBI. It is based on process knowledge with limited sampling, but it does not contain all contaminants of potential concern. | **UKNOWN** until post-retrieval sampling results confirm BBI. Additional COPCs will be analyzed[1]. |
| Best-Basis Inventory Updates | The BBI is presently undergoing a revision. The inventory used in this analysis was based on the current BBI, but scaled to the expected revision of the BBI scheduled to take place before the end of FY 2004. There could be a difference between scaling the current BBI and the actual BBI update. | **UNKNOWN** until actual revision and updated HTWOS runs are made. However, it is believed that there will be little impact to the tank residuals inventory and potential retrieval leaks. |
| HTWOS | Risk assessment uses retrieved inventory based on HTWOS projected inventory for salt cake tanks (Section 3.6.1). | **Base Case.** |
| **Inventory Uncertainty** | | |
| Simple Volume Ratio | Risk assessment uses retrieved inventory based on simple volume ratio (Section 3.6.1) instead of HTWOS (i.e., inventory for $^{99}$Tc is slightly lower for simple volume ratio). | **DECREASE/INCREASE →** The ILCR for residual tank waste will decrease or increase from the HTWOS estimate, depending on the change calculated for each contaminant's inventory. |
| Selected Phase Removal | Risk assessment uses residual inventory based on selected phase removal for sludge tanks.. | **DECREASE/INCREASE →** The residential ILCR risk for residual tank waste will decrease or increase from the HTWOS estimate, depending on the change calculated for each contaminant's inventory. |

Table 7-1. Uncertainties Associated with the Preliminary Risk Assessment Results. (6 sheets)

| Uncertainty | Uncertainty description | Impact on results (if known) |
|---|---|---|
| Pipeline Residuals | Risk assessment estimated the amount of inventory left in pipelines by calculating the number of linear feet of pipe and assumed that approximately 25% of it was blocked by waste (Section 3.6.1). | **UNKNOWN**, Part of the RFI/CMS process pipelines will be examined for residual waste[1]. |
| 8,000-gal Retrieval Leaks | Inventory used for retrieval leaks is calculated from concentrations supplied by HTWOS model runs based on either 5 molar sodium nitrate solution or 10 wt% solids (Section 3.6.1). | **Base Case.** Present results are believed to be highly conservative. It is likely that some tanks may not leak at all, and other tanks may leak more than 8,000 gal. It is expected that a number of the tanks will be equipped with a leak detection monitoring system, from which leak volume estimates will be made[1]. |
| 4,000 gal Retrieval Leak | Risk assessment uses a 8,000 gal leak for all S and SX tanks instead of 4,000 gal leak. | **DECREASE →** The residential ILCR for retrieval leaks will decrease by a factor of approximately 2.4 for most COPCs if the leak volume is decreased halved. |
| Unplanned Releases (or past leaks) | This risk assessment made estimates about the amount of contaminants lost through UPRs (either from tanks or from ancillary equipment). These estimates are documented in Section 3.6.1 and in RPP-15317. Estimates are based upon available data (processed records, borehole sampling and logging, etc.) Some UPRs have excellent records, but others do not. For those that have good records the inventory is probably correct; for those that do not, the inventory could be an order of magnitude off. | **Base Case.** Wells drilled and samples collected in WMA S-SX provide the data regarding the characteristics of past UPRs[1]. |
| **Release Mechanism Uncertainty** | | |
| Advection-Dominated Release Rate Model | In absence of characterization data for release models, an advection-dominated release model was used to simulate unstablized waste form covered with backfill and gravel, this would also cover a grout that fails completely. | **INCREASE →** The ILCR for residual tank waste will INCREASE by a factor of approximately 4.3 from the base case. |
| Diffusion-Dominated Release Rate Model | In absence of characterization data for release models, a diffusion-dominated release model was used to simulate a stabilized waste form covered with grout, assuming a diffusion coefficient of 6E-7 $cm^2/s$. | **Base Case.** Additional work is being done on evaluating diffusion-dominated release of grout. It is expected the diffusion coefficient will decrease with additional testing of grout. On the basis of modeling results at WMA C, reducing diffusion coefficient by a factor of 10 decreases ILCR by 20%[1]. |

Table 7-1. Uncertainties Associated with the Preliminary Risk Assessment Results. (6 sheets)

| Uncertainty | Uncertainty description | Impact on results (if known) |
|---|---|---|
| Solubility-Dominated Release Rate Model | In absence of characterization data for release models, a solubility-dominated release model was used to simulate dissolution of a stabilized saltcake waste form. It used a relatively high dissolution rate of 650 g/L in the tank solution, which is a rapid dissolution rate and comparable to the dissolution of a nitrate salt in water. Considerable uncertainty exists with the solubility-limited release model and its applicability to tank waste releases, as well as the dissolution rate values to use in contaminant migration analyses. | **INCREASE →** The ILCR for residual tank waste will INCREASE by a factor of approximately 4.3 from the base case. |
| Uniform Release Rate Model | In absence of characterization data for release models, a uniform release model was used to simulate the waste form. The release occurs at a uniform rate during two distinct release periods: $10^{-6}$ Ci/yr for 500 years and then $10^{-4}$ Ci/yr for 995 years. | **DECREASE →** The ILCR for residual tank waste will DECREASE by a factor of approximately 2 from the base case. |
| Steel Liner Longevity | Risk assessment for conservative purposes assumes the steel liner and surrounding grout instantaneously fail in the year 2050. It is likely, the steel liner would last much longer. | **Base Case.** If deemed necessary, then work needs to be developed that addresses the decomposition of the steel liner for residual waste. |
| Release Mechanism for Contaminants from Residual Waste | The risk assessment assumes the waste is not strongly bound to the solid matrix and all of it is available for transport. | **UNKNOWN/DECREASE →** Preliminary results from other tank farms indicate that the release of technetium and other mobile contaminants from the waste is much slower than previously believed. Work is ongoing and will cover additional contaminants of concern[1]. |
| Modified RCRA Subtitle C Barrier | This barriers design life is 500 years (Section 3.2.1) at which time it instantaneously fails. It is likely that the barrier would degrade slowly over time. | **UNKNOWN →** Barrier could either degrade faster or last longer than the design life. |
| Recharge Rates | The model used recharge rates of 3.5 mm/yr (pre-Hanford) 100 mm/yr (Hanford Operational Period), 0.5 mm/yr (barrier design life for 500 years), 3.5 mm/yr (post-barrier). According to PNNL-13033, recharge should be 0.9 mm/yr (pre-Hanford) 60 mm/yr (Hanford Operational Period), 0.1 mm/yr (barrier design life for 500 years), 0.9 mm/yr (post-barrier). | **DECREASE →** similar analysis for the B-BX-BY Field Investigation Report indicates lowering the recharge rate by one-half reduces the risk by one-half. Additional sensitivity cases may be made to show the impact of varying recharge rates[1]. |

