DOCUMENT RELEASE AND CHANGE FORM

Prepared For the U.S. Department of Energy, Assistant Secretary for Environmental Management
By Washington River Protection Solutions, LLC., PO Box 850, Richland, WA 99352
Contractor For U.S. Department of Energy, Office of River Protection, under Contract DE-AC27-08RV14800

TRADEMARK DISCLAIMER: Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States government or any agency thereof or its contractors or subcontractors. Printed in the United States of America.

Release Stamp

DATE: Oct 29,2020

HANFORD RELEASE

1. **Doc No:** RPP-RPT-58693 **Rev.** 00

2. **Title:**
Engineered System Data Package for Waste Management Area A-AX

3. **Project Number:** T2C25 ☐N/A

4. **Design Verification Required:** ☐Yes ☒No

5. **USQ Number:** ☒ N/A RPP-27195

6. **PrHA Number** **Rev.** ☒ N/A

Clearance Review Restriction Type: public

7. **Approvals**

Title	Name	Signature	Date
Clearance Review	Ayers, Lynn M	*Ayers, Lynn M*	10/29/2020
Document Control Approval	Scales, Anthony	*Scales, Anthony*	10/29/2020
Originator	Lee, Kearn (Pat)	*Lee, Kearn (Pat)*	09/03/2020
Quality Assurance	Lungu, Cris C	*Lungu, Cris C*	08/18/2020
Responsible Engineer	Lee, Kearn (Pat)	*Lee, Kearn (Pat)*	10/01/2020
Responsible Manager	Rutland, Paul L	*Rutland, Paul L*	10/08/2020

8. **Description of Change and Justification**

Initial Issue Rev.0

9. **TBDs or Holds** ☒N/A

10. **Related Structures, Systems, and Components**

a. **Related Building/Facilities** ☒N/A	b. **Related Systems** ☒N/A	c. **Related Equipment ID Nos. (EIN)** ☒N/A

11. **Impacted Documents – Engineering** ☒N/A

Document Number	Rev.	Title

12. **Impacted Documents (Outside SPF):**

N/A

13. **Related Documents** ☐N/A

Document Number	Rev.	Title
RPP-ENV-61497	00	Preliminary Performance Assessment of Waste Management Area A-AX, Hanford Site, Washington
RPP-ENV-62206	00	Analysis of Post-Closure Groundwater Impacts from Hazardous Chemicals in Residual Wastes in Tanks and Ancillary Equipment at Waste Management Area A-AX at the Hanford Site, Southeast Washington

14. **Distribution**

Name	Organization
Bergeron, Marcel P	CLOSURE & INTERIM MEASURES
Field, Jim G	PROCESS ENGINEERING
Lee, Kearn (Pat)	CLOSURE & INTERIM MEASURES
Rutland, Paul L	CLOSURE & INTERIM MEASURES
Singleton, Kristin M	CLOSURE & INTERIM MEASURES
Watson, David (Dj) J	CLOSURE & INTERIM MEASURES

INFORMATION CLEARANCE REVIEW AND RELEASE APPROVAL

Part I: Background Information

Title: Engineered System Data Package for Waste Management Area A-AX

Publish to OSTI? ☐ Yes ☑ No

Information Category:
☐ Abstract ☐ Journal Article ☐ Summary
☐ Internet ☐ Visual Aid ☐ Software
☐ Full Paper ☑ Report ☐ Other

Trademark/Copyright "Right to Use" Information or Permission Documentation	Yes	NA
	☐	☑

Document Number: RPP-RPT-58693 Revision 0 Date: September 2020

Author: Lee, Kearn (Pat)

Part II: External/Public Presentation Information

Conference Name: Not Applicable

Sponsoring Organization(s): DOE-ORP

Date of Conference: Not Applicable Conference Location: Not Applicable

Will Material be Handed Out? ☐ Yes ☑ No Will Information be Published? ☐ Yes ☑ No *(If Yes, attach copy of Conference format instructions/guidance.)*

Part III: WRPS Document Originator Checklist

Description	*Yes*	*N/A*	*Print/Sign/Date*		
Information Product meets requirements in TFC-BSM-AD-C-01?	☐	☑			
Document Release Criteria in TFC-ENG-DESIGN-C-25 completed? (Attach checklist)	☑	☐	Lee, Kearn (Pat)	IDMS Data File att.	09/14/2020
If product contains pictures, safety review completed?	☑	☐	Roberts, Sheryl K	IDMS Data File att.	08/19/2020

Part IV: WRPS Internal Review

Function	*Organization*	*Date*	*Print Name/Signature/Date*	
Subject Matter Expert	WRPS	10/06/2020	Lee, Kearn (Pat)	IDMS Data File att.
Responsible Manager	WRPS	08/19/2020	Rutland, Paul L	IDMS Data File att.
Other:				

Part V: IRM Clearance Services Review

Description	*Yes*	*No*	*Print Name/Signature*
Document Contains Classified Information?	☐	☒	If Answer is "Yes," ADC Approval Required Print Name/Signature/Date
Document Contains Information Restricted by DOE Operational Security Guidelines?	☐	☒	Reviewer Signature: Print Name/Signature/Date
Document is Subject to Release Restrictions? *If the answer is "Yes," please mark category at right and describe limitation or responsible organization below:*	☐	☒	Document contains: ☐ Applied Technology ☐ Protected CRADA ☐ Personal/Private ☐ Export Controlled ☐ Proprietary ☐ Procurement – Sensitive ☐ Patentable Info. ☐ OUO ☐ Predecisional Info. ☐ UCNI ☐ Restricted by Operational Security Guidelines ☐ Other (Specify)
Additional Comments from Information Clearance Specialist Review?	☐	☒	Information Clearance Specialist Approval APPROVED By Janis D. Aardal at 1:36 pm, Oct 06, 2020 Print Name/Signature/Date

When IRM Clearance Review is Complete – Return to WRPS Originator for Final Signature Routing (Part VI)

INFORMATION CLEARANCE REVIEW AND RELEASE APPROVAL

Part VI: Final Review and Approvals

Description	*Approved for Release*		*Print Name/Signature*	
	Yes	*N/A*		
WRPS External Affairs	☒	☐	IDMS Data File att.	Mc Cune, Hal C
WRPS Office of Chief Counsel	☒	☐	IDMS Data File att.	Roden, Mari L
DOE – ORP Public Affairs/Communications	☒	☐	IDMS Data File att.	Tyree, Geoff T
Other: ORP SME	☒	☐	IDMS Data File att.	Lobos, Rodrigo A
Other: DOE OCC	☒	☐	IDMS Data File att.	King Grace J

Comments Required for WRPS-Indicate Purpose of Document:

This document is being cleared for public release because it is a cited reference in both RPP-ENV-62206 and RPP-ENV-61497. Submittal of RPP-ENV-62206 and RPP-ENV-61497 to the Washington State Department of Ecology is a TPA milestone due 9/30/2020.

Photo safety review completed by Sheryl Roberts on 8/18/2020.

APPROVED
By Janis D. Aardal at 1:37 pm, Oct 06, 2020

Approved for Public Release; Further Dissemination Unlimited

Information Release Station

Was/Is Information Product Approved for Release? ☒ Yes ☐ No

If Yes, what is the Level of Releaser? ☑ Public/Unrestricted ☐ Other (Specify) _____

Date Information Product Stamped/Marked for Release: 10/06/2020

Was/Is Information Product Transferred to OSTI? ☐ Yes ☒ No

Forward Copies of Completed Form to WRPS Originator

```
- <workflow name="(JDA) Expedite - RPP-RPT-58693 R0_TPA Ref_Eng DP WMA A-AX"
    id="266846467">
  - <task name="Clearance Process" id="0" date-initiated="20200819T0752"
      performer="Janis D Aardal" performer-id="267960" username="h0090683">
      <comments>ATTN: Due Monday, August 31, 2020 - COB Please approve the
        Rev. 0 reference, Engineered System Data Package for Waste
        Management Area A-AX, cited in a TPA milestone due 9/30/20 and
        submitted by Pat Lee for public release. Thank you, Janis Aardal
        Information Clearance</comments>
    </task>
    <task name="Add XML" id="1" date-done="20200819T0753" />
    <task name="Expedite - Manager Approval" id="6" date-due="20200821T0752"
      date-done="20200819T1111" performer="Paul L Rutland" performer-
      id="140633218" username="h4494439" disposition="Approve"
      authentication="true" />
    <task name="Expedite - Document Reviewer4" id="19" date-
      due="20200821T1111" date-done="20200819T1126" performer="Sheryl K
      Roberts" performer-id="171787680" username="h0081997" disposition="Public
      Release" authentication="true" />
    <task name="Expedite - Document Reviewer1" id="16" date-
      due="20200821T1111" date-done="20200820T1615" performer="Hal C Mc
      Cune" performer-id="226350486" username="h7687509" disposition="Public
      Release" authentication="true" />
    <task name="Expedite - Document Reviewer2" id="17" date-
      due="20200821T1111" date-done="20200901T1451" performer="MARI L
      RODEN" performer-id="262637370" username="h0048955" disposition="Public
      Release" authentication="true" />
  + <task name="Expedite - Document Reviewer3" id="18" date-
      due="20200821T1111" date-done="20200909T1648" performer="RODRIGO A
      LOBOS" performer-id="232334741" username="h2488419" disposition="Public
      Release" authentication="true">
  - <task name="Doc Owner Clearance Review" id="13" date-due="20200910T1649"
      date-done="20200914T0714" performer="KEARN P LEE" performer-
      id="148796764" username="h8500694" disposition="Send On"
      authentication="true">
      <comments>Re-wrote paragraph on page 2-5 mentioning "closure plans" to
        align with language in the TC & WM EIS ROD (78 FR 75913), which uses
        term "closure operations".</comments>
    </task>
    <task name="Milestone 1" id="24" date-done="20200914T0716" />
  - <task name="ORP Document Reviewer1" id="57" date-due="20200916T0715"
      date-done="20200915T1341" performer="GRACE J KING" performer-
      id="211901436" username="h9807759" disposition="Public Release"
      authentication="true">
      <comments>Reviewed background information section - no legal
        concerns</comments>
    </task>
    <task name="ORP Document Reviewer2" id="58" date-due="20200916T0715"
      date-done="20201006T0720" performer="GEOFFREY T TYREE" performer-
      id="6158846" username="h0068565" disposition="Public Release"
      authentication="true" />
    <task name="Doc Owner Reviews ORP Comments" id="61" date-
      due="20201007T0720" date-done="20201006T0727" performer="KEARN P LEE"
      performer-id="148796764" username="h8500694" disposition="Send On"
```

```
authentication="true" />
  <task name="Milestone 2" id="62" date-done="20201006T0728" />
  <task name="Verify Doc Consistency" id="4" date-due="20201007T0727" date-
    done="20201006T1113" performer="JANIS D AARDAL" performer-id="267960"
    username="h0090683" disposition="Cleared" authentication="true" />
</workflow>
```

RPP-RPT-58693
Revision 0

Engineered System Data Package for Waste Management Area A-AX

A. K. Wahi
R. Khaleel
S. Mehta
A. Mayenna
INTERA, Inc.

W. J. McMahon
CH2M HILL Plateau Remediation Company

J. G. Field
M. P. Bergeron
R. A. Hiergesell (retired)
Washington River Protection Solutions, LLC

Prepared for the U.S. Department of Energy
Office of River Protection

Contract No. DE-AC27-08RV14800

Approved for Public Release;
Further Dissemination Unlimited

EXECUTIVE SUMMARY

This document provides data and information on the Waste Management Area A-AX engineered system to support preparation of a performance assessment for Waste Management Area A-AX as defined in Appendix I of the *Hanford Federal Facility Agreement and Consent Order* (Ecology et al. 1989). Topics covered in this document include the following:

- Key features of the existing engineered system
- Recharge estimates for the natural system, the disturbed natural system during the operational history, and the future engineered closure surface barrier
- Release models for residual wastes that may remain in the 241-A and 241-AX Tank Farms' single-shell storage tanks and ancillary equipment following future waste retrieval
- Steel corrosion and degradation
- Degradation of tank concrete structures and emplaced grout.

This page intentionally left blank.

TABLE OF CONTENTS

1.0 INTRODUCTION 1-1

1.1 OBJECTIVE 1-1
1.2 SCOPE OF REPORT 1-2
1.3 REPORT CONTENT 1-3

2.0 BACKGROUND INFORMATION 2-1

3.0 MAJOR FEATURES OF THE ENGINEERED SYSTEM 3-1

3.1 EXCAVATION AND BACKFILL 3-2
3.2 TANK FARM CONSTRUCTION AND INFRASTRUCTURE 3-24
3.2.1 Single-Shell Tanks 3-24
3.2.2 Ancillary Equipment 3-47
3.3 PROCESS FACILITIES 3-60
3.3.1 202-A Plutonium Uranium Extraction Plant 3-60
3.3.2 242-A Evaporator 3-62
3.3.3 204-AR 3-62
3.3.4 244-AR 3-63
3.3.5 241-A-431 3-65
3.3.6 241-AX-IX 3-65
3.4 LIQUID DISCHARGE SITES 3-67
3.4.1 Ponds and Ditches 3-67
3.4.2 Cribs, Trenches, and Retention Basins 3-70
3.4.3 Septic Systems 3-80

4.0 NATURAL RECHARGE AND ENGINEERED BARRIERS 4-1

4.1 BACKGROUND 4-1
4.2 KEY ASPECTS OF RECHARGE ESTIMATION 4-1
4.3 TEMPORAL EVOLUTION OF WASTE MANAGEMENT AREA A-AX SURFACE 4-4
4.3.1 Pre-operations 4-6
4.3.2 Construction and Operations 4-7
4.3.3 Early Post-Closure 4-9
4.3.4 Late Post-Closure 4-10
4.4 SPATIAL AND TEMPORAL VARIATION OF RECHARGE ESTIMATES 4-10
4.4.1 Pre-Operation Period 4-10
4.4.2 Operational Period 4-12

4.4.3 Early Post-Closure and a Functioning Surface Barrier 4-13
4.4.4 Late Post-Closure and a Degraded Surface Barrier 4-14
4.5 REPRESENTATIVE INITIAL RECHARGE ESTIMATES FOR WASTE MANAGEMENT AREA A-AX PERFORMANCE ASSESSMENT 4-15
4.6 IMPACTS DUE TO VEGETATION AND CLIMATE CHANGES 4-16

5.0 WASTE MANAGEMENT AREA A-AX CLOSED FACILITY PERFORMANCE 5-1

5.1 BASIS FOR CONTAMINANT RELEASES FROM TANK WASTE RESIDUALS 5-2
5.1.1 Source Term and Engineered Features 5-2
5.1.2 Effective Diffusion Coefficient for Transport Through Tank Structure 5-18
5.1.3 Sorption of Contaminants to Grout and Concrete 5-23
5.1.4 Evaluation of Diffusive Release Assumption for Intact Tank Condition 5-29
5.2 PARAMETERS USED IN SOURCE TERM CALCULATIONS 5-31

6.0 STEEL CORROSION AND DEGRADATION 6-1

7.0 CONCRETE AND EMPLACED GROUT DEGRADATION 7-1

7.1 GROUT DEGRADATION PROCESSES 7-1
7.1.1 Carbonation 7-1
7.1.2 Sulfate Attack 7-2
7.1.3 Alkali-Aggregate Attack 7-3
7.1.4 Acid Leaching (Decalcification) 7-3
7.2 GROUT MONOLITH STABILITY TESTING 7-3
7.3 BELOWGROUND CONCRETE STRUCTURE EVALUATION 7-4
7.4 ABOVEGROUND CONCRETE STRUCTURE EVALUATION 7-6
7.5 CARBONATION TIME FOR SINGLE-SHELL TANK CONCRETE AND INFILL GROUT AT WASTE MANAGEMENT AREA A-AX 7-6
7.6 ANCIENT ANALOGS 7-11

8.0 REFERENCES 8-1

LIST OF APPENDICES

A TANK 241-A-105 HISTORY ..... A-i
B EVALUATION OF DIFFUSIVE RELEASE ASSUMPTION FOR INTACT TANK CONDITION ..... B-i

LIST OF FIGURES

Figure 2-1. Locations of Tank Farms on Hanford Site. 2-2

Figure 2-2. 241-A and 241-AX Tank Farms and Surrounding Features. 2-3

Figure 2-3. Map of 241-A and 241-AX Tank Farms. 2-4

Figure 3-1. Ground Breaking of 241-A Tank Farm with View to Southwest. 3-4

Figure 3-2. Excavation of 241-A Tank Farm with View to Southwest Showing Grading for Tank Construction. 3-5

Figure 3-3. Preparation of Excavation Base Surface and Rebar for Tank Base Construction. 3-6

Figure 3-4. 241-A Tank Farm Excavation with View to Northwest Showing Placement of Rebar for Tank Sidewalls. 3-7

Figure 3-5. 241-A Tank Farm Excavation with View to Northwest Showing Tank Sidewall Steel Liner Sections Being Delivered and Hoisted for Welding. 3-8

Figure 3-6. 241-A Tank Farm Excavation with View to West Showing Completion of Tank Steel Liners with Diversion Box in Foreground. 3-9

Figure 3-7. 241-A Tank Farm Excavation with View to West Showing Completion of Tank Sidewall Concrete, Partial Backfill of Excavation, and Diversion Box in Foreground. 3-10

Figure 3-8. Supports and Rebar for Tank Sidewall and Dome Construction in 241-A Tank Farm. 3-11

Figure 3-9. Rebar for Tank Dome Construction in 241-A Tank Farm. 3-12

Figure 3-10. 241-A Tank Farm Excavation with View to West Showing Completion of Tank Dome Concrete, Partial Backfill, and Concrete Encasement for Pipelines. 3-13

Figure 3-11. 241-A Tank Farm Construction Photograph Showing Ventilation Header, Pits, and Backfill to Tops of Tanks. 3-14

Figure 3-12. 241-A Tank Farm Construction Photograph Showing Nearly Completed Backfill with East Portions of Ventilation Header and Pipeline Encasement Exposed. 3-15

Figure 3-13. Photograph Showing Construction of 241-AX Tank Farm Reinforced-Concrete Tank Bases with Drain Slots. 3-16

Figure 3-14. Construction Work on Reinforced-Concrete Base of Single-Shell Tank in 241-AX Tank Farm Excavation. 3-17

Figure 3-15. Photograph Showing Construction of 241-AX Tank Base Steel Liners and Rebar for Sidewalls. 3-18

Figure 3-16. Photograph Showing Construction of 241-AX Tank Steel Liners. 3-19

Figure 3-17. Photograph of Construction of Single-Shell Tanks in 241-AX Tank Farm Excavation with View to Southwest Showing Concrete Shell Completed in Stages Around Steel Liners. 3-20

Figure 3-18. Photograph of 241-AX Tank Farm Construction with View to East Showing Partial Backfill of Excavation, Partially-Completed Tank Domes, Concrete Encasement with Pipelines, and Leak Detection Wells. 3-21

Figure 3-19. Photograph of 241-AX Tank Farm Construction with View to North Showing Partial Backfill of Excavation, Partially-Completed Tank Domes, and Tank Sidewall Liner. 3-22

Figure 3-20. Excavation Plan for 241-A Tank Farm. 3-23

Figure 3-21. Plot Plan for 241-AX Tank Farm. 3-24

Figure 3-22. 241-A Farm and 241-SX Farm Single-Shell Tank Configuration. 3-26

Figure 3-23. 241-A Farm Tank Composite. 3-27

Figure 3-24. 241-AX Farm Tank Composite. 3-28

Figure 3-25. 241-AX Farm Tank Base Drain Slot Arrangement. 3-29

Figure 3-26. 241-AX Farm Tank Composite Section. 3-30

Figure 3-27. Airlift Circulator Position. 3-32

Figure 3-28. Airlift Circulator in Tank 241-AX-101. 3-33

Figure 3-29. Steam Coil in Tank 241-AX-101. 3-34

Figure 3-30. Tank 241-AX-102 In-Tank Equipment. 3-35

Figure 3-31. Tank 241-AX-103 In-Tank Equipment. 3-36

Figure 3-32. Tank 241-AX-103 Airlift Circulator Showing Waste Level. 3-37

Figure 3-33. Tank 241-AX-104 In-Tank Equipment. 3-38

Figure 3-34. Panoramic Images of 241-A Tank Farm Single-Shell Tank Interiors and Waste Surfaces Taken from 2014 to 2017. 3-39

Figure 3-35. Short Airlift Circulator in 241-A Tank Farm. 3-40

Figure 3-36. Tall Airlift Circulator in 241-A Tank Farm. 3-41

Figure 3-37. Ventilation Header Schematic. 3-42

Figure 3-38. Typical Dresser Coupling. 3-43

Figure 3-39. Schematic of Vapor and Condensate System. 3-44

Figure 3-40. Location of Drywells and Laterals in 241-A Tank Farm. 3-45

Figure 3-41. 241-A Tank Farm Leak Detection System Typical Section. 3-46

Figure 3-42. Lateral Lines and Caisson for Thermal Probes at Tank 241-A-105. 3-48

Figure 3-43. 241-AX Single-Shell Tank Leak Detection Pit Schematic. 3-49

Figure 3-44. Schematic of a Typical Diversion Box Transfer System. 3-52

Figure 3-45. Diversion Boxes. 3-53

Figure 3-46. 241-AX-151 Diversion Box and 241-AX-151CT Catch Tank. 3-55

Figure 3-47. 204-AR Waste Unloading Facility. 3-63

Figure 3-48. 244-AR Vault. 3-64

Figure 3-49. 241-A-431 Ventilation Building and French Drains. 3-65

Figure 3-50. 241-AX-IX Ion Exchange System. 3-66

Figure 3-51. Liquid Discharge Sites Near Waste Management Area A-AX. 3-73

Figure 3-52. 1953 Aerial Photograph of 200 East Area Showing 200-E-286 Ditch. 3-76

Figure 4-1. Conceptualized Closure Surface Barriers for 200 East Area. 4-2

Figure 4-2. Conceptual Representation of the Impact of Surface Features on Local Recharge (arrow size indicates relative recharge rate). 4-5

Figure 4-3. Surface Conditions In and Around Waste Management Area A-AX. 4-8

Figure 4-4. Soil Types on the Central Plateau. 4-11

Figure 4-5. Precipitation Reconstruction for Past 100,000 years Based on Pollen Data. 4-18

Figure 4-6. Temperature Reconstruction for Past 100,000 years Based on Pollen Data. 4-19

Figure 5-1. Technetium-99 Concentration in Single-Pass Flow-Through Leachates for Tank 241-C-103 as a Function of the Total Volume of Leachate that has Contacted the Waste in Terms of Leachate Solution to Solid (Initial) Weight Ratio. 5-7

Figure 5-2. Technetium-99 Concentration in Single-Pass Flow-Through Leachates for Tank 241-C-202 as a Function of the Total Volume of Leachate that has Contacted the Waste in Terms of Leachate Solution to Solid (Initial) Weight Ratio. 5-8

Figure 5-3. Technetium-99 Concentration in Single-Pass Flow-Through Leachates for Tank 241-C-203 as a Function of the Total Volume of Leachate that has Contacted the Waste in Terms of Leachate Solution to Solid (Initial) Weight Ratio. 5-9

Figure 5-4. Fractional Release of Technetium-99 for Single-Pass Flow-Through Experiments from Tank 241-C-103 Along with the Estimate of the First-Order Reaction Rate Constant of 8E-04 day^{-1}. 5-10

Figure 5-5. Fractional Release of Technetium-99 for Single-Pass Flow-Through Experiments from Tank 241-C-202 Along with the Estimate of the First-Order Reaction Rate Constant of 6E-04 day^{-1}. 5-11

Figure 5-6. Fractional Release of Technetium-99 for Single-Pass Flow-Through Experiments from Tank 241-C-203 Along with the Estimate of the First-Order Reaction Rate Constant of 5E-04 day^{-1}. 5-12

Figure 5-7. Simulated Versus Observed Effluent Concentrations of Technetium-99 (µg/L) from the Single-Pass Flow-Through Experiments Conducted on Tanks 241-C-103 and 241-C-202 Residual Waste. 5-13

Figure 5-8. Uranium and Total Inorganic Carbon Concentrations (A) and the Paragenetic Sequence of Uranium Phases Present in the Waste (B) as a Function of Reaction Progress for the $Ca(OH)_2$ Saturated Water Scenario. 5-15

Figure 5-9. Uranium and Total Inorganic Carbon Concentrations (A) and the Paragenetic Sequence of Uranium Phases Present in the Waste (B) as a Function of Reaction Progress for the $CaCO_3$ Saturated Water Scenario. 5-15

Figure 5-10. Uranium Solubility Model Implemented with Solubility Limits Varying with Time. 5-17

Figure 5-11. Comparison of Initially Imposed Uranium Solubility Limit of 1×10^{-4} M to the Observed Concentrations during the Single-Pass Flow-Through Conducted on Tank 241-C-202 Residual Waste. 5-18

Figure 5-12. Effluent Concentrations of Chromium (µg/L) from the Single-Pass Flow-Through Experiments Conducted on (a) Tank 241-C-202 and (b) Tank 241-C-203 Residual Waste. 5-20

Figure 5-13. Diffusive Pathway for Transport of Non-Volatile Contaminants to the Near-Field Environment. 5-21

Figure 5-14. Set-Up of the Diffusive Half-Cell Experiment Contacting Contaminant-Spiked Sediment (or Concrete) Sample with the Non-Spiked Sediment (or Concrete) Sample. 5-22

Figure 5-15. Technetium-99 Concentration Profiles in Concrete from Sediment-Concrete Half-Cell Experiments Conducted on (A) 4% Sediment Moisture, Carbonated Monoliths, (B) 4% Sediment Moisture, Non-Carbonated Monoliths, (C) 7% Sediment Moisture, Carbonated Monoliths, (D) 7% Sediment Moisture, Non-Carbonated Monoliths, (E) 15% Sediment Moisture, Carbonated Monoliths, and (F) 15% Sediment Moisture, Non-Carbonated Monoliths. 5-25

Figure 5-16. Effective Diffusion Coefficient of Technetium-99 in Concrete Based on Experiments Conducted Using Sediment-Concrete Half-Cells. 5-26

Figure 5-17. Porosity-Permeability Relationship as a Function of Hydration and Water to Cement Ratio. 5-31

Figure 7-1. Carbonation Process Acting on a Buried Tank Wall. 7-2

Figure 7-2. Demolition of (a) Pool 1 Monolith and (b) Pool 2 Monolith after Only 5 Days after the Capping Layer had been Poured. 7-7

Figure 7-3. Evaluation of 55-inch Diameter Reinforced Concrete Dome Plug from Tank 214-C-107. 7-8

Figure 7-4. Evaluation of Sidewall Concrete Core from Tank 241-A-106. 7-9

LIST OF TABLES

Table 3-1. Summary of Liquid Discharge Sites Data Near Waste Management Area A-AX. 3-74

Table 3-2. Summary of Estimated Discharges for Septic Systems Near Waste Management Area A-AX. 3-82

Table 4-1. Timeline Considered for Representing the Evolution of Waste Management Area A-AX. 4-6

Table 4-2. Construction Start Dates for Tank Farms Near Waste Management Area A-AX. 4-7

Table 4-3. Representative Recharge Rate (Net Infiltration) Estimates for Surface Conditions during the Pre-Construction, Operational, and Post-Closure Periods. 4-15

Table 5-1. Characteristics of Concrete Specimens Used in Sediment-Concrete Half-Cell Experiments Along with Derived Bulk Diffusion Coefficient of Technetium-99 for the Concrete. 5-24

Table 5-2. K_d Values (mL/g) for Grout/Concrete Used for Waste Management Area C Performance Assessment. 5-27

Table 5-3. Selected K_d Values (mL/g) for Grout. 5-28

Table 5-4. Contaminant Source Term Parameters for Residual Waste. 5-32

Table 7-1. Characteristics of Concrete Cores from Aboveground Structures at the Hanford Site. 7-10

Table 7-2. Bounding Depth of Carbonation for Buried Concrete Calculated for Different Exposure Times Under Hanford-Specific Conditions. 7-11

LIST OF TERMS

Abbreviations and Acronyms

ALC	airlift circulator
amsl	above mean sea level
ASR	alkali-silica reaction
BP	Before Present
COPC	contaminant of potential concern
C-S-H	calcium silicate hydrate
DI	deionized
DOE	U.S. Department of Energy
DST	double-shell tank
Ecology	State of Washington Department of Ecology
EPA	U.S. Environmental Protection Agency
ERDF	Environmental Restoration Disposal Facility
ET	evapotranspiration
FEPs	Features, Events, and Processes
FLTF	Field Lysimeter Test Facility
HEPA	high-efficiency particulate air (filter)
HFFACO	*Hanford Federal Facility Agreement and Consent Order*
HLW	high-level waste
HMAPS	Hanford Maps
HMS	Hanford Meteorological Station
IX	ion exchange
NAD 83	North American Datum of 1983
NAVD 88	North American Vertical Datum of 1988

NGVD 29	National Geodetic Vertical Datum of 1929
NEPA	National Environmental Policy Act of 1969
OU	operable unit
PA	performance assessment
PDF™	powder diffraction files
PHB	Prototype Hanford Barrier
PNNL	Pacific Northwest National Laboratory
PPF	Preprocessing Facility
PUREX	Plutonium Uranium Extraction (Plant)
PVC	polyvinyl chloride
RCRA	*Resource Conservation and Recovery Act of 1976*
RPPDF	River Protection Project Disposal Facility
SCC	stress corrosion cracking
SI	saturation index
SPFT	single-pass flow-through
SRNL	Savannah River National Laboratory
SST	single-shell tank
SST PA	DOE/ORP-2005-01, *Initial Single-Shell Tank System Performance Assessment for the Hanford Site*
SSTIP	Single-Shell Tank Integrity Project
TBP	tri-butyl phosphate
TEDF	Treated Effluent Disposal Facility
UPR	unplanned release
WAC	Washington Administrative Code
WIDS	Waste Information Data System
WMA	waste management area

WTP	Hanford Tank Waste Treatment and Immobilization Plant

Units

ft	foot
g	gram
gal	gallon
gpd	gallons per day
in.	inch
L	liter
m	meter
mg	milligram
mi^2	square mile
µg	microgram
pCi	picocurie
ºC	temperature in degrees Celsius [T(ºC) = T(K) – 273.15)]
Ci	curie, unit of radioactivity, equal to the amount of a radioactive isotope that decays at the rate of 3.7×10^{10} disintegrations per second
°F	temperature in degrees Fahrenheit {T(°F) = [T(°C) × 9/5] + 32}
µ	micro (prefix, 10^{-6})
µg	microgram
M	molarity, mol/L
mg	milligram
mL	milliliter
pCi	picocurie (10^{-12} curies)
wt%	weight percent

Conversions

English to Metric			Metric to English		
Multiply	**by**	**To get**	**Multiply**	**by**	**To get**
Area			**Area**		
square inches	6.4516	square centimeters	square centimeters	0.155	square inches
square feet	0.092903	square meters	square meters	10.7639	square feet
square yards	0.8361	square meters	square meters	1.196	square yards
acres	0.40469	hectares	hectares	2.471	acres
square miles	2.58999	square kilometers	square kilometers	0.3861	square miles
Length			**Length**		
inches	2.54	centimeters	centimeters	0.3937	inches
Feet	30.48	centimeters	centimeters	0.0328	feet
Feet	0.3048	meters	meters	3.281	feet
Yards	0.9144	meters	meters	1.0936	yards
Miles	1.60934	kilometers	kilometers	0.6214	miles
Temperature			**Temperature**		
degrees Fahrenheit	Subtract 32, then multiply by 0.55556	degrees Celsius	degrees Celsius	Multiply by 1.8, then add 32	degrees Fahrenheit
Volume			**Volume**		
fluid ounces	29.574	milliliters	milliliters	0.0338	fluid ounces
gallons	3.7854	liters	liters	0.26417	gallons
cubic feet	0.028317	cubic meters	cubic meters	35.315	cubic feet
cubic yards	0.76455	cubic meters	cubic meters	1.308	cubic yards
Weight			**Weight**		
Ounces	28.3495	grams	grams	0.03527	ounces
Pounds	0.45360	kilograms	kilograms	2.2046	pounds
short tons	0.90718	metric tons	metric tons	1.1023	short tons

1.0 INTRODUCTION

This document provides supporting information for the Waste Management Area (WMA) A-AX Engineered System. Information and data presented in this report is anticipated to be used to prepare the *Hanford Federal Facility Agreement and Consent Order* (HFFACO) (Ecology et al. 1989) Appendix I Performance Assessment (PA) for WMA A-AX.

Key items provided in this data package include:

- A detailed discussion of major features of the existing engineered system for WMA A-AX including single-shell tanks (SSTs), ancillary equipment, process facilities, and liquid discharge sites
- Recharge rates in and around WMA A-AX for past, current, and anticipated future near-surface conditions at and following site closure
- Waste form release rates from residual wastes in tanks and ancillary equipment after site closure
- Corrosion processes for steel components and elements (i.e., tank steel liners and pipelines, and related equipment)
- Tank structure and emplaced grout/concrete degradation processes and rates and how these processes and rates relate to contaminant release rates from residual wastes.

1.1 OBJECTIVE

The objective of this data package is to provide data regarding historic and future engineered features of WMA A-AX for potential use in the PA, including descriptions and dimensions of existing infrastructure, the most current estimates of historic and future recharge[1], and the most current understanding of mechanisms expected to control contaminant releases from waste residuals that may remain in WMA A-AX after closure. Information concerning the potential degradation of steel, concrete, and grouted components is relevant to rates of contaminant release and water infiltration over the timescale of hundreds to thousands of years to be analyzed in the WMA A-AX PA. Recharge rates have been estimated for areas in a natural and undisturbed state, areas where the vegetation has been disturbed, areas where both the vegetation and the soil have been disturbed, and areas that are engineered (e.g., surface barrier).

[1] As in common usage outside research settings, this data package uses the term *recharge* interchangeably with the term *infiltration* since the document is concerned with the near-surface environment rather than the groundwater aquifer, and the tabulated rates are generally for infiltration net of evapotranspiration (e.g., beyond the root zone). *Infiltration* is sometimes used herein to emphasize near-surface processes. Other PA documents may adopt a formal distinction for deep recharge.

This data package documents the basis and understanding concerning:

- Recharge estimates available to be used in the WMA A-AX PA for the range of temporal changes in near-surface conditions before and after site closure
- Contaminant release rates to be used in the WMA A-AX PA for grouted tank waste residuals left in place after tank waste retrieval and after site closure
- Key processes affecting potential corrosion and degradation of steel and metallic components of tanks, pipelines, and ancillary equipment
- Tank structure and emplaced grout degradation processes and rates and how these processes and rates relate to post-closure contaminant release rates from residual wastes considered in the PA.

1.2 SCOPE OF REPORT

General topics that are presented in this document to facilitate the development of a PA include the following:

- Existing Engineered Features of WMA A-AX
    - Excavation and backfill
    - SSTs
    - Ancillary equipment
- Natural Recharge and Engineered Barriers
    - Previous work on recharge
    - Technical approaches for estimating recharge
    - Climatic and surface conditions at WMA A-AX
    - Use and effects of engineered surface barriers on recharge
    - Estimated recharge rates proposed for use in the WMA A-AX PA
- Contaminant Releases from Tank Waste Residuals
    - Previous work on release models (assuming that contaminant release characteristics from WMA A-AX post-retrieval wastes are similar to those developed from laboratory analysis for WMA C post-retrieval wastes)
    - Technical approach and testing and characterization of tank waste residuals
    - Solid phase characterization of tank residuals

  - Estimate of contaminant release rates
  - Estimated contaminant release rates proposed for use in the WMA A-AX PA
- Corrosion of steel components and elements of tanks and ancillary equipment
- Concrete structure and emplaced grout degradation.

1.3 REPORT CONTENT

The following describes the main sections of this report.

- **Section 1.0, Introduction** – Describes the objectives and scope of this report.
- **Section 2.0, Background Information** – Provides a brief summary of the WMA A-AX facilities.
- **Section 3.0, Major Features of the Engineered System** – Presents a detailed description of the major features of the engineered system within WMA A-AX.
- **Section 4.0, Natural Recharge and Engineered Barriers** – Provides a discussion of conceptual models of recharge at WMA A-AX, a brief summary of previous work, the factors affecting recharge, methods used to characterize recharge, and recharge rates that are recommended for the WMA A-AX PA.
- **Section 5.0, Waste Management Area A-AX Closed Facility Performance** – Provides a summary of previous work related to waste release, methods used to characterize tank waste residuals, results of solid phase characterization and contaminant release model development for selected tank waste residual samples, and waste release rates for the WMA A-AX PA. Provides contaminant-specific transport parameters for transport through concrete or grout, including diffusion and sorption coefficients.
- **Section 6.0, Steel Corrosion and Degradation** – Discusses corrosion of steel and other metallic components in tanks and ancillary equipment.
- **Section 7.0, Concrete and Emplaced Grout Degradation** – Discusses concrete and grout degradation in the tank farms.
- **Section 8.0, References** – Lists reference documents cited in this report.
- **Appendix A, Tank 241-A-105 History** – Provides extended background information for damaged tank 241-A-105 of potential relevance to conceptual model of past leaks or of anticipated conditions of residual waste in tank 241-A-105 at the time of closure.

- **Appendix B, Evaluation of Diffusive Release Assumption for Intact Tank Condition** – Details a numerical modeling example demonstrating the dominance of diffusive contaminant transport in source areas of grouted tanks for nominal recharge, grout, and backfill sediment parameters.

2.0 BACKGROUND INFORMATION

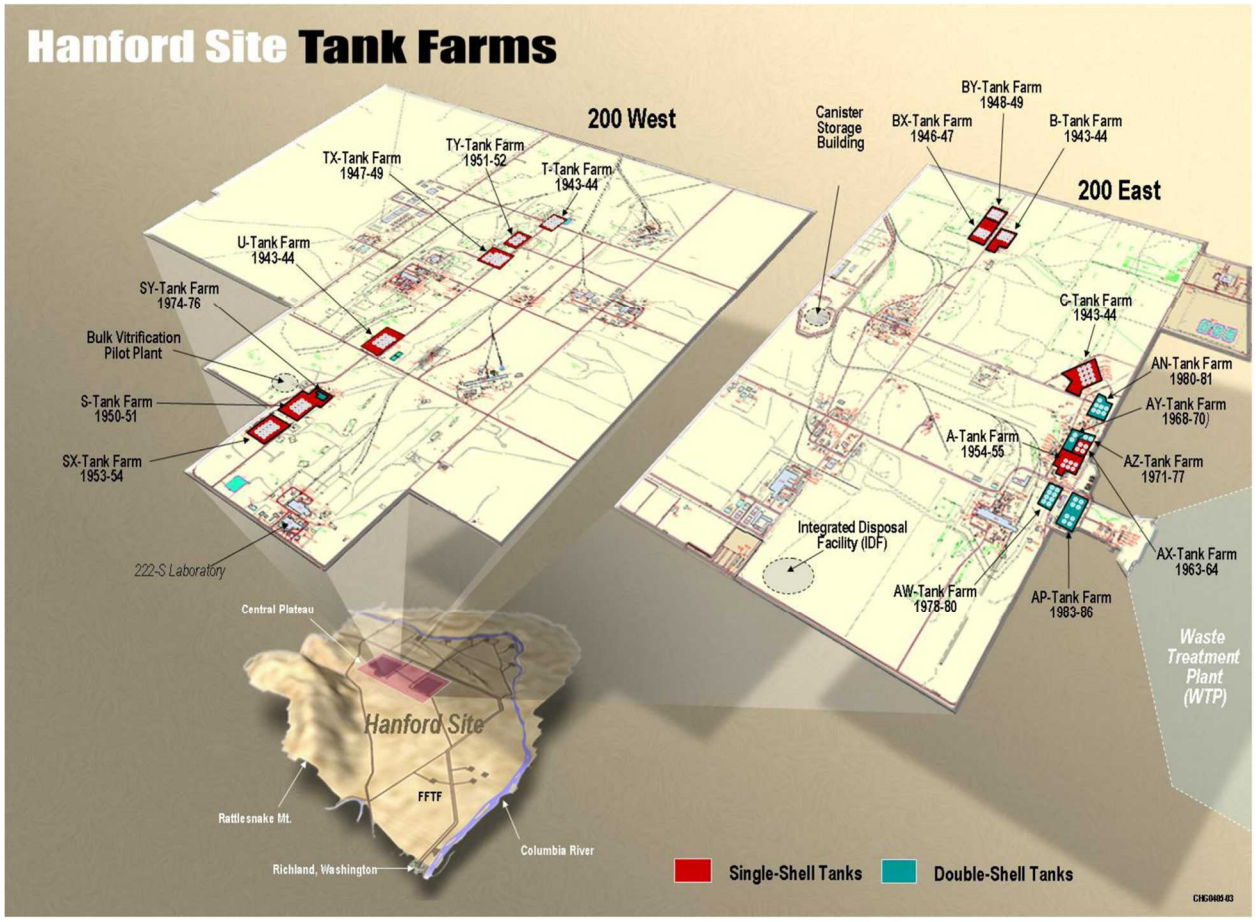
Waste Management Area A-AX, part of the SST system, is located in the Central Plateau of the Hanford Site, near the eastern edge of the 200 East Area (Figure 2-1). WMA A-AX includes the 241-A Tank Farm (A Farm), the 241-AX Tank Farm (AX Farm), associated ancillary equipment, and adjacent areas of soil contamination from unplanned releases (UPRs). Figure 2-2 is a map of features of potential interest in the region around WMA A-AX, and Figure 2-3 is a map on the scale of the 241-A and 241-AX Tank Farms. The six underground SSTs in A Farm are numbered 241-A-101 (A-101) through 241-A-106 (A-106). The four underground SSTs in AX Farm include tanks 241-AX-101 (AX-101), 241-AX-102 (AX-102), 241-AX-103 (AX-103), and 241-AX-104 (AX-104). A complex waste transfer system of ancillary equipment supported the transfer and storage of waste within WMA A-AX SSTs. This ancillary equipment includes pipelines (transfer lines), catch tanks, diversion boxes, vaults, valve pits, and other miscellaneous structures. Ancillary equipment is located (mostly buried) throughout WMA A-AX but concentrated around the SSTs. Other nearby engineered features (for example, several cribs, trenches, and septic systems), though not part of WMA A-AX, may be relevant to numerical modeling of vadose zone moisture conditions or contaminant transport in the area of interest for the WMA A-AX PA and are therefore described in this data package to assist in determining which features are potentially significant and should be considered in the modeling approach (Figure 2-2).

A Farm was constructed between 1954 and 1955 and operations began in 1956; AX Farm was constructed between 1963 and 1964 and operations began in 1965 (RPP-ENV-37956, "*Hanford 241-A and 241-AX Tank Farms Leak Inventory Assessment Report*"; RPP-35484, "*Field Investigation Report for Waste Management Areas C and A-AX*"). The later construction dates compared to other Hanford SSTs are associated with some differences in design (including differences between A Farm and AX Farm) such as the incorporation of leak monitoring features. One important design feature to consider in the risk assessment calculations is that these 100-series tanks have larger capacities (nominally 1,000,000 gal) resulting in deeper tank bases than other Hanford SSTs. Other unique design features are related to the use of the tanks to handle high-temperature waste associated with the Plutonium Uranium Extraction (PUREX) process, including the use of airlift circulators (ALCs) for cooling boiling wastes and underground vessel ventilation headers for removing off-gas and water vapor. Design details are discussed in Section 3.2.

According to current assessments summarized in RPP-ENV-37956, past leak events (losses of waste to the environment attributed to tank liner leaks) have occurred from tanks 241-A-104 (A-104) and 241-A-105 (A-105), and waste has been released from the 241-A-01B Pit at tank A-101. Releases from pipelines or diversion boxes may have occurred within or near to WMA A-AX. Off-gas from tank wastes or off-gas condensate has likely leaked from couplings in the tank vapor collection system in addition to intentional discharges of condensate from cribs, trenches, and drains. Near-surface contamination is widespread in WMA A-AX and has alternately been accounted for in different reference documents as a list of multiple UPRs, a single comprehensive UPR (i.e., 200-E-131), or subareas for each tank farm and for a discrete region around tank AX-101 (RPP-ENV-37956; DOE/RL-88-30, *Hanford Site Waste Management Units Report*, Rev. 26). In a few cases, contaminated soil has been removed over

small areas (RPP-ENV-37956; Appendix B of RPP-RPT-60227, "*Data Quality Objectives for Vadose Zone Characterization at Waste Management Area A-AX*"). RPP-ENV-37956 provides additional detail on releases and tank leaks.

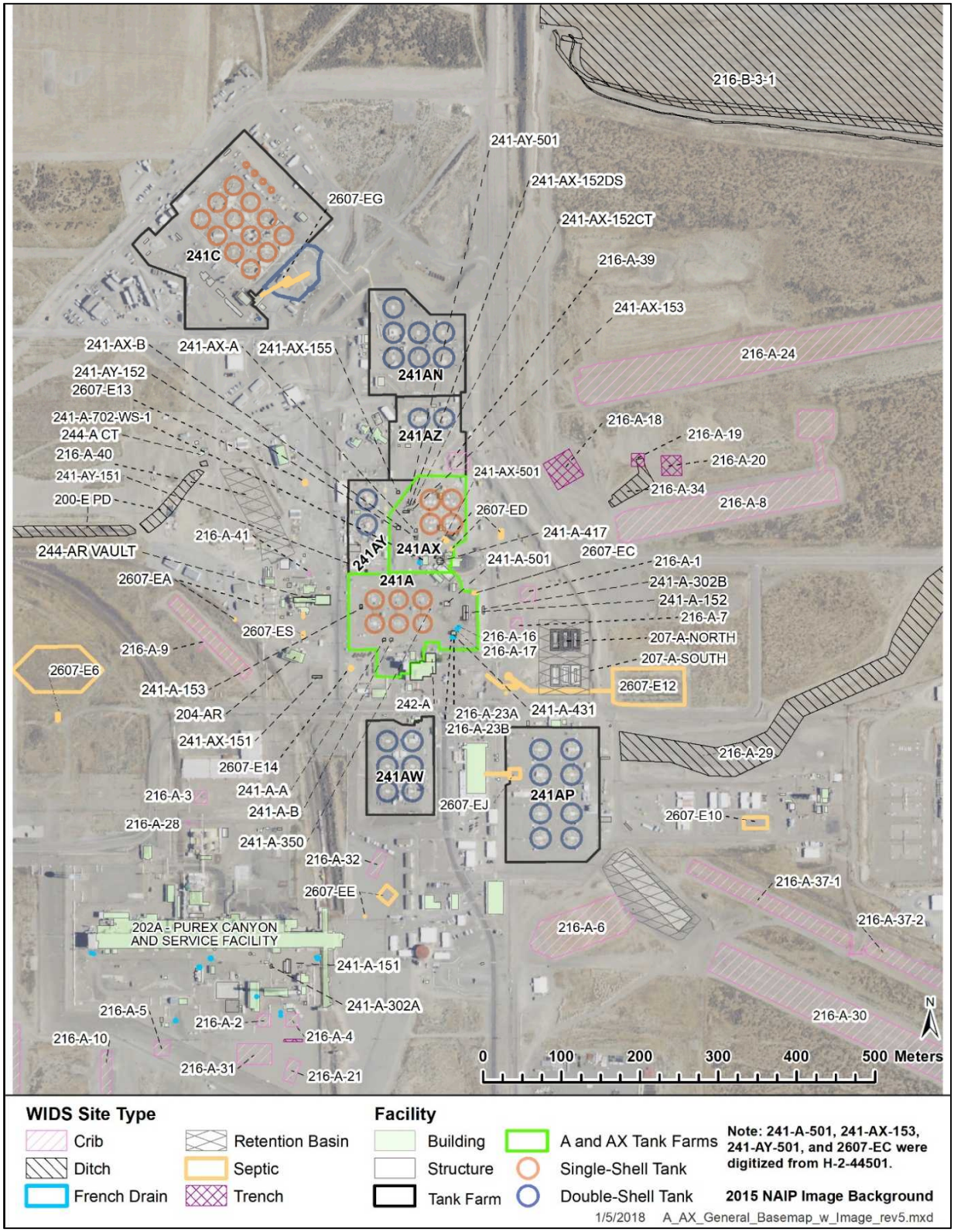
Figure 2-1. Locations of Tank Farms on Hanford Site.



Events leading to leaks from the A-105 tank liner, particularly a large heat buildup and steam release event, have left the tank in a damaged condition with a bulge upward in the steel liner of as much as 8.5 ft from the concrete base (WCC Project 13974A-0300, "*An Estimate of Bottom Topography, Volume and Other Conditions in Tank 105A, Hanford, Washington*"). This deformation of the liner has allowed some of the waste currently in the tank to reside above the liner, some below the liner, and some on bare concrete at the tank base. This condition has potential implications for the ability to safely use some waste retrieval technologies and for modeling of past leaks or future conditions in and near the tank; therefore, special discussion of tank A-105 is included in Appendix A.

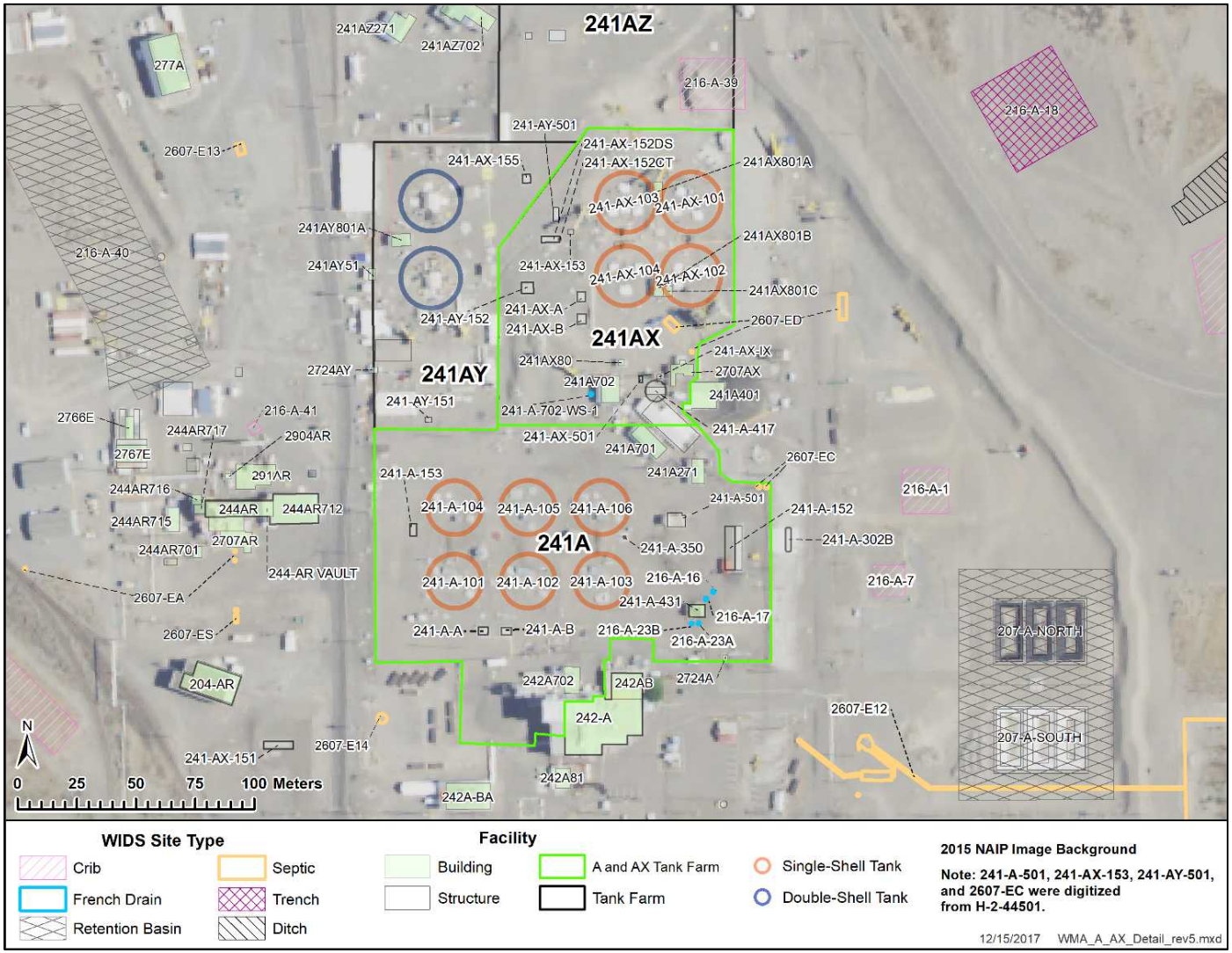
More information on the condition of tanks A-104 and A-105 may become available as retrieval planning for A Farm proceeds and/or with possible future field characterization.

Figure 2-2. 241-A and 241-AX Tank Farms and Surrounding Features.



NAIP = National Agriculture Imagery Program
PUREX = Plutonium Uranium Extraction (Plant)
WIDS = Waste Information Data System

Figure 2-3. Map of 241-A and 241-AX Tank Farms.



NAIP = National Agriculture Imagery Program WIDS = Waste Information Data System

Reference: H-2-44501, "Area Map, 200 East, A Plant Facilities."

All of the SSTs in WMA A-AX were declared inactive in the late 1970s to early 1980s and were subsequently interim stabilized by removing pumpable fluids. The A Farm and AX Farm SSTs have been saltwell pumped to mitigate leaks/releases from tanks, and preparations are underway to begin waste retrieval in AX Farm, then A Farm. Waste retrieval involves removal of remaining waste (mostly saltcake and sludge) to the extent practicable, with retrieval goals defined by the HFFACO (Ecology et al. 1989). Retrieval plans for AX Farm (RPP-RPT-58932, "*241-AX-101 Tank Waste Retrieval Work Plan*"; RPP-RPT-58933, "*241-AX-102 Tank Waste Retrieval Work Plan*"; RPP-RPT-58934, "*241-AX-103 Tank Waste Retrieval Work Plan*"; and RPP-RPT-58935, "*241-AX-104 Tank Waste Retrieval Work Plan*") involve sluicing waste with water and pumping waste slurry to the double-shell tank (DST) 241-AZ-102. Retrieval equipment will be installed in each AX Farm SST using existing risers that provide access to the tank interior from ground surface through ports in the dome of the tank. SSTs are isolated from transfer lines and other points of entry or exit prior to sluicing. Retrieval plans for A Farm have not yet been published. Alternative retrieval technologies may be deployed at any of the A Farm or AX Farm tanks if necessary and if approved by regulators.

Portions of wastes in SSTs and ancillary equipment that cannot be retrieved using the agreed technologies are known as residuals. Planned closure operations to immobilize the residual waste in the SSTs and ancillary equipment were established by a December 13, 2013 U.S. Department of Energy (DOE) Record of Decision (78 FR 75913, "Record of Decision: Final Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington") which (in part) selected Tank Closure Alternative 2B (which includes retrieval and treatment of 99% of waste in the SST system and landfill closure of the SSTs with a Modified RCRA Subtitle C Barrier) as the preferred alternative among those considered in DOE/EIS-0391, *Final Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington*. Planned closure operations call for SSTs to be filled with grout to minimize long-term risk from residuals and to prevent collapse. Additionally, an engineered surface barrier, whose final design has yet to be determined, will be placed over each tank farm to minimize infiltration and potential above-ground exposure. The barrier will be compliant with Subtitle C of the *Resource Conservation and Recovery Act of 1976* (RCRA); thus, it is known as a Modified RCRA Subtitle C Barrier. Long-term empirical studies of the efficacy of potential barrier designs evaluated using the Prototype Hanford Barrier (PHB) are summarized in DOE/RL-2016-37, *Prototype Hanford Barrier 1994 to 2015*.

Waste retrieval and tank farm closure involve removal and installation of engineered components. For example, in AX Farm, portions of the existing vapor header have been isolated or removed in order to temporarily install a new active ventilation system for worker protection during retrieval operations. The AX Farm retrieval work plans indicate few changes significant to the WMA A-AX PA, given the use of existing risers to access tank interiors and temporary aboveground equipment such as hose-in-hose transfer lines to move waste and skid-mounted portable exhausters for the ventilation system.

Tank Farms 241-AN, 241-AP, 241-AW, 241-AY, and 241-AZ (identified on Figure 2-2) contain buried DSTs and ancillary equipment in backfilled excavations. Together with WMA A-AX, these DST farms form the "A Complex" of tank farms which, given their proximity, are expected

to be closed with a common surface barrier or a set of essentially continuous surface barriers[2]. The features shown in Figure 2-2 are not all considered to be part of WMA A-AX, but several of them lie within the likely PA model domain and may be relevant to historical and long-term subsurface moisture conditions. Several features outside WMA A-AX also likely contribute to historical observations of subsurface contamination and/or historical changes to the water table and hydraulic gradient, which are discussed further in RPP-ENV-58578, "*Summary of the Natural System at Waste Management Area A/AX*" and RPP-RPT-60101, "*Model Package Report: Flow and Contaminant Transport Numerical Model used in WMA A-AX Performance Assessment and RCRA Closure Analysis*".

[2] Interim barriers may be used for individual tank farms pending closure of neighboring tank farms. As of April 2019, HFFACO Milestone M-045-00 requires all SST tank farms at Hanford to be closed by January 31, 2043, whereas Milestone M-042-00A requires the DST farms to be closed by September 30, 2052. Given the time remaining before the closure milestones and current plans to retrieve waste from the AX Farm and A Farm earlier than other remaining SST farms, there is potentially a lag of years or decades between placement of interim barriers over the SST farms and final closure of the DST farms, and there is uncertainty in the actual date(s) of closure.

3.0 MAJOR FEATURES OF THE ENGINEERED SYSTEM

This section describes the major engineered features in the 241-A and 241-AX Tank Farms. These include:

- SSTs (Section 3.2.1)
- Ancillary Equipment (Section 3.2.2)
- Process Facilities (Section 3.3)
- Liquid Discharge Sites (Section 3.4).

This data package attempts to summarize key dimensions and specifications of engineered system components that may be required for WMA A-AX PA calculations; however, it is no trivial task to compile a comprehensive summary of engineering design details, coming as they are from hundreds of engineering drawings and other documents maintained in the Hanford Site document management system. Whereas this data package is intended to be sufficiently complete and accurate for the purpose of WMA A-AX PA calculations, readers of this data package are hereby advised that the original engineering drawings should usually be considered more accurate than any later documents that merely summarize them. Not all engineering drawings containing required dimensions have been cleared for release to the public by the date this document was published; selected drawings are reproduced as figures in this data package for convenience, or else individual dimensions are stated for drawings that have not been released.

Note that spatial information from historical documents, for example horizontal coordinates on a local Hanford datum or elevations relative to "mean sea level," must be converted to Washington State Plane South northing and easting coordinates (Lambert Coordinate system, NOAA Manual NOS NGS 5, "State Plane Coordinate System of 1983") on the North American Datum of 1983 (NAD 83) and to elevations on the North American Vertical Datum of 1988 (NAVD 88) to be consistent with other modeling data. Elevations for WMA A-AX on NAVD 88 are 1.064 m ± 0.001 m higher than equivalent elevations on the National Geodetic Vertical Datum of 1929 (NGVD 29), based on conversions near the corners and center of WMA A-AX using Corpscon 6.0.1 (Army Geospatial Center, United States Army Corps of Engineers, Queried 05/19/2015, [Corpscon 6.0.1], http://www.agc.army.mil/Missions/Corpscon.aspx). A constant datum shift of 1.064 m is adopted herein when elevations are stated on NAVD 88; however, if high precision is needed for areas outside WMA A-AX, the original elevations should be converted in Corpscon. Use of NGVD 29 is implied by reference to "mean sea level," "amsl," or "msl"; or when Hanford documents are dated before 1988.

Information for engineered features is drawn heavily from the Hanford Site Waste Information Data System (WIDS), including geospatial data (accessed via the non-public Hanford Maps [HMAPS] application and reproduced on figures herein) and verbal summaries from an electronic WIDS library which are made publicly available via annual updates to DOE/RL-88-30.

3.1 EXCAVATION AND BACKFILL

Excavation for A Farm started after completing the tank farm construction specification in October 1953 (HWS-5614, *Specifications for PUREX Waste Disposal Facility Project CA-513-A*), with ground breaking in January 1954 (Figure 3-1) and the main excavation work completed by February 1954 (Figure 3-2). Figure 3-1 through Figure 3-12 are photographs from the time of A Farm construction which may be useful to visualize buried features discussed in the sections that follow and potentially to interpret details that may not be specifically mentioned; Figure 3-13 through Figure 3-19 are photographs from the time of AX Farm construction. A Farm construction was completed and tank A-101 was filled during the first quarter of 1956 (dates of service varied for the SSTs, but this section is concerned only with timing of excavation and backfill); most of the underground structural work and backfill had been completed by January 1955 (Figure 3-12). As shown in Figure 3-20, the land surface before excavation sloped from 690 ft above mean sea level (amsl) (211.4 m NAVD 88) in the southwest corner to 672 ft amsl (205.9 m NAVD 88) in the northeast corner, and the elevation at the base of the tanks ranges from ~636 to 633 ft amsl (194.9 to 194.0 m NAVD 88); the excavation has 1.5:1 side slopes.

Excavation for AX Farm started after completing the tank farm construction specification in May 1963 (HWS-8237, *Specification for PUREX 241-AX Tank Farm Project CAC-945*). The tank farm construction was completed and tank AX-101 was filled during the first quarter of 1965 (dates of service varied for the SSTs). As indicated in Figure 3-21, the land surface before excavation sloped from 670 ft amsl (205.3 m NAVD 88) in the southwest corner to 660 ft amsl (202.2 m NAVD 88) in the northeast corner and the elevation at the base of the tanks was ~627 ft amsl or 192.2 m NAVD 88 (H-2-44562, "Structural Waste Storage Tanks Composite Section & Details, 241-AX PUREX Waste Tank Farm").

During and after building the tanks, the volume between the tanks was backfilled. Backfill material is derived from excavated sediments. Backfill differs from the undisturbed sediments, however, in that stratification of contrasting textures is disrupted by excavation, and compaction occurred from driving tracked vehicles throughout the excavations and applying water (e.g., see Figure 3-2 through Figure 3-7, Figure 3-16 and Figure 3-17). A Farm backfill is consistent with material derived from the gravel-dominated Hanford H1 unit based on Figure 3-2 through Figure 3-11 and "typical" percentages in ARH-LD-127, *Geology of the 241-A Tank Farm* of 58% gravel[3], 41% sand (well-sorted, mostly very coarse sand), and 1% silt or clay. In contrast, AX Farm backfill is consistent with material from the sand-dominated Hanford H2 unit based on "typical" percentages in ARH-LD-128, *Geology of the 241-AX Tank Farm* of 80% poorly-sorted sand, 13% silt or clay, and 7% gravel. Other estimates of grain size percentages and variability are available from sieve data in the ROCSAN data set, accessible to authorized users via Hanford

[3] The backfill gravel fraction at A Farm is interpreted to be dominated by pebble gravel (defined as between 2-mm and 64-mm size in H-2-38978, "241-A Tank Farm Geologic Map Legend and Plot Plan"), because the text and cross-sections of ARH-LD-127 consistently describe "pebble" as opposed to cobbles or boulders, and because few cobbles and few or no boulders are apparent in Figure 3-1 through Figure 3-11. It is unclear to what extent grain size distributions for backfill may vary from the "typical" percentages; however, the apparent rarity of sizes coarser than pebble suggests that core barrel or split tube samples could be one reasonable means to estimate variability. Another means to support understanding of variability would be to opportunistically photograph excavations made in the backfill in the course of other work if safety permits.

Virtual Library. Figure 3-13 through Figure 3-19 appear to show few cobbles and perhaps slightly more cohesive sediments in AX Farm than in A Farm, consistent with somewhat finer texture. Backfill in the DST farms in the A Complex is derived from either the Hanford H1 unit, the Hanford H2 unit, or a mixture of the two according to which unit(s) are present near ground surface in adjacent, undisturbed sediments as interpreted in RPP-RPT-60171, "*Model Package Report: Geologic Framework Model used in WMA A-AX Performance Assessment and RCRA Closure Analysis*". In its current condition, the surface of the backfill material in the A Complex is largely made up of reworked sand and gravel that is kept clear of vegetation.

Moisture logging of drywells and direct push boreholes in AX Farm (RPP-ENV-58747, "*Fiscal Years 2014/2015 Completion Report for the 241-A and 241-AX Tank Farms Direct Push Characterization*") and nearby WMA C consistently shows elevated moisture in the backfill horizon relative to the underlying undisturbed sediments. This is interpreted to be occurrence of moisture accumulating above the compacted base of the original tank farm excavation (RPP-ENV-58782, "*Performance Assessment of Waste Management Area C, Hanford Site, Washington*"). Similar effects are expected to exist in the backfilled areas of the other tank farms in the A Complex. Based on the relatively few moisture logs available from A Farm, the vertical moisture profiles contrast somewhat with those in AX Farm in a manner consistent with the contrasting backfill grain size distributions. Moisture in the A Farm backfill horizon, although more variable than in underlying sediments, is not clearly elevated relative to underlying sediments except in the immediate vicinity of the compacted excavation base (e.g., borehole C9379). Such a pattern is consistent with the efficient drainage that would be expected from well-sorted, coarse-textured sediments. In contrast, vertical profiles from AX Farm show distinctly elevated moisture in the backfill horizon (e.g., borehole C9365), consistent with better moisture retention by poorly-sorted sediments. A more comprehensive evaluation of available moisture measurements and interpreted backfill properties are presented in RPP-RPT-60101.

Figure 3-1. Ground Breaking of 241-A Tank Farm with View to Southwest.

Source: 2472-PHOTO, January 20, 1954, "PUREX WASTE TANK FARM - 241-A GROUND BREAKING."

Figure 3-2. Excavation of 241-A Tank Farm with View to Southwest Showing Grading for Tank Construction.

Source: 2524-PHOTO, February 26, 1954, "PUREX WASTE TANK FARM - 241-A CONSTRUCTION PROGRESS (VIEW 1)."

Figure 3-3. Preparation of Excavation Base Surface and Rebar for Tank Base Construction.

Source: 2505-PHOTO, February 18, 1954, "PUREX WASTE TANK FARM - 241-A CONSTRUCTION PROGRESS (VIEW 3)."

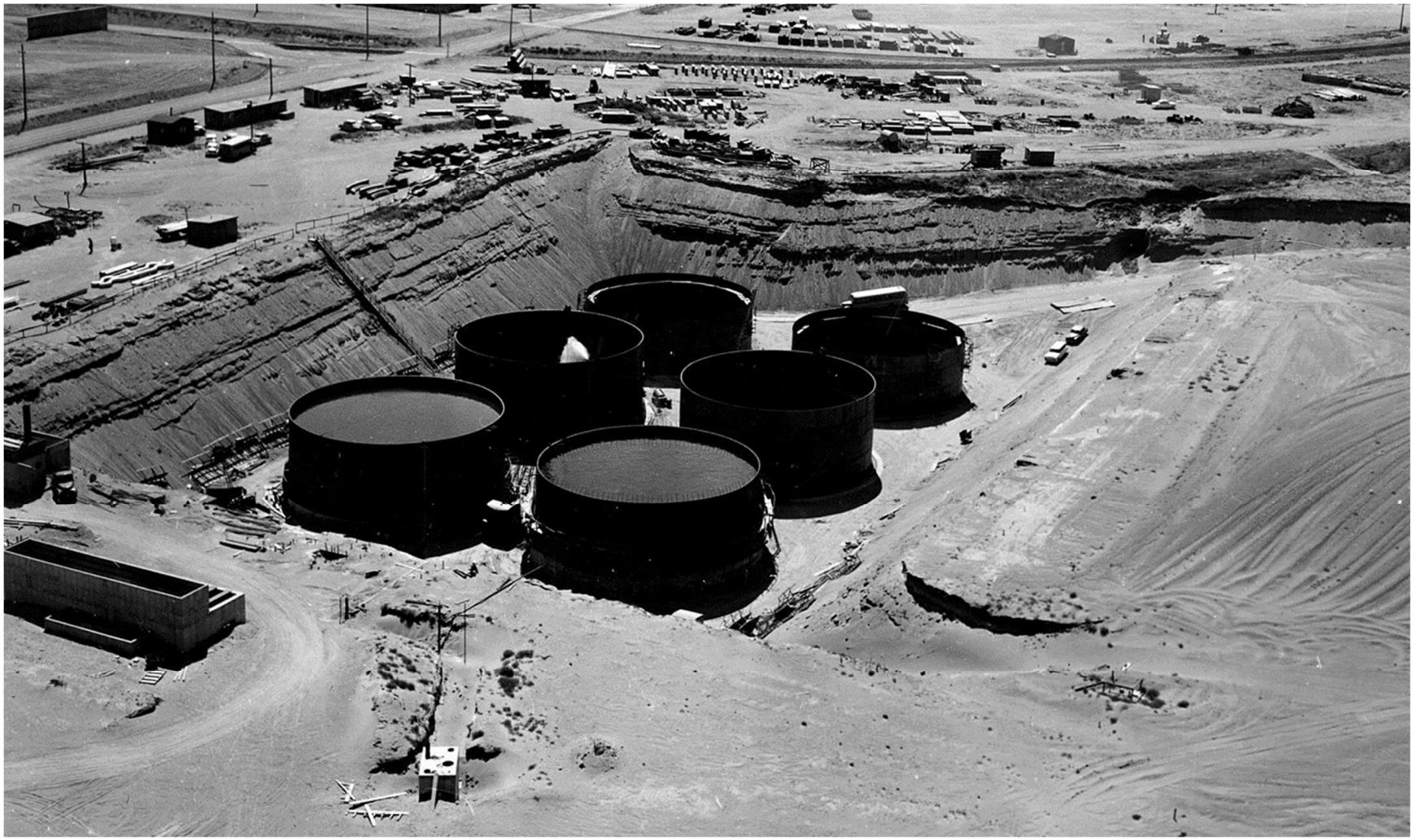
Figure 3-4. 241-A Tank Farm Excavation with View to Northwest Showing Placement of Rebar for Tank Sidewalls.

Source: 2641-PHOTO, March 29, 1954, "PUREX WASTE TANK FARM - 241-A CONSTRUCTION PROGRESS."

Figure 3-5. 241-A Tank Farm Excavation with View to Northwest Showing Tank Sidewall Steel Liner Sections Being Delivered and Hoisted for Welding.

Source: 2788-PHOTO, May 22, 1954, "WASTE STORAGE FACILITIES, PUREX - 241-A CONSTRUCTION PROGRESS."

Figure 3-6. 241-A Tank Farm Excavation with View to West Showing Completion of Tank Steel Liners with Diversion Box in Foreground.



Source: 2871-PHOTO, June 28, 1954, "PUREX WASTE TANK FARM - 241-A CONSTRUCTION PROGRESS."

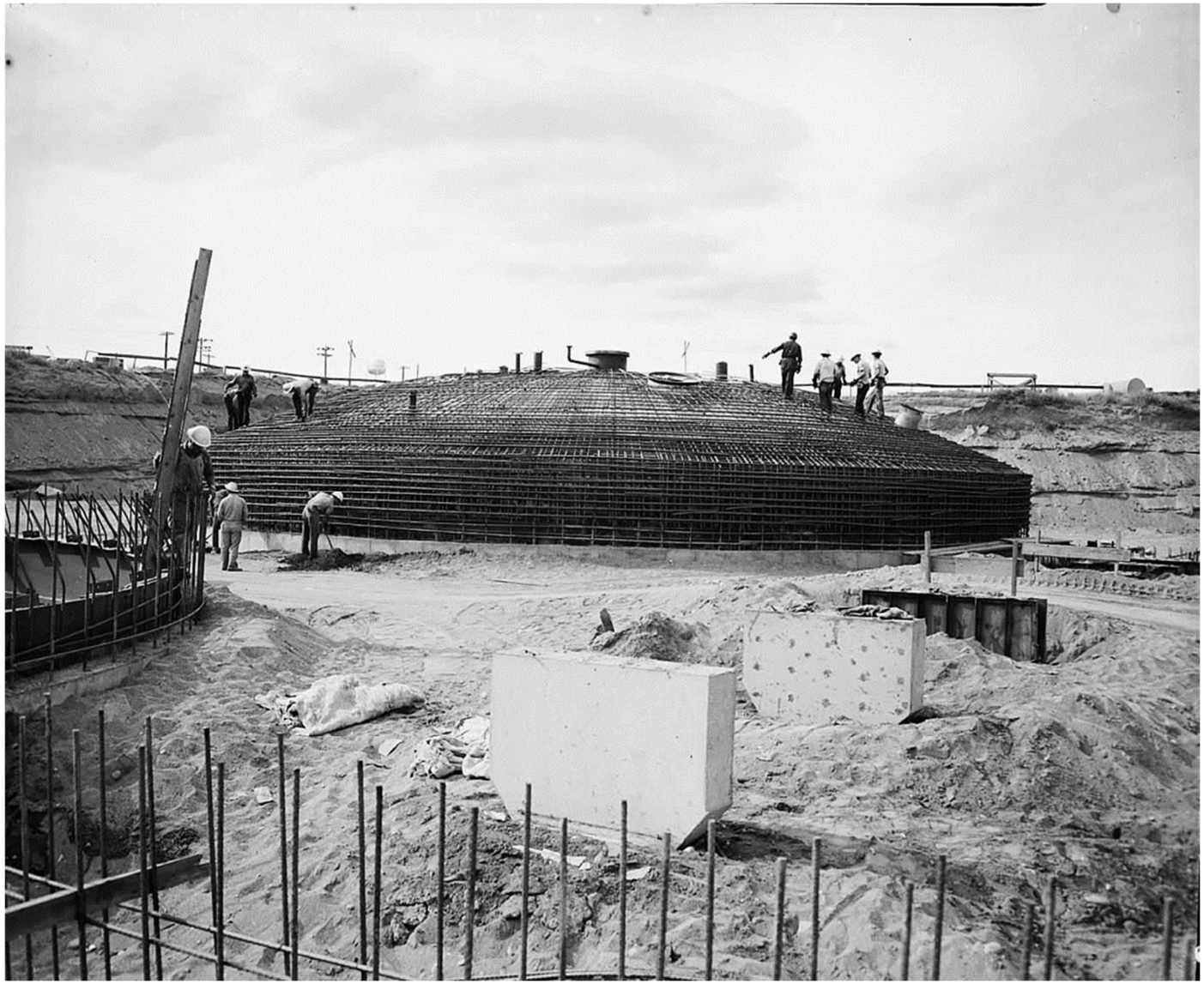
Figure 3-7. 241-A Tank Farm Excavation with View to West Showing Completion of Tank Sidewall Concrete, Partial Backfill of Excavation, and Diversion Box in Foreground.

Source: 2991-PHOTO, August 30, 1954, "241-A WASTE STORAGE TANK FARM."

Figure 3-8. Supports and Rebar for Tank Sidewall and Dome Construction in 241-A Tank Farm.

Source: 3099-1-PHOTO, October 8, 1954, "241-A WASTE STORAGE - CONSTRUCTION PROGRESS (VIEW 4)."

Figure 3-9. Rebar for Tank Dome Construction in 241-A Tank Farm.



Source: 3099-NEG-B, October 8, 1954, "241-A TANK DOMES."

Figure 3-10. 241-A Tank Farm Excavation with View to West Showing Completion of Tank Dome Concrete, Partial Backfill, and Concrete Encasement for Pipelines.

Source: 3099-NEG-D, October 8, 1954, "241-A TANK DOMES."

Figure 3-11. 241-A Tank Farm Construction Photograph Showing Ventilation Header, Pits, and Backfill to Tops of Tanks.

Source: 3186-PHOTO, December 24, 1954, "241-A - TANK FARM CONDENSOR SYSTEM."

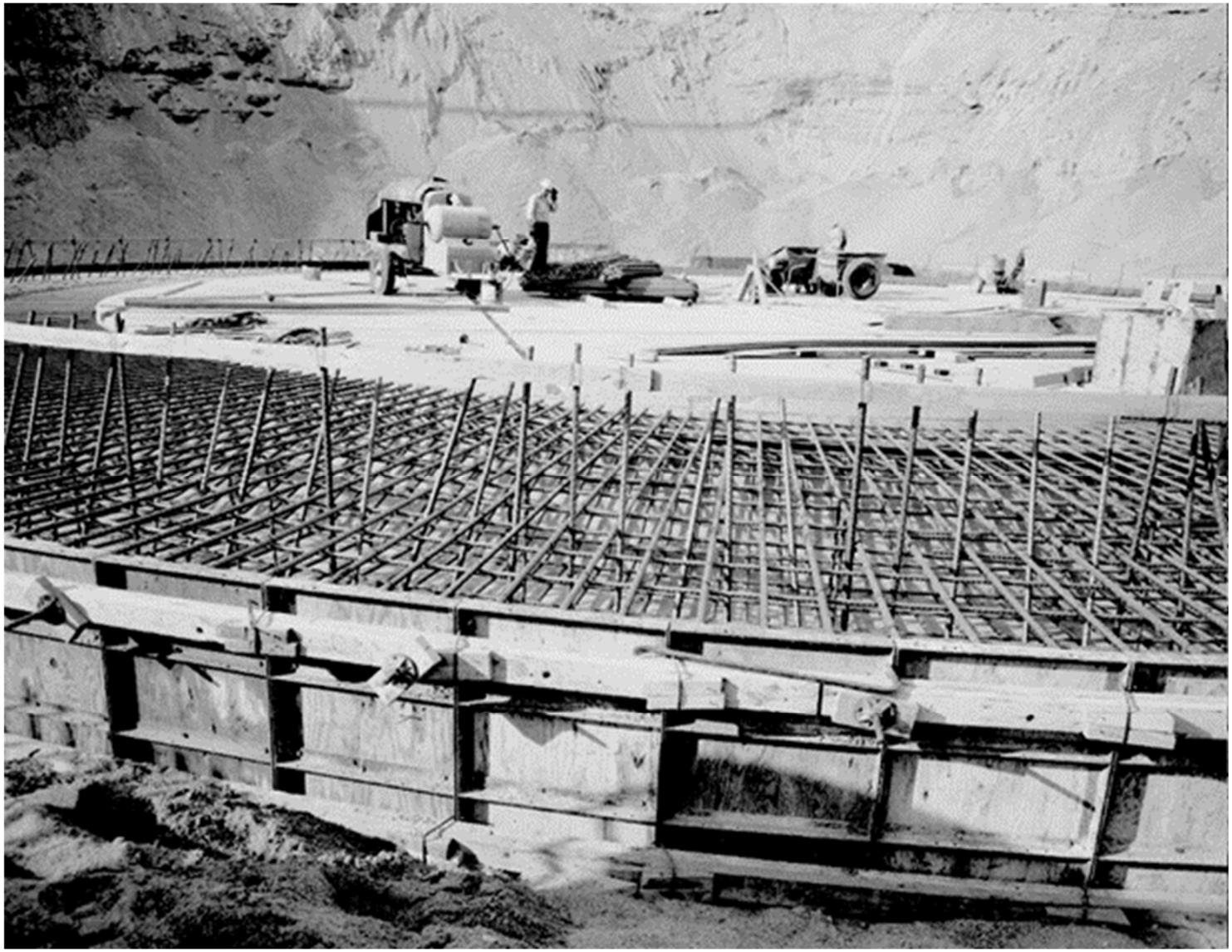
Figure 3-12. 241-A Tank Farm Construction Photograph Showing Nearly Completed Backfill with East Portions of Ventilation Header and Pipeline Encasement Exposed.

