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Revision 1

INDUSTRIAL WASTEWATER CLOSURE MODULE FOR THE LIQUID WASTE TANKS 18 AND 19

F-AREA TANK FARM, SAVANNAH RIVER SITE

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TABLE OF CONTENTS

REVISION SUMMARY 2
LIST OF FIGURES 5
LIST OF TABLES 7
LIST OF ACRONYMS 8
EXECUTIVE SUMMARY 10
1.0 INTRODUCTION 12
2.0 FACILITY DESCRIPTION 15
2.1 Tank 18 and 19 Design and Construction *16*
2.1.1 Type IV Waste Tank Design 16
2.2 Waste Tank Operational Service Histories *19*
2.2.1 Tank 18 Operational Service History 19
2.2.2 Tank 19 Operational Service History 20
3.0 WASTE REMOVAL 22
3.1 Tank 19 Waste Removal History *22*
3.1.1 Tank 19 Initial Condition Prior to Waste Removal 22
3.1.2 Phase 1: Bulk Liquid Waste Removal 23
3.1.3 Phase 2: Bulk Saltcake Waste Removal 25
3.1.4 Phase 3: Heel Removal with Flygt Mixers 27
3.2 Tank 18 Waste Removal History *37*
3.2.1 Tank 18 Initial Condition Prior to Waste Removal 38
3.2.2 Phase 1: Bulk Liquid Waste Removal 39
3.2.3 Phase 2: Bulk Sludge Waste Removal 40
3.2.4 Phase 3: Heel Removal with ADMP 42
3.3 Tank 18 and 19 Phase 4: Heel Removal with Mantis *48*
3.3.1 Technology Selection 48
3.3.2 Tank 19 Phase 4 Heel Removal with Mantis 55
3.3.3 Tank 18 Phase 4 Heel Removal with Mantis 62
3.4 Basis for Ceasing Mechanical Cleaning Using the Mantis *68*
3.4.1 Visual Observations 69
3.4.2 Technology Limitations of Mantis Equipment 71
3.4.3 Mantis Equipment Degradation 71
3.4.4 Impacts on Tank Space and the Liquid Waste System 72
3.4.5 Diminished Transfer Line Radiation Trends and Confirmatory Operation 73
3.4.6 Evaluation of a Replacement Mantis Deployment 75
3.4.7 Agreement to Proceed with Sampling and Analysis 76

4.0 RESIDUAL WASTE CHARACTERIZATION 78
4.1 Residual Volume Determination 78
4.2 Residual Waste Sampling 83
4.2.1 Representative Characterization 83
4.2.2 Floor Sampling Technique 84
4.2.3 Tank 18 Residual Waste Sampling 85
4.2.4 Tank 19 Residual Waste Sampling 87
4.3 Characterization of Waste Tank Residual Materials 88
4.3.1 Derivation of Constituents of Concern 88
4.3.2 Sample Analysis 93
4.3.3 Statistical Evaluation of Results 93
4.3.4 Quantification of Residual Contaminants 95
5.1 Performance Evaluation Modeling Results 100
5.2 Assessment Evaluation 103
6.0 ASSESSMENT OF THE IMPACT OF DEPLOYING ADDITIONAL REMOVAL TECHNOLOGY 104
6.1 Analysis of Potential Cleaning Technologies 104
6.1.1 Mechanical Cleaning Technologies 104
6.1.2 Chemical Cleaning Technologies 105
6.1.3 Vacuum Cleaning Technology 107
6.2 Estimated Dose Reduction 109
6.3 Assessment Conclusion 112
7.0 WASTE TANK SYSTEM ISOLATION PROCESS AND STABILIZATION STRATEGY 114
7.1 Waste Tank System Isolation Process 114
7.1.1 Tank 18 System Isolation 114
7.1.2 Tank 19 System Isolation 117
7.2 Structures and Equipment Involved with RFS 118
7.3 Stabilization Strategy 120
7.3.1 Waste Tank Grouting Selection 120
7.3.2 Waste Tank Grouting Plan 121
8.0 MAINTENANCE AND MONITORING PLANS 124
9.0 CONCLUSION 125
10.0 REFERENCES 131
APPENDIX A: WASTE TANK SYSTEM TRACKING 138

LIST OF FIGURES

Figure 1.0-1: SRS Operational Area Location Map 12
Figure 2.0-1: Layout of FTF 15
Figure 2.0-2: Layout of the GSA 16
Figure 2.1-1: Typical FTF Type IV Waste Tank Cross Section 17
Figure 2.1-2: Dome and Risers on Type IV Waste Tanks 18
Figure 2.1-3: Examples of Structural Steel Support Systems 19
Figure 3.1-1: Tank 19 Historical Timeline 22
Figure 3.1-2: Tank 19 Initial Condition Prior to Waste Removal (January 1980) 23
Figure 3.1-3: Tank 19 Phase 1 – Following Bulk Liquid Waste Removal (May 1980) 24
Figure 3.1-4: Tank 19 Following Bulk Liquid Waste Removal (May 1980) 24
Figure 3.1-5: Tank 19 Phase 2 – Bulk Saltcake Waste Removal (July 1980 – July 1981) 25
Figure 3.1-6: Typical Standard Mixer Pump 26
Figure 3.1-7: Tank 19 Hourglass Shaped Heel and Interior Photograph of Tank 19 Prior to Heel Removal with Flygt Mixers 28
Figure 3.1-8: Diagram of Tank 19 Access Area for Heel Removal Equipment 29
Figure 3.1-9: Prototype Flygt Mixer 33
Figure 3.1-10: Hydro-Lance in Operation Breaking Up Mound 35
Figure 3.1-11: Tank 19 Following Phase 3 – Heel Removal with Flygt Mixers (June 2001) 36
Figure 3.1-12: Tank 19 Residual Material Configuration Following Heel Removal with Flygt Mixers (Phase 3) 37
Figure 3.2-1: Tank 18 Historical Timeline 38
Figure 3.2-2: Tank 18 Initial Condition Prior to Waste Removal (January 1986) 39
Figure 3.2-3: Tank 18 Phase 1–Following Bulk Liquid Waste Removal (April 1986) 40
Figure 3.2-4: Tank 18 Phase 2 – Bulk Sludge Waste Removal Campaign 41
Figure 3.2-5: Tank 18 Heel Map Prior to Heel Removal with the ADMP 43
Figure 3.2-6: Diagram of Tank 18 Access Area for Heel Removal Equipment 44
Figure 3.2-7: ADMP Technology 45
Figure 3.2-8: Tank 18 Following Phase 3 – Heel Removal with ADMP (July 2003) 47
Figure 3.2-9: Tank 18 Residual Material Configuration Following Heel Removal with the ADMP (Phase 3) 47
Figure 3.3-1: Full Scale Demonstration Test Waste Tank Operation 50
Figure 3.3-2: Mantis 51
Figure 3.3-3: Mantis Eductor 52
Figure 3.3-4: Hose-In-Hose Transfer Route 53
Figure 3.3-5: LDB Location in Hose-In-Hose Transfer Line During Installation 54
Figure 3.3-6: Waste Mixing Chamber 54
Figure 3.3-7: Removal of Water Tank from Tank 19 55
Figure 3.3-8: Removal of the Existing Tank 19 Center Riser Plug 55
Figure 3.3-9: New Center Riser Cover Being Lowered onto Tank 19 55
Figure 3.3-10: Tank 19 Mantis Operational Timeline 59
Figure 3.3-11: Tank 19 Following Phase 4 Heel Removal with Mantis (April 2009) 60
Figure 3.3-12: Tank 19 Residual Material Configuration Following Heel Removal with Mantis (April 2009) 60
Figure 3.3-13: Tank 19 Waste Volume Reduction 61

Figure 3.3-14: Tank 19 Following Phase 1 – Bulk Removal of Liquid Waste (top – June 5, 1980) and Following Phase 4 – Heel Removal (bottom – August 8, 2009) 62
Figure 3.3-15: Core Drilling of New Mechanical Cleaning Riser in Tank 18 63
Figure 3.3-16: Tank 18 Mantis Operational Timeline 65
Figure 3.3-17: Tank 18 Following Phase 4 Heel Removal with Mantis (April 2009) 66
Figure 3.3-18: Tank 18 Residual Material Configuration Following Heel Removal with the Mantis (Phase 4) 66
Figure 3.3-19: Tank 18 Waste Volume Reduction 67
Figure 3.3-20: Tank 18 Following Phase 1 – Bulk Waste Removal (top – August 26, 1986) and Following Phase 4 – Heel Removal (bottom – July 21, 2009) 68
Figure 3.4-1: Tank 18 after Completion of Mantis Operations (July 2009) (View from New Mechanical Cleaning Riser Looking North) 69
Figure 3.4-2: Tank 19 after Completion of Mantis Operations (August 2009) (View from Northeast Riser Looking South) 70
Figure 3.4-3: Mantis Suction Head Screen and Blades 71
Figure 3.4-4: Radiation Monitor Data for Tank 18 Mechanical Cleaning 74
Figure 3.4-5: Radiation Monitor Data for Tank 19 Mechanical Cleaning 75
Figure 4.1-1: Lifting Plate Elevation View 79
Figure 4.1-2: Examples of Lifting Plate Depths 80
Figure 4.1-3: Tank 19 Residual Material Configuration (April 2009) 81
Figure 4.1-4: Tank 18 Residual Material Configuration (April 2009) 82
Figure 4.2-1: Waste Tank Floor Sampling Process During Mock-Up Testing 85
Figure 4.2-2: Tank 18 Floor Sample Locations 86
Figure 4.2-3: Tank 19 Floor Sample Locations 88
Figure 4.3-1: Chemicals of Interest Determination for Tank 18 and 19 90
Figure 4.3-2: Radionuclides of Interest Determination for Tank 18 and 19 92
Figure 4.3-3: Relative Standard Deviations for the Tank 18 Sample Results 94
Figure 4.3-4: Relative Standard Deviations for the Tank 19 Sample Results 95
Figure 4.3-5: Illustration of Various Levels of Conservatism 96
Figure 6.2-1: Major Sources of Radiation Exposure Near SRS 111
Figure 7.1-1: Tank 18 Riser and Transfer Line Locations 115
Figure 7.1-2: Tank 19 Risers and Piping Locations 117
Figure 7.3-1: Typical Tank 18 and 19 Grout Configuration 122
Figure 9.0-1: Tank 18 Waste Volume Reduction 125
Figure 9.0-2: Tank 19 Waste Volume Reduction 126
Figure 9.0-3: Tank 18 after Completion of Mantis Operations 127
Figure 9.0-4: Tank 19 after Completion of Mantis Operations 128

LIST OF TABLES

Table 3.1-1: Tank 19 Saltcake Dissolution Campaigns....27
Table 3.2-1: Tank 18 Bulk Sludge Waste Removal Campaigns....42
Table 3.3-1: Summary of Results of Waste Removal Activities in Tank 19....61
Table 3.3-2: Summary of Results of Waste Removal Activities in Tank 18....67
Table 4.1-1: Material Depth Criteria....79
Table 4.3-1: Chemical Analyte List for Tank 18 and 19 Samples....89
Table 4.3-2: Radiological Analyte List for Tank 18 and 19 Samples....91
Table 4.3-3: Residual Chemical Inventories for Tanks 18 and 19....97
Table 4.3-4: Residual Radiological Inventories for Tanks 18 and 19....98
Table 5.1-1: Modeling Results at the Assessment Point....101
Table 6.1-1: Estimated Project Cost Summary for the Development/Deployment of an Upgraded Mantis in Each Tank....108
Table 7.1-1: Tank 18 Penetrations....116
Table 7.1-2: Tank 19 Penetrations....118
Table 7.2-1: Equipment to Remain in Tank 18....119
Table 7.2-2: Equipment to Remain in Tank 19....120
Table 7.3-1: Mechanical and Chemical Requirements for Grout Material....123
Table A-1: FTF Waste Systems Tracking....138