Table 7-1. Uncertainties Associated with the Preliminary Risk Assessment Results. (6 sheets)

| Uncertainty | Uncertainty description | Impact on results (if known) |
|---|---|---|
| Hydraulic Conductivity of the Unconfined Aquifer | Reported modeling results use a hydraulic conductivity of 25 m/day. This value is based on PNNL-13447 and is consistent with the PNNL SAC model. Hydraulic conductivity values based on slug tests performed in WMA S-SX wells 299-W22-48, 299-W22-49, and 299-W22-50 range from 1.15 to 8.2 m/day (0.5 to 27 ft/day) (PNNL-13441). | **Base Case.** On the basis of sensitivity analysis conducted at WMA C, increasing the hydraulic conductivity by a factor of 10 decreased the concentrations by approximately same amount (i.e, going from 50 to 1,000 m/d decrease the concentration by a factor of 18.5)[1]. |
| Groundwater flow direction | Reported modeling results assume an east-west flow from the 200 West Area to the Columbia River. However, there is a possibility that some water may flow through the Gable Mtn Gap to the north. | **DECREASE/INCREASE →** If the flow field changes and there is some, but not all the flow going through the gap, the likely impact will be to reduce the concentrations. |
| Impacts from other facilities | This analysis did not address impacts from other facilities upgradient (such as the S-25 crib) or downgradient sources. That analysis is being completed as part of the composite analysis. | **INCREASE →** Additional source terms would provide more inventory to the groundwater. This will be analyzed as part of the composite analysis due out FY 2005. |
| 2-D Modeling vs. 3-D Modeling Results at the Fenceline | To account for the 3-D aspects, the calculated 2-D fenceline concentration was scaled by dividing by 40 on the basis of comparing 3-D and 2-D modeling results. | **Base Case.** |
| Analytical Stream tube Model at Downgradient Evaluation Points | To evaluate concentrations as points located beyond the WMA S-SX fenceline, movement of the contaminant plume was simulated using the analytical solution of the equation in Domenico and Schwart (1990). | **Base Case.** |

Table 7-1. Uncertainties Associated with the Preliminary Risk Assessment Results. (6 sheets)

| Uncertainty | Uncertainty description | Impact on results (if known) |
|---|---|---|
| Sitewide Groundwater Model at Downgradient Evaluation Points | To evaluate concentrations as points located beyond the WMA S-SX fenceline, movement of the contaminant plume was simulated using the 3-D Hanford Sitewide Groundwater Model (PNNL-11801, PNNL-13447) | **DECREASE/INCREASE →** Downgradident concentrations calculated using the SGM were about a factor of 2.8 less at the exclusion boundary and 1.7 less at the Columbia River than the analytical stream tube solution for the 8000-gal retrieval leak case. For the solubility-limited release case, the downgradident concentrations calculated using the SGM were about a factor of 2.8 less at the Exclusion Boundary, but about a factor 1.4 larger than the analytical stream tube solution at the Columbia River. |
| **Chemical Uncertainty** | | |
| Bulk Distribution Coefficients | Bulk distribution coefficient determine how well a contaminant adsorbs onto the soil. This risk assessment used a bulk distribution coefficient of 0.0 mL/g for all identified COPCs except uranium for uranium it used 0.6 mL/g. This report used a conservative value for constituents such as iodine-129 ($K_d$ = 0.0 mL/g, range 0.0 to 2.0 mL/g), and neptunium-237 ($K_d$ = 2.0 mL/g, range 2.0 to 30.0 mL/g). Reported $K_d$s and ranges are from *Hanford Contaminant Distribution Coefficient Database and User's Guide* (PNNL-13895). | **DECREASE →** since all identified COPCs except uranium were modeled with a $K_d$ = 0.0 mL/g would reduce the impact for those contaminants.<br>**INCREASE/DECREASE →** for uranium, PNNL-13895 recommends using a range from 0.2 to 4. Therefore, the impacts due to uranium could increase if a lower $K_d$ is used. Future iterations of this risk assessment will examine different $K_d$ for uranium[(1)]. |
| Chromium | This risk assessment assumed all chromium was $Cr^{+6}$. $Cr^{+6}$ was analyzed because it provides the greatest risk for ILCR. However, only the slope factors for inhalation are available, chromium is assumed to be inhaled through fugitive dust. | **DECREASE →** If all chromium is trivalent chromium, then chromium would be evaluated only as a non-carcinogen. |
| **Exposure Scenario Uncertainty** | | |
| Risk Parameters | Uncertainty is associated with the exposure assumptions used to estimate risk or dose from each exposure scenario. These other inputs might include various models (e.g., food chain model, toxicokinetic model) and model parameters (e.g., food chain transfer factors, exposure factors, dose factors, risk factors). | **UNKNOWN →** These inputs are applied after prediction of groundwater concentrations and are not trivial. |

Table 7-1. Uncertainties Associated with the Preliminary Risk Assessment Results. (6 sheets)

| Uncertainty | Uncertainty description | Impact on results (if known) |
|---|---|---|
| Exposure Scenarios | Section 6.0 provides the results for each exposure scenarios. All pathways farmer are representative (average) individuals. The Native American represents a bounding individual. Numerous variations of these basic exposure scenarios are possible. | **VARIES GREATLY→** The radionuclide ILCR for resident scenario for tank residual waste is factor of 22 higher than the industrial scenario, while the Native American scenario is a factor of 15 over the residential scenario. |

Notes:

(1) Indicates ongoing work either laboratory, modeling or field analysis to reduce the radius of uncertainty given in RPP-13774, Figure 4-2.

BBI = best-basis inventory.
COPC = contaminants of potential concern.
HTWOS = Hanford Tank Waste Operation Simulator.
ILCR = incremental lifetime cancer risk.
PNNL = Pacific Northwest National Laboratory
RCRA = *Resource Conservation and Recovery Act of 1976.*
RFI/CMS = Remedial Field Investigation/Corrective Measures Study.
SAC = System Assessment Capability.
SGM = Sitewide Groundwater Model.
UPR = unplanned release.
WMA = Waste Management Area.

Domenico, P. A. and F. W. Schwartz, 1990, *Physical and Chemical Hydrogeology,* John Wiley. New York, New York.

PNNL-11801, 1997, *Three-Dimensional Analysis of Future Groundwater Flow Conditions and Contaminant Plume Transport in the Hanford Site Unconfined Aquifer System: FY 1996 and 1997 Status Report,* Pacific Northwest National Laboratory, Richland, Washington.

PNNL-13033, 1999, *Recharge Data Package for the Immobilized Low-Activity Waste 2001 Performance Assessment,* Pacific Northwest National Laboratory, Richland, Washington.

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# 8.0 SUMMARY AND CONCLUSIONS OF WMA S-SX RISK ASSESSMENT

This section presents the summary and conclusions of the WMA S-SX risk assessment. Risk and dose contributed from past leaks, residual waste, potential retrieval leaks, and the pipe system were evaluated for each tank farm. Risk and dose estimates were estimated only for the year that the peak groundwater concentration occurs.

Risk to offsite receptors was estimated using the HSRAM industrial and HSRAM residential exposure scenarios and dose to offsite receptors was estimated using the all pathways farmer exposure scenario. Each scenario estimates potential human health impacts from exposure to radiological and nonradiological COPCs. Additionally, groundwater concentrations were compared to the national primary drinking water standards, as codified in 40 CFR 141. The resulting risk and dose estimates were then compared to appropriate performance objectives (Section 6.1). Risk and dose were also estimated at locations downgradient from WMA S-SX including the proposed core zone boundary and the Columbia River. Finally, cumulative effects from all source terms were evaluated.