Source: 3289-PHOTO, January 20, 1955, "PUREX FACILITY CONSTRUCTION - LIQUID WASTE DISPOSAL CRIB (VIEW 4)."

Figure 3-13. Photograph Showing Construction of 241-AX Tank Farm Reinforced-Concrete Tank Bases with Drain Slots.

Source: 6619-PHOTO, September 25, 1963, "NEW WASTE STORAGE TANKS – PUREX – FOUNDATION FOR TANKS."

Figure 3-14. Construction Work on Reinforced-Concrete Base of Single-Shell Tank in 241-AX Tank Farm Excavation.



Source: 33905-2, October 3, 1963, "SHOTS OF PROGRESS 241AX TANK FARMS [5 NEGATIVES]."

Figure 3-15. Photograph Showing Construction of 241-AX Tank Base Steel Liners and Rebar for Sidewalls.

Source: 6637-PHOTO, October 28, 1963, "NEW WASTE STORAGE TANKS – PUREX – CONCRETE BASES FOR STORAGE TANKS, START OF STEEL PLATE LAYOUT."

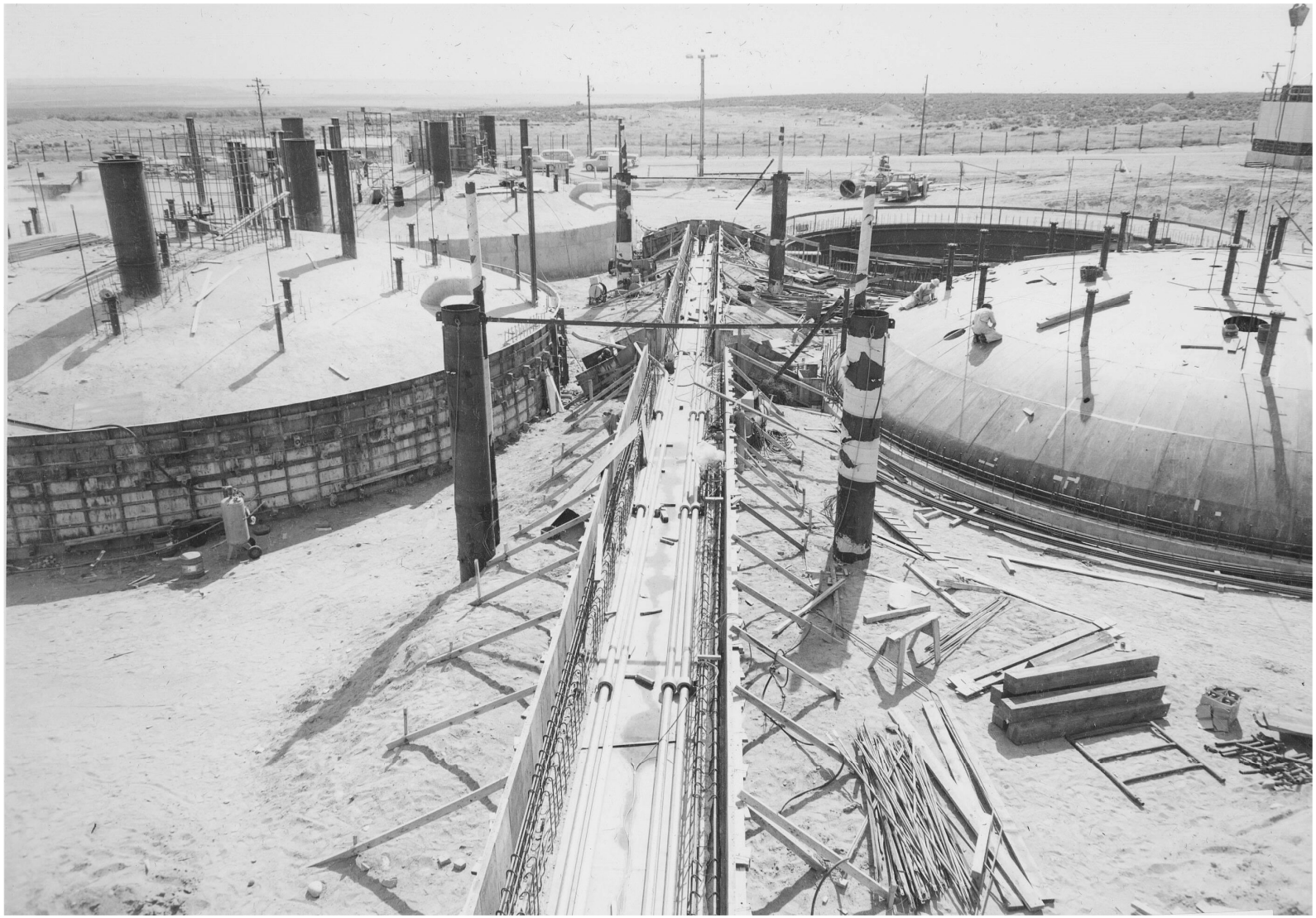
Figure 3-16. Photograph Showing Construction of 241-AX Tank Steel Liners.

Source: 6671-PHOTO, November 26, 1963, "NEW WASTE STORANGE TANKS – PUREX – TANK BOTTOM RAISED FOR WELDING."

Figure 3-17. Photograph of Construction of Single-Shell Tanks in 241-AX Tank Farm Excavation with View to Southwest Showing Concrete Shell Completed in Stages Around Steel Liners.

Source: 35799-1, April 1, 1964, "TANK FARM CONSTRUCTION [7 NEGATIVES]."

Figure 3-18. Photograph of 241-AX Tank Farm Construction with View to East Showing Partial Backfill of Excavation, Partially-Completed Tank Domes, Concrete Encasement with Pipelines, and Leak Detection Wells.

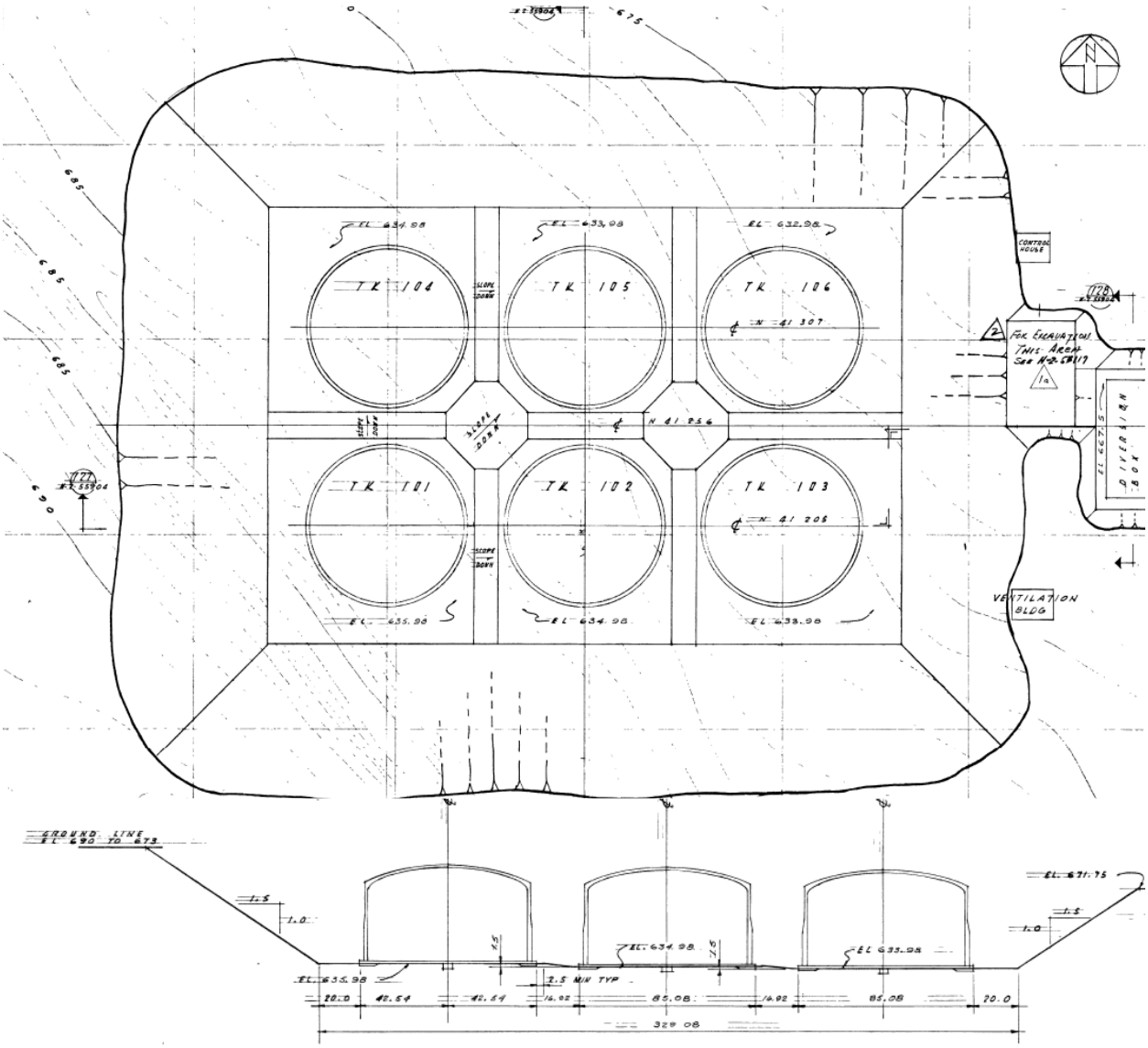


Source: 6863-PHOTO, June 23, 1964, "PUREX WASTE STORAGE FACILITIES ADDITION NO. 241-AX - 200 EAST AREA."

Figure 3-19. Photograph of 241-AX Tank Farm Construction with View to North Showing Partial Backfill of Excavation, Partially-Completed Tank Domes, and Tank Sidewall Liner.

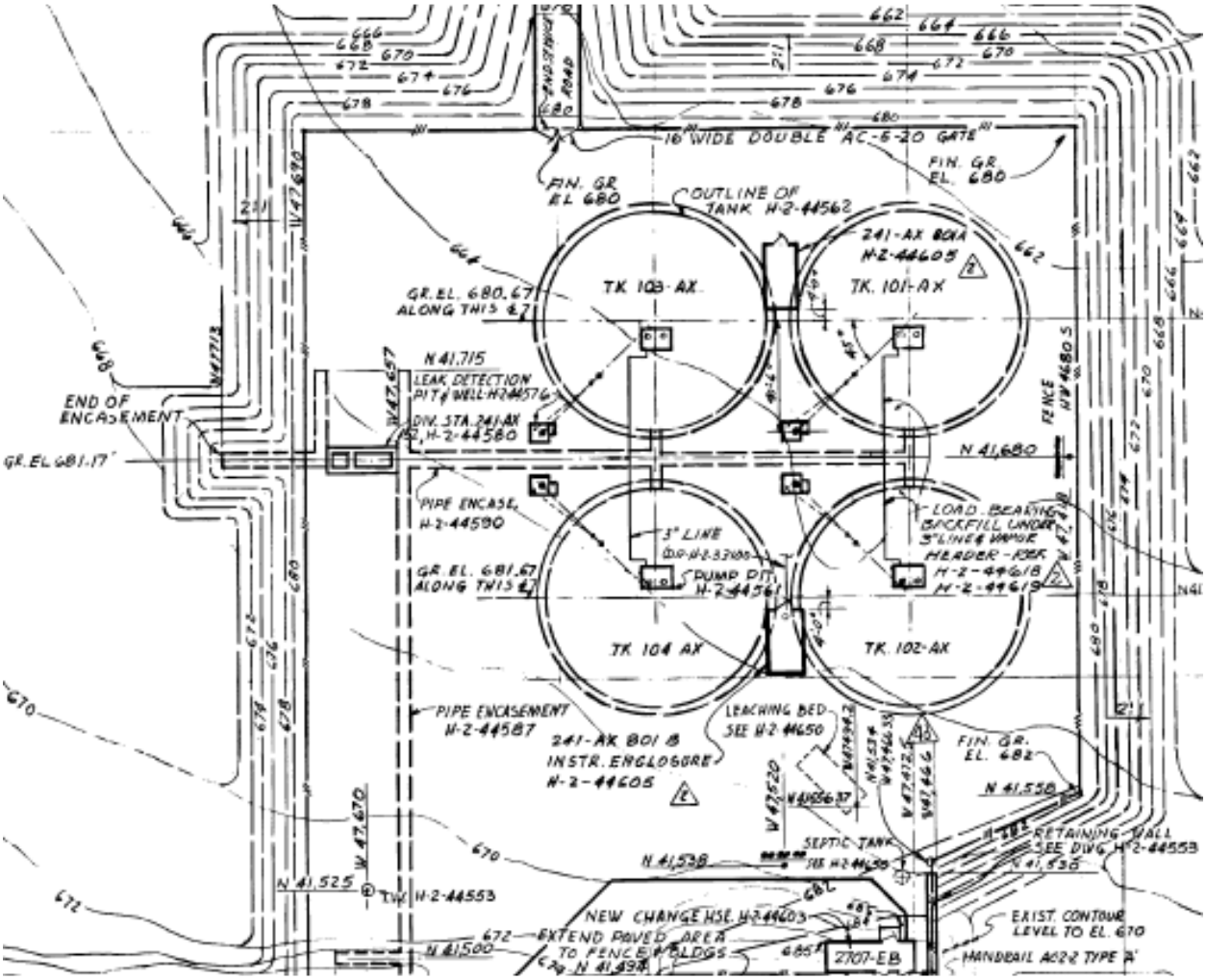
Source: 6864-PHOTO, June 23, 1964, "PUREX WASTE STORAGE FACILITIES ADDITION NO. 241-AX - 200 EAST AREA."

Figure 3-20. Excavation Plan for 241-A Tank Farm.



Source: H-2-55904, "Excavation Plan & Sections PUREX Waste Disposal Facility."

Figure 3-21. Plot Plan for 241-AX Tank Farm.



Source: H-2-44552, "Plot Plan Finished Grading and Facilities PUREX 241 Tank Farm."

3.2 TANK FARM CONSTRUCTION AND INFRASTRUCTURE

The following sections describe the tank farm construction and infrastructure. While most WMA A-AX components are physically located within the A Farm and AX Farm fence lines, some components extend beyond the fence line (e.g., pipelines) or are located outside the fence line (e.g., diversion boxes and cribs).

3.2.1 Single-Shell Tanks

The A Farm contains six 100-series tanks and AX Farm contains four 100-series tanks. The 100-series tanks are 23 m (75 ft) in diameter, have a 9-m (30-ft) operating depth, and have a nominal capacity of 3,785,000 L (1,000,000 gal) each. The tanks were designed to receive boiling waste from the PUREX process and have several unique design features, including: ALCs for cooling the boiling wastes, underground vessel ventilation headers to remove

condensate and volatiles, laterals 10 ft beneath the tank for leak detection (A Farm only), and leak detection pits (AX Farm only).

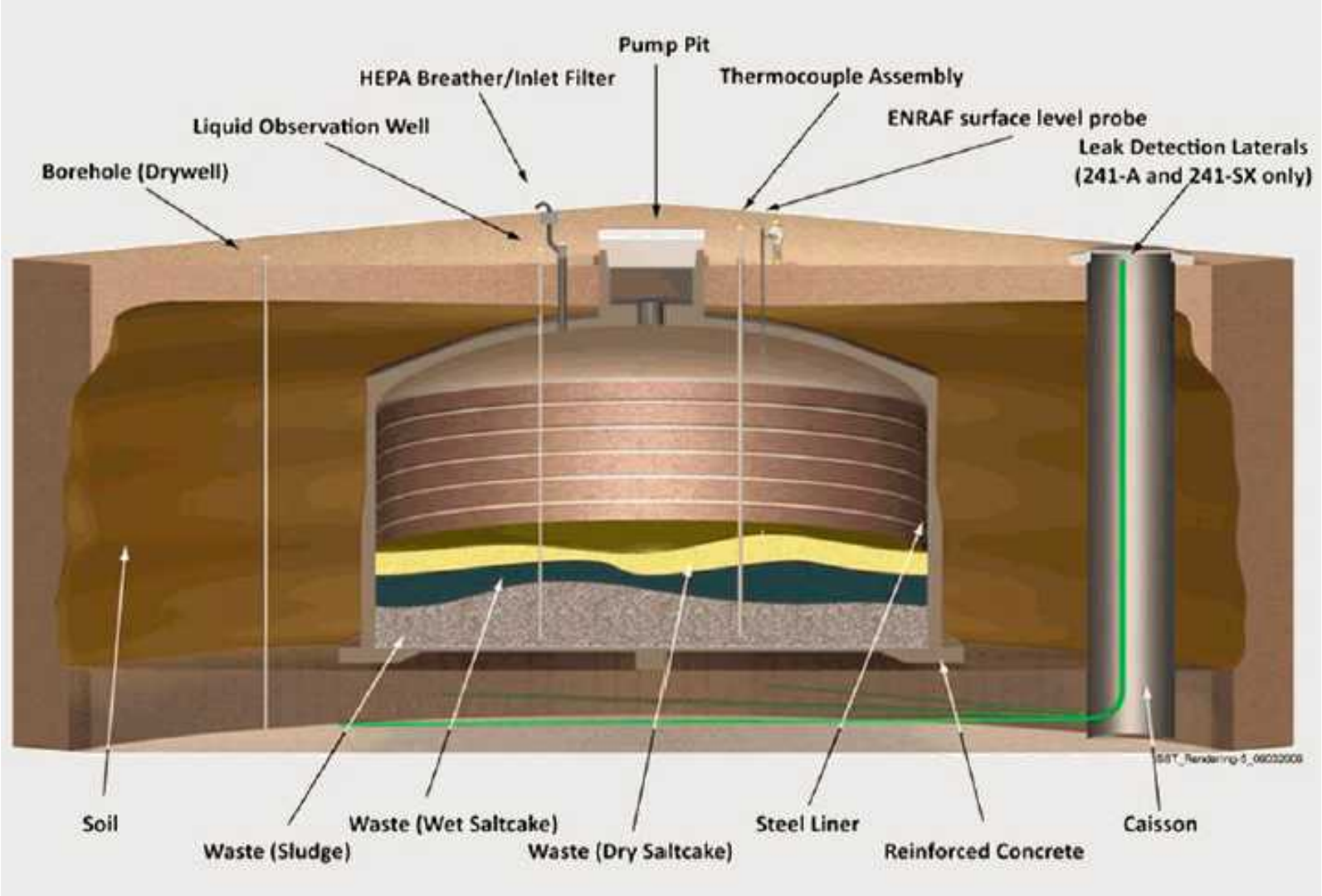
Figure 3-22 shows a schematic of a typical A Farm SST, and Figure 3-23 gives dimensions of the A Farm SSTs' concrete shells and steel liners. Figure 3-24 shows a schematic of a typical AX Farm SST. Design requirements for the tanks are summarized in RPP-10435, "*Single-Shell Tank System Integrity Assessment Report*," Appendix A. Each tank consists of a concrete shell with a steel plate lining having an inside diameter of 75 ft and an internal height of 32 ft 4 in. (A Farm) or 32 ft 6 in. (AX Farm) from the tank bottom to the top of the steel liner (H-2-55911, "Waste Storage Tanks Composite Section PUREX Waste Disposal Facility" and H-2-44562).

Waste was introduced to the tanks via inlet nozzles connecting fill pipelines through the shell several inches below the top of the steel liner (e.g., H-2-55973, "Waste Line Encasement Fill Line Layout, PUREX Waste Disposal Facility," Sheets 1 and 2). The tanks also had overflow inlets and outlets connected by short pipelines to allow any accidental overfill of one tank to drain by gravity into the next tank, though fill records and waste level monitoring do not indicate any definite overflows occurred in practice. The lowest point of any inlet or outlet port was thus the bottom lip of the overflow outlet, at 370 in. above the bottom liner in the case of the A Farm SSTs. RPP-10435 Tables A.8 and A.11 state that the AX Farm SSTs could be filled to within 9 in. below the spring line of the dome, or 381 in. above the bottom liner. RPP-10435 discusses other operational constraints such as the density of PUREX waste that in principle could reduce the operating capacity of the WMA A-AX SSTs to less than the fill limits under ordinary conditions.

The tanks are buried underground with ~6 to 7.5 ft of backfill over the crest of the dome to provide shielding from radiation exposure to operating personnel. The SSTs were constructed in place with 0.375-in.-thick carbon steel (ASTM A283-52T or ASTM A285-52T in A Farm and ASTM A201 Grade A in AX Farm) lining the bottom and the sides of a reinforced-concrete shell (RPP-10435 Table A.6). The A Farm and AX Farm tanks have flat bottoms; the tank steel bottoms intersect the sidewalls orthogonally (similar to 241-SX Farm tanks), unlike the dished bottoms of earlier-designed tank farms. The tanks are equipped with saltwell pump pits located on top of the tanks to provide access to the tank, pumps, and monitoring equipment.

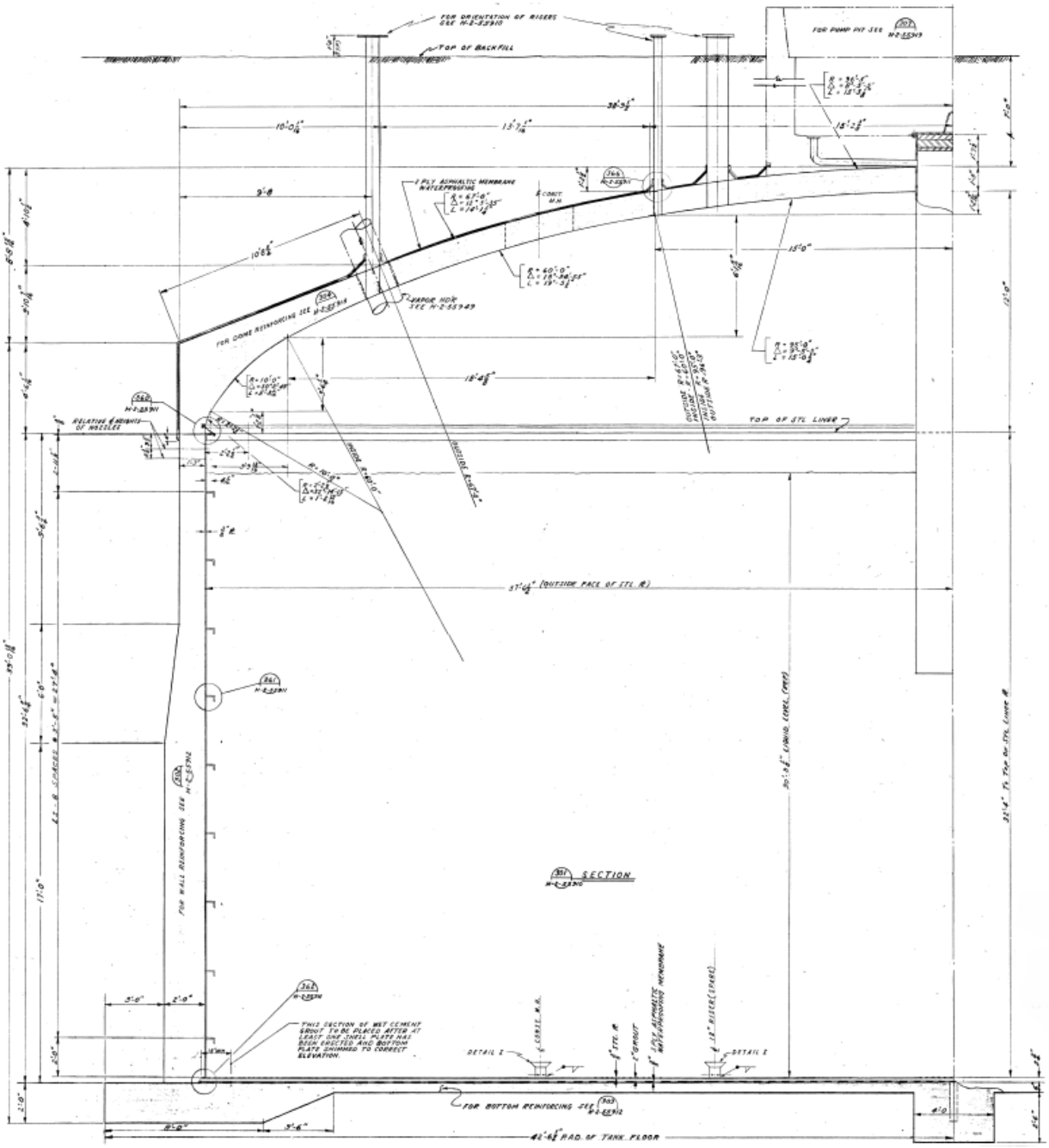
The A Farm SSTs were built by installing a reinforced-concrete base that is at least 6 in. thick. Three layers of asphalt-impregnated waterproofing cotton fabric were then applied to the concrete base. After the waterproofing was applied, 2 in. of grout were laid on top of it with the steel liner being fabricated on top of the grout. The AX Farm SSTs were similar in construction to the A Farm SSTs but featured a thicker base construction with a network of drain slots for leak detection. The AX Farm SST bases had a minimum of 18 in. of reinforced concrete overlying 2 in. of grout, except where the concrete thickness was reduced 2.5 in. by the drain slots (Figure 3-13, Figure 3-24, Figure 3-25, and Figure 3-26).

Figure 3-22. 241-A Farm and 241-SX Farm Single-Shell Tank Configuration.



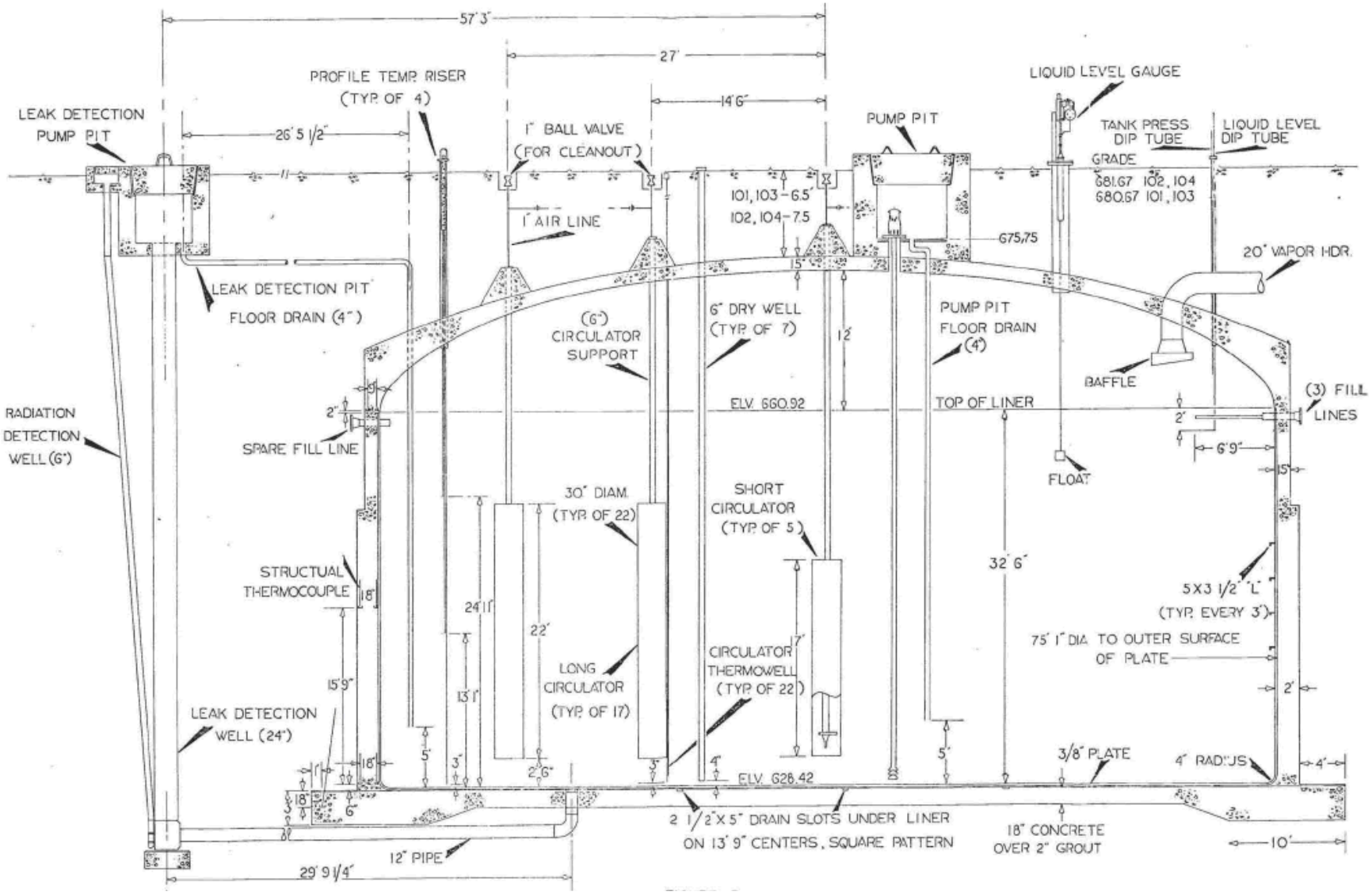
HEPA = high-efficiency particulate air (filter)
Source: HNF-EP-0182, "*Waste Tank Summary Report for Month Ending December 31, 2016*," Rev. 348.
Honeywell Enraf® is a registered trademark of Honeywell International Inc., Corporation Delaware, 101 Columbia Road Morristown, New Jersey.

Figure 3-23. 241-A Farm Tank Composite.



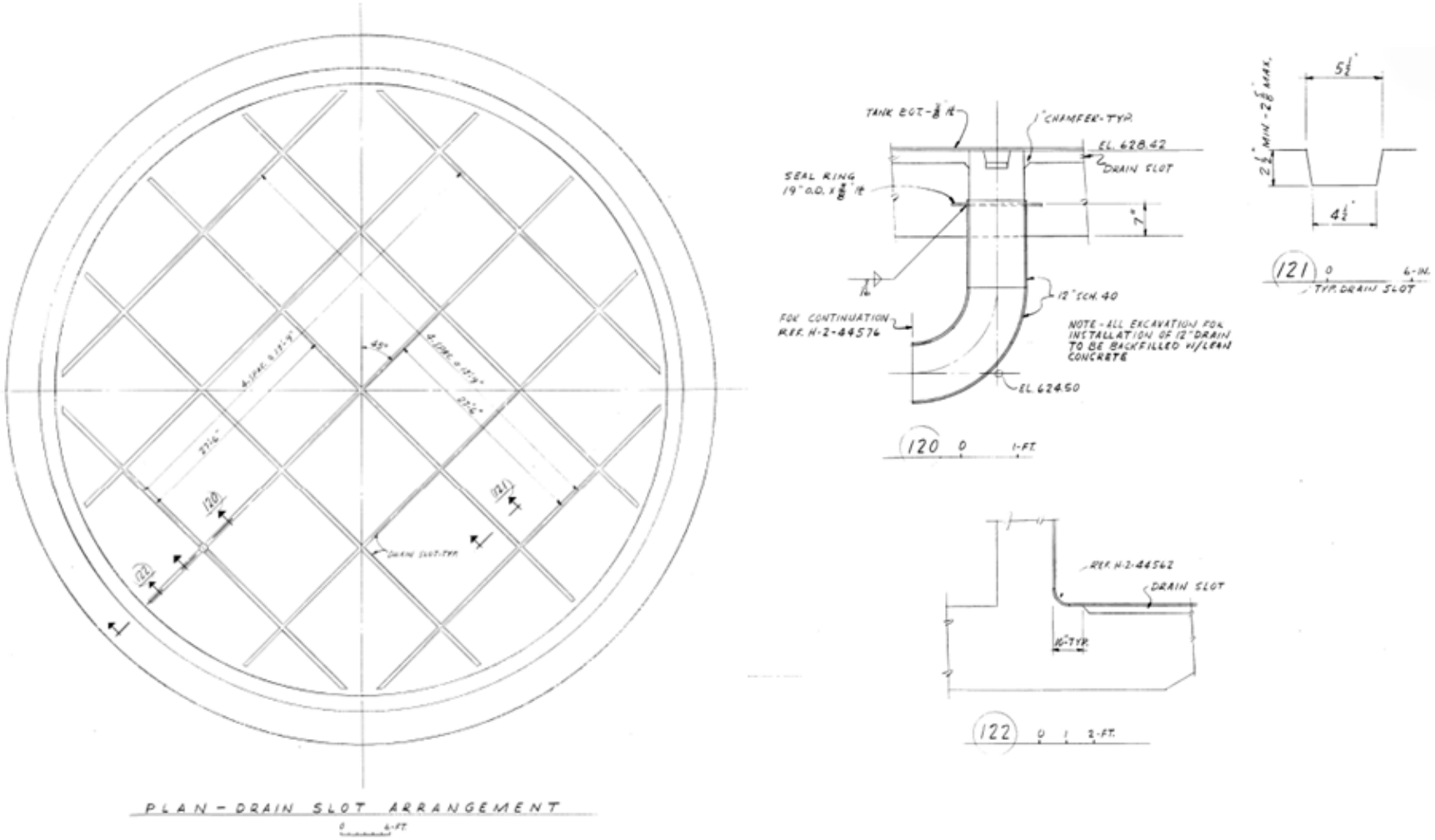
Source: H-2-55911, "Waste Storage Tanks Composite Section PUREX Waste Disposal Facility," Rev. 1.

Figure 3-24. 241-AX Farm Tank Composite.



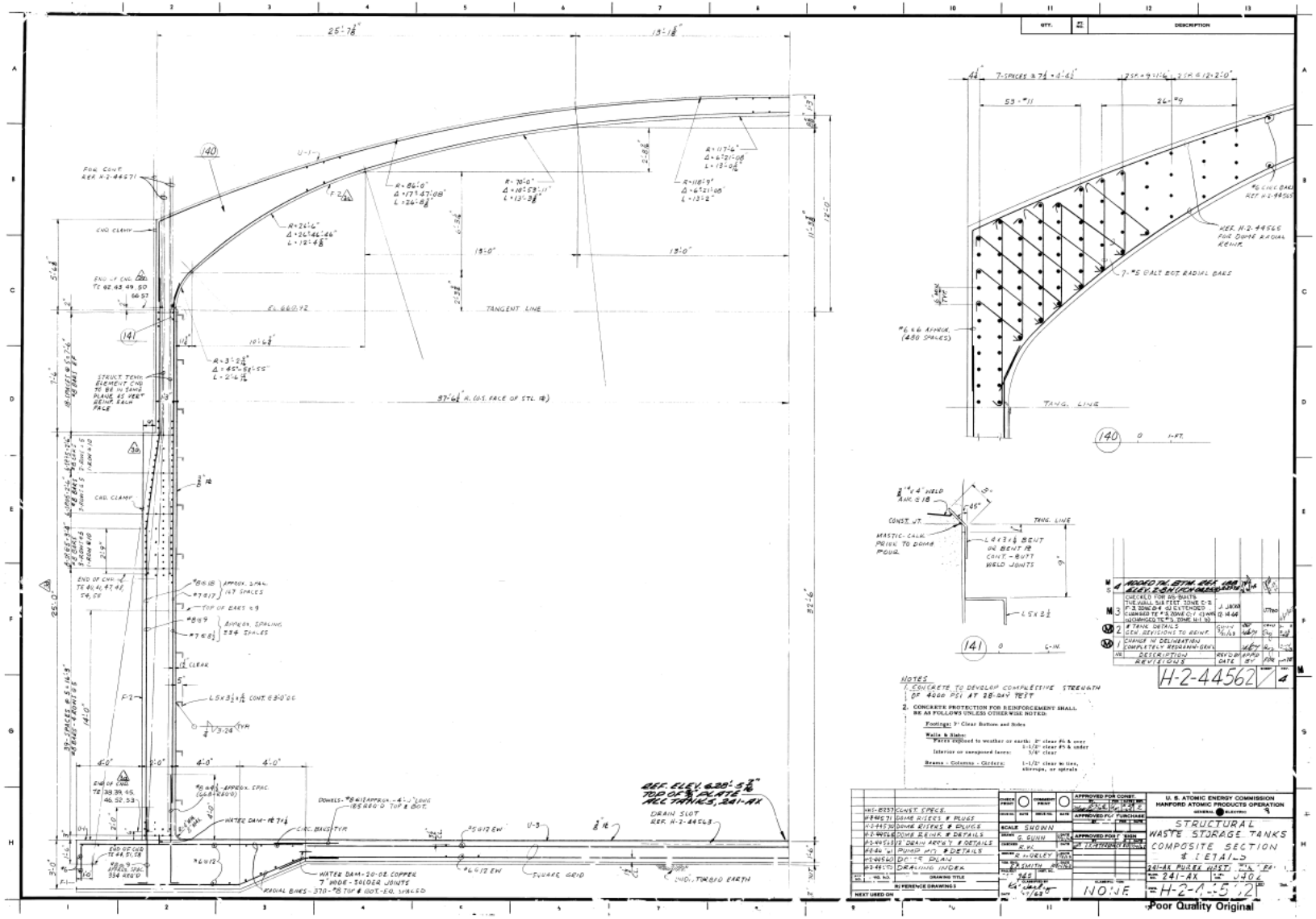
Source: RL-SEP-9, "*PUREX 241-AX Tank Farm and Waste Routing System Information Manual*."

Figure 3-25. 241-AX Farm Tank Base Drain Slot Arrangement.



Source: H-2-44563, "Structural Waste Storage Tanks Drain Arrangement & Details 241-AX PUREX Waste Tank Farm," Rev. 2.

Figure 3-26. 241-AX Farm Tank Composite Section.



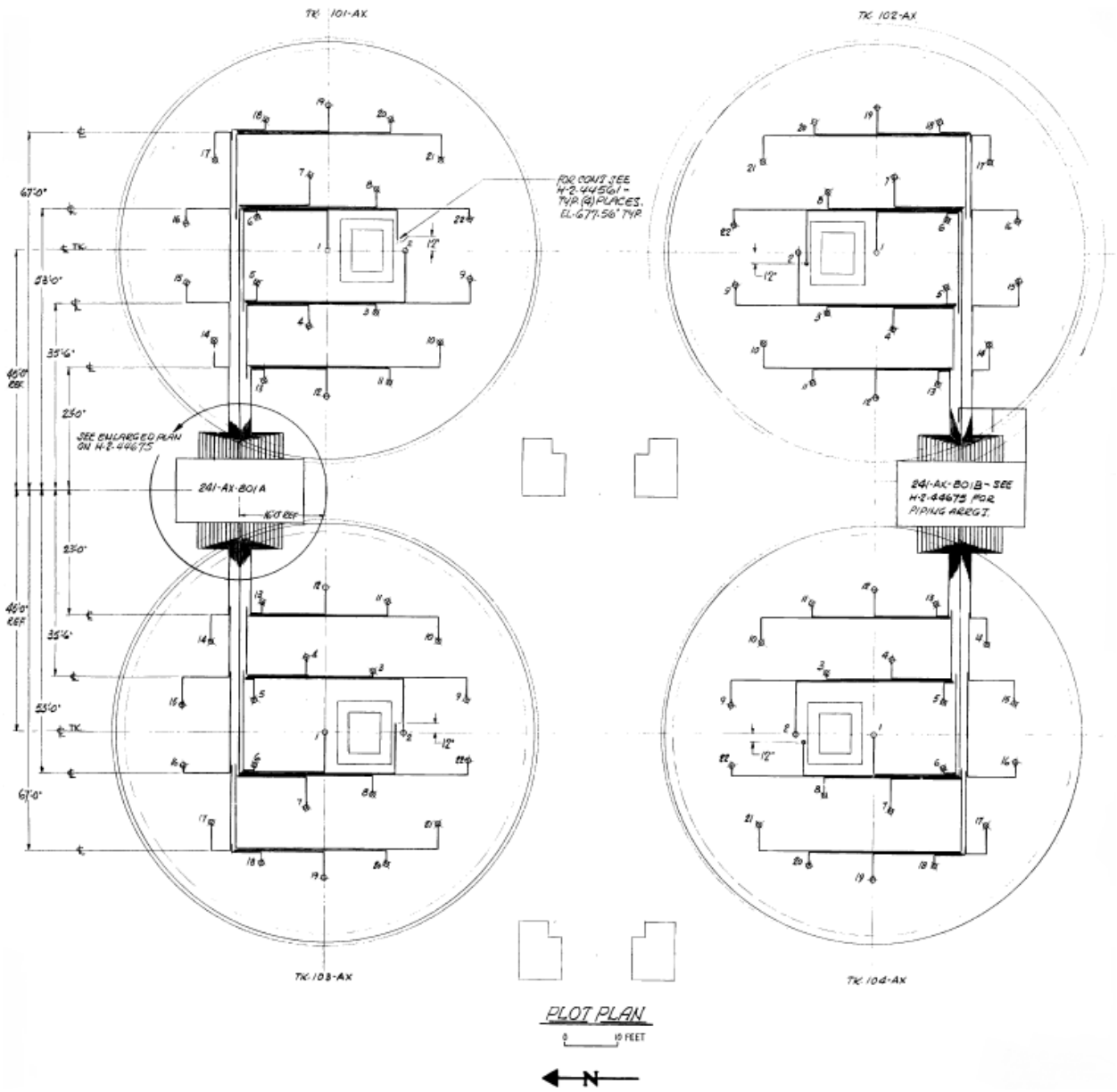
Source: H-2-44562, "Structural Waste Storage Tanks Composite Section & Details, 241-AX PUREX Waste Tank Farm," Rev. 4.

The concrete for the AX Farm SSTs had a higher compressive strength specification than that of other tank farms and utilized a different grade of rebar (i.e., HW-4798-S, *Standard Specification for Placing Reinforced Concrete*), whereas the 1.5-in. maximum aggregate specification was unchanged (RPP-10435 Table A.5). There are no other explicitly different specifications shown in RPP-10435 Table A.5 for the concrete formulation between the AX Farm SSTs and that of other farms, in lieu of which it is reasonable to assume empirical data from testing other tank concrete samples is applicable at AX Farm.

The steel liner was fabricated on top of the concrete for both A Farm and AX Farm SSTs, and it lay flat across the tops of the gaps for the drain slots in the AX Farm SST bases. Following the completion of the bottom of the tank, the sidewalls of the metal liner were welded together; some of the liner construction process for AX Farm can be seen in Figure 3-16. The A Farm SSTs used a "fillet" weld with the base plate extending 1 in. past the sidewall liner where the concrete shell would be cast around the base plate, holding it in a fixed position (H-2-55911 Detail 362; RPP-RPT-54912, "*Hanford Single-Shell Tank Leak Causes and Locations – 241-A Tank Farm*"). The AX Farm SSTs used a "double-V butt joint" weld with improved quality control testing including 100% radiography and hydrostatic testing (RPP-10435). To prevent corrosion, the interior surfaces of the liner bottom, sidewalls, and stiffeners were painted with "Red Lead" primer (1 coat in A Farm and 2 coats in AX Farm), and a lead drip edge was installed at the top edge of the liner (RPP-10435). The liner was encased in concrete at least 15 in. thick. In contrast to earlier SST designs, the A-100 series tank design eliminated the three-ply asphaltic membrane between the steel liner and the sidewall portion of the concrete shell, and it incorporated a 7-in.-high steel water stop, aka water dam, at the base footing to wall construction joint (H-2-55911; H-2-55912, "Waste Storage Tanks, Base Footing and Wall Reinforcing, PUREX Waste Disposal Facility"; RPP-RPT-54912). The water stop is visible in Figure 3-3. A concrete dome ~1.25 ft thick was erected on top of the tank. In A Farm, a two-ply asphaltic waterproof membrane was applied to the top of the dome (Figure 3-23), and a protective finish of 0.75 in. portland cement grout reinforced with chicken wire is believed to have been applied over the entire surface of the membrane. Photographs of a plug cut from a similarly-constructed concrete dome from tank 241-C-107 (C-107) in WMA C are presented in Section 7.0.

Particularly for the AX Farm SSTs, in-tank equipment is relatively dense to accommodate the necessary number of ALCs and other features. Figure 3-24 illustrates the vertical location of equipment within the AX Farm SSTs. Figure 3-27 partially illustrates the horizontal arrangement of equipment in a relatively dense and roughly uniform placement within the AX Farm SSTs. There are 54 risers penetrating the dome of each AX Farm SST in order to mount equipment, including 22 ALCs, at various small distances above the tank bottom. In contrast, the A Farm SSTs each have fewer than half as many risers and 4 ALCs mounted to the base liner and supported with cables. Complete lists of equipment on each riser for the AX Farm SSTs are found in RPP-RPT-58932 through RPP-RPT-58935, which also describe new equipment to be installed on the existing risers for retrieval purposes. Much of the in-tank equipment is of steel construction. Prior to closure, in-tank equipment must either be removed and disposed or decontaminated to the extent practicable and grouted in place. The density of in-tank equipment is assumed to be too small to significantly affect the performance of the grout either positively or negatively.

Figure 3-27. Airlift Circulator Position.



Source: H-2-44676, "Air-Lift Piping Arrgt. & Circulator Details," Rev. 6.

In-tank equipment provides additional surface area potentially coated with waste below the maximum historical fill level (Figure 3-24) and presents a minor obstacle to retrieval operations. For example, RPP-CALC-57152, "*Analysis of Potential Waste in Airlift Circulators and Steam Coils in AX Tanks Post Retrieval*" estimated that currently 2,483 ft^3 of waste completely fills the 22 ALCs and two steam coils in tank AX-101 and that some of that waste may remain as a residual coating on the equipment after retrieval. Tank AX-101 currently holds more saltcake and more total waste than other tanks in AX Farm (HNF-EP-0182, "*Waste Tank Summary Report for Month Ending December 31, 2016*," Rev. 348), so other tanks have less waste coating the equipment or none at all (RPP-CALC-57152). Similarly, tanks A-101 and A-103 currently hold larger volumes of saltcake and total waste than other tanks in A Farm (HNF-EP-0182).

Photographs or video still images of some of the ALCs and other in-tank equipment were compiled for the AX Farm tanks in RPP-CALC-57152 and are reproduced herein as Figure 3-28 through Figure 3-33. Recent panoramic images of the interiors of SSTs in A Farm are shown in Figure 3-34. Photographs of the interiors of tanks A-104 and A-105 may be found in RPP-RPT-54912, and additional photographs of several WMA A-AX SST interiors are compiled in RPP-ENV-37956 Appendix B.

Figure 3-28. Airlift Circulator in Tank 241-AX-101.

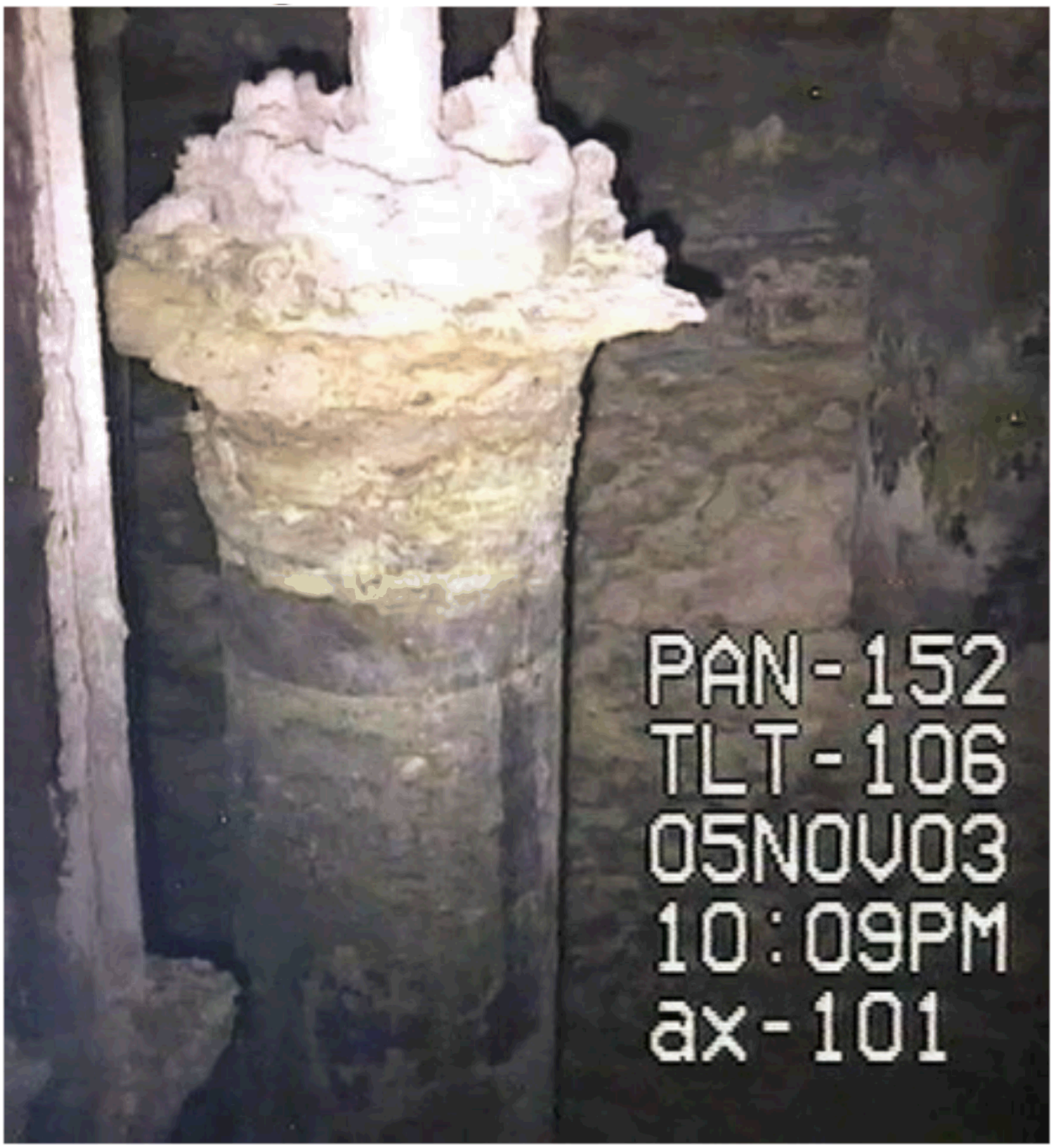


Figure 3-29. Steam Coil in Tank 241-AX-101.

3.2.1.1 Airlift Circulators. Details of ALCs for A Farm are given in H-2-56342, "Details Air-Lift Circulator, Circulation Facilities 241A Tank Farm" and H-2-56350, "Arrangement Air-Lift Circulators, Circulation Facilities 241-A Tank Farm." Details of ALCs in AX Farm are

given in RL-SEP-9, "*PUREX 241-AX Tank Farm and Waste Routing System Information Manual.*" Air is circulated through the cylinders to maintain sludge solids in suspension for a prolonged period and reduce the maximum sludge temperature in the tanks. The A Farm tanks contain 4 ALCs each (2 with 17.5-ft height and 2 with 8.5-ft height). Figure 3-35 and Figure 3-36 show the short and tall ALC designs used in A Farm, respectively. There are 22 ALCs in each of the AX Farm tanks (17 with 22-ft height and 5 with 17-ft height). The ALCs in AX Farm are 30-in.-diameter cylinders that extend to within 30 in. of the tank bottoms. The six A Farm SSTs were designed to cool tank wastes at a maximum temperature of 280 °F (RPP-10435, pp. A-42) and the AX Farm SSTs were designed for a maximum temperature of 350 °F (RPP-10435, pp. A-43). The horizontal arrangement of ALCs in the AX Farm SSTs is shown in Figure 3-27.

Figure 3-30. Tank 241-AX-102 In-Tank Equipment.

Figure 3-31. Tank 241-AX-103 In-Tank Equipment.

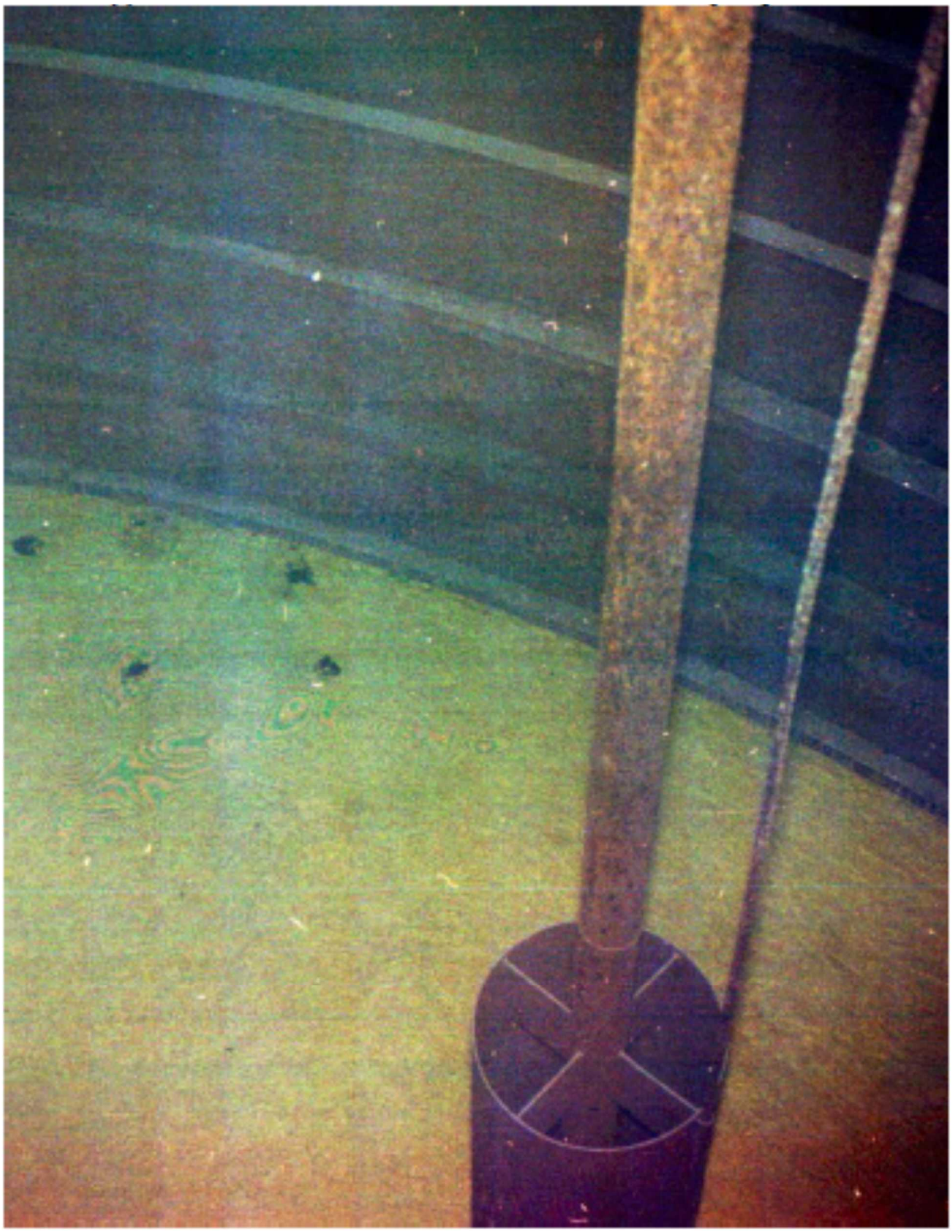
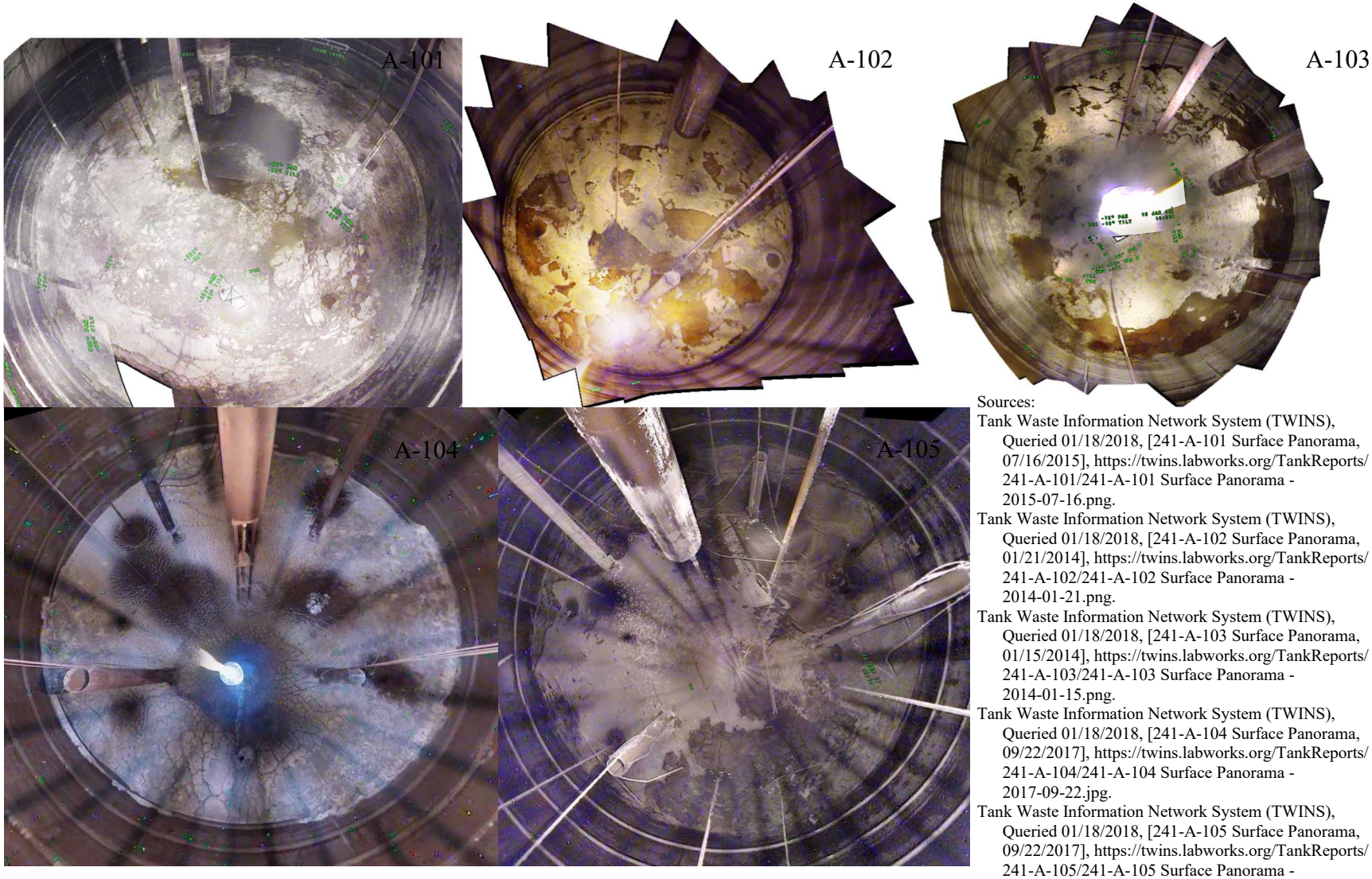


Figure 3-32. Tank 241-AX-103 Airlift Circulator Showing Waste Level.

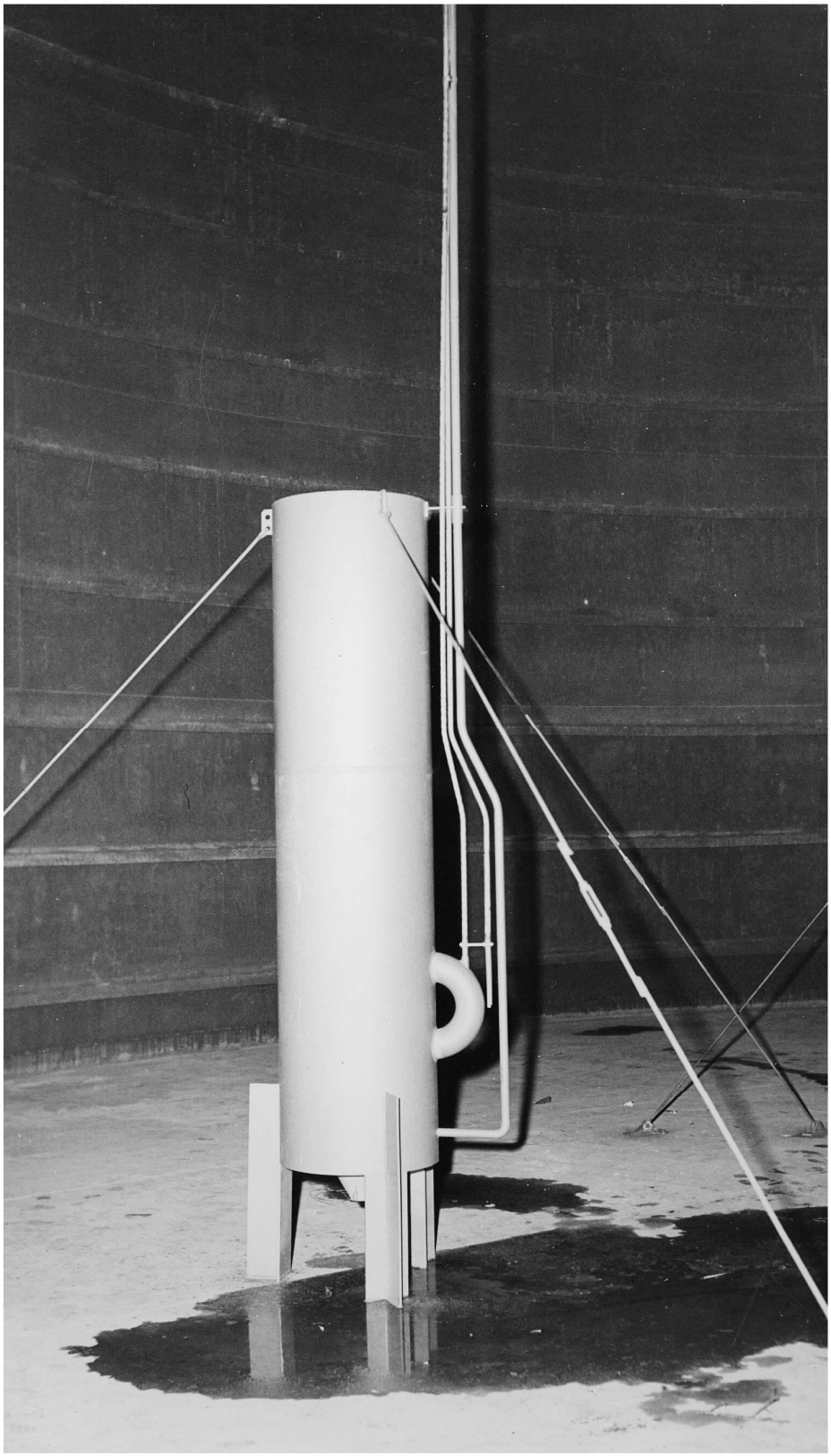
Figure 3-33. Tank 241-AX-104 In-Tank Equipment.

Figure 3-34. Panoramic Images of 241-A Tank Farm Single-Shell Tank Interiors and Waste Surfaces Taken from 2014 to 2017.



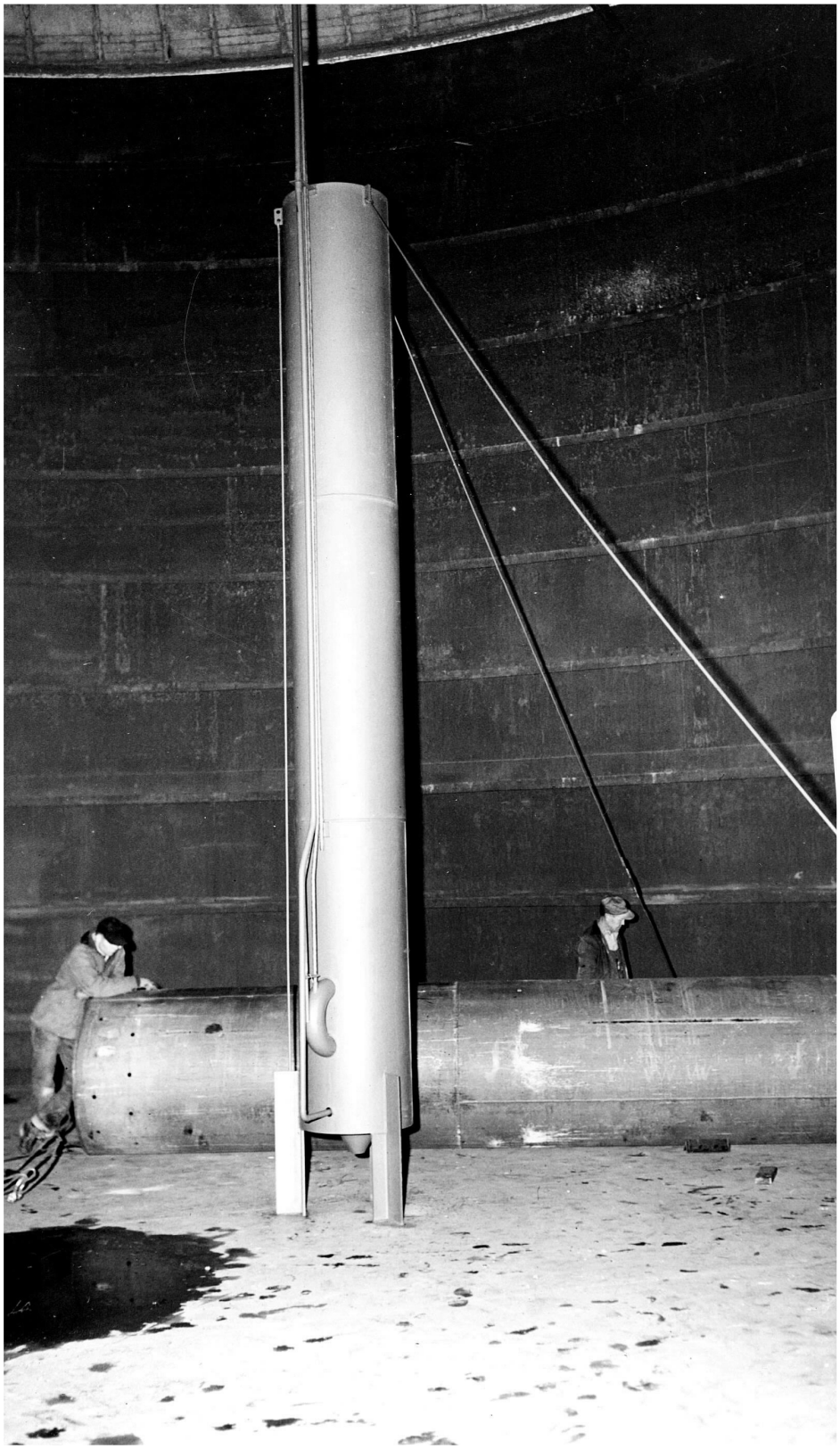
Sources:
Tank Waste Information Network System (TWINS), Queried 01/18/2018, [241-A-101 Surface Panorama, 07/16/2015], https://twins.labworks.org/TankReports/241-A-101/241-A-101 Surface Panorama - 2015-07-16.png.
Tank Waste Information Network System (TWINS), Queried 01/18/2018, [241-A-102 Surface Panorama, 01/21/2014], https://twins.labworks.org/TankReports/241-A-102/241-A-102 Surface Panorama - 2014-01-21.png.
Tank Waste Information Network System (TWINS), Queried 01/18/2018, [241-A-103 Surface Panorama, 01/15/2014], https://twins.labworks.org/TankReports/241-A-103/241-A-103 Surface Panorama - 2014-01-15.png.
Tank Waste Information Network System (TWINS), Queried 01/18/2018, [241-A-104 Surface Panorama, 09/22/2017], https://twins.labworks.org/TankReports/241-A-104/241-A-104 Surface Panorama - 2017-09-22.jpg.
Tank Waste Information Network System (TWINS), Queried 01/18/2018, [241-A-105 Surface Panorama, 09/22/2017], https://twins.labworks.org/TankReports/241-A-105/241-A-105 Surface Panorama - 2017-09-22.jpg.

Figure 3-35. Short Airlift Circulator in 241-A Tank Farm.



Source: 3615-PHOTO, December 27, 1955, "241-A TANK FARM - AIR LIFT CIRCULATOR."

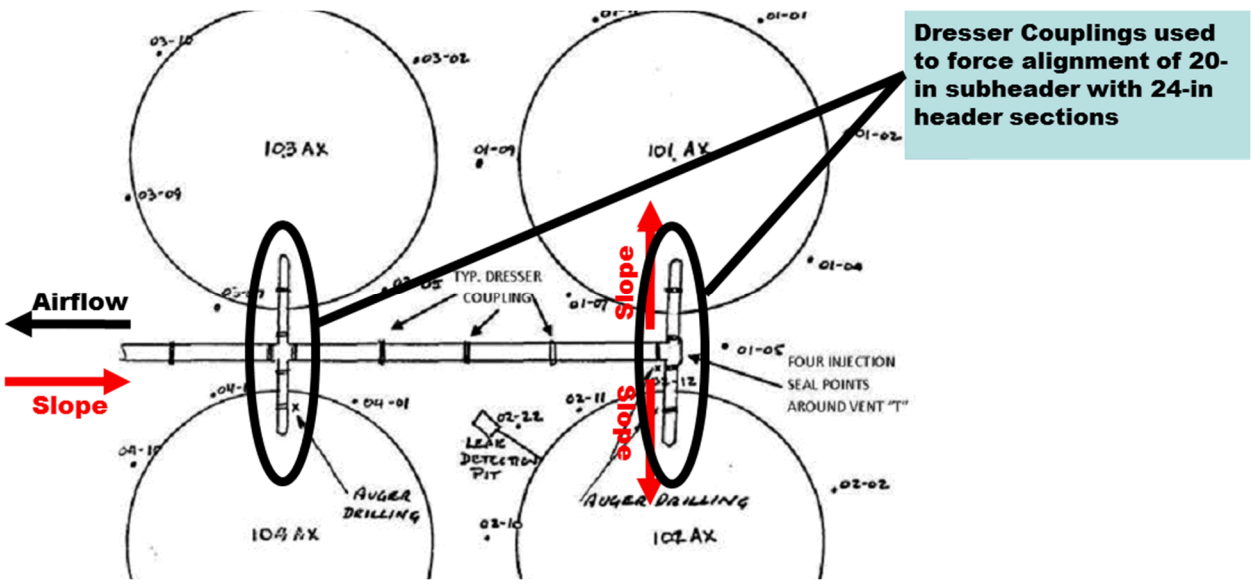
Figure 3-36. Tall Airlift Circulator in 241-A Tank Farm.



Source: 3616-PHOTO, December 27, 1955, "241-A TANK FARM - AIR LIFT CIRCULATOR."

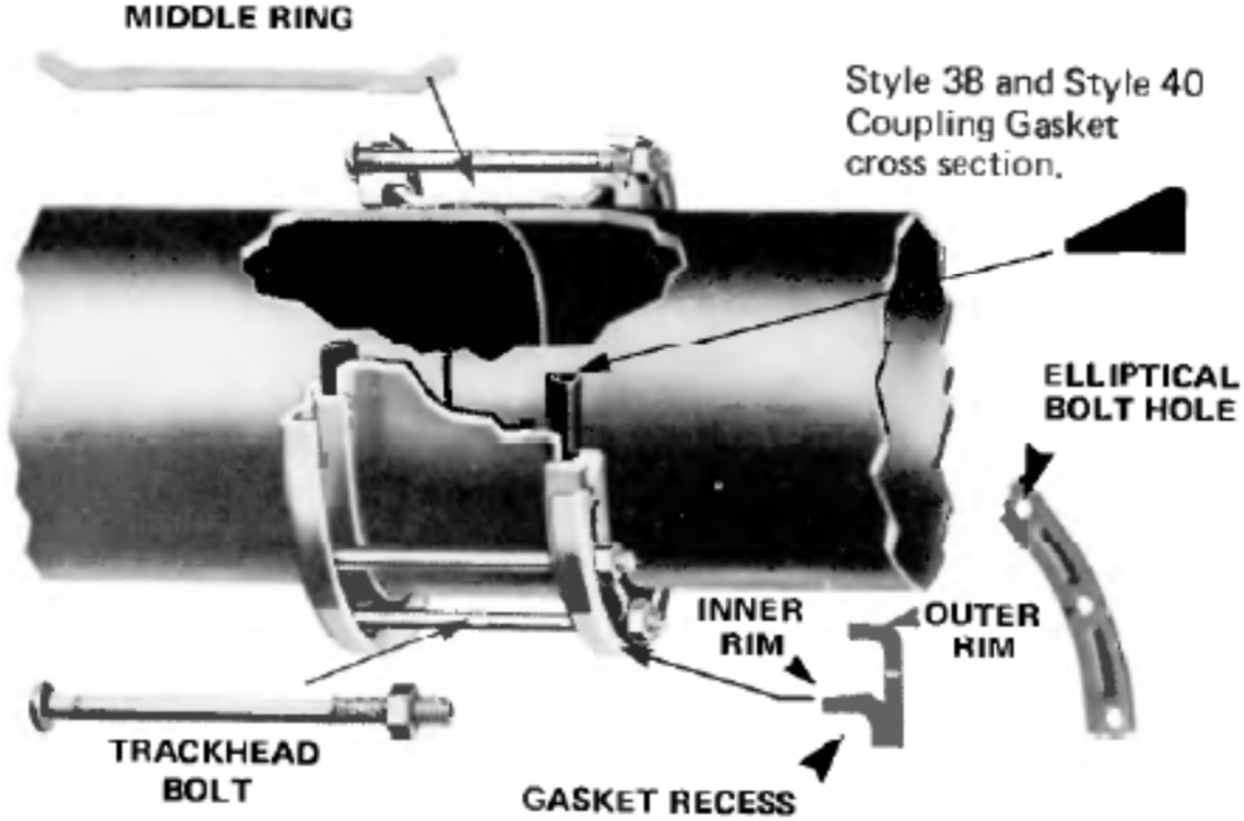
3.2.1.2 Ventilation System. The A Farm and AX Farm tanks were vented to underground vessel ventilation headers that connected between the farms and later to the 241-AY Tank Farm (AY Farm) (Figure 3-37). The purpose of the ventilation headers was to remove off-gas and water vapor from these tanks, which were often operated with the wastes at boiling conditions. The design of the ventilation headers included a baffled, 20-in.-diameter pipe inside each tank. The 20-in.-diameter pipe that exits the tank is connected to a 24-in.-diameter, stainless steel pipe header that is buried a minimum of 4 ft below grade. The 24-in. header in A Farm ran between the tanks to the 241-A-431 Ventilation Building. The header was supported above a concrete encasement containing the tank fill lines (Figure 3-12), which in turn was supported on concrete columns extending to undisturbed soil at the base of the excavation (H-2-55983, Sheet 1, "241-A Encasements, 241-A-152 to 241-A Structural DTL's, PUREX Waste Disposal Facilities"; H-2-55983, Sheet 2, "241-A Encasements Encasement and Cover Slabs Details Structural, PUREX Waste Disposal Facilities"; H-2-55983, Sheet 3, "241-A Encasements Vapor Header Support Structural, PUREX Waste Disposal Facilities"). The columns, footings, encasement, and vapor header can be seen in Figure 3-7 through Figure 3-12. The 24-in. header in AX Farm ran between the tanks to the 241-AX-152 Diverter Station and then to A Farm to tie in to that farm's ventilation header. The 241-AX ventilation header slopes upward toward the A Farm tie-in.

Figure 3-37. Ventilation Header Schematic.



Dresser couplings (Figure 3-38) provided a compression seal on the outer surface of vapor header piping segments that are ~25 ft in length. A Dresser coupling was also used to seal the 20-in.-diameter pipe from each tank to the 24-in. main vapor header. The couplings provided for expansion and contraction of the vapor header pipe segments. In 1975, auger drilling around the vapor headers showed that some of the dresser couplings near tanks AX-102 and AX-104 were leaking. The A Farm and AX Farm tanks were isolated from the ventilation headers in the early 1980s.

Figure 3-38. Typical Dresser Coupling.



Vapors removed from the SSTs through the ventilation header were routed through a ventilation system comprised of condensers, de-entrainment equipment, water seals, ventilation stacks, and other process equipment (see schematic in Figure 3-39). Condensate from this system could be returned to SSTs or discharged to cribs, trenches, or ponds. Details of the system changed over time; further information may be found in RPP-7494, *Historical Vadose Zone Contamination from A, AX, and C Tank Farm Operations.*

3.2.1.3 241-A Tank Farm Laterals. In addition to drywells, three pipes known as laterals were installed through vertical caissons (Caissons 1 and 2) extending outward in a nearly horizontal orientation ~10 ft beneath each of the A Farm tank concrete foundations in 1962 and 1963 (Figure 3-40, Figure 3-41, and Figure 3-22). Figure 3-41 indicates the elevations and slopes of the laterals. Comparison to the base of excavation elevations in Figure 3-1 indicates the laterals were installed in undisturbed native sediments as opposed to backfill. The laterals are 4-in. outer diameter, schedule 40 seamless carbon steel pipe installed in 10-ft lengths with flush joints (see H-2-31880, "241-A Tank Farm Leak Detection System Plan-Section-Detail" and H-2-31882, "241 A & 241 SX Tank Farms Leak Detection System Sections & Details," Sheet 1, detail C). These horizontal lateral pipes enter one of two caissons, transition to vertical orientation, and extend to an instrument enclosure at ground elevation. Probes can be inserted into each lateral to monitor for gamma radiation that could indicate waste leakage from a tank or pipeline.

Figure 3-39. Schematic of Vapor and Condensate System.