LIST OF ACRONYMS

ADMP	Advanced Design Mixer Pump
AEA	Atomic Energy Act
ALARA	As Low As Reasonably Achievable
BOA	Bulk Oxalic Acid
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CM	Closure Module
CMCOC	Contaminant Migration Constituents of Concern
Conex	Container Express
CRC	Cesium Removal Column
CTS	Concentrate Transfer System
DOE	United States Department of Energy
DWPF	Defense Waste Processing Facility
ECC	Enhanced Chemical Cleaning
ECR	Effective Cleaning Radius
EIS	Environmental Impact Statement
EPA	United States Environmental Protection Agency
EPD	Electronic Pocket Dosimeters
FDB	FTF Diversion Box
FFA	Federal Facility Agreement
FTF	F-Area Tank Farm
GCP	General Closure Plan
GDL	Gravity Drain Line
GSA	General Separations Area
HIHTL	Hose-in-Hose Transfer Line
HTF	H-Area Tank Farm
ICRP	International Commission on Radiological Protection
ICM	Integrated Conceptual Model
ID	Inner Diameter
IROD	Interim Record of Decision
LDB	Leak Detection Box
MCL	Maximum Contaminant Level
MWRS	Mechanical Waste Removal System
OA	Oxalic Acid
OD	Outer Diameter
OU	Operable Unit
PA	Performance Assessment
PNNL	Pacific Northwest National Laboratory
R&D	Research and Development
RCRA	Resource Conservation and Recovery Act
RFS	Removal from Service
RSL	Regional Screening Level
SA	Special Analysis

SCDHEC	South Carolina Department of Health and Environmental Control
SDF	Saltstone Disposal Facility
SEE	Systems Engineering Evaluation
SMP	Submersible Mixing Pump
SPF	Saltstone Production Facility
SRNL	Savannah River National Laboratory
SRR	Savannah River Remediation
SRS	Savannah River Site
SWPF	Salt Waste Processing Facility
TFA	Tanks Focus Area
TMR	TMR Associates, LLC
TTP	Telescoping Transfer Pump
TTR	Technical Task Request
UHP	Ultra-High Pressure
UTR	Upper Three Runs
VT 150	VersaTrax™ Robotic Platform
WL	Water Lance
WMC	Waste Mixing Chamber
WTS	Waste Transfer System

EXECUTIVE SUMMARY

The United States Department of Energy (DOE) and the State of South Carolina have developed the *Industrial Wastewater General Closure Plan for F-Area Waste Tank Systems* (LWO-RIP-2009-00009) to support the removal from service (RFS) of the F-Area Tank Farm (FTF) underground radioactive waste tanks and ancillary structures at the Savannah River Site (SRS). The FTF General Closure Plan (GCP) establishes the protocol by which DOE intends to close FTF waste tank systems at SRS and receive approval from the South Carolina Department of Health and Environmental Control (SCDHEC) following a public comment period. This Closure Module (CM) has been prepared in accordance with the FTF GCP to support the RFS of underground radioactive waste Tanks 18 and 19 in the FTF under the *Construction Permit #17,424-IW, SRS F/H-Area, Aiken and Barnwell County* (hereinafter referred to as Permit #17,424-IW). [DHEC_01-25-1993]

The SRS is a Federal facility managed by DOE. Since beginning operations in the early 1950s, uranium and plutonium recovery processes have generated liquid radioactive waste, which is currently stored in underground waste tanks in the F and H Areas at the site. The DOE intends to remove from service all of the waste tanks with priority being given to the old-style waste tanks that do not meet the standards established in Appendix B of the SRS Federal Facility Agreement (FFA). [WSRC-OS-94-42] The FFA has been entered into pursuant to Section 120 of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), Sections 3008(h) and 6001 of the Resource Conservation and Recovery Act (RCRA), as amended by the Hazardous and Solid Waste Amendments of 1984 (hereinafter jointly referred to as RCRA) and the Atomic Energy Act of 1954 (AEA), as amended, 42 U.S.C. § 2011.[1] After SCDHEC, the United States Environmental Protection Agency (EPA) and DOE mutually agree that waste removal from the tanks may cease, any residual contaminants will be stabilized and Tanks 18 and 19 will be removed from service under Permit #17,424-IW. [DHEC_01-25-1993] Subsequently, the stabilized tanks will be monitored and maintained in accordance with the requirements of an Interim Record of Decision (IROD) and the SRS RCRA Hazardous Waste Permit, Module VIII as solid waste management units.

This CM describes the processes by which DOE has removed waste from Tanks 18 and 19, sampled residual contaminants, characterized remaining residual inventory, and isolated the tanks from the FTF facilities that remain operable. The DOE intends to remove from service Tanks 18 and 19 at SRS in accordance with SCDHEC Regulation 61-82, *Proper Closeout of Wastewater Treatment Facilities*, and SCDHEC Regulation 61-67, *Standards for Wastewater Facility Construction*. In addition, RFS of Tanks 18 and 19 by this process is intended to be consistent with the applicable requirements of RCRA and CERCLA described in the FFA, which will control the subsequent remediation of the FTF operable unit (OU). These regulations were reviewed at the time of development of this CM and have been verified to have no change since the GCP was issued. [SCDHEC R.61-82, SCDHEC R.61-67, WSRC-OS-94-42]

A performance assessment (PA) has been developed to assess the long-term fate and transport of residual contamination in the environment resulting from the RFS of the FTF waste tanks. [SRS-

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[1] DOE's submittal of this plan does not waive any DOE claim of jurisdiction over matters reserved to it under the Atomic Energy Act of 1954.

REG-2007-00002] Considering the layout of the FTF and the presumed footprint of a potential closure cap, it is expected that monitoring wells will be located approximately 100 meters from the FTF boundary (i.e., line of demarcation enclosing the FTF waste tanks). The FTF PA has used 100 meters as a point of assessment to predict long-term performance.

Before initiating this RFS process for Tanks 18 and 19 under SCDHEC Regulation R.61-82 and R.61-67, DOE removed waste using mechanical agitation and vacuum removal cleaning. The DOE then characterized radiological and non-radiological residual contamination in the individual tanks and used the FTF PA to assess the long-term impact of this residual contamination. This evaluation concluded that the stabilized Tanks 18 and 19 would be protective of human health and the environment.

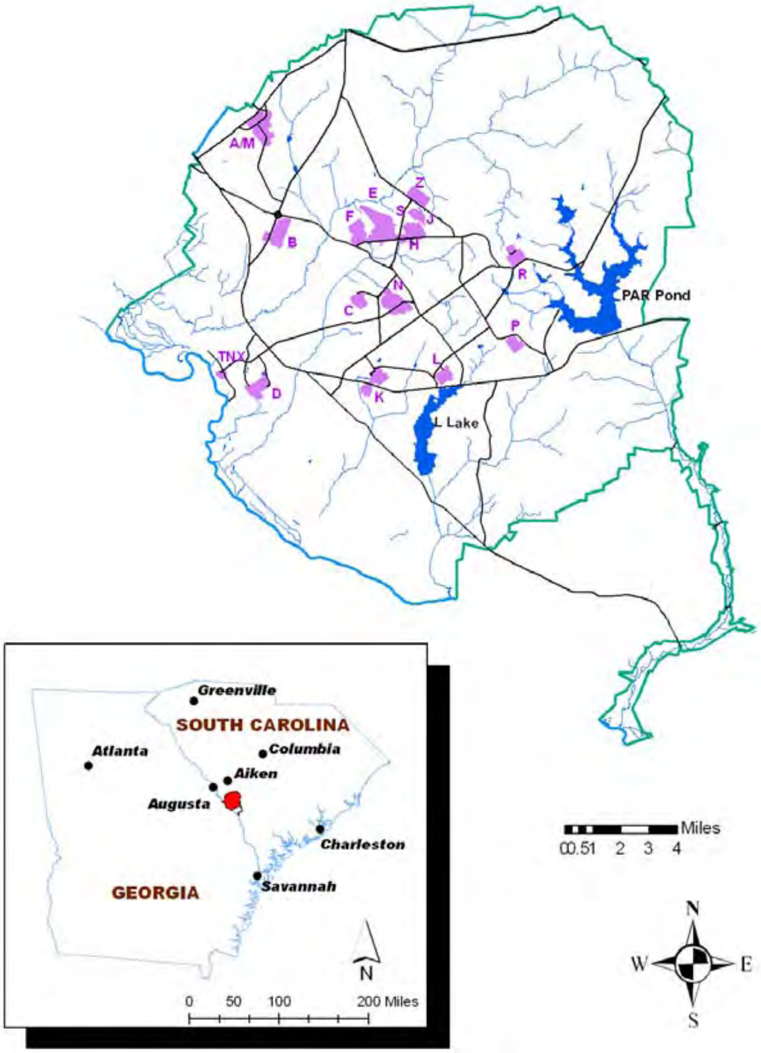
Based on the information provided in this CM and supporting documents, it may be concluded that (1) there is reasonable assurance that, at the time of final FFA corrective/remedial actions, groundwater concentrations derived from residual contamination in the tanks and ancillary structures will be within the maximum contaminant levels (MCLs) and (2) further residue removal is not technically practicable from an engineering perspective.

The DOE has determined that all FTF GCP requirements have been met to proceed with removing Tanks 18 and 19 from service and is ready to complete the process by stabilizing the tanks with grout. Through approval of this CM, SCDHEC is agreeing that waste removal activities for Tanks 18 and 19 can cease and authorizes stabilization of the tanks and the residual contaminants under Permit #17,424-IW. Following stabilization, DOE will submit a Final Configuration Report for Tanks 18 and 19 to SCDHEC (as described in the GCP) with certification that the RFS activities have been performed in accordance with the FTF GCP (LWO-RIP-2009-00009) and this CM.

1.0 INTRODUCTION

Since the early 1950s, the primary mission of SRS had been to produce nuclear materials primarily for national defense and deep space missions. A legacy of the SRS mission was the generation of liquid waste from chemical separations processes in both F and H Areas. Since the beginning of SRS operations, an integrated Liquid Waste System consisting of several facilities designed for the overall processing of liquid waste has evolved. Two of the major components of this system are the FTF and H-Area Tank Farm (HTF) located in F Area and H Area, respectively, which are near the center of the site (Figure 1.0-1). In F Area, plutonium, uranium and other radionuclides were separated from target assemblies using chemical separations processes. The tank farms, which store and process waste from the chemical separations processes, include waste tanks, evaporators, transfer line systems, and other ancillary structures.

Figure 1.0-1: SRS Operational Area Location Map



In support of environmental remediation activities at SRS, DOE, the EPA, and SCDHEC signed the SRS FFA pursuant to Section 120 of CERCLA, Sections 3008(h) and 6001 of RCRA and the AEA. The agreement became effective in August 1993. As part of this comprehensive agreement, DOE committed to comply with a schedule to remove from service those liquid radioactive waste tank systems that do not meet the standards set forth in Appendix B of the FFA. Appendix B of the FFA also describes the specific radioactive waste tank systems that are subject to the agreement. [WSRC-OS-94-42]

The FTF GCP establishes the general protocols for removal of the FTF waste tanks and ancillary structures from service in accordance with SCDHEC R.61-82 and SCDHEC R.61-67. This CM provides specific information on the RFS of Tanks 18 and 19 at the FTF and demonstrates that activities have been performed in accordance with the protocols presented in the FTF GCP. The activities described in this CM for Tanks 18 and 19 follow the requirements set forth in Section 6.0 of the FTF GCP. [LWO-RIP-2009-00009]

This CM contains the following elements:

Introduction (Section 1.0) – Defines the purpose and scope of this CM.