## 8.1 SUMMARY OF RISK ESTIMATES FOR THE HSRAM INDUSTRIAL AND RESIDENTIAL SCENARIOS

### 8.1.1 HSRAM Industrial Scenario

**S Tank Farm.** The radiological ILCR from past leaks, residual tank waste, and the S tank farm pipe system was either less than the lower EPA threshold value of $1 \times 10^{-6}$ (pipe system) or within the EPA risk range of $1 \times 10^{-4}$ to $1 \times 10^{-6}$ (past leaks, retrieval leaks, and residual tank waste) (Table 6-1).

The nonradiological ILCR from each source evaluated was either less than the lower EPA threshold value of $1 \times 10^{-6}$ (potential retrieval leaks, residual tank waste, and pipe system) or within the EPA risk range of $1 \times 10^{-4}$ to $1 \times 10^{-6}$ (past leaks) and did not exceed the threshold value of $1 \times 10^{-5}$ recommended in WAC 173-340-745 for industrial land use. The HI reported from each source evaluated was less than the EPA and WAC recommended threshold value of 1 (Tables 6-2 and 6-3).

**Locations Downgradient from S Tank Farm.** The radiological and nonradiological ILCR from each source and each downgradient location evaluated is less than the EPA lower risk threshold of $1 \times 10^{-6}$ and is less that the threshold value of $1 \times 10^{-5}$ recommended in WAC 173-340-745 for industrial land use. Additionally, the HI from each source and each downgradient location evaluated are less than the EPA and WAC recommended threshold value of 1 (Table 6-19).

**SX Tank Farm.** The radiological and nonradiological ILCR from residual tank waste and the SX tank farm pipe system was either less than the lower EPA threshold value of $1 \times 10^{-6}$ (pipe

system) or within the EPA risk range of $1 \times 10^{-4}$ to $1 \times 10^{-6}$ (residual tank waste) (Tables 6-4 and 6-5).

For past leaks, the radiological ILCR from both soil and water at year 2046 is $3.4 \times 10^{-3}$ and the nonradiological ILCR from soil is $2.9 \times 10^{-4}$. The primary contributors to ILCR include $^{99}Tc$, $^{129}I$, $^{14}C$, and $Cr^{+6}$. For potential retrieval leaks, the radiological ILCR from both soil and water at year 2060 is $1.3 \times 10^{-4}$ and the nonradiological ILCR from soil is $4.2 \times 10^{-6}$. The primary contributors to risk include $^{99}Tc$, $^{129}I$, and $Cr^{+6}$. The ILCR reported for past leaks and potential retrieval leaks are either greater than the EPA upper risk threshold of $1 \times 10^{-4}$ (radiological constituents) or within the EPA risk range of $1 \times 10^{-4}$ to $1 \times 10^{-6}$ (nonradiological constituents) and are greater than the threshold value of $1 \times 10^{-5}$ recommended in WAC 173-340-745 for industrial land use.

The HI reported from residua tank waste and the SX tank farm pipe system were less than the EPA and WAC recommended threshold value of 1. For past leaks, the HI reported from soil and water exposure pathways is 96; the primary contributors include Cr, $NO_2$, and $NO_3$. For potential retrieval leaks, the HI reported from the water and soil exposure pathways is 1.7; the primary contributor is $Cr^{+6}$ (Table 6-6).

**Locations Downgradient from SX Tank Farm.** The radiological and nonradiological ILCR from each source and each downgradient location evaluated is less than the EPA lower risk threshold of $1 \times 10^{-6}$ and is less that the threshold value of $1 \times 10^{-5}$ recommended in WAC 173-340-745 for industrial land use. Additionally, the HI from each source and each downgradient location evaluated is less than the EPA and WAC recommended threshold value of 1 (Table 6-19).

### 8.1.2 HSRAM Residential Scenario

**S Tank Farm.** For residual tank waste and the S tank farm pipe system, the radiological ILCR is within the EPA risk range of $1 \times 10^{-4}$ to $1 \times 10^{-6}$ (Table 6-7).

For residual tank waste and the S tank farm pipe system, the nonradiological ILCR is either less than (pipe system) or slightly greater than (residual tank waste) the EPA lower risk threshold value of $1 \times 10^{-6}$ and is less than or slightly greater than the threshold value of $1 \times 10^{-6}$ recommended in WAC 173-340-740 for unrestricted land use (Table 6-8).

For past leaks and potential retrieval leaks, the ILCR for radiological constituents is greater than the EPA upper risk threshold of $1 \times 10^{-4}$, the ILCR for nonradiological constituents is within the EPA risk range of $1 \times 10^{-4}$ to $1 \times 10^{-6}$, and both are greater than the threshold value of $1 \times 10^{-6}$ recommended in WAC 173-340-740 for unrestricted land use. For past leaks, the radiological ILCR from both soil and water at year 2046 is $2.8 \times 10^{-4}$ and the nonradiological ILCR from soil is $2.5 \times 10^{-6}$. For potential retrieval leaks, the radiological ILCR from both soil and water at year 2060 is $1.8 \times 10^{-3}$ and the nonradiological ILCR from soil is $5.3 \times 10^{-6}$. The primary contributors to ILCR from both past and potential retrieval leaks include $^{99}Tc$, $^{129}I$, $^{14}C$, and $Cr^{+6}$.

The HI reported for residual tank waste and the S tank farm pipe system was less than the EPA and WAC recommended threshold value of 1. For past leaks, the HI reported from the soil and water exposure pathways is 7.3; the primary contributors are $Cr^{+6}$ and $NO_2$ For potential retrieval leaks, the HI reported from the water and soil exposure pathways is 5.7; the primary contributors are $Cr^{+6}$ and $NO_2$ (Table 6-9).

**Locations Downgradient from S Tank Farm.** The radiological and nonradiological ILCR from each source and each downgradient location evaluated is less than the EPA lower risk threshold of $1 \times 10^{-6}$ and is less that the threshold value of $1 \times 10^{-6}$ recommended in WAC 173-340-740 for unrestricted land use. Additionally, the HI from each source and each downgradient location evaluated is less than the EPA and WAC recommended threshold value of 1 (Table 6-20).

**SX Tank Farm.** For residual tank waste, the radiological and nonradiological ILCR is within the EPA risk range of $1 \times 10^{-4}$ to $1 \times 10^{-6}$ and the nonradiological ILCR is greater than the threshold value of $1 \times 10^{-6}$ recommended in WAC 173-340-740 for unrestricted land use. The primary contributors to risk include $^{99}Tc$ and $Cr^{+6}$ (Tables 6-10 and 6-11).

For the SX tank farm pipe system, the radiological ILCR is within the EPA risk range of $1 \times 10^{-4}$ to $1 \times 10^{-6}$ and the nonradiological ILCR is less than the EPA lower risk threshold value of $1 \times 10^{-6}$; only the radiological ILCR is greater than the threshold value of $1 \times 10^{-6}$ recommended in WAC 173-340-740 for unrestricted land use. The primary contributor to risk is $^{99}Tc$ (Tables 6-10 and 6-11).