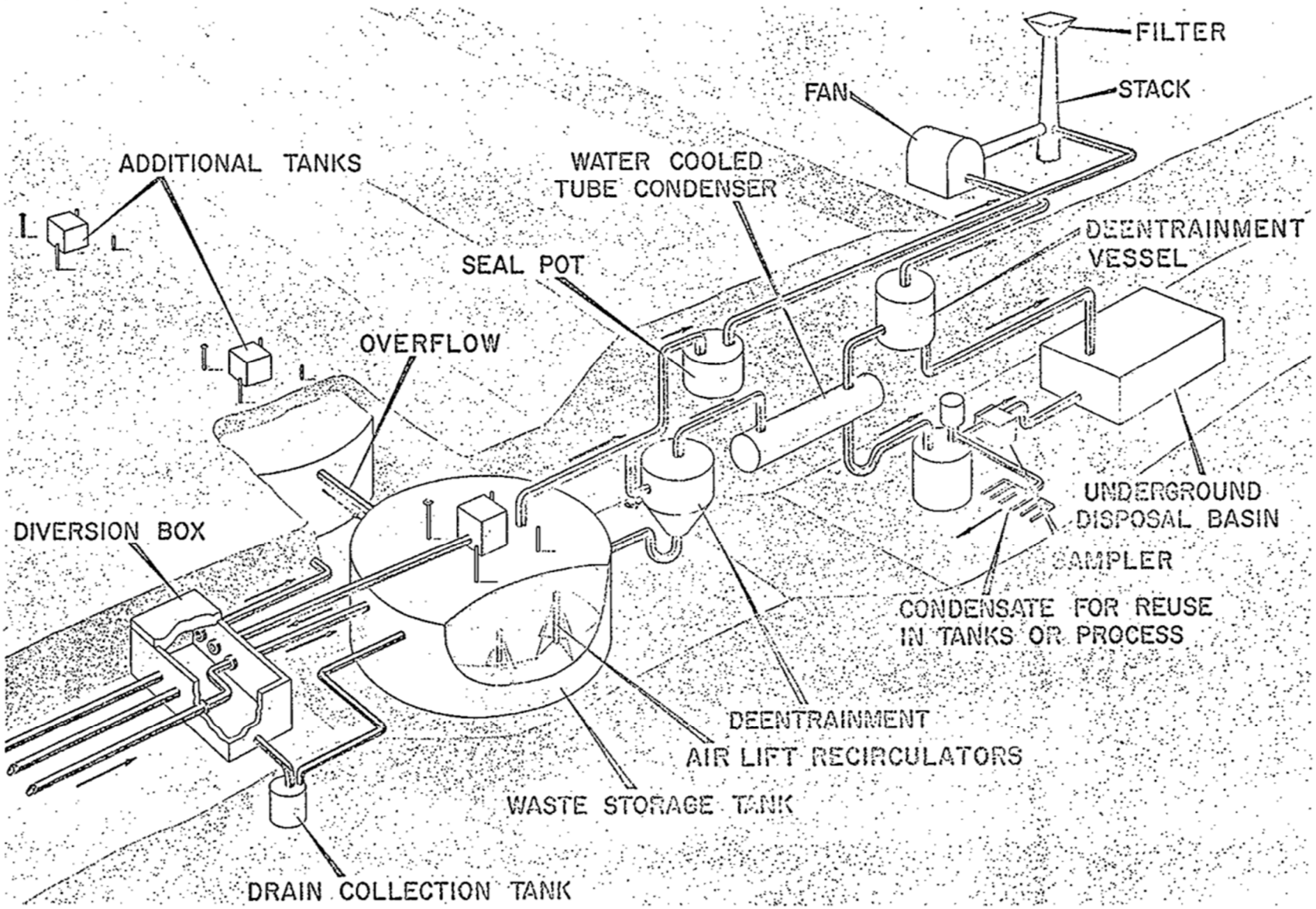
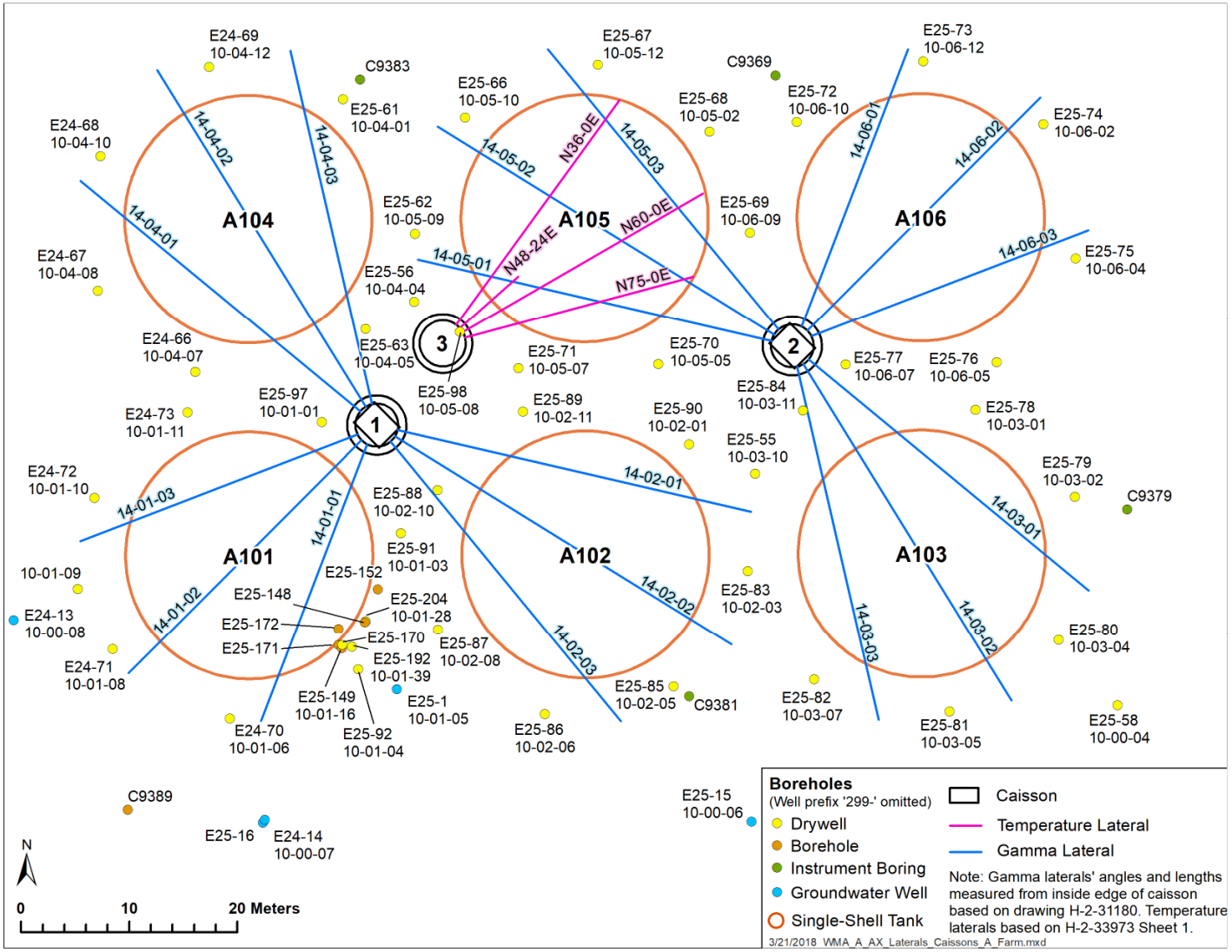
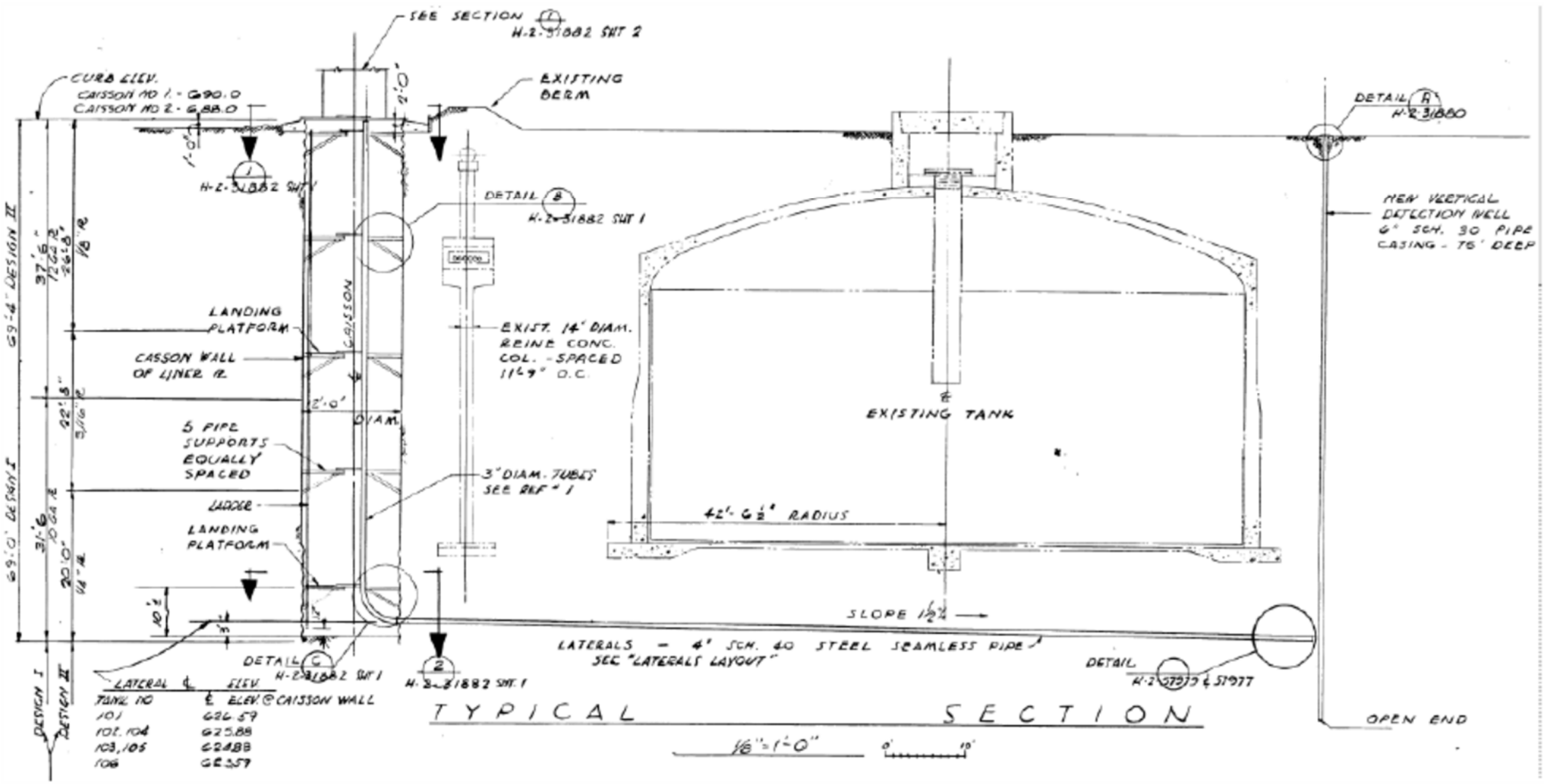


Figure 3-40. Location of Drywells and Laterals in 241-A Tank Farm.



References:
H-2-31880, "241-A Tank Farm Leak Detection System Plan-Section-Detail."
H-2-33973, "Thermal Probes Under Tk. 105-A," Sheet 1.

Figure 3-41. 241-A Tank Farm Leak Detection System Typical Section.



Source: H-2-31880, "241-A Tank Farm Leak Detection System Plan-Section-Detail."

A second set of four lateral lines and a third caisson were similarly installed to accommodate thermal probes for additional monitoring of tank A-105 (Figure 3-40; Figure 3-42; H-2-33973, "Thermal Probes Under Tk. 105-A," Sheet 1, Rev. 1). The engineering drawing of this equipment is dated December 1967. The 6-in. clearance below the tank concrete specified in Figure 3-42 corresponds to an elevation of 631.98 ft on the drawing datum (193.692 m NAVD 88), and measured vertical deviations ranged from -9.875 in. to +11.05 in. (H-2-33973, "Thermal Probes Under 105-A Tank," Sheet 2, Rev. 0). The ~84-ft length of the longer lateral lines and the maximum one-degree deviation from azimuth indicated in H-2-33973 Sheet 1 suggest these lateral lines are within 0.5 m of the indicated positions. Positions of thermocouples within the temperature laterals are provided on H-2-34043, "Thermal Probe Assembly & Detail TK 105-A," and the wiring of the thermocouples to the computer input terminal is provided on H-2-34086, "Electrical Detail 105-A Thermal Probe." Lateral temperature data as well as in-tank temperature data are recorded in the Surveillance Analysis Computer System.

The two vertical caissons for the laterals with gamma instruments have 12-ft diameters (Figure 3-41). The third vertical caisson for the thermal probes has a 13-ft diameter (H-2-33973). At closure of the tank farm, the lateral lines are expected to be grouted and the caissons backfilled and/or grouted and sealed to avoid leaving a preferential pathway for flow.

3.2.1.4 241-AX Tank Farm Leak Detection Pits. Each AX Farm tank has its own internal leak detection pit consisting of a network of drain slots in the concrete base immediately below the carbon steel liner (Figure 3-43). A 12-in. carbon steel pipe connects the drain network with a leak detection well. The 60-ft deep leak detection well consists of a 24-in., schedule 20 carbon steel pipe, surmounted by a concrete pump pit. A waste transfer line connects the leak detection pit with a pump pit atop the AX Farm tank. The leak detection well is vented to the main vent header through a water-filled seal pot. The leak detection pump pits drain into their respective storage tanks through a 4-in. line that extends 5 ft from the tank bottom. Each leak detection pit has a separate 6-in. radiation detection well that intersects the soil adjacent to the bottom of the leak detection pit. The radiation well is used as a cost-effective and non-invasive method to monitor changes in gamma activity within the leak detection pit.

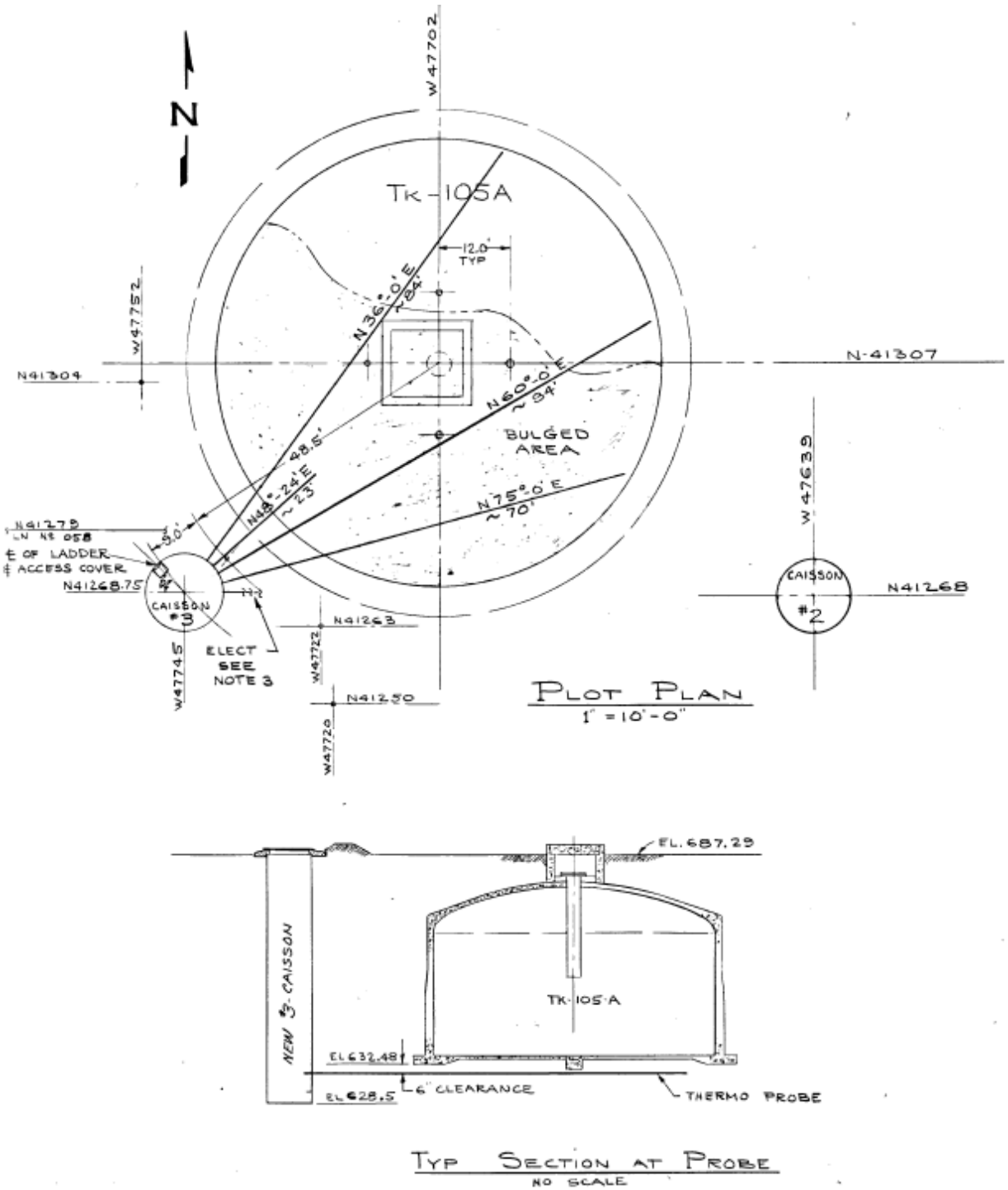
3.2.2 Ancillary Equipment

To support the transfer and storage of waste within WMA A-AX SSTs, there is a complex waste transfer system of pipelines, i.e., transfer lines (Section 3.2.2.1), diversion boxes (Section 3.2.2.2), catch tanks (Section 3.2.2.3), valve pits (Section 3.2.2.4), French drains (Section 3.2.2.5), and vaults (discussed among process facilities in Section 3.3). Collectively, these are referred to as ancillary equipment. Operating capacities and other dimensions of ancillary equipment, if not provided herein, may be found in RPP-RPT-58156, "*Basis for Miscellaneous Underground Storage Tanks and Special Surveillance Facilities Waste Volumes Published in HNF-EP-0182 Revision 320 'Waste Tank Summary Report for Month Ending August 31, 2014"*.

3.2.2.1 Pipelines. An extensive network of transfer lines connects the various components of the tank farms. The transfer lines were designed to convey wastes. The piping network conveyed a variety of process wastes, typically in a slurry form. Some lines were installed for

specific purposes (e.g., drain lines, saltwell lines), while others were used for general transfers between facilities in the 200 Areas.

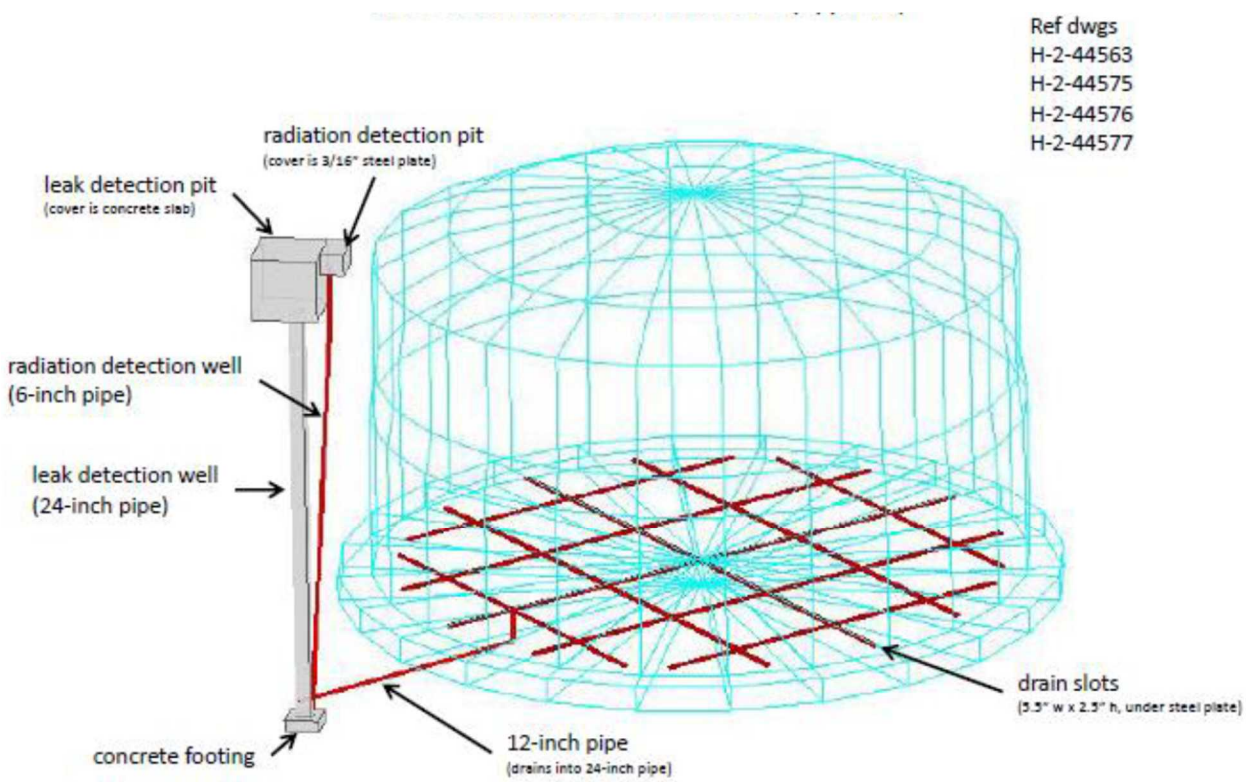
Figure 3-42. Lateral Lines and Caisson for Thermal Probes at Tank 241-A-105.



Source: H-2-33973, "Thermal Probes Under Tk. 105-A," Sheet 1, Rev. 1.

Pipelines are evaluated in the WMA A-AX PA as potential sources of waste residuals based on uncertainty as to whether pipelines are now completely drained as intended (or will be at the time of closure) or are partially full from incomplete flushing and drainage. In the worst case, portions of some lines may be completely full if they have become plugged. RPP-15043, "*Single-Shell Tank System Description*" reported that only five cases of plugged transfer lines were documented in the Hanford Site SST system as of 2003. Although additional cases have since been documented (RPP-ENV-37956 Table 5-2; SGW-59881, "*200-IS-1 Operable Unit Scoping*"; RPP-PLAN-47559, "*Single-Shell Tank Waste Management Area C Pipeline Feasibility Evaluation*," Rev. 1; RPP-25113, "*Residual Waste Inventories in the Plugged and Abandoned Pipelines at the Hanford Site*," Rev. 0-A), the number remains a small fraction of the number of lines in the system, indicating a low probability of any given line being plugged. During operations, flushing procedures were implemented to prevent the build-up of residual waste inside the piping. No discernible residual waste was observed in pipelines studied in 241-SY Tank Farm and ~4% of the pipe volume contained waste in 15- to 18-in. vitrified clay pipes between the 231-Z Building and Z Ditches (RPP-PLAN-47559) (no pipeline retrieval). However, some lines in A Farm and AX Farm are known to have plugged in the past; some were flushed and unplugged, but some may have remained plugged and some failed lines were capped and abandoned in place (RPP-ENV-37956 Table 5-2, as cited in RPP-RPT-58293, "*Hanford 241-A and 241-AX Farm Tank and Ancillary Equipment Residual Waste Inventory Estimates*").

Figure 3-43. 241-AX Single-Shell Tank Leak Detection Pit Schematic.



References:
H-2-44563, "Structural Waste Storage Tanks Drain Arrangement & Details 241-AX PUREX Waste Tank Farm."
H-2-44575, "Structural Leak Detection Pit Tanks 102, & 104-AX."
H-2-44576, "Structural - Leak Detection Pit Tanks 101 & 103-AX."
H-2-44577, "Structural Leak Detection Pit Details."

The analysis performed in RPP-15043 identified at least 121 pipelines (9.1 miles ± 3 miles) in A Farm and 119 pipelines (7.93 miles ± 2.3 miles) in AX Farm. The identities of these pipelines and the facilities they connect are given in Table 1-1 of RPP-RPT-58293. For lines connecting facilities inside and outside the tank farms, one-half the length of the pipeline was attributed to the tank farm in the RPP-15043 estimates. This assumption for inventory estimation purposes may differ from the manner in which pipelines extending beyond the WMA are actually dispositioned to achieve Hanford Site closure; in particular, the 200-IS-1 operable unit is defined in part to address portions of pipelines and associated equipment that fall between fence lines of WMAs or other operable units.

Across the Hanford SST system, most pipeline segments were directly buried; however, sections of several pipelines within A Farm and AX Farm were routed through concrete encasements (Figure 3-10 and Figure 3-18), which were often used to provide additional safety for high level waste transfer lines. Many of these were 4-in. diameter lines and were placed within support sleeves in small stacks within the encasement (e.g., see H-2-44633, "Process Waste Lines Tk. Farm Area Plans & Sections, 241-AX Tank Farm"). In general, for the transfer lines serving the 149 SSTs at the Hanford Site, diameters range in size from 5.1 to 15.2 cm (2 to 6 in.) in diameter.

WIDS gives detailed information in some cases of pipelines classified as waste sites. 200-E-200-PL is a waste site assigned to WMA A-AX comprising four underground, 15-cm (6-in.)-diameter carbon steel pipelines that are directly buried in the same soil trench (DOE/RL-88-30). Pipelines 801, 802, 805, and 806 extend from the 244-AR Vault Building to diversion boxes within the fence line of WMA A-AX. The lines split into a "Y" west of the A Farm fence. Lines 802 and 806 divert to the 241-AY-152 Diversion Box. Lines 801 and 805 divert to the 241-A-153 Diversion Box. Dates of usage in WIDS are from 1966 to 1985. The lines carried reprocessed PUREX waste.

200-E-151-PL is a waste site associated with V050, a plugged, 3-in.-diameter, tank farm process waste pipeline from tank 241-C-104 to the 241-A-152 Diversion Box. As of 2017, this site was flagged "TBD" in WIDS, indicating it has not been assigned to a WMA or Operable Unit (DOE/RL-88-30). A plugged segment of V050 within WMA C from the main line to the 241-CR-151 Diversion Box was abandoned in place and capped in 1966, and the line was rerouted directly to tank 241-C-104. A replacement pipeline (also named V050) was set in the trench above the plugged line. From this information, it does not appear that any segment of V050 located within WMA A-AX is plugged.

RPP-ENV-37956 Appendix B contains a summary from a 2008 meeting in which a recommendation was made to add a UPR to WIDS for a pipeline leak between tank AX-102 and the 102C pump pit at tank 241-C-102 in WMA C. As of 2017, the leak was incorporated into the summary of the comprehensive UPR for WMA A-AX, designated 200-E-131 (DOE/RL-88-30). On January 29, 1968, hot water and a pressurized line from a fire truck was used to try to unplug the 241-AX-102 to 241-C-102 pipeline. Liquid was noticed coming up from the ground near the AX-103 pump pit, so the flushing operation was discontinued. Citing ARH-258 DEL, "*Chemical Processing Division Daily Production Reports January, 1968 through March, 1968*," RPP-ENV-37956 Table 5-2 indicates that over the next few days, some contaminated soil near

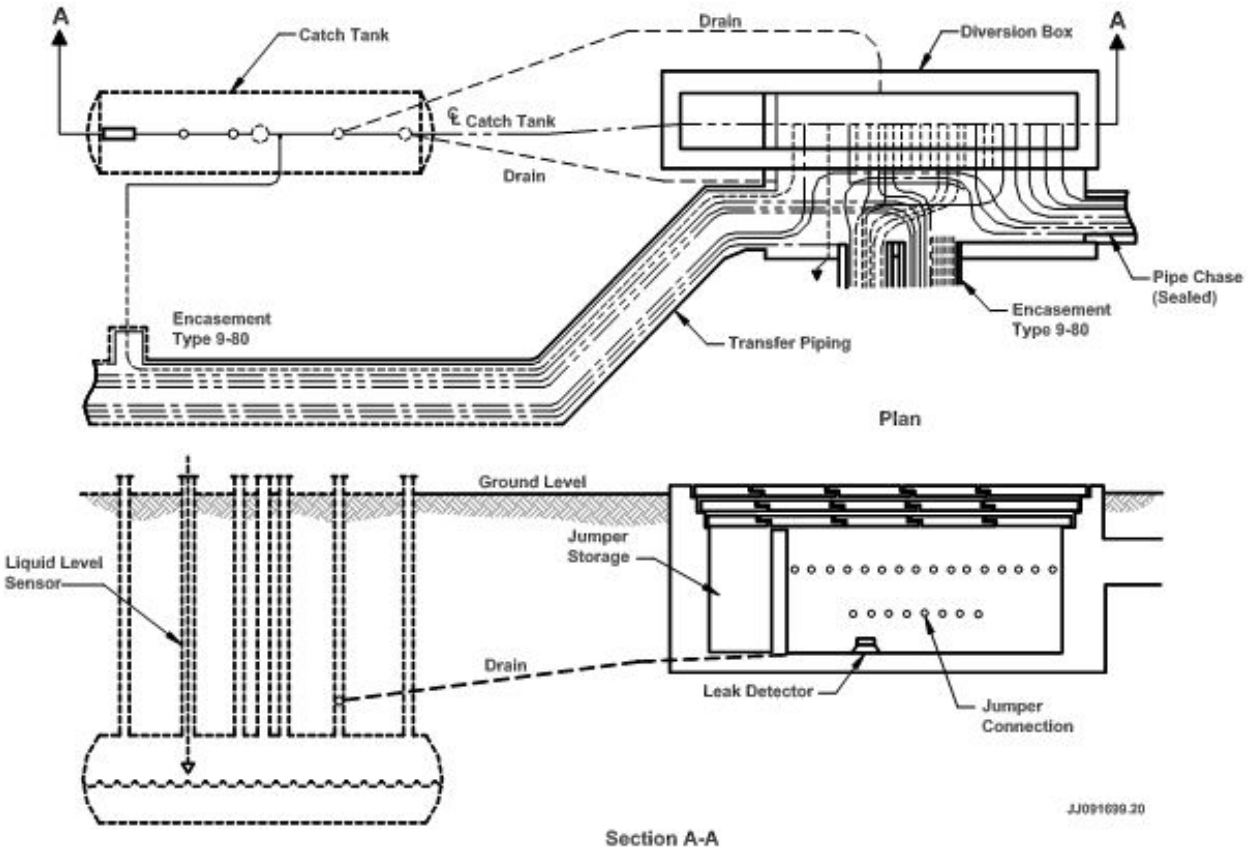
ground surface was removed, and additional flushing attempts appeared to successfully unplug the line. According to the summary in RPP-ENV-37956, ^{137}Cs was observed at 25 ft below ground surface. Monitoring drywells in AX Farm were re-logged in 2014 for spectral gamma profiles that may allow a more precise interpretation.

Spatial data for the larger pipelines between tank farms and other facilities may be obtained using a combination of existing shapefiles provided by Mission Service Alliance, WIDS, and the Enhanced Pipeline Database found in HMAPS. Spatial data for smaller pipelines connecting individual tanks and other ancillary equipment inside WMA A-AX may be obtained from original engineering drawings, from computer-aided design (CAD) files based on those drawings, or from geophysical surveys. H-2-44502, "Flow Diagram Waste Transfer and Storage Facilities" illustrates the routing of many or all of these pipelines as well as approximate elevations, and in some cases handwritten annotations indicate lines that failed or leaked and were capped. H-2-44612, "Engineering Flow Diagram 241-AX Tank Farm" lists the diameter and material type (e.g., steel specification) for many or all of the lines in AX Farm. H-14-104175, "Waste Transfer Piping Diagram 200 East Area" illustrates the routing of several pipelines but is not comprehensive and does not reflect the layout or paths of pipelines over the tank domes, through encasements, and between facilities. Care must be taken when interpreting diagrams that show waste transfer pipelines together with raw water lines, process air lines, and/or vapor/condensate lines. Geophysical surveys are difficult to interpret for the same reason.

Uncertainty in residual inventories for pipelines can be significant and is a function of uncertainty in the total volume of the many pipelines in WMA A-AX and in the fraction of volume that may be occupied by waste residuals at closure. Partly to address the same uncertainties for pipelines at WMA C, RPP-PLAN-47559 compiled detailed information for all known pipelines in the area and evaluated the likely distribution of residuals based on information for pipelines across the Hanford Site. RPP-PLAN-47559 also reviewed the potential incidence of plugged pipelines in WMA C based on information for the complete SST system cited in RPP-25113. A similar approach combining the spatial data with the design data from the sources discussed in this section could be taken for WMA A-AX if necessary for the PA objectives.

3.2.2.2 Diversion Boxes. The routing of liquid waste from the operations buildings to the tank farms was accomplished using underground transfer lines, diversion boxes, and valve pits. The diversion boxes housed jumpers (remote pipeline connectors) where waste could be routed from one transfer line to another. The diversion boxes are belowground, reinforced-concrete boxes that were designed to contain any waste that leaked from the high-level waste (HLW) transfer line connections. The interior surfaces of diversion boxes were coated with a chemically resistant paint (INDC-356-VOL3, "*Construction Hanford Engineer Works, U.S. Contract No. W-7412-ENG-1 Du Pont Project 9536 History of the Project Volume III*," pp. 923). If waste leaked into a diversion box, it generally drained by gravity to nearby catch tanks where any spilled waste was stored and then pumped to SSTs (DOE/RL-92-04, *PUREX Source Aggregate Area Management Study Report*).
Figure 3-44 shows a schematic of a typical diversion box. Photographs of diversion boxes are shown in Figure 3-45.

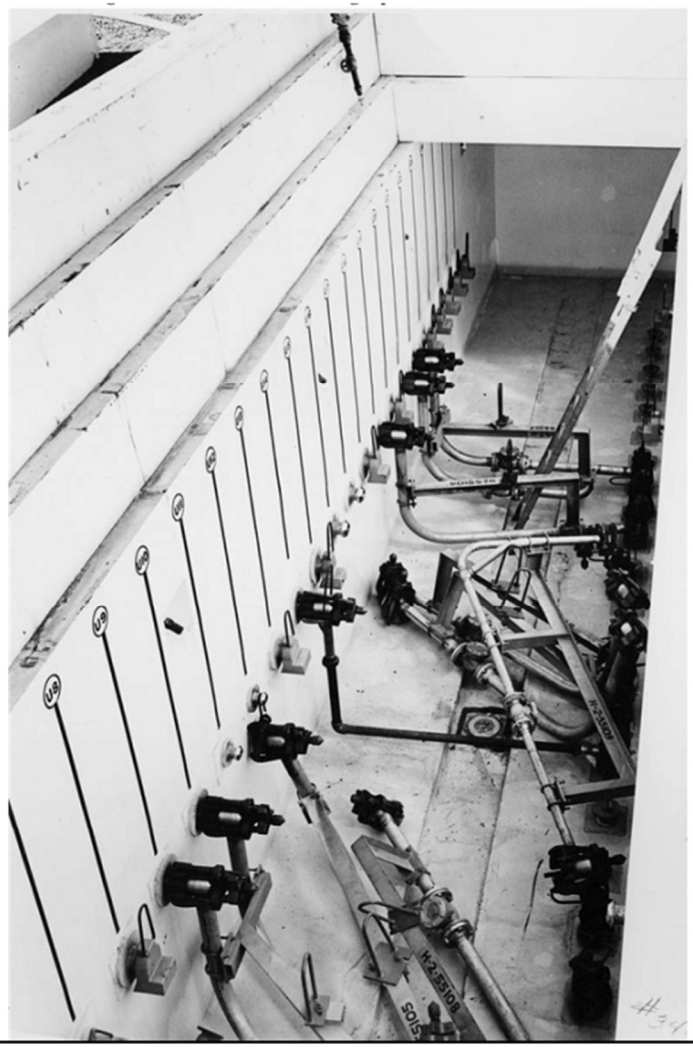
Figure 3-44. Schematic of a Typical Diversion Box Transfer System.



The following diversion boxes are located in or associated with WMA A-AX (Figure 2-3): 241-A-151, 241-A-152, 241-A-153, 241-AX-151, 241-AX-152DS, 241-AX-153, 241-AX-155, 241-AY-151 and 241-AY-152. The first diversion box, 241-A-151, is located south of the 202-A PUREX Building (Figure 2-2) outside the likely model domain and is mentioned only because it is the endpoint for five pipelines connecting to 241-A-152 (H-2-44502, Sheet 13, Rev. 4). Unplanned releases that have been attributed to the 241-A-151 Diversion Box do not affect closure of WMA A-AX from a modeling point of view (see also Section 3.3.1 regarding closure of ancillary equipment located at 202-A). The other diversion boxes are discussed in more detail because they are potential sources of contaminant inventory within the likely model domain, although some of them outside the fence line may or may not have their closure coordinated with that of WMA A-AX. Information on the diversion boxes comes primarily from DOE/RL-88-30.

3.2.2.2.1 241-A-152. This diversion box is a reinforced-concrete structure containing four stainless steel transfer pipes and adequate space to allow for jumper replacement activities. The major portion of the diversion box is below grade with concrete cover blocks and lifting hooks. The diversion box is located inside the A Farm fence, east of tank A-106, and is attributed to WMA A-AX in WIDS.

Figure 3-45. Diversion Boxes.

Historical Photograph of a Diversion Box	Historical Photograph 241-A Diversion Box
	

Diversion Box 241-A-152 routed waste from the 241-A-151 Diversion Box to the 241-CR-151 Diversion Box through a pipe encasement containing four stainless steel lines. Waste transferred through the diversion box included fuel de-cladding waste, organic wash waste, sump waste, and laboratory waste. Lead shielding may also be contained inside the diversion box. The diversion box was first used around 1956, and the last documented waste transfer was May 1980.

Waste sites associated with 241-A-152 include the 241-A-302-B Catch Tank, drain line V062, 216-A-7 crib, 200-E-182-PL and 200-E-207-PL.

3.2.2.2.2 241-A-153. This diversion box is a reinforced-concrete structure sized to accommodate the pipes and provide space for jumper replacement. The 241-A-153 is one type of diversion box, known as a transfer box. It connects one common pipe to several others, one at a time, uses only one jumper and has the several nozzles arranged in a circle about the common nozzle. The 241-A-153 Diversion Box is located inside the A Farm fence, southwest of tank A-104, and is attributed to WMA A-AX in WIDS.

Diversion Box 241-A-153 routed waste from A Farm to the 244-AR Vault and handled PUREX HLW and PUREX organic wash waste. Lead shielding may also be contained inside the diversion box. The diversion box was first used around 1956, and the last documented waste transfer was July 1985. The diversion box has been isolated with plastic foam to prevent infiltration of water into the unit.

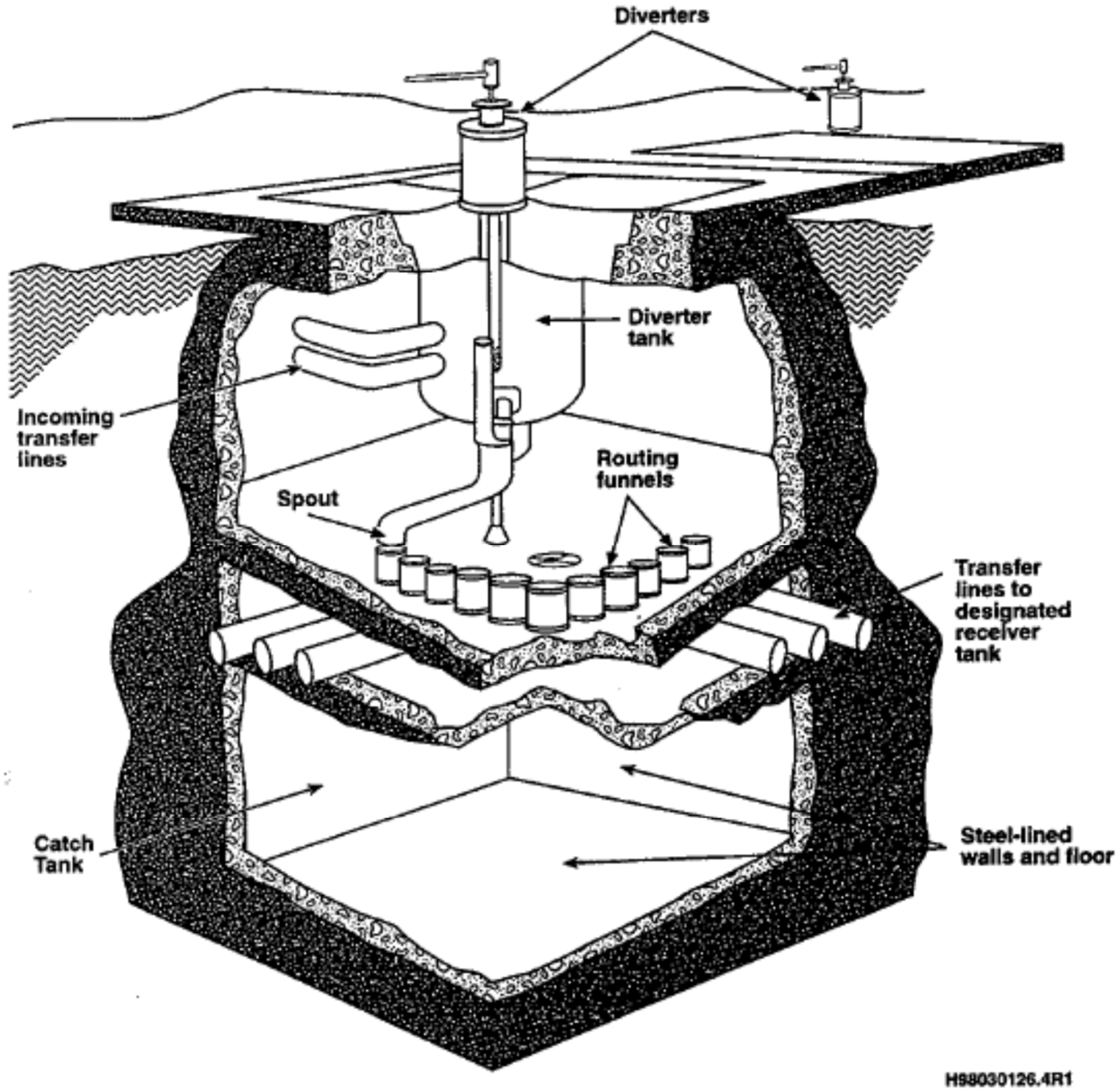
3.2.2.2.3 241-AX-151. Diversion box 241-AX-151 is an underground reinforced-concrete structure located southwest of A Farm (Figure 2-3). There are four diverter tanks (tanks 241-AX-151-TK-D, 241-AX-151-TK-E, 241-AX-151-TK-F and 241-AX-151-TK-G) in individual cells and a catch tank (241-AX-151CT, also known as 241-AX-151:1) in a pump pit (Figure 3-46). Each diverter tank is a 602-L capacity stainless steel tank with a diameter of 76.2 cm and a height of 132 cm. Each cell has a stainless steel liner on the floor that extends approximately one foot up the wall. The cells and pump pit drain into the stainless steel-lined catch tank below. The catch tank has a capacity of 12,200 gal according to RPP-RPT-31102, "*Catch Tank 241-AX-151-CT Liquid Level Assessment Report*." The diversion box is associated with UPR-200-E-42. The structure is surrounded with posts and chain. It is posted with radiological and Inactive Miscellaneous Underground Storage Tank signs.

Diversion box 241-AX-151 routed waste from the 202-A Plant to the 244-AR Vault and to AY Farm and 241-AZ Tank Farm (AZ Farm). Waste transferred also included PUREX acid waste and B Plant neutralized HLW. It is estimated that approximately 50 pounds (23 kilograms) of lead is stored in each diversion box. Pipeline waste sites associated with this diversion box include 200-E-143-PL, 200-E-144-PL, 200-E-146-PL, and 200-E-227-PL. This unit was isolated by the B-231 project. The diversion box was first used around 1962, and the last documented waste transfer for this site was in 1977. Gravel was placed on the east and south side slopes in April 2005 to prevent soil erosion.

3.2.2.2.4 241-AX-152DS. The 241-AX-152 Diverter Station (241-AX-152DS) is a reinforced-concrete structure with the top at ground level. There are two diverter tanks in a

common cell with a stainless steel liner on the floor that extends ~1 ft up the cell wall. There is also a pump pit that does not have a stainless steel liner. The cell and pump pit drain to a catch tank below.

Figure 3-46. 241-AX-151 Diversion Box and 241-AX-151CT Catch Tank.



Source: HNF-2503, *Authorization Basis Status Report (Miscellaneous TWRS Facilities, Tanks and Components)*.

This diverter station is located in the western portion of AX Farm and is attributed to WMA A-AX in WIDS. It was used to transfer mixed waste solutions from processing and decontamination operations. The diversion box was used from ~1965 to 2001. The unit was pumped out on August 29, 1992 and declared isolated in March 2002. Waste sites associated

with 241-AX-152DS include the 241-AX, 241-AZ, and 241-AY Tank Farms and the 241-AX-152 Catch Tank. The drain line is V713.

3.2.2.2.5 241-AX-153. This diversion box is an underground cement structure with cement cover blocks and is also called the 241-AX-153 Isolation Jumper Pit. The diversion box is located west of tank AX-103 and east of the 241-AX-152 Diverter Station, inside AX Farm. Although 241-AX-153 is a WIDS site associated with WMA A-AX, it was missing from the WIDS geospatial data; therefore, it was digitized from drawing H-2-44501, "Area Map, 200 East, A Plant Facilities" in order to map its location (Figure 2-3).

The isolation jumper pit had three 3-in. transfer lines going into it: line number 4021 (line bypasses the 241-AX-152 Diverter Station) and two lines both numbered 4026 (one from 241-AX-152 Diverter Station and the other a construction pipe that has been isolated – welded cap). Line 4021 was isolatable from the 241-AX-152 Diverter Station because of this isolation jumper pit.

3.2.2.2.6 241-AX-155. This 241-AX-155 Diversion Box is located inside AY Farm, adjacent to the 241-AX/241-AY dividing fence. The surface features of the diversion box have been sprayed with a weather-protective coating.

The unit transported waste solutions from processing and decontamination operations. Quantities are variable according to specific plant operation. Lead shielding may also be contained inside the diversion box. It is estimated that approximately 50 pounds (23 kilograms) of lead waste is stored in each diversion box. The diversion box was first used around 1983. This unit is associated with the 241-AX, 241-AY and the 241-AZ Tank Farms and the 241-AX-152 Diversion Box. Line V713 drains to Diversion Box 241-AX-152.

3.2.2.2.7 241-AY-151. This diversion box is an underground, reinforced concrete structure containing four PUREX style nozzles. The diversion box is located in the southern portion of AY Farm.

DOE/RL-88-30 describes the unit as "associated with A Farm and AX Farm" but does not list it among the WIDS sites attributed to WMA A-AX. The diversion box transferred liquid process waste between the processing plants and the tank farms. These wastes included PUREX organic wash, aging PUREX, PUREX acid, and B Plant HLWs. Lead shielding may also be contained inside the diversion box. The diversion box was first used around 1975.

3.2.2.2.8 241-AY-152. This diversion box is an underground, reinforced-concrete structure located in the western portion of AX Farm, and is attributed to WMA A-AX in WIDS. It is also known as the 241-AY-152 Diverter Station or the 241-AY-152 Sluice Transfer Box. The drain line is DR0074.

The unit is associated with A Farm and AX Farm. This unit was used to transport radioactive waste solutions between storage and process facilities from around 1971 until around 1985. This diversion box received PUREX organic wash, PUREX acid, PUREX HLW and B Plant HLW. Lead shielding may also be contained inside the diversion box.

3.2.2.3 Catch Tanks. Catch tanks are components of tank farms that collect spills and/or leaks during waste transfers between processing facilities and tank farms. Catch tanks also received any water from rainfall, snowmelt, or dust that entered the diversion boxes (the diversion boxes were later weatherproofed). There are four catch tanks in A Farm and AX Farm and attributed to WMA A-AX in WIDS: 241-A-350, 241-A-417, 241-A-302B, 241-AX-152CT. Also, the 241-AX-151CT Catch Tank is located just outside A Farm to the southwest and is discussed along with Diversion Box 241-AX-151 in Section 3.2.2.2.3, and the 204-AR-TK-1 Catch Tank associated with the 204-AR Unloading Facility is mentioned in Section 3.3.3.

Two other catch tanks associated with equipment in WMA A-AX are not anticipated to be modeled in the PA. The 241-A-302A Catch Tank associated with the 241-A-151 Diversion Box is located outside the likely model domain (see also Section 3.3.1 regarding closure of ancillary equipment located at 202-A). The 244-A Catch Tank (244-A CT, aka 244-A DCRT) is located at the 244-A lift station which is northwest of A Farm and AX Farm beyond the 216-A-40 Retention Basin (Figure 2-2). This location is expected to lie beyond the extent of any feasible surface barrier developed for closure of the A Complex, so it is unclear whether its closure would be coordinated with that of WMA A-AX. Although 244-A CT provided lag storage for waste transferred from the 241-ER-153 Diversion Box to the 241-A valve pits, the types of waste routed through the lift station do not appear to be related to operations of A Farm and AX Farm (see DOE-RL-88-30).

3.2.2.3.1 241-A-350. This catch tank is an underground reinforced-concrete pump pit, with a cover block. The pump pit drains any leaks from the pump through the pump pit floor drain to an 800-gal (3,000-L) stainless steel tank below. The tank is located inside the A Farm fence, southeast of tank A-106. It is designed to receive drainage from the 241-A-A and 241-A-B valve pits, 241-A service pit, 241-A&B flush pits, 241-A clean out boxes, 241-A-431 ventilation equipment, and out-of-specification 241-A-207 retention basin solution.

3.2.2.3.2 241-A-417. This catch tank is an underground cylindrical concrete vault lined with an all-welded steel liner. Two overflow lines near the top of the vault prevent overflow of the tank. Above the tank are two rectangular pits, a pump pit and a valve pit. The floors of both pits slope to drains that empty to the tank. The tank is located inside AX Farm, east of the 241-A-702 Building. The tank collects condensate from the 241-A-401 Condenser House, 241-A-702, and from 241-AZ-154. Condensate may be pumped back to AX Farm or overflow to the 216-A-24 crib. On March 25, 1980, a routine pressure test of the underground F-100 condensate return pipeline from the AX-501 Valve Pit to the 241-A-417 Condensate Catch Tank failed. An April 3, 1980 investigation found a leak at the flange connection. An excavation at the pipeline leak was done. Two barrels of contaminated soil, reading 10,000 counts per minute, were taken to a burial ground.

3.2.2.3.3 241-A-302B. This catch tank was used for transfer of waste solutions from processing and decontamination operations to the tank farms and is buried outside the tank farm perimeter fence, east of A Farm (Figure 2-3). Shotcrete surrounds the area where the 241-A-302B Catch Tank is located. A riser and electrical box are visible. A staircase has been installed to provide access to the tank surface. The underground tank is positioned horizontally. The tank is marked and radiologically posted.

The tank received liquid effluents from the 241-A-151 Diversion Box, located south of PUREX, and the 241-A-152 Diversion Box, inside the A Farm fence. The tank was isolated in 1985 and interim stabilized in 1990.

3.2.2.3.4 241-AX-152CT. The 241-AX-152 Catch Tank and Diverter Station are located in the western portion of AX Farm and are part of the same structure. They have been consolidated in WIDS. The catch tank is located under the diverter station. It is constructed of 0.76-m (2.5-ft)-thick concrete walls. The tank walls and floor are lined with stainless steel. The drain line is V713. This unit transferred mixed waste solutions from processing and decontamination operations. The tank was constructed in 1962 and declared a "leaker" in March 2001. The tank was stabilized by removing all liquid in March 2001, and isolated by December 2001 using both administrative and engineering controls (External letter CHG-0200089, "Contract Number DE-AC27-99RL14047; Stabilization and Isolation of Catch Tank 241-AX-152").

3.2.2.4 Valve Pits. The valve pits contained valve assemblies that were used for routing the liquid waste through transfer lines. There are seven valve pits in A Farm and AX Farm and attributed to WMA A-AX in WIDS: 241-A-501, 241-A-A, 241-A-B, 241-AX-A, 241-AX-B, 241-AX-501, and 241-AY-501.

3.2.2.4.1 241-A-501. The 241-A-501 Valve Pit is located inside A Farm, west of the 241-A-152 Diversion Box and east of tank A-106. The valve pit received raw water and cooling water from the PUREX facility, via the 241-A201 storage tank. The cooling water ran out of the valve pit to the E-411 (EP-241-A-161) and E-412 (EP-241-A-162) contact condensers. The output from the contact condensers went to the 241-A-401 Condenser Building. Although 241-A-501 is a WIDS site associated with WMA A-AX, it was missing from the WIDS geospatial data; therefore, it was digitized from drawing H-2-44501 Sheet 69 Rev. 12 in order to map its location (Figure 2-3).

3.2.2.4.2 241-A-A and 241-A-B. The 241-A-A and 241-A-B Valve Pits are underground structures built in 1974 with reinforced-concrete walls, floor, and cover blocks located inside the A Complex tank farms, south of tanks A-101 and 241-A-102. The A Farm valve pits were used to route wastes to and from the 242-A Evaporator; 241-AN, 241-AW, 241-AY, and 241-AZ Tank Farms; PUREX; and the 244-A CT. The 204-AR Facility was connected to 241-A-A Valve Pit, but waste was re-routed to 241-AW-A Valve Pit in 2003 when line LIQW-702 was tied into line SN-220. Transfers from the 244-A CT may have included cross-site, 244-CR Vault, and B Plant wastes.

3.2.2.4.3 241-AX-A and 241-AX-B. The 241-AX-A and 241-AX-B Valve Pits were built in 1965 and are underground reinforced-concrete structures with 1-ft-thick walls and floor located inside AX Farm, southwest of tank AX-104. The 241-AX-A and 241-AX-B Valve Pits were used to direct slurry into tanks or supernate out of tanks and to route waste solutions from processing and decontamination operations.

3.2.2.4.4 241-AX-501. The 241-AX-501 Valve Pit is a reinforced-concrete structure located inside the north end of A Farm that contains a valve that routes AX Farm condensate to the 241-A-417 Pump Pit and tank.

3.2.2.4.5 241-AY-501. The 241-AY-501 Valve Pit is an underground concrete structure with concrete cover blocks. The valve pit is located inside the AX Farm fence, east of tank 241-AY-101 and west of tank AX-103. Although 241-AY-501 is a WIDS site associated with WMA A-AX, it was missing from the WIDS geospatial data; therefore, it was digitized from drawing H-2-44501 in order to map its location (Figure 2-3).

The 241-AY-501 valve pit was used to distribute condensate from the 702-A ventilation system to the 241-AX, 241-AY and 241-AZ tank farms. The condensate collected in the 241-A-417 tank. The valve pit has been isolated and weather sealed.

3.2.2.5 French Drains. French drains, sometimes referred to as drywells, received liquid effluent discharges to the soil. There are five French drains located in WMA A-AX and attributed to the WMA in WIDS: 216-A-16, 216-A-17, 241-A-702-WS-1, 216-A-23A and 216-A-23B. Additional unnamed "dry wells" appear near buildings on engineering drawings (H-2-44501 Sheet 69 Rev. 12 and H-2-61964, "Plot Plan Yard Piping 241-AX Tank Farm"), but they are not identified WIDS sites, and more information could not be readily located.

French drains are potentially of comparable significance to that of the cribs and trenches in terms of their effect on soil moisture prior to tank farm closure. The French drains discharged dilute wastes such as condensate that had only small contaminant inventories. Relative to cribs and trenches, the French drains discharged liquids to the subsurface over smaller areas such that even lower overall volumes of discharge may equate to comparably high infiltration rates.

Operational years and total volumes received by French drains as estimated in RPP-26744, "*Hanford Soil Inventory Model, Rev. 1*," and areas attributed to French drains in the WIDS geospatial data, are tabulated along with other liquid discharge sites in Section 3.4. Geospatial data for areas of small features such as French drains should be considered less accurate than dimensions from engineering drawings; however, the latter were not readily located when this data package was initially prepared.

3.2.2.5.1 216-A-16. This French drain is composed of a bell-end concrete pipe, 1.8 m (6 ft) long, placed vertically 3.4 m (11 ft) below grade. The unit is rock-filled with a 1.9-cm (0.75-in.) carbon-steel cover. A 5-cm (2-in.) steel vent riser extends 0.9 m (3 ft) from the top. There is a carbon steel inlet pipe, ~0.6 m (2 ft) long coming from the 216-A-17 French Drain. The French drain is located in the southeast corner of A Farm, inside the tank farm fence.

French Drain 216-A-16 received 60,000 L of contaminated water from floor drainage and 296-A-11 Stack drainage from the 241-A-431 Building. The waste is low in salt, neutral to basic, and contains less than 10 Ci total beta activity. This unit receives the overflow from the 216-A-17 French Drain. The piping was water-sealed when the 296-A-11 Stack exhaust system was deactivated.

3.2.2.5.2 216-A-17. This French drain is composed of a bell-end concrete pipe, 1.8 m (6 ft) long, placed vertically 3.3 m (11 ft) below grade. The unit is rock-filled with a carbon steel cover. The side slope of the excavation is assumed to have been 1:1. The French drain is in the southeast corner of A Farm, inside the tank farm fence.

French Drain 216-A-17 received 122,000 L of contaminated water from floor drainage and 296-A-11 Stack drainage from the 241-A-431 Building. The waste is low in salt, neutral to basic, and contains less than 1 Ci total beta activity. Overflow from the 216-A-17 French Drain is routed to the 216-A-16 French Drain.

3.2.2.5.3 241-A-702-WS-1. This French Drain is a concrete or clay pipe 1.22 m (4 ft) in diameter and ~2.44 m (8 ft) deep (CP-49279, "*Central Plateau Waste Site Dimensions*") that received steam condensate from the 241-A-702 Ventilation Building. The unit is located inside AX Farm, west of the 241-A-702 Ventilation Building.

Process steam was used in steam heaters during normal and reduced operating conditions to raise the temperature of vent gases from the AY Farm and AZ Farm tanks to prevent wetting of filters. The drain was used in conjunction with a steam trap for the system. The drain was isolated October 26, 1995.

3.2.2.5.4 216-A-23A and 216-A-23B. These French drains are 1.07-m (3.5-ft)-diameter, 1.8-m (6-ft)-long bell-end concrete pipes, placed vertically 1.98 m (6.5 ft) below grade. The concrete pipes are filled with 0.9 m (3 ft) of rock and have carbon steel covers. These French drains are located in the southeast corner of A Farm, just south of the 241-A-431 Fan House Building.

These drains received the de-entrainer tank condensate and the back flush waste from the 241-A-431 Building. The waste is low in salt, neutral to basic and contains less than 50 Ci total beta activity. The total amount discharged by this waste stream, 6,000 L (1,580 gal), applies to both 216-A-23A and 216-A-23B. The 216-A-23A French Drain is connected to the 216-A-23B French Drain, located 3 m (10 ft) to the west, by an underground overflow pipe. The sites were deactivated by water-sealing the piping leading to the drains.

3.3 PROCESS FACILITIES

3.3.1 202-A Plutonium Uranium Extraction Plant

The 202-A Plutonium Uranium Extraction Plant, also known as PUREX, was the major source of wastes initially handled at WMA A-AX (RPP-RPT-58291, "*Hanford Waste Management Area A-AX Soil Contamination Inventory Estimates*") and also generated waste streams disposed at waste sites near to WMA A-AX. As of 2017, this site was assigned to operable unit 200-CP-1 in WIDS (DOE/RL-88-30). It is not a focus of the WMA A-AX PA, because it is expected to follow a different closure process than the SST system (for example, it lies outside the assumed area of the surface barrier to be constructed over the tank farms at closure as discussed in Section 4.0). Nor is it expected to influence PA calculations given its location hundreds of meters southwest of A Farm and AX Farm (Figure 2-2). However, a brief discussion of PUREX may aid in understanding the nature of wastes and operations at WMA A-AX.

PUREX is a large, reinforced-concrete structure that includes a concrete canyon with below grade cells that contain equipment used for chemical separations. Various support structures are

associated with PUREX but will not be discussed herein. Diversion boxes, catch tanks, and pipelines that connected from PUREX to equipment within WMA A-AX are mentioned in appropriate parts of Section 3.2.2, though these may also be closed with 202-A or operable unit 200-IS-1 instead of WMA A-AX.

As summarized in DOE/RL-88-30, PUREX was constructed for the purpose of extracting plutonium, uranium, and neptunium from irradiated fuel rods discharged from Hanford reactors. The PUREX (Plutonium/Uranium Extraction) chemical separation process was based on removing the cladding (usually aluminum) from the fuel rods with sodium hydroxide, dissolving the fuel using nitric acid, and conducting multiple purification processes of the resultant aqueous solution (RPP-8847, "*Best-Basis Inventory Template Compositions of Common Tank Waste Layers*"). These operations occurred inside the canyon cells.

More detailed discussion of PUREX operations is found in RPP-8847, RPP-7494 and ARH-78, "*PUREX TK-105-A Waste Storage Tank Liner Instability and its Implications on Waste Containment and Control*," pp. 11-12. The process recovered plutonium in the form of plutonium nitrate and uranium in the form of uranium nitrate hexahydrate in a continuous solvent extraction process, and also recovered nitric acid and the tri-butyl phosphate (TBP) organic solvent for reuse. PUREX generated various low-level waste streams and three HLW streams: PUREX acid waste, PUREX coating wastes, and organic wash waste. PUREX acid waste contained close to 100% of the fission products.

PUREX and A Farm were constructed in the same time frame for the purpose of sending waste from the PUREX process, the third and final plutonium separation process used at the Hanford Site, to the A-100 series tanks, the next generation of SSTs with new design features to accommodate high-temperature, highly-concentrated, self-boiling PUREX waste. AX Farm and the AX-100-series tanks were constructed a decade later to expand storage capacity and incorporate further tank design improvements based on experience gained with the A-100-series and other Hanford Site SSTs.

PUREX cold startup occurred in November and December of 1955, and PUREX operations occurred in two campaigns, one from 1956 to 1972, and the next from 1983 to 1988 (RPP-7494 pp. 8). Some other documents state a slightly later end date, but according to RPP-7494 (pp. 13), "Final PUREX shutdown was in 1988, and the closure order came in 1992."

PUREX acid waste was sent to A Farm beginning in January 1956 (RPP-7494 pp. 8). Before being sent to SSTs, PUREX acid waste was neutralized to high pH with sodium hydroxide, giving a high molarity (M) of sodium (ARH-78). Self-boiling wastes in the SSTs could concentrate to 7 or 8 M before heat generation became unmanageable. The molarity of neutralized acid waste before boiling would be lower. Additional methods to remove some nitrate were reportedly attempted for waste delivered to tank A-105 in order to reduce the amount of sodium hydroxide required. Further discussion of process operations and PUREX waste compositions is presented elsewhere.

3.3.2 242-A Evaporator

The 242-A Building is located adjacent to the south side of A Farm, outside the tank farm. As of 2017, this site was flagged "Not Applicable" in WIDS, used when sites "do not fit the criteria to be assigned to an OU or WMA" (DOE/RL-88-30). It contains the evaporator vessel, supporting process equipment, and the principal process components of the evaporator-crystallizer system. The building comprises two adjoining, structurally-independent structures, designated A and B. Structure A houses the processing and service areas while structure B houses operating and personnel support areas.

The 242-A Evaporator is used to treat mixed waste from the DST System by removing water and most volatile organics. Two waste streams leave the 242-A Evaporator following the treatment process. The first waste stream, the concentrated slurry, is pumped back into the DST System (Tank Farms 241-AN, 241-AW, and/or 241-AP). The second waste stream, process condensate, is routed through condensate filters for treatment before release to the Liquid Effluent Retention Facility and receives final treatment at the Effluent Treatment Facility. Waste types include: dilute non-complexed radioactive waste, PUREX dilute miscellaneous waste, PUREX cladding removal waste, and complexed radioactive waste. Hazardous chemicals used include: sodium nitrate used to regenerate ion exchange (IX) column, sodium hydroxide used for decontamination applications, and the antifoam agent used in the evaporator vessel.

Hanford Site evaporators processed tank supernate to reduce the waste volume by evaporating liquids, with saltcake wastes as the products. Sample-based compositions for saltcake used in waste templates in the BBI are given in RPP-8847. Saltcake is mostly made up of sodium salts of nitrate, nitrite, carbonate, and sulfate. Aluminum was the second most abundant cation by mass in saltcake from the 242-A Evaporator. Saltcake received in WMA A-AX from the 242-A Evaporator was produced in a steam-heated evaporation/crystallization process under partial vacuum, as was the saltcake received by the 241-S Tank Farm from the 242-S Evaporator. The sample-based compositions of saltcake solids are similar between saltcake produced at various times at 242-A and 242-S; for liquid phases, the sample data from both evaporators were combined in a single template.

3.3.3 204-AR

The 204-AR Unloading Facility (Figure 3-47) is northwest of the 241-AX-151 Diversion Box and south of the 244-AR Vault and is a reinforced-concrete structure. As of 2017, this site was flagged "Not Applicable" in WIDS, used when sites "do not fit the criteria to be assigned to an OU *(operable unit)* or WMA" (DOE/RL-88-30). The structure includes a shielded railcar unloading room, floor drains, a 1,500-gal capacity catch tank (204-AR-TK-1), transfer pumps and four chemical storage tanks. The chemical tanks contain caustic, nitrite and pH buffer solutions.

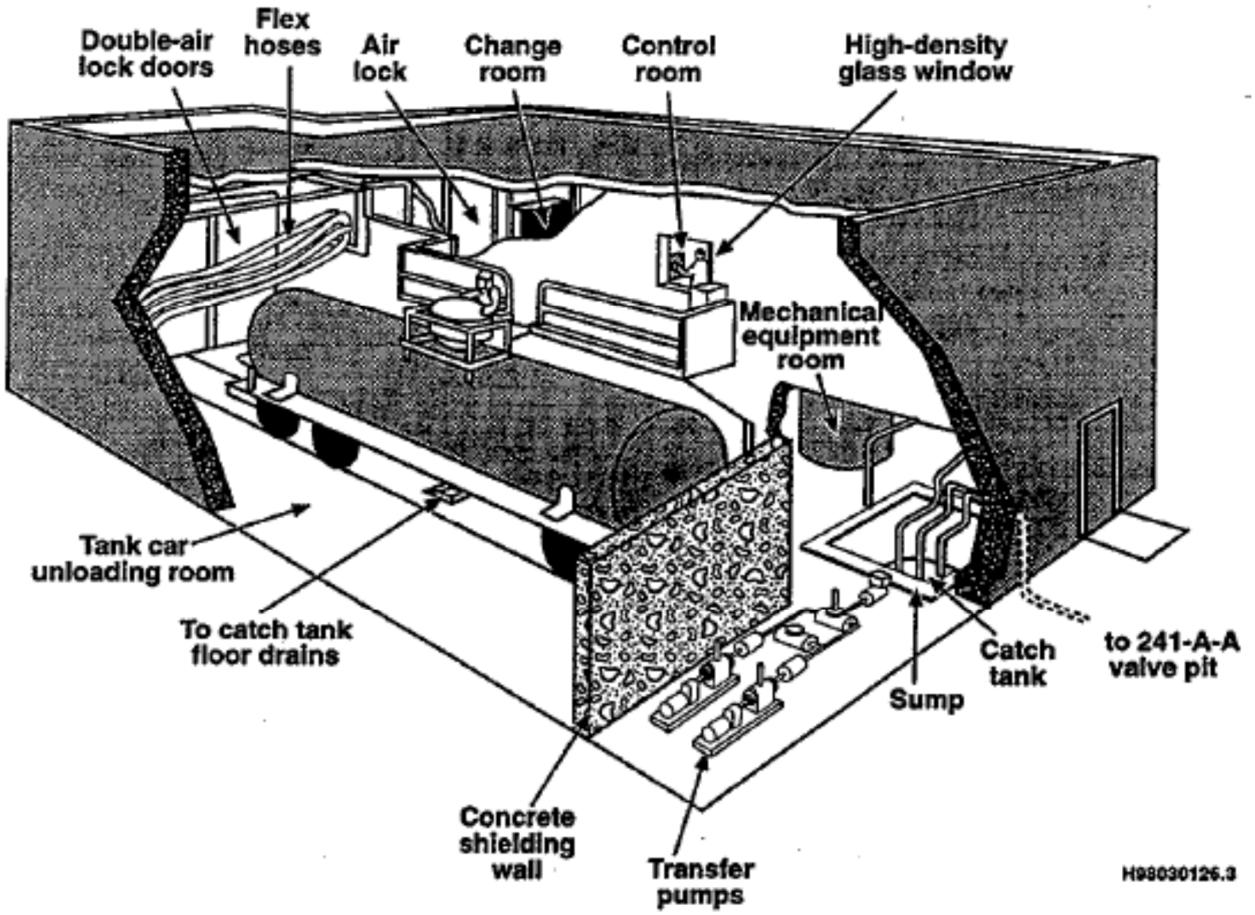
The 204-AR Facility received railroad tank cars of liquid radioactive waste to be remotely unloaded inside a fully enclosed, heated, and ventilated building. The rail cars were pumped, sampled, and sluiced as needed. When sample results showed the contents of the railroad car or

the catch tank did not meet tank farm specifications, chemical adjustments were made inside the rail car or catch tank. Liquids in the catch tank were periodically sent to the tank farm on a batch basis. Liquid in excess of the catch tank capacity overflows into the sump pit, from which it can be pumped to the 241-A-A valve pit. The unit also received wastes generated from decontamination and regeneration operations in the 100 and 200 Areas; from recovery, fuels fabrication, and laboratory operations in the 200 and 300 Areas; and from decontamination operations in the 400 Area. The waste is chemically adjusted in-line during pump-out to double-shell underground storage tanks to meet corrosion specifications.

3.3.4 244-AR

The 244-AR Vault (Figure 3-48) was built in 1966 and is located west of A Farm. As of 2017, this site was assigned to operable unit 200-CW-1 in WIDS (DOE/RL-88-30). Facilities include a canyon building, a service building, two concrete housings, and a change room. The canyon building is a reinforced-concrete, two-level, multi-cell structure. The lower process cells contain four tanks and a failed equipment cell, while the upper cells contain the associated piping and equipment. The upper and lower cells are separated by cover blocks with recessed lifting bails.

Figure 3-47. 204-AR Waste Unloading Facility.

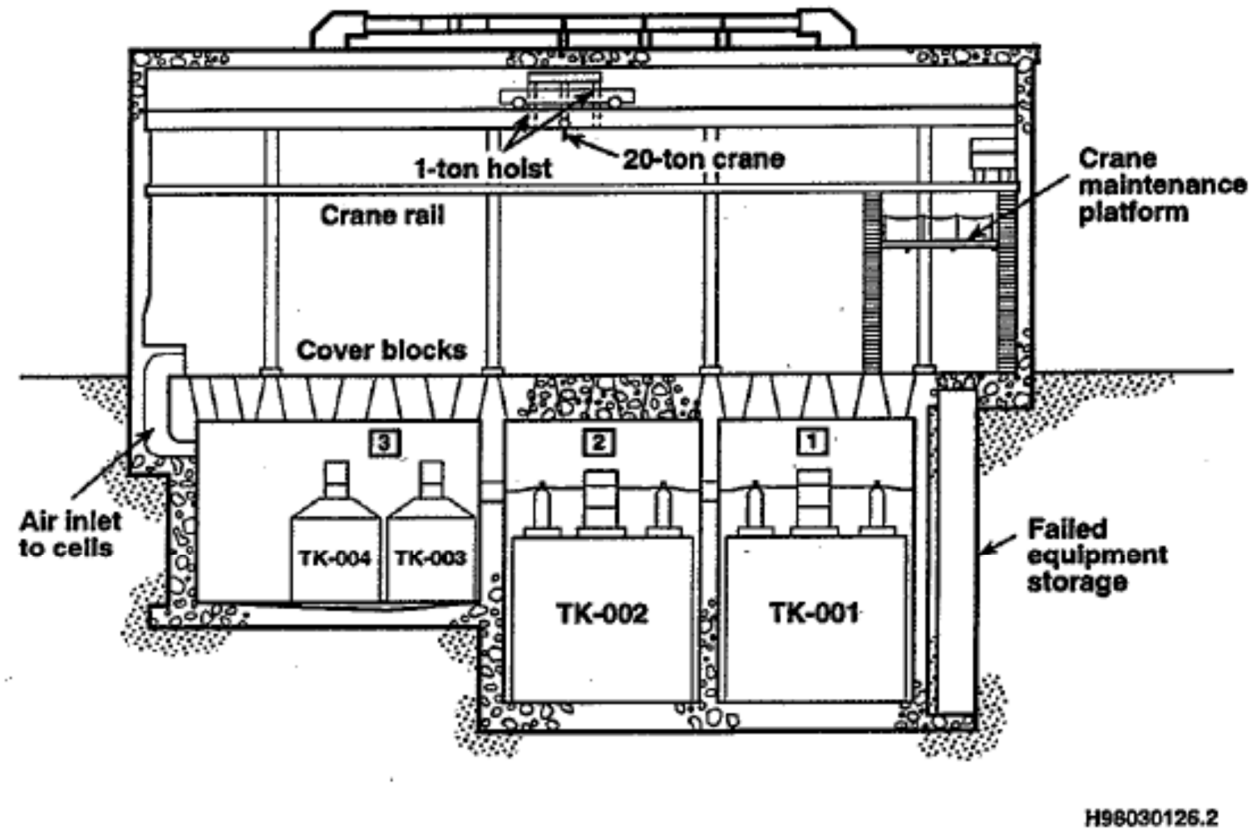


Source: HNF-2503, *Authorization Basis Status Report (Miscellaneous TWRS Facilities, Tanks and Components)*.

The unit received waste sluiced from A Farm and AX Farm. Processing took place, then the waste was shipped to B Plant. The facility was the focal point for reprocessing and routing of PUREX-generated waste between the tank farms and B Plant facilities in the late 1960s and between the tank farms and the Waste Encapsulation Storage Facility in the late 1970s. In 1984, a decision was made to upgrade the 244-AR Vault for use as a waste transfer facility. The extensive upgrading effort provided improved features for the safe and efficient transferring of PUREX-generated waste between the tank farms and B Plant. The waste consisted of cladding removal waste en route to B Plant and transuranic waste from B Plant/Waste Encapsulation Storage Facility to the tank farms.

The vault was placed in a standby mode in 1978. The last documented waste transfer for this site was in 1978. The facility was isolated from steam and water in 1996. In June 2003, ~18,000 gal of liquid waste were pumped from the vault to the DST System. In April and May of 2003, all the pumpable liquid in the facility was consolidated into tank 001 and sampled. In June 2003, ~66,880 L (17,600 gal) of waste and flush water were pumped out of tank 001 and transferred to tank 241-AY-102. Facility isolation and intrusion prevention was done in August 2003.

Figure 3-48. 244-AR Vault.



Source: HNF-2503, *Authorization Basis Status Report (Miscellaneous TWRS Facilities, Tanks and Components)*.

There are an estimated 660 gal of sludge and up to 194 gal of liquid in tank 001 cell 1 (RPP-12051, *244-AR Vault Interim Stabilization Completion Report*, pp. 3-2). In tank 002 cell 2, there are an estimated 2,080 gal of sludge and up to 194 gal of liquid (RPP-12051, pp. 3-3). The

facility is posted with multiple radiological postings including Internally Contaminated Systems, Radiation Area, Underground Radioactive Material Area, Radiological Buffer Area, Radioactive Material Area, Contamination Area, High Contamination Area, and Fixed Contamination Area.

3.3.5 241-A-431

The 241-A-431 Ventilation Building, located southeast of tank 241-A-103 inside the A Farm fence, is a concrete structure with the lower portion below grade. The 241-A-431 Ventilation Building provided off-gas de-entrainment for A Farm in one section and received the 296-A-11 Stack drainage in a second section. The unit contains radioactively-contaminated equipment and concrete. The building is 25 ft high, with the lower 16 ft below grade. Figure 3-49 is a photograph of the building in which above grade portions of associated French drains are visible.

Figure 3-49. 241-A-431 Ventilation Building and French Drains.

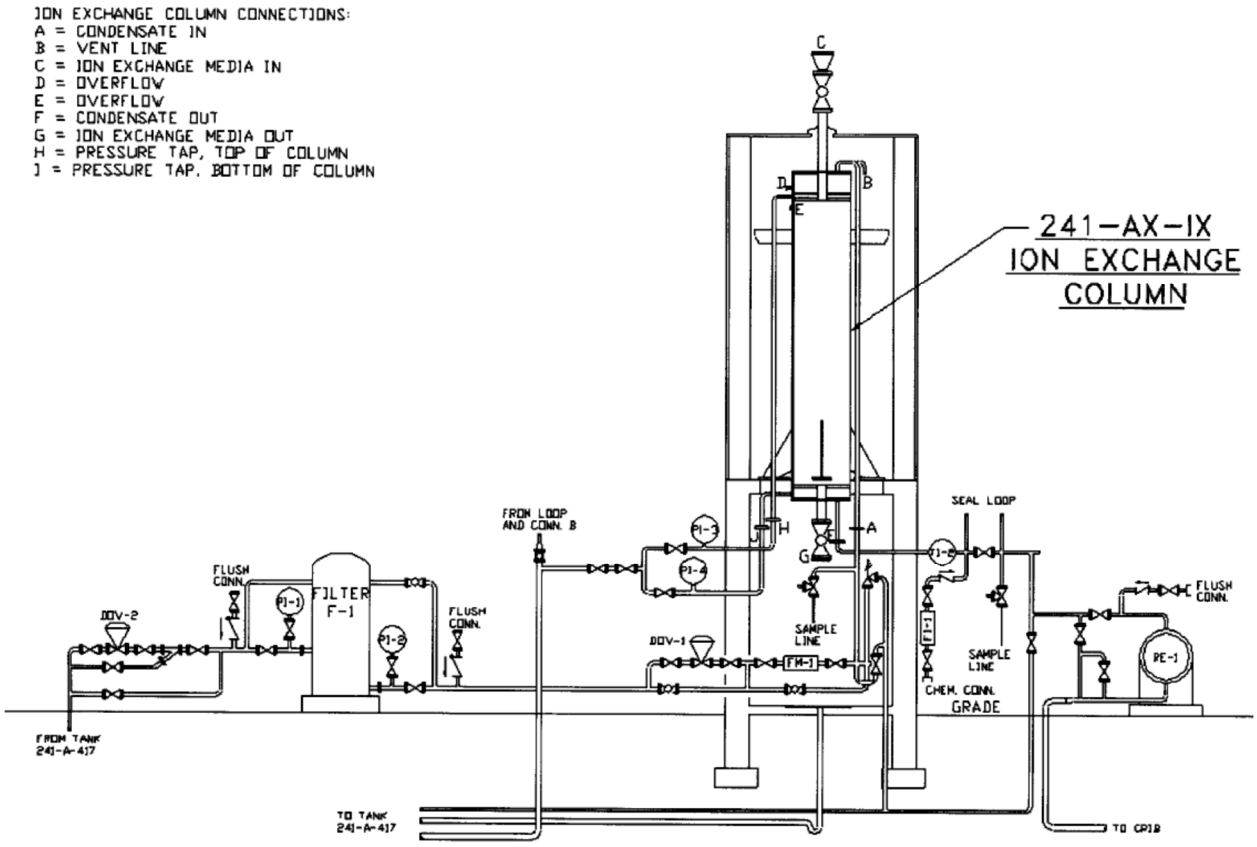
3.3.6 241-AX-IX

The 241-AX-IX ion exchange system (Figure 3-50) is located in the southern portion of AX Farm. It is northeast of the 241-A-417 condensate hold up tank, between A Farm and AX Farm. The following summary is based on DOE/RL-88-30 and RPP-RPT-31126, *241-AX-IX Liquid Level Assessment Report* with dimensions reported in Imperial units restated in metric units. The 241-AX-IX ion exchange system consists of an aboveground filter and IX column

and underground piping. The IX column is 24 in. (61 cm) in diameter and 11 ft 6 in. (3.51 m) high with a capacity of 260 gal (980 L). The IX column is enclosed in a shielded structure that is open at the top. The shielded structure has a corrugated metal pipe exterior (6 ft 6 in. [1.98 m] outside diameter) and a concrete interior (5 ft [1.5 m] inside diameter). The column and enclosure sit atop a 6 ft 8 in. [2.03 m]-square by 8 ft 2 in. [2.49 m]-tall concrete structure on grade.