Facility Description (Section 2.0) – Describes Tanks 18 and 19 and provides a history of these waste tanks and the waste types that have been managed in the system.

Waste Removal and Closure Configuration (sections as annotated below) – Describes the process used to remove waste from Tanks 18 and 19. These sections focus on the following sub-elements:

- Summary description of the technology selection process for waste removal (Section 3.0)
- Details of the waste removal process (Section 3.0)
- Characterization of residual waste (Section 4.0), including sampling and analysis details (Section 4.2)
- Waste tank system isolation process (Section 7.1)
- Description of structures and equipment that are part of this RFS activity including any equipment that will remain in the waste tanks at the time of stabilization and RFS (Section 7.2)
- Stabilization strategy including type and characteristics of fill material, as appropriate (Section 7.3)

Performance Evaluation (Section 5.0) – Using the fate and transport model from the FTF PA, information is presented concerning the peak groundwater concentrations.

Waste Removal Analysis (Section 6.0) – An analysis is provided to demonstrate that it is not technically practicable from an engineering perspective to continue with active waste removal activities. This analysis considers technology capabilities, schedule impacts, and relative benefit.

Maintenance and Monitoring (Section 8.0) – This section provides a description of the FTF maintenance and monitoring plans that will be used for the interim period from the time Tanks 18 and 19 are removed from service until the final closure of the FTF OU.

Conclusion (Section 9.0) – This section provides the conclusion that DOE has demonstrated that the proposed RFS configuration is protective of human health and the environment and that the closure actions will continue to be supportive of meeting the applicable performance standards for the closure of the FTF OU.

Waste Tank Systems Tracking (Appendix A) – This section will track the tanks and ancillary structures to ensure that all components of the FTF are addressed in a CM. This table will be updated in each CM with the RFS date and the document number of the CM that addresses each of the tanks and ancillary structures.

2.0 FACILITY DESCRIPTION

The FTF is a 22-acre site consisting of 22 underground liquid waste storage tanks, two evaporator systems, transfer pipelines, six diversion boxes, one catch tank, three pump pits, and a concentrate transfer system. Figure 2.0-1 shows the general layout of FTF. There are three major waste tank types in FTF with nominal capacity ranging from 750,000 gallons (Type I waste tanks) to 1.3 million gallons (Type III/ IIIA and Type IV waste tanks) and that have varying degrees of secondary containment and tank internal structures, such as cooling coils and roof support columns. The FTF was constructed to receive waste generated by various SRS production, processing, and laboratory facilities. The FTF and HTF facilities are in place to store and treat the accumulated sludge and salt waste (supernate and salt cake) to enable the management of these wastes within other SRS facilities (i.e., Defense Waste Processing Facility (DWPF) and Saltstone Production Facility (SPF)). These treatment facilities convert the sludge and salt waste to more stable forms suitable for permanent disposal in a Federal Repository or the Saltstone Disposal Facility (SDF), as appropriate. Detailed descriptions of the FTF facilities are provided in the FTF PA. [SRS-REG-2007-00002]

The FTF site was originally chosen because of its favorable terrain, proximity to the F-Canyon Separations Facility (the major waste generation source), and isolation distance (at least 5.5 miles) from the SRS boundaries. Figure 2.0-2 shows the setting of F Area and FTF within the General Separations Area (GSA).

Figure 2.0-1: Layout of FTF

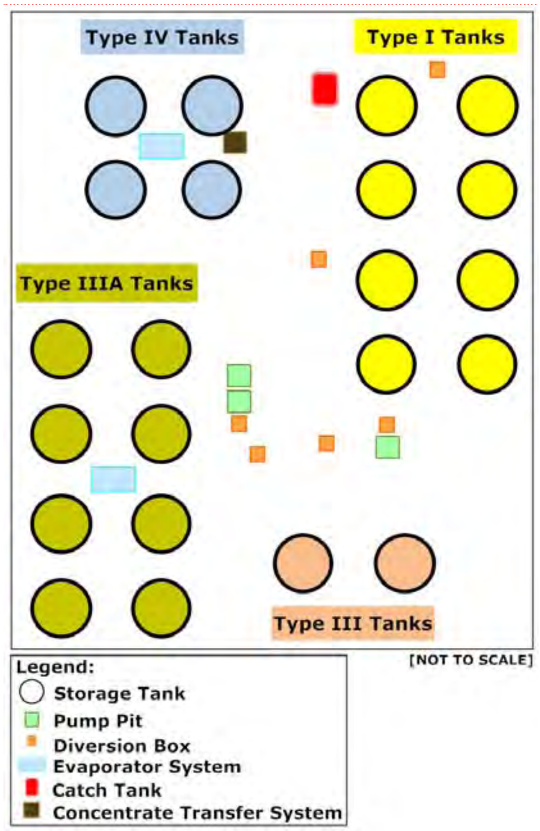
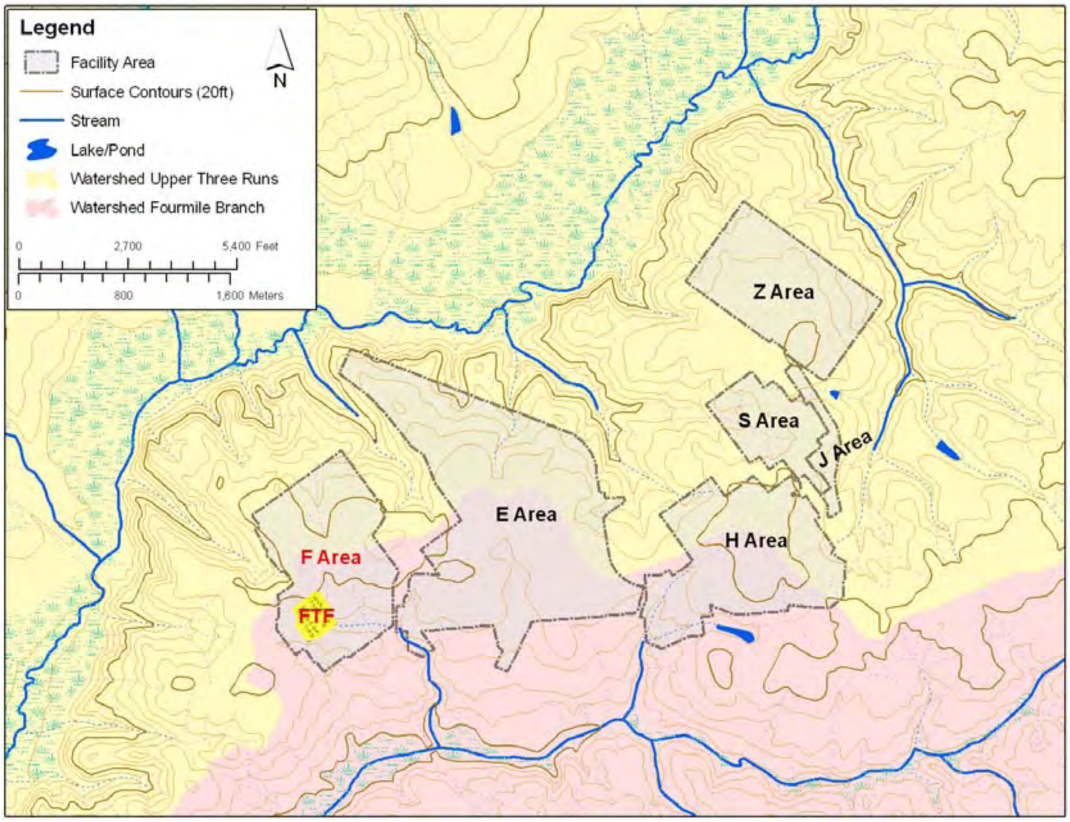


Figure 2.0-2: Layout of the GSA

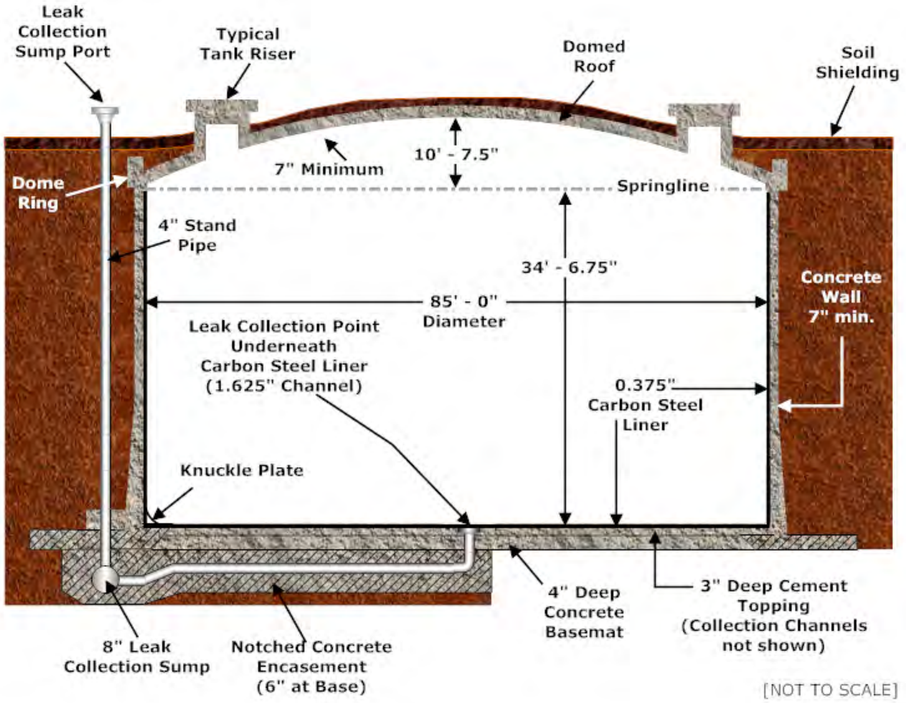


2.1 Tank 18 and 19 Design and Construction

2.1.1 Type IV Waste Tank Design

Tanks 18 and 19 are part of the group of four Type IV tanks (Tanks 17 through 20) in the FTF. The characteristics of typical Type IV tanks are shown in Figure 2.1-1. The FTF Type IV tanks were constructed in the late 1950s to receive low-heat waste only and did not require the addition of cooling coils. These waste tanks all have the same design. Tanks 17 and 20 were removed from service in 1997 under SCDHEC approved CMs. [PIT-MISC-0002, PIT-MISC-0004] Additional details of the FTF facilities are provided in the FTF PA. [SRS-REG-2007-00002]

Figure 2.1-1: Typical FTF Type IV Waste Tank Cross Section



A 4-inch thick reinforced concrete slab covered with a 3-inch thick wire-mesh reinforced cement layer comprises a nominal 7-inch thick waste tank basemat for the Type IV tanks. Drainage channels to be used for leak detection below the carbon steel waste tank liners were formed in the 3-inch thick cement topping layer and drain to a collection point, that in turn empties to a collection chamber (sump) below the waste tank footing at the edge of the waste tank wall (Figure 2.1-1). A riser pipe to the surface enables a leak detection probe to be placed in the chamber.