For past leaks, the ILCR for radiological and nonradiological constituents is greater than the EPA upper risk threshold of $1 \times 10^{-4}$ and the nonradiological ILCR is greater than the threshold value of $1 \times 10^{-6}$ recommended in WAC 173-340-740 for unrestricted land use. The radiological ILCR from both soil and water at year 2046 is $7.3 \times 10^{-2}$ and the nonradiological ILCR from soil is $6.7 \times 10^{-4}$. The primary contributors to risk include $^{99}Tc$, $^{129}I$, $^{14}C$, and $Cr^{+6}$ (Tables 6-10 and 6-11).

For potential retrieval leaks, the ILCR for radiological constituents is greater than the EPA upper risk threshold of $1 \times 10^{-4}$, the ILCR for nonradiological constituents is within the EPA risk range of $1 \times 10^{-4}$ to $1 \times 10^{-6}$, and is greater than the threshold value of $1 \times 10^{-6}$ recommended in WAC 173-340-740 for unrestricted land use. The radiological ILCR from both soil and water at year 2060 is $2.8 \times 10^{-3}$ and the nonradiological ILCR from soil is $9.8 \times 10^{-6}$. The primary contributors to risk include $^{99}Tc$, $^{129}I$, $^{14}C$, and $Cr^{+6}$ (Tables 6-10 and 6-11).

The HI reported for the SX tank farm pipe system is less than the EPA and WAC recommended threshold value of 1. For past leaks, residual tank waste, and potential retrieval leaks, the HI reported from the soil and water exposure pathways is 587, 1.8, and 10, respectively. The primary contributors include $Cr^{+6}$ (all sources), $NO_2$ (past leaks and potential retrieval leaks), and $NO_3$ (past leaks) (Table 6-12).

**Locations Downgradient from SX Tank Farm.** With the exception of radiological risk from past leaks at the core zone boundary and the Columbia River, the radiological and nonradiological ILCR from each source and each downgradient location evaluated are less than

the EPA lower risk threshold of $1 \times 10^{-6}$ and is less that the threshold value of $1 \times 10^{-6}$ recommended in WAC 173-340-740 for unrestricted land use. Radiological risk from past leaks at the core zone boundary and the Columbia River are within the EPA risk range of $1 \times 10^{-4}$ to $1 \times 10^{-6}$ and are greater than the threshold value of $1 \times 10^{-6}$ recommended in WAC 173-340-740 for unrestricted land use. Additionally, the HI from each source and each downgradient location evaluated are less than the EPA and WAC recommended threshold value of 1 (Table 6-20).

## 8.2 SUMMARY OF DOSE ESTIMATES FOR THE ALL PATHWAYS FARMER SCENARIO

**S Tank Farm.** The total EDE dose from both soil and water for each source evaluated is less than the threshold value of 25 mrem/yr for representative members of the public (Table 6-13).

**SX Tank Farm.** With the exception of past leaks, the total EDE dose from soil and water for each source evaluated were less than the threshold value of 25 mrem/yr for representative members of the public (Table 6-14).

For past leaks, a total EDE dose of 702 mrem/yr was reported from both soil and water and greater than the DOE recommended threshold value of 25 mrem/yr for representative members of the public. The primary contributors to dose are $^{99}Tc$, $^{129}I$, and $^{14}C$.

**Locations Downgradient from WMA S-SX.** The total EDE dose from each source and each downgradient location evaluated are less than the threshold value of 25 mrem/yr for representative members of the public (Table 6-21).

## 8.3 COMPARISON TO MAXIMUM CONTAMINANT LEVELS

**S Tank Farm.** For radiological constituents, only $^{129}I$ and $^{99}Tc$ groundwater concentrations from past leaks and $^{129}I$ groundwater concentrations from potential retrieval leaks were above the MCL-derived concentration. All remaining concentrations of radiological constituents were below their respective MCL-derived concentration. For nonradiological constituents, all concentrations from each source evaluated were less their respective MCL (Table 6-16).

**SX Tank Farm.** For past leaks, all radiological groundwater concentrations were greater than their respective MCL-derived concentration and Cr, $NO_3$, and $NO_2$ groundwater concentrations were greater than their respective MCLs. For residual tank waste and the SX tank farm pipe system, all radiological and nonradiological groundwater concentrations were less than respective MCL-derived concentration or MCL, respectively. For potential retrieval leaks, concentrations of $^{99}Tc$, $^{129}I$, Cr, and $NO_2$ in groundwater were greater than their respective MCL-derived concentration or MCLs, respectively (Table 6-17).

## 8.4 CUMULATIVE EFFECTS OF ALL SOURCE TERMS

Cumulative effects of all source terms at the WMA S-SX fenceline were evaluated by identifying the tank row with the maximum contribution from an individual source. For the industrial exposure scenario, retrieval leaks and past leaks were evaluated to show a distinctive three-hump curve (Figure 6-1). The first peak arrives before the barrier is emplaced (past leaks), the second peak arrives approximately 1,000 years into the future (after the barrier has decayed), and a third peak arrives approximately 10,000 years into the future (associated with early releases). This indicates that the placement of a barrier over the tank farm at closure will have a minimal impact at controlling the early releases of contaminants. For tank waste residuals, the impacts do not start appearing until approximately 1,500 years into the future and reaches a peak approximately 3,000 years into the future, before slowly tapering off.

A composite curve was generated showing the total cumulative risk from all sources within a tank row. Four distinct peaks are associated with a composite curve, the first peak is associated with the early release of mobile contaminants followed by a much smaller second peak arriving approximately 1,000 years into the future. A third peak arrives approximately 3,000 years into the future, which is associated with residual tank waste, and finally the fourth curve is associated with the early releases of less mobile contaminants (Figures 6-2 through 6-6).

This analysis shows that past leaks and potential retrieval leaks have the greatest impact to the unconfined aquifer. Furthermore, the results of this analysis are consistent with the reports of Field Investigation Report for the Waste Management Area S-SX (RPP-7884). In that report, the following was recommended:

"A possible accelerated interim measure would be the placement of interim barriers. Numerical simulation results summarized in Section 4.2 (RPP-7884) suggest that compared to the no action alternative, placement of an interim surface barrier provides very little reduction in peak concentrations for mobile contaminants. It is premature to implement additional interim measures such as an interim surface barrier until the impact of capping water lines and run-on and run-off barriers can be ascertained and documented. If closure of the tank farms is delayed, safety issues associated with an interim barrier that could increase exposure to workers during waste retrieval efforts must be balanced against long-term environmental concerns. An engineering study for placing an interim surface barrier on tank farms should be conducted to determine the costs and impacts on tank farm operations and waste retrieval actions."

This report concurs with the recommendations given in RPP-7884.

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# APPENDIX A

# NATIVE AMERICAN EXPOSURE SCENARIO

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## RISK ESTIMATES FOR THE NATIVE AMERICAN SUBSISTENCE SCENARIO

This section provides the risk estimates for the Native American subsistence exposure scenario at S tank farm and SX tank farm. Risk estimates are provided only for the year which the peak groundwater concentration occurs. Summary tables showing radiological incremental lifetime cancer risk (ILCR), nonradiological ILCR and the hazard index (HI), primary contaminants of potential concern (COPC) contributing to the risk estimate, and primary exposure pathway for each source term follow the tank farm discussion.