241-AX-IX was installed in 1967 to 1969 and operated routinely from 1973 to 1976 to remove cesium from the 702-A aging waste ventilation system condensate collected in the 241-A-417 tank. The IX resin was introduced through a 3-in. [7.6-cm] ball valve and pipe on top of the IX column. Screens located 6 in. [15.2 cm] above the bottom and 12 in. (30.5 cm) down from the top held the IX resin in the column. Condensate was pumped from 241-A-417 through the filter and into the top of the IX column. The condensate would gravity flow through the resin in the column, and the treated condensate exited at the bottom and would normally be discharged to the 218-A-8 crib.

Figure 3-50. 241-AX-IX Ion Exchange System.



Source: RPP-RPT-31126, *241-AX-IX Liquid Level Assessment Report*.

A liquid level inspection in 2006 found the column contained ~440 L of desiccated resin but no free liquid (RPP-RPT-31126). Because the facility is above ground except for some piping, it is assumed it would be demolished before closure and would not be a source of any cesium and other contaminant inventory after closure.

3.4 LIQUID DISCHARGE SITES

Numerous liquid discharge sites have existed in and around WMA A-AX (Figure 3-51), many of which are within the likely PA model domain. A few liquid discharge sites, for example the French drains discussed in Section 3.2.2.5, are attributed to WMA A-AX and included in PA evaluations much like any other ancillary equipment. Most of the liquid discharge sites in this section, however, will follow closure processes entirely separate from WMA A-AX. Information is provided for these sites because they may have a significant effect on infiltration rates and soil moisture in parts of the model domain prior to Hanford Site closure. Table 3-1 provides an overview of liquid discharge data primarily from RPP-26744; if needed, data are also available on an annual basis from Hanford Virtual Library or BHI-00608, "*Hanford Sitewide Groundwater Flow and Transport Model Calibration Report*." Discharge data for septic systems are separately tabulated in Section 3.4.3, because they tend to be estimated as discharge rates, unlike the total volume estimates for other liquid discharge sites. Descriptions of individual sites are organized in subsections for ponds and ditches (Section 3.4.1); cribs, trenches, and retention basins (Section 3.4.2); and septic systems (Section 3.4.3).

3.4.1 Ponds and Ditches

In the area of interest for the WMA A-AX PA, there is a former pond and ditch system (200-E-286) that disposed of large volumes of cooling water from the 284-E Powerhouse prior to construction of WMA A-AX, and there is a smaller ditch (216-A-34) that routed liquid wastes from A Farm to nearby cribs. To understand these liquid discharges in the context of the broader Hanford Site, it is important to understand that liquid discharge sites too far away from WMA A-AX to warrant analysis of vadose zone conditions were historically much more significant drivers of changes to groundwater elevations and gradients. Thus, although it is beyond the scope of this report to fully recount past observations and modeling of the highest volume discharge sites, it should be recognized that some of these more distant sites profoundly affected and continue to affect the migration of existing groundwater contamination plumes to a degree that far outweighs any similar effect of liquid discharge sites highlighted in this data package. Conversely, the featured sites that are relatively close to WMA A-AX have potential to influence vadose zone contaminant transport calculations relevant to the PA that are highly unlikely to be affected by more distant sites.

Multiple liquid discharge sites contributed to a large groundwater mound in the 200 West Area throughout the Hanford Site history, which was enhanced due to geological factors, and which has yet to fully dissipate decades after most of the discharges ceased (e.g., see RPP-RPT-60101 or RPP-ENV-58578). Around 200 East the ponds that received the bulk of liquid discharges were B Pond and Gable Mountain Pond, and these have formed their own, smaller groundwater mounds and generally elevated the water table of the Central Plateau, but to lesser degree than in 200 West (RPP-RPT-60101 or RPP-ENV-58578). Water levels in 200 East have declined relatively rapidly with the cessation of most discharges and are anticipated to revert to pre-operational conditions by the time of WMA closure. Any past contaminant releases from WMA A-AX must be understood in the context of these regional driving forces,

e.g., contamination unrelated to WMA A-AX operations has likely been carried upward with the past rise in the water table, and past releases for WMA A-AX or nearby discharge sites have had the travel distance to groundwater foreshortened and then gradually recovered.

B Pond, formally designated 216-B-3, together with a series of ditches and expansion ponds, forms a large, L-shaped system northeast of WMA-AX beyond the 200 East Area boundary. B Pond received waste between April 1945 and May 1994. A portion of the 216-B-3-1 ditch that flows southeast into B Pond can be seen in the northeast corner of Figure 2-2. The 216-A-29 ditch is also visible on the east side of Figure 2-2; this ditch flowed northeast into the B Pond system. Gable Mountain Pond, formally designated 216-A-25, was a large, water-filled pond that received cooling water from PUREX and B-Plant operations from 1957 to 1987. The PUREX operations discharging cooling water or condensate to Gable Mountain Pond included units associated with WMA A-AX. The pond had a total surface area of 0.32 km^2 (82 acres), including a 0.28 km^2 main pond and a 0.044 km^2 overflow pond. Volumes discharged to these ponds are analyzed elsewhere; although the ditches feeding the ponds likely had seepage losses, there are not any generally accepted estimates of discharges from ditches to the subsurface.

The pond and ditches near to WMA A-AX are discussed in the subsections that follow.

3.4.1.1 200-E-286 Pond and Ditch. The 200-E-286 pond was a shallow depression also known as the "A Swamp," the "Powerhouse Swamp," or the "Original 200 East Area Powerhouse Effluent Pond" (DOE/RL-88-30). This pond was used from 1946 to receive discharge from the 200-E-286 Ditch (Figure 3-52), until 1953 when A Farm construction began. The abandoned portion of the ditch is known as the 200-E-286 Ditch while the portion of the ditch originating at the 284-E Powerhouse and rerouted to the 216-B-3 Pond is known as the 200 East Powerhouse Ditch (200-E PD). This data package is concerned only with the pond and the abandoned portion of the ditch that formerly ran through WMA A-AX. In 1954, the 200-E-286 Ditch effluent was redirected to B Pond. 200-E-286 was rejected as a WIDS site in 2009, but the pond and ditch potentially have significance for soil moisture conditions just prior to tank farm construction, especially since 200-E PD ran through the location where tank A-101 was later constructed (Figure 3-51). Discharges to 200-E-286 may also have initially contributed to the observed rise in the water table that began earlier than discharges to the other cribs and trenches discussed in this section.

The liquid effluent stream from the powerhouse contained boiler blowdown, cooling water, floor drain water, and water softener regeneration solution (DOE/RL-89-28, *216-B-3 Expansion Ponds Closure Plan*, pp. 3-19 to 3-20). It is estimated that ~578,000 L/day (150,000 gal/day) was discharged to the swamp between 1945 and April 1953, with a total discharge volume estimated at 1.7×10^9 L (4.5×10^8 gal) (HW-28121, "*Release of Radioactive Wastes to Ground*"). The ditch was unlined. During the water softening process at the powerhouse, sanitary water passed through a water softener to remove calcium and magnesium prior to heading to the boiler in order to minimize scaling on the tube bundles. When the resin in the IX column became saturated with calcium and magnesium, ion exchange no longer occurred, and the resin had to be regenerated. This was accomplished by passing a concentrated solution of sodium chloride through the column. DOE/RL-2015-49, *Interim-Status Groundwater Quality Assessment Plan for the Single-Shell Tank Waste Management Area A-AX* (pp. 1-3, 2-10, and 2-29 through 2-32

therein) suggests that liquids discharged to the 200-E-286 Ditch may be responsible for the corrosion that damaged multiple groundwater monitoring well casings near the southwest corner of A Farm, although the document also acknowledges the detection of constituents not obviously attributable to powerhouse discharges (nitrate and ^{99}Tc) in sidewall core samples from affected wells.

It has been suggested that 200-E-286 was a major contributor to the rise in water table throughout 200 East by the early 1950s (RPP-7494 pp. 11). Although it is more likely that discharges to B Pond dominated the water table response in 200 East even at early times, attention to the process is warranted given the proximity of 200-E-286 to WMA A-AX and the volume and timing of liquid discharges to the pond relative to other nearby facilities. Data in HW-28121 (Tables 3 and 4 therein) demonstrates that from 1945 through the spring of 1953, cooling water discharges to the Powerhouse Swamp were indeed "large volume wastes" relative to "cribbed waste." However, for the same time period, discharges to B Pond were an order of magnitude greater, and interpreted groundwater elevations for January 1953 indicated a mound centered on B Pond without any obvious enhancement near 200-E-286 from measurements available at the time (HW-28121 Table 4 and Figure 1).

There are no longer any visible signs of the A Swamp or the distal end of the ditch. The eastern end of the ditch originally terminated east of where A Farm was built. The eastern end of the ditch was removed during the construction of A Farm and the later construction of 241-AP Tank Farm (AP Farm). The area where the swamp had been located is now underneath where the Grout Facility and Waste Treatment Plant were built.

3.4.1.2 216-A-29 Ditch. The head end of the 216-A-29 ditch was located approximately in the same location as the 200-E-286 Pond. The ditch conveyed waste from PUREX to the B Pond system between November 1955 and September 1991. The head end of the 216-A-29 ditch was modified several times. The final relocation of the head end occurred in 1983, during the construction of AP Farm. From 1955 through 1991, the 216-A-29 ditch followed a natural depression, known as Snow's Canyon, toward the 216-B-3 ditch and pond area. The ditch was backfilled and surface stabilized in 1991. It is posted as an Underground Radioactive Material area and is associated with UPR-200-E-51.

The chemical sewer line that fed the ditch is sitecode 200-E-187-PL. The ditch had two earth dams with wooden gate structures to regulate water flow.

The unit received waste from 202-A Chemical Sewer, acid fractionator condensate and condenser cooling water that flow to 216-B-3 Pond. Until December 1957, the site received process cooling water and chemical sewer waste from 202-A. From December 1957 to February 1958, the site received all of the above, but the process cooling water was rerouted to 216-A-25 Pond. From February 1958 to December 1962, the ditch received the above plus acid fractionator condensate from 202-A. From December 1962 to December 1963, the ditch also received seal cooling water from air sampler vacuum pumps in 202-A. From December 1963 to January 1966 the vacuum pump cooling water was rerouted to 216-A-35 French Drain.

3.4.1.3 216-A-34 Ditch. The 216-A-34 ditch, aka 216-A-34 crib, is located east of the 200 East Area perimeter fence and north of the 216-A-8 crib. According to WIDS, the site received cooling water from the contact condenser in the 241-A-431 Building from November 1955 until December 1957; however, RPP-7494 pp. 9 argues that cooling water could not have been separated from condensate in the contact condenser and therefore 216-A-34 likely received only cold startup waste, whereas cooling water went to 216-A-8.

As described in DOE/RL-88-30, a 15-in. (38-cm)-diameter clay pipe fed the 216-A-34 ditch and was connected to the headwall. Ditch effluent was reportedly routed to the 216-A-19 and 216-A-20 trenches, although DOE/RL-88-30 notes, "drawings do not show the 216-A-34 Ditch connecting to the 216-A-19 Grave." One account describes 216-A-34 as two ditches, one ditch measuring 280 ft (85 m) long and 30 ft (9 m) wide and a second ditch measuring 130 ft (39.6 m) long and 30 ft (9 m) wide; DOE/RL-88-30 states the site may comprise a single ditch and a headwall structure with its length matching the "second ditch" and its width increasing from 10 ft (3 m) to 40 ft (12 m). The headwall structure had 1:2 side slopes. The headwall structure tapered off into an open ditch which terminated at the 216-A-20 crib. The site is vegetated with "a small amount of bunch grass" (DOE/RL-88-30). The pipeline to the 216-A-34 crib is discussed in sitecode 200-E-166-PL and UPR-200-E-145 in WIDS.

Disposal at this site was terminated due to the potential for release of contamination to the environment. The pipeline to the ditch was valved out and the effluent was rerouted to the 216-A-8 crib. The ditch was backfilled. This site was surface stabilized in September 1990.

WIDS site 200-E-166-PL, "Pipeline from 241-A Tank Farm to 216-A-34 Ditch," is associated with UPR-200-E-145 (DOE/RL-88-30). In 1993, while excavating for the installation of a new pipeline (Project W-049H) and exposing existing utility lines, contaminated soil with a radiological reading of 300,000 disintegrations/minute beta-gamma was detected at a depth of 0.8 m (2.5 ft). The contamination was found above an existing 38-cm (15-in.) vitrified clay pipe, which was suspected to be the source. Sample analysis of the green-colored soil indicated it was uranium oxide.

3.4.2 Cribs, Trenches, and Retention Basins

Millions of gallons of waste (mostly cooling water and decontamination water) were discharged to cribs, trenches, and retention basins near WMA A-AX. These facilities include: 216-A-1, 216-A-7, 216-A-18, 216-A-19, 216-A-20, 216-A-8, 216-A-24, 216-A-9, and 216-A-39 cribs/trenches; and 216-A-40, 207-A South and 207-A North retention basins. The cribs and trenches discharged dilute wastes that had only small contaminant inventories. They are potentially significant for the large volumes of moisture added to the vadose zone, although 216-A-39 is an exception for which closure in coordination with WMA A-AX is perhaps of more concern than the limited discharge at that crib. Retention basins may have a similar effect to cribs and trenches if leaks developed.

3.4.2.1 216-A-1 and 216-A-7 Cribs and 216-A-18, 216-A-19 and 216-A-20 Trenches. Initially, cold start-up wastes from PUREX were discharged into five cribs and trenches located just north and east of A Farm (216-A-1, 216-A-7, 216-A-18, 216-A-19, and 216-A-20).

Approximately 1.6×10^6 L of waste, containing ~2,600 kg of uranium, were disposed in these cribs between November 1955 and January 1956. Shortly thereafter, full-scale PUREX operations began, and several other liquid discharge facilities began to receive a variety of wastes. Of these five cribs, only 216-A-7 received waste after January 1956. Small amounts of overflow waste from Diversion Box 241-A-152 continued to discharge into crib 216-A-7 (8×10^4 L in 1955 and 1956) until it was replaced by the 241-A-302B Catch Tank. In November 1966, the crib received waste from the 202-A Building (DOE/RL-2007-27, *Threatened and Endangered Species Management Plan: Salmon, Steelhead, and Bull Trout*).

The 216-A-1 and 216-A-7 cribs are located within the same radiologically posted area. They are marked and posted with Underground Radioactive Material signs and are located inside the 200 East Area perimeter fence extension, east of A Farm. 216-A-1 crib received the depleted uranium waste from the cold startup run in the 202-A Building during November and December 1955 via an over ground pipeline (DOE/RL-92-04). 216-A-7 crib received waste via below grade perforated 15-cm (6-in.) vitrified clay pipe (DOE/RL-2007-27). The waste included overflow from Diversion Box 241-A-152, and in November 1966 the crib received a one-time discharge of organic waste from the 202-A Building.

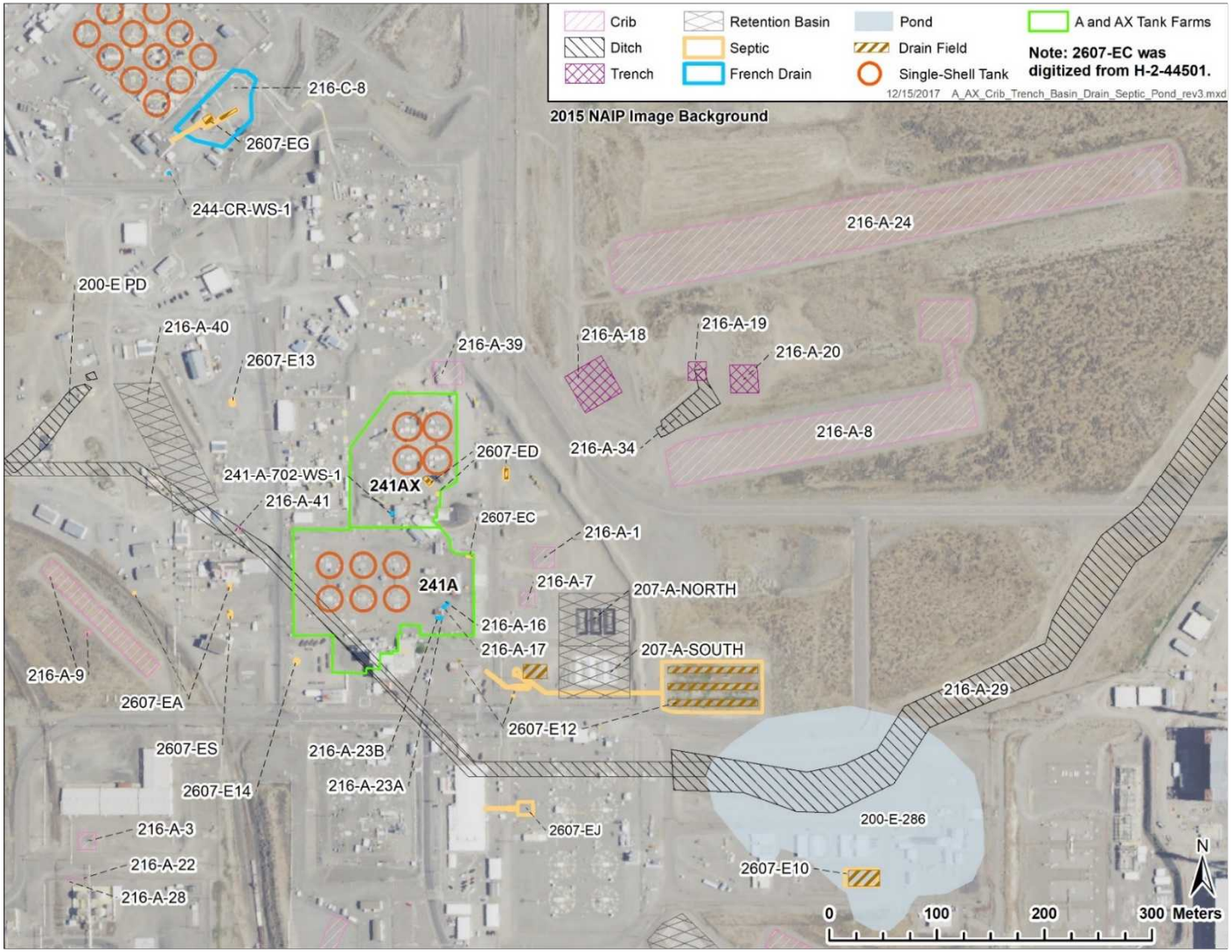
In addition to uranium, some ^{137}Cs, ^{60}Co and ^{90}Sr is present. When the estimated specific retention capacity associated with 216-A-1 crib was reached, the crib was deactivated by removing the over ground piping and backfilling. 216-A-7 crib was deactivated in 1966 by blanking the effluent pipeline to the crib from the 241-A-152 Diversion Box sump. In 1992, nearby contaminated soil was scraped and consolidated on top of the 216-A-1 and 216-A-7 cribs. The area was covered (stabilized) with 46 to 61 cm (18 to 24 in.) of uncontaminated backfill, increasing the surface elevation by ~1 m (3 ft) (DOE/RL-2007-27). The posting was changed to Underground Radioactive Material.

The 216-A-18 trench is located outside of the 200 East Area perimeter fence, east of AX Farm. The trench received waste via an aboveground pipeline. The site was an excavation with a side slope of 1:2. No crib structure was built. The 216-A-18 trench received the depleted uranium waste from the cold start-up run at 202-A Building. The site was deactivated by removing the over ground piping and backfilling the excavation when the specific retention capacity associated with the trench was reached. The trench was removed from service in December 1955 and surface stabilized in September 1990. The site is marked and posted with Underground Radioactive Material signs.

The 216-A-19 trench is located east of the 200 East Area perimeter fence, north of the 216-A-8 crib. The site received PUREX start-up waste during November and December 1955. The site was deactivated by removing the over ground piping and backfilling the excavation when the specific retention capacity associated with the trench was reached. The site was surface stabilized in September 1990. In February 2001, a narrow area posted with Soil Contamination Area signs extended between the 216-A-19 southern site boundary and northern boundary of 216-A-34. This area was stabilized and down-posted to Underground Radioactive Material in October 2001.

The 216-A-20 trench is located east of the 200 East Area perimeter fence, north of the 216-A-8 crib. The 216-A-20 trench was originally a test hole excavated with a drag line and used for PUREX start-up waste. The site received the 241-A-431 Building contact condenser cooling water via the 216-A-34 Ditch and the depleted uranium waste from the cold start-up run at the 202-A Building. The site was deactivated in 1955 by removing the over ground piping and backfilling the excavation when the specific retention capacity associated with the trench was reached. HW-60807, "*Unconfined Underground Radioactive Waste and Contamination in the 200 Areas–1959*" notes that the 216-A-20 trench overflowed, covering an area measuring ~30 m (100 ft) north and 60 m (200 ft) east of the crib site. It is unknown if actions were taken at the time to stabilize the overflow surface, but the site was surface stabilized in 1990. In April 2007, more surface contamination was stabilized with clean dirt. The site is marked and posted with Underground Radioactive Material signs.

Figure 3-51. Liquid Discharge Sites Near Waste Management Area A-AX.



NAIP = National Agriculture Imagery Program

Reference: H-2-44501, "Area Map, 200 East, A Plant Facilities."

Table 3-1. Summary of Liquid Discharge Sites Data Near Waste Management Area A-AX. (2 sheets)

Site Number	Site Type	Area (m^2)	Operational Year(s)	Total Volume Received (L)	Waste Type
200-E-286	Pond and Ditch	35,885 (Pond) 10,554 (Ditch)	1946-1953	1.7×10^9 (HW-28121)	284-E Powerhouse boiler blowdown, cooling water, floor drain water, and water softener regeneration solution (DOE/RL-89-28)
207-A-NORTH	Retention Basin	3,203	1977-1999 (DOE/RL-88-30)	No data located	242-A Evaporator steam condensate (DOE/RL-88-30)
207-A-SOUTH	Retention Basin	3,184	1977-1989 (DOE/RL-88-30)	No data located	242-A Evaporator steam condensate (DOE/RL-88-30)
216-A-1	Crib	381	1955	9.84×10^4	Plutonium Uranium Extraction Plant (PUREX) cold start waste
216-A-16	French Drain	0.95	1956-1969	6.00×10^4 (DOE/RL-88-30)	PUREX miscellaneous drainage
216-A-17	French Drain	0.95	1956-1969	1.22×10^5 (DOE/RL-88-30)	PUREX miscellaneous drainage
216-A-18	Trench	1,530	1955	4.88×10^5	PUREX cold start waste
216-A-19	Trench	281	1955	1.10×10^6	PUREX cold start waste
216-A-20	Trench	672	1955	9.61×10^5	PUREX cold start waste, PUREX process condensate
216-A-23A	French Drain	0.65	1957-1969	2.99×10^3	PUREX tank farm condensate
216-A-23B	French Drain	0.65	1957-1969	2.99×10^3	PUREX tank farm condensate
216-A-24	Crib	23,200	1958-1967, 1971-1976, 1978	8.21×10^8	PUREX tank farm condensate
216-A-29	Ditch	43,213	1955-1991 (DOE/RL-88-30)	No data located for ditch; discharged to 216-B-3	PUREX chemical sewer, acid fractionator condensate, condenser cooling water, process cooling water, vacuum pump cooling water (DOE/RL-88-30)

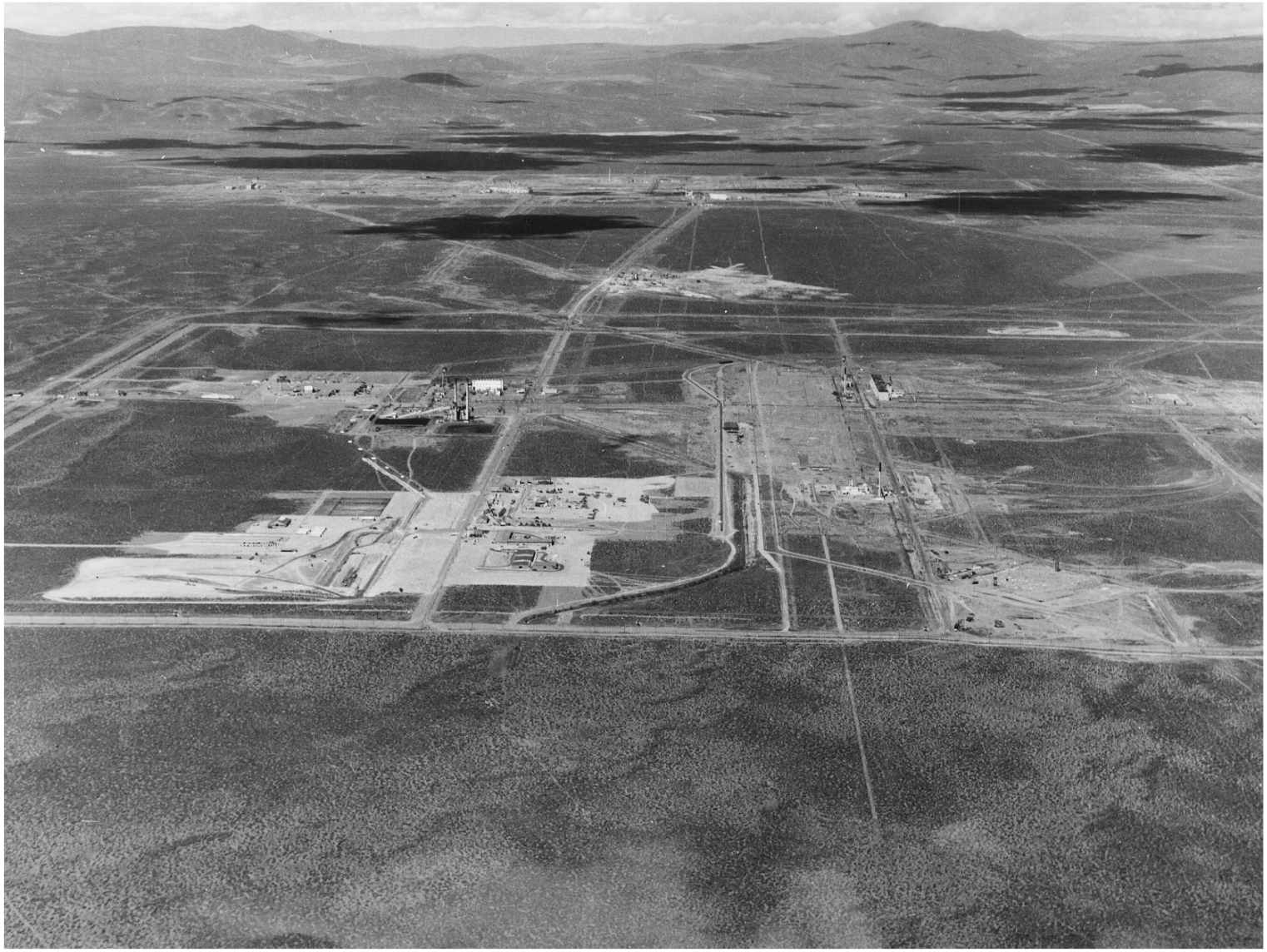
Table 3-1. Summary of Liquid Discharge Sites Data Near Waste Management Area A-AX. (2 sheets)

Site Number	Site Type	Area (m^2)	Operational Year(s)	Total Volume Received (L)	Waste Type
216-A-34	Ditch	1,270	1955-1957 (DOE/RL-88-30)	No data located for ditch; discharged to 216-A-19 and/or 216-A-20	241-A-431 contact condenser cooling water or PUREX cold startup waste (RPP-7494)
216-A-39	Crib	586	1966, ca. 1969 (DOE/RL-88-30)	2.00×10^1 (volume of tank waste only)	241-AX-103 tank waste and raw water/chemical flush, 241-AX-801-B floor drainage (DOE/RL-88-30; RPP-ENV-37956 Rev. 3 pp. A-15)
216-A-40	Retention Basin	4,824	1968-1979 or 1968 only	9.46×10^5	B Plant cooling water and steam condensate
216-A-41	Crib	21	1968-1974	1.0×10^4	PUREX stack drainage and process condensate
216-A-7	Crib	179	1955-1956, 1966	3.27×10^5	PUREX miscellaneous drainage
216-A-8	Crib	13,423	1955-1958, 1966-1976, 1978, 1983-1985	1.15×10^9	PUREX tank farm condensate, organic waste, and cooling water
216-A-9	Crib	2,248	1956-1958, 1966-1967	9.81×10^8	PUREX chemical sewer, cooling water, tank farm condensate, and N Reactor decontamination waste
241-A-702-WS-1	French Drain	1.1	1968-1995 (DOE/RL-88-30)	No data located	241-A-702 steam condensate (DOE/RL-88-30)

Notes: Years and volumes are from RPP-26744, "*Hanford Soil Inventory Model, Rev. 1*" Table A5-21 except as noted (see Section 8.0 for complete reference information). Areas are from Waste Information Data System geospatial data and have not been compared to engineering drawings. Areas less than 10 m^2 are given to 2 digits, otherwise areas are to nearest 1 m^2.

References:
DOE/RL-89-28, *216-B-3 Expansion Ponds Closure Plan*, Rev. 2.
DOE/RL-88-30, *Hanford Site Waste Management Units Report*, Rev. 26.
HW-28121, "Release of Radioactive Wastes to Ground."
RPP-7494, *Historical Vadose Zone Contamination from A, AX, and C Tank Farm Operations*.
RPP-ENV-37956, "*Hanford 241-A and 241-AX Tank Farms Leak Inventory Assessment Report*," Rev. 3.

Figure 3-52. 1953 Aerial Photograph of 200 East Area Showing 200-E-286 Ditch.



Source: 2049-NEG, June 8, 1953, "AERIAL VIEW OF 200E AREA LOOKING WEST."

3.4.2.2 216-A-8 and A-24 Cribs. After PUREX startup, the largest volume of waste discharges into nearby cribs were generated by tank condenser operations. Both condensate and condenser cooling water were intentionally discharged, and the majority of the discharges occurred in facilities east of WMA A-AX. The waste is low in salt, neutral to basic and has a record of organic content.

The first facility to receive this waste was the 216-A-8 crib, which was built in 1955 and is located east of A Farm. This crib received 9.3×10^8 L of tank condensate and condenser cooling water from November 1955 through May 1958, when the crib had reached its radionuclide capacity. At that point, crib 216-A-24, also located just north of crib 216-A-8, began receiving this waste (RPP-7494 pp. 9). RPP-7494 pp. 11 states that "crib 216-A-8 broke through to groundwater in December 1956" (RPP-7494 does not indicate how that was determined) and attributed the breakthrough to the water table rise below 200 East, which in turn was attributed to large discharges of cooling water to ponds up to that date (Section 3.4.1.1).

In 1960, an order of magnitude reduction in annual receipt volume was achieved (from $\sim 3 \times 10^8$ L/yr to $< 3 \times 10^7$ L/yr), when a more efficient condenser system was installed that permitted diversion of the condenser cooling water to Gable Mountain Pond. By 1967, $\sim 8.2 \times 10^8$ L of fluid had been discharged into 216-A-24. In 1966, condensate discharge reverted back to crib 216-A-8, which received another 2×10^8 L through 1976. Subsequently, at crib 216-A-8, additional condensate was received in 1978 (600 L) and from 1983 through 1985, $\sim 1.5 \times 10^6$ L because of PUREX restart.

It has been suggested that 216-A-8 and 216-A-24 are likely sources of high groundwater nitrate contamination detected east of WMA A-AX in the 1960s (RPP-35484 pp. 6-8). Other cribs and trenches in the area discharged as large or larger quantities of nitrate in the 1950s and 1960s according to inventories in RPP-RPT-58291, which are based on RPP-26744. There may also be other sources of nitrate with potentially rapid vadose zone transport times; for example, septic systems like 2607-EC could hypothetically have contributed and have not been evaluated for groundwater impacts to the authors' knowledge. RPP-35484 pp. 6-8 notes that nitrate and radionuclide contamination have been detected below WMA A-AX dating to at least the earliest operations of A Farm and AX Farm and apparently to before their construction. This discussion of the cribs' possible groundwater impacts is provided for context and is not intended to resolve the question of probable sources of past impacts.

The 216-A-8 crib overflow was routed through a 16-in.-diameter pipe exiting to the north at the east end of the crib. The pipe emptied into a narrow ditch that flowed northward. A small overflow pond was excavated at the northeast end of the ditch to receive the excess waste water from the crib. The crib was surface stabilized in September 1990.

The 216-A-24 crib was built with four sections, each 107 m (350 ft) long, separated by soil berms. The sections were installed at increasingly lower elevations, to allow the effluent to cascade from one section to the next. The 216-A-24 crib was believed to have been deactivated in 1966 by valving out the pipeline at the 216-A-508 Diversion Box (adjacent to the 216-A-8 crib), but in 1979 when excess moisture and radioactive contamination were encountered during excavation of fill material for the 241-AN Tank Farm, the valve was

discovered to be open and allowing fluid to migrate to crib 216-A-24. The volume of waste released from 1967 through 1979 is unknown. A corrective action backfill was done in 1981 following the contamination spread. The entire crib was surface stabilized in 1988.

The 216-A-8 and 216-A-24 cribs were isolated in 1995 by filling the distribution box with concrete and removing the control structure filter and crib vent filters. The cribs and overflow area are surrounded by chain and concrete AC-540 markers and posted with Underground Radioactive Material signs.

3.4.2.3 216-A-9 Crib. The 216-A-9 crib located 500 ft west of A Farm received acid fractionator condensate and cooling water from PUREX between 1956 and 1958 (9.8×10^8 L). The crib surpassed its capacity in 1958 and was taken out of service. The crib was approved to receive contamination waste from N reactor in 1966 (2×10^6 L), and then was again inactive until August 1969, when PUREX acid fractionator waste was transported to the crib in tanker trucks.

The site contains a 10-in. Schedule 30 steel perforated pipe, placed horizontally, 9 ft below grade. The site has 65,000 ft^3 of gravel fill and has been backfilled. The side slope is 2:1. The site was deactivated by blanking the effluent pipeline (200-E-238-PL) to the unit after replacing 100 ft of the pipeline that had failed. The truck unloading station at this site was interim stabilized in 1991. In 1993, filters were removed from the crib risers, surveyed, and disposed of as nonradioactive waste. The crib surface was covered with 18 to 24 in. of uncontaminated backfill. In July 2000, the vent risers were sealed as a preventative measure for potential passive radioactive emissions. The crib is a surface stabilized area, marked with light post and chain. It is posted as an Underground Radioactive Material area.

3.4.2.4 216-A-39 Crib. The 216-A-39 crib is located near the southeast corner of AZ Farm, inside the tank farm fence and adjacent to AX Farm. The site consists of a crib and two, 0.9-m (3-ft)-deep trenches dug from the 241-AX-801-A Building (the instrument building) to accommodate a release of tank waste liquid from tank AX-103 that contaminated the building (DOE/RL-88-30; see also RPP-ENV-37956 Table 5-2 and pp. A-15).

In June 1966, a team was changing out a valve on the 241-AX-103 ALC line. The line pressurized and resulted in a release of radioactive liquid to the floor of 241-AX-801-A. Dose rates from the release were greater than 5 rad per hour at a distance of 3 m (10 ft). A trench was dug extending from the north side of the 241-A-801-A Building to the brow of the north hill, continuing over the hill to the flat ground below. The trench continued eastward 27 m (90 ft). A hole was cut through the back side of the building and a fire hose was used to wash the contamination out the door and into the trench. The first trench was covered with dirt and a second trench was dug, parallel to the first, to receive a second rinsing of the 241-AX-801-A Building floor. This trench was also backfilled. A residual dose rate remained on the floor of the building.

In 1969, a pipeline was added that connected the 241-AX-801-B Building to the 216-A-39 crib. Drawing H-2-33295, "216-A-39 Crib for Inst. Enclosure 241-AX 801-B Plot Plan & Details," shows the crib structures. Each crib has three Schedule 40 pipes. The drawing also states the

crib was covered with ~6 m (20 ft) of dirt in 1973. The risers were extended above the new grade in May 1973.

As estimated in RPP-26744 Table A5-21 and RHO-CD-673, "*Handbook 200 Areas Waste Sites*," the crib received 20 L of high-activity waste from 241-AX-103. It received an unknown volume of raw water and possibly chemical solutions used to flush the tank waste. It later received an unknown volume of 241-AX-801-B floor drainage via the pipeline installed in 1969 (DOE/RL-88-30).

A summary of a 2008 meeting (pp. A-15 of RPP-ENV-37956) estimated a volume of "10 to 20 gal of high activity waste discharge," and RPP-ENV-37956 Table 5-2 states 20 gal; however, this data package relies on the 20-L estimate. The meeting summary likewise found no estimate of the flush volumes, but it stated that the "instrument building was decontaminated intermittently over a three week period using water and chemical (sodium hydroxide, citric acid, oxalic acid, tartaric acid, tri-sodium phosphate, and potassium permanganate) flushing." RPP-ENV-37956 Table 5-2 describes the chemical solutions as caustic-tartrate, caustic-permanganate, and tartaric acid.

DOE/RL-88-30 indicates that a statement in RHO-CD-673 that the release occurred at the 241-AX-801-B Building is contradicted by physical evidence and employee interviews showing it occurred at 241-AX-801-A.

3.4.2.5 216-A-40 Retention Basin. The 216-A-40 retention basin is located ~500 ft west of AX Farm and consists of a trench 400 ft long by 20 ft wide. The basin received 9.46×10^5 L of steam condensate and cooling water from the AR vault in 1968. The site was originally an open, rubber-lined trench that was divided into three sections. A 12-in.-diameter Schedule 40 distribution pipe ran horizontally through the south end of the unit, 12 ft below grade. Collapsible rubber bladders were utilized to contain the contaminated cooling water and steam condensate. Contaminated cooling water and steam condensate from the 244-AR Vault were diverted to the 216-A-40 Retention Basin when the effluent was above standard release limits for the water to be sent to the 216-B-3 or 216-A-25 Ponds. The retention basin bladders failed in 1979 and the unit was removed from service.

Although it was not being used, it remained an open basin until 1994. Contaminated soil and the bladders were consolidated into the east end of the trench. Contaminated soil from the adjacent Soil Contamination Area (UPR-200-E-143 and remnants of UPR-200-E-100) was also scraped into the east end of the basin. The basin was backfilled with clean material. This eastern end was posted as an Underground Radioactive Material Area. The remaining portion was released from radiological control.

3.4.2.6 207-A South Basin. The 207-A South retention basin is located east of the 242-A Evaporator Building and consists of three unlined concrete cells that are coated with a white polyurethane sealant. The cells were fed from the pump pit, located between the 207-A South and 207-A North basins. A 4-in. fill line entered each cell inside the basin structure. A 3-in. drain line exits the bottom of each cell. The 200-E-236-PL basin distribution pipelines were consolidated into the 207-A South basin waste site.

When operating, the three cells of the 207-A South basin were filled alternately, sampled, and discharged to the 216-A-37-1 crib after meeting release specifications. The 242-A Evaporator could retrieve the liquid waste for reprocessing or storage in the tank farm, via line 300, if discharge specifications were not met. After the 207-A North and South basins ceased to operate, the effluent was diverted to the 200 Area Treated Effluent Disposal Facility (TEDF). The 207-A South basin received waste between March 1977 and April 12, 1989.

Operation of the 207-A South basin was discontinued in April 1989. The basins were pumped out and radiologically surveyed. The basins initially remained posted as a Contamination Area due to low levels of fixed contamination in the sump areas. The radiological postings were removed in May 2003.

3.4.2.7 207-A North Basin. The 207-A North basin is located east of 242-A Evaporator Building and consists of three Hypalon-lined concrete basins. Each of the three basins is 55 ft long, 10 ft wide at the bottom, and 7 ft deep with a total capacity of 210,000 gal. A 4-in. fill line enters each basin, ~2 ft long (inside basin structure), and a 3-in. drain line exits. The basins were alternately filled, sampled, and emptied when meeting specifications.

The basins received steam condensate from the 242-A Evaporator since 1977. Effluent was originally sent to the 216-A-25 (Gable) Pond and later to the B Pond system. When the B Ponds became inactive, effluent was diverted to TEDF. The basins discharged via pipeline to the 216-B-3C pond. Discharge to the 216-B-3C pond was discontinued in early 1997 and the basin effluent was diverted to the 200 Area TEDF.

The 207-A North basins were physically isolated and ceased to operate in November 1999. The basins are surrounded with posts and chain. There is no radiological posting on the north basins.

3.4.3 Septic Systems

Several septic systems of widely varying designs have been used historically in the vicinity of WMA A-AX (Figure 3-51). Two systems, 2607-EC and 2607-ED, are located within the tank farm fences and might be considered part of WMA A-AX with respect to final closure of the tank farms. Several others are located in or near the likely PA model domain and are potentially of comparable significance to that of the cribs and trenches in terms of their effect on soil moisture prior to tank farm closure. Septic systems discharge sanitary sewage and are not ordinarily expected to be sources of radiological contamination. Relative to cribs and trenches, most septic systems discharged water to the subsurface over smaller areas such that even lower overall volumes of discharge may equate to temporarily higher infiltration rates.

Estimates of historical discharge volumes from septic systems were obtained for only one or a few points in time per system. Information in this section relies in major part on WIDS data (e.g., DOE/RL-88-30), supplemented and in a few cases corrected with other documents as indicated. In attempting to examine the original basis for some estimates in DOE/RL-88-30 when no citation was given, review of the non-public WIDS library found internal citations that indicate some information was initially compiled three decades ago in *Hanford Site Waste*

Management Units Report (Cramer 1987)[4], a document which predates Rev. 0 of DOE/RL-88-30 and which could not be readily located in its entirety. Some estimates attributed to conditions in the mid-1990s based on dates of subsequent documents were also found to be restated estimates from the 1987 document. Efforts initiated in the 1990s to upgrade or abandon older septic systems in favor of centralized, permitted systems resulted in planning documents that have since periodically provided updated estimates for those systems that remained in use.

Current discharges to septic systems near WMA A-AX are planned to be consolidated into sewer lines discharging to a facility in the 200 West Area by 2019 (HNF-6612, "*Hanford Site Sewer System Master Plan*" Rev. 5). All sanitary sewer and septic systems are expected to be abandoned by the time of Hanford Site closure.

Table 3-2 provides estimated years of operation and discharge rates from the summaries in the following subsections and areas attributed to septic systems or their drain field components in the WIDS sites spatial data shown in Figure 3-51 or calculated from engineering drawings for smaller systems when available.

3.4.3.1 2607-EC. Septic tank 2607-EC includes a tank and drywell and is located in the northeast corner of A Farm, near the fence (Figure 3-51). Although the description of the system and its general location appear roughly correct in WIDS documentation (e.g., DOE/RL-88-30) and in HNF-SD-LL-SP-001, *200 and 600 Areas Sanitary Wastewater Master Plan*, Rev. 1 (see pp. 104-105), the exact location and dates of use have apparently been given incorrectly in WIDS geospatial data and other references, with multiple incorrect locations appearing inside and outside WMA A-AX on various maps. The location of 2607-EC on maps in this data package was digitized from drawing H-2-44501 Sheet 69 Rev. 12, which is consistent with the as-built drawing H-2-56041, "Control House 4" C.I. Sewer Line Plan & Profile." The drawing was approved for construction in September 1953 and marked as-built in May 1956, consistent with the construction time frame for A Farm and the need for a system to handle sanitary sewage from A Farm when operations began and ideally also during construction. The 1963 construction date stated in HNF-SD-LL-SP-001 and DOE/RL-88-30 may be a typographical error. A barricade shown surrounding the tank and drywell in H-2-56041 is visible in a January 20, 1955 site construction photograph [3289-PHOTO, January 20, 1955, "PUREX FACILITY CONSTRUCTION - LIQUID WASTE DISPOSAL CRIB (VIEW 4)" – the photo is not publicly available], confirming the location and time of construction. BHI-00178, "*PUREX Plant Aggregate Area Management Study Technical Baseline Report*" estimated that 2607-EC began operating in 1955 (see BHI-00178 pp. 7-5). The description on BHI-00178 pp. 7-12 of its authors' inability to access the system to ground-truth the location during a 1991 site visit may have later been misinterpreted in WIDS as uncertainty about the correct location. This septic system is in a radiation zone.

H-2-56041 indicates dimensions and elevations of the system components. The tank is a 200-gal (757-L) upright circular cylinder with a 38-in. (97-cm) diameter and 48-in. (122-cm) height. The tank invert elevation is 679.80 ft NGVD 29 (208.3 m NAVD 88) and the base is at ~676 ft NGVD 29 (207.1 m NAVD 88). The drywell is an upright circular concrete pipe with a 42-in.

[4] Cramer, K. H., 1987, *Hanford Site Waste Management Units Report*, May 1987, Westinghouse Hanford Company, Richland, Washington.

(107-cm) diameter and 72-in. (183-cm) height. A 42-in. circle has an area of 0.89 m^2. The drywell invert elevation is 679.50 ft NGVD 29 (208.2 m NAVD 88) and the base is at ~676 ft NGVD 29 (207.1 m NAVD 88) in a gravel bed. These elevations are above the original grade and below the final grade. The tank was connected to the drywell by a 4-in. (10-cm) pipe constructed of "V.C.P." which is interpreted to mean vitreous clay pipe. The system connected to the 241-AR-271 control house by a 4-in. (10-cm) pipe constructed of "C.I. Soil Pipe Code M-33" which is interpreted to mean cast iron.

Table 3-2. Summary of Estimated Discharges for Septic Systems Near Waste Management Area A-AX.

Site Number	Area (m^2)	Operational Years	Discharge Rate (m^3/d)
2607-E6	(Drain Fields)	1956-1972 and 1983-1988	43.5
2607-E10	464.6 (Drain Field)	1993-2023	1.81
2607-E12	509.1 (Drain Field 1)	1992-2019 (for 3 Larger On Site System Drain Fields)	12.5 (1992-2014) 6.45 (2015-2019)
	512.1 (Drain Field 2)		
	506.5 (Drain Field 3)		
	Unused (Drain Field 4)		
	288.3 (Original Drain Field)		
	3.0 (Seepage Pit)		
2607-E13	13.9 (Drain Field)	1980-1996	1.70
2607-E14	Unknown	Unknown (<1998)-2001	Unknown
2607-EA	7.3 (Drywell)	1976-1991	0.060
2607-EC	0.89 (Drywell)	1955-1991	0.45
2607-ED	34.1 (Original Leaching Bed)	1963-1967 (Original Leaching Bed) 1980-1991 (New Drain Field)	0 to 0.28 (1963 to 1967) 0.28 (1980-1991)
	38.3 (Drain Field)		
2607-EG	128.2 (Drain Field)	1953-1991	0.17
2607-EJ	210.5 (Drain Field)	No reliable data located	No reliable data located
2607-ES	7.3 (Drywell Only); 29 (Including gravel)	1982-2009	See Section 3.4.3.11

The control house facilities that tied in to the sewer pipe included a toilet, wash basin, safety shower, and an evaporative cooler (H-2-56038, "Control House 241-A-271 Equipment Arrangement & Piping," Rev. 4). BHI-00178 cited an estimated waste generation rate of ~0.45 m^3 per day or ~120 gpd from Cramer (1987). BHI-00178 pp. 7-5 and 7-12 described the system as "active," and the document noted its information was current as of 1991 (BHI-00178 pp. 1-1). Although the only basis cited for the active status was Cramer (1987), the chart on BHI-00178 pp. 7-4 indicates its authors estimated the system was continuously active from 1955 through 1991. HNF-SD-LL-SP-001 indicates flows were unknown in 1998 and the system was

scheduled to be abandoned in 1999 or 2000. Later information in WIDS indicated the system was inactive but yet to be abandoned as of 2008.

3.4.3.2 2607-ED. The 2607-ED Septic Tank received sanitary wastewater and sewage from the 2707-AX Building and drained to a tile drain field (DOE/RL-88-30). The system was constructed in 1963 and modified in 1967 (HNF-SD-LL-SP-001). The drain field has a capacity of 973 L (257 gal) per day (HNF-SD-LL-SP-001). This tank lies south of tank AX-102, inside the AX Farm fence. This site is in a radiation zone.

BHI-00178 cited an estimated waste generation rate of ~0.28 m^3 per day or ~74 gpd from Cramer (1987). BHI-00178 indicated 2607-ED was active as of 1991 and had operated since 1980 (see BHI-00178 pp. 5-5, 5-9, and 5-31), although the construction and modification dates suggest the possibility of earlier use.

H-2-44501 Sheet 69 Rev. 12, which is dated 1978, indicates a line ran from the tank to an abandoned leaching bed close to tank AX-101 (less than ~12 m), and another line tied in at a Y-junction and ran outside the tank farm to the drain field. It is possible the leaching bed was a temporary arrangement during the construction phase of the AX Farm or for a short time after the tank farm construction, i.e., from 1963 to 1967, but there is no documentation it was ever used. In lieu of data for this early period, discharge could be assumed to be negligible, or it could be assumed similar to the rate estimated in Cramer (1987) during the second PUREX campaign. Any undocumented use of the new drain field outside the AX Farm between 1967 and 1980 is not likely to be significant given the relatively low rate estimated after 1980.

2607-ED was recorded to have been abandoned in place as of 1998 (HNF-SD-LL-SP-001), yet the same source stated it was scheduled to be abandoned in 2000. WIDS states that in January 2016, a worker walking across the septic tank caused the unmarked tank to collapse, resulting in a cave-in above the tank; therefore, a 10-ft by 20-ft steel plate was placed on top of the tank to serve as a work platform.

3.4.3.3 2607-E6. The 2607-E6 site is a septic tank and two drain fields located between two railroad spurs northwest of PUREX (Figure 2-2). The tank capacity was 14,377 gal or 54,420 L (HNF-SD-LL-SP-001 pp. 183). The drain fields are surrounded by a hexagonal wooden fence. The ground surface above the drain fields is vegetated with brush. Compared to other septic systems discussed herein, the location is relatively distant from WMA A-AX, but it is mentioned because the estimated discharge rate was relatively high.

The site received sanitary wastewater and sewage from MO-405 and PUREX at an estimated rate of 43.5 m^3 per day or ~11,500 gpd (DOE/RL-88-30), which was based on Cramer (1987). The system was constructed in 1953 and abandoned in place and replaced with a new regional system in 1997 (HNF-SD-LL-SP-001 pp. 169). BHI-00178 estimated 2607-E6 had operated continuously from 1954 through 1991 (see BHI-00178 pp. 3-4, 3-7, and 3-13). PUREX operated from 1956 to 1972 and from 1983 to 1988 (Section 3.3.1). The high discharge rate estimated in Cramer (1987) may not have been applicable before 1983, although it may be a reasonable approximation for the first PUREX campaign from 1956 to 1972.

3.4.3.4 2607-E10. This system was constructed in 1993 and was permitted to discharge up to 1,100 gpd via a tile field (HNF-SD-LL-SP-001). Estimated usage was 479 gpd (1.81 m^3/d) in a 1998 document (HNF-SD-LL-SP-001). The system included a 2,000-gal tank and the 1,100-gpd drain field (HNF-SD-LL-SP-001). It was scheduled for abandonment around 2023.

3.4.3.5 2607-E12. This system is classified as a Larger On Site System. It includes a septic tank, a seepage pit, the three large drain fields depicted in Figure 3-51, and an unused spare drain field to the north. This arrangement of the drain fields was once a standard for similar systems at Hanford.

This system was reconstructed in 1992 and was permitted to discharge up to 6,667 gpd (HNF-SD-LL-SP-001). HNF-SD-LL-SP-001 (pp. 52 and 184) stated two different usage estimates of 2,362 gpd (8.94 m^3/d) or 3,300 gpd (12.5 m^3/d); it is unclear which was current when the document was completed in 1998. Estimated usage in 2015 was 1,704 gpd or 6.45 m^3/d (HNF-6612). It is planned to be consolidated into a sewer line discharging to a facility in the 200 West Area by 2019 (HNF-6612). To test whether 2607-E12 discharges have any consequence for the WMA A-AX moisture field, the maximum rate can be assumed to apply from 1992 through 2014. Two of the three active drain fields would be used at any given time, but an assumption can be made that discharges are distributed evenly over all three over time.

3.4.3.6 2607-E13. This system comprises a tank of either fiberglass or polyethylene construction and a drain field of unknown capacity (HNF-SD-LL-SP-001). The date of construction is unknown but may have been in the early 1980s. A table in HNF-SD-LL-SP-001 has an entry for "2607-E13" for a 1,000-gal tank and drain field and a second entry for a "2607-E13 holding tank" of 6,000-gal capacity with estimated usage of 450 gpd (1.70 m^3/d). It was determined to be failed in February 1996 when effluent surfaced above the drain field. The holding tank serviced MO-398, MO-919, and MO-570 until it was abandoned in May 2015 (DOE/RL-88-30). Assuming the holding tank replaced comparable usage by the drain field, the 450 gpd rate as of 1998 may be a reasonable estimate for the former system as of the mid-1990s.

The location of 2607-E13 shown on Figure 3-51 is based on current Hanford Site geospatial data; however, it is noted that the approximate drain field location on a drawing on pp. 101 of HNF-SD-LL-SP-001 is near the southeast corner of 216-A-40 and closer to A Farm and AY Farm, which is supported by photographs (HNF-SD-LL-SP-001, pp. 100 and 150) showing a sign labeled "SEPTIC TANK" mounted on a bollard next to the MO-569 trailer and another view showing the holding tank.

3.4.3.7 2607-E14. This system includes a tank and drain field whose date of construction is unknown (HNF-SD-LL-SP-001). The underground septic tank services the A Farm Pipefitters shop building and is also known as 242-AC Septic (DOE/RL-88-30). Although 2607-E14 is a WIDS site, there is no geospatial data for it in WIDS. The location was determined from HNF-SD-LL-SP-001 pp. 101b, which was only adequate to determine coordinates but not accurate dimensions. As of 1998, flows were "significantly above drainfield design capacities" and the tank was being pumped "at least twice a month" (HNF-SD-LL-SP-001, pp. 101a). The system was scheduled to be tied in to regional system 2607-E1A in 2001.

3.4.3.8 2607-EA. This system is a small septic tank and drywell constructed in 1962 that served 244-AR and 2707-AR (HNF-SD-LL-SP-001, DOE/RL-88-30). The septic tank is ~3.0 m (10 ft) long and 2.4 m (8 ft) wide with rounded ends. The associated drywell is 5 ft (1.5 m) in diameter and connected to the tank by a short (~5-ft [1.5-m]-long) pipeline. A 5-ft-diameter circle has an area of 7.3 m^2. The drywell is constructed of eight courses of concrete blocks arranged in a circle. The alternating courses of blocks have staggered joints with no mortar. It is filled with gravel and capped with a concrete lid with a vent in the middle. A vent pipe extends from the lid to 0.6 m (2 ft) above grade.

According to DOE/RL-88-30, when in use, the system was estimated to receive waste at the rate of 0.060 m^3/day (16 gal/day). DOE/RL-88-30 lists a "start date" of 1976; it is unclear why the first use was estimated so long after construction. BHI-00178 (pp. 3-4, 3-7, and 3-13 therein) indicates the start date and discharge rate originated from Cramer (1987), and that 2607-EA was active as of 1991. In 1998 it was unknown whether there were current flows to 2607-EA. The system was scheduled for abandonment or tie-in to regional system 2607-E1A in 2001.

3.4.3.9 2607-EG. This system was constructed in 1951 and replaced in 1972 (HNF-SD-LL-SP-001). It included a drain field with 619-gpd or 2.34-m^3/d capacity (HNF-SD-LL-SP-001). The drain field was at grade and covered with gravel (BHI-00178). This site is in a radiation zone.

BHI-00178 (pp. 5-31) cited an estimated waste generation rate of ~0.17 m^3 per day or ~45 gpd from Cramer (1987). BHI-00178 estimated 2607-EG had operated continuously from 1953 through 1991 (see BHI-00178 pp. 5-5, 5-9, and 5-31). The site was scheduled to be abandoned in 1999 or 2000 (HNF-SD-LL-SP-001).

3.4.3.10 2607-EJ. The 2607-EJ Septic System was at a location of possible interest for the WMA A-AX PA, but it does not appear to have had an exceptionally large capacity or to have been used for a long time, and it is relatively distant from sources of residual waste in WMA A-AX, so in lieu of reliable discharge estimates it is reasonable to ignore this system.

DOE/RL-88-30 summarizes information on 2607-EJ, which was reclassified as closed out in WIDS in 2001. 2607-EJ was the original system that serviced the 272-AW Building. 241-AW Tank Farm was constructed in 1976. The 2607-EJ Septic System was removed during the construction of AP Farm in 1982. The tank and drainfield were removed as part of the 15-m (50-ft)-deep excavation for AP Farm.

The concrete septic tank was divided into two compartments with volumes of 7,800 L (2,000 gal) and 3,900 L (1,000 gal). It measured 5.9 m (19.5 ft) long, 2.1 m (7 ft) wide, and 1.8 m (6 ft) deep (outer dimensions). The tank had three 0.6-m (2-ft) access ports which were covered with concrete lids. The tank was connected to a small concrete distribution box which routed the waste from the tank to the sanitary drainfield. The drainfield consisted of five 15-m (50-ft) runs of perforated drain tile.

Data for 2607-EJ in BHI-00178 are suspect. BHI-00178 (pp. 5-31) cited an estimated waste generation rate of ~0.32 m^3 per day or ~85 gpd from Cramer (1987). BHI-00178 estimated

2607-EJ had operated continuously from 1980 through 1991 (see BHI-00178 pp. 5-5, 5-9, and 5-32), and the authors stated they visited the site in 1991. However, since AP Farm was constructed in 1982, even if the discharge rate is plausible for the system size, the estimated dates of use cannot be correct.

3.4.3.11 2607-ES. This system is a septic tank and attached drywell, which serviced the 204-AR Building and was located north of the building (DOE/RL-88-30). Estimated waste generation rates were not identified in documents reviewed (DOE/RL-88-30, BHI-00178, HNF-SD-LL-SP-001, and HNF-6612 Revs. 1 and 5). DOE/RL-88-30 indicates a "start date" of 1982 for the 204-AR Building itself. Unpublished communications in the WIDS library indicate that as of 2009 the building was unoccupied but the water was on and the restroom and septic facilities were still functional. Drawing H-2-70698, "Plumbing Plans Details & Diagrams," released for construction in 1977, shows plumbing for 204-AR facilities including a shower, toilet, and wash basin. The drawing shows doorways connected a locker room to a toilet and shower room and then to a soiled clothes room, which, given the operations at 204-AR (Section 3.3.3), suggests the shower was intended for end-of-shift use as opposed to just emergency use. Drawing H-2-70684, "Civil 2"-ST Line & Dry Well Details" shows the drywell was an upright circular cylinder with an inner diameter of 5 ft and inner height of ~6 ft constructed of concrete blocks without mortar and surrounded by gravel in a 10-ft diameter excavation. The inside volume of the drywell would thus be ~13 m^3. A 10-ft diameter circle has a total area of ~29 m^2. Drawing H-2-70683, "Civil Profiles" shows the invert elevation of the inlet to the septic tank was 687.46 ft NGVD, and the bottom of the drywell was at ~682 ft NGVD 29.

HNF-SD-LL-SP-001 (pp. 110-111) described a system designated "SWS #E-204-AR" which "was most likely constructed in the 1960's" and for which it provided an approximate location of a "drain field"; however, there was too little data either to determine whether that system was the same as 2607-ES or to verify any details given. For example, since HNF-SD-LL-SP-001 stated "no design data or flow information is available" and its authors were "unable to locate the exact location for the E-204-AR system," it could not be confirmed whether any drain field was constructed near 204-AR. Rev. 1 of HNF-6612 listed a non-permitted system as "2607-ES (204AR)" assigned to "FH" (Fluor Hanford) and yet to be abandoned as of 2007, but the document provided no further insight. Rev. 5 of HNF-6612, dated 2016, does not mention a system by any of the above designations, suggesting the system was formally abandoned and removed from the master plan between 2009 and 2016.

4.0 NATURAL RECHARGE AND ENGINEERED BARRIERS

4.1 BACKGROUND

In order to simulate the assumed hydrologic evolution of WMA A-AX and the surrounding area through time, recharge rates (i.e., fluxes of water reaching the water table after leaving the evapotranspiration zone) need to be estimated for each ground surface zone. This section is organized as follows:

- Key aspects of recharge estimation
- Temporal evolution of WMA A-AX surface and the nearby regions
  - Pre-operations
  - Operations
  - Early post-closure
  - Late post-closure
- Spatial and temporal variation of recharge estimates
  - Basis for estimated recharge
- Impacts due to vegetation and climate changes.

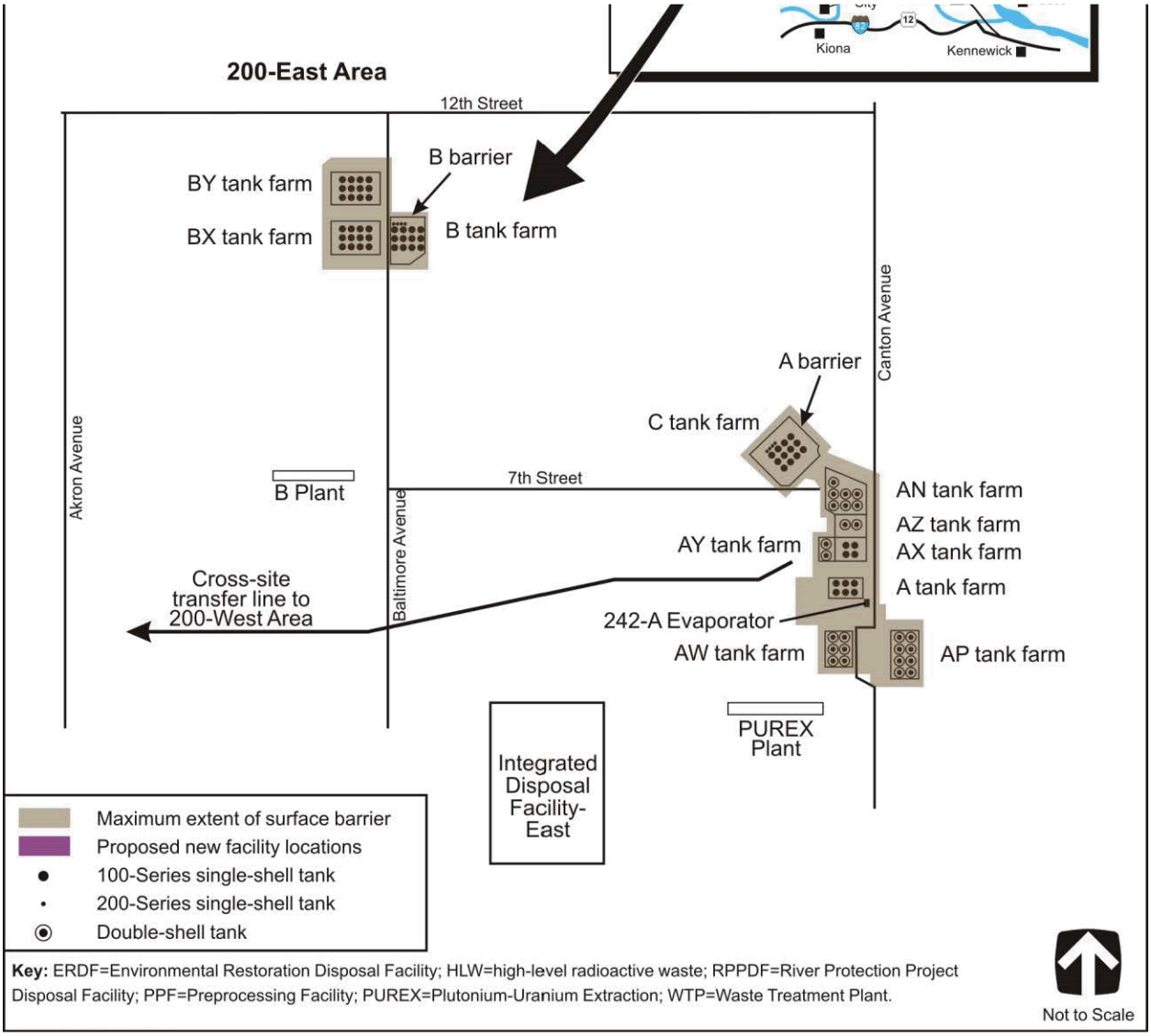
Historical volumes released intentionally from liquid discharge sites are discussed in Section 3.4.

4.2 KEY ASPECTS OF RECHARGE ESTIMATION

Several key considerations associated with the infiltration/recharge component include the following.

- According to assumptions outlined for landfill closure in the Tank Closure and Waste Management Environmental Impact Statement (DOE/EIS-0391) and the December 13, 2013 Record of Decision (78 FR 75913), a closure surface barrier (RCRA Subtitle C [modified]) will cover the entire A Complex (including WMA A-AX and the 241-AN, 241-AP, 241-AW, 241-AY, and 241-AZ Tank Farms) and the adjacent WMA C (Figure 4-1). Although the DST tank farms in the A Complex are not part of WMA A-AX and are not evaluated for contaminant releases in the WMA A-AX PA, the DST tank farms lie within the likely model domain and are assumed to have similar recharge patterns to those of the SST farms based on similar surface conditions and similar plans for closure. The A Complex portion of the surface is assumed to have an essentially continuous barrier at closure, whether it comprises one or multiple barriers and whether or not interim cover is placed first in some tank farms.

Figure 4-1. Conceptualized Closure Surface Barriers for 200 East Area.



Reference: DOE/EIS-0391, *Final Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington*, Appendix E, Figure E-31.

- During the 500-year design life of the closure surface barrier, the average net infiltration rate is set at 0.5 mm/yr, and afterward it is assumed to increase to a higher rate for the remainder of the simulation by assuming degraded capability of the surface barrier.
    - This assumption is considered to be conservative (i.e., higher than expected infiltration rates which lead to faster contaminant transport). Based on two decades of monitoring data, DOE/RL-2016-37 found that the 200-BP-1 PHB limited average drainage to 0.005 mm/yr, two orders of magnitude lower than the 0.5 mm/yr design standard. Performance remained better than the design standard despite three years of artificially enhanced precipitation, three 1,000-year return, 24-hour simulated rainstorms, and a controlled fire during the study period.

- RPP-ENV-58782 made the same assumption for WMA C, notwithstanding the estimate in PNNL-14744, "*Recharge Data Package for the 2005 Integrated Disposal Facility Performance Assessment*" that the expected performance for such a barrier is on the order of 0.1 mm/yr for the life of the barrier.

- DOE/EIS-0391 made the same assumption for future surface barriers at WMA A-AX and elsewhere on the Hanford Site.

- It is also concluded that, with appropriate design considerations, the possibility of the most likely natural failure mechanisms (i.e., biointrusion of the silt loam layer, wind erosion, and accretion of windblown sand) to occur is quite low, and that the emplaced silt-loam soils are expected to perform as designed indefinitely. DOE/RL-2016-37 found that animal burrows did not discernibly affect barrier function and that the PHB naturally recovered soil wettability and vegetation sufficient to maintain performance following the controlled fire experiment.

- For purposes of estimating recharge rates, side slopes of the surface barrier are assumed to be made of compacted silty soil and assumed not to have enhanced recharge compared to the top portion of the surface barrier. Recharge estimates for surface barrier side slopes based on monitoring of the PHB indicate a generally decreasing trend in the ratio of drainage to precipitation, and 13 of the 20 possible side slope drainage measurements between 2005 and 2009 were less than 5 mm/yr (0.20 in./yr) (PNNL-18845, "*200-BP-1 Prototype Hanford Barrier – 15 Years of Performance Monitoring*"). These measurements indicate that the side slopes are already functioning somewhat like a native soil, even though neither side slope incorporates any silt loam or plant-promoting features (PNNL-18845). At WMA A-AX, the area covered by the side slopes would be limited in extent and located outside of the SST footprints; therefore, variation in recharge in this zone is not perceived to have a significant impact on contaminant transport.

- During the construction period, the disturbed zone around the facility has no vegetation cover, but "mature shrub steppe" (Shrub-Steppe and Grassland Restoration Manual for the Columbia River Basin [Benson et al. 2011]) vegetation will reclaim the surface during the subsequent 100-year institutional control period.

- Revegetation of the surface barrier and land impacted by construction with native plants (e.g., sagebrush [Artemisia tridentate] and small bunchgrasses [*Elymus wawawaiensis* and *Poa secunda*]) is assumed to be successful. Revegetation of the land is specifically required (for example, by the Record of Decision for the nearby Environmental Restoration Disposal Facility), along with other measures to mitigate the ecological impacts caused by construction, including restoration of the site.

- According to Benson et al. (2011), restoration assists the recovery of an ecosystem that has been degraded, damaged, or destroyed, with the intent to return it to its historic condition. The manual includes the technical information necessary to successfully plan and execute habitat restoration projects for shrub-steppe habitat.

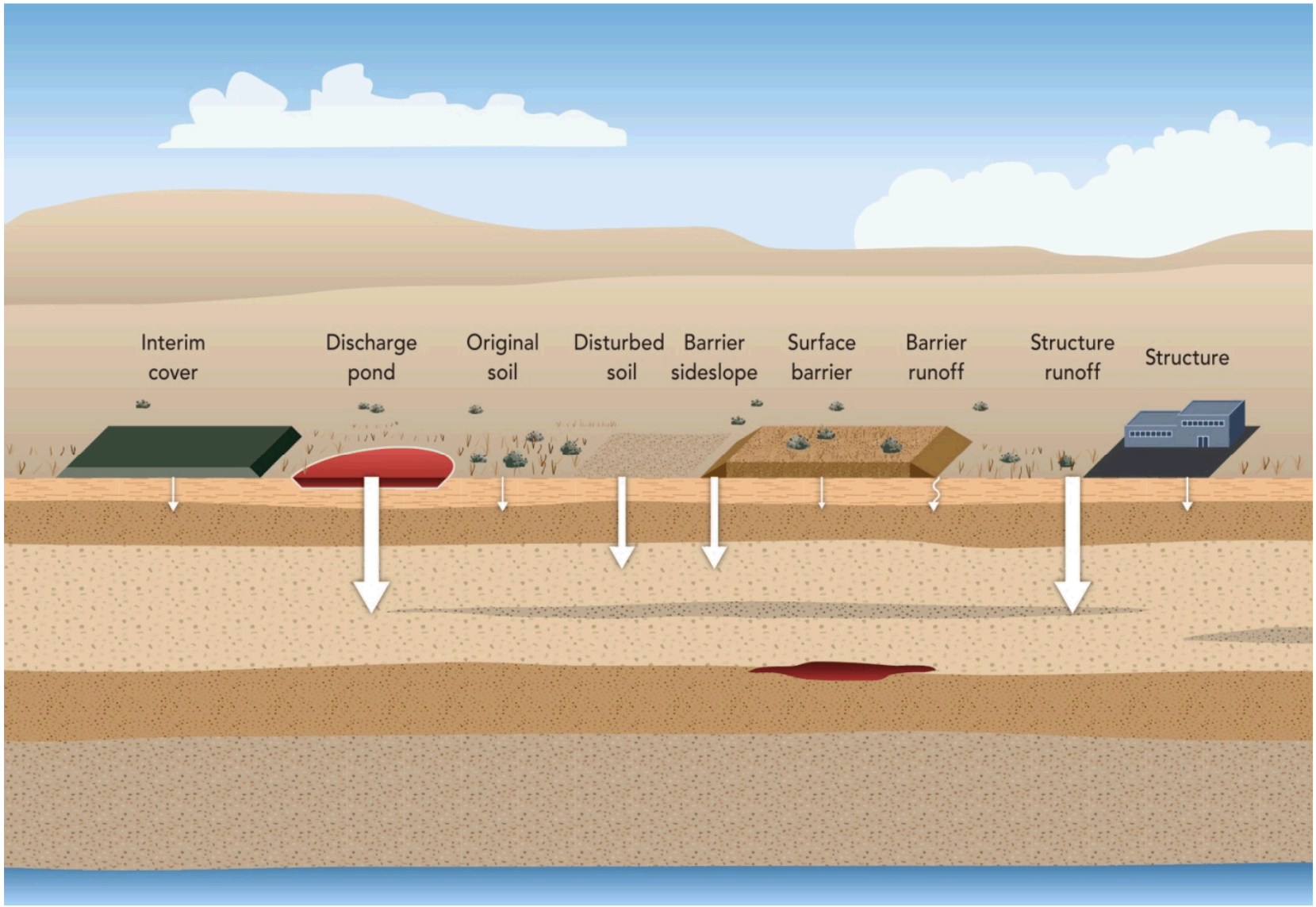
4.3 TEMPORAL EVOLUTION OF WASTE MANAGEMENT AREA A-AX SURFACE

Net infiltration, deep percolation, and recharge of water are the major transport mechanisms for moving contaminants from the closed system to the groundwater. In arid and semiarid regions with thick vadose zones, such as the Hanford Site, long-term factors like climate change, changes in the annual precipitation rates, and changes in vegetation structure and community are necessary to influence the deep vertical water fluxes (Figure 4-2). In these regions, large seasonal fluctuations in soil water potential are generally contained within the upper few meters of soil, and the spatially- and temporally-varying moisture fluxes even out within the deep subsurface above the water table.

Multi-year evaluations of soil moisture regime data collected from vegetated desert soils throughout the United States indicate that the matric potentials remain largely negative and relatively invariant below depths of 2 to 5 m (6.6 to 16.4 ft) ("Ecohydrological Control of Deep Drainage in Arid and Semiarid Regions" [Seyfried et al. 2005]). In response to intermittent years of elevated precipitation such as those caused by El Nino in the southwestern United States, the biomass usage of water by deep-rooted xeric vegetation increases, depleting the excess water, and no net increase in groundwater recharge occurs ("Global synthesis of groundwater recharge in semiarid and arid regions" [Scanlon et al. 2006], Analysis of Techniques for Estimating Potential Recharge and Shallow Unsaturated Zone Water Balance near Yucca Mountain, Nevada [Leary 1990]). Simulation results representing the impact of a 20-year period of temporally-varying precipitation on a surface barrier and a clean, graveled surface indicate that the temporal variation in drainage can effectively be ignored, and that an average value can be used with little loss of accuracy (WHC-EP-0332, "*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*," pp. 18-21).

Based on the preceding, the following two assumptions pertain to recharge: (1) that net infiltration through the thick, heterogeneous vadose zone in the 200 Areas dampens the effect of discrete events, and therefore episodic precipitation events can be replaced by an average annual recharge rate; and (2) impacts resulting from plausible climate change that may occur during the PA evaluation period do not adversely impact the safety functions of the surface or vadose zone.

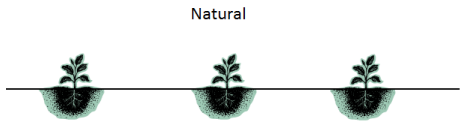
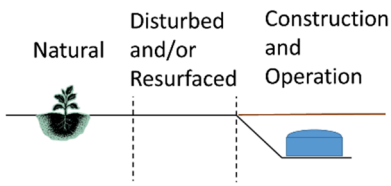
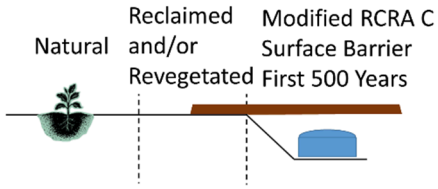
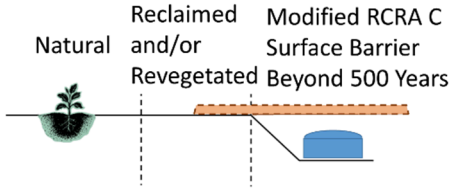
Figure 4-2. Conceptual Representation of the Impact of Surface Features on Local Recharge (arrow size indicates relative recharge rate).



As described below, with expected changes to the land cover over time due to growth of vegetation, several time periods have been conceptualized (Table 4-1) to represent the changes in recharge rates and hydrologic conditions at WMA A-AX. For the PA, the recharge rates can be divided into four distinct time periods, as noted below, representing different surface conditions consistent with the variable conditions expected for the facility:

- Recharge Estimates for Pre-Construction Condition
- Recharge Estimates During Construction and Operations
- Early Post-Closure and a Functioning Surface Barrier
- Late Post-Closure and a Degraded Surface Barrier.

Table 4-1. Timeline Considered for Representing the Evolution of Waste Management Area A-AX.

Phase	Conditions	Duration	Conceptual Half Cross Section of Waste Management Area A-AX
Pre-operations	Before beginning construction of facilities	Until steady-state moisture conditions are achieved for the year.	
Construction and Operations	Current conditions	Dates of tank farm construction (or initial surface disturbance) until assumed closure date	
Early Post-Closure	Transition to conditions of restricted recharge due to modified RCRA Subtitle C barrier	First 500 years after assumed closure date	
Late Post-Closure	Degraded surface barrier conditions	500 years to 10,000 years after assumed closure date (end of sensitivity and uncertainty analysis evaluation period)	

RCRA = *Resource Conservation and Recovery Act of 1976*

4.3.1 Pre-operations

Hydrologic conditions prior to construction of facilities control the initial moisture content and the matric potential in the vadose zone. To estimate the initial conditions, a pre-operations phase is considered, which produces initial moisture conditions for subsequent temporal changes

conceptualized at WMA A-AX. A vegetation cover representative of natural conditions is assumed over the whole domain during this period.

Facility construction dates based on the year of initial construction given in the Waste Tank Summary Report (HNF-EP-0182) are provided in Table 4-2. The construction dates for A Farm and AX Farm are significant because they establish dates of departure from background moisture conditions for the sediments underlying sources of contamination to be analyzed in the WMA A-AX PA. Nearby facility construction dates affect simulation of the adjacent moisture field but not the immediate contaminant transport pathways for sources of interest in the PA.

Table 4-2. Construction Start Dates for Tank Farms Near Waste Management Area A-AX.