There is no secondary containment for Type IV tanks. The Type IV tank primary container is an 85-foot diameter by 34-foot 6.75-inch high open-topped liner with walls and floor of 0.375-inch thick carbon steel plates, reinforced on the interior with three, 4-inch by 4-inch, L-shaped carbon steel bands, referred to as stiffener bands. The bands and waste tank liner are anchored to the enclosing concrete vault wall. The waste tanks have sidewall penetrations near the top for 3-inch diameter stainless steel inlet and outlet transfer lines and 4-inch diameter stainless steel transfer lines. The penetrations and risers for Tanks 18 and 19 are discussed in Section 7.1 and 7.2, respectively. [SRS-REG-2007-00002]

The Type IV primary containers are completely enclosed in concrete vaults. The Type IV waste tank roof is a self-supporting, hemispherical dome made of 7-inch to 10-inch thick concrete. The dome has an internal curvature radius of 90 feet, 4 inches and a maximum rise of 10 feet 7.5 inches above the springline. The concrete roof is not lined with carbon steel on the inside (Figure 2.1-1).

The Type IV tanks have a nominal capacity of 1.3 million gallons that equates to 3,540 gal/in (depth) of stored material. The carbon steel tank floor is essentially flat with no sump, significant low points, or slope.

The concrete vault of a Type IV tank was built around the primary liner using a technique called “shotcrete.” The core wall was constructed of 0.75-inch to 1.5-inch thick layers of shotcrete, which were allowed to harden three days between the installations of layers. Tests showed that the bond between layers was so strong that, when cores were broken, they invariably broke at locations other than the joint between layers. Since no annulus exists, a three-layer backfilling system was used to surround the sidewalls of the concrete vault. The backfill consisted of a vermiculite fill layer, a special manually compacted fill of soil, and a test controlled compacted fill of soil. The vermiculite fill provides a cushion layer for expansion of the primary tank with temperature variations of the waste tank and waste tank contents. [SRS-REG-2007-00002]

As originally designed and constructed, the dome of Tank 18 and Tank 19 had seven access risers. [W167477] The six original perimeter risers are only 2 feet in diameter (opening to waste tank interior), approximately 5-feet long, and approximately 37 feet from the bottom of the riser to the waste tank bottom. The single center riser is approximately 8 feet in diameter (opening to waste tank interior) and approximately 5-feet long, and 45 feet from the bottom of the riser to the bottom of the waste tank. The waste tank riser design configuration provides limited access to the waste tank interior (Figure 2.1-2).

Figure 2.1-2: Dome and Risers on Type IV Waste Tanks

A structural steel support system was later added to both Tank 18 and Tank 19 to support equipment used in their respective waste removal campaigns (Figure 2.1-3). [SRS-REG-2007-00002]

Figure 2.1-3: Examples of Structural Steel Support Systems

Prior to backfilling, each waste tank was hydrostatically tested by filling with water to the normal fill line. The waste tank remained filled until it was placed in use for waste storage. The waste tanks were finally covered with a minimum of 3 feet 8 inches of compacted soil.

Tank 18 is similar to Tank 19 with the exception of two "pillboxes" over the southeast and southwest risers. These pillboxes were constructed of steel reinforced concrete walls built around the risers that were designed to accommodate the original 242-F Evaporator feed equipment.

2.2 Waste Tank Operational Service Histories

This section presents a summary of the wastes received and processed through Tanks 18 and 19. Details on the waste removal operations conducted in each waste tank are provided in Section 3.0. In October 1959, before the FTF Type IV waste tanks were put into service, liquid was detected in the leak collection sumps. Analysis indicated that the fluid was the result of groundwater intrusion and not due to leakage from the waste tanks. [DPSPU 82-11-10]

2.2.1 Tank 18 Operational Service History

Tank 18 was constructed in 1958 and entered service in 1959 as an F-Canyon waste receipt tank. This waste tank remained active and in operational service until 1986 when waste removal activities were initiated. The largest volume of waste stored in Tank 18 was approximately 1.3 million gallons. [WSRC-TR-2004-00284, CBU-PIT-2004-00024] A further discussion of the waste type (i.e., supernate, saltcake, sludge, etc.) is included in Section 3.2. From 1959 to 1977, Tank 18 received waste from F Canyon during multiple periods. Tank 18 also supported the 242-F Evaporator operations, as both a receiver of concentrated supernate and returned overheads, and as a feed tank for the evaporator. From 1962 to 1981, Tank 18 received concentrated supernate and from 1966 to early 1983, overheads from the 242-F Evaporator. From 1960 through 1976, Tank 18 was used as a feed tank for the 242-F Evaporator. In 1973, Tank 18 also received approximately 12,000 gallons of waste from HTF evaporator overheads and in 1974 approximately 719,000 gallons of waste from HTF were received.

Tank 18 was designed as the sole conventional transfer route to exit FTF Type IV Tanks 17 through 20 (i.e., all waste being transferred out of Tanks 17, 19, and 20 went through Tank 18). In 1980 and 1981, Tank 18 received salt and/or sludge removal waste from Tanks 17, 19, and 20 waste removal activities. During this operation, some of the spent zeolite resins, which were originally confined to Tank 19, were transferred to, and settled in, Tank 18. [CBU-PIT-2005-00124] Supernate removal and bulk sludge removal from Tank 18 occurred in 1986. Initial mechanical heel removal occurred in Tank 18 in 2003 using an advanced design mixer pump (ADMP). Subsequently, additional heel removal was performed in 2009 using a robotic crawler-based ultra-high pressure (UHP) eductor retrieval system, referred to as the mantis that reduced the volume of residual solids with associated interstitial supernate to approximately 4,000 gallons. [U-ESR-F-00041] Details on the waste removal efforts are provided in Section 3.0. Tank 18 has no known leak sites. [SRR-STI-2010-00283]

2.2.2 Tank 19 Operational Service History

Tank 19 was constructed in 1958 and entered service in 1961 as an F-Canyon waste receipt tank. This waste tank remained active and in operational service until 1980 when waste removal activities were initiated. The largest volume of waste stored in Tank 19 has been approximately 1.3 million gallons. [WSRC-TR-93-425, CBU-PIT-2005-00124] A further discussion of the waste type (i.e., supernate, saltcake, sludge, etc.) is included in Section 3.1. Tank 19 initially received canyon waste from Tank 17, the primary F-Canyon waste receipt tank, to create space in Tank 17 for receipt of additional canyon waste. Tank 19 served this function by receiving waste in the first six months of operation and again from 1969 to 1972. In July 1973, and again in 1989 radioactivity began to be detected in the Tank 19 sump samples. No tank liner leaks were revealed. The contamination source was determined to be condensate from the inner surface of the domed concrete roof leaking down the interface between the concrete waste tank wall and the steel liner and reaching the leak collection grid in the basemat-topping layer. [DPSPU 82-11-10, SRR-STI-2010-00553]

From 1962 to 1976, Tank 19 served as an evaporator concentrate receipt tank for the 242-F Evaporator. Overheads from the evaporator process were treated with a resin (i.e., zeolite) in a cesium removal column (CRC) to remove cesium from the overheads stream. When the spent zeolite resin in the CRC, located in the Tank 19 northeast riser, became “loaded” with radionuclides, it was directly discarded into Tank 19. An estimated 13,000 gallons of spent zeolite resin were placed in Tank 19 from 1964 to 1984. During this 20-year period, numerous batches of spent zeolite resin were directly discarded onto various layers of saltcake formed from waste transferred into Tank 19. Tank 19 salt removal was conducted in 1980 and 1981. In 2000 and 2001, mechanical heel removal was performed using submersible jet mixer pumps (Flygt Mixers). [CBU-PIT-2005-00124] Additional heel removal was performed in 2008 and 2009 using the Mantis and this reduced the volume of residual solids to approximately 2,000 gallons. [U-ESR-F-00042] Details on the waste removal efforts are provided in Section 3.0. Tank 19 has a history of in-leakage of groundwater into the waste tank. Visual inspections have revealed two sites where in-leakage occurred prior to 1994. Two additional in-leakage sites were documented in 2009 but, upon further evaluation, it was concluded that these two anomalies were likely to be collections of zeolite compounds on the wall where a spent zeolite resin mound had been located. [SRR-STI-2010-00283, SRR-STI-2010-00553]

3.0 WASTE REMOVAL

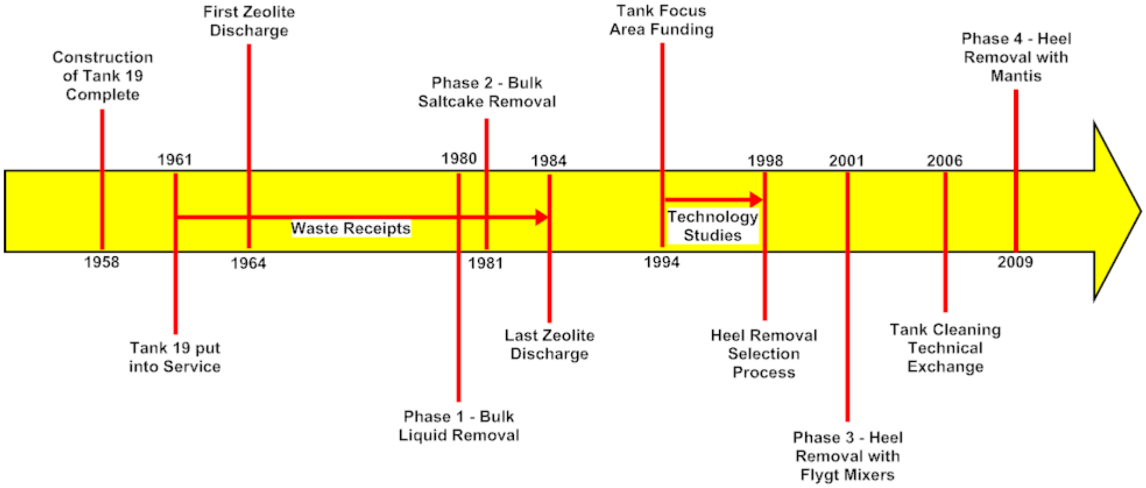
3.1 Tank 19 Waste Removal History

In January 1980, DOE began the waste removal process in Tank 19. [DPSP-84-17-7] Waste removal from Tank 19 was conducted in four phases:

- Phase 1: Bulk liquid waste removal
- Phase 2: Bulk saltcake waste removal
- Phase 3: Heel removal with Flygt mixers
- Phase 4: Heel removal with mantis (discussed in Section 3.3)

See Figure 3.1-1 for the Tank 19 historical timeline that includes waste removal activities. The key activities (including the definition of associated terms and phrases) on this timeline will be described in more detail throughout this section.