### S TANK FARM

**Past Leaks**. A summary of radiological risk estimates from past leaks is provided in Table A-1. The radiological ILCR from both soil and water at year 2046 is $4.1 \times 10^{-3}$. The primary contributors to ILCR include $^{99}Tc$ ($3.6 \times 10^{-3}$; 88% contribution), $^{129}I$ ($1.3 \times 10^{-4}$ 3% contribution), and $^{14}C$ ($1.2 \times 10^{-4}$; 2% contribution). The ILCR for past leaks is greater than the U.S. Environmental Protection Agency (EPA) upper risk threshold of $1 \times 10^{-4}$.

A summary of the nonradiological risk estimates and HIs are provided in Tables A-2 and A-3, respectively. The nonradiological ILCR from soil at year 2046 is $3.7 \times 10^{-6}$. The ILCR reported for past leaks is within the EPA risk range of $1 \times 10^{-4}$ to $1 \times 10^{-6}$. The HI reported from the soil and water exposure pathways is 6.1, which is greater than the EPA and *Washington Administrative Code* (WAC) recommended threshold value of 1. The primary contributor to the HI is nitrite (hazard quotient [HQ]=1.7), chromium (HQ=1.6), and nitrate (HQ=1.0) from the water ingestion pathway.

**Residual Tank Waste**. A summary of radiological risk estimates from residual tank waste is provided in Table A-1. The radiological ILCR from both soil and water at year 4902 is $7.6 \times 10^{-4}$. The primary contributors to ILCR include $^{99}Tc$ ($7.6 \times 10^{-4}$; > 99% contribution) and $^{129}I$ ($2.3 \times 10^{-6}$; 0.3% contribution). The ILCR for residual tank waste is greater than the EPA upper risk threshold of $1 \times 10^{-4}$.

A summary of the nonradiological risk estimates and HIs are provided in Tables A-2 and A-3, respectively. The nonradiological ILCR from soil at year 4092 is $2.1 \times 10^{-6}$. The ILCR reported for past leaks is slightly greater than the EPA lower risk threshold of $1 \times 10^{-6}$ and is slightly greater than the threshold value of $1 \times 10^{-6}$ recommended in WAC 173-340-740 for unrestricted land use. The HI reported from the water and soil exposure pathways is 1.1, which is slightly greater than the EPA and WAC recommended threshold value of 1. No individual constituents are reported with an HQ greater than the threshold value of 1.

**Potential Retrieval Leaks**. A summary of radiological risk estimates from potential retrieval leaks is provided in Table A-1. The radiological ILCR from both soil and water at year 2060 is $2.5 \times 10^{-2}$. The primary contributors to ILCR include $^{99}Tc$ ($2.4 \times 10^{-2}$, 96% contribution), $^{129}I$ ($7.0 \times 10^{-4}$; 3% contribution), and $^{14}C$ ($4.0 \times 10^{-4}$; 2% contribution). The ILCR reported for potential retrieval leaks is greater than the EPA upper risk threshold of $1 \times 10^{-4}$.

A summary of the nonradiological risk estimates and HIs are provided in Tables A-2 and A-3, respectively. The nonradiological ILCR from soil at year 2060 is 7.9 x $10^{-6}$ (chromium 100% contribution). The ILCR reported for potential retrieval leaks is within the EPA risk range of 1 x $10^{-4}$ to 1 x $10^{-6}$ and is greater than the threshold value of 1 x $10^{-6}$ recommended in WAC 173-340-740 for unrestricted land use. The HI reported from the water and soil exposure pathways is 5.7, which is greater than the EPA and WAC recommended threshold value of 1. The primary contributors to the HI include chromium (HQ=3.4) and nitrite (HQ=1.0) from the water ingestion pathway. No other constituents are reported with an HQ greater than the threshold value of 1.

**S Tank Farm Pipe System**. A summary of radiological risk estimates for the pipe system is provided in Table A-1. The radiological ILCR from both soil and water at year 4177 is 1.6 x $10^{-4}$. The primary contributors to ILCR include $^{99}$Tc (1.5 x $10^{-4}$, 93% contribution), $^{129}$I (6.1 x $10^{-6}$; 4% contribution), and $^{14}$C (5.9 x $10^{-6}$; 4% contribution). The ILCR reported for potential retrieval leaks is greater than the EPA risk threshold of 1 x $10^{-4}$.

A summary of the nonradiological risk estimates and HIs are provided in Tables A-2 and A-3, respectively. The nonradiological ILCR from soil at year 4177 is 7.2 x $10^{-8}$. The ILCR reported for the pipe system is less than the EPA lower risk threshold of 1 x $10^{-6}$ and is less than the threshold value of 1 x $10^{-6}$ recommended in WAC 173-340-740 for unrestricted land use. The HI reported from the water and soil exposure pathways is 0.048, which is less than the EPA and WAC recommended threshold value of 1.

**SX TANK FARM**

**Past Leaks**. A summary of radiological risk estimates from past leaks is provided in Table A-4. The radiological ILCR from both soil and water at year 2046 is 1.0 x $10^{-0}$. The primary contributors to risk include $^{99}$Tc (9.3 x$10^{-1}$; 93% contribution), $^{129}$I (3.3 x$10^{-2}$; 3.3% contribution), and $^{14}$C (3.3 x$10^{-2}$; 3.3% contribution). The ILCR reported for past leaks is greater than the EPA upper risk threshold of 1 x $10^{-4}$.

A summary of the nonradiological risk estimates and HIs are provided in Tables A-5 and A-6, respectively. The nonradiological ILCR from soil at year 2046 is 5.1 x $10^{-3}$ (hexavalent chromium; 100% contribution). The ILCR reported for past leaks is greater than the EPA upper risk threshold of 1 x $10^{-4}$ and is greater than the threshold value of 1 x $10^{-6}$ recommended in WAC 173-340-740 unrestricted land use. The HI reported from soil and water exposure pathways is 609, which is greater than the EPA and WAC recommended threshold value of 1. The primary contributors to the HI of 609 are hexavalent chromium (HQ=371) and nitrite (HQ=81).

**Residual Tank Waste**. A summary of radiological risk estimates from residual tank waste is provided in Table A-5. The radiological ILCR from both soil and water at year 4902 is 3.8 x $10^{-4}$. The primary contributors to the ILCR include $^{99}$Tc (3.8 x $10^{-4}$; 93% contribution) and $^{129}$I (2.7 x$10^{-6}$; 0.7% contribution). The ILCR reported for residual tank waste is greater than the EPA upper risk threshold of 1 x $10^{-4}$.

A summary of the nonradiological risk estimates and HIs are provided in Tables A-5 and A-6, respectively. The nonradiological ILCR from soil at year 4092 is $1.2 \times 10^{-6}$ (hexavalent chromium; 100% contribution). The ILCR reported for residual tank waste is slightly greater than the EPA lower risk threshold of $1 \times 10^{-6}$ and is slightly greater than the threshold value of $1 \times 10^{-6}$ recommended in WAC 173-340-740 for unrestricted land use. The HI reported from the water and soil exposure pathways is 0.13, which is less than the EPA and WAC recommended threshold value of 1.