Tank Farm (241-)	A	AX	AN	AP	AW	AY	AZ	C
Construction Start Year	1953	1963	1977	1982	1976	1968	1970	1943

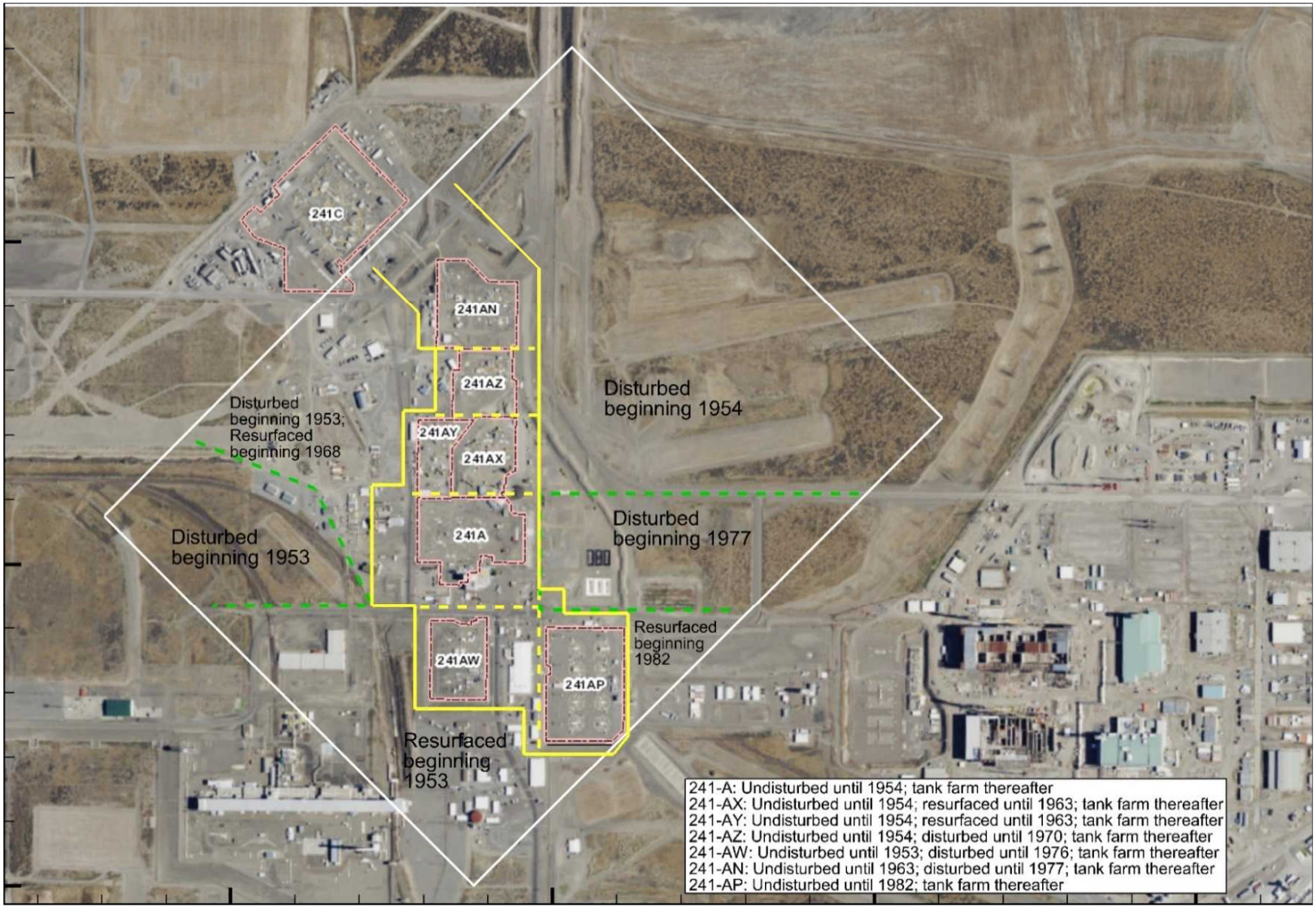
Note that review of historical photographs shows that initial disturbance of the surface preceded the actual construction of some tank farms; for example, the January 20, 1954 photograph in Figure 3-1 shows the area of not just A Farm but also AX Farm and AY Farm had all vegetation removed in late 1953 or early 1954 (the June 8, 1953 photograph in Figure 3-52 showed the area undisturbed except for the 200-E-286 ditch). In such cases the recharge rate likely increased above the pre-construction rate, but not necessarily as much as during tank farm operations. Figure 4-3 indicates the times that the pre-operations period is interpreted to have ended for each tank farm area.

4.3.2 Construction and Operations

The operations period (current condition) is considered to represent the WMA A-AX construction phase along with operations until closure of the WMA. This period starts in 1953 or later (Figure 4-3) and is assumed to end in 2050 when a surface barrier is placed over the facility. A distinct recharge rate will be assigned to the following zones during this period (Figure 4-3):

- The disturbed zone around the facility that has scant, deep-rooted vegetation but extensive grass cover
- The resurfaced zone around the facility that has no vegetation cover
- The tank farm zone that corresponds to the A Complex gravel backfill that is not covered by vegetation and to WMA C, if applicable. The tank farm zone may be subdivided to more precisely sequence changes at individual tank farms as appropriate.

Figure 4-3. Surface Conditions In and Around Waste Management Area A-AX.



Notes: White boundary shows approximately the anticipated area of interest for the Waste Management Area A-AX performance assessment. "Disturbed" and "Resurfaced" areas apply from Construction and Operations through Late Post-Closure. Yellow closure barrier zone varies with time according to modeling assumptions.

As stated in Section 2.0, there is uncertainty in the actual tank farm closure date(s) given the time remaining before the HFFACO closure milestones. An alternative assumption could be made of earlier closure of A Farm and AX Farm with an interim barrier placed pending closure of the entire A Complex. Such an assumption would limit infiltration earlier and likely lead to calculation of longer times for contaminant transport to groundwater. The opposite assumption of a delay in closure or placement of interim cover would likely lead to shorter transport times.

4.3.3 Early Post-Closure

At the end of the operations period, the early post-closure period is considered to represent the time when the modified RCRA C barrier functions according to its design specifications for 500 years (DOE/RL-93-33, *Focused Feasibility Study of Engineered Barriers for Waste Management Units in the 200 Areas*). The closure barrier functions to limit the flow of infiltrating moisture into the system by a combination of evapotranspiration, water storage capacity, low-permeability layers, and built-in engineered capillary breaks, depending on the final design. The PHB incorporates all of those features and has demonstrated performance superior to the design standard for a period of two decades, even when stressed beyond anticipated conditions (DOE/RL-2016-37). Decision of a final barrier design for WMA A-AX is deferred to allow for further possible research, development, and optimization.

The barrier design is assumed to occupy an area beyond the present (2017) fence lines of the tank farms in order to incorporate ancillary equipment and UPRs as appropriate and to allow space for a relatively flat barrier surface over the tank farms plus a surrounding berm/side slopes. Pending the final barrier design, the exact area is uncertain, but the assumption is necessary because, for example, the AX Farm SSTs are too close to the present fence line to construct side slopes such as used in the PHB without moving the fence outward[5].

During the early post-closure period, distinct recharge rates are assigned to spatially distinct zones (Figure 4-3):

- The undisturbed zone, away from the surface barrier and the surrounding berm, characterized by an undisturbed native vegetation cover
- The disturbed zone, away from the surface barrier and the surrounding berm, characterized by an artificially-introduced vegetation cover attempting to reclaim the surface with native vegetation species
- The resurfaced zone, away from the surface barrier and the surrounding berm, characterized by an artificially-introduced vegetation cover attempting to reclaim the surface with native vegetation species
- The zone beneath the extent of the surface barrier that is designed to minimize infiltration of meteoric waters.

[5] The approach to defining the boundary of the closed WMA A-AX for purposes of PA calculations is described in RPP-RPT-60101.

4.3.4 Late Post-Closure

Finally, a late post-closure period is considered to represent the functioning of a degraded surface barrier. This period will start at the end of the assumed 500-yr design life of the surface barrier and will continue through the rest of the simulated time period. DOE/RL-2016-37 concluded that the PHB is likely to perform for at least 1,000 years, so the assumption of degradation after 500 years is relatively pessimistic. A distinct recharge rate will be assigned to different zones during the late post-closure period (Figure 4-3):

- The undisturbed, disturbed, and resurfaced zones away from the surface barrier characterized by undisturbed or reclaimed native vegetation cover

- The degraded surface barrier fully covered with vegetation that has undergone reclaiming soil and ecological processes.

4.4 SPATIAL AND TEMPORAL VARIATION OF RECHARGE ESTIMATES

Results are available from more than four decades of work on meteoric recharge estimates at the Hanford Site. Net infiltration (recharge) can vary greatly depending on factors such as climate, vegetation, surface condition, and soil texture. Studies conducted over the last decade at the Hanford Site ("Variations in Recharge at the Hanford Site" [Gee et al. 1992]; PNNL-11367, "*Hanford Prototype-Barrier Status Report: FY 1996*"; "Quest for the Perfect Cap" [Wing and Gee 1994]; PNL-10285, "*Estimated Recharge Rates at the Hanford Site*"; "Estimating Recharge Rates for a Groundwater Model Using a GIS" [Fayer et al. 1996]; PNL-11463, "*A Comprehensive Analysis of Contaminant Transport in the Vadose Zone Beneath Tank SX-109*"; PNNL-13033, "*Recharge Data Package for the Immobilized Low-Activity Waste 2001 Performance Assessment*") suggest that recharge rates can vary from less than 0.1 mm/yr (0.004 in./yr) on a variety of soil and vegetation combinations to greater than 130 mm/yr (5.1 in./yr) on bare basalt outcrops or bare, gravel-covered waste sites (Gee et al. 1992). In interpreting empirical data, it is important to distinguish between measurements of transient rates over short time periods and measurements or estimates of longer-term average infiltration rates. Detailed experimental work has also been performed on infiltration rates through surface barriers (DOE/RL-2016-37, PNNL-14744) and discussed in PNNL-16688, "*Recharge Data Package for the Hanford Single-Shell Tank Waste Management Areas*."

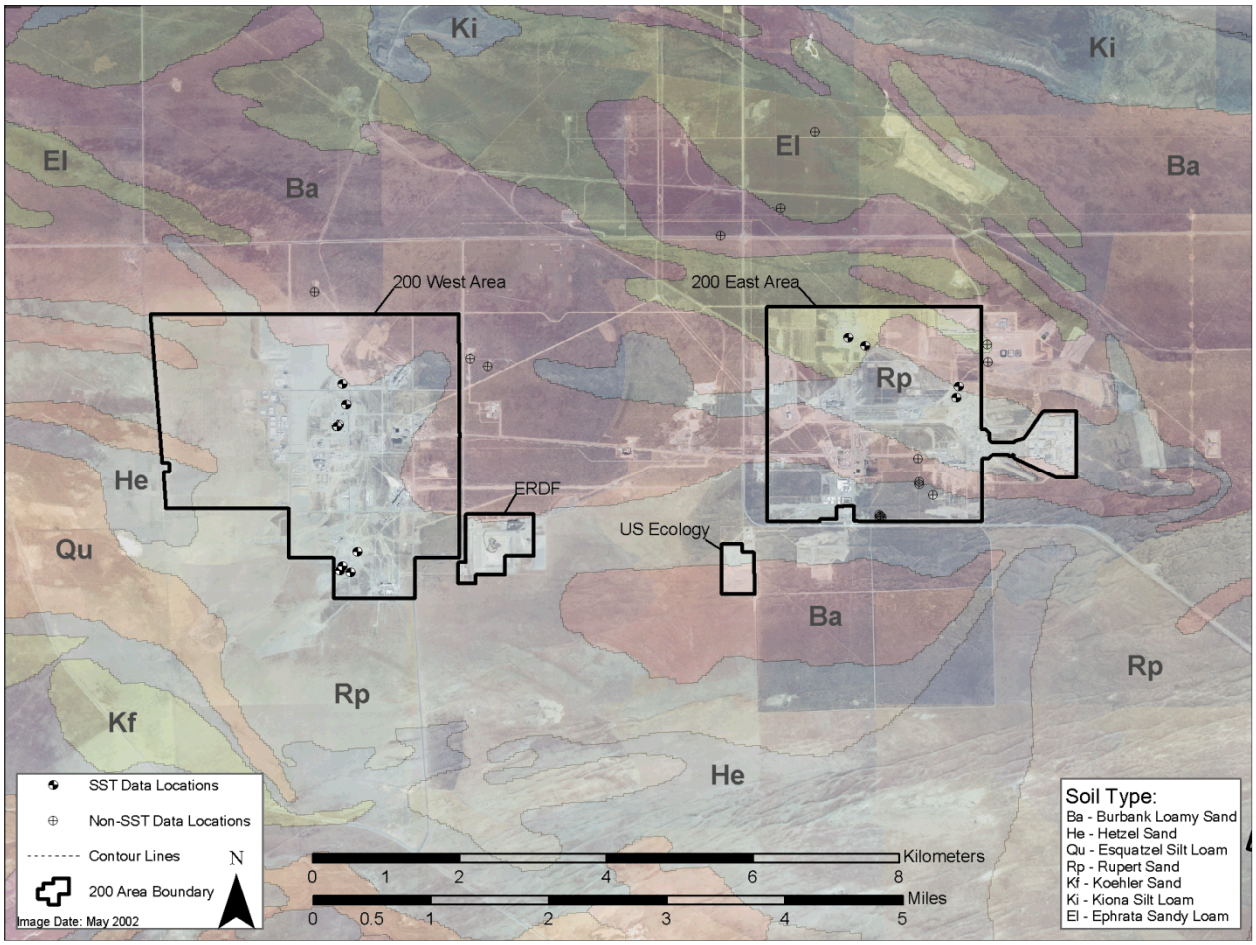
For the PA, the recharge rates can be divided into four distinct time periods, as noted in Section 4.3. Estimates (including their basis) are provided below for each of the time periods.

4.4.1 Pre-Operation Period

During the time prior to facilities construction, the area currently occupied by the A Complex and WMA C appears to have been covered by a mature shrub-steppe plant community growing in Rupert sand or Burbank loamy sand soil. It is difficult to distinguish between the two soil types because the divide between the Rupert sand and Burbank loamy sand soil appears to

coincide with the northeastern boundary of WMA C (Figure 4-3); soil types on the Central Plateau are shown in Figure 4-4.

Figure 4-4. Soil Types on the Central Plateau.



ERDF = Environmental Restoration Disposal Facility SST = single-shell tank

Rupert Sand.
This mapping unit represents one of the most extensive soils on the Hanford Project. The surface is a brown to grayish brown ($10YR^5/2$) coarse sand, which grades to a dark grayish brown ($10YR^4/2$) sand at ~36 inches. Rupert soils developed under grass, sagebrush, and hopsage in coarse sandy alluvial deposits, which were mantled by wind-blown sand. Relief characteristically consists of hummocky terraces and dune-like ridges. This soil may be correlated as Quincy sand, which was not separated here. Active sand dunes are present. Some dune areas are separated; however, many small dunes, blow-outs, and associated small areas of Ephrata and Burbank soils are included.

Burbank Loamy Sand.
This is a dark-colored [surface is very dark grayish brown ($10YR^3/2$); subsoil is dark grayish brown ($10YR^4/2$)], coarse-textured soil which is underlain by gravel. The surface soil is usually ~16 in. thick but can be 30 in. thick. The gravel content of the subsoil may range from 20 to 80 volume percent. Areas of Ephrata and Rupert are included.

PNNL-14702, "*Vadose Zone Hydrogeology Data Package for Hanford Assessments*" recommended using the Wye Barricade data (4 mm/yr [0.36 in./yr]) as the best estimate for vegetated Rupert Sands, although the surface is described in PNNL-14702 as a stabilized dune area with low shrub cover. PNNL-16688 later revised the estimate of PNNL-14702 by

considering an average of three available tracer estimates (4, 0.26, and 0.9 mm/yr [0.36, 0.01, and 0.03 in./yr]). In addition, PNNL-16688 reported a good agreement between its suggested mean value (1.7 mm/yr [0.06 in./yr]) and modeling results that considered a 50-year weather record (including the two wettest years: 1995 and 1996) yielding a rate of 1.9 mm/yr (0.07 in./yr). Consequently, the recommended estimate is 1.7 mm/yr (0.06 in./yr) for vegetated Rupert sand soil (PNNL-16688).

PNNL-14702 recommended the average value of 3.0 mm/yr of three chloride tracer-based estimates of recharge in vegetated Burbank loamy sand (0.66 mm/yr, 2.8 mm/yr, and 5.5 mm/yr). PNNL-16688 augmented these data with five additional tracer-based estimates that decreased the average to 1.9 mm/yr, and with the results of a simulation that suggest a rate of 5.2 mm/yr, which is near the upper end of the range of tracer estimates. PNNL-16688 recommends the value of 1.9 mm/yr because the tracer estimates are considered to be a better estimator of recharge.

The pre-construction recharge estimate for tank farm sediments is considerably higher than the average estimates recommended by PNNL-16688 for vegetated Rupert Sand soil and Burbank loamy sand. RPP-RPT-44042, "*Recharge and Waste Release within Engineered System in Waste Management Area C*" presents two values that appear to represent lower and upper bounds for recharge: 1.9 mm/yr and 5.2 mm/yr. The average of these two values is approximately equal to 3.5 mm/yr, which is the recommended PA recharge estimate for the time prior to construction of WMA A-AX and WMA C. The WMA C PA (RPP-ENV-58782) adopted that estimate.

4.4.2 Operational Period

The operational period, which started in 1953 or later in various areas around WMA A-AX, is assumed to last until the landfill closure of the tank farms with construction of a Modified RCRA Subtitle C surface barrier. During the operational period, recharge estimates for WMA A-AX are broadly considered for undisturbed and disturbed zones.

4.4.2.1 Undisturbed Zone. As the undisturbed zone is conceptualized to be under the influence of the initial natural conditions observed prior to the tank farm construction (vegetated Rupert Sand), the recharge estimate over this zone will be the same as the pre-operation period previously described.

4.4.2.2 Disturbed Zone. The disturbed zone corresponds to three types:

(a) a disturbed gravel zone without vegetation (bare surface) within the WMA,
(b) a disturbed revegetated region (Hanford sand with vegetation), and
(c) a disturbed nonvegetated region (Hanford sand with no vegetation) outside the WMA.

For type (a), i.e., a disturbed zone without vegetation and with gravel cover, a recharge estimate of 100 mm/yr (Gee et al. 1992) is recommended for WMA A-AX surface regions, as adopted in the WMA C PA (RPP-ENV-58782). This is essentially the maximum observed recharge for bare surfaces at the Hanford Site. The upper bounding 140 mm/yr value is the result of an enhanced precipitation experiment on the "sandy gravel side slope" of the Hanford Prototype

Barrier installed at the 216-B-57 Crib. This treatment is referenced as being "useful for characterizing deep drainage rates at the high-level waste tank farms at Hanford" (PNNL-14744). The enhanced precipitation represented 3 times the average precipitation. Approximately 140 mm of the precipitation was observed to have infiltrated. For a lower bounding value, CP-14873, "*200-BP-1 Prototype Hanford Barrier Annual Monitoring Report for Fiscal Year 2002*" reported that 21.5% of precipitation (37.8 mm/yr) became recharge through sparsely vegetated sandy gravel representing the "sandy gravel side slope." Such a percentage (i.e., 21.5%) represents a lower value of ~40 mm/yr. However, for a triangular distribution having mean and mode values of 100 mm/yr, and a maximum value of 140 mm/yr, the minimum value must be 60 mm/yr. Therefore, the minimum value in the uncertainty analysis is 60 mm/yr.

For type (b), areas around the WMAs include surfaces where the existing shrub-steppe vegetation has been destroyed (e.g., by Hanford operations), but shallow-rooted plants have been allowed or introduced to re-vegetate the land. Very few recharge data are available for this condition, and PNNL-16688, for example, does not provide a recommended recharge estimate for this condition. However, PNNL-14702 estimates that the existing plant cover will limit recharge rates to between 22 and 26 mm/yr on such surfaces in the eastern portion of 200 East Area. A recharge estimate of 22 mm/yr is recommended for the PA modeling for such disturbed areas.

Type (c) disturbed areas include construction and operations outside the WMAs which removed the surface soil, broke up any near-surface layering, and exposed Hanford formation sands. These sediments tend to be coarser than the original soil, and, as indicated in photographs of the area around the WMAs, plants have difficulty growing on them. PNNL-14702 recommends a recharge rate of 63 mm/yr for this type of surface. This value is supported by drainage data collected from the 300 North Lysimeter, which contains coarse Hanford formation material screened to less than 1% gravel (material > 2 mm); the long-term recharge rate averaged 62 mm/yr from 1981 to 2005 (PNNL-16688). A recharge estimate of 63 mm/yr is recommended for the PA modeling for such disturbed areas.

4.4.3 Early Post-Closure and a Functioning Surface Barrier

Current plans (consistent with 78 FR 75913) are to use a modified RCRA-compliant closure cover. The current conceptual design of the Modified RCRA Subtitle C Barrier is based on DOE/RL-93-33. The conceptual design provides 1.7 m (5.6 ft) of depth in its basic design, which could be modified if necessary to provide at least 5 m (16.4 ft) depth to the top-most waste zone in the closed configuration. The basic design includes a layer of grading fill of variable thickness, 10 cm of asphalt base course and 15 cm of asphaltic concrete to serve as a barrier to infiltration and bio-intrusion, 15 cm of drainage aggregate at 2% slope to divert water to the cover margin, 15 cm of gravel filter, 15 cm of sand filter, ≥50 cm of compacted topsoil to retard infiltration, and ≥50 cm of silt loam and gravel admixture covered with vegetation to promote evapotranspiration, retain moisture, and limit wind erosion. PA modeling typically focuses not on the detailed cover design but on its key functions. Specifically, by reducing infiltration, the cover reduces vadose zone transport of contaminants to groundwater. The cover also enhances the resistance to burrowing animals, deep-rooting plants, wind erosion, and inadvertent human intrusion, among other design criteria stated in DOE/RL-93-33. Prior to cover construction,

specific closure cover designs will be evaluated and the most appropriate closure cover design will be selected for construction.

Extensive laboratory and modeling work and limited field testing of surface barriers have been performed; results are summarized in PNNL-14744. Lysimeter testing has been performed for different surface barrier concepts including a Modified RCRA Subtitle C Barrier with silt loam layers having depths between 1 and 2 m. Lysimeter data from the prototype Hanford barrier (Wing and Gee 1994) have also been collected and analyzed. Finally, modeling has been performed to address potential climate change impacts and no vegetation impacts on surface barrier performance.

The lysimeter drainage data that have been collected since 1989 suggest that the recharge rate beneath surface barriers having at least 1 m of silt loam is zero under ambient precipitation conditions. Most of these lysimeters did not contain an asphalt layer. Simulation results reported in PNNL-14744 investigated the sensitivity of the lysimeter data to climate change, silt loam hydraulic properties, vegetation changes, erosion, and dune formation above the surface barrier. Results indicated that the performance of these surface barriers was robust in that the estimated recharge rates remained below 0.1 mm/yr. For the cases investigated, only in the case of dune formation and no vegetation on the surface barrier were the simulated recharge rates above 0.1 mm/yr.

Based on a review of the results, as stated earlier, PNNL-14744 recommend an expected recharge performance for surface barrier with at least a 1-m layer of silt loam above a gravel layer to be on the order of 0.1 mm/yr for the life of the barrier. This estimate did not take any credit for the asphalt layer that is part of the Modified RCRA Subtitle C Barrier design.

The final design for the WMA surface barrier has not been developed; however, based on the extensive testing reported in PNNL-14744, surface barriers that will limit recharge rates are achievable. For a fully-functioning barrier for the early closure period for 500 years, a recharge rate of 0.5 mm/yr (0.02 in./yr) is proposed. This is consistent with estimates used in PAs of WMA C and the Environmental Restoration Disposal Facility, and in DOE/EIS-0391.

4.4.4 Late Post-Closure and a Degraded Surface Barrier

For a degraded surface barrier, a range of potential recharge rates can be envisioned. PNNL-14744 investigated the possibility of the most likely natural failure mechanisms (i.e., bioturbation of the silt loam layer, wind erosion, and accretion of windblown sand). With appropriate design considerations, PNNL-14744 presents an argument that the failure possibility of these natural systems is quite low, and the emplaced silt-loam soils will continue to perform for as long as they remain in place. Based on these arguments, it is concluded that the long-term effectiveness of the surface barrier would continue to limit recharge rates to less than 0.1 mm/yr (0.004 in./yr) for thousands of years (PNNL-14744).

Since the final design for the surface barrier has not been developed and it is difficult to defend the continued performance of a surface barrier for indefinite periods of time, the closure barrier is expected to maintain the recharge rate (i.e., barrier design goal) at or below 0.5 mm/yr

(0.02 in./yr) for 500 years. At the end of 500 years, the closure barrier is assumed to degrade to permit an infiltration rate of 3.5 mm/yr (0.039 in./yr) and maintain that infiltration rate for the remainder of the PA simulation. The underlying assumption is that the upper-bound recharge from the degraded surface barrier would approach the expected recharge of undisturbed soil. These upper-bounding values are considered sufficient to accommodate the increased uncertainty in the weather cycles and changes in the fire cycle during periods after the design life of the barrier.

4.5 REPRESENTATIVE INITIAL RECHARGE ESTIMATES FOR WASTE MANAGEMENT AREA A-AX PERFORMANCE ASSESSMENT

Table 4-3 summarizes various timelines and the corresponding initial estimates of recharge for a variety of surface conditions (e.g., undisturbed, disturbed, cells under construction, fully functional barrier, and degraded barrier).

Table 4-3. Representative Recharge Rate (Net Infiltration) Estimates for Surface Conditions during the Pre-Construction, Operational, and Post-Closure Periods.

Period	Waste Management Areas and Surface Condition	Representative Recharge Rate (mm/yr)
Pre-construction	Undisturbed region (Rupert sand with vegetation)	3.5
Operational period (from construction until assumed closure)	Undisturbed region (Rupert sand with vegetation)	3.5
	A Complex Surface regions (Gravel without vegetation)	100
	Disturbed revegetated region (sand with vegetation)	22
	Disturbed un-revegetated region (sand with no vegetation)	63
Early post-closure (first 500 years after assumed closure)	Undisturbed region (Rupert sand with vegetation)	3.5
	A Complex Surface regions (Surface barrier with vegetation beginning at closure)	0.5
	Disturbed revegetated region (sand with vegetation beginning at closure with vegetation recovery completed 30 years after closure)	3.5
	Disturbed un-revegetated region (sand with no vegetation until vegetation recovery begins at closure and completes 30 years later)	3.5
Late post-closure (>500 years after assumed closure)	Undisturbed region (Rupert sand with vegetation)	3.5
	A Complex Surface region (Degraded surface barrier with vegetation beginning 500 years after closure)	3.5
	Disturbed revegetated region (sand with vegetation recovery completed 30 years after closure)	3.5
	Disturbed un-revegetated region (sand with vegetation recovery completed 30 years after closure)	3.5

4.6 IMPACTS DUE TO VEGETATION AND CLIMATE CHANGES

The vegetation on the surface barrier and surrounding area is assumed to remain shrub-steppe indefinitely after closure of the tank farms, and exert the same control on recharge that it has in the past. If the estimates of the mean annual precipitation during the past 75,000 years, which range from 50% below to 128% above modern levels (BHI-00007, "*Prototype Hanford Surface Barrier: Design Basis Document*") are indicative and inclusive of future conditions, then the anticipated changes in precipitation rates and patterns resulting from changes in the local climate do not appear to be substantial enough to change the dominant shrub-steppe vegetation or its characteristic ability to control recharge.

The period of evaluation considered in this study is 1,000 to 10,000 years post-closure. In contrast, the next glaciation period has been estimated to occur tens of thousands of years into the future. The wet and dry cycles that have occurred over the past 10,000 years will likely continue over the next 10,000 years (see Section 2.2.5 of DOE/ORP-2000-24, *Hanford Immobilized Low-Activity Waste Performance Assessment: 2001 Version*). The variations in the recharge in the future (over next 10,000 years) are therefore expected to be about the same as that of the past. This all assumes that the human disturbances are minimal.

Interagency report Circular 1331, "*Climate Change and Water Resources Management: A Federal Perspective*" was prepared by the U.S. Geological Survey, U.S. Army Corps of Engineers, Bureau of Reclamation, and National Oceanic and Atmospheric Administration to explore strategies to improve water management by tracking, anticipating, and responding to climate change. As its title states, the report represents a Federal perspective on climate change and water resources management. Several points are worth noting:

- The evidence indicates that climate change is occurring but the effects differ regionally
- The assumption of stationarity in hydroclimatic variables should be evaluated
- Paleoclimate information can be useful for developing climate scenarios (a best approach has yet to be determined)
- Adaptive management is an approach that may be useful in dealing with the additional uncertainty introduced by potential climate change.

In Global Climate Change Impacts in the United States: A State of Knowledge Report from the U.S. Global Change Research Program, Karl et al. (2009) projects that in the Pacific Northwest, regionally averaged temperatures are expected to increase 3 to 10 °F during this century. They also noted that temperatures rose 1.5 °F over the past century and some areas saw increases up to 4 °F. Karl et al. (2009) also suggests that winter precipitation will increase and summer precipitation will decrease. Most of the concern is with snowpack because it dominates water storage for irrigation and hydrosystem functioning. "*Scenarios of future climate for the Pacific Northwest*" (Mote et al. 2008) stated that the best estimate of future temperature change in the

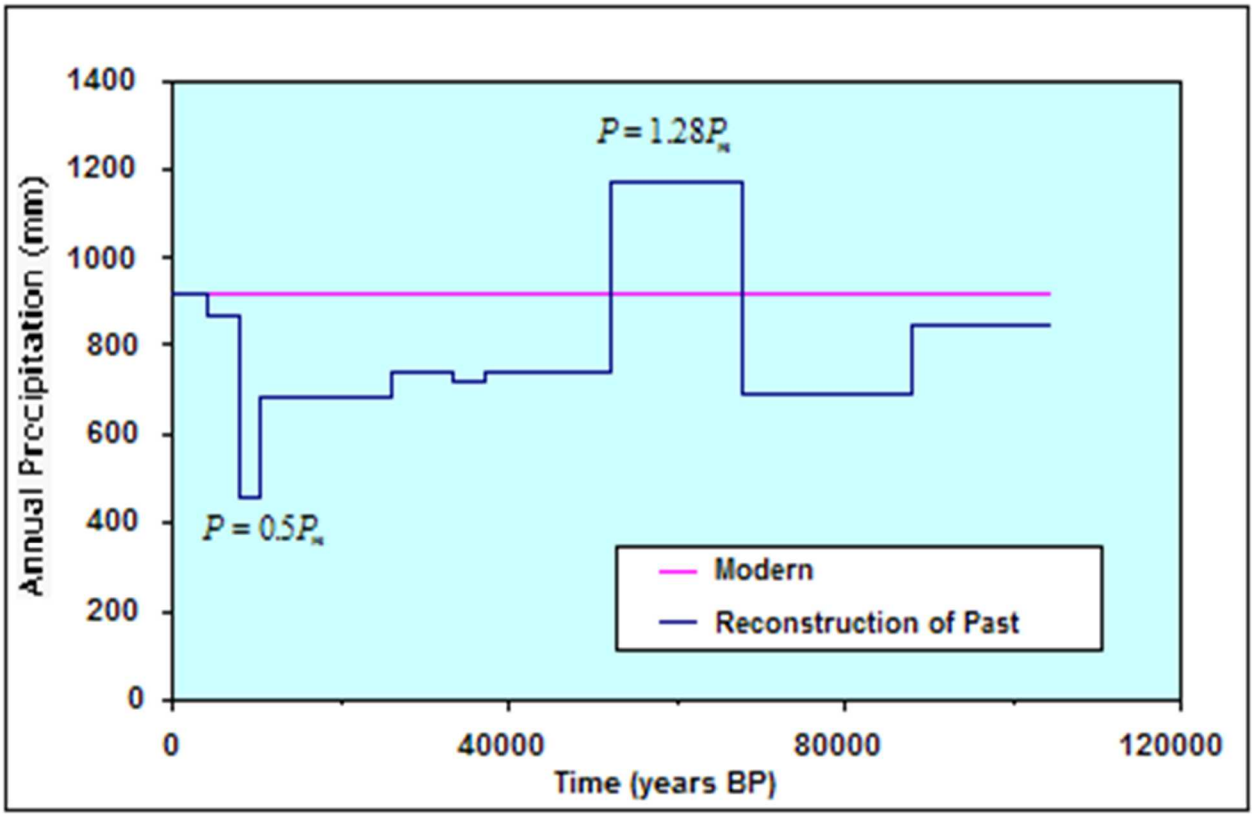
Pacific Northwest is 0.5 °F per decade until about 2050. Mote et al. 2008 estimated precipitation changes would range from -10% to +20% by the year 2080. They also noted that warming will be greater in summer than in the other seasons.

The Columbia Basin appears to be in an interglacial cooling period that began ~6,000 years ago and is expected to continue for the next 5,000 to 10,000 years (PNL-10788, "*The Role of Plants and Animals in Isolation Barriers at Hanford, Washington*"). While human activity may influence the change in climate, it cannot prevent the ultimate onset of the next ice age (PNL-10788). For an analysis of recharge in the 200 East Area, PNNL-13033 represented future climate conditions by scaling the current temperature and precipitation data to match paleoclimate observations derived from pollen data. "Vegetation and climate change in northwest America during the past 125 kyr" (Whitlock and Bartlein 1997) described a 125,000-year paleoclimate record constructed from the pollen record in cores taken from Carp Lake, near Goldendale, Washington. Carp Lake is located ~175 km southwest of the Hanford Site, at an elevation of 714 m. Similar pollen records at the Hanford Site were eliminated during the glacial flooding 13,000 years ago. Thus, Carp Lake provides a proxy for paleoclimate information. BHI-00144, "*Long-Term Climate Change Effects Task for the Hanford Site Permanent Isolation Barrier Development Program: Final Report*" described the Carp Lake pollen interpretation relative to precipitation and temperature. For the entire Holocene (i.e., the last 10,000 years), the data suggest that annual temperatures and precipitation ranged from 0 to 2.8°C warmer and 0% to 50% drier compared to modern climate. During the glacial period prior to the Holocene, annual temperatures ranged from 0.2 °C warmer to 2.5 °C cooler and precipitation ranged from 75% to 128% of modern levels. In summary, for the last 100,000 years, annual precipitation ranged from 50% to 128% of modern levels and annual temperatures ranged from -2.5 to 2.8 °C (-4.5 to 5 °F) of modern levels. These ranges appear to bracket the latest estimates for precipitation and temperature changes in the Pacific Northwest. Figure 4-5 and Figure 4-6 illustrate the pollen-derived precipitation and temperature records, respectively. Based on the Carp Lake data, it was concluded that there is no evidence that the long-term precipitation average ever reached 3 times that of modern levels, which has been taken as the upper bounding annual amount to test the prototype barrier (BHI-00007).

It should be noted that the current average annual precipitation at the Hanford Site (178 mm [6.98 in.]) (PNNL-15160, "*Hanford Site Climatological Summary 2004 with Historical Data*") is near the range associated with sagebrush-dominated ecosystems (200 to 500 mm/yr) (U.S. Department of Agriculture, Natural Resources Conservation Service, Queried 12/18/2015, [Fact Sheets & Plant Guides/Artemisia tridentata ssp. tridentata] http://plants.usda.gov/plantguide/pdf/pg_artrt.pdf). Therefore, a factor of 1.28 increase in the annual precipitation increases the annual amount to 228 mm/yr, which is still lower than the average (i.e., 350 mm/yr) of the range (200 to 500 mm/yr). The water usage cycle of sagebrush—its ability to photosynthesize very early in the spring, mine water at depth, and curtail its photosynthetic activity and shed leaves to reduce moisture loss during the summer—give it an adaptive advantage over sod-forming grasses. These characteristics also allow it to coexist with Pacific Northwest bunchgrasses that are ideally suited to take advantage of the secondary spring maxima, and then die back during the summer drought (PNL-10788).

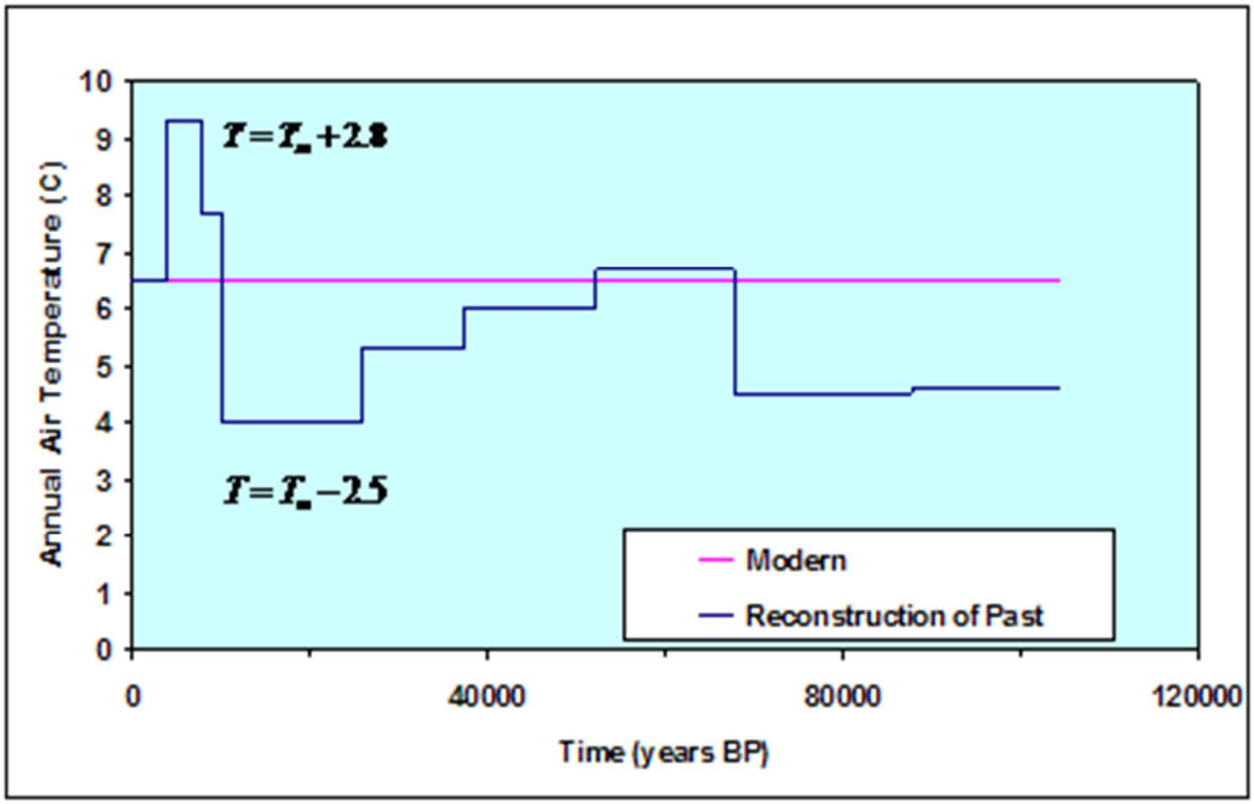
The sensitivity-uncertainty period of analysis extends to 10,000 years. Therefore, impacts to the safety functions of the vadose zone caused by climate change during the evaluation period are plausible. However, climate change is not likely to affect the safety functions of the vadose zone appreciably. Recharge rates applied to the design and post-design periods of the modeling are likely to remain unchanged, even if the precipitation increases as a consequence of climate change. Long-term climate studies indicate that for the last 10,000 years precipitation ranged from 0% to 50% less than current levels, and ranged between 75% and 128% of modern levels during the glacial period before the Holocene (PNNL-13033, pp. C.9). The average annual precipitation (172.2 mm [6.78 in.]) at the Hanford Site for 1981 to 2010 is actually less than the lower end of the range typically associated with sagebrush-dominated ecosystems (200 to 500 mm/yr [7.87 to 19.69 in.], U.S. Department of Agriculture 12/18/2015). Thus, the sagebrush community appears capable of exploiting any increases in soil moisture caused by increases in the annual precipitation consistent with or even in excess of the previous glacial period.

Figure 4-5. Precipitation Reconstruction for Past 100,000 years Based on Pollen Data.



BP = Before Present

Figure 4-6. Temperature Reconstruction for Past 100,000 years Based on Pollen Data.



BP = Before Present

This page intentionally left blank.

5.0 WASTE MANAGEMENT AREA A-AX CLOSED FACILITY PERFORMANCE

As of 2017, WMA A-AX stored 1.389 million gallons of waste in SSTs (HNF-EP-0182 Rev. 348) and contained additional waste in ancillary equipment (RPP-RPT-58293). The majority of the waste in the SSTs in WMA A-AX will be retrieved, treated onsite, and properly disposed, either onsite (as low-activity waste) or in a deep geologic repository (as HLW). The DOE is bound by HFFACO (Ecology et al. 1989) with the State of Washington Department of Ecology and the U.S. Environmental Protection Agency to retrieve at least 99% of the waste or as much as can be retrieved with available technology. Waste that cannot be retrieved from the tanks using available retrieval technologies will be left in place. Most of this residual waste is expected to be present on the bottom of each tank in a layer no more than an inch (2.54 cm) thick. However, some waste may be attached to the tank walls and other objects remaining in the tanks after waste retrieval (e.g., risers, circulation pumps, liquid level sensors and supports). As part of the closure process, the retrieved tanks will be filled with grout to maintain the physical integrity of the tanks and limit water access to the residual waste.

Below grade tanks and equipment will be grouted when feasible to structurally stabilize residual waste and fill void spaces. Pipelines are assumed not to be grouted because complete grouting is assumed not to be feasible. It has not been demonstrated whether grouting the space around pipelines within encasements in WMA A-AX is feasible or necessary. Assumptions of whether or not other types of ancillary equipment (catch tanks, vaults, diversion boxes, valve pits, etc.) will be grouted will need to be developed based on dimensions and operational information. Grouting of the tanks and accessible ancillary equipment is intended to stabilize these structures (prevent collapse) and to minimize the release of radionuclides. The specific formulation of the grout has not yet been established, but consistent with DOE/EIS-0391, the fill material for the tanks will be similar to the cold-cap grout formulation developed by the U.S. Army Corps of Engineers for the Hanford Grout Vault Program.

In each SST, grout will occupy a space within the steel liner ~10 m (~32.8 ft) and 22.86 m (75 ft) in diameter, as well as the space between the top of the liner and the dome. The height of the steel liner is 32 ft 4 in. (~32.33 ft) in the A Farm SSTs (Figure 3-23) and 32.5 ft in the AX Farm SSTs (Figure 3-24 and Figure 3-26). The space from the top of the liner to the dome is up to 12 ft high in both designs. Any in-tank equipment remaining at closure is assumed not to affect the fill grout either positively or negatively.

A key set of assumptions for the closed facility includes the following.

- Facility Closure – The WMA A-AX tanks will be filled with grout according to the basic assumptions outlined for landfill closure in the Tank Closure and Waste Management Environmental Impact Statement (DOE/EIS-0391) and the December 13, 2013 Record of Decision (78 FR 75913).

- Demolition and Decommissioning Activities – All above grade facilities, equipment, utilities, and tank farm features are dispositioned, and all existing drywells and groundwater wells are decommissioned.

In the long term, the tank residual waste is a potential source of contamination to the subsurface environment when the tank containment system fails and infiltrating water leaches contaminants from the waste material. As part of the tank closure process and the PAs being conducted for the tanks, contaminant release models are being developed for the residual waste by studying its composition and leaching characteristics. Contaminant release characteristics along with degradation processes of the tank structure are discussed in the next few sections in the following manner:

- Contaminant Releases from Tank Waste Residuals (this section)
    - Previous work on release models
    - Technical approach and testing and characterization of tank waste residuals
    - Solid phase characterization of tank residuals
    - Estimate of contaminant release rates
    - Proposed release rates for WMA A-AX residual tank wastes

- Corrosion of steel components and elements of tanks and ancillary equipment (Section 6.0)

- Degradation of concrete and emplaced grout (Section 7.0).

Section 5.1 presents empirical evidence forming the basis for modeled contaminant releases from tank waste residuals. Section 5.2 summarizes the recommended model parameters determined from the empirical information and other assumptions.

5.1 BASIS FOR CONTAMINANT RELEASES FROM TANK WASTE RESIDUALS

Section 5.1.1 discusses releases of contaminants from residual wastes. Section 5.1.2 discusses the basis for the diffusion coefficients for the aqueous and air transport pathways. Section 5.1.3 discusses the basis for the sorption of contaminants of potential concern (COPCs) in the grout/concrete layer. Section 5.1.4 presents the basis for considering diffusive releases for the source term when tank structures and infill grout material are intact.

5.1.1 Source Term and Engineered Features

The processes associated with the release of contaminants into the pore waters of the material in the tank and ancillary equipment, and their migration from the residual waste matrix through the surrounding engineered barriers, are denoted as the “source term” in PA modeling. Information is included for source terms for both radionuclides and non-radionuclides that have been empirically demonstrated to interact with components of the engineered system beyond the common assumptions employed for most COPCs.

The objective of this section is to present the mathematical description of the processes implemented for modeling the release of COPCs from the waste form (source) through the engineered features (tank) to the near-field just outside the tanks and ancillary equipment. Much of the discussion below is excerpted from Chapter 6 of the WMA C PA (RPP-ENV-58782).

Because of the lack of characterization data for WMA A-AX residual wastes, the following discussion relies primarily on the extensive testing and analyses done for WMA C residual wastes. This is necessary as of 2017, because unlike the WMA C PA, the initial WMA A-AX PA is deliberately being completed before any tanks in the WMA have been retrieved; thus, characterization of tank-specific residuals will not be possible until future updates to the PA. Use of WMA C residuals as a proxy may be reasonable, or alternative assumptions may be made such as immediate availability of all residual inventory of all waste constituents for transport (i.e., complete and instantaneous solubility). The latter are mathematically simple, pure assumptions that do not have an empirical basis requiring lengthy explanation; therefore, the discussion in this data package is focused on use of the WMA C residuals while recognizing that other assumptions could possibly serve the objectives of the initial PA.

There are differences between the wastes historically stored at WMA A-AX versus WMA C and in the retrieval technologies to be deployed, each of which may lead to different chemical compositions or physical properties in WMA A-AX residuals than those of the WMA C residuals for which data are available. WMA C residuals were sampled from the hard heel of sludge phases remaining after sluicing with a supernate solution and multiple rinses. Phases of wastes stored in WMA A-AX SSTs pending retrieval, which are reported in monthly updates to HNF-EP-0182, in some cases include significant amounts of saltcake in varying proportion to sludge. The first retrieval technology to be deployed for the AX Farm SSTs is sluicing using hot water, and cold water may also be used (RPP-RPT-58932 through RPP-RPT-58935); retrieval technologies have not been selected for A Farm as of 2018. It is expected that water sluicing will preferentially remove the most soluble waste constituents in each phase, leaving the least soluble contaminants in any residual phases; it is further expected that water will dissolve and preferentially remove most saltcake, whereas relatively insoluble sludge is more likely to dominate the material remaining in any residual phases of wastes that may escape being physically sluiced and pumped out of the tanks. The anticipated preferential removal of saltcake and dominance of sludge in WMA A-AX residuals supports the proposition that WMA C residuals are adequately similar for purposes of modeling contaminant release behaviors in the initial WMA A-AX PA. Use of water rather than supernate for sluicing may achieve greater dissolution of some contaminants from either sludge or saltcake due to a higher chemical concentration gradient, in which case assuming contaminant releases similar to WMA C residuals may potentially overestimate the availability of some soluble contaminants to be released from WMA A-AX residuals.

Some limited data relevant to dissolution of saltcake and resulting residual phases are available from the retrieval of tank 241-S-112 in the 241-S Tank Farm, the only saltcake SST retrieved as of 2018. Retrieval of 241-S-112 removed 95% of an initial 82,080 ft^3 of saltcake waste by dissolution with water and another 4% using a high-pressure water device, and after retrieving a small additional amount of waste by caustic leaching, a final volume of 319 ft^3 of waste residuals remained (RPP-RPT-35112, "*Retrieval Data Report for Single-Shell Tank 241-S-112*"). Post-retrieval sampling of the residual waste was conducted for various constituents to estimate the residual inventory, and analyses were reported in RPP-RPT-35112 and PNNL-17593, "*Hanford Tank 241-S-112 Residual Waste Composition and Leach Test Data*." Percent retrieval and residual composition results from 241-S-112 generally support the assumptions previously stated for saltcake retrieval at WMA A-AX.

While the tank (and ancillary equipment) grout infill material remains intact, it is assumed that releases occur by diffusion through the base of the tank base mat, consisting of grout and concrete layers. For volatile contaminants released from the residual wastes, it is assumed that their transport through the tank infill grout material and the soil overburden is controlled by upward diffusion.

Both mineral phase solubility-limited and matrix-degradation-rate-limited processes are considered for the key analytes. These have been studied in detail in the laboratory, and the laboratory results have been incorporated in the source term analysis. In particular, the following release models are considered, which are based on empirical evidence:

- a matrix-degradation-rate-based release of ^{99}Tc,
- solubility-controlled releases of uranium, and
- solubility-controlled releases of chromium.

In the three subsections that follow, the empirical evidence for the release models for ^{99}Tc, uranium, and chromium is established. Detailed leaching studies have been conducted on tank residual samples focused on leaching behavior of these key COPCs. Based on evaluation of the results, models based on solubility control or matrix degradation are considered for PA calculations for ^{99}Tc, isotopes of uranium, and chromium, as discussed below. Although testing of WMA C residuals for release of ^{99}Tc provides evidence for matrix-degradation-rate-limited processes, the default assumption of instantaneous solubility of ^{99}Tc could be used as the primary release model for initial PA calculations, because it would be expected to yield a higher release rate in the first 1,000 years after closure. For all other COPCs, a release model is assumed in which the inventory is completely available in solution within the residual waste volume and available for an immediate release; this default release model is anticipated to yield earlier arrival of COPCs at the water table and higher groundwater concentrations than alternative models that might be developed if empirical data were available for more COPCs.

5.1.1.1 Source Release Model for Technetium-99. The matrix-degradation-rate-based release model developed for ^{99}Tc is based on the results of the single-pass flow-through (SPFT) experiments conducted on residual waste in tanks 241-C-103 (C-103), 241-C-202 (C-202), and 241-C-203 (C-203) (Chapter 6, RPP-ENV-58782). The experimental setup and analyses results are presented in PNNL-20616, "*Contaminant Release from Hanford Tank Residual Waste – Results of Single-Pass Flow-Through Tests*" and in "Single-pass flow-through test elucidation of weathering behavior and evaluation of contaminant release models for Hanford tank residual radioactive waste" (Cantrell et al. 2013). These tests were conducted under low flow conditions (~0.1 mL/hr [0.06 in.^{3}/hr]) for a period of about six months with no stirring of residual waste in the solution. The initial solution-to-solid weight ratio is 120 (based on 0.06 L [0.016 gal] of initial solution in contact with 0.5 g [0.018 oz] sample), and the residence time of the solution in the reaction vessel was calculated to be 25 days. The initial concentrations of ^{99}Tc reported in the samples were: 0.23 µg/g (0.0081 oz/ton) for tank C-103, 0.23 µg/g (0.0081 oz/ton) for tank C-202, and 0.11 µg/g (0.0039 oz/ton) for tank C-203. Appendix A of PNNL-20616 provides the complete tabulation of the analytical results that are relevant to the PA for the

three leachates—namely, deionized (DI) water, $CaCO_3$ saturated solution, and 0.005 M $Ca(OH)_2$ solution. The results of the leaching for the three tank residual waste samples are presented in Figure 5-1 through Figure 5-3. The ^{99}Tc concentrations in all three leachates are very similar, with the concentrations appearing to drop off exponentially with increasing solution-to-solid ratio. The initial sample concentration was low because the leachate solutions contained no ^{99}Tc.

The results of the SPFT experiments were further analyzed to quantify the fractional leaching rate of ^{99}Tc using the 0.005 M $Ca(OH)_2$ solution, since it is expected that infill grout will condition the chemistry of incoming waters for a very long time period.

a) The results presented in Table A of PNNL-20616 in terms of solution-to-solid ratio are first converted to elapsed time (in days), based on 25 days of residence time in the reaction vessel being equivalent to 120 initial solution-to-solid ratio.

b) The initial concentration of ^{99}Tc in the residual waste sample is used, along with the mass of the sample, to estimate the initial ^{99}Tc mass (in terms of grams).

c) Based on reported ^{99}Tc concentrations (µg/L) in the effluent, the cumulative mass of ^{99}Tc leached is calculated and then converted to fraction of initial mass leached. From this, the fraction of mass remaining in the solid sample is calculated as a function of time.

d) An exponential trend line is fitted to the fraction remaining (as a function of time) and the rate constant is derived (in units of day^{-1}), which represents a first-order release rate from the solid to the solution. The trend line is fitted to the dataset following flushing of resident vessel volume (approximately 25 days) and while the concentrations are above the detection limit.

The fraction remaining for ^{99}Tc along with the fitted trend line results are presented in Figure 5-4 through Figure 5-6. The results indicate that the first-order reaction rate constant defining the release of ^{99}Tc from the residual waste varies over a narrow range of 5×10^{-4} to 8×10^{-4} day^{-1}. This rate constant reflects the longer-term rate of release of ^{99}Tc following the initial release as noted by the early spike in concentration in Figure 5-1 through Figure 5-3. The percent ^{99}Tc leached from the various SPFT experiments varied from 4.5 to 15% (see Table 5-3 in RPP-ENV-58782) and is influenced more by the particular sample type than by the type of the leachate.

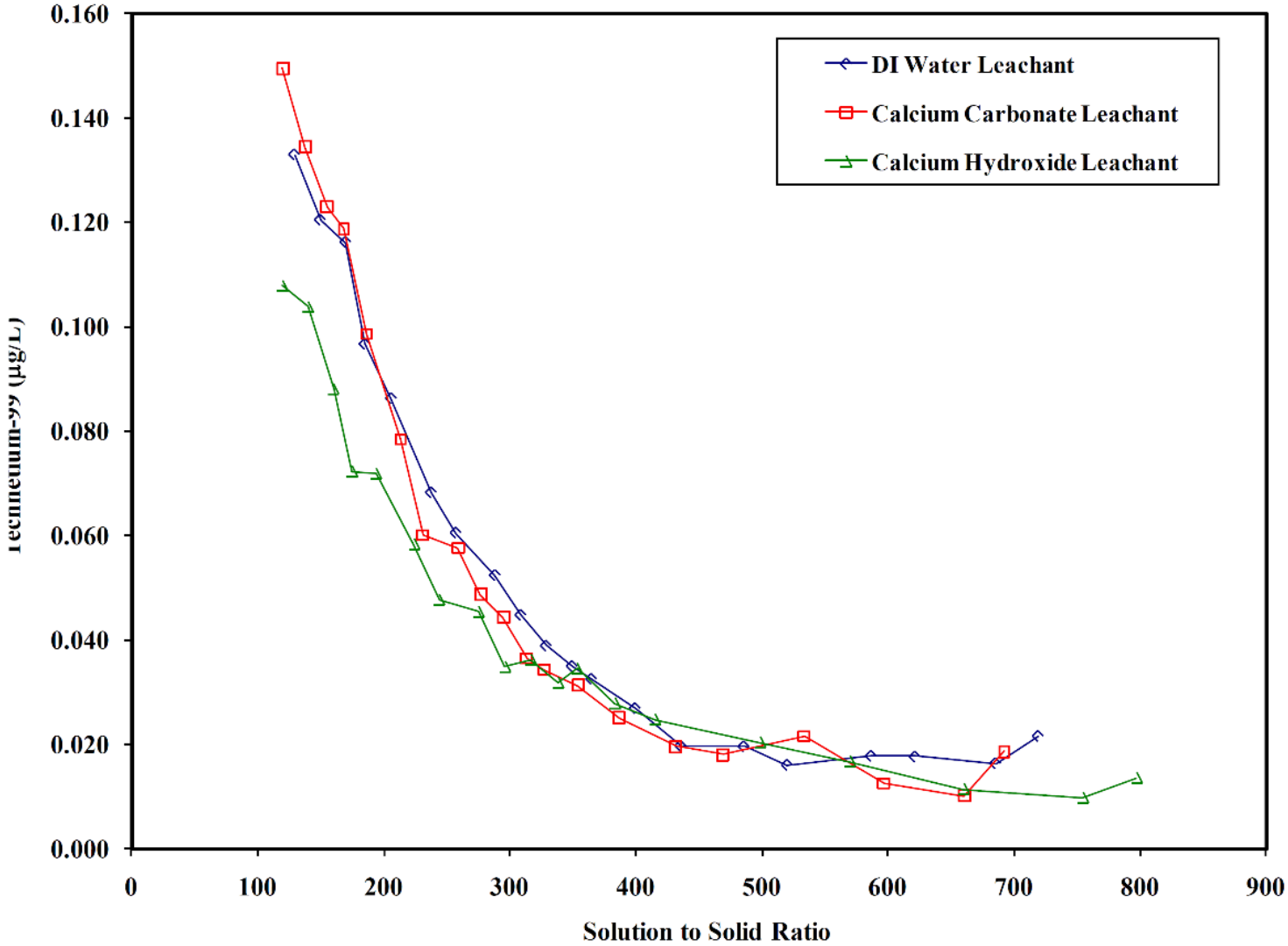
To make the source release model for ^{99}Tc consistent with the observations, an initial 6% fraction of the ^{99}Tc inventory is considered to be instantaneously available for release, while the remaining 94% fraction undergoes relatively slower release at the fractional rate of 6×10^{-4} day^{-1}. These estimates of parameters are implemented in the WMA C PA and are expected to be adequately representative for WMA A-AX residuals as well. The uncertainty in the initial release fraction and the fractional release rate is evaluated separately (Section 8 in RPP-ENV-58782).

In order to evaluate the adequacy of the ^{99}Tc release model, a calculation is performed using the estimated parameters to simulate the release of ^{99}Tc from the SPFT experiments, which were

then compared to the observed concentration in C-103 and C-202 tank effluents. The calculation setup is similar to the reactor vessel volume and flow rate used for doing the SPFT experiments. The results of the calculations are presented in Figure 5-7, indicating that the estimated parameters capture the release of ^{99}Tc (green line) and lead to higher dissolved concentrations for calculating the diffusive flux.

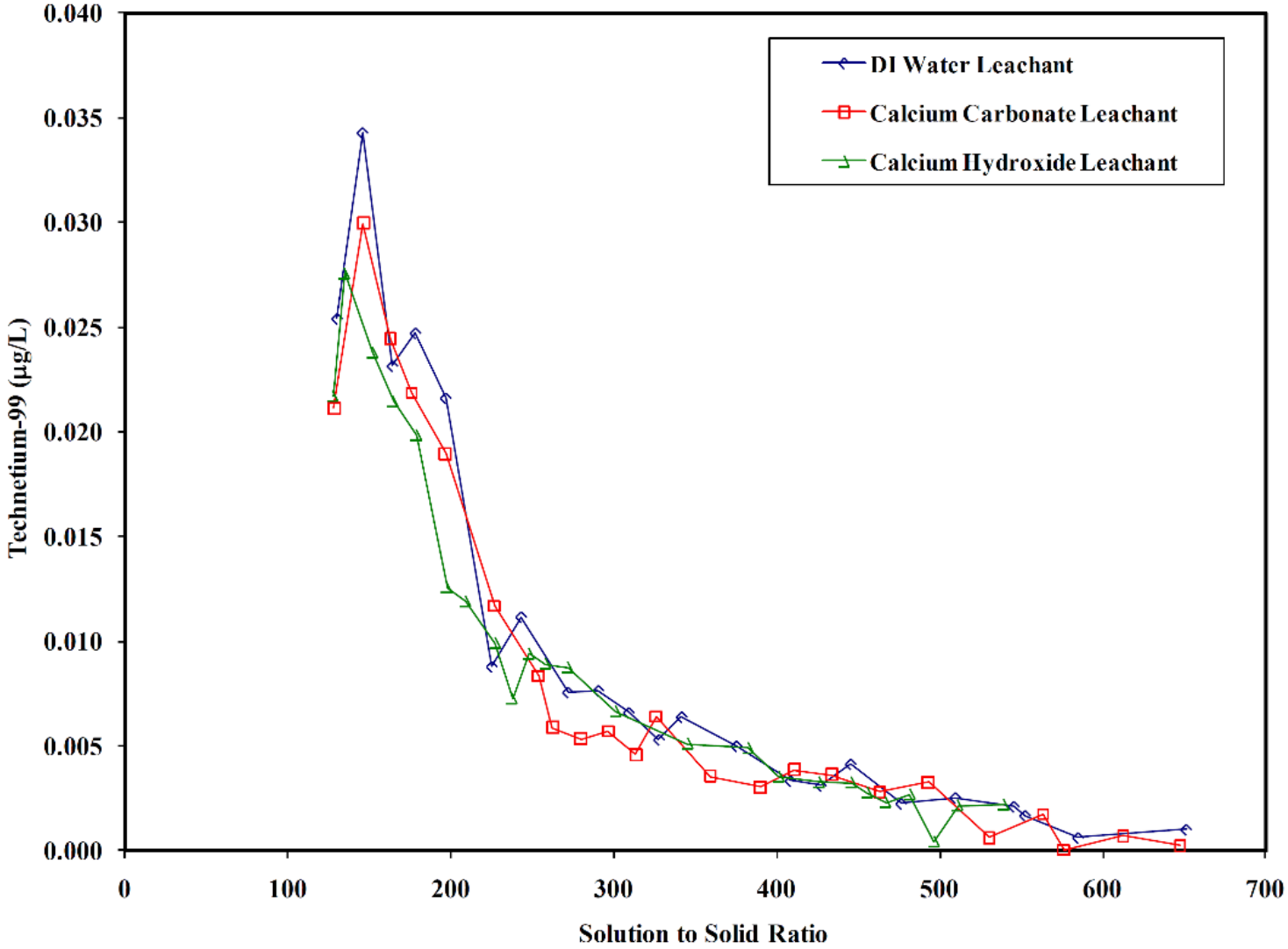
5.1.1.2 Source Release Model for Uranium. Laboratory leaching tests have been conducted on residual waste samples from various tanks in WMA C. Cantrell et al. (2013) provided the analysis of residual waste following leaching with three different leachates—namely, DI water, $CaCO_3$ saturated solution, and 0.005 M $Ca(OH)_2$ solution. These three leachates represent a range of possible water types contacting the residual waste. The $CaCO_3$ saturated solution was used to simulate a leachate produced by aged carbonate cement or a typical Hanford vadose zone pore water, 0.005 M $Ca(OH)_2$ solution was used to represent the likely influence of interaction of infiltrating vadose zone pore water with portlandite [$Ca(OH)_2$] in the grouted tanks, and the DI water was used as a baseline for the leach tests to evaluate the influence of waters that have not been altered by reactions with the $Ca(OH)_2$ and $CaCO_3$ leachates.

Figure 5-1. Technetium-99 Concentration in Single-Pass Flow-Through Leachates for Tank 241-C-103 as a Function of the Total Volume of Leachate that has Contacted the Waste in Terms of Leachate Solution to Solid (Initial) Weight Ratio.



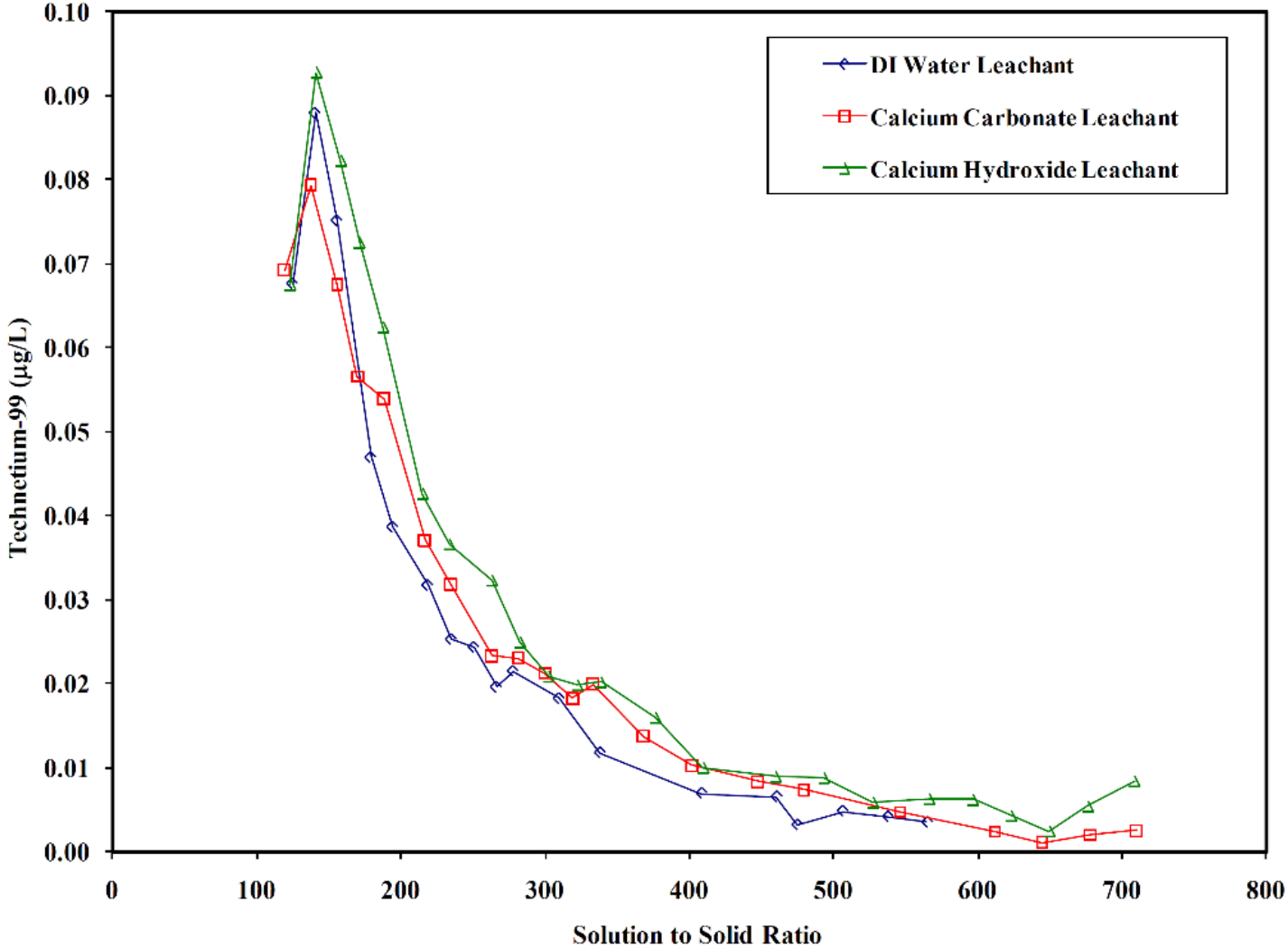
DI = deionized
Reference: RPP-ENV-58782, "*Performance Assessment of Waste Management Area C, Hanford Site, Washington*," Chapter 6.

Figure 5-2. Technetium-99 Concentration in Single-Pass Flow-Through Leachates for Tank 241-C-202 as a Function of the Total Volume of Leachate that has Contacted the Waste in Terms of Leachate Solution to Solid (Initial) Weight Ratio.



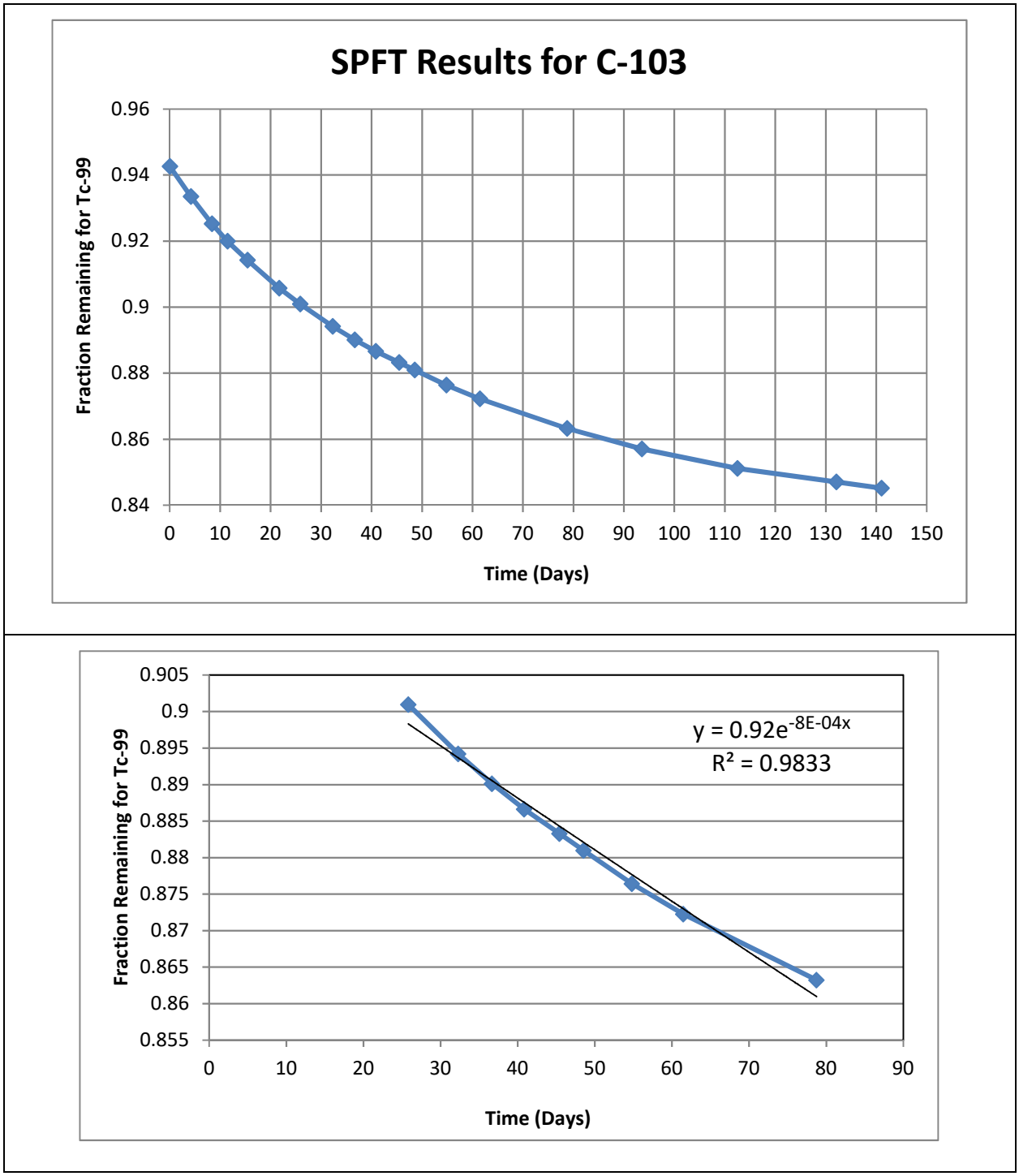
DI = deionized
Reference: RPP-ENV-58782, "*Performance Assessment of Waste Management Area C, Hanford Site, Washington*," Chapter 6.

Figure 5-3. Technetium-99 Concentration in Single-Pass Flow-Through Leachates for Tank 241-C-203 as a Function of the Total Volume of Leachate that has Contacted the Waste in Terms of Leachate Solution to Solid (Initial) Weight Ratio.



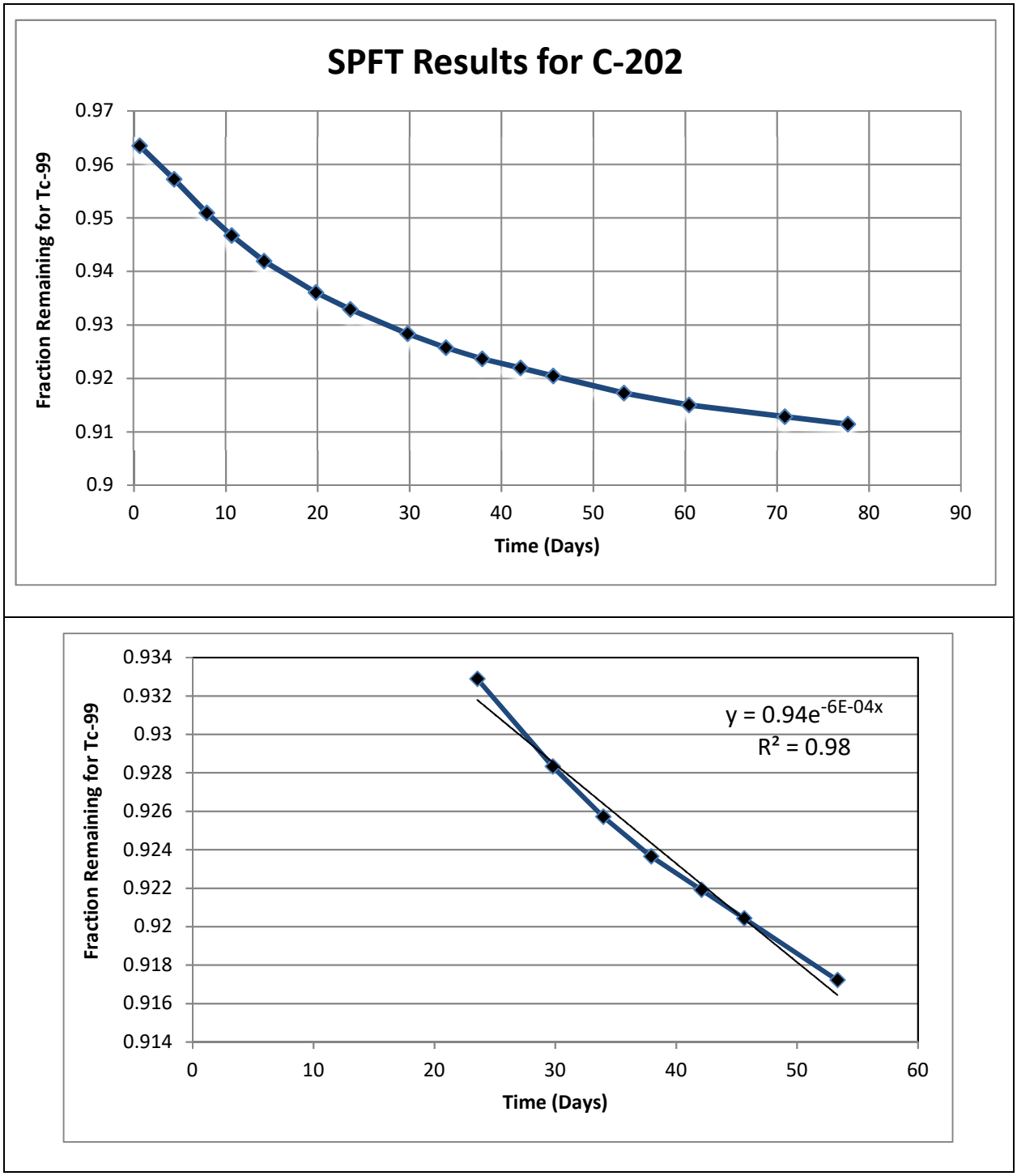
DI = deionized
Source: PNNL-20616, "*Contaminant Release from Hanford Tank Residual Waste – Results of Single-Pass Flow-Through Tests*."
Reference: RPP-ENV-58782, "*Performance Assessment of Waste Management Area C, Hanford Site, Washington*," Chapter 6.

Figure 5-4. Fractional Release of Technetium-99 for Single-Pass Flow-Through Experiments from Tank 241-C-103 Along with the Estimate of the First-Order Reaction Rate Constant of 8E-04 day^{-1}.



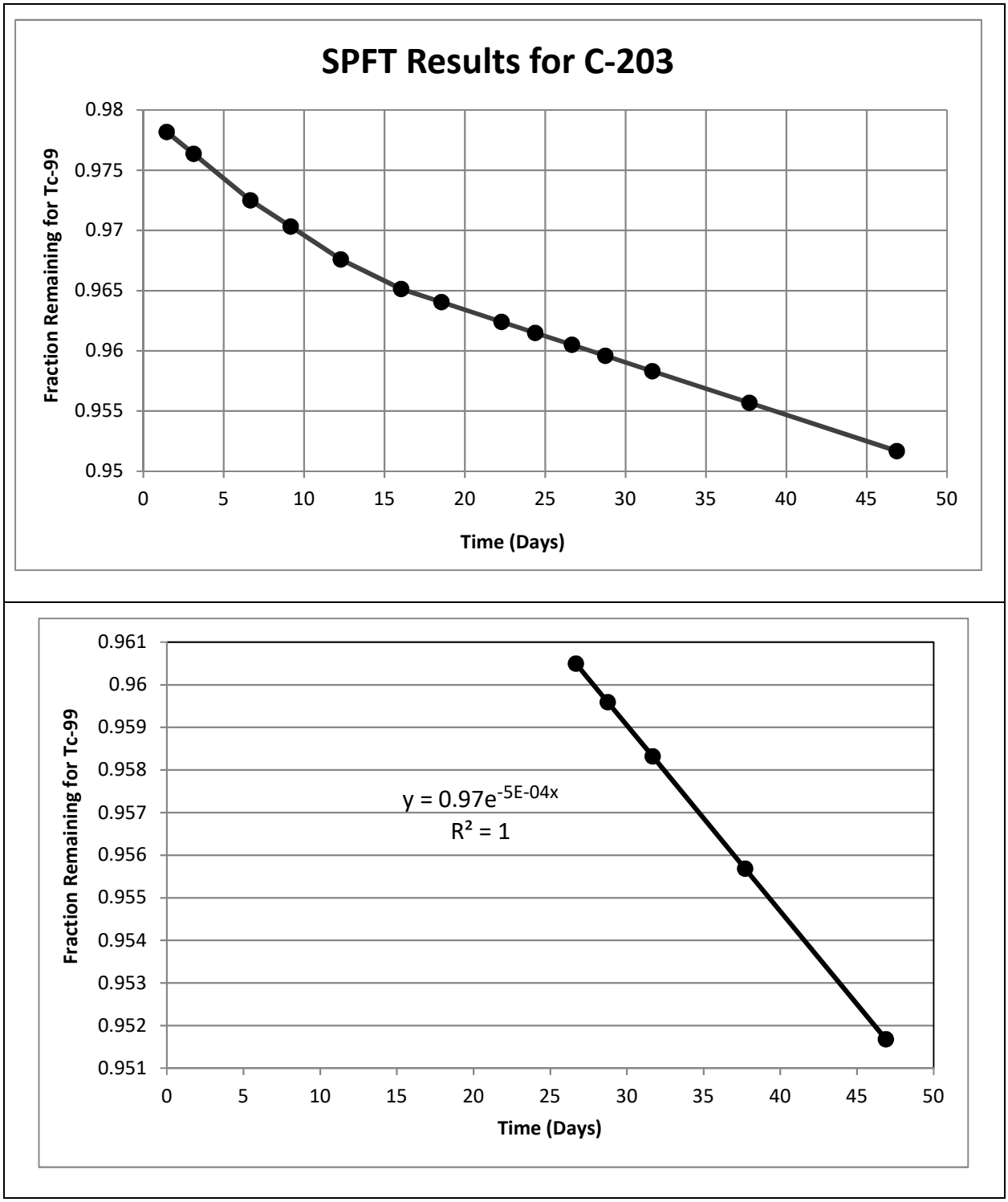
SPFT = Single-Pass Flow-Through
Reference: RPP-ENV-58782, "*Performance Assessment of Waste Management Area C, Hanford Site, Washington*," Chapter 6.

Figure 5-5. Fractional Release of Technetium-99 for Single-Pass Flow-Through Experiments from Tank 241-C-202 Along with the Estimate of the First-Order Reaction Rate Constant of 6E-04 day^{-1}.