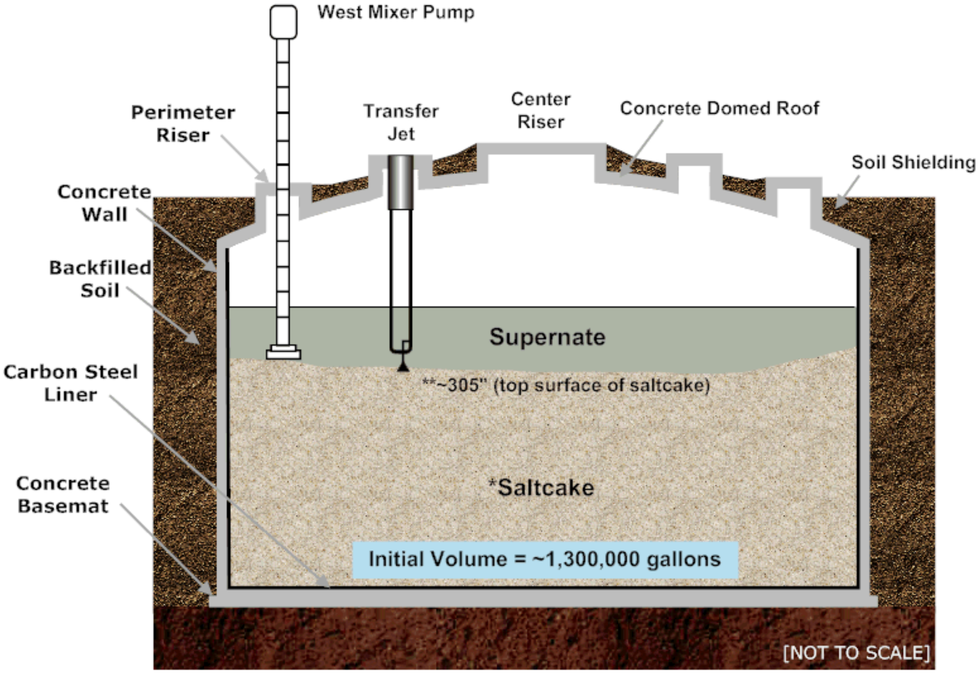
Figure 3.1-1: Tank 19 Historical Timeline



3.1.1 Tank 19 Initial Condition Prior to Waste Removal

The Tank 19 contents, prior to beginning the waste removal campaign, included approximately 1.3 million gallons of total waste. Approximately 1.1 million gallons of this waste was in a wet solids form (mostly saltcake with approximately 12,000 gallons of insoluble solids and 13,000 gallons of spent zeolite resin.) This volume includes associated interstitial liquid (liquid retained in the crystalline matrix of the saltcake). Saltcake is a precipitated salt waste from the concentrated supernate resulting from evaporator operations to volume-reduce the supernate and is comprised principally of inert salts such as nitrites and nitrates. Zeolite resin is a natural material known for its ability to capture and retain cesium. Zeolite resin was used in ion exchange columns called the CRC as part of the evaporator overheads system. The saltcake and spent zeolite resin in Tank 19 was a result of its service as the 242-F concentrated supernate receipt tank as described in Section 2.2.2. Additionally, approximately 200,000 gallons of "free-standing" liquid (liquid above the saltcake) were present in the waste tank (Figure 3.1-2). This liquid is referred to as supernate. [DPSP-84-17-7, CBU-PIT-2005-00206]

Figure 3.1-2: Tank 19 Initial Condition Prior to Waste Removal (January 1980)

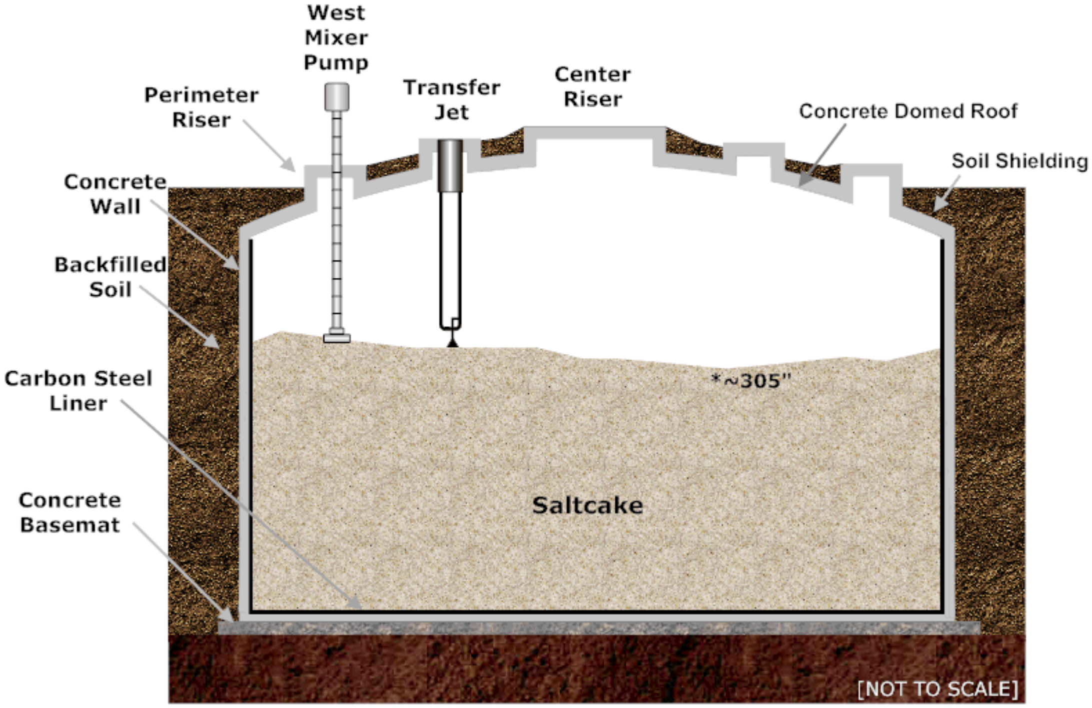


* Saltcake includes crystallized salts, interstitial liquid, insoluble solids and zeolite solids.
** Indicates approximate average height above the tank bottom.

3.1.2 Phase 1: Bulk Liquid Waste Removal

During this phase, the concentrated liquid waste, both free-standing and some interstitial, was removed in three separate transfers beginning in January 1980 and completing in late April 1980. A fixed-length transfer jet was used as the prime mover of this waste stream. A total of 277,000 gallons was removed to provide sufficient space for water additions to support bulk saltcake dissolution and removal. The liquid waste stream was transferred to Tank 18 for future processing/storage throughout FTF. After the desired volume of liquid waste was removed, a saltcake formation with an estimated volume of approximately 1.1 million gallons remained (Figure 3.1-3). This saltcake contained free-standing liquid, interstitial liquid and approximately 13,000 gallons of spent zeolite resin interspersed within the saltcake. The number related to saltcake height represents approximate average height. A photograph of the Tank 19 interior following Phase 1 is shown in Figure 3.1-4. [DPSP-84-17-7, CBU-PIT-2005-00206, WSRC-TR-93-425]

Figure 3.1-3: Tank 19 Phase 1 – Following Bulk Liquid Waste Removal (May 1980)



* Indicates approximate average height of saltcake above the tank bottom.

Figure 3.1-4: Tank 19 Following Bulk Liquid Waste Removal (May 1980)

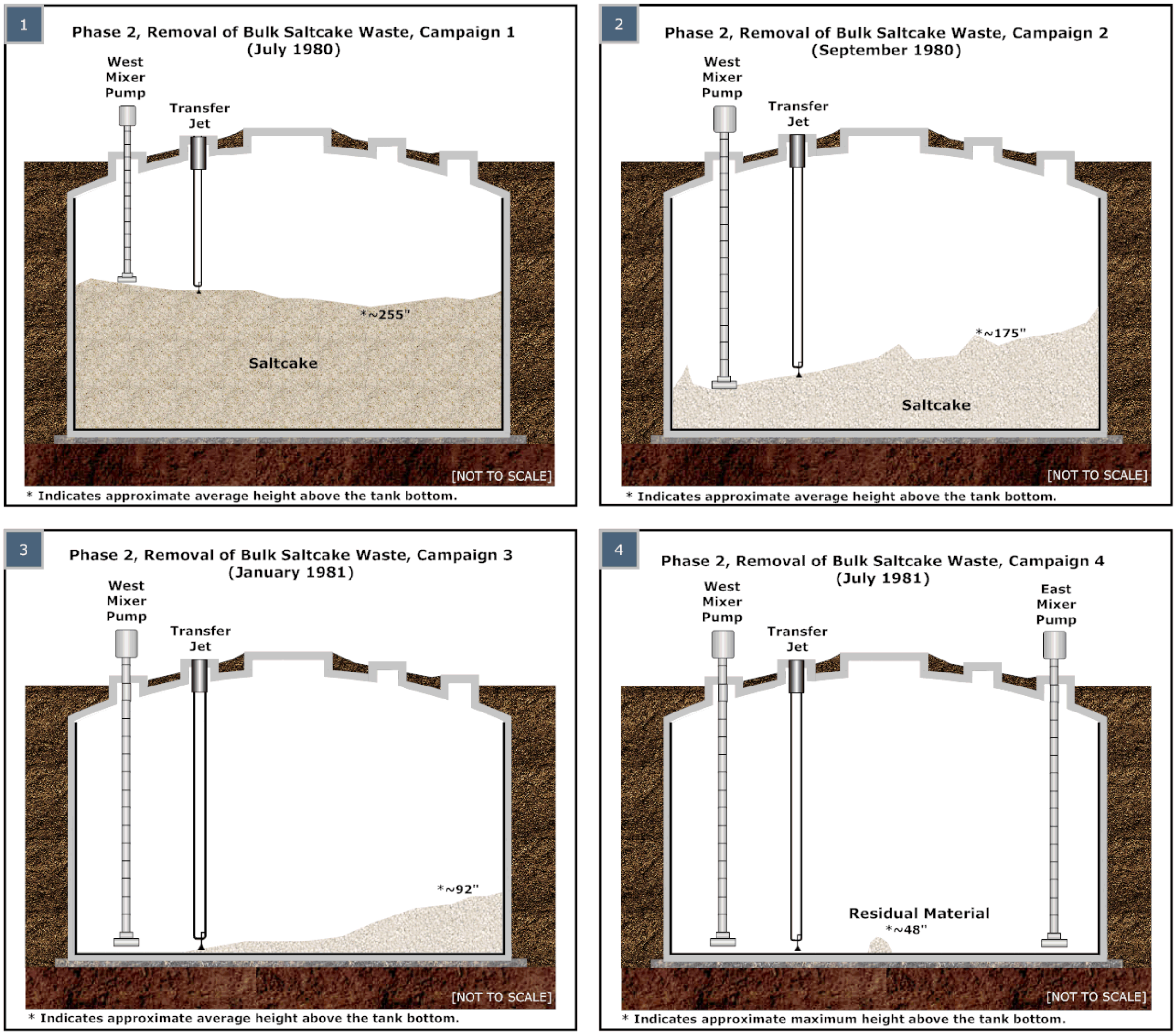
Note: Photos are View of West riser and Northwest riser from Southwest riser (June 1980).

3.1.3 Phase 2: Bulk Saltcake Waste Removal

The SRS began testing long-shaft centrifugal mixer pumps as a high-pressure jet replacement for bulk waste removal in the late 1970's. [DP-1468] These standard mixer pumps were successfully demonstrated in HTF Tank 16 in 1979 and became the baseline mixers for bulk waste removal. [DPSP-79-17-17] The height of the mixer pumps (and the associated discharge nozzles at the base of the pumps) within the waste tank could be raised or lowered to optimize the dissolution of the saltcake.

During Phase 2, SRS operated one standard mixer pump in the west riser and performed bulk saltcake waste removal in a series of three removal campaigns. (Figure 3.1-5, Panels 1 through 3). The pump and transfer jet were lowered between each campaign. After determining one mixer pump was not adequate to provide agitation throughout the waste tank, a second standard mixer pump was installed in the east riser and operated to optimize the fourth bulk saltcake waste removal campaign (Figure 3.1-5, Panel 4). [DPSP-84-17-7]

Figure 3.1-5: Tank 19 Phase 2 – Bulk Saltcake Waste Removal (July 1980 – July 1981)



1 Phase 2, Removal of Bulk Saltcake Waste, Campaign 1 (July 1980)

* Indicates approximate average height above the tank bottom.