**Potential Retrieval Leaks**. A summary of radiological risk estimates from potential retrieval leaks is provided in Table A-4. The radiological ILCR from both soil and water at year 2060 is $4.0 \times 10^{-2}$. The primary contributors to risk include $^{99}Tc$ ($3.8 \times 10^{-2}$; 96% contribution), $^{129}I$ ($1.1 \times 10^{-3}$; 2.8% contribution), and $^{14}C$ ($6.0 \times 10^{-4}$; 1.5% contribution). The ILCR reported for potential retrieval leaks is above the EPA upper risk threshold of $1 \times 10^{-4}$.

A summary of the nonradiological risk estimates and HIs are provided in Tables A-5 and A-6, respectively. The nonradiological ILCR from soil at year 2060 is $3.6 \times 10^{-5}$ (hexavalent chromium; 100% contribution). The ILCR reported for potential retrieval leaks is within the EPA risk range of $1 \times 10^{-4}$ to $1 \times 10^{-6}$ and is greater than the threshold value of $1 \times 10^{-6}$ recommended in WAC 173-340-740 for unrestricted land use. The HI reported from the water and soil exposure pathways is 7.2, which is greater than EPA and WAC recommended threshold value of 1. The primary contributors to HI of 7.2 are hexavalent chromium (HQ=2.6) and nitrite (HQ=2.6).

**SX Tank Farm Pipe System**. A summary of radiological risk estimates for the pipe system is provided in Table A-4. The radiological ILCR from both soil and water at year 4177 is $1.2 \times 10^{-4}$. The primary contributors to risk include $^{99}Tc$ ($1.0 \times 10^{-4}$; 93% contribution), $^{129}I$ ($4.0 \times 10^{-6}$; 3.3% contribution), and $^{14}C$ ($4.0 \times 10^{-6}$; 3.3% contribution). The ILCR reported for the pipe system is slightly greater the EPA upper risk threshold of $1 \times 10^{-4}$.

A summary of the nonradiological risk estimates and HIs are provided in Tables A-5 and A-6, respectively. The nonradiological ILCR from soil at year 4177 is $3.7 \times 10^{-7}$. The ILCR reported for the pipe system is less than the lower risk threshold of $1 \times 10^{-6}$ and is less than the threshold value of $1 \times 10^{-6}$ recommended in WAC 173-340-740 for unrestricted land use. The HI reported from water and soil exposure pathways is less than 0.047, which is less than the EPA and WAC recommended threshold value of 1.

## DOSE ESTIMATES FOR THE NATIVE AMERICAN SUBSISTENCE SCENARIO

This section provides the dose estimates for the Native American subsistence exposure scenario at S tank farm and SX tank farm. Risk estimates are provided only for the year which the peak groundwater concentration occurs. Summary tables showing radiological dose, primary COPCs contributing to the dose estimates, and primary exposure pathways for each source term follow the tank farm discussion.

### S TANK FARM

**Past Leaks**. A summary of soil and water dose estimates from past leaks is provided in Table A-7. The EDE dose from soil at year 2046 is 4.6 mrem/yr and the EDE dose from water at

year 2046 is 5.9 mrem/yr. The total EDE dose (11 mrem/yr) from both soil and water is less than the threshold value of 25 mrem/yr for representative members of the public and is also less than the EPA dose threshold of 15 mrem/yr.

**Residual Waste**. A summary of soil and water dose estimates from residual waste is provided in Table A-7. The EDE dose from soil at year 4902 is 0.42 mrem/yr and the EDE dose from water at year 4902 is 0.36 mrem/yr. The total EDE dose from both soil and water (0.78 mrem/yr) is less than the DOE recommended threshold value of 25 mrem/yr for representative members of the public and is also less than the EPA dose threshold of 15 mrem/yr.

**Potential Retrieval Leaks**. A summary of soil and water dose estimates from retrieval leaks is provided in Table A-7. The EDE dose from soil at year 2060 is 22 mrem/yr and the EDE dose from water at year 2060 is 13 mrem/yr. The total EDE dose from both soil and water (35 mrem/yr) is greater than the DOE recommended threshold value of 25 mrem/yr for representative members of the public and is also greater than the EPA dose threshold of 15 mrem/yr. The primary contributors to dose are $^{99}$Tc (22 mrem/yr; 62% contribution) and $^{129}$I (9.8 mrem/yr; 28% contribution).

**S Tank Farm Pipe System**. A summary of soil and water dose estimates from the pipe system is provided in Table A-7. The EDE dose from soil at year 4177 is 0.17 mrem/yr and the EDE dose from water at year 4177 is 0.096 mrem/yr. The total EDE dose from both soil and water (0.27 mrem/yr) is less than the DOE recommended threshold value of 25 mrem/yr for representative members of the public and is also less than the EPA dose threshold of 15 mrem/yr.

**SX TANK FARM**

**Past Leaks**. A summary of soil and water dose estimates from past leaks is provided in Table A-8. The EDE dose from soil at year 2046 is 1,059 mrem/yr and the EDE dose from water at year 2046 is 603 mrem/yr. The total EDE dose (1,660 mrem/yr) from both soil and water is greater than the DOE recommended threshold value of 25 mrem/yr for representative members of the public and is also greater than the EPA dose threshold of 15 mrem/yr. The primary contributors to dose are $^{99}$Tc (880 mrem/yr; 53% contribution), $^{129}$I (485 mrem/yr; 29% contribution), and $^{14}$C (287 mrem/yr; 17% contribution).

**Residual Waste**. A summary of soil and water dose estimates from residual waste is provided in Table A-8. The EDE dose from soil at year 4902 is 0.21 mrem/yr and the EDE dose from water at year 4902 is 0.17 mrem/yr. The total EDE dose from both soil and water (0.38 mrem/yr) is less than the DOE recommended threshold value of 25 mrem/yr for representative members of the public and is also less than the EPA dose threshold of 15 mrem/yr.

**Potential Retrieval Leaks**. A summary of soil and water dose estimates from retrieval leaks is provided in Table A-8. The EDE dose from soil at year 2060 is 34 mrem/yr and the EDE dose from water at year 2060 is 21 mrem/yr. The total EDE dose from both soil and water (2356 mrem/yr) is greater than the DOE recommended threshold value of 25 mrem/yr for representative members of the public and is also greater than the EPA dose threshold of 15 mrem/yr. The primary contributors to dose are $^{99}$Tc (35 mrem/yr; 62% contribution) and $^{129}$I (16 mrem/yr; 29% contribution).

**SX Tank Farm Pipe System.** A summary of soil and water dose estimates from the pipe system is provided in Table A-8. The EDE dose from soil at year 4177 is 0.012 mrem/yr and the EDE dose from water at year 4177 is 0.068 mrem/yr. The total EDE dose from both soil and water (0.19 mrem/yr) is less than the DOE recommended threshold value of 25 mrem/yr for representative members of the public and is also less than the EPA dose threshold of 15 mrem/yr.