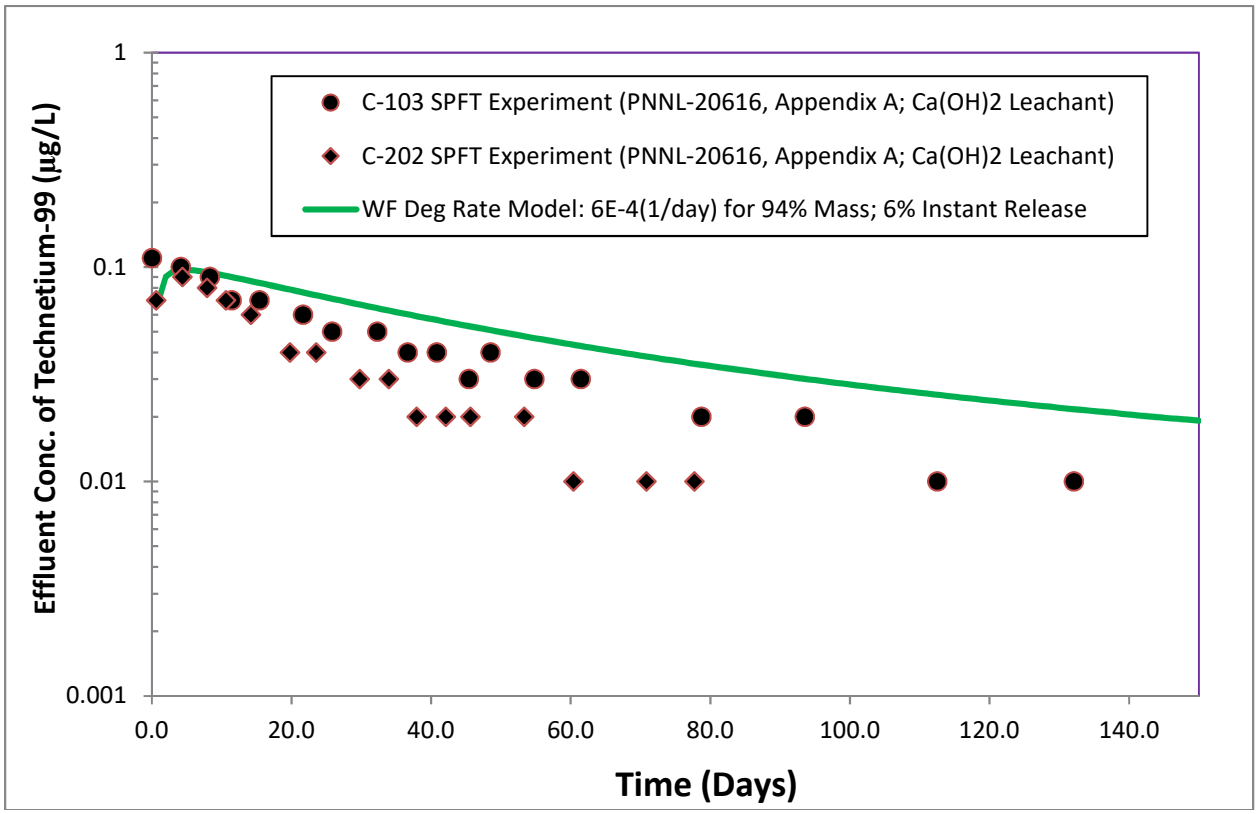
SPFT = Single-Pass Flow-Through
Reference: RPP-ENV-58782, "*Performance Assessment of Waste Management Area C, Hanford Site, Washington*," Chapter 6.

Figure 5-6. Fractional Release of Technetium-99 for Single-Pass Flow-Through Experiments from Tank 241-C-203 Along with the Estimate of the First-Order Reaction Rate Constant of 5E-04 day^{-1}.



SPFT = Single-Pass Flow-Through
Reference: RPP-ENV-58782, "*Performance Assessment of Waste Management Area C, Hanford Site, Washington*," Chapter 6.

Figure 5-7. Simulated Versus Observed Effluent Concentrations of Technetium-99 (µg/L) from the Single-Pass Flow-Through Experiments Conducted on Tanks 241-C-103 and 241-C-202 Residual Waste. The simulated concentrations are based on best-estimate release parameters from residual waste.



SPFT = Single-Pass Flow-Through
References:
PNNL-20616, "*Contaminant Release from Hanford Tank Residual Waste – Results of Single-Pass Flow-Through Tests*."
RPP-ENV-58782, "*Performance Assessment of Waste Management Area C, Hanford Site, Washington*," Chapter 6.

The general trends in uranium leachate concentrations for the C-103, C-202, and C-203 tank residual wastes were very similar. The results are presented for tank C-202 in Chapter 5, Figure 5-8, RPP-ENV-58782. The leached uranium concentration using DI water and $CaCO_3$ saturated solution were significantly higher than those in the 0.005 M $Ca(OH)_2$ leachates. This is attributed to formation of Ca-rich precipitates (Ca phosphate and calcite) on the surfaces of the waste particles when using $Ca(OH)_2$ leachate, inhibiting dissolution of the underlying uranium phases in the waste. Since the tanks are planned to be grouted prior to closure, the primary leachate is expected to be $Ca(OH)_2$ saturated solution ("Hanford tank residual waste – Contaminant source terms and release models" [Deutsch et al. 2011]), which is likely to reduce the leaching of uranium.

To investigate this leaching behavior, thermodynamic equilibrium modeling was conducted. The saturation indices (SIs) calculated for the tank C-202 SPFT effluents for the three leachates indicated that DI water and $CaCO_3$ saturated leachate give similar SI results, while the $Ca(OH)_2$

leachate SI results are quite different. Results from DI water and $CaCO_3$ saturated leachates indicate that $NaUO_2PO_4.xH_2O$ is near equilibrium while Ca-containing phases (such as calcite and hydroxylapatite) were all undersaturated. The SI results for the $Ca(OH)_2$ leachates indicate all uranium-bearing phases to be highly undersaturated but are near-saturated or oversaturated with respect to Ca-containing phases. Calcite was near saturation, while hydroxylapatite and flourapatite were consistently highly oversaturated.

These results are consistent with the observed leaching behavior of uranium. It is hypothesized that precipitation of Ca-rich phases resulted in coatings on the waste particles that could have temporarily inhibited dissolution and attainment of equilibrium for any uranium phase in contact with $Ca(OH)_2$ leachate solutions.

These results indicate that as long as the infiltrating water though the tank passes through the infill grout material, it will be conditioned to be similar to a dilute $Ca(OH)_2$ leachate solution and the uranium dissolution will remain inhibited (Cantrell et al. 2013). At some distant time in the future when the tank is assumed to be sufficiently degraded such that large open fractures develop that do not allow appreciable residence time for infiltrating waters to contact and equilibrate with the grout material, the leachate would be similar to the $CaCO_3$ saturated water, and at that time the uranium concentrations may increase when the residual waste is contacted.

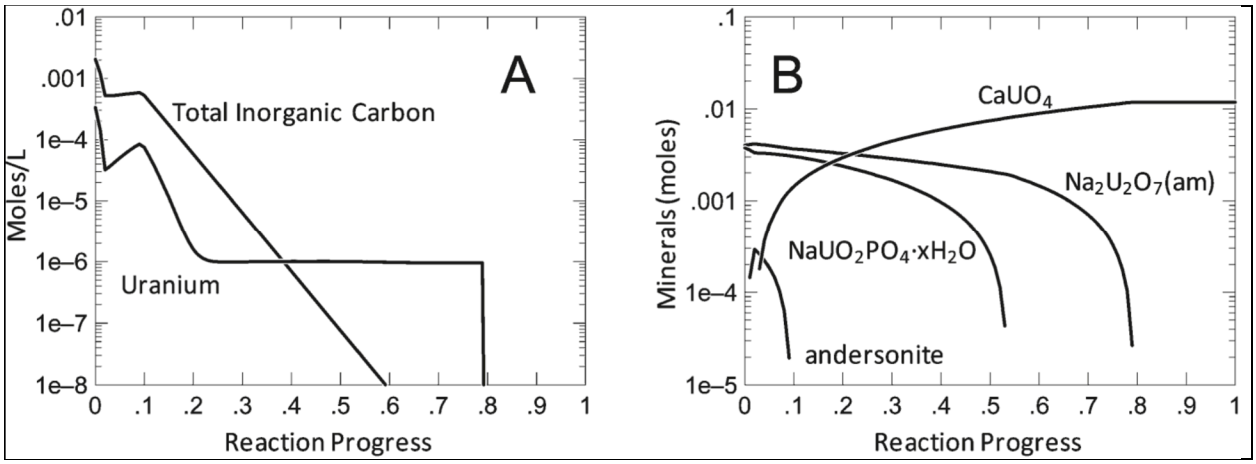
Reaction-path modeling was undertaken in "Thermodynamic Model for Uranium Release from Hanford Site Tank Residual Waste" (Cantrell et al. 2011) to evaluate the uranium release under the $Ca(OH)_2$ and $CaCO_3$ saturated waters by applying an infiltration rate of 1 mm/yr (0.039 in./yr) through the tank material over 10,000 years. The steel of the tank itself was assumed to have no impact on the hydrology or system chemistry, and the waste was assumed to be uniformly distributed at the bottom of the tank. The results of this reaction-path modeling are summarized below.

For $Ca(OH)_2$ saturated water, the tank was assumed to be filled with cementitious material (i.e., concrete or grout), and the composition of the simulated pore water was assumed to be 0.015 M $Ca(OH)_2$ and 1×10^{-5} M SI. The results of the reaction progress in terms of the uranium and total inorganic carbon concentrations and the paragenetic sequence of uranium phases over the course of 10,000 years are shown in Figure 5-8. Initially, high uranium concentrations occur in solution (~3×10^{-4} M) because of high carbonate complexation of uranium, but concentrations decline rapidly and rebound somewhat as a small amount of andersonite [$Na_2CaUO_2(CO_3)_3.6H_2O$] first precipitates and then dissolves. As the reaction progress continues, $NaUO_2PO_4.xH_2O$ dissolved preferentially to $Na_2U_2O_7$(am). As carbonate continues to leach from the waste, uranium concentrations continue to decline until a plateau is reached at ~1×10^{-6} M. This occurs at the approximate point where $CaUO_4$ becomes the dominant phase. A dramatic reduction in uranium concentrations occurs when $Na_2UO_2O_7$ (am) dissolves completely, leaving $CaUO_4$ as the only phase to control uranium release concentrations. A reaction progress of 1.0 is equivalent to 1 mm/yr (0.039 in./yr) of flow for 10,000 years, and therefore represents 10,000 mm (394 in.) of flow.

A similar reaction progress modeling calculation for the $CaCO_3$ saturated waters is shown in Figure 5-9. Initial high uranium concentrations in solution (~3×10^{-4} M) occur because of high

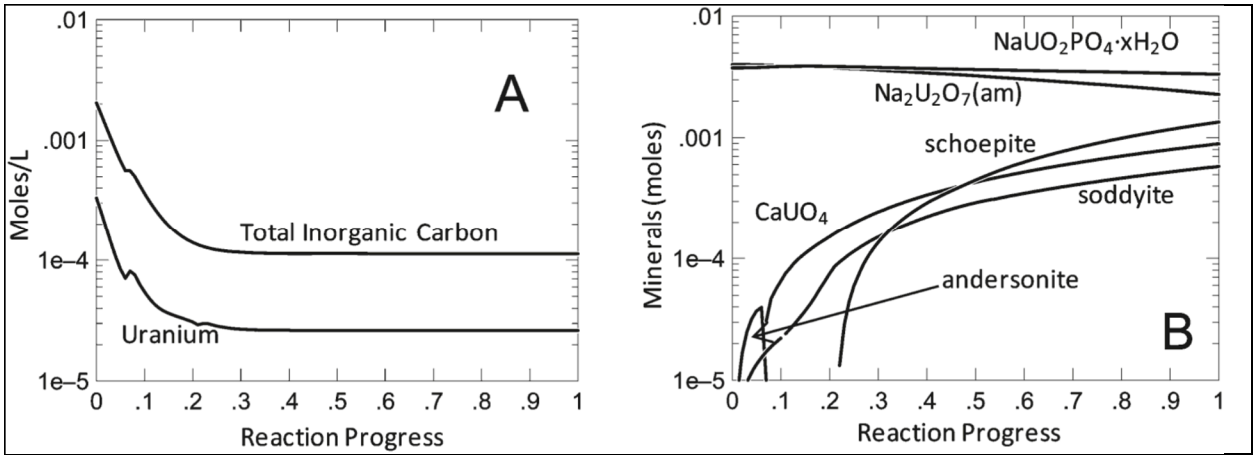
carbonate complexation of uranium due to soluble Na_2CO_3 or cejkaite [$Na_4(UO_2)(CO_3)_3$]. As very soluble carbonate phases dissolve, the uranium concentration of ~2.6×10^{-5} M is maintained primarily by dissolution of $NaUO_2PO_4.xH_2O$ and $Na_2U_2O_7$(am), although schoepite ($UO_3 \cdot 2H_2O$) also becomes important.

Figure 5-8. Uranium and Total Inorganic Carbon Concentrations (A) and the Paragenetic Sequence of Uranium Phases Present in the Waste (B) as a Function of Reaction Progress for the $Ca(OH)_2$ Saturated Water Scenario. A reaction progress of 1 is equivalent to 10,000 years of infiltration at 1 mm/yr.



Reference: RPP-ENV-58782, "*Performance Assessment of Waste Management Area C, Hanford Site, Washington*," Chapter 6.

Figure 5-9. Uranium and Total Inorganic Carbon Concentrations (A) and the Paragenetic Sequence of Uranium Phases Present in the Waste (B) as a Function of Reaction Progress for the $CaCO_3$ Saturated Water Scenario. A reaction progress of 1 is equivalent to 10,000 years of infiltration at 1 mm/yr.



Reference: RPP-ENV-58782, "*Performance Assessment of Waste Management Area C, Hanford Site, Washington*," Chapter 6.

Over the course of these simulations, 2% of the uranium in the waste is calculated to be dissolved in the $Ca(OH)_2$ saturated water, compared to 6.4% for the $CaCO_3$ saturated water.

This is attributed to the formation of relatively insoluble $CaUO_4$ phase under high Ca and high pH conditions.

The results of the reaction progress modeling were used in the WMA C PA to impose solubility limits for uranium. As a conservative calculation, it is assumed that the infill grout is not a barrier to flow through the tank, and the recharge rates imposed on the backfill material (0.5 mm/yr [0.019 in./yr] for the first 500 years and 3.5 mm/yr [0.138 in./yr] afterwards) are also the flow rates through the tanks, even though the rates are likely to be far lower due to lower permeability. Given these flow rates, it is calculated that in the 1,000-year post-closure compliance time period, a total of 2,000 mm (78.7 in.) of water would flow (0.5 mm/yr [0.019 in./yr] × 500 years + 3.5 mm/yr [0.138 in./yr] × 500 years). This is equivalent to a reaction progress of 0.2 presented in Figure 5-8 and Figure 5-9. Using this information, the following solubility controls were imposed on the uranium concentrations in the WMA C PA, as shown in Figure 5-10.

- Apply solubility limit of 1×10^{-4} M for 1,000 years (equivalent to reaction progress of 0.2) based on the assumption that amorphous uranium mineral phases such as $Na_2U_2O_7$(am) control the solubility.

- After 1,000 years, apply the solubility limit of 1×10^{-6} M, assuming $CaUO_4$ as the solubility-controlling mineral phase under $Ca(OH)_2$ saturated conditions (infill grout saturated and intact-tank conditions).

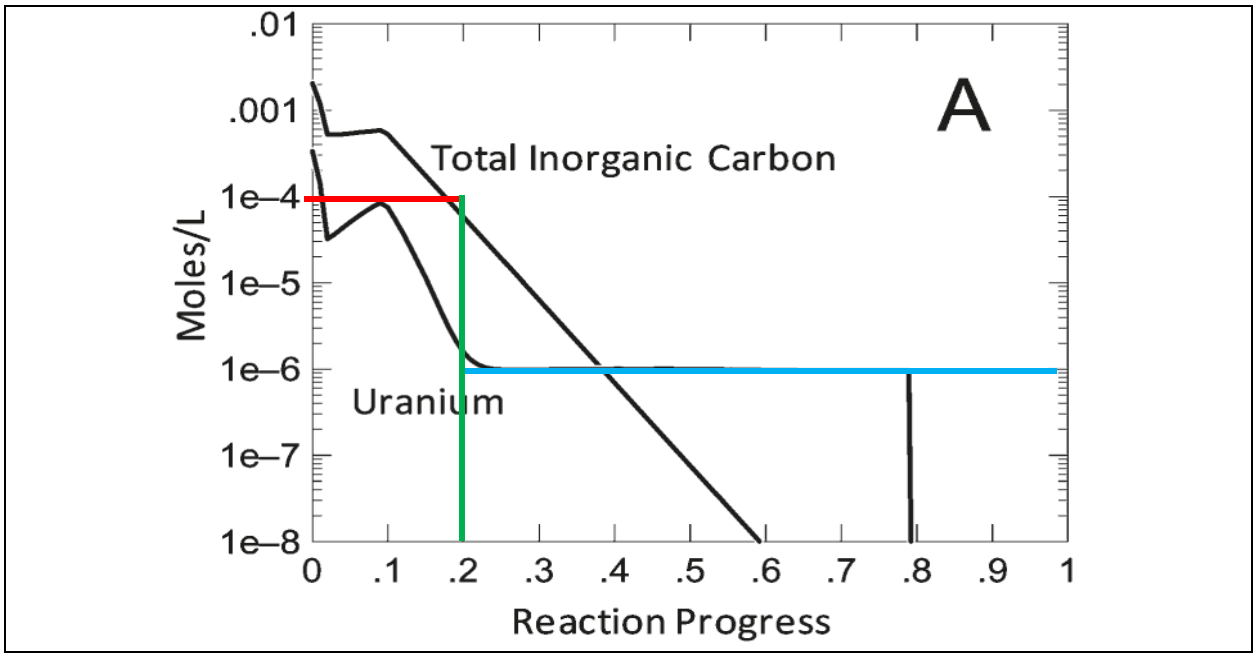
- If and when the tank is assumed to be degraded such that flow rates are fast enough not to equilibrate with the infill grout material and rather are $CaCO_3$ saturated (vadose zone water), then apply a solubility limit of 1×10^{-4} M for 1,000 years. Beyond this time, apply solubility limit of 2×10^{-5} M based on the long-term uranium concentrations shown in Figure 5-10, assuming minimal influence of $Ca(OH)_2$ water.

The reaction progress modeling calculations are performed under relatively static conditions. The SPFT tests discussed in Section 5.0 can be considered as analogous to column flow-through experiments. These are conducted under low flow conditions (~0.1 mL/hr [0.06 in.^{3}/hr]) for a period of about six months (at the sediment mass-to-solution ratio of 0.5 g [0.02 oz] to 0.06 L [3.66 in.^{3}]) with no stirring of the waste form in the solution. Even under these conditions, the application of the initial high solubility limit of 1×10^{-4} M is conservative for the 1,000-year time period. The SPFT test conducted on tank C-202 residuals (Figure 5-9) indicates that peak uranium concentrations for the $CaCO_3$ saturated water reached the solubility limit 1×10^{-4} M for a short duration at an early time, but later dropped to much lower numbers, and therefore represents a likely bounding uranium solubility value under all conditions at WMA C or WMA A-AX. This solubility limit can be imposed for pipeline releases as well, where the releases are likely to be advection dominated if pipelines are not grouted and encasements are ignored. This assumption is justified by the same logic about flow rates presented above.

5.1.1.3 Source Release Model for Chromium. Chromium concentrations in the three SPFT leachates (DI, $CaCO_3$, and $Ca[OH]_2$) are presented in Figure 5-12 for the C-202 and C-203 tank

residual waste samples (PNNL-20616). Results for C-103 tank residuals are not presented because most of the measured concentrations were below the detection limit of 5 ppb.

Figure 5-10. Uranium Solubility Model Implemented with Solubility Limits Varying with Time.



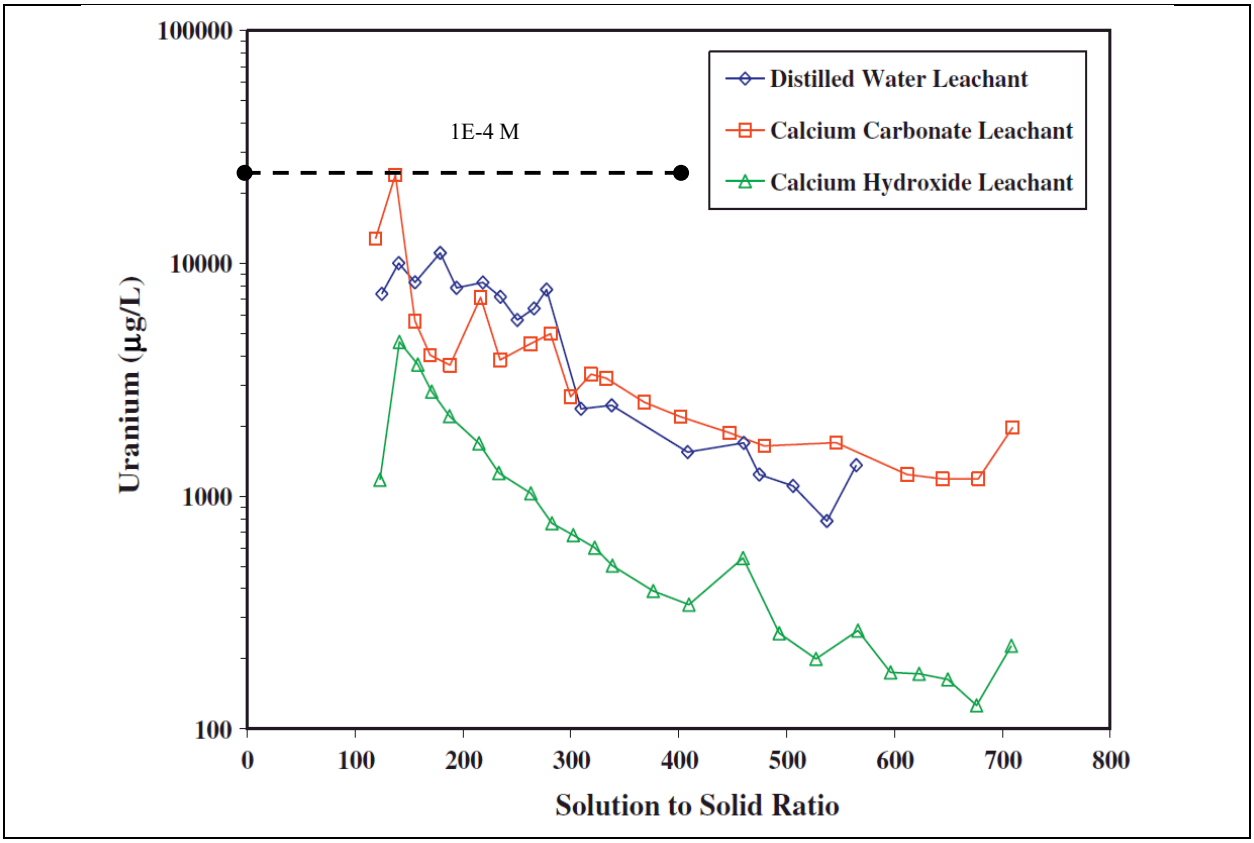
Reference: RPP-ENV-58782, "*Performance Assessment of Waste Management Area C, Hanford Site, Washington*," Chapter 6.
Note: Reaction progress of 0.2 is equivalent to 1,000 years of flow under recharge conditions through the backfill material assumed for the Waste Management Area C Performance Assessment.

Chromium in the SPFT leachates for tank C-202 residual waste shows relatively high release concentrations initially, with concentrations in the $Ca(OH)_2$ leachates being much higher than those of the DI water and $CaCO_3$ leachates. The relatively high concentrations of chromium in $Ca(OH)_2$ leachate were not found for tanks C-103 or C-203, and the reason for this difference is not readily apparent. These results indicate large variations in the chromium release characteristics, and perhaps reflect the variability in the chromium present in trivalent and hexavalent oxidation states along with association with iron oxides/hydroxides. Cantrell et al. (2013) hypothesized that some chromate may have been co-precipitated with phosphate in $NaUO_2PO_4.xH_2O$. As residual waste is leached with $Ca(OH)_2$, and portions of $NaUO_2PO_4.xH_2O$ are converted to $CaUO_4$, both PO_4 and CrO_4 are slowly released. The high chromium concentrations observed in the C-202 and C-203 tank leachates are indicative of chromium being released in the form of highly soluble chromate (CrO_4^{2-}), i.e., Cr(VI) oxidation state also known as hexavalent chromium. This is not the case for tank C-103 residual waste. The low concentrations observed in these leachates could be due to chromium being present in the Cr(III) oxidation state, also known as trivalent chromium, in the form of a $Cr(OH)_3$-$Fe(OH)_3$ solid solution (PNNL-20616).

These results indicate large variations in the chromium release characteristics, and perhaps reflect the variability in the chromium present in trivalent and hexavalent oxidation states, along

with association with iron oxides/hydroxides. For the purpose of the modeling calculations, a constant dissolved concentration limit of 2,000 µg/L is recommended. This value is at the high end of observed values in tank C-202 leachate and higher than maximum observed values in leachates of residuals from tanks C-103 and C-203.

Figure 5-11. Comparison of Initially Imposed Uranium Solubility Limit of 1 × 10^{-4} M to the Observed Concentrations during the Single-Pass Flow-Through Conducted on Tank 241-C-202 Residual Waste.



Reference: RPP-ENV-58782, "*Performance Assessment of Waste Management Area C, Hanford Site, Washington*," Chapter 6.

5.1.2 Effective Diffusion Coefficient for Transport Through Tank Structure

Observations of retrieved tanks show that the residual waste is primarily distributed on the tank bottoms (see Section 5.2 of RPP-RPT-42323, "*Hanford C-Farm Tank and Ancillary Equipment Residual Waste Inventory Estimates*"). Consequently, the residual waste is represented as a uniform layer at the base of the tank. Under the likely scenario, where tank wall integrity is maintained and the infill grout is not physically degraded, the primary contaminant transport process will be diffusive. The shortest diffusive pathway for release to the near-field environment is through the base of the tank as presented in Figure 5-13.

The diffusive thickness being considered for the A Farm SSTs is the 0.203-m (8-in.) combined thickness of concrete and grout layer located at the base of the tank (ignoring the overlying steel plate and the asphaltic layer between the concrete and grout). The diffusive thickness considered

for the AX Farm SSTs is the 0.445-m (17.5-in.) combined thickness of concrete and grout at the tank base along the drain slots (see Section 7.5). The aqueous phase diffusive transport will occur along the water phase within the pore spaces of the grout and concrete layer. The effective diffusion coefficient (which includes effects of tortuosity), concentration gradient, and sorption behavior within the grout and concrete layer control the diffusive mass flux.

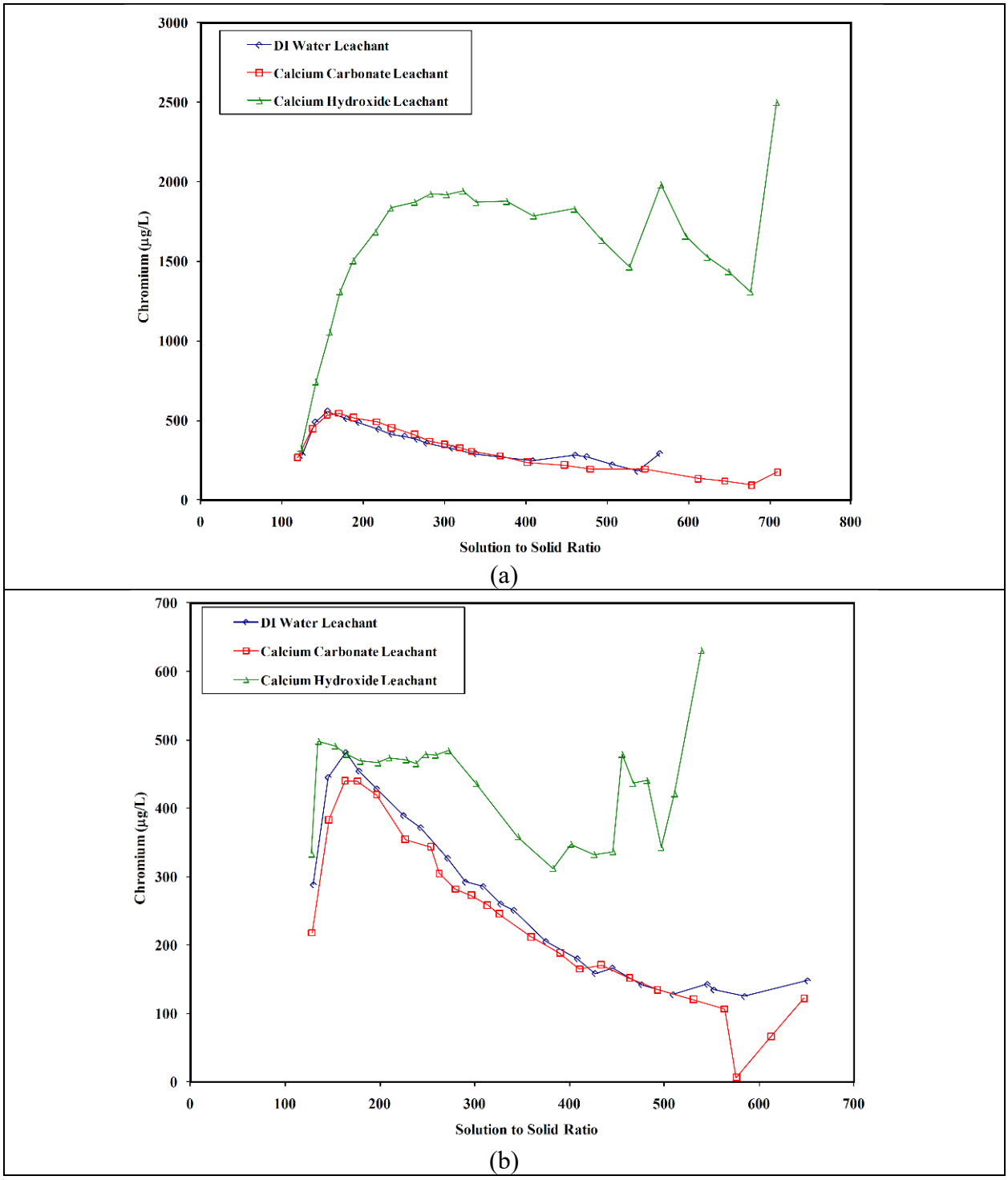
The effective diffusion coefficient of mobile COPCs (such as ^{99}Tc) through the combined grout and concrete base mat is considered a key parameter that controls the diffusive flux. Over the past decade, several experiments have been conducted to determine the effective bulk diffusion coefficient through concrete for relatively mobile COPCs under unsaturated conditions. The results of various experiments are presented in PNNL-23841, "*Radionuclide Migration through Sediment and Concrete: 16 Years of Investigations*." Of particular interest are the sediment-concrete half-cell experiments conducted in Year 2008 (for a period of 351 days) with ^{99}Tc and stable iodine.

Laboratory-scale concrete mixtures were prepared by omitting coarse aggregates and using 40 to 60 mesh size sand instead. The concrete mix prepared consisted of mainly Type I/II sulfate resistant portland cement (27%), Class F fly ash (4%), sand (51%), and steel fiber (4%). The water-to-cement ratio was 0.5.

The experiments were conducted using cylindrical cells made of Schedule 40 polyvinyl chloride (PVC) pipe (Figure 5-14). Caps were machined to fit into both ends of the PVC pipe and fitted with O-rings to minimize moisture loss during the test. For the sediment-concrete half-cells, the cell containing contaminant-spiked sediment was placed in contact with a non-spiked concrete monolith. The diffusion tests were run horizontally and undisturbed, with periodic rotation of the cell by 90 degrees. At the completion of the experiment, the concrete half-cells were sectioned parallel to the sediment-concrete interface. The concrete slices were then ground and two-to-one extracts (due to small sample size) by mass were performed on concrete fractions using the distilled deionized water.

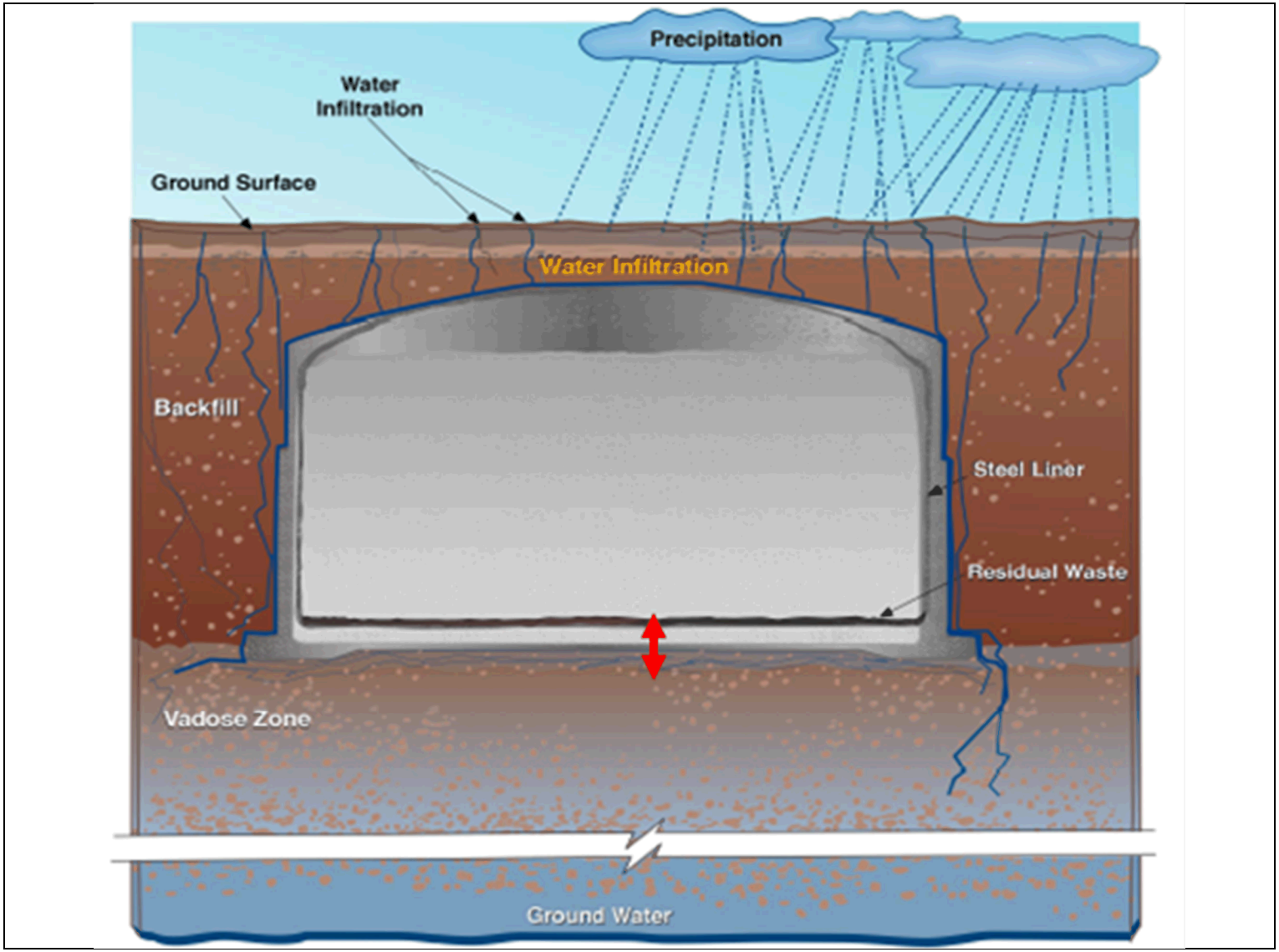
The concentration profiles developed in the concrete are analyzed by fitting the analytical solution to Fick's second law, with the assumption of zero concentration downstream boundary condition, and deriving a bulk diffusion coefficient for the media. This bulk diffusion coefficient implicitly incorporates the effects of porosity and tortuosity due to diffusion that primarily occurs along the water films in the concrete. For the purpose of modeling mass transport along the water (liquid) phase, the effective diffusion coefficient in the water phase is needed (instead of bulk diffusion coefficient), which can be derived by multiplying bulk diffusion coefficient with the moisture content. Since the moisture content of the base mat concrete and grout material is not known and would likely change with time due to slow but steady physical and chemical degradation, the effective diffusion coefficient is assumed to be the same as the measured bulk diffusion coefficient for the purpose of source-term modeling. In other words, the reduction due to multiplying with moisture content is not applied for calculating the diffusive flux. Note that the effective diffusion coefficient incorporates the effects of tortuosity resulting from transport along water films in the porous media.

Figure 5-12. Effluent Concentrations of Chromium (µg/L) from the Single-Pass Flow-Through Experiments Conducted on (a) Tank 241-C-202 and (b) Tank 241-C-203 Residual Waste.



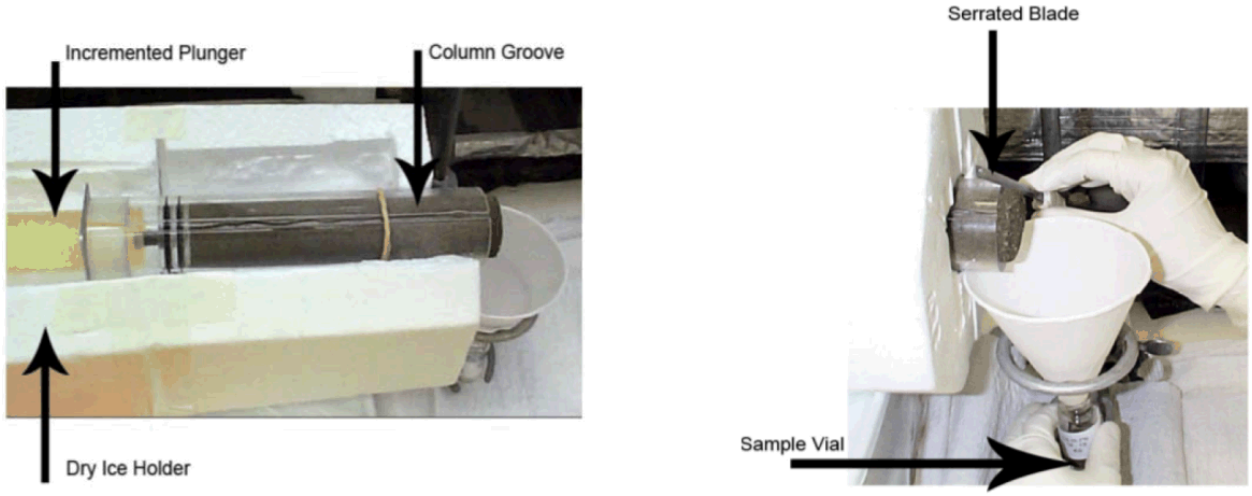
DI = deionized
Source: PNNL-20616, "*Contaminant Release from Hanford Tank Residual Waste – Results of Single-Pass Flow-Through Tests*."

Figure 5-13. Diffusive Pathway for Transport of Non-Volatile Contaminants to the Near-Field Environment.



Reference: RPP-ENV-58782, "*Performance Assessment of Waste Management Area C, Hanford Site, Washington*," Chapter 6.

Figure 5-14. Set-Up of the Diffusive Half-Cell Experiment Contacting Contaminant-Spiked Sediment (or Concrete) Sample with the Non-Spiked Sediment (or Concrete) Sample.



Reference: RPP-ENV-58782, "*Performance Assessment of Waste Management Area C, Hanford Site, Washington*," Chapter 6.

Sediment-concrete diffusion experiments were initiated to investigate the effect of sediment moisture, concrete iron content, and concrete carbonation on the diffusivity of ^{99}Tc from sediment into concrete (PNNL-23841, Section 4.2.2). Sediment half-cell specimens were spiked with ^{99}Tc (4.2×10^{-4} mg ^{99}Tc/g sediment) to achieve a measurable diffusion profile in the concrete part of the half-cell. Hanford fine sand was used for the sediment half-cell. In these experiments, iron content was varied in the concrete specimens from 0% to 12%, sediment moisture content was varied (4%, 7%, or 15%), and half of the concrete monoliths were carbonated prior to preparing the half-cells. The characteristics of the concrete half-cells are listed in Table 5-1. Half-cell sampling was conducted at 351 days. Figure 5-15 presents the concentration profiles developed in the concrete.

The calculated effective diffusion coefficients of ^{99}Tc derived from the experimental results are presented in Figure 5-16 and tabulated in Table 5-1. They range from 6.6×10^{-9} cm^2/s to 1.6×10^{-7} cm^2/s (1.0×10^{-7} in.^{2}/s to 2.5×10^{-6} in.^{2}/s), with a median value of ~3×10^{-8} cm^2/s (4.7×10^{-7} in.^{2}/s). No particular measurable trend exists to indicate whether the effective diffusion coefficient varies with moisture content of the sediment. The highest ^{99}Tc diffusivities were predominantly observed in the non-carbonated concrete cores contacting spiked sediments. A clear effect from the addition of iron was not observed. In general, the increased carbonation reduced diffusion coefficients.

Similar experiments, as described above, were performed using stable iodine in 2008, where the sediment half-cell specimens were spiked with stable iodine at concentrations of ~7 mg of iodine per gram (246.9 oz/ton) of sediment (PNNL-23841, Section 4.1.2). The concentration profiles for the concrete half-cells were evaluated and the effective diffusion coefficient was determined for iodine, which ranged from 1.4×10^{-8} cm^2/s to 9.7×10^{-8} cm^2/s (2.17×10^{-7} in.^{2}/s to 1.50×10^{-6} in.^{2}/s) with a median value of 2.6×10^{-8} cm^2/s (4.03×10^{-7} in.^{2}/s). The non-carbonated samples exhibited a larger depth of diffusion compared to the carbonated

samples, similar to the observations made for ^{99}Tc. The range of effective diffusion coefficient (and the median value) for iodine in concrete is very similar to that for ^{99}Tc.

Experiments were also performed to assess the effect of fractures in the concrete on diffusion of ^{99}Tc and iodine. For this purpose, the concrete monoliths were wrapped in shrink-wrap (to prevent the formation of rubble), and the end of a flathead screwdriver was placed directly in the center of the core and struck once. Each fractured concrete monolith had a single midline fracture that penetrated the length of the core. A set of sediment-to-fractured concrete diffusion half-cell experiments were conducted, by varying the iron content using both carbonated and non-carbonated concrete but keeping the moisture content in the sediment half-cell constant at 4%. The sediment half-cell specimens were spiked with ^{99}Tc at a concentration of 3.24×10^{-4} mg per gram (0.011 oz/ton) of sediment. The derived effective diffusion coefficient ranged from 1.9×10^{-9} cm^2/s to 2.5×10^{-8} cm^2/s (2.94×10^{-8} in.^{2}/s to 3.88×10^{-7} in.^{2}/s). Similar experiments conducted using stable iodine (spiked at 7 mg per gram [246.9 oz/ton] of sediment) resulted in effective diffusion coefficient that ranged from 4.7×10^{-9} cm^2/s to 8.4×10^{-8} cm^2/s (7.29×10^{-8} in.^{2}/s to 1.30×10^{-6} in.^{2}/s). These ranges are similar to the ranges calculated for diffusion in the unfractured concrete monolith.

For the purpose of the PA calculations, the experimental median value of 3×10^{-8} cm^2/s (4.65×10^{-7} in.^{2}/s) is chosen as the best estimate for the effective diffusion coefficient in concrete. This value is applied to all species diffusing through the concrete. Based on the range presented in Figure 5-16, an uncertainty range with a minimum and maximum value of 6×10^{-9} cm^2/s and 2×10^{-7} cm^2/s (9.30×10^{-8} in.^{2}/s and 3.10×10^{-6} in.^{2}/s) will be evaluated as part of uncertainty analysis.

Based on an extensive database on grout effective diffusion coefficients, the Savannah River National Laboratory (SRNL) found that the diffusion coefficients are not strongly dependent on formulation (e.g., dry mix, with and without slag) (SRNL-STI-2016-00175, "*Solid Secondary Waste Data Package Supporting Hanford Integrated Disposal Facility Performance Assessment*"). The diffusion coefficients for an experimental database of 100 samples (Table 7-2, SRNL-STI-2016-00175) had a geometric mean of ~3×10^{-8} cm^2/s (4.65×10^{-7} in.^{2}/s), with the lower and upper ranges being 1.1×10^{-9} cm^2/s and 8.1×10^{-7} cm^2/s; these values compare well with the data presented in Figure 5-16 and the preceding maximum and minimum values used in the WMA C PA.

5.1.3 Sorption of Contaminants to Grout and Concrete

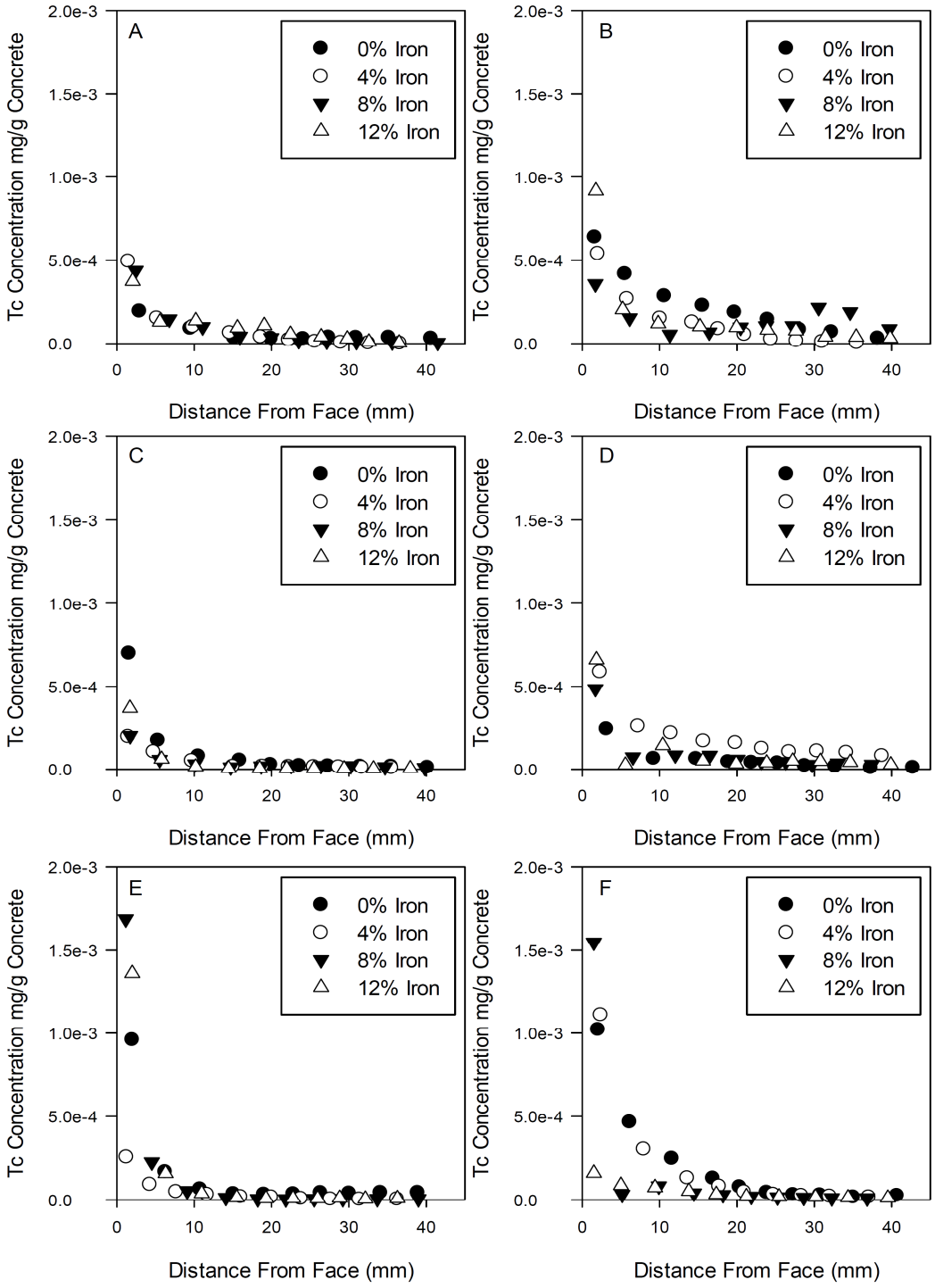
A linear sorption isotherm (using a K_d approach) is considered for determining sorption within the grout and concrete layer for various COPCs as they undergo diffusive (and advective) transport through the tank. The K_d values are presented in Table 5-2 in terms of best estimate and the uncertainty range that are derived from relevant published literature for chemical conditions that are likely to exist within the grout/concrete layer within the tanks. This table of K_d values was recently developed for the WMA C PA and is considered applicable for the WMA A-AX PA.

Table 5-1. Characteristics of Concrete Specimens Used in Sediment-Concrete Half-Cell Experiments Along with Derived Bulk Diffusion Coefficient of Technetium-99 for the Concrete.

Core ID	Length (cm)	Diameter (cm)	Surface Area (cm^2)	Volume (cm^3)	Weight (g)	Density (g/cm^3)	Iron (wt%)	Carbonated	Initial Sediment Moisture Content (%)	Technetium-99 Diffusivity (cm^2/s)
C-08-3-0-325	4.09	4.33	84.97	60.1	131.44	2.19	0	N	4	7.08E-08
C-08-3-0-329	4.32	4.33	88.13	63.53	139.5	2.2	0	N	7	6.55E-08
C-08-3-0-330	3.85	4.33	81.77	56.65	123.5	2.18	0	N	15	3.51E-08
C-08-3-0-332	4.33	4.32	88.09	63.48	139.65	2.2	0	Y	4	2.23E-08
C-08-3-0-333	4.35	4.33	88.57	64	140.79	2.2	0	Y	7	2.25E-08
C-08-3-0-334	4.07	4.32	84.56	59.67	130.55	2.19	0	Y	15	1.22E-08
C-08-3-4-350	3.84	4.32	81.43	56.28	127.25	2.26	4	N	4	3.21E-08
C-08-3-4-351	4	4.33	83.92	58.96	132.78	2.25	4	N	7	1.57E-07
C-08-3-4-353	4.01	4.33	83.99	59.04	133.38	2.26	4	N	15	3.09E-08
C-08-3-4-357	3.9	4.32	82.19	57.11	128.77	2.25	4	Y	4	3.09E-08
C-08-3-4-359	3.83	4.32	81.25	56.09	126.5	2.26	4	Y	7	1.07E-08
C-08-3-4-360	4.11	4.33	85.47	60.64	136.11	2.24	4	Y	15	3.26E-08
C-08-3-8-401	4.07	4.32	84.4	59.5	135.91	2.28	8	N	4	7.76E-09
C-08-3-8-402	3.81	4.32	81.02	55.84	127.31	2.28	8	N	7	2.85E-08
C-08-3-8-403	4	4.33	83.87	58.91	133.35	2.26	8	N	15	1.62E-08
C-08-3-8-404	4.05	4.33	84.61	59.71	133.69	2.24	8	Y	4	5.34E-08
C-08-3-8-405	3.86	4.33	81.77	56.65	126.96	2.24	8	Y	7	9.25E-09
C-08-3-8-406	3.94	4.33	83.08	58.05	130.61	2.25	8	Y	15	6.61E-09
C-08-3-12-425	4.33	4.27	87.54	62.88	143.44	2.28	12	N	4	1.07E-07
C-08-3-12-426	4.33	4.33	88.35	63.76	145.77	2.29	12	N	7	1.31E-08
C-08-3-12-427	4.33	4.22	86.94	62.23	141.71	2.28	12	N	15	8.21E-08
C-08-3-12-432	4.02	4.32	83.83	58.88	134.09	2.28	12	Y	4	4.6E-08
C-08-3-12-433	4.15	4.33	85.81	61.01	139.8	2.29	12	Y	7	6.95E-09
C-08-3-12-435	3.88	4.33	82.22	57.12	130.04	2.28	12	Y	15	7.09E-09

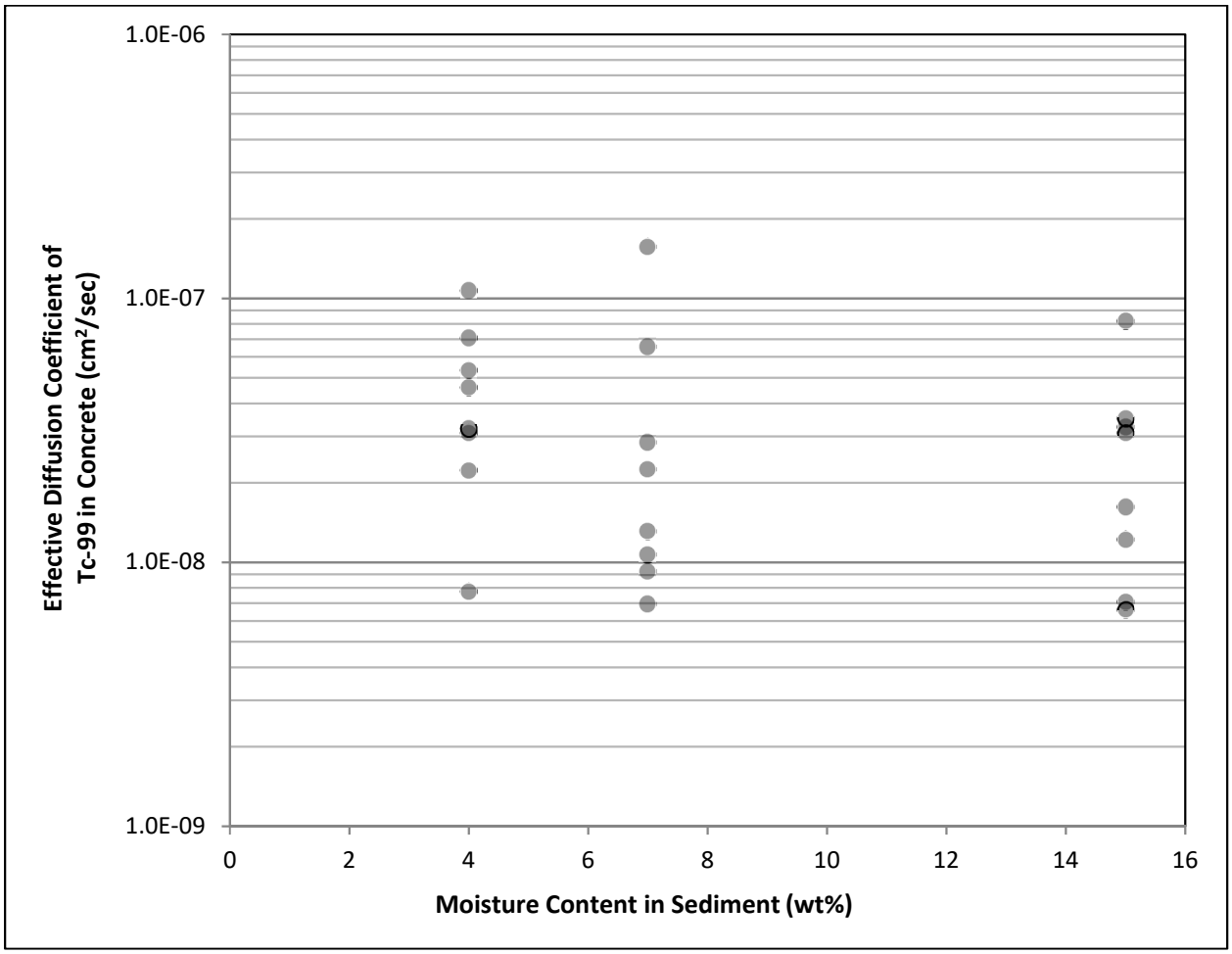
Note: For the purpose of source-term calculations, the bulk diffusion coefficient is considered to be the same as effective diffusion coefficient.
Reference: RPP-ENV-58782, "*Performance Assessment of Waste Management Area C, Hanford Site, Washington*," Chapter 6.

Figure 5-15. Technetium-99 Concentration Profiles in Concrete from Sediment-Concrete Half-Cell Experiments Conducted on (A) 4% Sediment Moisture, Carbonated Monoliths, (B) 4% Sediment Moisture, Non-Carbonated Monoliths, (C) 7% Sediment Moisture, Carbonated Monoliths, (D) 7% Sediment Moisture, Non-Carbonated Monoliths, (E) 15% Sediment Moisture, Carbonated Monoliths, and (F) 15% Sediment Moisture, Non-Carbonated Monoliths.



Reference: RPP-ENV-58782, "*Performance Assessment of Waste Management Area C, Hanford Site, Washington*," Chapter 6.

Figure 5-16. Effective Diffusion Coefficient of Technetium-99 in Concrete Based on Experiments Conducted Using Sediment-Concrete Half-Cells.



References:
PNNL-23841, "*Radionuclide Migration through Sediment and Concrete: 16 Years of Investigations*."
RPP-ENV-58782, "*Performance Assessment of Waste Management Area C, Hanford Site, Washington*," Chapter 6.

Development of a sophisticated sorption model depends on the availability of complete sets of experimental data, including measurement of isotherm, and dependence on solid-to-liquid ratio under conditions that are applicable to the near-field environment. Presently the vast majority of sorption data on cementitious material are based on single-point measurements, and information on uptake mechanisms and uptake controlling phases in cement systems are lacking to a large extent (NAGRA NTB 02-20, "*Cementitious Near-Field Sorption Data Base for Performance Assessment of an ILW Repository in Opalinus Clay*"). Until studies are performed at the molecular level to discern uptake processes, sorption databases, in conjunction with scientific expertise, can be used to select site-specific sorption values.

Table 5-3 lists the SRNL reported K_d (mL/g) values (SRNL-STI-2016-00175) for varying oxidizing stages for three long-lived mobile radionuclides of interest to the WMA A-AX PA. The K_d values for the three species are consistent with the data reported in Table 5-2.

Table 5-2. K_d Values (mL/g) for Grout/Concrete Used for Waste Management Area C Performance Assessment.

Element	Minimum	Best	Maximum	Reference
Ac	3.00E+04	1.00E+05	3.30E+05	NAGRA NTB 02-20
Al	0	0	0	No relevant information
Am	2.00E+02	1.00E+03	5.00E+03	SKB R-05-75
B	0	0	0	No relevant information
C	1.00E+01	2.00E+02	4.00E+03	SKB R-05-75
Cd	2.00E+00	4.00E+01	8.00E+02	SKB R-05-75
Cm	2.00E+02	1.00E+03	5.00E+03	SKB R-05-75
CN	0	0	0	No relevant information
Co	4.00E+00	4.00E+01	4.00E+02	SKB R-05-75
Cr	0	0	0	No relevant information
Cs	1.00E-01	1.00E+00	1.00E+01	SKB R-05-75
Eu	1.00E+03	5.00E+03	2.50E+04	SKB R-05-75
F	0	0	0	No relevant information
Fe	0	0	0	No relevant information
H	7.14E-02	1.00E-01	1.40E-01	NAGRA NTB 02-20
Hg	0	0	0	No relevant information
I	3.00E-01	3.00E+00	3.00E+01	SKB R-05-75
Mn	0	0	0	No relevant information
Nb	1.00E+02	5.00E+02	2.50E+04	SKB R-05-75
Ni	8.00E+00	4.00E+01	2.00E+02	SKB R-05-75
NO_2	0	0	0	No relevant information
NO_3	0	0	0	No relevant information
Np	7.14E+01	1.00E+02	1.40E+02	NAGRA NTB 02-20
Pa	7.14E+01	1.00E+02	1.40E+02	NAGRA NTB 02-20
Pb	3.60E+02	5.00E+02	7.10E+02	NAGRA NTB 02-20
Pu	7.14E+01	1.00E+02	1.40E+02	NAGRA NTB 02-20
Ra	5.00E+00	5.00E+01	5.00E+02	SKB R-05-75
Rn	0	0	0	No relevant information
Se	1.00E-01	6.00E+00	4.00E+02	SKB R-05-75
Sm	1.00E+03	5.00E+03	2.50E+04	SKB R-05-75
Sn	2.50E+01	5.00E+02	1.00E+04	SKB R-05-75
Sr	5.00E-01	1.00E+00	5.00E+01	SKB R-05-75
Tributyl phosphate	0	0	0	No relevant information
Tc	7.14E-01	1.00E+00	1.40E+00	NAGRA NTB 02-20
Th	1.00E+03	3.00E+04	1.00E+06	NIROND-TR 2008-23 E
U	1.43E+03	2.00E+03	2.80E+03	NAGRA NTB 02-20
Zr	3.03E+03	1.00E+04	3.30E+04	NAGRA NTB 02-20

References:

NAGRA NTB 02-20, "*Cementitious Near-Field Sorption Data Base for Performance Assessment of an ILW Repository in Opalinus Clay*."

NIROND-TR 2008-23 E, "*Review of sorption values for the cementitious near field of a near surface radioactive waste disposal facility, Project near surface disposal of category A waste at Dessel*."

PSI Bericht Nr. 95-06, "*Sorption Databases for the Cementitious Near-Field of a L/ILW Repository for Performance Assessment*."

RPP-ENV-58782, "*Performance Assessment of Waste Management Area C, Hanford Site, Washington*," Chapter 6.

SKB Rapport R-05-75, "*Assessment of uncertainty intervals for sorption coefficients, SFR-1 uppföljning av SAFE*."

Table 5-3. Selected K_d Values (mL/g) for Grout.

Rad	State	Oxidizing Cement Stage I	Oxidizing Cement Stage II	Oxidizing Cement Stage III
I	Best	4	8	2
	Min	0	1	0
	Max	10	20	4
Tc	Best	0.8	0.8	0.5
	Min	0	0	0
	Max	2	2	1
U	Best	1,000	5,000	5,000
	Min	100	1,000	1,000
	Max	2,000	10,000	10,000

Source: SRNL-STI-2016-00175, "*Solid Secondary Waste Data Package Supporting Hanford Integrated Disposal Facility Performance Assessment*," Table 8-4.

As described below, selections for sorption values (K_d) have been made based on review of past reports that are focused on developing internally consistent cement sorption databases for cementitious near-field material (hardened cement paste) based on the composition of cement porewaters and stage of cement degradation.

- Conditions in the closed tank farm are expected to be moderately oxidizing, owing to the position of the waste in unsaturated conditions. Where data are available to differentiate between oxidizing and reducing conditions, K_d values under oxidizing conditions are preferentially selected, as it leads to lower K_d values relative to reducing conditions.

- Composition of the cementitious material (grout or concrete) may have different chemical compositions, and therefore differ in contaminant uptake mechanisms and cement phases. Due to lack of information, the differences in sorption between various types of cements and concrete are ignored.

- The selected K_d values are based on assumption of $Ca(OH)_2$ saturated waters contacting the waste, and therefore represent the so-called stage II of the chemical degradation of cementitious material. In this stage, chemical composition of the alkali-depleted cement pore water is controlled by the solubility of portlandite. The impact on K_d values during evolution of chemical conditions from stage I (higher alkali content and pH) to stage II is expected to be minor and incorporated within the uncertainty range. Stage III conditions are not expected to develop for many tens of millenia based on slow degradation of the grout monolith as described in Section 7.0 and low infiltration rates as estimated in Appendix B and similar evaluations in SRNL-STI-2016-00175.

- The reviews of SKB Rapport R-05-75, "*Assessment of uncertainty intervals for sorption coefficients, SFR-1 uppföljning av SAFE*" and NIROND-TR 2008-23 E, "*Review of sorption values for the cementitious near field of a near surface radioactive waste disposal facility, Project near surface disposal of category A waste at Dessel*" are more recent, and represent critical reviews and independent data from NAGRA NTB 02-20 and

PSI Bericht Nr. 95-06, "*Sorption Databases for the Cementitious Near-Field of a L/ILW Repository for Performance Assessment*." Where appropriate values are available from these more recent references, they are preferred to the older ones.

- When K_d values are absent from these references, a value of zero has been assumed for the analyte since chemical equivalences between similar analytes have not been performed to justify nonzero K_d values. As necessary, chemical equivalences suggested by SKB R-05-75 may be used to update K_d values in future iterations of the PA modeling.

- When there was significant disagreement between literature sources, the lower (less sorptive) K_d value has been chosen. For example, K_d values under oxidizing conditions were selected over those measured under reducing conditions. Also, the assumption by default in RPP-ENV-58782 that chromium is non-sorbing leads to zero values for K_d in contrast to SRNL-STI-2016-0075 Table 8.4 values of 3 mL/g (best estimate), 0 (minimum), and 6 mL/g (maximum). The same assumption for mercury leads to zero values in contrast to SRNL-STI-2016-0075 Table 8.4 values of 300 mL/g (best estimate), 30 mL/g (minimum), and 600 mL/g (maximum) during Stages 1 and 2. For some other constituents, the K_d values obtained from SKB Rapport R-05-75 are somewhat lower than values reported in SRNL-STI-2016-0075.

The K_d values were compared to values used in Savannah River F and H tank farm PAs [WSRC-STI-2007-00369, "*Hydraulic and Physical Properties of Tank Grouts and Base Mat Surrogate Concrete for FTF Closure*" and WSRC-STI-2007-00607, "*Chemical Degradation Assessment of Cementitious Materials for the HLW Tank Closure Project (U)*"]. The values in Table 5-2 are generally consistent with or more conservative than comparable values used for the facility-specific grout used at Savannah River. When the Table 5-2 values are more conservative (i.e., with lower K_d indicating less retardation), it is for one of the following two reasons.

- The grout used at Savannah River produces reducing conditions. In the absence of a specific grout formulation for Hanford tank farms, it has been assumed that oxidizing conditions will exist in the grout, which leads to lower K_d values and thereby higher doses for some radionuclides of interest.

- When data were ambiguous or insufficient in any way, it was more efficient to assume a low K_d than to spend resources to resolve the value in greater detail. So, for instance, when data are lacking for a contaminant its K_d is assigned a value of zero, which leads to earlier arrival times and higher doses.

5.1.4 Evaluation of Diffusive Release Assumption for Intact Tank Condition

Based on the tank infill grout and concrete degradation mechanisms discussed in Section 7.0, it was determined that tanks are not likely to be fully degraded within the modeled time period of 10,000 years. Due to the unlikely development of continuous fracture pathways within the infill grout over the 10,000 years, infiltration is likely to be very slow, to the extent that advective transport is negligible. Therefore, the primary contaminant transport process will be diffusion

(in the aqueous phase), where concentration differences across the grout and concrete tank base mat provide a gradient leading to diffusion. The predominance of diffusion with negligible amount of advection, if any, is based on the following reasoning.

1. The backfill material surrounding the tank structure will provide a preferential pathway for any water infiltrating through the surface cover. Due to large contrast in relative permeability (several orders of magnitude) between gravel-dominated backfill material and grout monolith inside the tank under ambient conditions, most of the infiltrating water will flow around and bypass the tank structure.

2. The capillary forces within the grout micropores are much larger than surrounding backfill soil. Therefore, initially when the grout is emplaced in the tank, the grout will wick water from the surrounding material and hold it in place, much like a clay lens within a sand body. With increasing degree of hydration over time that leads to formation of calcium silicate hydrate (C-S-H) gel, the amount of interconnected pore space is known to reduce, and some capillary pores will become discontinuous. This is likely to further reduce the permeability appreciably ("Relationships between permeability and pore structure of hardened cement paste" [Nyame and Illston 1981]) as shown in Figure 5-17.

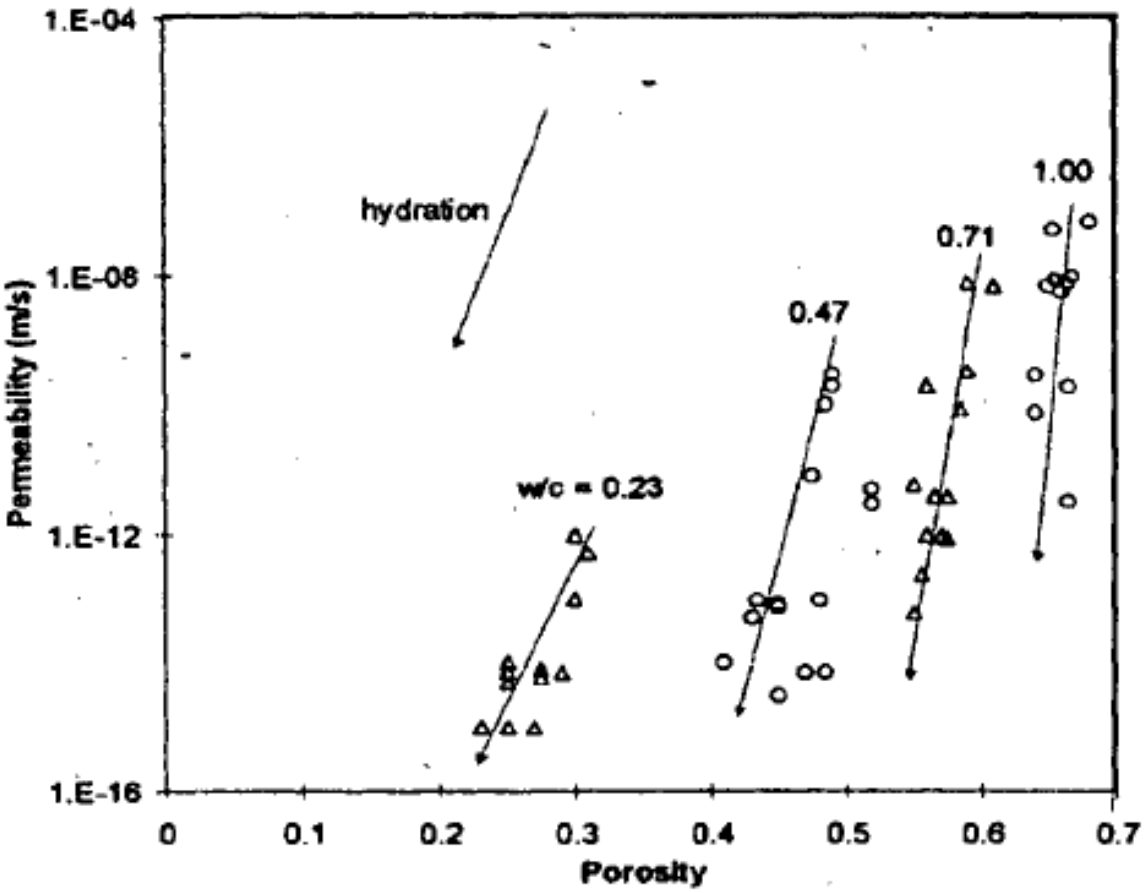
A numerical simulation of flow around the grouted tank surrounded by backfill material was undertaken to evaluate the relative importance of advective flow (Appendix B). The numerical calculations were performed in a two-dimensional vertical cross-section for a row of C-100-series tanks under a 3.5 mm/yr constant recharge rate (same as the long-term post-closure recharge rate). The C-100-series tanks are adequately similar to the A-100-series and AX-100-series tanks for purposes of this analysis, given that they have the same nominally 75-ft diameter, similar base and dome construction, and roughly similar spacing between tanks. The C-100-series tanks are about half the volume and depth of the A-100-series and AX-100-series tanks, so the grout monolith modeled is conservatively small while similar in horizontal geometry. For this analysis, the tank construction was simplified by assuming that the concrete wall behaved identically to grout in hydraulic properties. The hydraulic properties assigned to the grout were chosen from WSRC-STI-2007-00369 that represented strong grout material. The corresponding characteristic curves are presented in Appendix B.

Simulation results indicate that the vertical Darcy flux in the grout remains over three orders of magnitude lower than through the backfill. The Darcy flux in the grout is negligibly small for the first few thousand years, and gradually increases as the large capillary suction draws water in, eventually increasing the unsaturated hydraulic conductivity compared to the initial state.

To compare the relative importance of advection and diffusion, the dimensionless Peclet number (ratio of advective transport to diffusive transport rate) was calculated for the simulated results at 10,000 years (Appendix B). The Peclet number for transport in the tank was ~0.1 while in the backfill it was ~2, indicating that transport through the tank is predominantly diffusion-controlled while transport through the backfill has a higher advective component. During the first 1,000 years, the Peclet number for the tank is close to zero due to negligibly small Darcy flux, and thereafter increases gradually. Therefore, during the 10,000-year period, it

is clear that diffusion dominates transport within the grouted tank; whereas in the backfill, both advection and diffusion play a role in transport. These analyses support the assumption of diffusion-dominated releases from an intact tank.

Figure 5-17. Porosity-Permeability Relationship as a Function of Hydration and Water to Cement Ratio.



Reference: "Relationships between permeability and pore structure of hardened cement paste" (Nyame and Illston 1981).

5.2 PARAMETERS USED IN SOURCE TERM CALCULATIONS

Table 5-4 presents the list of parameters recommended in developing WMA A-AX source-term release calculations.

Table 5-4. Contaminant Source Term Parameters for Residual Waste. (2 sheets)

Parameter	Value	Reference
Porosity of Residual Waste Layer	0.4	Assumed; based on evaluation of sludge waste phase from the retrieved tanks for WMA C.
Saturation of Residual Waste Layer	1	Assumed fully saturated to maximize diffusive release
Residual Waste Volume	Variable by source	Chapter 3 information and data
Porosity of Concrete and Grout layer below the waste layer	0.11	SRNL-STI-2008-00421, Table 39
Porosity of in-fill Grout within the tank (at closure)	0.269	WSRC-STI-2007-00369, Table 29; Strong grout assumed.
Saturation of Concrete and Grout layer below the waste layer	1	Assumed to maximize diffusive release
Bulk Density of Concrete and Grout layer below the waste layer	2.41 g/cm^3 (151 lb/ft^3)	RPP-RPT-50934, pp. C-3 (C-107 dome core density of 2.41 g/cm^3 [151 lb/ft^3])
Diffusive Length of Waste form layer	0 m (0 ft)	Assumed to maximize diffusive release
Diffusive Length of Concrete and Grout layer below the waste layer	0.203 m (8 in.) for 241-A SSTs; 0.445 m (17.5 in.) for 241-AX SSTs	Minimum diffusive thickness based on tank bottom geometry (Chapter 3 and discussion in 7.4)
Diffusive Area for source term release	Variable by source (i.e., SST or type of ancillary equipment)	Base area for tanks and ancillary equipment based on information and data provided in Chapter 3.
Effective Diffusion Coefficient through grout and concrete layer (incorporates effects of tortuosity)	3×10^{-8} cm^2/s (4.7×10^{-7} in.^{2}/s)	Section 6.3.1 of RPP-ENV-58782
Uranium solubility for intact tank conditions	1×10^{-4} M for 1,000 years; 1×10^{-6} M for time >1,000 years	Section 6.3.1 of RPP-ENV-58782
Uranium solubility for degraded tank conditions	1×10^{-4} M for 1,000 years; 2×10^{-5} M for time >1,000 years	Section 6.3.1 of RPP-ENV-58782
Chromium solubility for degraded tank conditions	2,000 µg/L dissolved concentration limit	Section 5.1.1.3
Technetium-99 release	Instantaneous release model will be used; or 6% of the waste inventory available for release instantaneously, and remaining 94% waste form inventory made available based on first order fractional release rate of 6×10^{-4} day^{-1}.	Section 6.3.1 of RPP-ENV-58782

Table 5-4. Contaminant Source Term Parameters for Residual Waste. (2 sheets)

Parameter	Value	Reference
Contaminant K_d values for transport through the grout and concrete layer	Variable; See Table 5-2	Table 5-2
Release Type	Diffusive release from tanks under intact conditions; Both advective and diffusive release for tanks under degraded conditions; Both advective and diffusive release for pipelines; Release from other ancillary equipment to be determined based on residual inventory data package	

SST = single-shell tank WMA = waste management area

References:
RPP-ENV-58782, "*Performance Assessment of Waste Management Area C, Hanford Site, Washington*," Chapter 6.
RPP-RPT-50934, "*Inspection and Test Report for the Removed 241-C-107 Dome Concrete*."
SRNL-STI-2008-00421, "*Hydraulic and Physical Properties of Saltstone Grouts and Vault Concretes*."
WSRC-STI-2007-00369, "*Hydraulic and Physical Properties of Tank Grouts and Base Mat Surrogate Concrete for FTF Closure*."

6.0 STEEL CORROSION AND DEGRADATION

Carbon steels and stainless steels were used in the construction of the HLW storage facilities at WMA A-AX. Exposure to service and post-closure conditions can cause degradation of these materials, manifested by loss of strength, loss of ductility, cracking, thinning, pitting, buckling, etc. This section elaborates on the rationale for assuming steel components will fail early relative to the long time period analyzed in the PA, with attention to factors that potentially contributed to past failures of some components at WMA A-AX and elsewhere at the Hanford Site, drawing on relevant analysis completed for WMA C in RPP-RPT-46879, "*Corrosion and Structural Degradation within Engineered System in Waste Management Area C*." For the purpose of conducting WMA A-AX PA calculations, no credit for waste retention by the SST liners or pipelines will be taken.

Identifying and understanding the degradation mechanisms for the steel materials provides insight into potential for failure of steel components which in some cases may lead to waste releases. Degradation mechanisms identified for WMA C in RPP-RPT-46879 included: waste chemistry-induced corrosion, high heat loads, soil conditions, and in-situ mechanical loads. Most of the findings for WMA C apply to WMA A-AX and are summarized as follows.

Laboratory and field work implies that several factors can contribute to the failure of steel liners in various SSTs across the Hanford Site. Liners that were not heat treated to remove stresses in the weldments and tanks that were constructed without knuckles may have contributed to some liner failures. Several Hanford wastes were potentially corrosive; for example, wastes that had high nitrate ion concentrations and low nitrite ion concentrations at pH less than 10 could induce pitting or stress corrosion cracking (SCC), although these reactions are inhibited by nitrite, hydroxide, and pH greater than 10, so neutralization of PUREX wastes transferred to WMA A-AX may have been effective in limiting corrosion. Wastes with high hydroxide ion concentrations could also induce corrosion in the absence of inhibiting reactions. Tanks that operated for years at boiling temperatures were also associated with liner failures. These conditions enhanced corrosion rates and led to thermal excursions that superheated water trapped beneath the solid layers causing bumping and vigorous steam eruptions. Collectively, these chemical and physical conditions could cause failure of SST liners by pitting, SCC, and mechanical ruptures.

Transfer lines are subject to galvanic corrosion; uniform corrosion occurs but remains the most benign of the active degradation processes. Nitrate-induced SCC is considered a primary corrosion mechanism, and the basis for the chemistry control program implemented for the DST system. Localized pitting and concentration cell corrosion are the most likely mechanisms that threaten the integrity of the steel. Pitting corrosion on the interior of the transfer lines due to stagnant residual flush water at low spots or accelerated uniform corrosion on the exterior of the transfer lines from improper application/operation of cathodic protection systems pose the viable mechanism for loss of integrity.

Since RPP-RPT-46879 was issued, additional studies have been completed to assess the cause of past liner leaks in the tank farms. RPP-RPT-54909, "*Hanford Single-Shell Tanks Leak Causes, Locations, and Rates: Summary Report*" assesses the causes of liners assumed to have leaked

and concludes that the most probable causes of liner failure in tank A-104 were temperature rate of increase exceeding structural limits, storage temperature exceeding tank design temperature, and corrosion and SCC accelerated by excessive thermal stresses. According to RPP-RPT-54909, the most probable cause for tank A-105 leaking was a large bulge in the tank floor that exceeded the yield strength of the steel; the bulge resulted from steam pressurization beneath the tank floor from possible high temperature rate of rise. Evaluation of past leaks from tanks A-105 and A-104 and contributing causes continues as new field data is generated and further historical information is reviewed (for further discussion of tank A-105 see Appendix A). The orthogonal construction design limited thermal expansion of the liner. RPP-RPT-55804, "*Common Factors Relating to Liner Failures in Single-Shell Tanks*" identifies 28 potential mechanisms for liner failures and concludes, "Likely common factors for a significant number of tank liner failures are the lack of post-weld stress relieving, tank liner bottom to wall transition design, high operational temperatures, and storage of waste types conducive to nitrate-induced stress corrosion cracking. Nitrate-induced stress corrosion cracking involved waste storage from the tri-butyl phosphate (TBP) process, REDOX process, and in-farm nitrate leaching." Note that PUREX waste is not specifically mentioned. RPP-RPT-46879 mentions past experiments with PUREX simulants demonstrating they did not cause SCC in conditions tested.