2 Phase 2, Removal of Bulk Saltcake Waste, Campaign 2 (September 1980)

* Indicates approximate average height above the tank bottom.

3 Phase 2, Removal of Bulk Saltcake Waste, Campaign 3 (January 1981)

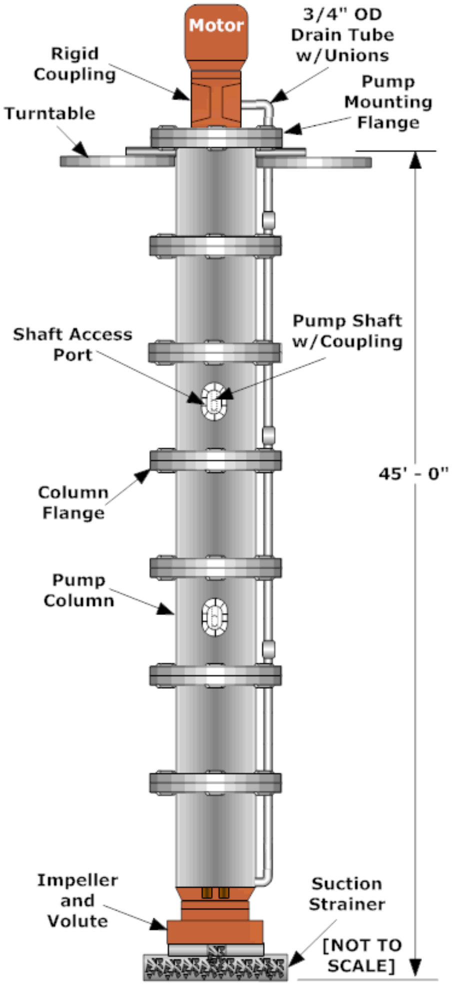
* Indicates approximate average height above the tank bottom.

4 Phase 2, Removal of Bulk Saltcake Waste, Campaign 4 (July 1981)

* Indicates approximate maximum height above the tank bottom.

The two standard mixer pumps utilized in Tank 19 (Figure 3.1-6) required installation of new infrastructure (steel trusses) to prepare Tank 19 for saltcake removal. The two mixer pumps were mounted on the new supporting truss work. Each mixer pump had a 150-hp motor and ran at 1,800 rpm. Each pump had a 45-foot shaft with cylindrical support columns that were filled with clean water. The column was pressurized to prevent cross-contamination between the waste and the top part of the waste tank. Inhibited water (well water with chemicals added to meet waste tank chemistry corrosion control requirements) was added to the waste tank and the mixer pumps exerted a sweeping liquid jet action on the saltcake to promote saltcake dissolution and removal of soluble constituents. A telescoping transfer jet was employed to transfer the dissolved salt solution from Tank 19 to Tank 18. [DPSP-84-17-7]

Figure 3.1-6: Typical Standard Mixer Pump



[WSRC-TR-2001-00313]

Inhibited water was added to Tank 19 in four different campaigns from July 1980 to July 1981 to dissolve saltcake to form a salt solution. As the saltcake level was lowered, the mixer pump(s) were lowered farther into the waste tank in each successive run. During each campaign, the solids (including the spent zeolite resins) that were entrained within the saltcake were extensively washed, stripping out the soluble Cs-137 and other soluble species and leaving behind Cs-137 chemically bound to zeolite and insoluble particles. The insoluble particulate matter entrained in the saltcake and interstitial liquid settled to the waste tank bottom along with an existing sludge layer. Bulk saltcake waste removal (Phase 2) stopped after the fourth dissolution campaign because the increasing water-to-saltcake ratio indicated the decreasing solubility of the remaining solids as reflected in Table 3.1-1. The majority of the soluble saltcake was successfully removed. As expected, no measurable amount of spent zeolite resin was removed during this step because its insoluble, hardened, and fast-settling characteristics make it resistant to this salt removal method. [DPSP-84-17-7]

Table 3.1-1: Tank 19 Saltcake Dissolution Campaigns

Dissolution Campaigns	Saltcake Removed (gallons)	Water Removed (gallons)	Water to Salt Cake Ratio	Figure 3.1-5
First (July 1980)	172,000	236,000	1.4	Panel 1
Second (September 1980)	281,000	442,000	1.6	Panel 2
Third (January 1981)	271,000	529,000	2.0	Panel 3
Fourth (July 1981)	309,000	1,175,000	3.8	Panel 4
Total	1,033,000	2,382,000		

[DPSP-84-17-7]

During the four saltcake dissolution campaigns, more than 1 million gallons of saltcake was dissolved using approximately 2.4 million gallons of inhibited water.

3.1.4 Phase 3: Heel Removal with Flygt Mixers

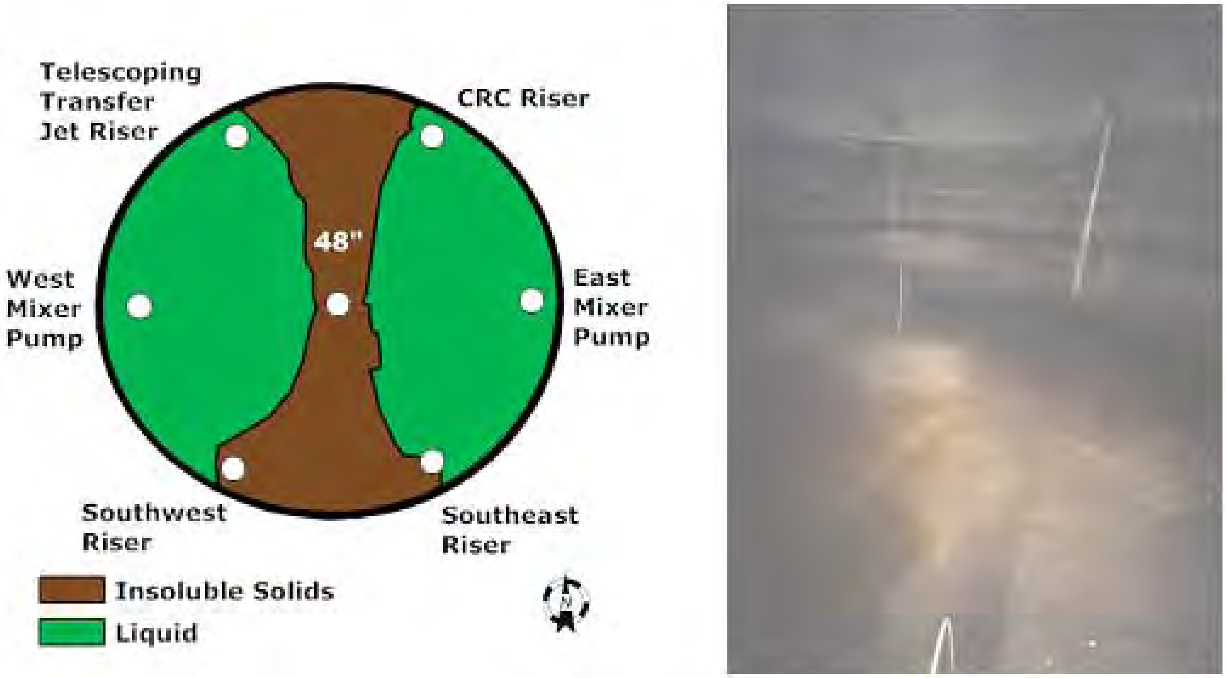
3.1.4.1 Tank 19 Conditions Prior to Heel Removal with Flygt Mixers

Following the final salt solution transfer in July 1981, the waste tank residual material was sampled. An inspection and volume estimate determined there were approximately 33,000 gallons of solids remaining in Tank 19 in an hourglass shaped mound (Figure 3.1-7). The location of the remaining solids in the waste tank was attributed to the location of the mixer pumps in the east and west risers. The mound appeared to be continuous with the highest point approximately 48 inches tall. Sample analysis revealed that the approximate composition of the remaining solids was:

- 20,000 gallons of insoluble solids (fine particles of settled metal oxides (sludge), insoluble salts and other inert materials)
- 13,000 gallons of spent zeolite resin

This residual material became known as the heel.

Figure 3.1-7: Tank 19 Hourglass Shaped Heel and Interior Photograph of Tank 19 Prior to Heel Removal with Flygt Mixers

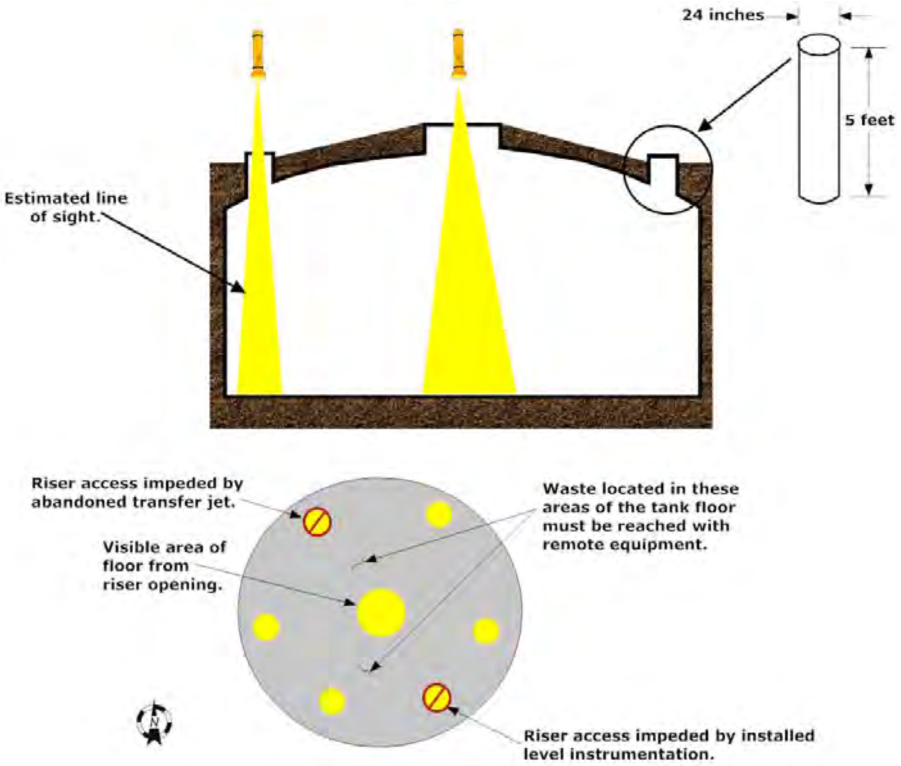


[DPSP-84-17-7]
Note: Photo is View from Southwest Riser Looking Northeast (August 1981)

After completion of the bulk saltcake removal in July 1981, Tank 19 remained inactive (except for routine surveillance and maintenance) until June 2000. However, beginning in 1984 and continuing through 1998, various evaluations were conducted to develop or identify the best technologies for heel removal. Requirements and factors that impact technology selection included physical configuration of the waste tank, the physical properties of the spent zeolite resin, limited storage space within FTF and HTF and occupational radiological exposure risks. [CBU-PIT-2005-00099, PNNL-13532, PIT-MISC-0040]

Physical configuration factors impacting selection of the best technology for heel removal in Tank 19 included the carbon-steel waste tank construction material, the large size of the waste tank, the essentially flat waste tank floor design (no sump, significant low points, or slope to aid in heel removal), and limited visual and equipment manipulation access in the waste tank interior. The large size of the waste tank (85 feet in diameter by 45-feet high at the top of the domed roof) influences the types of equipment that can be successfully deployed. The design configuration of waste tank risers (access openings) provides very limited access to the waste tank interior. The waste tank has one center riser and six perimeter risers. Each perimeter riser is a cylinder nominally 24 inches in diameter and approximately 5-feet long. The cylindrical shape of the risers restricts the ability to view and manipulate equipment inside the waste tank. Two small (10-inch diameter) openings are installed in the center riser cover. The standard mixer pumps previously installed in the east and west risers were removed and refurbished for additional waste removal service in other tanks following bulk saltcake waste removal (Phase 2) in Tank 19. Existing waste tank equipment, including a transfer jet and level instrumentation, were installed in two of the perimeter risers. Therefore, these two risers were undesirable locations for heel removal equipment, as change out of equipment in these risers would result in significant occupational radiation exposure and generation of additional radiological waste. Furthermore, riser configuration above the waste tank top limits direct equipment access and allows only a restricted view of the waste tank floor (Figure 3.1-8).