Table A-1. Summary of Radiological Risk Estimates for the Native American Exposure Scenario for S Tank Farm.

| Source | Media | Radiological ILCR | Peak year | Primary radionuclide | Percentage of total risk | Primary pathway (%) |
|---|---|---|---|---|---|---|
| Past Leaks[1] | Soil<br>Water<br>Total ILCR | 3.7E-03<br>4.6E-04<br>4.1E-03 | 2046 | Tc-99<br>Iodine-129<br>Carbon-14 | 88%<br>3.1%<br>2.8% | Garden Produce(50.1)<br>Egg (19.4)<br>Milk (17) |
| Residuals[2] | Soil<br>Water<br>Total ILCR | 7.2E-04<br>4.2E-05<br>7.6E-04 | 4902 | Tc-99<br>Iodine-129<br>Carbon-14 | 99.6%<br>0.3%<br>0.1% | Garden Produce(55.6)<br>Egg (21.9)<br>Milk (15.6) |
| Retrieval Leaks[3] | Soil<br>Water<br>Total ILCR | 2.4E-02<br>1.5E-03<br>2.5E-02 | 2060 | Tc-99<br>Iodine-129<br>Carbon-14 | 95.5%<br>2.8%<br>1.6% | Garden Produce(53.8)<br>Egg (21)<br>Milk (17.4) |
| Pipe System | Soil<br>Water<br>Total ILCR | 1.5E-04<br>9.6E-06<br>1.6E-04 | 4177 | Tc-99<br>Iodine-129<br>Carbon-14 | 92.5%<br>3.8%<br>3.7% | Garden Produce(52.6)<br>Egg (20.4)<br>Milk (18.5) |

Notes:
[1]Maximum rad-ILCR risk for tank leaks is from single-shell tank S-104.
[2]Maximum rad-ILCR risk for tank residuals is from tank row S-104 to S-106.
[3]Maximum rad-ILCR risk for tank residuals is from tank row S-110 to S-112.
ILCR = incremental lifetime cancer risk

1

Table A-2. Summary of Nonradiological Risk Estimates for the Native American Exposure Scenario for S Tank Farm.

| Source | Media | Non-radiological ILCR | Peak year | Primary contaminant | Percentage of total risk | Primary pathway |
|---|---|---|---|---|---|---|
| Past Leaks[1] | Soil<br>Water<br>Total ILCR | 3.7E-06<br>N/A<br>3.7E-06 | 2046 | Chromium | 100% | Soil Inhalation[4] |
| Residuals[2] | Soil<br>Water<br>Total ILCR | 2.1E-06<br>N/A<br>2.1E-06 | 4902 | Chromium | 100% | Soil Inhalation[4] |
| Retrieval Leaks[3] | Soil<br>Water<br>Total ILCR | 7.9E-06<br>N/A<br>7.9E-06 | 2060 | Chromium | 100% | Soil Inhalation[4] |
| Pipe System | Soil<br>Water<br>Total ILCR | 7.2E-08<br>N/A<br>7.2E-08 | 4177 | Chromium | 100% | Soil Inhalation[4] |

Notes:

[1]Maximum nonrad-ILCR risk for tank leaks is from single-shell tank S-104.

[2]Maximum nonrad-ILCR risk for tank residuals is from tank row S-104 to S-106.

[3]Maximum nonrad-ILCR risk for hypothetical retrieval leaks is from tank row S-110 to S-112.

[4]Water inhalation pathway was not considered because chromium is not volatile.

HQ = hazard quotient

ILCR = incremental lifetime cancer risk.

2

1

Table A-3. Summary of Hazard Index Estimates for the Native American Exposure Scenario for S Tank Farm.

| Source | Media | Hazard index | Peak year | Primary contaminants | Percentage of total risk | Primary pathway[5] |
|---|---|---|---|---|---|---|
| Past Leaks[1] | Soil<br>Water<br>Total HI | 0.95<br>5.1<br>6.1 | 2046 | Chromium (HQ=1.4) | 23% | Water Ingestion (77.8)<br>Garden Produce (10.4)<br>Water Dermal (6.5) |
| Residuals[2] | Soil<br>Water<br>Total HI | 0.28<br>0.79<br>1.1 | 4902 | | | |
| Retrieval Leaks[3] | Soil<br>Water<br>Total HI | 1.1<br>4.3<br>5.5 | 2060 | Chromium (HQ=4.0) | 73% | Water Ingestion (64.4)<br>Garden Produce (14.1)<br>Water Dermal (13.6) |
| Pipe System | Soil<br>Water<br>Total HI | 0.012<br>0.035<br>0.048 | 4177 | Chromium<br>Nitrate<br>Nitrite | 75.5%<br>6.6%<br>9.9% | Water Ingestion (59.3)<br>Garden Produce (15.4)<br>Water Dermal (14.2) |

Notes:

[1]Maximum HI for tank leaks is from single-shell tank S-104.

[2]Maximum HI for tank residuals is from tank row S-104 to S-106.

[3]Maximum HI for hypothetical retrieval leaks is from tank row S-101 to S-103.

[4]No individual contaminant with a hazard quotient above 1.0.

[5]Water inhalation pathway was not considered for chromium because chromium is not volatile.

HI = hazard index.

HQ = hazard quotient.

ILCR = incremental lifetime cancer risk.

2

1

Table A-4. Summary of Radiological Risk Estimates for the Native American Exposure Scenario for SX Tank Farm.

| Source | Media | Radiological ILCR | Peak year | Primary radionuclide | Percentage of total risk | Primary pathway (%) |
|---|---|---|---|---|---|---|
| Past Leaks[1] | Soil<br>Water<br>Total ILCR | 9.8E-01<br>6.2E-02<br>1.0E+00 | 2046 | Tc-99<br>Iodine-129<br>Carbon-14 | 93.3%<br>3.3%<br>3.3% | Garden Produce (52.9)<br>Egg (20.6)<br>Milk (18.1) |
| Residuals[2] | Soil<br>Water<br>Total ILCR | 3.6E-04<br>2.1E-05<br>3.8E-04 | 4902 | Tc-99<br>Iodine-129<br>Carbon-14 | 99.2%<br>0.7%<br>0.1% | Garden Produce (55.3)<br>Egg (21.8)<br>Milk (15.8) |
| Retrieval Leaks[3] | Soil<br>Water<br>Total ILCR | 3.7E-02<br>2.3E-03<br>4.0E-02 | 2060 | Tc-99<br>Iodine-129<br>Carbon-14 | 95.6%<br>2.8%<br>1.5% | Garden Produce (53.8)<br>Egg (21)<br>Milk (17.3) |
| Pipe System | Soil<br>Water<br>Total ILCR | 1.1E-04<br>7.0E-06<br>1.2E-04 | 4177 | Tc-99<br>Iodine-129<br>Carbon-14 | 93.3%<br>3.3%<br>3.3% | Garden Produce (52.9)<br>Egg (20.6)<br>Milk (18.2) |

Notes:

[1]Maximum rad-ILCR risk for tank leaks is from tank row SX-107 to SX-109.

[2]Maximum rad-ILCR risk for tank residuals is from tank row SX-113 to SX-115.

[3]Maximum rad-ILCR risk for hypothetical retrieval leaks is from tank row SX-104 to SX-106.

ILCR = incremental lifetime cancer risk.