The A Farm and AX Farm tanks and piping have been exposed to many degradation mechanisms including fill and empty cycles and temperature changes due to thermal and operational loads during waste processing and storage; though such stresses should be reduced by interim stabilization of the SSTs, declining thermal loads, and future retrieval. These loads have likely led to fatigue in the steel liners and piping. This fatigue, coupled with no pre-heating processes for the steel liners and piping of the tanks and high structural loads/pressures causing yielding, leads to a large uncertainty in the tank liner integrity. According to RPP-10435 (pp. A-3), "The carbon steel floors of all the A and AX farm tanks developed inelastic folds or creases that are well distributed over the entire floors with heights of about 6 inches and widths of up to 2 feet," not including the more severe inelastic bulging of the tank A-105 liner. While in most cases the folding of the liners has not been sufficient to cause a present loss of integrity, the observed fatigue of the steel liners of all SSTs in WMA A-AX challenges the viability of any assumption of long-term integrity. The liners have already exceeded their design lives, e.g., the 25-year life for the AX Farm tanks based on $1/16^{th}$ in. corrosion allowance (RPP-10435, Table A.8). Therefore, as in the WMA C PA, no credit (waste retention) for the tank liner will be taken in the WMA A-AX PA calculations.

For simplicity, and consistent with the assumption that the tank liner plays no long-term role in limiting releases from waste residuals, the residuals on the bottom of a tank after waste retrieval may be assumed to be present across the entire tank bottom as a circular cylinder of constant thickness on top of the concrete and/or grout. It is assumed that an attempt will be made in AX Farm to grout the drain slots below the liner; the simplified circular cylinder geometry assumed for residuals is sufficient for modeling purposes even if grouting is not complete.

7.0 CONCRETE AND EMPLACED GROUT DEGRADATION

This section considers the potential timing, mode, and extent of degradation of cementitious materials such as concrete and emplaced grout over time periods up to many thousands of years. The section is organized as follows:

- Grout Degradation Processes (Section 7.1)
- Grout Monolith Stability Testing (Section 7.2)
- Belowground Concrete Structure Evaluation (Section 7.3)
- Aboveground Concrete Structure Evaluation (Section 7.4)
- Carbonation Time for Single-Shell Tank Concrete and Infill Grout at Waste Management Area A-AX (Section 7.5)
- Ancient Analogs (Section 7.6).

7.1 GROUT DEGRADATION PROCESSES

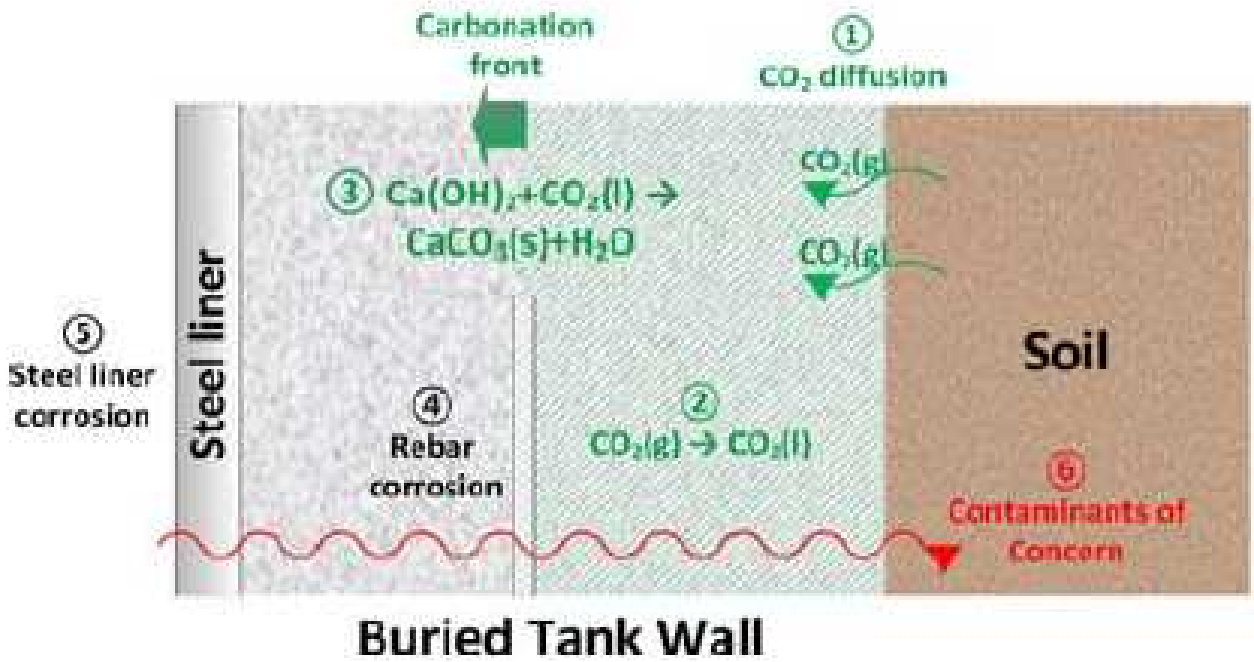
After closure, the tank concrete and grout is exposed to a combination of physical and chemical processes. Some processes may be beneficial (for example, continuing hydration and self-sealing of cracks), while others may create deleterious changes, such as shrinkage and thermal cracking. Although the geochemical conditions at the Hanford Site are favorable to preventing grout and concrete degradation, there are potential chemical degradation mechanisms that under certain conditions could lead to degradation of concrete forming the tank wall and the tank infill grout material. These key chemical degradation mechanisms are discussed and evaluated below for WMA A-AX.

7.1.1 Carbonation

Carbonation is the process whereby the CO_2 available in the soil-gas reacts with the calcium hydroxide in concrete to form calcium carbonate. This process is shown in Figure 7-1 where the CO_2 (g) is supplied by gaseous diffusion through the soil column. The carbonation reaction front is defined as the interface where the $Ca(OH)_2$ actively reacts with CO_2 gas and where the pH transitions from >12 [reflecting $Ca(OH)_2$ equilibrated pore water] to pH of 9 (reflecting $CaCO_3$ equilibrated pore water). Carbonation of concrete is a slow and continuous process that progresses from the outer surface inwards but slows down with increasing diffusive length. Detailed studies have indicated that movement of a carbonation front is typically proportional to the square root of exposure time. Carbonation has two effects: it increases the mechanical strength of concrete by reducing permeability and reducing porosity (calcite has higher molar volume than portlandite), but it also decreases alkalinity, which is essential for corrosion prevention of the steel liner and other reinforcement steel. Below a pH of 10, the steel's thin layer of surface passivation dissolves and corrosion is promoted. Depending on the amount of

steel present and its role in maintaining structural integrity of the tank, the stability of the tank can be compromised. Unlike normal reinforced concrete where significant amounts of rebar are present, the SSTs have relatively little equipment (and therefore steel) incorporated into the grout.

Figure 7-1. Carbonation Process Acting on a Buried Tank Wall.



The process of carbonation continues until all of the $Ca(OH)_2$ is dissolved. At this point, the dissolution chemistry is controlled by other hydrated calcium silicate and aluminate phases. When all of the $Ca(OH)_2$ has been leached away, other constituents become exposed to chemical decomposition. This decomposition eventually leaves behind silica and alumina compounds, which have little or no strength.

7.1.2 Sulfate Attack

Sulfate attack represents a complex set of chemical and physical processes where the hydrated and unreacted phases in portland cement react with sulfate ions to form solid phases. This can lead to increased cracking due to formation of sulfate-bearing phases such as ettringite and gypsum, with considerable local expansion. Sulfate attack is typically managed by minimizing the reactive component (tricalcium aluminate) in the cement. The source of sulfate can be external (infiltrating water) or internal (from the concrete/cement itself). Delayed ettringite can form from an internal sulfate source such as sulfate present in the tank residuals. Although there may be some sulfate in the tank residuals, this amount is generally small (compared to the amount of grout infill) due to extensive washing and cleaning steps undertaken to remove the sludge. In addition, the grout is produced using low sulfate water with aggregate (fine sand) that is low in sulfate. The external source of sulfate is going to be slowly infiltrating waters, which have low sulfate content. Due to limited availability of sulfate, the impact from sulfate attack is not expected to be important for grout degradation in the SSTs.

7.1.3 Alkali-Aggregate Attack

The alkali-aggregate reaction occurs when aggregates containing reactive silica react with sodium and potassium oxides in the portland cement to form an alkali-silica gel. This gel can absorb water, which in turn can lead to expansion and cracking of the grout. In the mixes for Hanford tank fill, non-reactive quartz sand will likely be used. In addition, it is known that substitution of fly ash and blast furnace slag for some of the portland cement will mitigate the impact of the alkali-aggregate reactions. Finally, portland cements produced today intentionally have low amounts of alkali content to avoid alkali-aggregate reaction. Therefore, it appears unlikely that cracking due to alkali-aggregate reaction would occur in the SSTs.

7.1.4 Acid Leaching (Decalcification)

Acid leaching or decalcification refers to leaching of calcium ions (coupled with hydroxide ions) from pore solutions and dissolution of calcium hydroxide, C-S-H, and hydrated calcium aluminate phases in cementitious materials (WSRC-STI-2007-00607). This form of degradation occurs when concrete is in contact with acidic water for long periods of time. The ultimate residue produced by decalcification consists of hydrous forms of silica (silica gel), alumina (alumina gel), and iron oxide. The rate of attack depends on the flow rate and the chemistry of water. Since ambient Hanford pore waters have high alkalinity and are at near saturation with calcite mineral phase, the process of decalcification is likely to be very slow, if it occurs at all.

Current evaluations of chemical conditions inside the tank (based on residual waste chemistry) and outside the tank (based on pore water chemistry) indicate very benign conditions with regard to chemical degradation of concrete and tank-fill grout material. Consequently, the degradation due to chemical processes will progress at a very slow rate. Among the processes evaluated, carbonation was identified as the most likely chemical degradation mechanism, which will proceed naturally due to availability of CO_2 via gaseous diffusion (Figure 7-1).

7.2 GROUT MONOLITH STABILITY TESTING

During scale-up testing for tank infill material, two monolith structures were created and tested for strength. The details are presented in WSRC-TR-2005-00195, "*Summary of Grout Development and Testing for Single Shell Tank Closure at Hanford*." Figure 7-2 shows the two monolith structures produced by placing three layers of grout into 4.6-m (15-ft)-diameter swimming pools during scale-up testing. These monoliths remained after the swimming pool structures were removed. The layered monoliths displayed significant strength, as demonstrated by the difficulty encountered in breaking them apart. In fact, the bulldozer and the heavy-duty forklift shown in Figure 7-2 were unable to turn over the monoliths. Both monoliths were repeatedly lifted on one side and dropped without breaking. Eventually, the bulldozer was able to break the monoliths along horizontal planes by ramming the bulldozer blade at the level of the interfacial areas. These tests indicate substantial increase in strength even though these monoliths were in initial phase of curing (only 5 days after the capping grout had been poured, and about 8 total days since the pouring of the first stabilization layer). Compressive strength

measurements confirmed this and indicate that significant strengthening likely continues to occur out to 90 days of curing.

7.3 BELOW GROUND CONCRETE STRUCTURE EVALUATION

As part of the initiative to evaluate the structural integrity of the tanks (called Single-Shell Tank Integrity Project or SSTIP), a 1.4-m (55-in.)-diameter reinforced-concrete dome "Plug" was removed from tank C-107 in December 2010. More recently, an 11.6-m (38-ft) sidewall concrete core was removed from WMA A-AX tank A-106 in May 2014. Results from inspection, physical testing, and petrographic examination of the concrete cores are reported in RPP-RPT-50934 and RPP-RPT-58254, "*Concrete Core Testing Report for the Single-Shell Tank 241-A-106 Sidewall Coring Project*." These analyses are important in predicting the tank wall degradation because they provide empirical evidence on the state of concrete wall material after being left underground for 60 to 70 years. The results of analyses that are relevant for the PA are discussed below.

The 1.4-m (55-in.)-diameter concrete section ("Plug") removed from the center of the dome of tank C-107 is shown in Figure 7-3. It was removed using a combination of high-pressure water and garnet abrasive. Fourteen cores were taken from the concrete "Plug," each 10.7 cm (4.2 in.) in diameter. Of those 14 cores, 12 underwent mechanical testing and 2 underwent petrographic examination. No cracks or large air voids were found during the inspection process. Additionally, the protective asphaltic membrane and mortar layers that were laid out during the construction were found to be intact. The average compressive strength of all of the tested cores was ~55,158 kPa (8,000 psi). For comparison, the original 28-day design strength specified at the time of construction was 4,000 psi for the SSTs in AX Farm and 3,000 psi for other Hanford SSTs (RPP-10435 Table A.8). Based on the results of petrographic examination, the concrete represented by the cores was in good condition. No distress (cracking or excessive microcracking) was observed in either core. The concrete showed no evidence of chemical attack, significant alkali-aggregate reactions, or other deleterious mechanisms involving aggregates and/or paste constituents. The concrete in both cores exhibited good physical paste properties. Apart from localized softer paste at the immediate top surface, the paste in the cores was hard and dense through the depth of the concrete. Distribution of aggregates and other paste constituents was uniform. Macroscopically, the cores were well consolidated (i.e., contained no large voids). The concrete was nearly completely hydrated. The penetration depth (from the top surface of both cores) due to carbonation was reported to be 1 to 2 mm (0.04 to 0.08 in.).

Sidewall coring of tank A-106 was completed over two weeks in May 2014. Over 11.6 m (38 ft) of concrete core (8.4-cm [3.3-in.] diameter) was successfully removed to a depth approximately halfway through the tank footing. This tank was chosen due to its high heat load history and concerns over the thermal degradation of the concrete from heat exposure. The collected concrete cores are shown in Figure 7-4. Physical testing for structural integrity indicated favorable results, with values generally greater, and in many cases significantly greater, than expected. It was concluded that the effects of thermal degradation on the mechanical properties of the concrete appear to be negligible. No deficiencies were found with regard to the structural integrity of the tank. Petrographic analyses determined that the concrete is in overall good

condition, with a minor amount of microcracking and minor evidence of deleterious mechanisms that do not appear to have significantly affected the overall quality and integrity of the concrete. The concrete was composed of siliceous natural gravel coarse aggregate and natural sand fine aggregate uniformly distributed in a portland cement paste binder. The paste appeared to be of good quality, although some degree of paste alteration (leaching of calcium hydroxide from the paste) was observed, along with a small amount of secondary ettringite mineral, possibly from sulfate-containing impurities in the paste. Only one crack and very few microcracks were observed in the examined core segments. A very minor degree of alkali-silica reaction had occurred in the concrete; however, no deterioration (no associated cracks or microcracks) was observed. Given the age of the concrete and current degree of alkali-silica reaction, further reaction and/or associated expansion is deemed unlikely. The depth of penetration of carbonation front was found to be shallow and ~1 to 4 mm from outer surface in some core segments.

Results of material properties tests of concrete cores from the haunch and wall of tank 241-SX-115 (SX-115) and PUREX have been evaluated and documented in RHO-RE-CR-2, "*Strength and Elastic Properties Tests of Hanford Concrete Cores – 241-SX-115 Tank and 202-A Purex Canyon Building*." Both structures were built during the 1953 to 1954 time frame using the same concrete mix design. Compression strength and tensile strength tests on concrete samples taken from tank SX-115 in year 1981 indicated a pattern of possible decreasing strength with depth, but all samples were above the design value (compressive strength of 20,680 kPa [3,000 psi]). Material property tests were conducted on 17 specimens from PUREX under three temperature conditions: unheated, heated to 93.3 °C (200 °F), and heated to 93.3 °C (200 °F) and then cooled to ambient temperature. The rate of heating was set at 23.9 °C/day (75 °F/day) to determine if the heat-up rate was significant in affecting the strength. The compressive strength for samples tested after heating to 93.3 °C (200 °F) showed a small decline compared to the unheated samples. However, for samples that were heated to 93.3 °C (200 °F) and then allowed to cool to ambient temperature, some strength recovery was observed with values falling well within the range of strengths measured for the unheated concrete. The compressive strengths of the PUREX concrete specimens were in excess of 20,680 kPa (3,000 psi) design value in all cases.

A visual inspection of 37 concrete core samples from tank SX-115 and 17 concrete core samples from PUREX indicated that most of the samples had no visible signs of concrete deterioration. However, four tank farm cores and two PUREX cores were found to have visible cracks, ranging from ~5 to 25 cm (2 to 10 in.) in length, possibly from coring activities.

A number of tests have been performed to evaluate the strength and elastic properties of the Hanford Tank Farm concrete core materials for temperatures varying from 22.2 °C to 121.1 °C (72 °F to 250 °F) (RHO-RE-CR-2). These tests were conducted on 7.6 cm by 15.2 cm (3 in. by 6 in.) cylinders fabricated from core materials from the 241-A, 241-S, 241-T, and 241-U Tank Farms. The A Farm concrete compressive and tensile strengths were ~45% greater than those values obtained from tank SX-115 concrete; however, the elastic properties were essentially equal. This could be due to variations between concrete batches or the fact that SX-115 tank wall concrete was subjected to higher temperatures during tank farm operations than the dome

concrete in A Farm. In no case did compressive strength of any tank SX-115 specimen fall below 20,680 kPa (3,000 psi). The lowest strength measured was 26,372 kPa (3,825 psi).

The preceding data suggest that the concrete walls for WMA A-AX tanks are likely to be structurally stable and in relatively good condition. The elevated temperatures experienced due to heat introduced by the waste and generated from radioactive decay and chemical reactions within the tanks are unlikely to cause any appreciable decline in strength of the concrete tank walls.

7.4 ABOVE GROUND CONCRETE STRUCTURE EVALUATION

In addition to the concrete samples taken from SSTs, some information on chemical degradation is also available from concrete cores taken from aboveground concrete structures on the Hanford Site. PNNL-23841 summarizes the characteristics of three concrete cores from aboveground structures that have been exposed to Hanford weather for 14, 28, and 57 years. The characterization summary is presented in Table 7-1. A minor degree of microcracking is noticeable, along with a moderately tight paste-aggregate bond. Ettringite is observed in the void spaces. The depth of carbonation increases with increasing age of the concrete. In the oldest specimen (213J), the carbonation penetrated ~50 mm (1.97 in.) into the concrete wall. Given the limited data, the rate of carbonation of concrete at the Hanford Site can be estimated at ~0.3 to 0.9 mm (0.01 to 0.04 in.) per year. This carbonation rate provides an upper bound value that can be expected for concrete under Hanford Site conditions.

7.5 CARBONATION TIME FOR SINGLE-SHELL TANK CONCRETE AND INFILL GROUT AT WASTE MANAGEMENT AREA A-AX

Observations of the cores for buried Hanford tanks indicate the carbonation depth ranges from 1 to 4 mm (0.04 to 0.16 in.). Considering about 60 to 70 years of burial time, the carbonation rates are calculated to be ~0.01 to 0.07 mm/yr (0.0004 to 0.0028 in./yr). For the aboveground concrete structure, the carbonation rate is expectedly much higher and calculated to be ~0.3 to 0.9 mm/yr (0.01 to 0.04 in.). However, the rate of carbonation would be affected by several factors, such as concrete composition, porosity, and the degree of exposure to weathering.

Simplifying carbonation as a sharp moving front (Figure 7-1), a simple analytical expression for the location x_c (mm) of the carbonation front when the relative humidity exceeds 50% can be given as follows ("Modeling Carbonation of High-Level Waste Tank Integrity and Closure" [Brown et al. 2013]):

$$x_c = A\sqrt{t}$$

where A is the proportionality constant and a function of initial CO_2 concentration, effective diffusivity of CO_2, etc., while t is exposure time.

Figure 7-2. Demolition of (a) Pool 1 Monolith and (b) Pool 2 Monolith after Only 5 Days after the Capping Layer had been Poured.

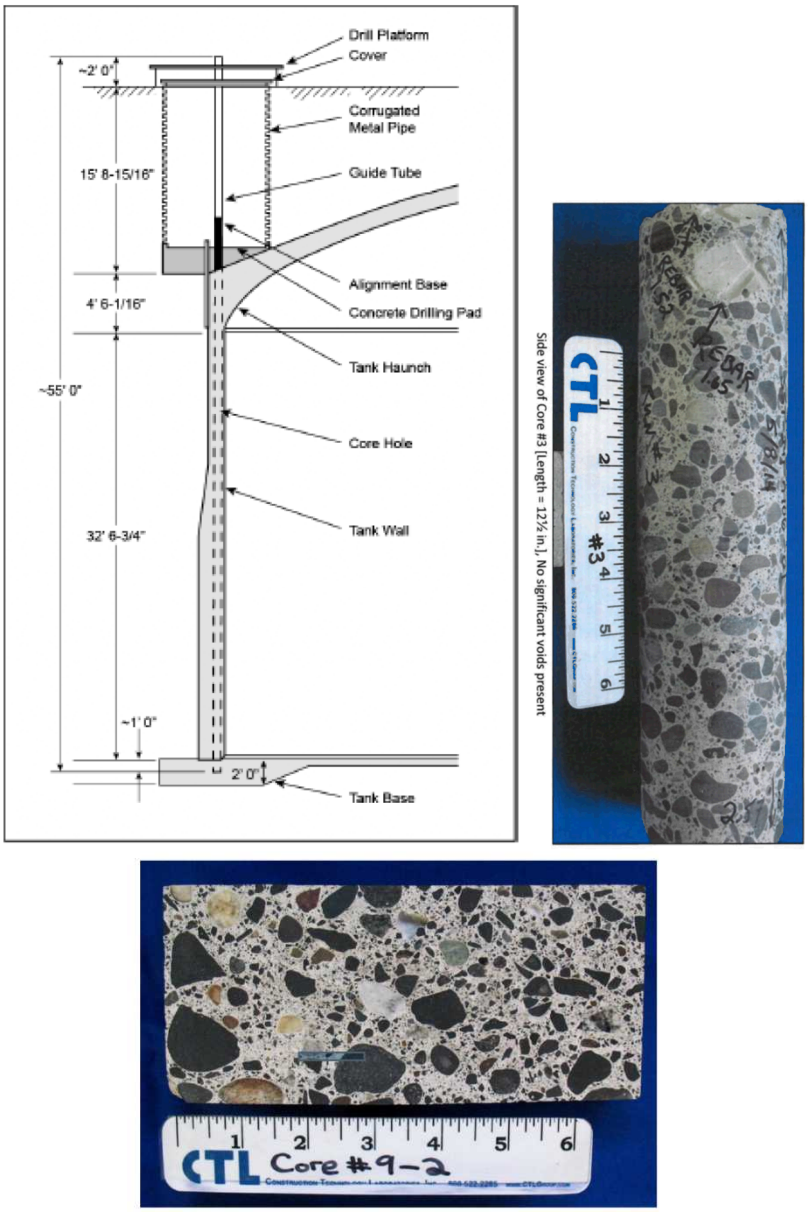
Note that monolith from Pool 2 is in the foreground in (a). Also note the vertical crack in Pool 2 monolith that occurred during the demolition.

Figure 7-3. Evaluation of 55-inch Diameter Reinforced Concrete Dome Plug from Tank 214-C-107.

Experimental results have confirmed this non-linear relationship between the carbonation front and square root of exposure time. For the sake of simplicity, and in order to do a bounding calculation, one can assume that the maximum depth of carbonation within the buried concrete tank structure is 10 mm (0.39 in.) (instead of the observed 1 to 4 mm [0.039 to 0.157 in.]). Next, considering about 70 years of exposure time (approximate burial time of tank C-107, the older of the two samples, prior to analysis), the proportionality constant (A) can be calculated from the above equation to be 1.2 mm (0.05 in.) per square root of time (year). This Hanford Site-specific proportionality constant can then be used to calculate the depth of carbonation front as a function of time. Depths of carbonation front are calculated for arbitrary time periods in Table 7-2. Considering, for example, that a 0.203 m (8 in.) minimum thickness of concrete (6 in.) plus grout

(2 in.) layer exists at the base of each A Farm tank, the time for the carbonation front to propagate through this thickness is estimated to be 29,000 years. The actual time frames would be even longer, since the observed depth of carbonation is 1 to 4 mm (0.039 to 0.157 in.) instead of the assumed 10 mm (0.39 in.) for this calculation.

Figure 7-4. Evaluation of Sidewall Concrete Core from Tank 241-A-106.



For each AX Farm tank, most of the base is 20 in. thick including 18 in. of concrete over 2 in. of grout (Figure 3-24 and Figure 3-26). There are presently drain slots 2.5 in. deep (H-2-44563, "Structural Waste Storage Tanks Drain Arrangement & Details 241-AX PUREX Waste Tank Farm," as shown in Figure 3-25) directly below the steel liner (i.e., the steel is in contact with air in the slots), such that the minimum thickness of cementitious materials in the tank base is

17.5 in. (0.445 m). It is assumed that the drain slots would be grouted at closure[6] and that, with the flowability of existing grout formulations under pressure, the width of the slots (4.5 in. at the base and 5.5 in. at the top) would permit complete grouting of the drain slot network to give a minimum 20-in. thickness below the liner (Figure 3-25). Even if a portion of the drain slot network remained un-grouted, e.g., if the grout bridged at one of the 90-degree intersections, there would still be a 17.5-in. minimum thickness for each AX Farm tank. For the same assumptions just used to estimate the carbonation time for the base of an A Farm tank, the time for a 17.5-in. thickness of an AX Farm tank base is estimated to be well over 100,000 years.

Table 7-1. Characteristics of Concrete Cores from Aboveground Structures at the Hanford Site.

Characteristic	Field Lysimeter Test Facility Sample	622C Sample	213J Sample
Age	14	28	57
Carbonation Depth (mm)	1 – 10	2 – 8	48 – 53
Air Content (%)	4 – 5	2 – 4	1 – 2
Water/Cement Ratio	0.5 – 0.55	0.5 – 0.55	0.52 – 0.57
Secondary Deposits	Abundant ettringite lining voids	Ettringite lining voids	None in outer 50 mm – minor ettringite lining voids
Microcracks	Minor	Minor	Common in outer 50 mm
Steel	#4 ~103 mm cover	None	#4 ~80 mm cover
Unit Weight (pcf)	153	152	148
Aggregates	Well-graded siliceous gravel, 19 mm top size	Well-graded siliceous gravel, 23 mm top size	Well-graded siliceous gravel, 21 mm top size
Paste-Aggregate Bond	Moderately tight	Moderately tight	Moderately tight to moderately weak

Reference: PNNL-23841, "*Radionuclide Migration through Sediment and Concrete: 16 Years of Investigations*."

The above calculated times do not include carbonation through the infill grout material, which will also have to undergo chemical degradation (likely carbonation) before tank integrity can be assumed to be lost. A simple calculation, using at least 10 m (~32.81 ft) grout thickness in the tank, and assuming carbonation front propagating from top as well as from bottom, and assuming a bounding 0.1 mm/yr (0.004 in./yr) linear carbonation rate, suggests that the grout will not be fully degraded for more than another 50,000 years. As a result, the total time for the carbonation front to move through both the concrete shell and the infill grout can easily exceed 70,000 years in either tank farm. Results from recent modeling conducted by Brown et al. (2013) under

[6] If there were no attempt to grout at least the 12-in. pipe connecting the drain slot network to the leak detection well (Figure 3-18), then the pathway between the steel liner and the subsurface environment could completely bypass the cementitious materials of the tank base. Given the unacceptability of such a condition at the time of closure, it is reasonable to assume an attempt will be made to grout both the pipe and the drain slot network as completely as practicable.

Hanford subsurface conditions (assuming 2.4% CO_2 in soil gas at 90% concrete saturations) indicates that the carbonation front propagation rate is < 0.1 mm/yr (0.004 in./yr).

Table 7-2. Bounding Depth of Carbonation for Buried Concrete Calculated for Different Exposure Times Under Hanford-Specific Conditions.

Elapsed Time (yr)	Depth (mm)	Depth (inches)
1,000	37.8	1.5
5,000	84.5	3.3
10,000	119.5	4.7
20,000	169.0	6.7
50,000	267.3	10.5
100,000	378.0	14.9

The information presented above suggests that it is highly unlikely for the tank degradation to occur within the modeled time period of 10,000 years. As a result, the water entry in the tank is likely to be very slow or nonexistent. For the purpose of the PA analysis, the infill grout is conceptualized to be located above the thin residual waste layer and separated from the grout/concrete layer at the base of the tank. While the infill grout is intact, no water can flow through the residual waste, and therefore the primary contaminant transport pathway is by diffusion through water in the pore spaces to the base of the tank and into the underlying vadose zone.

7.6 ANCIENT ANALOGS

A way to gain insight into the longevity (durability) of grout, concrete, and mortar is through consideration of some of the well-studied ancient structures such as the Pantheon in Rome, Hadrian's Wall in Scotland, and the Roman Aqueducts system, as discussed in WSRC-TR-2005-00195. Such ancient structures that use pozzolanic materials in conjunction with hydrated lime [$Ca(OH)_2$] best simulate modern day concrete, grout, and mortar. Some of these ancient structures have existed for over 2,000 years despite being subjected to weather, abrasion, wars, and neglect. "Mechanical resilience and cementitious processes in Imperial Roman architectural mortar" (Jackson et al. 2014) concluded from laboratory analysis of 1,900-year-old Roman concrete mortar that conglomeratic concretes may "maintain their chemical resilience and structural integrity in seismically active environments at the millennial scale." The longevity of these ancient structures, which is attributable to materials selection and placement techniques, suggests that the lifetimes for the grout monoliths within the protected, underground SSTs at Hanford could also extend into the thousands of years.

This page intentionally left blank.

8.0 REFERENCES

2049-NEG, June 8, 1953, "AERIAL VIEW OF 200E AREA LOOKING WEST."

2472-PHOTO, January 20, 1954, "PUREX WASTE TANK FARM - 241-A GROUND BREAKING."

2505-PHOTO, February 18, 1954, "PUREX WASTE TANK FARM - 241-A CONSTRUCTION PROGRESS (VIEW 3)."

2524-PHOTO, February 26, 1954, "PUREX WASTE TANK FARM - 241-A CONSTRUCTION PROGRESS (VIEW 1)."

2641-PHOTO, March 29, 1954, "PUREX WASTE TANK FARM - 241-A CONSTRUCTION PROGRESS."

2788-PHOTO, May 22, 1954, "WASTE STORAGE FACILITIES, PUREX – 241-A CONSTRUCTION PROGRESS."

2871-PHOTO, June 28, 1954, "PUREX WASTE TANK FARM - 241-A CONSTRUCTION PROGRESS."

2991-PHOTO, August 30, 1954, "241-A WASTE STORAGE TANK FARM."

3099-1-PHOTO, October 8, 1954, "241-A WASTE STORAGE - CONSTRUCTION PROGRESS (VIEW 4)."

3099-NEG-B, October 8, 1954, "241-A TANK DOMES."

3099-NEG-D, October 8, 1954, "241-A TANK DOMES."

3186-PHOTO, December 24, 1954, "241-A - TANK FARM CONDENSOR SYSTEM."

3289-PHOTO, January 20, 1955, "PUREX FACILITY CONSTRUCTION - LIQUID WASTE DISPOSAL CRIB (VIEW 4)."

3615-PHOTO, December 27, 1955, "241-A TANK FARM - AIR LIFT CIRCULATOR."

3616-PHOTO, December 27, 1955, "241-A TANK FARM - AIR LIFT CIRCULATOR."

6619-PHOTO, September 25, 1963, "NEW WASTE STORAGE TANKS – PUREX – FOUNDATION FOR TANKS."

6637-PHOTO, October 28, 1963, "NEW WASTE STORAGE TANKS – PUREX – CONCRETE BASES FOR STORAGE TANKS, START OF STEEL PLATE LAYOUT."

6671-PHOTO, November 26, 1963, "NEW WASTE STORANGE TANKS – PUREX – TANK BOTTOM RAISED FOR WELDING."

6863-PHOTO, June 23, 1964, "PUREX WASTE STORAGE FACILITIES ADDITION NO. 241-AX - 200 EAST AREA."

6864-PHOTO, June 23, 1964, "PUREX WASTE STORAGE FACILITIES ADDITION NO. 241-AX - 200 EAST AREA."

33905-2, October 3, 1963, "SHOTS OF PROGRESS 241AX TANK FARMS [5 NEGATIVES]."

35799-1, April 1, 1964, "TANK FARM CONSTRUCTION [7 NEGATIVES]."

78 FR 75913, 2013, "Record of Decision: Final Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington," *Federal Register*, Vol. 78, pp. 75913–75919 (December 13).

ARH-78, 1967, "PUREX TK-105-A Waste Storage Tank Liner Instability and its Implications on Waste Containment and Control," Atlantic Richfield Hanford Company, Richland, Washington.

ARH-258 DEL, 1968, "Chemical Processing Division Daily Production Reports January, 1968 through March, 1968," Atlantic Richfield Hanford Company, Richland, Washington.

ARH-LD-127, 1976, *Geology of the 241-A Tank Farm*, Atlantic Richfield Hanford Company, Richland, Washington.

ARH-LD-128, 1976, *Geology of the 241-AX Tank Farm*, Atlantic Richfield Hanford Company, Richland, Washington.

Army Geospatial Center, United States Army Corps of Engineers, Queried 05/19/2015, [Corpscon 6.0.1], http://www.agc.army.mil/Missions/Corpscon.aspx.

Benson, J. E., R. T. Tveten, M. G. Asher and P. W. Dunwiddie, 2011, Shrub-Steppe and Grassland Restoration Manual for the Columbia River Basin, Washington Department of Fish and Wildlife, Olympia, Washington.

BHI-00007, 1994, "*Prototype Hanford Surface Barrier: Design Basis Document*," Rev. 00, Bechtel Hanford, Inc., Richland, Washington.

BHI-00144, 1995, "Long-Term Climate Change Effects Task for the Hanford Site Permanent Isolation Barrier Development Program: Final Report," Bechtel Hanford Company, Richland, Washington.

BHI-00178, 1995, "*PUREX Plant Aggregate Area Management Study Technical Baseline Report*," Rev. 0, Bechtel Hanford, Inc., Richland, Washington.

BHI-00608, 1997, "*Hanford Sitewide Groundwater Flow and Transport Model Calibration Report*," Rev. 1, Bechtel Hanford, Inc., Richland, Washington.

Brown, K. G., J. Arnold, S. Sarkar, G. Flach, H. van der Sloot, J. C. L. Meeussen and D. S. Kosson, 2013, "Modeling Carbonation of High-Level Waste Tank Integrity and Closure," *EPJ Web of Conferences*, Vol. 56, pp. 1–10.

Cantrell, K. J., K. C. Carroll, E. C. Buck, D. Neiner, K. N. Geiszler, 2013, "Single-pass flow-through test elucidation of weathering behavior and evaluation of contaminant release models for Hanford tank residual radioactive waste," *Applied Geochemistry*, Vol. 28, pp. 119–127.

Cantrell, K. J., W. J. Deutsch, and M. J. Lindberg, 2011, "Thermodynamic Model for Uranium Release from Hanford Site Tank Residual Waste," *Environmental Science & Technology*, Vol. 45, No. 4, pp. 1473–1480.

CHG-0200089, 2002, "Contract Number DE-AC27-99RL14047; Stabilization and Isolation of Catch Tank 241-AX-152" (external letter from D. I. Allen to J. H. Swailes, U.S. Department of Energy, Office of River Protection, January 17), CH2M HILL Hanford Group, Inc., Richland, Washington.

Circular 1331, 2009, "*Climate Change and Water Resources Management: A Federal Perspective*," U.S. Geological Survey, Reston, Virginia.

CP-14873, 2003, "*200-BP-1 Prototype Hanford Barrier Annual Monitoring Report for Fiscal Year 2002*," Rev. 0, CH2M HILL Hanford Group, Inc./CH2M HILL Hanford, Inc./ Pacific Northwest National Laboratory, Richland, Washington.

CP-49279, 2011, "*Central Plateau Waste Site Dimensions*," Rev. 0, CH2M HILL Plateau Remediation Company, Richland, Washington.

Cramer, K. H., 1987, *Hanford Site Waste Management Units Report*, May 1987, Westinghouse Hanford Company, Richland, Washington.

Deutsch, W. J., K. J. Cantrell, K. M. Krupka, M. L. Lindberg, and R. J. Serne, 2011, "Hanford tank residual waste – Contaminant source terms and release models," *Applied Geochemistry*, Vol. 26, pp. 1681–1693.

DOE/EIS-0391, 2012, *Final Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington*, U.S. Department of Energy, Washington, D.C.

DOE/ORP-2000-24, 2001, *Hanford Immobilized Low-Activity Waste Performance Assessment: 2001 Version*, Rev. 0, U.S. Department of Energy, Office of River Protection, Richland, Washington.

DOE/RL-88-30, 2017, *Hanford Site Waste Management Units Report*, Rev. 26, U.S. Department of Energy, Richland, Washington.

DOE/RL-89-28, 1994, *216-B-3 Expansion Ponds Closure Plan*, Rev. 2, U.S. Department of Energy, Richland, Washington.

DOE/RL-92-04, 1993, *PUREX Source Aggregate Area Management Study Report*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-93-33, 1996, *Focused Feasibility Study of Engineered Barriers for Waste Management Units in the 200 Areas*, Rev. 1, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2007-27, 2014, *Threatened and Endangered Species Management Plan: Salmon, Steelhead, and Bull Trout*, Rev. 1, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2015-49, 2015, *Interim-Status Groundwater Quality Assessment Plan for the Single-Shell Tank Waste Management Area A-AX*, Draft Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2016-37, 2016, *Prototype Hanford Barrier 1994 to 2015*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

Ecology, EPA, and DOE, 1989, *Hanford Federal Facility Agreement and Consent Order – Tri-Party Agreement*, 2 vols., as amended, State of Washington Department of Ecology, U.S. Environmental Protection Agency, and U.S. Department of Energy, Olympia, Washington.

Fayer, M. J., G. W. Gee, M. L. Rockhold, M. D. Freshley and T. B. Walters, 1996, "Estimating Recharge Rates for a Groundwater Model Using a GIS," *Journal of Environmental Quality*, Vol. 25, pp. 510–518.

Gee, G. W., M. J. Fayer, M. L. Rockhold, and M. D. Campbell, 1992, "Variations in Recharge at the Hanford Site," *Northwest Science*, Vol. 66, No. 4, pp. 237–250.

H-2-31880, 1968, "241-A Tank Farm Leak Detection System Plan-Section-Detail," Rev. 2, H. E. Bovay Jr., Consulting Engineers, Richland, Washington.

H-2-31882, 1983, "241 A & 241 SX Tank Farms Leak Detection System Sections & Details," Sheet 1, Rev. 2, H. E. Bovay Jr., Consulting Engineers, Richland, Washington.

H-2-33295, 1973, "216-A-39 Crib for Inst. Enclosure 241-AX 801-B Plot Plan & Details," Rev. 3, U.S. Atomic Energy Commission, Richland Operations Office, Richland, Washington.

H-2-33973, 1967, "Thermal Probes Under Tk. 105-A," Sheet 1, Rev. 1, U.S. Atomic Energy Commission, Richland Operations Office, Richland, Washington.

H-2-33973, 1968, "Thermal Probes Under 105-A Tank," Sheet 2, U.S. Atomic Energy Commission, Richland Operations Office, Richland, Washington.

H-2-34043, 1967, "Thermal Probe Assembly & Detail TK 105-A," Rev. 1, U.S. Atomic Energy Commission, Richland, Washington.

H-2-34086, 1967, "Electrical Detail 105-A Thermal Probe," U.S. Atomic Energy Commission, Richland Operations Office, Richland, Washington.

H-2-38978, 1976, "241-A Tank Farm Geologic Map Legend and Plot Plan," Energy Research & Development Administration, Richland Operations Office, Richland, Washington.

H-2-44501, 1980, "Area Map, 200 East, A Plant Facilities," Sheet 69, Rev. 12, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

H-2-44502, 1970, "Flow Diagram Waste Transfer and Storage Facilities," U.S. Atomic Energy Commission, Richland, Washington.

H-2-44552, 1965, "Plot Plan Finished Grading and Facilities PUREX 241 Tank Farm," Rev. 5, Bovay Engineers, Inc., Richland, Washington.

H-2-44562, 1962, "Structural Waste Storage Tanks Composite Section & Details, 241-AX PUREX Waste Tank Farm," Rev. 4, U.S. Atomic Energy Commission Hanford Atomics Products Operation, Richland, Washington.

H-2-44563, 1965, "Structural Waste Storage Tanks Drain Arrangement & Details 241-AX PUREX Waste Tank Farm," Rev. 2, U.S. Atomic Energy Commission Hanford Atomics Products Operation, Richland, Washington.

H-2-44575, 1965, "Structural Leak Detection Pit Tanks 102, & 104-AX," Rev. 2, Bovay Engineers, Inc., Richland, Washington.

H-2-44576, 1965, "Structural - Leak Detection Pit Tanks 101 & 103-AX," Rev. 2, Bovay Engineers, Inc., Richland, Washington.

H-2-44577, 1965, "Structural Leak Detection Pit Details," Rev. 2, Bovay Engineers, Inc., Richland, Washington.

H-2-44612, 1990, "Engineering Flow Diagram 241-AX Tank Farm," Bovay Engineers, Richland, Washington.

H-2-44633, 1972, "Process Waste Lines Tk. Farm Area Plans & Sections, 241-AX Tank Farm," Rev. 4, Bovay Engineers, Inc., Richland, Washington.

H-2-44676, 1973, "Air-Lift Piping Arrgt. & Circulator Details," Rev. 6, U.S. Atomic Energy Commission Hanford Atomic Products Operation, Richland, Washington.

H-2-55904, 1956, "Excavation Plan & Sections PUREX Waste Disposal Facility," Rev. 2, U.S. Atomic Energy Commission Hanford Works, Richland, Washington.

H-2-55911, 1953, "Waste Storage Tanks Composite Section PUREX Waste Disposal Facility," Rev. 1, U.S. Atomic Energy Commission Hanford Works, Richland, Washington.

H-2-55912, 1956, "Waste Storage Tanks, Base Footing and Wall Reinforcing, PUREX Waste Disposal Facility," Rev. 1, General Electric Company, Richland, Washington.

H-2-55973, 1956, "Waste Line Encasement Fill Line Layout, PUREX Waste Disposal Facility," Sheet 1, Rev. 2, U.S. Atomic Energy Commission Hanford Atomic Products Operation, Richland, Washington.

H-2-55973, 1971, "Waste Line Encasement Fill Line Layout, PUREX Waste Disposal Facility," Sheet 2, Rev. 2, U.S. Atomic Energy Commission Hanford Atomic Products Operation, Richland, Washington.

H-2-55983, 1956, "241-A Encasements: 241-A-152 to 241-A Structural DTL's, PUREX Waste Disposal Facilities," Sheet 1, Rev. 4, U.S. Atomic Energy Commission, Hanford Atomic Products Operation, Richland, Washington.

H-2-55983, 1956, "241-A Encasements Encasement and Cover Slabs Details Structural, PUREX Waste Disposal Facilities," Sheet 2, Rev. 3, U.S. Atomic Energy Commission, Hanford Atomic Products Operation.

H-2-55983, 1956, "241-A Encasements Vapor Header Support Structural, PUREX Waste Disposal Facilities," Sheet 3, Rev. 2, U.S. Atomic Energy Commission, Hanford Atomic Products Operation.

H-2-56038, 1956, "Control House 241-A-271 Equipment Arrangement & Piping," Rev. 4, General Electric Company, Richland, Washington.

H-2-56041, 1956, "Control House 4" C.I. Sewer Line Plan & Profile," Rev. 1, General Electric Company, Richland, Washington.

H-2-56342, 1955, "Details Air-Lift Circulator, Circulation Facilities 241A Tank Farm," General Electric Company, Richland, Washington.

H-2-56350, 1955, "Arrangement Air-Lift Circulators, Circulation Facilities 241-A Tank Farm," General Electric Company, Richland, Washington.

H-2-61964, 1968, "Plot Plan Yard Piping 241-AX Tank Farm," Rev. 2, U.S. Atomic Energy Commission, Richland Operation Office, Richland, Washington.

H-2-70683, 1982, "Civil Profiles," Rev. 1, Vitro Engineering Corporation, Richland, Washington.

H-2-70684, 1982, "Civil 2"-ST Line & Dry Well Details," Rev. 1, Vitro Engineering Corporation, Richland, Washington.

H-2-70698, 1982, "Plumbing Plans Details & Diagrams," Rev. 1, Vitro Engineering Corporation, Richland, Washington.

H-14-104175, 2014, "Waste Transfer Piping Diagram 200 East Area," Rev. 41, U.S. Department of Energy, Office of River Protection, Richland, Washington.

HNF-2503, 1998, *Authorization Basis Status Report (Miscellaneous TWRS Facilities, Tanks and Components)*, Duke Engineering and Services Hanford, Inc., Richland, Washington.

HNF-6612, 2016, "*Hanford Site Sewer System Master Plan*," Rev. 5, Mission Support Alliance, Richland, Washington.

HNF-EP-0182, 2017, "*Waste Tank Summary Report for Month Ending December 31, 2016*," Rev. 348, Washington River Protection Solutions, LLC, Richland, Washington.

HNF-SD-LL-SP-001, 1998, *200 and 600 Areas Sanitary Wastewater Master Plan*, Rev. 1, Fluor Daniel Northwest, Inc., Richland, Washington.

HW-28121, 1953, "*Release of Radioactive Wastes to Ground*," General Electric Company, Hanford Atomic Products Operation, Richland, Washington.

HW-4798-S, 1951, *Standard Specification for Placing Reinforced Concrete*, Rev. 6, General Electric Company, Richland, Washington.

HW-60807, 1959, "*Unconfined Underground Radioactive Waste and Contamination in the 200 Areas–1959*," General Electric Company, Richland, Washington.

HWS-5614, 1953, *Specifications for PUREX Waste Disposal Facility Project CA-513-A*, Hanford Atomics Products Operation, Richland, Washington.

HWS-8237, 1963, *Specification for PUREX 241-AX Tank Farm Project CAC-945*, Rev. 2, Hanford Atomics Products Operation, Richland, Washington.

INDC-356-VOL3, 1945, "*Construction Hanford Engineer Works, U.S. Contract No. W-7412-ENG-1 Du Pont Project 9536 History of the Project Volume III*," E. I. du Pont de Nemours and Company, Wilmington, Delaware.

Jackson, M. D., E. N. Landis, P. F. Brune, M. Vitti, H. Chen, Q. Li, M. Kunz, H. Wenk, P. J. M. Monteiro, and A. R. Ingraffea, 2014, "Mechanical resilience and cementitious processes in Imperial Roman architectural mortar," *Proceedings of the National Academy of Sciences of the United States of America*, Vol. 111, No. 52, pp. 18484–18489.

Karl, T. R., J. M. Melillo, and T. C. Peterson, (eds.), 2009, Global Climate Change Impacts in the United States: A State of Knowledge Report from the U.S. Global Change Research Program, Cambridge University Press, New York, New York.

Leary, K. D., 1990, Analysis of Techniques for Estimating Potential Recharge and Shallow Unsaturated Zone Water Balance near Yucca Mountain, Nevada, M.S. Thesis, University of Nevada, Reno, Nevada.

Mote, P. E., E. P. Salathé, V. Dulière, and E. Jump, 2008, "*Scenarios of future climate for the Pacific Northwest*," Climate Impacts Group, University of Washington, Seattle, Washington.

NAGRA NTB 02-20, 2002, "*Cementitious Near-Field Sorption Data Base for Performance Assessment of an ILW Repository in Opalinus Clay*," Technical Report 02-20, National Cooperative for the Disposal of Radioactive Waste, Hardstrasse, Zurich, Switzerland.

National Geodetic Vertical Datum of 1929, National Geodetic Survey, U.S. Department of Commerce.

NIROND-TR 2008-23 E, 2009, "*Review of sorption values for the cementitious near field of a near surface radioactive waste disposal facility, Project near surface disposal of category A waste at Dessel*," Belgian Agency for Radioactive Waste and Enriched Fissile Materials, Brussels, Belgium.

NOAA Manual NOS NGS 5, 1990, "State Plane Coordinate System of 1983," National Geodetic Survey, U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Rockville, Maryland.

North American Datum of 1983, National Geodetic Survey, U.S. Department of Commerce.

North American Vertical Datum of 1988, National Geodetic Survey, U.S. Department of Commerce.

Nyame, B. K. and J. M. Illston, 1981, "Relationships between permeability and pore structure of hardened cement paste," *Magazine of Concrete Research*, Vol. 33, No. 116, p. 139–146.

PNL-10285, 1995, "*Estimated Recharge Rates at the Hanford Site*," Pacific Northwest Laboratory, Richland, Washington.

PNL-10788, 1995, "*The Role of Plants and Animals in Isolation Barriers at Hanford, Washington*," Pacific Northwest Laboratory, Richland, Washington.

PNL-11463, 1994, "*A Comprehensive Analysis of Contaminant Transport in the Vadose Zone Beneath Tank SX-109*," Pacific Northwest National Laboratory, Richland, Washington.

PNNL-11367, 1996, "*Hanford Prototype-Barrier Status Report: FY 1996*," 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.

PNNL-14702, 2006, "*Vadose Zone Hydrogeology Data Package for Hanford Assessments*," Rev. 1, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-14744, 2004, "*Recharge Data Package for the 2005 Integrated Disposal Facility Performance Assessment*," Pacific Northwest National Laboratory, Richland, Washington.

PNNL-15160, 2005, "*Hanford Site Climatological Summary 2004 with Historical Data*," Pacific Northwest National Laboratory, Richland, Washington.

PNNL-16688, 2007, "*Recharge Data Package for Hanford Single-Shell Tank Waste Management Areas*," Pacific Northwest National Laboratory, Richland, Washington.

PNNL-17593, 2008, "*Hanford Tank 241-S-112 Residual Waste Composition and Leach Test Data*," Pacific Northwest National Laboratory, Richland, Washington.

PNNL-18845, 2011, "*200-BP-1 Prototype Hanford Barrier – 15 Years of Performance Monitoring*," Rev. 1, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-20616, 2011, "*Contaminant Release from Hanford Tank Residual Waste – Results of Single-Pass Flow-Through Tests*," Pacific Northwest National Laboratory, Richland, Washington.

PNNL-23841, 2014, "*Radionuclide Migration through Sediment and Concrete: 16 Years of Investigations*," Pacific Northwest National Laboratory, Richland, Washington.

PSI Bericht Nr. 95-06, 1995, "*Sorption Databases for the Cementitious Near-Field of a L/ILW Repository for Performance Assessment*," Paul Scherrer Institute, Switzerland.

Resource Conservation and Recovery Act of 1976, 42 USC 6901, et seq.

RHO-CD-673, 1979, "*Handbook 200 Areas Waste Sites*," Rockwell Hanford Operations, Richland, Washington.

RHO-RE-CR-2, 1982, "*Strength and Elastic Properties Tests of Hanford Concrete Cores – 241-SX-115 Tank and 202-A Purex Canyon Building*," Construction Technology Laboratories, Skokie, Illinois.

RL-SEP-9, 1964, "*PUREX 241-AX Tank Farm and Waste Routing System Information Manual*," Hanford Atomics Products Operation, Richland, Washington.

RPP-7494, 2001, *Historical Vadose Zone Contamination from A, AX, and C Tank Farm Operations*, Rev. 0, Fluor Federal Services, Richland, Washington.

RPP-8847, 2004, "*Best-Basis Inventory Template Compositions of Common Tank Waste Layers*," Rev. 1, CH2M HILL Hanford Group, Inc. and Los Alamos Technical Associates, Inc., Richland, Washington.

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

RPP-12051, 2003, *244-AR Vault Interim Stabilization Completion Report*, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-15043, 2003, "*Single-Shell Tank System Description*," Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-25113, 2006, "*Residual Waste Inventories in the Plugged and Abandoned Pipelines at the Hanford Site*," Rev. 0-A, Meier Enterprises, Inc., Richland, Washington.

RPP-26744, 2005, "*Hanford Soil Inventory Model, Rev. 1*," Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-35484, 2008, "*Field Investigation Report for Waste Management Areas C and A-AX*," Rev. 1, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-CALC-57152, 2014, "*Analysis of Potential Waste in Airlift Circulators and Steam Coils in AX Tanks Post Retrieval*," Rev. 1, Washington River Protection Solutions, LLC, Richland, Washington.

RPP-ENV-37956, 2017, "*Hanford 241-A and 241-AX Tank Farms Leak Inventory Assessment Report*," Rev. 3, Washington River Protection Solutions, LLC, Richland, Washington.

RPP-ENV-58578, 2018 (in preparation), "*Summary of the Natural System at Waste Management Area A/AX*," Rev. 1, Washington River Protection Solutions, LLC, Richland, Washington.

RPP-ENV-58747, 2015, "*Fiscal Years 2014/2015 Completion Report for the 241-A and 241-AX Tank Farms Direct Push Characterization*," Rev. 0, EnergySolutions, Government Group Inc./Washington River Protection Solutions, LLC, Richland, Washington.

RPP-ENV-58782, 2016, "*Performance Assessment of Waste Management Area C, Hanford Site, Washington*," Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.

RPP-PLAN-47559, 2012, "*Single-Shell Tank Waste Management Area C Pipeline Feasibility Evaluation*," Rev. 1, Washington River Protection Solutions, LLC/Cenibark International, Inc., Richland, Washington.

RPP-RPT-31102, 2006, "*Catch Tank 241-AX-151-CT Liquid Level Assessment Report*," Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-RPT-31126, 2006, *241-AX-IX Liquid Level Assessment Report*, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-RPT-35112, 2007, "*Retrieval Data Report for Single-Shell Tank 241-S-112*," Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-RPT-42323, 2015, "*Hanford C-Farm Tank and Ancillary Equipment Residual Waste Inventory Estimates*," Rev. 3, Washington River Protection Solutions, LLC, Richland, Washington.

RPP-RPT-44042, 2010, "*Recharge and Waste Release within Engineered System in Waste Management Area C*," Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.

RPP-RPT-46879, 2011, "*Corrosion and Structural Degradation within Engineered System in Waste Management Area C*," Rev. 2, Washington River Protection Solutions, LLC, Richland, Washington.

RPP-RPT-50934, 2012, "*Inspection and Test Report for the Removed 241-C-107 Dome Concrete*," Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.

RPP-RPT-54909, 2014, "*Hanford Single-Shell Tanks Leak Causes, Locations, and Rates: Summary Report*," Rev. 0, Washington River Protection Solutions, LLC/AEM Consulting, LLC/Columbia Energy and Environmental Services, Richland, Washington.

RPP-RPT-54912, 2013, "*Hanford Single-Shell Tank Leak Causes and Locations – 241-A Tank Farm*," Rev. 0, Washington River Protection Solutions, Richland, Washington.

RPP-RPT-55804, 2015, "*Common Factors Relating to Liner Failures in Single-Shell Tanks*," Rev. 1, Washington River Protection Solutions, LLC, Richland, Washington.

RPP-RPT-58156, 2014, "*Basis for Miscellaneous Underground Storage Tanks and Special Surveillance Facilities Waste Volumes Published in HNF-EP-0182 Revision 320 'Waste Tank Summary Report for Month Ending August 31, 2014'*," Rev. 0, Washington River Protection Solutions, LLC/AEM Consulting LLC, Richland, Washington.

RPP-RPT-58254, 2014, "*Concrete Core Testing Report for the Single-Shell Tank 241-A-106 Sidewall Coring Project*," Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.

RPP-RPT-58291, 2017, "*Hanford Waste Management Area A-AX Soil Contamination Inventory Estimates*," Rev. 1, Washington River Protection Solutions, LLC, Richland, Washington.

RPP-RPT-58293, 2017, "*Hanford 241-A and 241-AX Farm Tank and Ancillary Equipment Residual Waste Inventory Estimates*," Rev. 1, Washington River Protection Solutions, LLC, Richland, Washington.

RPP-RPT-58932, 2017, "*241-AX-101 Tank Waste Retrieval Work Plan*," Rev. 1, Washington River Protection Solutions, LLC/INTERA, Inc., Richland, Washington.

RPP-RPT-58933, 2017, "*241-AX-102 Tank Waste Retrieval Work Plan*," Rev. 1, Washington River Protection Solutions, LLC/INTERA, Inc., Richland, Washington.

RPP-RPT-58934, 2017, "*241-AX-103 Tank Waste Retrieval Work Plan*," Rev. 1, Washington River Protection Solutions, LLC/INTERA, Inc., Richland, Washington.

RPP-RPT-58935, 2017, "*241-AX-104 Tank Waste Retrieval Work Plan*," Rev. 1, Washington River Protection Solutions, LLC/INTERA, Inc., Richland, Washington.

RPP-RPT-60101, 2018, "*Model Package Report: Flow and Contaminant Transport Numerical Model used in WMA A-AX Performance Assessment and RCRA Closure Analysis*," Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.

RPP-RPT-60171, 2018, "*Model Package Report: Geologic Framework Model used in WMA A-AX Performance Assessment and RCRA Closure Analysis*," Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.

RPP-RPT-60227, 2017, "*Data Quality Objectives for Vadose Zone Characterization at Waste Management Area A-AX*," Washington River Protection Solutions, LLC, Richland, Washington.

Scanlon, B. R., K. E. Keese, A. L. Flint, L. E. Flint, C. B. Gaye, W. M. Edmunds, and I. Simmers, 2006, "Global synthesis of groundwater recharge in semiarid and arid regions," *Hydrological Processes*, Vol. 20, Issue 15, pp. 3335–3370.

Seyfried, M. S., S. Schwinning, M. A. Walvoord, W. T. Pockman, B. D. Newman, R. B. Jackson, and F. M. Phillips, 2005, "Ecohydrological Control of Deep Drainage in Arid and Semiarid Regions," *Ecology*, Vol. 86, No. 2, pp. 277–287.

SGW-59881, 2016, "*200-IS-1 Operable Unit Scoping*," Rev. 0, CH2M HILL Plateau Remediation Company, Richland, Washington.

SKB Rapport R-05-75, 2005, "*Assessment of uncertainty intervals for sorption coefficients, SFR-1 uppföljning av SAFE*," Swedish Nuclear Fuel and Waste Management Company, Stockholm, Sweden.

SRNL-STI-2008-00421, 2008, "*Hydraulic and Physical Properties of Saltstone Grouts and Vault Concretes*," Rev. 0, Savannah River National Laboratory, Savannah River Nuclear Solutions, Aiken, South Carolina.

SRNL-STI-2016-00175, 2016, "*Solid Secondary Waste Data Package Supporting Hanford Integrated Disposal Facility Performance Assessment*," Rev. 0, Savannah River National Laboratory, Savannah River Nuclear Solutions, Aiken, South Carolina.

Tank Waste Information Network System (TWINS), Queried 01/18/2018, [241-A-101 Surface Panorama, 07/16/2015], https://twins.labworks.org/TankReports/241-A-101/241-A-101 Surface Panorama - 2015-07-16.png.

Tank Waste Information Network System (TWINS), Queried 01/18/2018, [241-A-102 Surface Panorama, 01/21/2014], https://twins.labworks.org/TankReports/241-A-102/241-A-102 Surface Panorama - 2014-01-21.png.

Tank Waste Information Network System (TWINS), Queried 01/18/2018, [241-A-103 Surface Panorama, 01/15/2014], https://twins.labworks.org/TankReports/241-A-103/241-A-103 Surface Panorama - 2014-01-15.png.

Tank Waste Information Network System (TWINS), Queried 01/18/2018, [241-A-104 Surface Panorama, 09/22/2017], https://twins.labworks.org/TankReports/241-A-104/241-A-104 Surface Panorama - 2017-09-22.jpg.

Tank Waste Information Network System (TWINS), Queried 01/18/2018, [241-A-105 Surface Panorama, 09/22/2017], https://twins.labworks.org/TankReports/241-A-105/241-A-105 Surface Panorama - 2017-09-22.jpg.

U.S. Department of Agriculture, Natural Resources Conservation Service, Queried 12/18/2015, [Fact Sheets & Plant Guides/Artemisia tridentata ssp. tridentata], http://plants.usda.gov/plantguide/pdf/pg_artrt.pdf.

WCC Project 13974A-0300, 1978, "*An Estimate of Bottom Topography, Volume and Other Conditions in Tank 105A, Hanford, Washington*," Woodward-Clyde Consultants for Atomics International Rockwell-Hanford Operations, Richland, Washington.

WHC-EP-0332, 1989, "*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*," Westinghouse Hanford Company, Richland, Washington.

Whitlock, C. and P. J., Bartlein, 1997, "Vegetation and climate change in northwest America during the past 125 kyr," *Nature*, Vol. 388, pp. 57–61.

Wing, N. R. and G. W. Gee, 1994, "Quest for the Perfect Cap," *Civil Engineering*, Vol. 64, No. 10, pp. 38–41.

WSRC-STI-2007-00369, 2007, "*Hydraulic and Physical Properties of Tank Grouts and Base Mat Surrogate Concrete for FTF Closure*," Rev. 0, Savannah River National Laboratory/ Washington Savannah River Company, Aiken, South Carolina.

WSRC-STI-2007-00607, 2007, "*Chemical Degradation Assessment of Cementitious Materials for the HLW Tank Closure Project (U)*," Rev. 0, Washington Savannah River Company/ Savannah River National Laboratory, Aiken, South Carolina.

WSRC-TR-2005-00195, 2005, "*Summary of Grout Development and Testing for Single Shell Tank Closure at Hanford*," Rev. 0, Savannah River National Laboratory, Aiken, South Carolina.

APPENDIX A

TANK 241-A-105 HISTORY

LIST OF FIGURES

Figure A-1. Picture of Tank Bottom and Liner Damage from Tank 241-A-105 Steam Release Event on January 8, 1965. ..... A-7

Figure A-2. Estimated Topography of Tank 241-A-105 Inside Bottom Surface (1977)..... A-8

LIST OF TERMS

Abbreviations and Acronyms

ALC	airlift circulator
ASTM	American Society for Testing and Materials
HLW	high-level waste
PUREX	Plutonium Uranium Extraction (process)
SST	single-shell tank

APPENDIX A

TANK 241-A-105 HISTORY

The past history of tank 241-A-105 (A-105) presents unique challenges for planned model evaluation efforts needed to support decisions to the waste retrieval process, possible corrective measures, and eventual closure of the 241-A Tank Farm (A Farm). Tank A-105 suffered physical damage from a rapid pressurization and steam release event that occurred in 1965. Evidence also suggests that waste has potentially leaked to the subsurface from this specific tank at multiple times from the early 1960s to the late 1970s. Potential validation of initial model evaluations of these past waste loss events is hindered by the fact that currently-available characterization and monitoring data are limited to indirect measurements of potential impacts that include total gamma radiation, spectral gamma radiation, and temperature from existing drywells and lateral lines. Any field work planned, including certain types of intrusive data collection, are complicated at Waste Management Area A-AX and other tank farms at the Hanford Site due to the presence of considerable infrastructure found at shallow depths above, in between, and below the tanks and ancillary equipment and a range of safety constraints beyond what is typical even at analogous hazardous waste sites.

Plans to complete an angled borehole for soil sampling beneath tank A-105 and to collect neutron moisture gauge and other measurements from the drywells in 2015 (RPP-PLAN-57332, "*Field Sampling and Analysis Plan for Soil Samples at Waste Management Area A-AX*") were interrupted and have not been completed as of early 2018; therefore, such data will not be available in time for the initial model analysis of these leaks in the Waste Management Area A-AX preliminary performance assessment. Any data to be generated during waste retrieval activities that may be useful to the model evaluation may be unavailable for the initial performance assessment, which is purposely being developed prior to retrieval to support end-of-retrieval decisions.

This summary recounts relevant details of tank A-105's design and history to aid development of a conceptual model for past waste loss events of this tank and to understand current conditions that may influence the anticipated conditions of waste residuals at the time of closure. Various estimates of the volumes and contaminant inventories of past leaks from tank A-105 have been reported elsewhere. This summary includes some leak volume estimates available to date, but it is not intended to provide new or best estimates which are the subject of ongoing work and may continue to be refined as new information becomes available.

Tank A-105 is one of six single-shell tanks (SSTs) in A Farm that were constructed from late 1953 to early 1956. The six SSTs and their associated ancillary equipment were constructed in place and backfilled to bury the SSTs to depth of ~6 to 7.5 ft below land surface. Each of the A Farm 100-series SSTs has a capacity of 1,000,000 gal and consists of a reinforced-concrete shell lined with a 0.375-in.-thick carbon steel plate (American Society for Testing and Materials [ASTM] A283-52T or ASTM A285-52T) having an inside diameter of 75 ft and an internal height of 32 ft 4 in. from the tank bottom to the top of the steel liner (RPP-10435, "*Single-Shell Tank System Integrity Assessment Report*," Table A.6; H-2-55911, "Waste Storage Tanks Composite Section PUREX Waste Disposal Facility").

Waste was introduced to the tanks via inlet nozzles connecting fill pipelines through the shell several inches below the top of the steel liner (e.g., H-2-55973, "Waste Line Encasement Fill Line Layout, PUREX Waste Disposal Facility"). The tanks also had overflow inlets and outlets connected by short pipelines to allow any accidental overfill of one tank to drain by gravity into the next tank, though fill records and waste level monitoring do not indicate any definite overflows occurred in practice. The lowest point of any inlet or outlet port was thus the bottom lip of the overflow outlet, at 370 in. above the bottom liner in the case of the A Farm SSTs. RPP-10435 Tables A.8 and A.11 state that the AX Farm SSTs could be filled to within 9 in. below the spring line of the dome, or 381 in. above the bottom liner. RPP-10435 discusses other operational constraints such as the density of PUREX waste that in principle could reduce the operating capacity of the WMA A-AX SSTs to less than the fill limits under ordinary conditions.

The A Farm SSTs were built by installing a reinforced-concrete base that is at least 6 in. thick and increases in thickness toward the outside edge, with a maximum thickness of 2 ft for the outer 8 ft of the base, which extends 3 ft beyond the tank sidewall (H-2-55911). Three layers of asphalt-impregnated waterproofing cotton fabric were then applied to the concrete base. After the waterproofing was applied, 2 in. of grout were laid on top of it, with the steel liner being fabricated on top of the grout. The sidewalls of the liner were welded to the flat bottom with an orthogonal intersection. The A Farm SSTs used a "fillet" weld with the base plate extending 1 in. past the sidewall liner where the concrete shell would be cast around the base plate, holding it in a fixed position (H-2-55911; H-2-55912, "Waste Storage Tanks, Base Footing and Wall Reinforcing, PUREX Waste Disposal Facility"; RPP-RPT-54912, "*Hanford Single-Shell Tank Leak Causes and Locations – 241-A Tank Farm*"). To prevent corrosion, the interior surfaces of the liner bottom, sidewalls, and stiffeners were painted with 1 coat of "Red Lead" primer, and a lead drip edge was installed at the top edge of the liner (RPP-10435). The liner was encased in concrete at least 15 in. thick. In contrast to earlier SST designs, the A-100 series tank design eliminated the three-ply asphaltic membrane between the steel liner and the sidewall portion of the concrete shell, and it incorporated a 7-in.-high steel water stop, aka water dam, at the base footing to wall construction joint (H-2-55911; H-2-55912; RPP-RPT-54912). A concrete dome ~1.25 ft thick was erected on top of the tank. The concrete tank dome thickness increases to ~3.5 ft along the sidewalls. A two-ply waterproof asphaltic membrane was applied to the top of the dome (H-2-55911), and a protective finish of 0.75 in. portland cement grout reinforced with chicken wire is believed to have been applied over the entire surface of the membrane. The tanks are equipped with saltwell pump pits located on top of the domes to provide access to the tank, pumps, and monitoring equipment. The arrangement of pits and risers providing access to tank A-105 is shown in H-2-63099, "105-A TK. ARRGT. AS BUILT."

Each tank was originally equipped with 9 to 11 risers, a 20-in.-diameter vapor exhaust pipeline that penetrated the tank dome, and four airlift circulators (ALCs) that were operated to suspend solids, mix the tank contents, and dissipate heat (H-2-56350, "Arrangement Air-Lift Circulators, Circulation Facilities 241-A Tank Farm"; ARH-78, "*PUREX TK-105-A Waste Storage Tank Liner Instability and its Implications on Waste Containment and Control*"). At some point after initial construction, apparently in the late 1960s or early 1970s, additional risers were installed in each tank and thermocouples were relocated to one or more of the new risers; the final riser configuration in tank A-105 is indicated in Figure 2-4 of RPP-RPT-58864, "*Derivation of Best-Basis Inventory for Tank 241-A-105 as of September 1, 2018*." The A Farm SSTs were designed

to receive boiling waste from the Plutonium Uranium Extraction (PUREX) process by using ALCs in each tank for cooling the boiling wastes and underground vessel ventilation headers to remove condensate and volatiles. The four ALCs (two with 17.5-ft height and two with 8.5-ft height) were mounted to the base liner and supported with cables (H-2-56350). Details of A Farm ALCs are given in drawing H-2-56342, "Details Air-Lift Circulator, Circulation Facilities 241A Tank Farm." The ventilation header connected to all six tanks and routed the exhaust to deentrainment vessels, condensers, vent stacks, and cribs or French drains; a bypass loop contained a water-filled seal pot intended to be blown out in the event of a "tank bump" (pressure excursion) so that vapors could bypass the deentrainment equipment and directly exit the 241-A-11 stack (see Section 3.3.2 in RPP-7494, *Historical Vadose Zone Contamination from A, AX, and C Tank Farm Operations*).

The A Farm tanks were originally designed to contain liquid and solid waste at a maximum temperature of 140 °C (280 °F) (RPP-10435, pp. A-42). After installation of ALCs, the operating temperature limit was revised to a maximum of 150 °C (300 °F) at the tank bottom (RPP-10435 Table A.11). Wastes at higher temperatures could cause buckling of the steel liner, softening or liquification of the asphaltic coatings, and/or structural damage to the concrete shell. Specifications compiled in RPP-10435 also indicate pH limits to control corrosion and fill limits for waste with high specific gravity.

Figure B3-2 in RPP-ENV-37956, "*Hanford 241-A and 241-AX Tank Farms Leak Inventory Assessment Report*" shows quarterly tank transfer levels and history. Additional tank waste transfer information is included in WHC-MR-0132, "*A History of the 200 Area Tank Farms*," LA-UR-97-311, "*Waste Status and Transaction Record Summary (WSTRS Rev. 4)*" and tank waste summary reports.

Tank A-105 was built in 1955 and was filled with approximately 18 in. of water until it was placed into service in 1962 (RPP-10435 pp. D-15). In May 1962, 330,000 gal of aged (no longer self-boiling) PUREX high-level waste (HLW) supernate was first added to this tank from tank 241-A-103 (A-103). Additionally, aged PUREX HLW supernate was added to tank A-105 from tank 241-A-102 (A-102) in December 1962. Then the contents of tank A-105 were pumped to tanks 241-C-103 and 241-A-101 in January 1963, leaving a 10-in. (~27,600-gal) heel of waste in tank A-105.

In 1962 and 1963 three pipes known as laterals were installed through vertical caissons (Caissons 1 and 2) extending outward in a nearly horizontal orientation ~10 ft beneath the each of the A Farm tank concrete foundations to facilitate monitoring for leaks (H-2-31880, "241-A Tank Farm Leak Detection System Plan-Section-Detail")[7].

[7] H-2-31880 indicates the elevations and slopes of the laterals. Comparison to the base of excavation elevations in H-2-55904, "Excavation Plan & Sections PUREX Waste Disposal Facility" indicates that the laterals were installed in undisturbed native sediments as opposed to backfill. The laterals are 4-in. outer diameter, schedule 40 seamless carbon steel pipe installed in 10-ft lengths with flush joints (see H-2-31880 and H-2-31882, "241 A & 241 SX Tank Farms Leak Detection System Sections & Details," Sheet 1 Rev. 2 detail C). These horizontal lateral pipes enter one of two caissons, transition to vertical orientation, and extend to an instrument enclosure at ground elevation. Probes can be inserted into each lateral to monitor for gamma radiation that could indicate waste leakage from a tank or pipeline.

In January 1963, thermally hot condensate was added to tank A-105 to heat the tank in preparation to receive PUREX self-boiling waste. Beginning in February 1963, tank A-105 began to receive PUREX HLW directly from the 202-A PUREX Plant. Tank wastes reached boiling temperature on March 5, 1963 (RPP-RPT-54912 Section 5.2). RPP-RPT-54912 Section 5.4.3 suggests that the increase in temperature in early 1963 while the waste level was still low may have vaporized moisture from the grout layer to a vapor pressure exceeding the hydrostatic pressure on the steel liner, causing the liner to bulge. RPP-RPT-54912 Sections 5.8 and 6.0 concluded that the hypothesized differential pressure gradient was the most likely cause of an interpreted leak in November 1963 and suggested that the liner could have not only bulged but also possibly developed fissures.

The fill level rose quickly from the 10-in. heel in early 1963 to roughly 300 in. in late 1963 (RPP-RPT-54912 Figure 5-2; RPP-ENV-37956 pp. B-66 and B-57). In July 1963, the level was raised from 260 in. to 280 in., which has also been suggested as the cause initiating a leak in November 1963 if it occurred from the sidewall as discussed below (RPP-ENV-37956 pp. B-64). In September 1963, the waste level rose 12 in. (i.e., equivalent to ~33,000 gal; see RPP-ENV-37956 pp. B-64). Some past investigators have interpreted this unexplained waste level rise to indicate steam was forming under the tank liner and deforming it upward (WHC-MR-0250, "*Waste Tank 241-A-105 Supporting Documentation Miscellaneous Reports, Letters, Memoranda, and Data*"; RPP-RPT-54912 Section 5.4.3). As possible evidence that deformation of the liner may have begun earlier than 1965, an obstruction was reportedly encountered below the 4-in. vacuum break riser during a routine sludge depth measurement "several months" before January 1965 (ARH-78 pp. 11-12), and the maximum deformation measured after January 1965 occurred at the same location (ARH-78 Table 2; RPP-RPT-54912 Section 5.4.3).

As space became available in tank A-105 as a result of waste evaporation, periodic transfers of PUREX HLW were received until January 1965, at which time it contained 866,000 gal of waste. The maximum reported waste temperature in tank A-105 was ~320 °F in March 1963, but generally was controlled to 180 °F to 260 °F from February 1963 through March 1965 (RHO-CD-1172, *Survey of the Single-Shell Tank Thermal Histories*, pp. B-39 through B-45).

On November 19, 1963, radioactivity detected in lateral 14-05-03 provided an indication that this tank developed a small leak (ARH-78). Gross gamma activity in the lateral was an order of magnitude higher than it had been the previous week (RPP-RPT-54912 Appendix C2). It was initially concluded that the tank had developed a sidewall leak between the elevations of 260 to 280 in. which are the waste levels before and after the addition in July 1963. The waste level was lowered to 260 in. and activity in the lateral slowly decreased. Because of a lack of other storage space, the tank was allowed to refill to the suspected leak zone by October 1964. No further leakage was detected, so the tank was filled to capacity in December 1964. The detection of radioactivity on the east side of the tank corresponds with the location of the overflow line outlet; however, the elevation of the outlet at 370 in. above the bottom liner is several feet above the waste level at any time before or after the detection (RPP-ENV-37956).

A rapid pressurization event ("bump") and steam release occurred at 2:50 PM on January 28, 1965 (ARH-78). Minutes of a February 3, 1965 meeting and of several follow-up meetings

provide a detailed account of the circumstances of the release (WHC-MR-0250). The 241-AX Tank Farm (AX Farm) had recently been constructed, and on the day of the bump, workers had been preparing to make the final weld in a line to connect tank A-105 to the 241-AX-151 Diverter Station. Though not specifically mentioned, the vapor header systems in A Farm and AX Farm were also connected as part of the AX Farm construction. The new connections and the sealing of the new waste line by welding work may have affected state conditions (i.e., pressure) in the tank A-105 headspace in the leadup to the bump. Vapors had entered and contaminated the line earlier, prompting the workers to wear masks. A photograph of AX Farm taken on January 26, 1965 (6958-NEG, "PUREX WASTE STORAGE FACILITIES - COMPLETED 241-AX TANK FARM LOOKING NORTH") showed roughly two inches of snow accumulated on the ground, implying air temperatures were likely cold two days later at the time of the steam release. No PUREX waste was added to tank A-105 the day of the release, but condensate was added. Condensate derived from the offgas of boiling tank waste is a much more dilute solution than the waste itself, so perhaps it could have perturbed the boiling regime, although condensate was regularly added to the A Farm SSTs without incident. Before the release, the ALCs were operating to add air to the tank waste at the recommended rate of 8 cubic feet per minute. The tank farm operators noted that the bump was the first known to occur with ALCs operating, and they subsequently increased the airflow to the ALCs. The waste level was at 317 in. prior to the bump.

As described by witness accounts in WHC-MR-0250, the steam release blew a lead sheet off of a riser in tank A-103 and vented for half an hour[8], caused "a decided shaking of the ground," shook the line being welded, and sprayed condensed fluids through the opening of the line being sealed onto the ground of the work pit and onto some workers' clothing and skin. The event immediately prompted an intensive series of investigations to determine its cause and to determine appropriate responses, as documented in minutes of regular meetings in 1965 in WHC-MR-250 and in numerous formal reports continuing to the present day, e.g., RPP-RPT-54912.

Calculations done in 1965 following the release estimated a pressure of at least 0.13 psi or ~3.5 in. of water were needed to move the lead sheet, which was a 16-in. square with 0.0625 in. thickness (WHC-MR-0250). Tank A-102 is between tanks A-103 and A-105 in the vapor train. The bypass seal pot with a 60-in. water seal intended to blow out in the event of a bump was not blown[9], so the pressure exceeded the weight of the lead cover on the A-103 riser but was lower than or did not remain above 60 in. H_20 at the point of the water seal. Water seals in A Farm seal

[8] Under high pressure, vapor could have traveled between the A Farm tanks through the ventilation header or the overflow lines (e.g., see H-2-63099). The pipeline directly connecting tank A-105 to tank A-103 was installed in 1965 after the steam release event (H-2-33981, "Emergency Sluicing in TK-105-A - General Piping ARRG'T"), so it was not a pathway during the event. A bypass loop in the ventilation system was intended to vent vapor through the header directly to the 241-A-11 stack during a tank bump (see Section 3.3.2 in RPP-7494). The recorded observation of steam venting from tank A-103 during the steam release event implies steam likely traveled through much of the A Farm infrastructure and may have exited less visibly through any other available openings. Radiation increased in the 241-A-417 Catch Tank, which received condensate of tank farm vapors.