Figure 3.1-8: Diagram of Tank 19 Access Area for Heel Removal Equipment



In addition, the size of the access ports limited the manipulation of long-handled mechanical tools. Creating multiple additional access ports by drilling through the existing concrete domed roof had the potential to weaken the waste tank top, increasing the risk of waste tank top collapse. Ensuring waste tank-top integrity added significant cost to the waste removal efforts. Finally, due to internal obstructions and access port geometry, choices were very limited as to the kinds of remote equipment that could be successfully deployed.

Bulk waste removal efforts in Phase 1 and 2 were unsuccessful in removing the bulk of the spent zeolite resins with the associated relatively short-lived Cs-137. [DPSP-84-17-7] Spent zeolite resin becomes denser and hardens over time in the caustic environment within a waste tank, making it difficult to slurry for removal from a waste tank. [WSRC-TR-2002-00288]

Because of the lack of available waste tank space within FTF and HTF, an important criterion for the choice of the heel removal technique is the amount of additional liquid waste that the removal technique would generate. Most of the SRS new-style waste storage tanks

(Type III/IIIA tanks with full secondary containment) were already at or near full capacity at the time technology selection for Tank 19 heel removal was being conducted. [HLW-2001-00040_SUPERSEDED] Projected available waste tank space is carefully tracked to ensure the waste tank farms do not become "water logged," a term meaning that so much of the usable new-style waste tank space has been filled that normal operations and waste removal and processing operations cannot continue. Substantial amounts of waste tank space are required in order to safely and effectively remove tank waste and prepare it for disposal. Sludge waste must be washed with large volumes of water to remove the soluble salts to prepare it for vitrification through DWPF. All liquid waste generated during the vitrification process (e.g., canister decontamination streams and water used in transferring the sludge waste from HTF to DWPF) must be returned to the waste tanks for storage and subsequent treatment. These liquid waste streams are commonly collectively referred to as DWPF Recycle. The preparation of saltcake for disposition also requires significant waste tank space because the solid saltcake must be dissolved to make it mobile for processing. The dissolution of saltcake typically requires a ratio of approximately three gallons of water to one gallon of saltcake in order to properly dissolve the saltcake back into the salt solution. [CBU-SPT-2003-00224] Waste tank space for this liquid addition to the waste tank farm inventory must be available to allow for efficient salt processing and disposition. A portion of the available waste tank space must also be reserved as contingency space should a new waste tank leak be realized. The working capacity of the waste tank farms has steadily decreased, and this trend will continue until several years after the Salt Waste Processing Facility (SWPF) becomes operational at full capacity, or the system becomes water logged. [PIT-MISC-0085, CBU-PIT-2005-00130_SUPERSEDED] Aggressive management and conservation efforts are in place to maximize limited storage capacity.

Radiation exposure risk to workers was a primary consideration during technology selection. All waste tank intrusive work is performed in a radiological environment and must be planned to minimize exposure risks to workers, consistent with as low as reasonably achievable (ALARA) principles.

3.1.4.2 Technology Selection Process for Initial Tank 19 Heel Removal (1998)

3.1.4.2.1 Technology Selection Process

In 1994, DOE authorized a tanks focus area (TFA) initiative (including national and international groups) to study and design/build new tank waste retrieval devices that could potentially be used across the DOE Complex. The national program was formed to increase integration and realize greater benefits from the science and technology development budget. The TFA was responsible for managing, coordinating, and leveraging science and technology development to support the needs of DOE's radioactive liquid waste tank remediation programs. [PNNL-13532]

In 1998, SRS used a systematic technology selection process for further Tank 19 heel removal, which was documented in a Systems Engineering Evaluation (SEE). The selection process investigated a broad range of technologies that can be grouped into three general categories: (1) mechanical agitation equipment, (2) mechanical retrieval equipment, and (3) chemical treatment. Waste tank farm operation and engineering personnel identified

21 options involving potential heel removal technologies and evaluated these options using several criteria, including the following: [PIT-MISC-0040]

- Safety – The degree to which the technology could be constructed and operated with regard to protection of the occupational workers and the public in the area of industrial safety and radiological controls.
- Effectiveness/Probability of Success – The degree of confidence that the technology would perform the function for which it was proposed.
- Complexity – The degree of complexity of the technology with regard to design, construction, testing, and operation.
- Technical Maturity – The degree to which the technology had been developed and/or had been demonstrated in a radioactive waste removal application.
- Authorization Basis Impact – The degree of changes required in the waste tank farm facility safety basis documentation to implement the technology.
- System Integration – The degree to which the technology was compatible with existing regulatory programs, processes, and infrastructure.
- Reliability – The degree of confidence as to how well the technology equipment would perform the needed function without failure.

The SEE evaluated a variety of technologies, as described below.

Mechanical Agitation Equipment

Examples of mechanical agitation options include mixer pumps (standard and "advanced" design), pulse tube agitators, submersible agitators, and blade mixers as described below:

- Standard Mixer Pumps – This standard mixer pump, previously used in waste removal projects, consists of a submerged pump assembly driven by a top-mounted 150-hp electric motor. The pump draws suction from the waste tank bottom and shoots out opposing jet streams in the horizontal plane. The jetting action mobilizes solids in a circular area. This mixer pump scored low against the criteria of effectiveness because it was determined to have an inadequate cleaning radius for the level of heel remaining in Tank 19.
- The ADMP – This mixer pump is similar to the standard mixer pump; however, it is powered by a 300-hp motor (versus a 150-hp motor for the standard mixer pump). The ADMP pump scored low due to the size of the unit and the required supporting services. This pump could only be installed in the center riser, which would have required removal of existing tank top equipment and completely redesigning the existing steel truss system.
- Pulse Tube Agitator – This agitator uses a pulse jet pump to provide a charge vessel with either vacuum or pressure. Under vacuum, the charge vessel pulls in liquid. Pressurized air discharges liquid from nozzles to mix solids. The pulse tube agitator scored low on the criteria of safety authorization basis impact (i.e., concerns with aerosolization of waste and resultant high loading of tank ventilation system filters) and effectiveness.
- Jet Mixing Pump – This pump consists of a submersible motor and propeller that discharge liquid through a shroud to mix solids. This technology, when deployed

with the capability to oscillate, scored high for the criteria of probability of success and was the selected technology for Tank 19 heel removal.

Mechanical Retrieval Equipment

Examples of mechanical retrieval options included robotics, vacuum conveying systems, mechanical conveyance systems, robotic arm systems, and alternative pumping systems as described below:

- Robotics – Various configurations of remotely operated platforms were evaluated. These platforms are used to move retrieval equipment in the waste tank. This technology scored relatively low on the criteria of technical maturity because of a potential lack of mobility due to in-tank obstructions and hose management issues.
- Vacuum Conveying Systems – This technology retrieves the heel by using displaced air to create a vacuum that lifts and transfers the material. This technology scored relatively low on the criteria of technical maturity and complexity because of limited history in a large radioactive waste tank and design features required for potentially contaminated air handling equipment.
- Robotic Arm Systems – These remotely controlled systems have the capability to extend vertically and horizontally to position cleaning equipment in the waste tank. This technology scored relatively low on the criteria of technical maturity and reliability because of the complex equipment associated with large robotic arm systems required to reach the expansive interior areas of the waste tanks.
- Alternative Pumping Systems – These mechanical retrieval systems consist of pumps that operate on the principles of positive displacement, centrifugal force, or vacuum. Evaluation of these various pumping systems resulted in the selection of submersible centrifugal pumps for transferring the residual heel out of Tank 19 because of high scores for system integration, safety authorization basis impact, reliability, and complexity.

Chemical Treatment

Chemical treatment with oxalic acid (OA) was evaluated as an option for Tank 19 heel removal during the technology selection process. OA cleaning had been performed at SRS with varying levels of success.

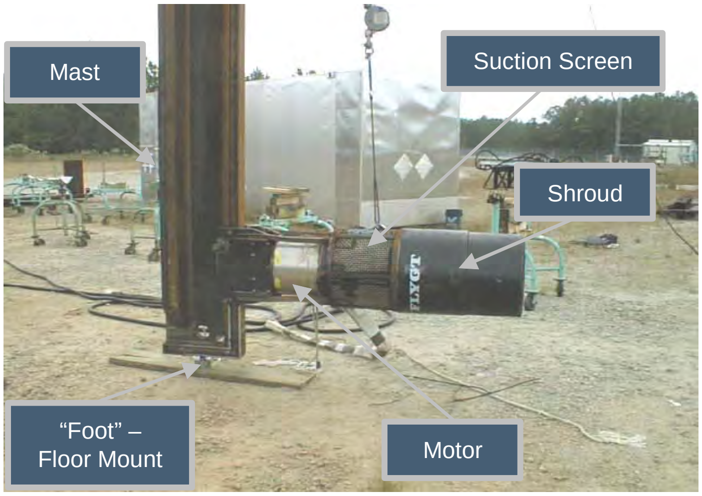
The HTF Tank 16 waste removal experiences showed repeated OA rinses were effective in removing sludge. However, the acid had to be of sufficient strength and required heating to be effective. Later research showed OA was ineffective in dissolving insoluble sodium alumina-silicate compounds (such as that in the annulus of HTF Tank 16). [WSRC-RP-99-00124] In addition, in 1984, two OA washes were completed in HTF Tank 24 on the spent zeolite resin heel remaining after bulk waste removal activities were completed. It was anticipated that two slurry treatments with OA would dissolve up to 70 weight percent (wt%) of the insoluble solids into a finely divided solid that would be easier to mix. The results were less than expected and only approximately 45wt% of the solids was removed. [CBU-PIT-2005-00099] Approximately 10,000 gallons of spent zeolite resin remained in Tank 24 after the chemical cleaning campaign. [DPST-85-782-TL] Experience in HTF Tank 24 showed OA helped remove some spent zeolite resin but was not effective in a zeolite-rich environment.

The Tank 19 technology selection evaluation rejected chemical cleaning as a heel removal option because of concerns about downstream process impacts (system integration), safety and the relatively low anticipated cleaning impact in a waste form containing large amounts of spent zeolite resin. The system integration impacts included, but were not limited to, waste tank space requirements to neutralize the acid and DWPF processing issues (i.e., processability impacts of oxalates).