2

1

Table A-5. Summary of Nonradiological Risk Estimates for the Native American Exposure Scenario for SX Tank Farm.

| Source | Media | Non-radiological ILCR | Peak year | Primary contaminant | Percentage of total risk | Primary pathway |
|---|---|---|---|---|---|---|
| Past Leaks[1] | Soil<br>Water<br>Total ILCR | 5.1E-03<br>N/A<br>5.1E-03 | 2046 | Chromium | 100% | Soil Inhalation[4] |
| Residuals[2] | Soil<br>Water<br>Total ILCR | 1.2E-06<br>N/A<br>1.2E-06 | 4902 | Chromium | 100% | Soil Inhalation[4] |
| Retrieval Leaks[3] | Soil<br>Water<br>Total ILCR | 3.6E-08<br>N/A<br>3.6E-08 | 2060 | Chromium | 100% | Soil Inhalation[4] |
| Pipe System | Soil<br>Water<br>Total ILCR | 3.7E-07<br>N/A<br>3.7E-07 | 4177 | Chromium | 100% | Soil Inhalation[5] |

Notes:

[1]Maximum nonrad-ILCR risk for tank leak s is from tank row SX-107 to SX-109.

[2]Maximum nonrad-ILCR risk for tank residuals is from tank row SX-101 to SX-103.

[3]Maximum nonrad-ILCR risk for hypothetical retrieval leaks is from tank row SX-101 to SX-103.

[4]Water inhalation pathway was not considered because chromium is not volatile

ILCR = incremental lifetime cancer risk.

N/A = not applicable.

2

Table A-6. Summary of Hazard Index Estimates for the Native American Exposure Scenario for SX Tank Farm.

| Source | Media | Hazard index | Peak year | Primary contaminants | Percentage of total HI | Primary pathway[5] |
|---|---|---|---|---|---|---|
| Past Leaks[1] | Soil<br>Water<br>Total HI | 148<br>461<br>609 | 2046 | Chromium<br>Nitrite | 61%<br>13.3% | Water Ingestion (61.8)<br>Garden Produce (16.2)<br>Water Dermal (15.9) |
| Residuals[2] | Soil<br>Water<br>Total HI | 0.039<br>0.089<br>0.13 | 4902 | --[4] | --[4] | --[4] |
| Retrieval Leaks[3] | Soil<br>Water<br>Total HI | 1.4<br>5.8<br>7.2 | 2060 | Chromium<br>Nitrite | 36%<br>36% | Water Ingestion (66)<br>Garden Produce (14)<br>Water Dermal (13.8) |
| Pipe System | Soil<br>Water<br>Total HI | 0.011<br>0.036<br>0.047 | 4177 | --[4] | --[4] | --[4] |

Notes:

[1]Maximum HI for tank leaks is from tank row SX-107 to SX-109.

[2]Maximum HI for tank residuals is from tank row SX-101 to SX-103.

[3]Maximum HI for hypothetical retrieval leaks is from tank row SX-101 to SX-103.

[4]No individual contaminant with a hazard quotient above 1.0

[5]Water inhalation pathway was not considered for chromium because chromium is not volatile

HI = hazard index.

Table A-7. Summary of Radiological Dose (EDE) Estimates for the Native American Exposure Scenario for S Tank Farm.

| Source | Media | Radiological dose (mrem/yr) | Peak year | Primary radionuclide | Percentage of total dose | Primary pathway (%) |
|---|---|---|---|---|---|---|
| Past Leaks[1] | Soil<br>Water<br>Total Dose | 4.6<br>5.9<br>11 | 2046 | Tc-99<br>Iodine-129<br>Carbon-14 | 54%<br>29%<br>16% | Water Ingestion (34.7)<br>Water Inhalation (21.8)<br>Milk (17.7) |
| Residuals[2] | Soil<br>Water<br>Total Dose | 0.42<br>0.36<br>0.78 | 4902 | Tc-99<br>Iodine-129<br>Carbon-14 | 95%<br>4.0%<br>0.7% | Water Ingestion (37.1)<br>Garden Produce (29.5)<br>Egg (11.7) |
| Retrieval Leaks[3] | Soil<br>Water<br>Total Dose | 22<br>13<br>35 | 2060 | Tc-99<br>Iodine-129<br>Carbon-14 | 62%<br>28%<br>9.8% | Water Ingestion (32.4)<br>Garden Produce (21.6)<br>Milk (25.1) |
| Pipe System | Soil<br>Water<br>Total Dose | 0.17<br>0.096<br>0.27 | 4177 | Tc-99<br>Iodine-129<br>Carbon-14 | 50%<br>32%<br>19% | Water Ingestion (30.5)<br>Milk (29.9)<br>Garden Produce (18.8) |

Notes:

[1]Maximum Radiological Dose for tank leaks is from single-shell tank S-104.

[2]Maximum Radiological Dose for tank residuals is from tank row S-104 to S-106.

[3]Maximum Radiological Dose for hypothetical retrieval leaks is from tank row S-110 to S-1112.

EDE = effective dose equivalent.

Table A-8. Summary of Radiological Dose (EDE) Estimates for the Native American Exposure Scenario for SX Tank Farm.

| Source | Media | Radiological dose (mrem/yr) | Peak year | Primary radionuclide | Percentage of total dose | Primary pathway (%) |
|---|---|---|---|---|---|---|
| Past Leaks[1] | Soil<br>Water<br>Total Dose | 1059<br>603<br>1661 | 2046 | Tc-99<br>Iodine-129<br>Carbon-14 | 53.0%<br>29.2%<br>17.3% | Water Ingestion (31)<br>Milk (28.5)<br>Garden Produce (19.6) |
| Residuals[2] | Soil<br>Water<br>Total Dose | 0.21<br>0.17<br>0.38 | 4902 | Tc-99<br>Iodine-129<br>Carbon-14 | 89.0%<br>9.8%<br>1.1% | Water Ingestion (36.3)<br>Garden Produce (28)<br>Milk (14) |
| Retrieval Leaks[3] | Soil<br>Water<br>Total Dose | 34<br>21<br>56 | 2060 | Tc-99<br>Iodine-129<br>Carbon-14 | 62.0%<br>28.7%<br>9.3% | Water Ingestion (32.4)<br>Milk (25)<br>Garden Produce (21.6) |
| Pipe System | Soil<br>Water<br>Total Dose | 0.12<br>0.068<br>0.19 | 4177 | Tc-99<br>Iodine-129<br>Carbon-14 | 52.9%<br>29.5%<br>17.5% | Water Ingestion (30.9)<br>Milk (28.7)<br>Garden Produce (19.5) |

Notes:

[1]Maximum Radiological Dose for tank leaks is from tank row SX-107 to SX-109.

[2]Maximum Radiological Dose for tank residuals is from tank row SX-113 to SX-115.

[3]Maximum Radiological Dose for hypothetical retrieval leaks is from tank row SX-104 to SX-106.

EDE = effective dose equivalent.

**Attachment 5**
**04-TPD-092**

**Certification for the Hanford Facility Dangerous Waste Permit Application Documentation, Single-Shell Tank System Closure Plan for Attachments 1 - 4**

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including coversheet)

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PART B CERTIFICATION [K]

"I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations."

Owner/Operator — Date: 9/27/04

Roy J. Schepens, Manager
U.S. Department of Energy
Office of River Protection

*Co-operator — Date: 9/21/04

Edward S. Aromi Jr., President and General Manager
CH2M HILL Hanford Group, Inc.

*Co-operator under the Department of Energy Office of River Protection Contract Number DE-AC27-99RL14047