[9] The bypass seal pot water seal apparently functioned as intended. It was blown by three consecutive bumps in tank A-103 in September 1956, after which the ALCs were started in tank A-103 to prevent reoccurrence (RPP-ENV-37956 Rev. 3 pp. B-1).

pots were found to be normal except for a blown seal in the tank A-103 overflow, which connected to tank 241-A-106 upstream of the bypass seal pot.

Accounts in some documents imply or definitively state that the 1965 release was the cause of liner failure in tank A-105 and contaminated the area around the tank, but review of available information shows that both liner failure and soil contamination apparently occurred earlier, regardless of whether the 1965 release caused additional breaching of the liner and whether it increased contamination outside the tank. That is, past reports acknowledge that in November 1963 the liner leaked (either at the sidewall or the base), that the 1963 leak contaminated the soil, and that migration of contamination from the 1963 leak could possibly account for some radiation measurements from early 1965 (e.g., see RPP-ENV-37956 or RPP-RPT-54912). There was no further indication of potential liquid waste leakage from the tank until March 1965, when activity increased to 250,000 to 350,000 cpm in a small area of lateral no. 3 (RPP-ENV-37956 pp. B-52)[10]. WHC-MR-0250 indicates the radiation probe for the laterals "gave indications of malfunction prior to [January] the 28th and was undergoing repair at the time of the 'bump,'" but the readings on February 2, 1965 "indicated no abnormal radiation levels." Gross gamma data from lateral no. 3 from November 26, 1963 and from drywells from January 3 to 7, 1965 suggest soils up to 30 ft below the base of the tank were already contaminated before the steam release event (RPP-RPT-54912 Appendices C2 and D2). It is unclear from the gamma data for drywells tabulated in RPP-RPT-54912 Appendix D2 that radioactivity increased significantly after January 28, 1965.

Investigations following the steam release determined that the tank bottom liner had severely bulged upward in one area of the tank, creating a void space volume of ~80,000 gal containing a significant amount of waste. Lowering the waste level by pumping in 1968 allowed for this visual inspection. Figure A-1 shows a photograph of the damaged interior of tank A-105. The maximum height of the upward bulging was estimated as 8.5 ft in WCC Project 13974A-0300, "*An Estimate of Bottom Topography, Volume and Other Conditions in Tank 105A, Hanford, Washington*."

In 1977, photographs (including stereographic photographs) taken inside tank A-105 in 1969, 1970, and 1977 were reviewed to determine the amount of sludge remaining in the tank as well as develop a topographical map of the tank bottom (WCC Project 13974A-0300). The topographical map of the tank bottom produced in 1977 is shown in Figure A-2. This topographical map shows that the bottom of the steel liner in tank A-105 is ripped and separated from the sidewall along ~75% of the tank bottom. Subsequent to the initial preparation of this document, Revision 1 of RPP-RPT-58864 reported a 2017 visual inspection of the interior of A-105 and incorporated a Video Camera/CAD Modeling System (CCMS) residual waste volume estimate, with accompanying revision of the A-105 BBI reflecting much lower volume of waste on top of the liner than estimated in WCC Project 13974A-0300.

Additional photographs of the tank A-105 interior are available in RPP-ENV-37956, RPP-RPT-54912, and an unpublished compilation by Battelle Northwest.

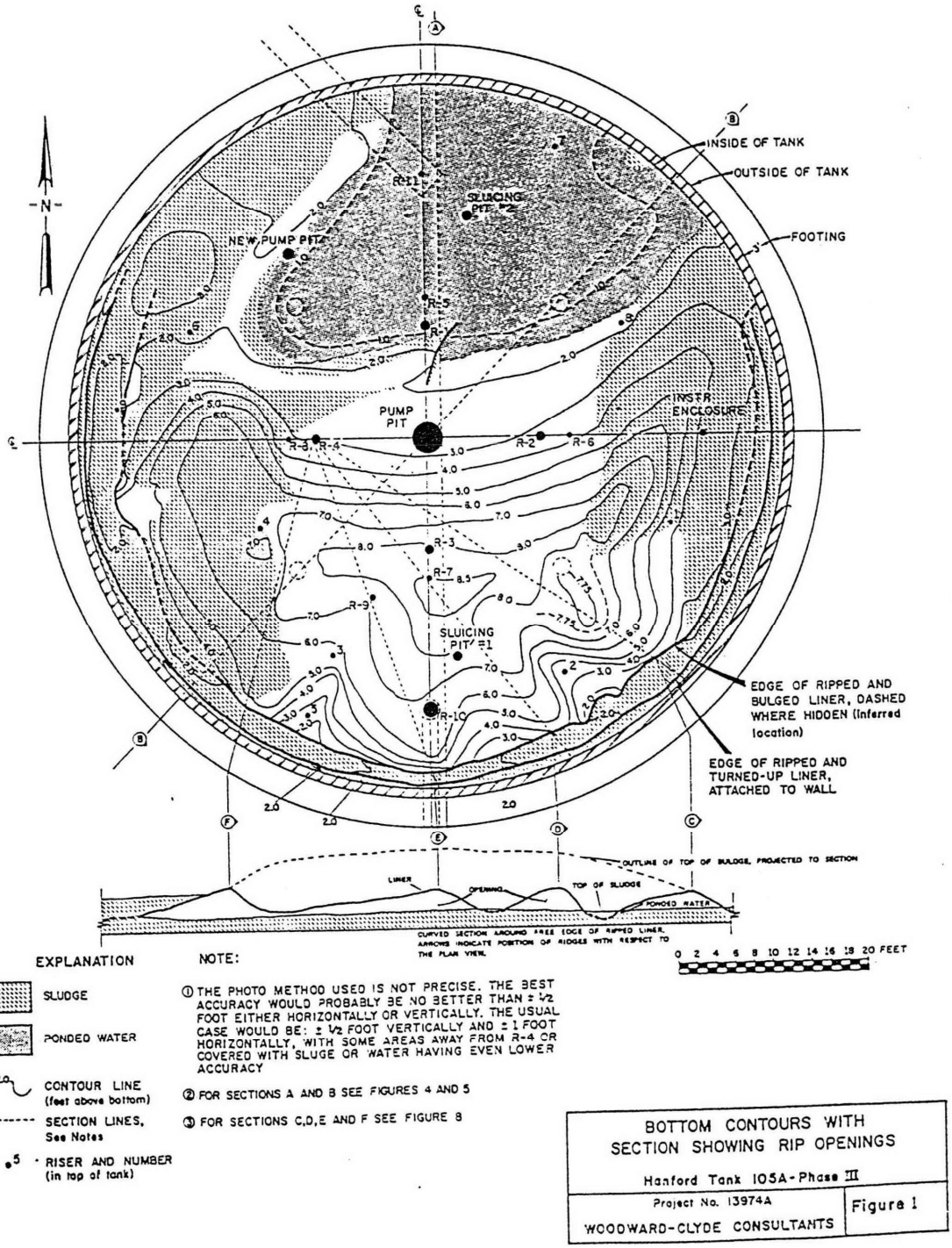
[10] Note that these data differ from data given in RPP-RPT-54912 Appendix C2 which lists only one set of measurements for March 1965 in lateral no. 3 in which a maximum of 195,000 cpm occurred at 95.6 ft from the caisson.

Waste levels in the tank remained unchanged from 1965 until April 1967, when surface level fluctuations began to occur. It was concluded that the fluctuations were caused by collapse and re-growth of a steam bubble in the void space below the tank bottom. The activity detected in lateral no. 3 did not significantly change from March 1965 through January 1968. As discussed in WHC-MR-0264, "*Tank 241-A-105 Leak Assessment*," radioactivity was also detected in lateral no. 2 beneath tank A-105 in October 1967. After that time, the addition of cooling water to the tank helped maintain the tank liquid level between 850,000 and 887,000 gal through January 1968.

Figure A-1. Picture of Tank Bottom and Liner Damage from Tank 241-A-105 Steam Release Event on January 8, 1965.

In March 1968, tank A-105 was declared a "confirmed leaker" (RPP-RPT-54912), a designation used at Hanford to distinguish SSTs with evidence of leaks deemed to be conclusive from SSTs that are "sound" or "assumed or suspected leakers."

Figure A-2. Estimated Topography of Tank 241-A-105 Inside Bottom Surface (1977).



Source: WCC Project 13974A-0300, "*An Estimate of Bottom Topography, Volume and Other Conditions in Tank 105A, Hanford, Washington*."

A second set of four lateral lines and a third caisson were installed to accommodate thermal probes for additional monitoring of tank A-105 (H-2-33973, "Thermal Probes Under Tk. 105-A," Sheet 1, Rev. 1). The engineering drawing of this equipment is dated December 1967. The 6-in. clearance below the tank concrete specified in H-2-33973 corresponds to an elevation of 631.98 ft on the drawing datum (193.692 m NAVD 88), and measured vertical deviations ranged from -9.875 in. to +11.05 in. (H-2-33973, "Thermal Probes Under 105-A Tank," Sheet 2). The ~84-ft length of the longer lateral lines and the maximum one-degree deviation from azimuth (horizontal) indicated in H-2-33973 Sheet 1 suggest these lateral lines are within 0.5 m of the indicated positions. Positions of thermocouples within the temperature laterals are provided on H-2-34043, "Thermal Probe Assembly & Detail TK 105-A," and the wiring of the thermocouples to the computer input terminal is provided on H-2-34086, "Electrical Detail 105-A Thermal Probe." Lateral temperature data as well as in-tank temperature data are recorded in the Surveillance Analysis Computer System.

The supernate in tank A-105 was removed from February 1968 through August 1968, by which time the tank waste was pumped down to the 35-in. waste level. Following the dilution and flushing of supernate, three sluicing campaigns were conducted to remove the waste heel (some reports describe only two campaigns, but three distinct campaigns are identified herein).

The first sluicing campaign, conducted from August through November 1968, used cesium-denuded supernate derived from operation of the cesium ion exchange process in B Plant (Interoffice memorandum 7G420-06-004, "Estimation of Tank 241-A-105 Supernatant Cesium-137 Concentration During Sluicing in August 1968"). The cesium ion exchange supernate is waste type CSR as defined in RPP-26744, "*Hanford Soil Inventory Model, Rev. 1*." The ^{137}Cs concentration of the CSR supernate was estimated to be 0.53 Ci/gal to 0.58 Ci/gal (decay corrected to January 2006). The tank A-105 flush solution was transferred to tank A-103, then tank 241-AX-102, and finally to B Plant for cesium removal processing. Radioactivity in laterals nos. 1 and 2 began to increase during the campaign from August to November 1968 (RPP-RPT-54912 Section 5.6.3). Sluicing of tank A-105 sludge was halted when little of the remaining sludge could be removed. A hard crust layer atop the remaining sludge was thought to be responsible for preventing effective sluicing. Approximately half of the sludge was removed during this first sluicing campaign. Samples of the sludge were collected and analyzed in 2-in. to 3-in. vertical increments for cations, anions, and fission products.

In the second sluicing campaign conducted in July to August 1969, 1M sulfuric acid containing 1,500 ppm of the inhibitor Rhodine A4 was sprayed onto the top layer of hard sludge (Interoffice memorandum 7G420-06-005, "Estimation of Tank 241-A-105 Supernatant Cesium-137 Concentration During Second Sluicing in Capgaign *[sic]* Conducted July 1969 through November 1970"). The acid was sprayed at a low flow rate in small volumes calculated to have a minimal stoichiometric ratio between the total acid in each addition and the total alkalinity of the sludge in the tank, with each addition of acid followed as soon as possible by sluicing with an alkaline fluid. The same cesium-denuded supernate used in the first campaign was used as the sluicing fluid. The sludge sluiced from tank A-105 was transferred into tank A-103.

No additional sludge removal activities in tank A-105 were conducted until August 25, 1970, when a third sluicing campaign was initiated. Prior to this campaign, the liquid level was

reported at 24 in. (RPP-RPT-54912 Section 5.6.3). To begin, inhibited sulfuric acid was again used to soften the sludge. The softened sludge was then sluiced until November 1970 using cesium-denuded supernate contained in tank A-103. The supernate was from a different source than used for sluicing in 1968 and 1969. The ^{137}Cs concentration was estimated at 0.51 Ci/gal, decayed to January 2006 (7G420-06-005 – Interoffice memorandum). The sludge slurry was transferred from tank A-105 to tank A-103. The final sluicing campaign was halted in November 1970 after significant increases of activity were detected in all the laterals (RPP-RPT-54912 Section 5.6.3). Following the completion of this phase of the sludge removal from tank A-105, ~33,000 gal of supernate and 33,000 gal of sludge were reported to remain within this tank. Samples were obtained, one of dry solids and one of a wet slurry, from different areas of the tank and analyzed for cations; the dry solids were also analyzed for bulk density and particle density (SD-WM-TI-302, "*Hanford Waste Tank Sluicing History*" pp. 133-135, 146-147). The supernate contained in tank A-105 was described as being a mixture of B Plant cesium ion exchange waste (i.e., cesium denuded ion exchange waste) and PUREX HLW.

Noting the 35-in. and 24-in. waste levels at the start of the respective sluicing campaigns, RPP-RPT-54912 Section 5.6.3 concluded it is likely the leak site or sites are below the 24-in. waste level since radioactivity was detected in the laterals during the August through November 1968 sluicing campaign and increased during the August through November 1970 sluicing campaign.

By some estimates, the largest releases of contaminants from tank A-105 occurred in the period 1968 to 1970 during sluicing activities. WHC-MR-0264 estimates total releases of 5,000 to 15,000 gal prior to August 1968, releases of 5,000 to 30,000 gal during sluicing from August 1968 to November 1970, and effectively zero releases thereafter. As of 2017, HNF-EP-0182 still cites WHC-MR-0264 as one of two alternative estimates it considers for tank A-105 leak volumes in its tabulation. The relative significance of different leak periods is a subject of uncertainty, and other estimates are available as described herein.

To stabilize the in-tank temperature at safe levels that would not further damage the concrete, an estimated 610,000 gal of water for evaporative cooling is estimated to have been periodically added to tank A-105 from November 1970 through December 1978 (WHC-MR-0264, pp. 22). Water was added continually to maintain in-tank liquid levels, suggesting that some of the water was being lost from the tank[11]. Some water undoubtedly evaporated and exhausted from the tank through the exhaust system (WHC-EP-0410, "*Tank 241-A-105 Evaporation Estimate 1970 through 1978*"). However, the volume of water added seems to exceed the volume that could have evaporated, indicating that some of the fluid escaped the tank and entered the adjacent soils. The amount of water evaporated from tank A-105 from November 1970 through December 1978 was estimated to be between 378,000 to 410,000 gal (WHC-EP-0410). Therefore, an estimated 200,000 to 232,000 gal of water are unaccounted for and may have leaked from tank A-105.

In February 1978, a raw water line leak estimated at 60,000 gal flowed from a hole near the 501 Valve Pit Building and apparently caused a cave-in between tanks A-105 and A-102 the next

[11] An inadvertent addition of excess water to tank A-105 in 1975 raised the in-tank liquid levels ~4 in. before the liquid level was corrected.

day (RPP-ENV-37956 Table 5-2). Water may have been channeled along the pipeline encasement from the leak location to the cave-in location. RPP-RPT-54912 attributes a large spike in gross gamma radiation in May 1978 to redistribution of contaminants already present in the vadose zone by infiltration of the leaked water. RPP-ENV-37956 indicates the location of the radiation increase was near the caisson. RPP-14430, *Subsurface Conditions Description of the C and A-AX Waste Management Area* pp. 4-9 similarly attributed increases in spectral gamma radiation further away in drywells between tanks 241-A-101 and A-102 to mobilization of existing contamination by the raw water leak (it described the contamination as waste from a transfer line leak; however, the location is consistent with a leak from the A-101B sluice pit more recently interpreted in RPP-RPT-58291, "*Hanford Waste Management Area A-AX Soil Contamination Inventory Estimates*"). Thus, multiple reports suggest the leak was large enough to affect observations in drywells around A Farm.

Increasing counts in the leak detection laterals and drywells in 1978 could possibly be interpreted to mean that gamma-emitting radionuclides migrated to where they could be detected, but interpretation is complicated by the fact that drywells around tank A-105 were deepened in 1978 using methods that may have dragged contamination downward with the casings. GJ-HAN-110, "*Hanford Tank Farms Vadose Zone: Tank Summary Data Report for Tank A-105*" describes the methods of deepening, and also notes that difficulties in deepening two drywells (10-05-02 and 10-05-10) led to discovery of corrosion of their casings at elevations a short distance below the base of tank A-105. For example, the casing of drywell 10-05-10 was described to be "rotted out" at 60 to 70 ft below ground surface on the side facing tank A-105. A third drywell (10-06-12) near tank A-105 was also later interpreted to be damaged by corrosion, apparently on the basis that the casing parted at 54 ft below ground surface during advancement when attempting to deepen the drywell (RPP-ENV-37956 pp. 4-10; GJ-HAN-111, "*Hanford Tank Farms Vadose Zone: Tank Summary Data Report for Tank A-106*"). GJ-HAN-110, GJO-98-64-TAR, "*Hanford Tank Farms Vadose Zone: A Tank Farm Report*" and GJO-98-64-TARA, "*Hanford Tank Farms Vadose Zone: Addendum to the A Tank Farm Report*," and RPP-8820, *Analysis and Summary Report of Historical Dry Well Gamma Logs for the 241-A Tank Farm – 200 East* interpret historical total gamma and spectral gamma logging of the drywells and laterals from the 1970s to the 1990s using various methods to reach different conclusions, among which are shape factor analyses offered in support of interpretations that contamination was localized along vertical segments of drywell casings or boreholes in many cases. More recent logging and sampling has been completed or planned and may lead to reinterpretation of contamination distributions near tank A-105.

Various estimates of leak volumes from tank A-105 have been made by past investigators and continue to be refined. Some past estimates are summarized in the following paragraphs.

BNWL-CC-376, "*Techniques for Calculating Tank Temperatures and Soil Temperatures Near Leaks – Application to PUREX Waste Tank 105A*" estimated that between 5,000 and 15,000 gal leaked from the tank in January 1965 based on temperatures recorded in thermocouples beneath the tank.

HNF-EP-0182, "*Waste Tank Summary Report for Month Ending December 31, 2016*," Rev. 348 states that tank A-105 is designated a confirmed leaker with an estimated loss of liquid attributed to a breach in tank liner integrity at 10,000 to 277,000 gal, based on the following.

1. WHC-MR-0264.

    a. An estimate of 5,000 to 15,000 gal for the initial leak prior to August 1968.

    b. An estimate of 5,000 to 30,000 gal for the leak while the tank was being sluiced from August 1968 to November 1970.

    c. An estimate of 610,000 gal of cooling water was added to the tank from November 1970 to December 1978, but it was estimated that the release from the tank was likely small during this period. "Sufficient heat was generated in the tank to evaporate most, and perhaps nearly all, of this water" (WHC-MR-0264). This result leads to an estimate of no gallons released from the tank during the period of November 1970 to December 1978.

2. WHC-EP-0410 estimates that 378,000 to 410,000 gal evaporated out of the tank from November 1970 to December 1978. Subtracting the minimum evaporation estimate from the cooling water added estimate provides a range from 0 to 232,000 gal of cooling water leakage from November 1970 to December 1978.

Further investigations have disputed the sludge leak volume estimate, because activities and temperatures in the tank laterals have remained comparatively low. Estimated leak volumes for this tank range from 10,000 to 277,000 gal, with much of the uncertainty for the larger volume coming from uncertainty in estimating how much of 610,000 gal of cooling water added was lost to evaporation. The initial event is estimated to have leaked a lower bound 10,000 to 45,000 gal.

In conclusion, process and historical records, along with data from logging of the drywells and leak detection laterals beneath tank A-105, suggest that fluids have escaped from the tank and spread into the soils. The gamma-emitting radionuclides are tracers of leaked waste, so it is reasonable to assume that other alpha- and beta-emitting radionuclides as well as nonradioactive contaminants are also present in the soils. However, data may be too limited to know leak compositions or delineate the extent of releases with certainty.

REFERENCES

6958-NEG, January 26, 1965, "PUREX WASTE STORAGE FACILITIES - COMPLETED 241-AX TANK FARM LOOKING NORTH."

7G420-06-004, 2006, "Estimation of Tank 241-A-105 Supernatant Cesium-137 Concentration During Sluicing in August 1968" (interoffice memo from M. E. Johnson, Technical Integration Program to J. G. Field, February 28), CH2M HILL Hanford Group, Inc., Richland, Washington.

7G420-06-005, 2006, "Estimation of Tank 241-A-105 Supernatant Cesium-137 Concentration During Second Sluicing in Capaign *[sic]* Conducted July 1969 through November 1970" (interoffice memo from M. E. Johnson, Technical Integration Program to J. G. Field, March 22), CH2M HILL Hanford Group, Inc., Richland, Washington.

ARH-78, 1967, "*PUREX TK-105-A Waste Storage Tank Liner Instability and its Implications on Waste Containment and Control*," Atlantic Richfield Hanford Company and Pacific Northwest Laboratory, Richland, Washington.

BNWL-CC-376, 1965, "Techniques for Calculating Tank Temperatures and Soil Temperatures Near Leaks – Application to PUREX Waste Tank 105A," Battelle Northwest, Richland, Washington.

GJ-HAN-110, 1998, "*Hanford Tank Farms Vadose Zone: Tank Summary Data Report for Tank A-105*," U.S. Department of Energy, Albuquerque Operations Office/Grand Junction Office, Grand Junction, Colorado.

GJ-HAN-111, 1998, "*Hanford Tank Farms Vadose Zone: Tank Summary Data Report for Tank A-106*," U.S. Department of Energy, Albuquerque Operations Office/Grand Junction Office, Grand Junction, Colorado.

GJO-98-64-TAR, 1999, "*Hanford Tank Farms Vadose Zone: A Tank Farm Report*," U.S. Department of Energy, Albuquerque Operations Office/Grand Junction Office, Grand Junction, Colorado.

GJO-98-64-TARA, 2000, "*Hanford Tank Farms Vadose Zone: Addendum to the A Tank Farm Report*," U.S. Department of Energy, Albuquerque Operations Office/Grand Junction Office, Grand Junction, Colorado.

H-2-31880, 1968, "241-A Tank Farm Leak Detection System Plan-Section-Detail," Rev. 2, H. E. Bovay Jr., Consulting Engineers, Richland, Washington.

H-2-31882, 1983, "241 A & 241 SX Tank Farms Leak Detection System Sections & Details," Sheet 1, Rev. 2, H. E. Bovay Jr., Consulting Engineers, Richland, Washington.

H-2-33973, 1967, "Thermal Probes Under Tk. 105-A," Sheet 1, Rev. 1, U.S. Atomic Energy Commission, Richland Operations Office, Richland, Washington.

H-2-33973, 1968, "Thermal Probes Under 105-A Tank," Sheet 2, U.S. Atomic Energy Commission, Richland Operations Office, Richland, Washington.

H-2-33981, 1971, "Emergency Sluicing in TK-105-A - General Piping ARRG'T," Rev. 5, U.S. Atomic Energy Commission, Richland Operation Office, Richland, Washington.

H-2-34043, 1967, "Thermal Probe Assembly & Detail TK 105-A," U.S. Atomic Energy Commission, Richland, Washington.

H-2-34086, 1967, "Electrical Detail 105-A Thermal Probe," U.S. Atomic Energy Commission, Richland Operations Office, Richland, Washington.

H-2-55904, 1956, "Excavation Plan & Sections PUREX Waste Disposal Facility," Rev. 2, U.S. Atomic Energy Commission Hanford Works, Richland, Washington.

H-2-55911, 1953, "Waste Storage Tanks Composite Section PUREX Waste Disposal Facility," Rev. 1, U.S. Atomic Energy Commission Hanford Works, Richland, Washington.

H-2-55912, 1956, "Waste Storage Tanks, Base Footing and Wall Reinforcing, PUREX Waste Disposal Facility," Rev. 1, General Electric Company, Richland, Washington.

H-2-55973, 1956, "Waste Line Encasement Fill Line Layout, PUREX Waste Disposal Facility," Sheet 1, Rev. 2, General Electric Company, Richland, Washington.

H-2-55973, 1971, "Waste Line Encasement Fill Line Layout, PUREX Waste Disposal Facility," Sheet 2, Rev. 2, General Electric Company, Richland, Washington.

H-2-56342, 1955, "Details Air-Lift Circulator, Circulation Facilities 241A Tank Farm," General Electric Company, Richland, Washington.

H-2-56350, 1955, "Arrangement Air-Lift Circulators, Circulation Facilities 241-A Tank Farm," General Electric Company, Richland, Washington.

H-2-63099, 1971, "105-A TK. ARR'G'T. AS BUILT", Rev. 2, U.S. Atomic Energy Commission, Richland Operations Office, Richland, Washington.

HNF-EP-0182, 2017, "*Waste Tank Summary Report for Month Ending December 31, 2016*," Rev. 348, Washington River Protection Solutions, LLC, Richland, Washington.

LA-UR-97-311, 1997, "*Waste Status and Transaction Record Summary (WSTRS Rev. 4)*," Los Alamos National Laboratory, Los Alamos, New Mexico.

RHO-CD-1172, 1981, *Survey of the Single-Shell Tank Thermal Histories*, Rockwell Hanford Operations, Richland, Washington.

RPP-7494, 2001, *Historical Vadose Zone Contamination from A, AX, and C Tank Farm Operations*, Rev. 0, Fluor Federal Services, Richland, Washington.

RPP-8820, 2003, *Analysis and Summary Report of Historical Dry Well Gamma Logs for the 241-A Tank Farm – 200 East*, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

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

RPP-14430, 2003, *Subsurface Conditions Description of the C and A-AX Waste Management Area*, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-26744, 2005, "*Hanford Soil Inventory Model, Rev. 1*," Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-ENV-37956, 2017, "*Hanford 241-A and 241-AX Tank Farms Leak Inventory Assessment Report*," Rev. 3, Washington River Protection Solutions, LLC, Richland, Washington.

RPP-PLAN-57332, 2016, "*Field Sampling and Analysis Plan for Soil Samples at Waste Management Area A-AX*," Rev. 1, Washington River Protection Solutions, LLC, Richland, Washington.

RPP-RPT-54912, 2013, "*Hanford Single-Shell Tank Leak Causes and Locations – 241-A Tank Farm*," Rev 0, Washington River Protection Solutions, Richland, Washington.

RPP-RPT-58291, 2017, "*Hanford Waste Management Area A-AX Soil Contamination Inventory Estimates*," Rev. 1, Washington River Protection Solutions, LLC, Richland, Washington.

RPP-RPT-58864, 2018, "*Derivation of Best-Basis Inventory for Tank 241-A-105 as of September 1, 2018*," Rev. 1, Washington River Protection Solutions, LLC, Richland, Washington.

SD-WM-TI-302, 1987, "*Hanford Waste Tank Sluicing History*," Rev. 0, Westinghouse Hanford Company, Richland, Washington.

WCC Project 13974A-0300, 1978, "*An Estimate of Bottom Topography, Volume and Other Conditions in Tank 105A, Hanford, Washington*," Woodward-Clyde Consultants for Atomics International Rockwell-Hanford Operations, Richland, Washington.

WHC-EP-0410, 1991, "*Tank 241-A-105 Evaporation Estimate 1970 through 1978*," Westinghouse Hanford Company, Richland, Washington.

WHC-MR-0132, 1990, "*A History of the 200 Area Tank Farms*," Westinghouse Hanford Company, Richland, Washington.

WHC-MR-0250, 1991, "*Waste Tank 241-A-105 Supporting Documentation Miscellaneous Reports, Letters, Memoranda, and Data*," Westinghouse Hanford Company, Richland, Washington.

WHC-MR-0264, 1991, "*Tank 241-A-105 Leak Assessment*," Westinghouse Hanford Company, Richland, Washington.

APPENDIX B

EVALUATION OF DIFFUSIVE RELEASE ASSUMPTION FOR INTACT TANK CONDITION

LIST OF FIGURES

Figure B-1. Conceptual Model of Tank after Site Closure. B-2

Figure B-2. Cross-Section Location for the Two-Dimensional Model. B-3

Figure B-3. Hydrogeologic Units for the Model. B-4

Figure B-4. Soil-Moisture Characteristics Curves for the Grout Hydraulic Properties Evaluated. B-5

Figure B-5. Infiltration at (a) Year 10, (b) Year 500, and (c) Year 20,000. ..... B-6

Figure B-6. Moisture Content at (a) Year 10, (b) Year 500, and (c) Year 20,000. ..... B-8

Figure B-7. Output Node Locations. B-10

Figure B-8. Comparison of Matric Potential Between Selected Tank and Backfill Nodes. B-11

Figure B-9. Comparison of Vertical Darcy Flux Between Selected Tank and Backfill Nodes. B-12

Figure B-10. Comparison of Volumetric Moisture Content Between Selected Tank and Backfill Nodes. B-13

Figure B-11. Comparison of Peclet Number Between Selected Tank and Backfill Nodes. B-14

LIST OF TABLES

Table B-1. Hydraulic Properties of Backfill and Grout. B-5

APPENDIX B

EVALUATION OF DIFFUSIVE RELEASE ASSUMPTION FOR INTACT TANK CONDITION

In support of the performance assessment for Waste Management Area C (RPP-ENV-58782, "*Performance Assessment of Waste Management Area C, Hanford Site, Washington*"), a numerical simulation of flow around grouted tanks surrounded by backfill material was undertaken to evaluate the relative importance of advective and diffusive transport to the long-term release of contaminants from waste residuals. As shown in Figure B-1, the conceptual model of each tank after closure includes a thin layer of residual waste at the bottom of the tank with the remainder of the tank interior filled with grout. Based on an analysis of potential degradation mechanisms presented in RPP-ENV-58782, the grout is assumed to remain effectively intact throughout the 20,000-year simulation. The numerical calculations were performed in a two-dimensional vertical cross-sectional Subsurface Transport Over Multiple Phases (STOMP)[1] model for a row of C-100-series tanks under a constant, 3.5 mm/yr recharge rate representing long-term post-closure conditions. The two-dimensional cross-section is shown in Figures B-2 and B-3.

Each C-100-series tank consists of a reinforced-concrete shell with steel plates lining the base and sidewalls. The tanks have an inside diameter of 75 ft and an internal height of 5.5 m from the bottom liner to the top of the side plates, which is also the spring line for the dome. The tanks are buried underground with 7 ft of backfill over the top of the dome to provide shielding from radiation exposure.

For this analysis, the tank construction was simplified by ignoring steel components and assuming that the concrete wall behaved identically to grout in hydraulic properties. The hydraulic properties assigned to the grout were chosen from WSRC-STI-2007-00369, "*Hydraulic and Physical Properties of Tank Grouts and Base Mat Surrogate Concrete for FTF Closure*" to represent strong grout material and are given in Table B-1. The corresponding characteristic curves are presented in Figure B-4. The backfill hydraulic properties in Table B-1 were defined based on analogue samples with gravelly textures similar to that of tank farm backfill sediments, as described in RPP-ENV-58782 Section B.2.3.

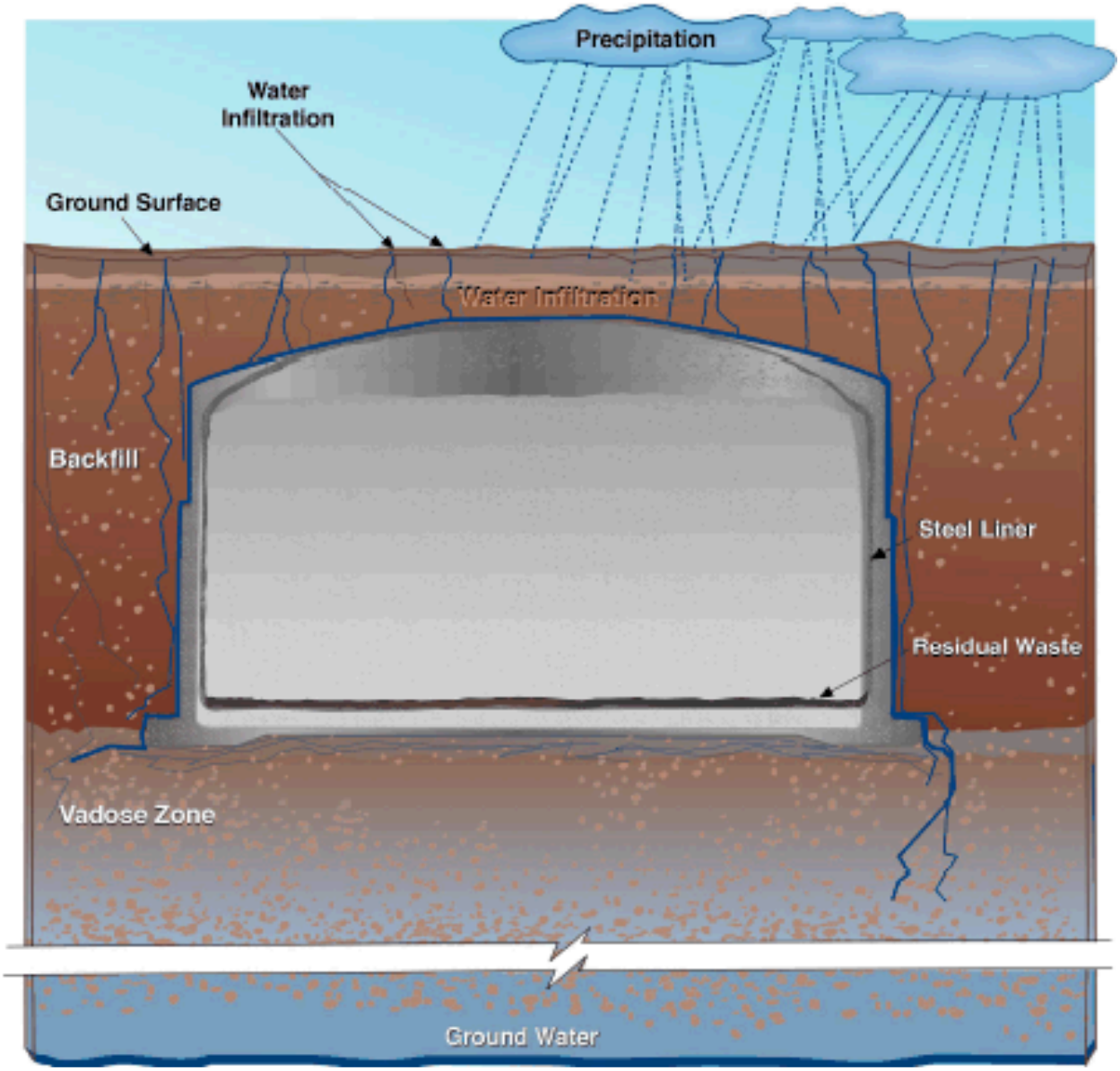
To define the initial conditions for the transient calculations, the matric potential for the tank nodes was initially set to be -2,000 cm, representing conditions that are between fully saturated and near residual saturations. A constant, 3.5-mm/yr recharge rate was applied to the ground surface at the top of the model as a boundary condition.

A close-up view of the flow field simulated at various times in the upper part of the cross-sectional model containing the tanks and backfill is shown in Figure B-5, and corresponding views of the simulated moisture content are shown in Figure B-6. The vertical Darcy flux in the backfill material is orders of magnitude higher than in the tanks as infiltration diverts around the tanks and focuses into the backfill, consistent with the choice of parameters. Figure B-6 shows that a shadow effect in the moisture content is observed beneath the tanks

[1] Subsurface Transport Over Multiple Phases (STOMP) is developed and distributed by Battelle Memorial Institute.

throughout the simulation. Figures B-5a and B-5b show that for hundreds of years after closure the vertical Darcy flux at the base of each tank is nearly zero, and Figure B-5c shows that after thousands of years it has increased but remains much lower than the applied recharge rate. Figure B-5c represents the long-term near-steady-state flow field after 20,000 years.

Figure B-1. Conceptual Model of Tank after Site Closure.



To quantify the differences in conditions between the backfill and within the grouted tank, model output was selected from one node from each as shown in Figure B-7. The changes over time in matric potential, vertical Darcy flux, and volumetric moisture content are presented in Figures B-8 through B-10 for these two nodes. These results indicate that the vertical Darcy flux in the grout remains over three orders of magnitude lower than in the backfill. The Darcy flux in the grout is negligibly small for the first few thousand years, and gradually increases as the large

capillary suction (negative matric potential) draws water in, eventually increasing the unsaturated hydraulic conductivity compared to the initial state. At 10,000 years after closure, the Darcy flux was 2.58×10^{-3} mm/yr at the selected tank node versus ~13.5 mm/yr in the backfill.

Figure B-2. Cross-Section Location for the Two-Dimensional Model.

Subsurface Transport Over Multiple Phases (STOMP) is developed and distributed by Battelle Memorial Institute.

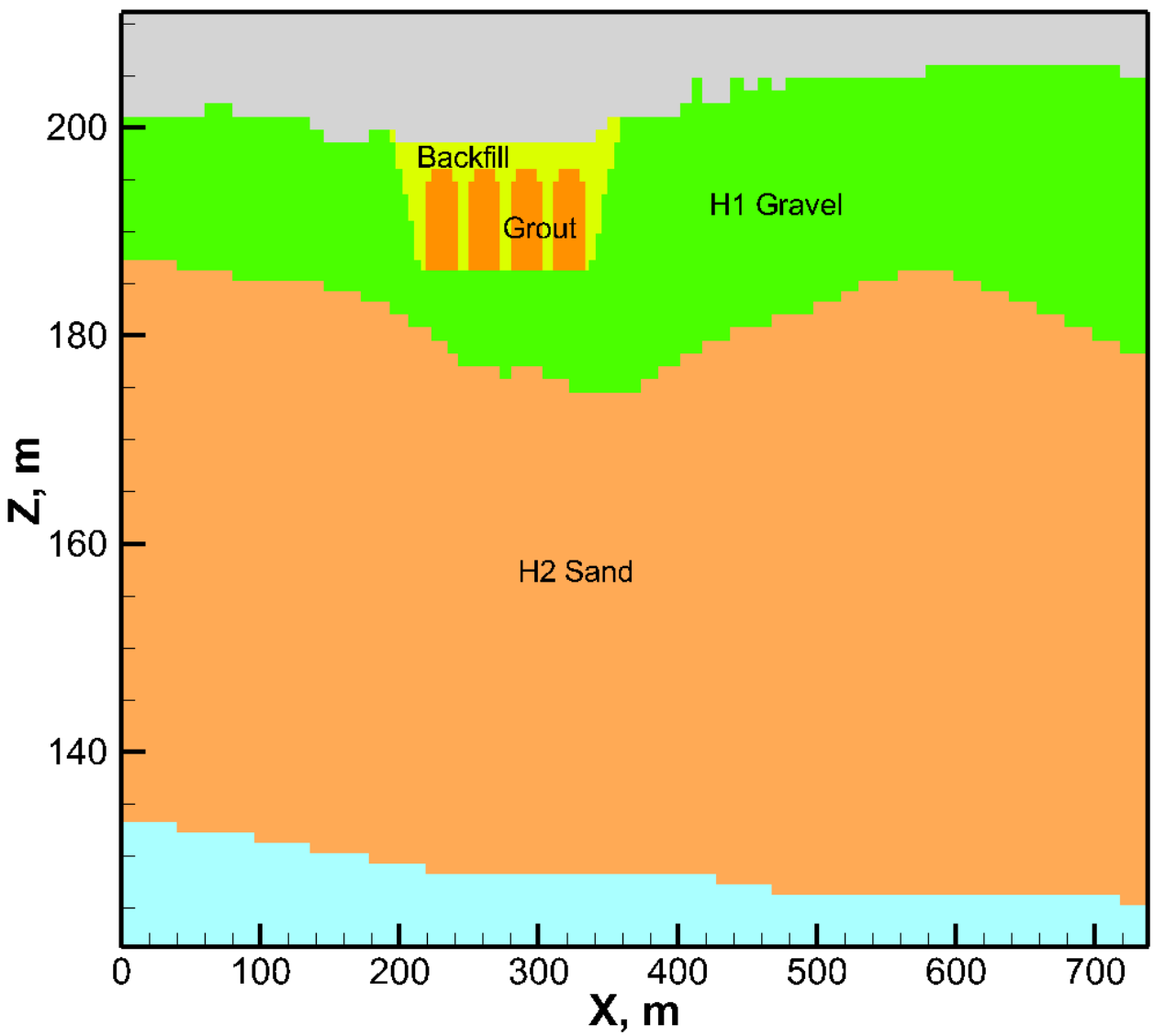
To compare the relative importance of advection and diffusion, the dimensionless Peclet number (ratio of advective transport rate to diffusive transport rate) was calculated for the simulated results. The model grid Peclet number is given by the following equation (Contaminant Hydrogeology [Fetter 1993]):

$$Pe = \frac{V_D \cdot \Delta z}{n_e \cdot D_L}$$

Where:

V_D = Darcy flux (cm/s),
n_e = effective porosity,
Δz = discretization along direction of flow (cm),
D_L = longitudinal hydrodynamic dispersion coefficient (cm^2/s).

Figure B-3. Hydrogeologic Units for the Model.



The dispersion coefficient is defined as follows (Fetter 1993):

$$D_L = \alpha_L \left(\frac{V_D}{n_e}\right) + D$$

Where:

α_L = longitudinal dispersivity (cm),

D = molecular diffusion coefficient (cm^2/s).

Table B-1. Hydraulic Properties of Backfill and Grout.

Material	Backfill	Grout
Vertical Saturated Hydraulic Conductivity, $K_{s,v}$ (cm/s)	5.60E-04	1.47E-08
Saturated Volumetric Moisture Content, θ_s (cm^3/ cm^3)	0.138	0.296
Residual Volumetric Moisture Content, θ_r (cm^3/ cm^3)	0.011	0.2341
van Genuchten Alpha Parameter, α (1/cm)	0.021	0.006
van Genuchten n Parameter, n (dimensionless)	1.374	1.153
Residual Saturation, $S_r = \theta_r/\theta_s$ (dimensionless)	0.080	0.791
Particle Density, ρ_s (g/cm^3)	2.47	2.50

Figure B-4. Soil-Moisture Characteristics Curves for the Grout Hydraulic Properties Evaluated.

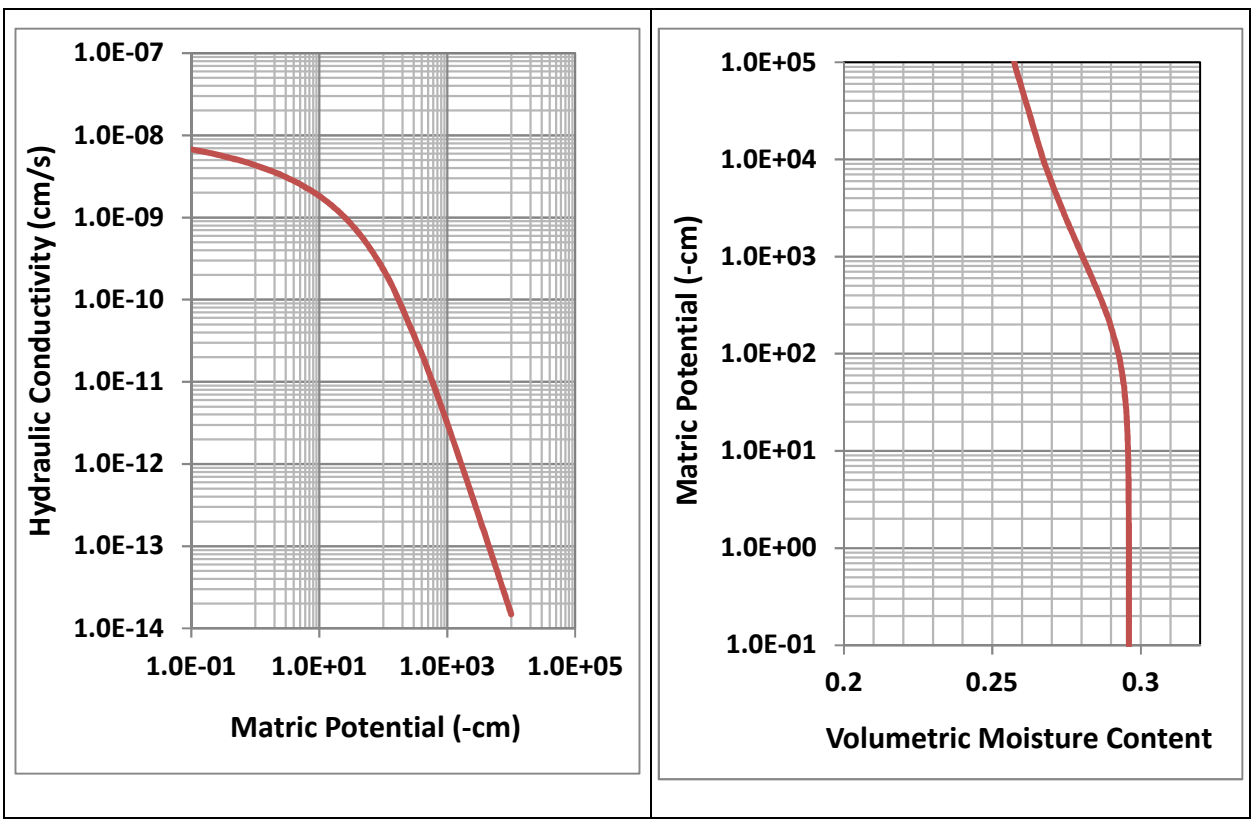
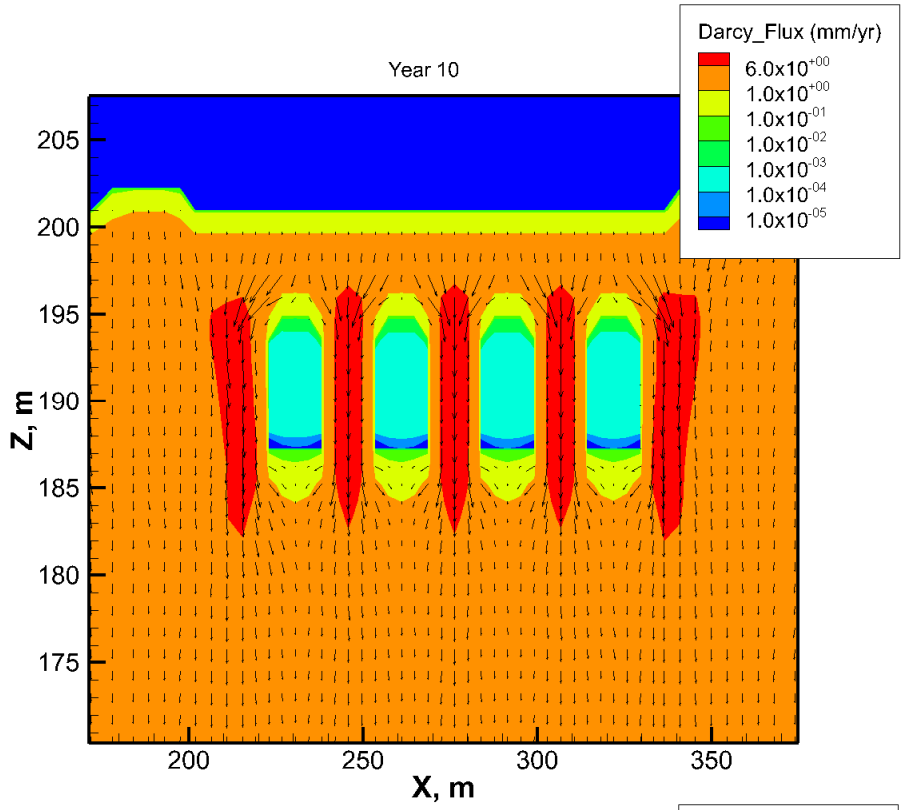


Figure B-5. Infiltration at (a) Year 10, (b) Year 500, and (c) Year 20,000. (1 of 2 sheets)

(a)



(b)

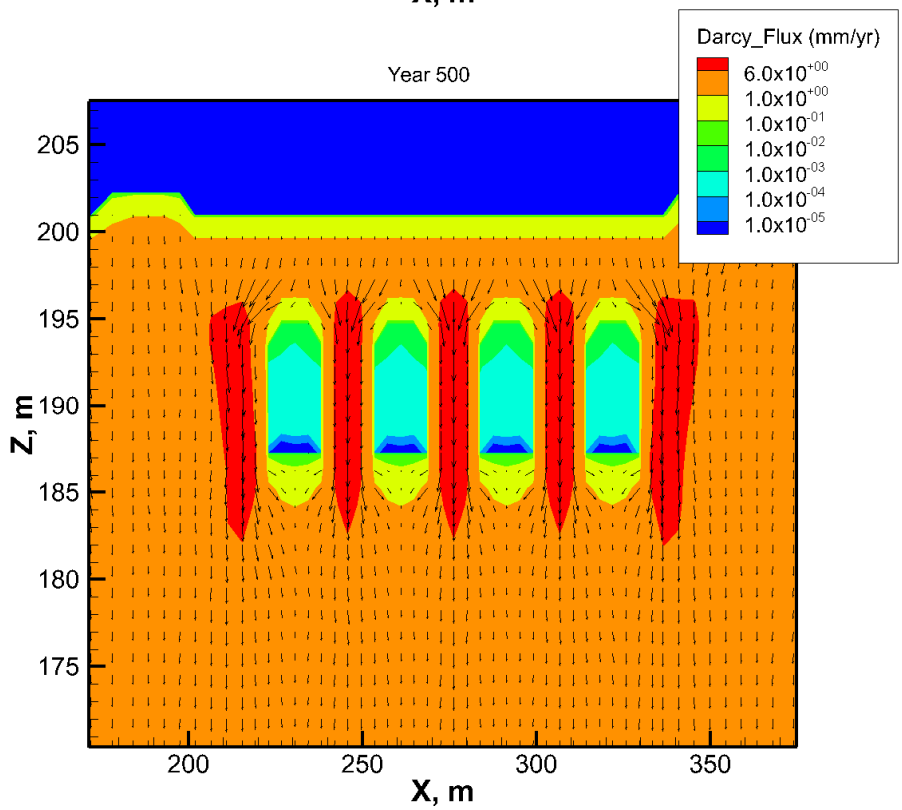
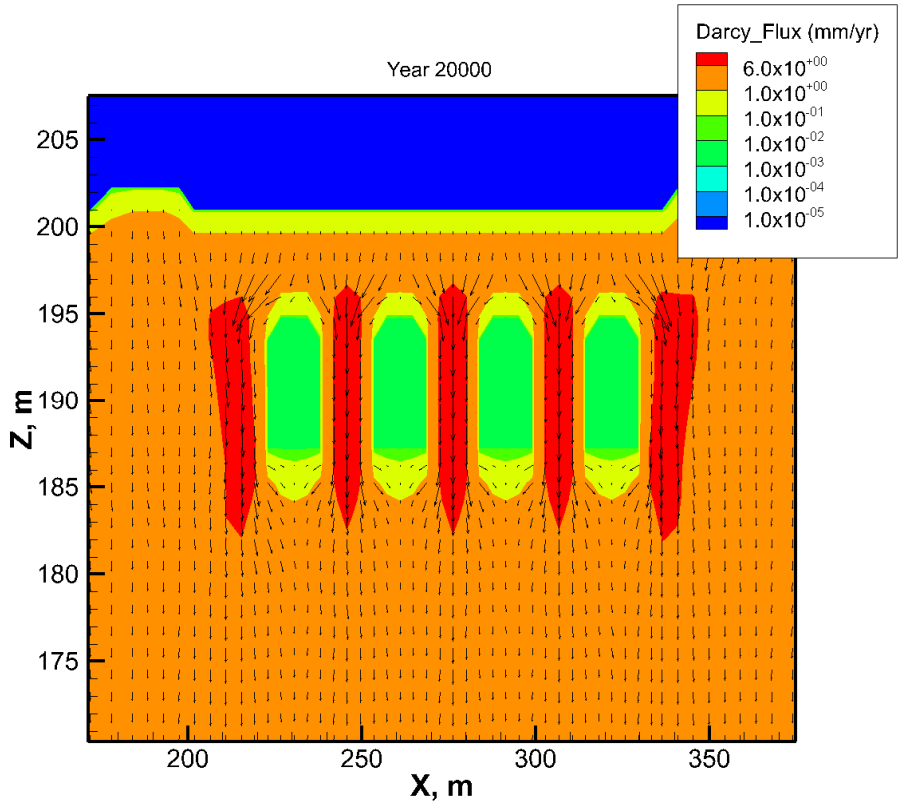


Figure B-5. Infiltration at (a) Year 10, (b) Year 500, and (c) Year 20,000. (2 of 2 sheets)

(c)



Note: Arrows show direction of moisture flux and colors indicate magnitude of vertical component of Darcy flux.

The vertical grid discretization over which the Darcy flux was computed was 1.25 m. For the backfill,

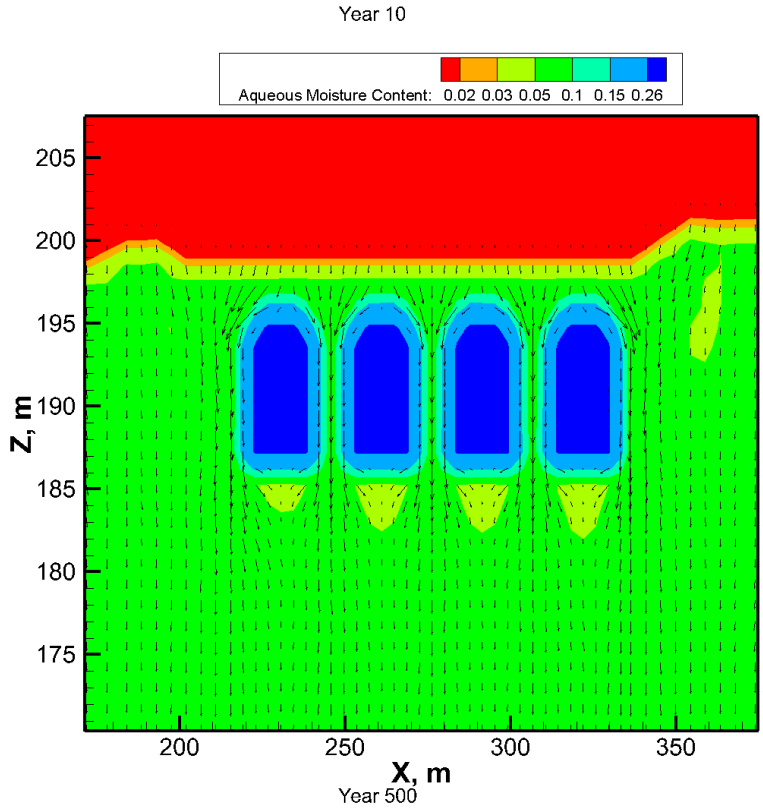
$$n_e = 0.0645, D = 2.5 \times 10^{-5} \frac{cm^2}{s}, \propto_L = 20\ cm$$

For the grout,

$$n_e = 0.283, D = 3.0 \times 10^{-8} \frac{cm^2}{s}, \propto_L = 20\ cm$$

Figure B-6. Moisture Content at (a) Year 10, (b) Year 500, and (c) Year 20,000. (1 of 2 sheets)

(a)



(b)

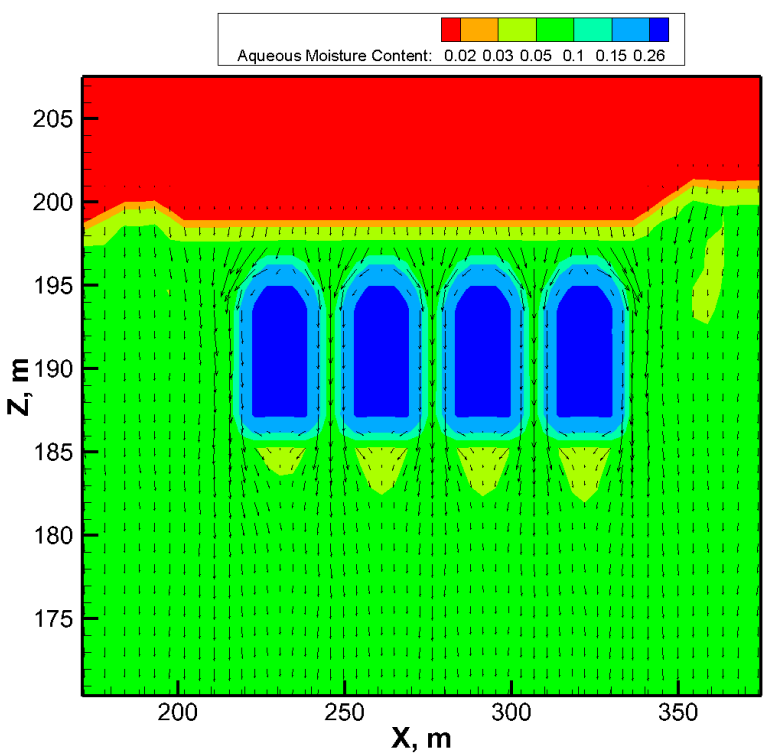
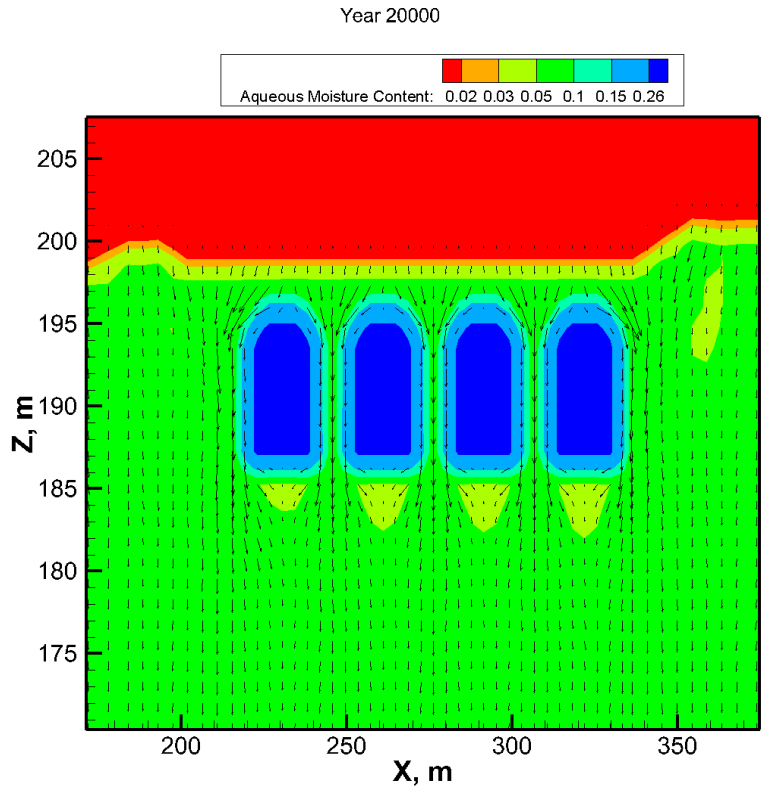


Figure B-6. Moisture Content at (a) Year 10, (b) Year 500, and (c) Year 20,000. (2 of 2 sheets)

(c)



Note: Arrows show direction of moisture flux and colors indicate volumetric moisture content.

Figure B-11 shows that the Peclet number for the tank is close to zero during the first 1,000 years due to negligibly small Darcy flux and that it increases gradually thereafter until becoming nearly asymptotic around 20,000 years. At 10,000 years, the Peclet number in the tank is 0.12, indicating that transport through the tank is predominantly diffusion-controlled (Fetter 1993), whereas in the backfill the Peclet number is 2.2, indicating transport through the backfill has a higher advective component. Therefore, during the period 10,000 years after closure and beyond, it is clear that diffusion dominates transport within the grouted tank; whereas in the backfill, both advection and diffusion play a role in transport.

These analyses support the assumption of diffusion-dominated releases from an intact tank.

Figure B-7. Output Node Locations.

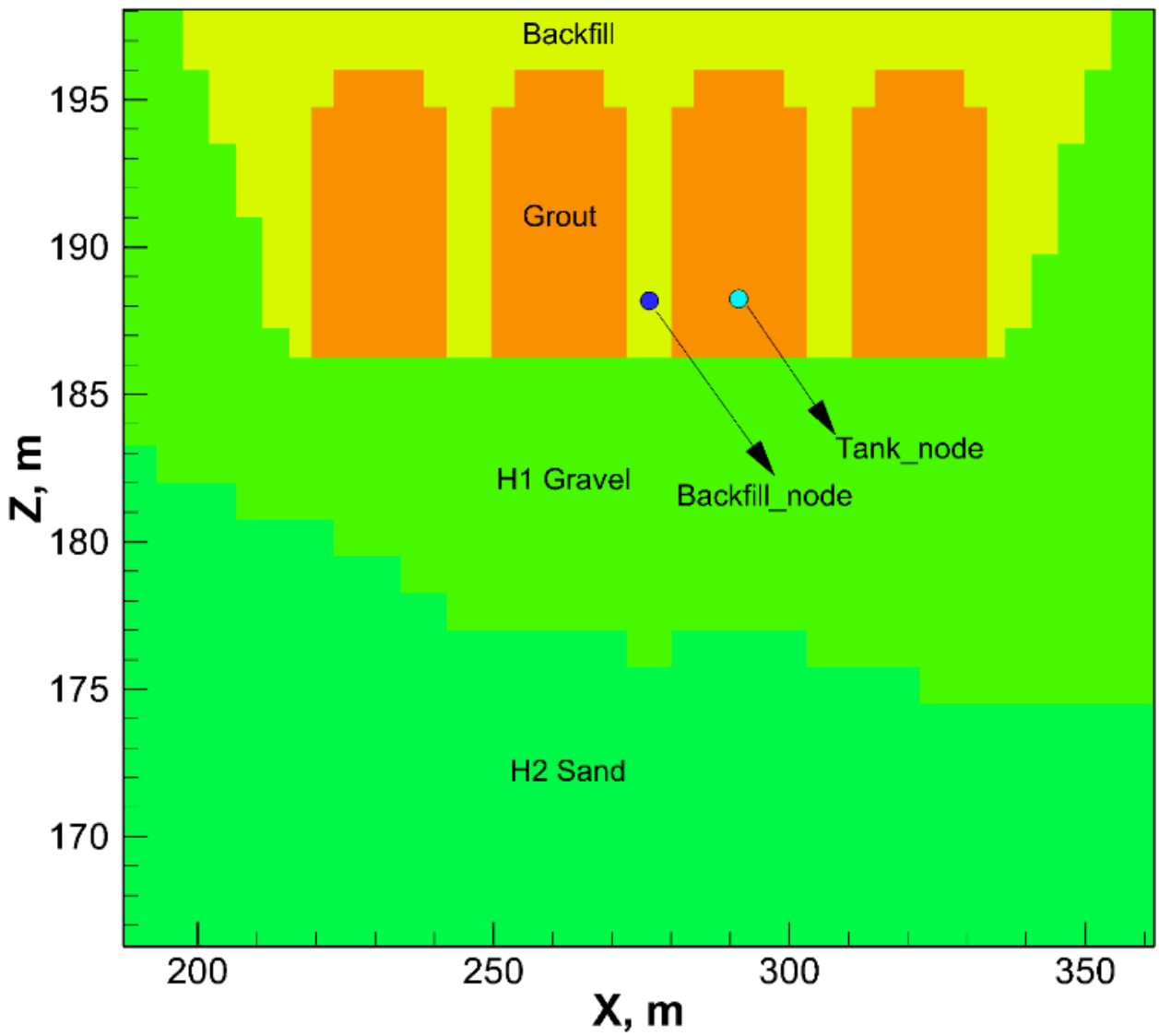


Figure B-8. Comparison of Matric Potential Between Selected Tank and Backfill Nodes.

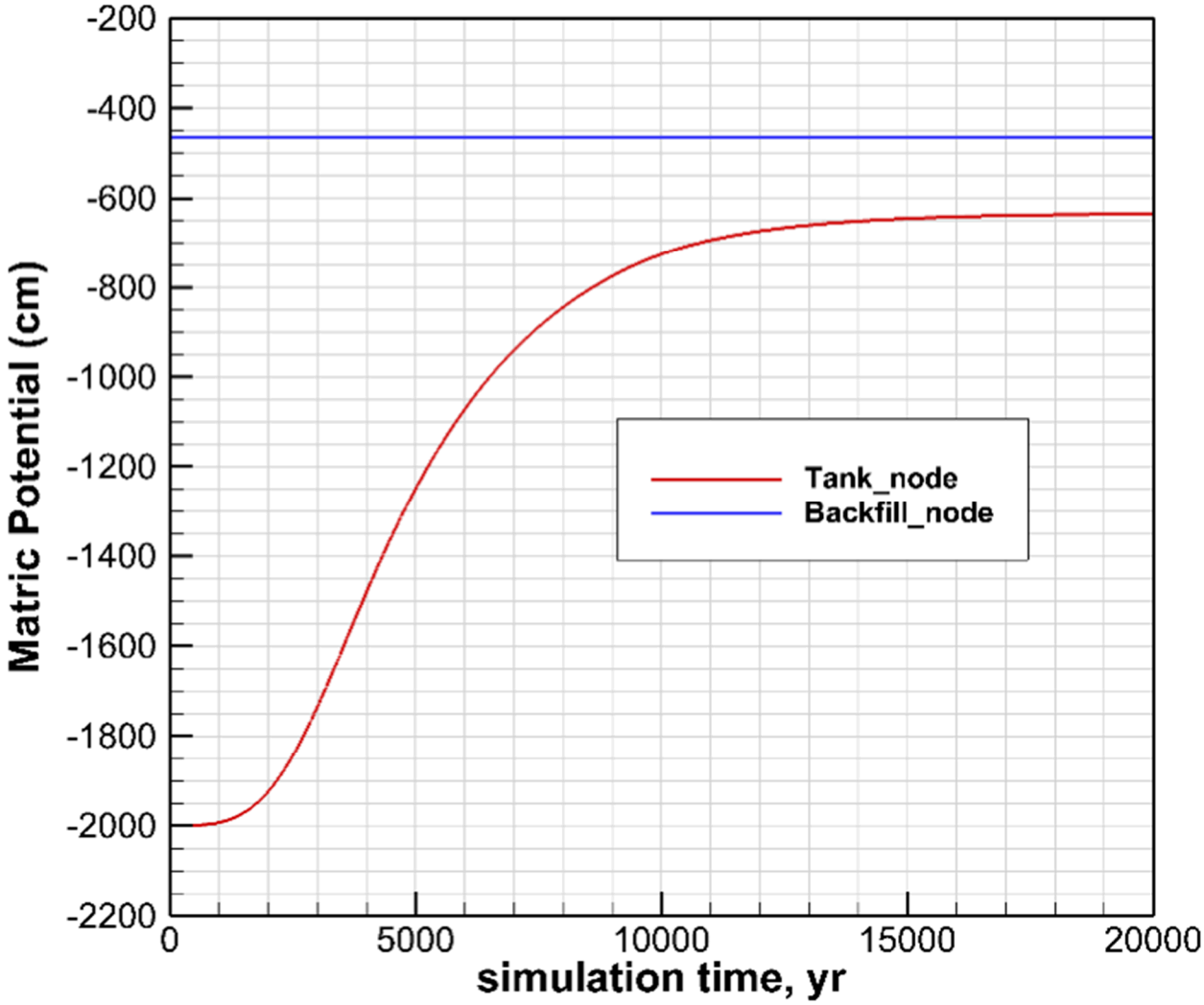


Figure B-9. Comparison of Vertical Darcy Flux Between Selected Tank and Backfill Nodes.

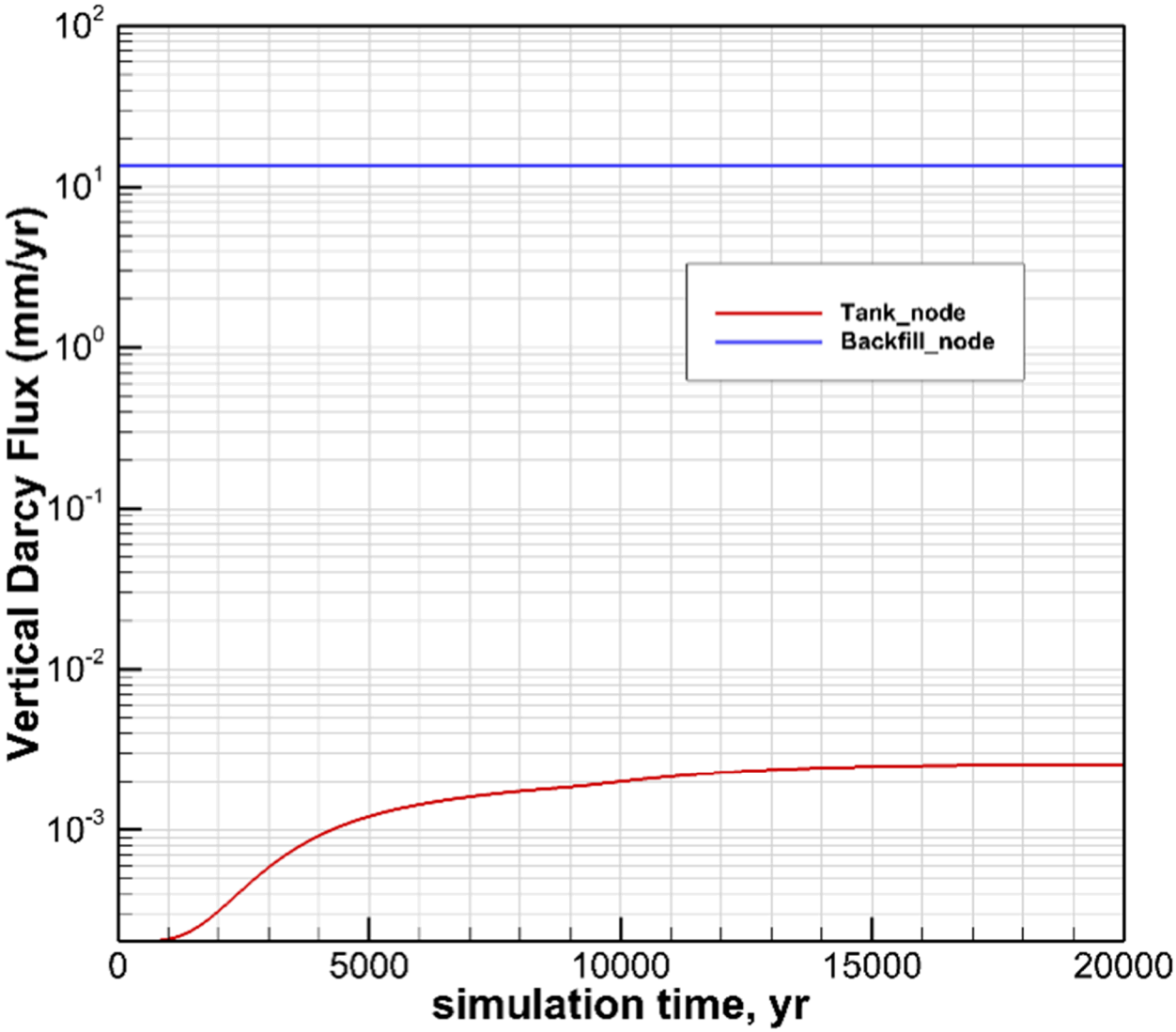


Figure B-10. Comparison of Volumetric Moisture Content Between Selected Tank and Backfill Nodes.

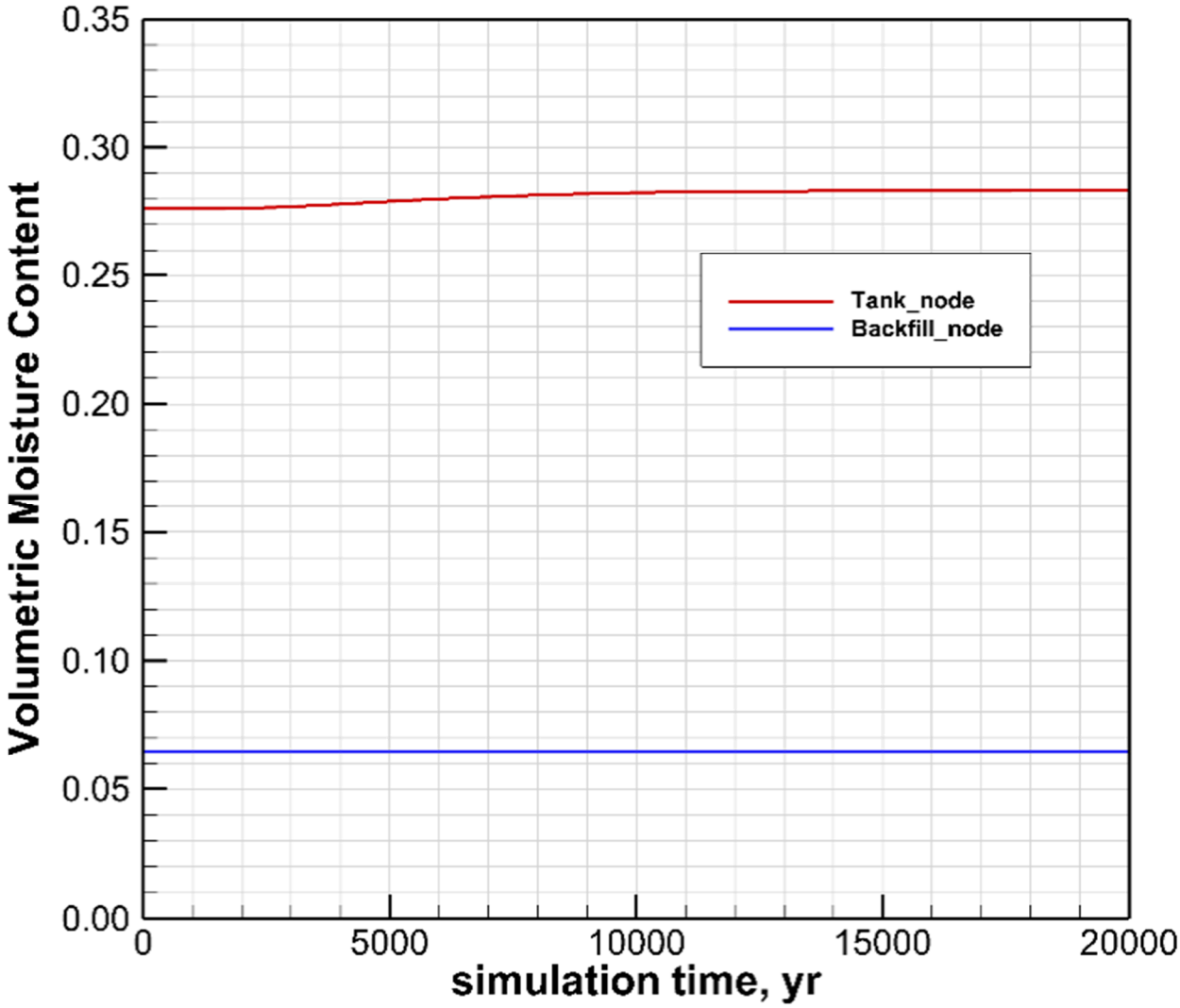
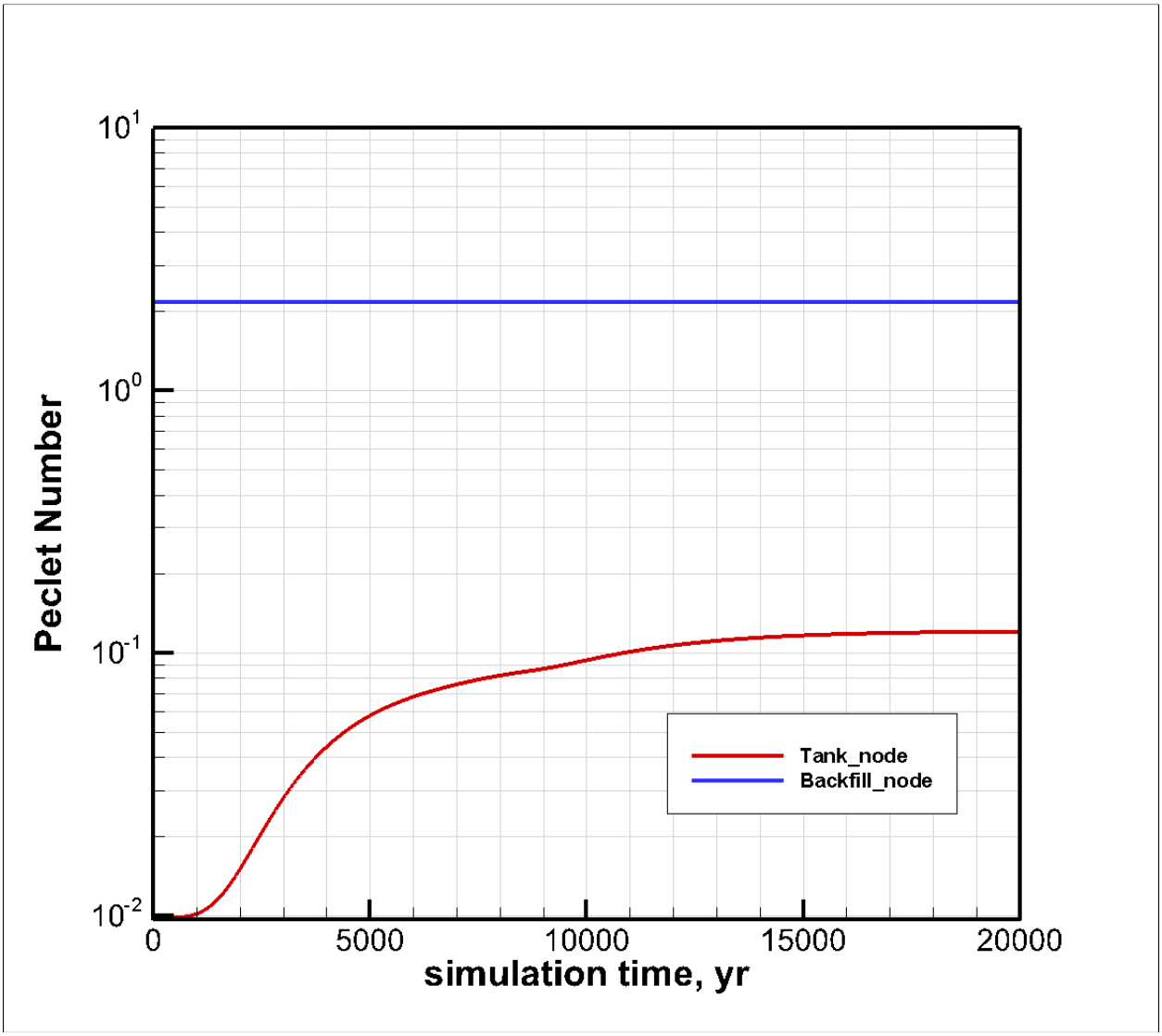


Figure B-11. Comparison of Peclet Number Between Selected Tank and Backfill Nodes.



REFERENCES

Fetter, C. W., 1993, Contaminant Hydrogeology, Macmillan Publishing Company, New York.

RPP-ENV-58782, 2016, "*Performance Assessment of Waste Management Area C, Hanford Site, Washington*," Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.

WSRC-STI-2007-00369, 2007, "*Hydraulic and Physical Properties of Tank Grouts and Base Mat Surrogate Concrete for FTF Closure*," Rev. 0, Savannah River National Laboratory/Washington Savannah River Company, Aiken, South Carolina.