3.1.4.2.2 Technology Selection Process Conclusion

The study concluded that use of three 50-hp rotating submersible jet mixer pumps (Flygt Mixers) (Figure 3.1-9) along with a recycle liquid waste stream was the preferred heel removal method. The older spent zeolite resin that was present in Tank 19 was faster settling and denser than the newer zeolite resin. The jet mixer pumps were chosen because of their ability to keep the older spent zeolite resin suspended longer. Traditional mixer pumps would quickly lift the spent zeolite resin particles into suspension, but once the jetting action of the pump stream passes by, the particles would just as quickly settle. [WSRC-TR-2002-00288] Therefore, removing the spent zeolite resin would require a mixing regimen that promoted overall waste tank agitation, rather than localized mixing. The use of a recycle stream means that liquid added to Tank 19 to suspend the remaining solids would be recycled back from the transfer receipt tank and re-used for additional suspension campaigns. The recycle stream was necessary because the studies revealed that a significant number of mixing campaigns and transfers would be required to achieve desired results and there was insufficient tank space or evaporator capacity to support the generation of large volumes of new waste from each cleaning cycle. A new transfer pump riser was installed adjacent to the Tank 19 northeast riser to tie into the existing transfer line from Tank 19 to Tank 18 to provide a transfer/recycle path for Phase 3 heel removal with Flygt mixers. [U-ESR-F-00011] A more detailed discussion of the recycle method is included in Section 3.1.4.3.

Figure 3.1-9: Prototype Flygt Mixer



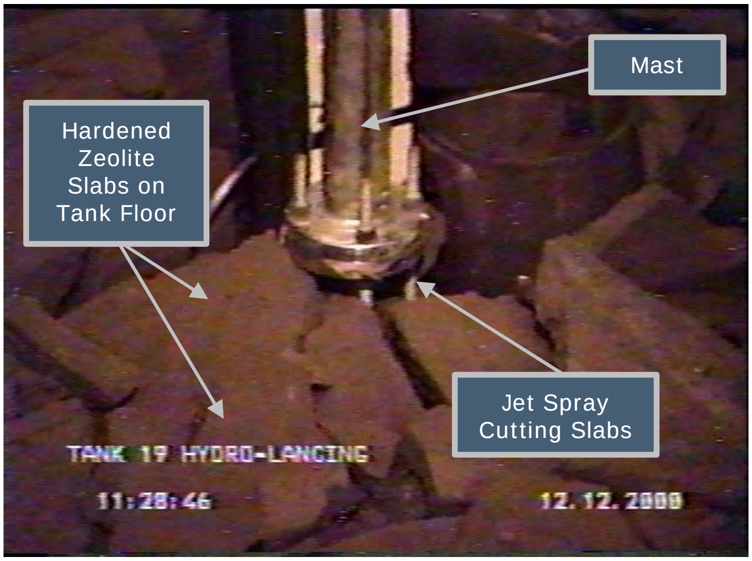
3.1.4.2.3 Selected Technology Testing

The selected technology for Tank 19 was extensively tested prior to installation and operation in the radioactive waste tank. The testing of Flygt Mixers for Tank 19 was performed at SRS and other facilities (both partial and full scale). Scale testing revealed the 50-hp Flygt Mixers provided the waste tank agitation characteristics desired for spent zeolite resin removal, and the overall waste tank agitation option was consequently selected as the preferred method. [WSRC-TR-2000-00311] Flygt Mixer testing was conducted at three locations; 1) Flygt corporate headquarters located in Trumbull, Connecticut, 2) Pacific Northwest National Laboratory (PNNL), Richland, Washington, and 3) SRS. Testing results indicated three oscillating jet flow mixers would be effective for Tank 19. [PNNL-12168] The testing results were used to determine optimum Flygt Mixer placement, shroud enhancement, run speed optimization, durability, vibration analysis, and failure/recovery analysis. Based on the results of these tests, the optimum placements for the three Flygt Mixers were identified. Three Flygt Mixers were purchased, and functionally tested at SRS, and installation began in July 2000. The Flygt Mixers were placed on the bottom of the waste tank in the locations that the tests indicated would be most effective. Each pump was attached to a 45-foot long, 5-ton rotating mast. Each Flygt Mixers was flow rated at 17,500 gpm. [PNNL-12168]

3.1.4.3 Tank 19 Phase 3 Heel Removal with Flygt Mixers Operation and Results

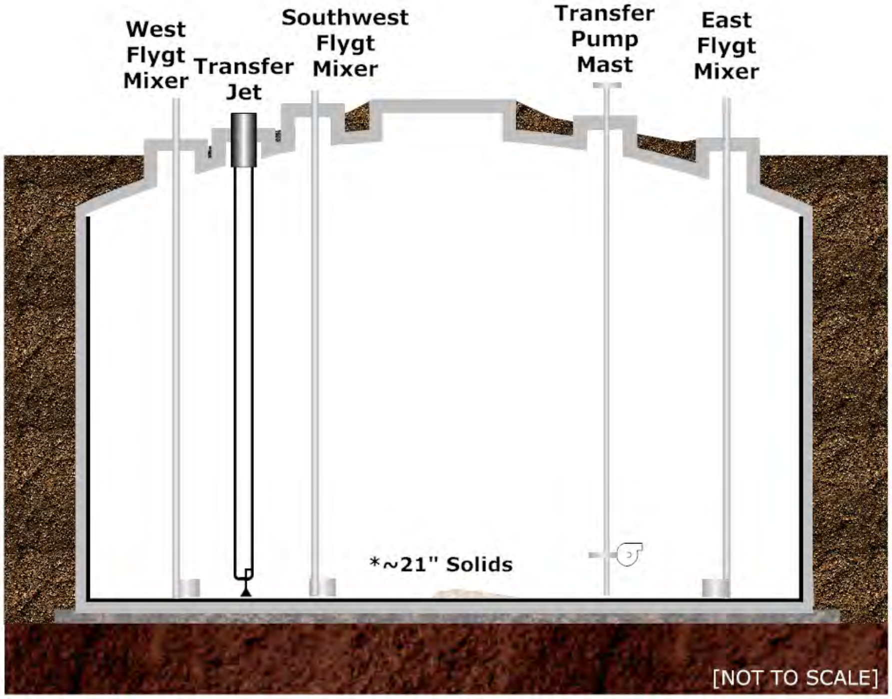
During planning and preparation for equipment installation, it was determined that hardened spent zeolite resin slabs were present in a mound located under the northeast riser on the floor of Tank 19. The northeast riser was the location of the CRC. It was necessary to break up this mound before the transfer pump mast could be installed. A special tool, called a hydro-lance, was designed to apply 10,000 pounds per square inch (psi), 32-gpm water stream directly to the hardened slab (Figure 3.1-10). Two separate hydro-lance campaigns were performed in Tank 19 using approximately 3,000 gallons of inhibited water to successfully break up the hardened zeolite mounds**.** These hydro-lance campaigns cleared the way for the transfer pump mast to be fully seated at the bottom of the waste tank, thus allowing the transfer pump to pump from a lower level in the waste tank. It also reduced the size of the spent zeolite resin mass to improve mixing, washing, and transfer capabilities. [U-ESR-F-00011]

Figure 3.1-10: Hydro-Lance in Operation Breaking Up Mound



In addition to the use of the Flygt Mixers, a different liquid addition for suspension and transfer technique was used to remove the heel from Tank 19. In the past, well water had been added to a waste tank and standard mixer pumps had stirred the contents. The suspension had then been transferred out as a slurry mixture. However, the spent zeolite resin solids in Tank 19 were fast settling, and it was unlikely that a single transfer would sufficiently remove the solids. In fact, early studies suggested that it would take dozens of water additions and transfer sequences to transfer a significant amount of heel to another waste tank. [U-ESR-F-00011] To complicate matters, the waste tank farm system did not have the available space to handle water additions in the volumes needed. To address these challenges, a recycle technique was devised that transferred the solids to another waste tank while reusing existing waste tank liquid as the transport medium. This was accomplished by making an initial addition of 280,000 gallons of existing tank farm supernate from Tank 18, stirring the contents with Flygt Mixers, and then transferring the slurry back to Tank 18. [WSRC-TR-2000-00311] The fast-settling solids quickly dropped to the bottom of the receiving waste tank (Tank 18), allowing that liquid to be used as the transfer medium again. The liquid was then decanted (removed from the top portion of Tank 18) back to Tank 19 to start the process over again. The waste solution transfer cycles were continued until they were no longer effective (i.e., no significant amount of residual heel continued to be removed). The solids removal rate declined as the transfer cycles progressed. Heel removal operations stopped after using 46 such cycles, which would have been equivalent to adding over 10 million gallons of new waste to the waste tank farm system if fresh water was used for each mixing and transfer cycle. [WSRC-TR-2000-00311] In summary, this newly adopted recycle method resulted in significant tank space savings during execution of this step and, therefore, afforded the technical capability for more solids to be removed from Tank 19. Figure 3.1-11 illustrates the condition of Tank 19 following Phase 3 heel removal.

Figure 3.1-11: Tank 19 Following Phase 3 – Heel Removal with Flygt Mixers (June 2001)



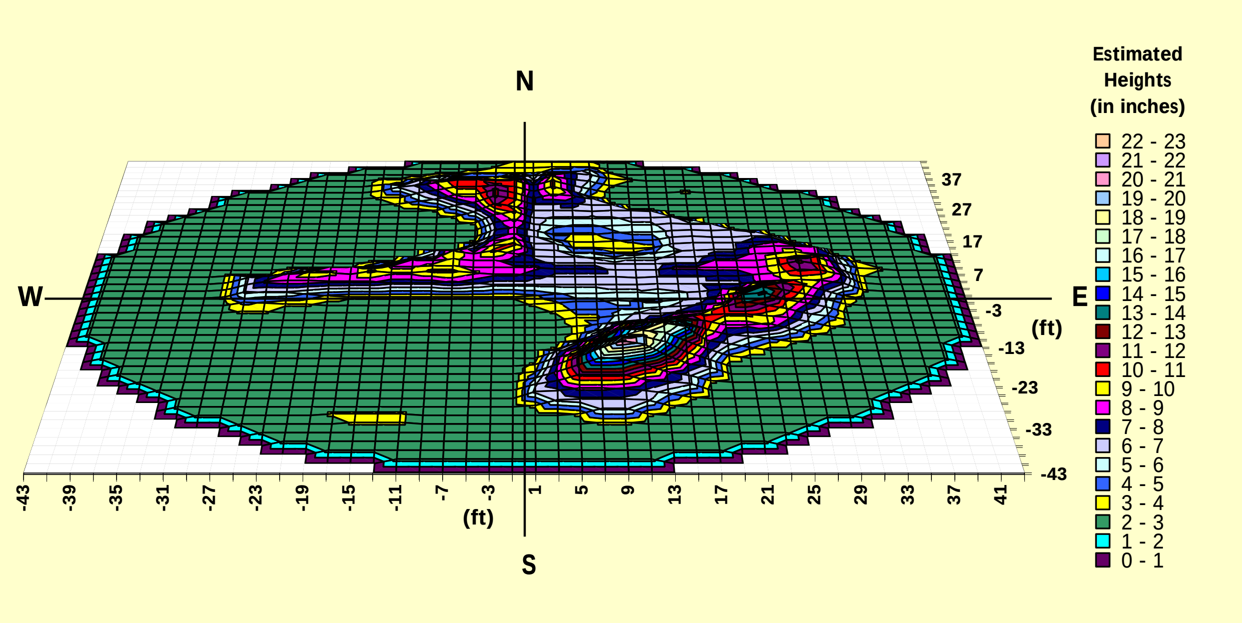
* Indicates approximate maximum height above the tank bottom.

Also, during this phase of heel removal from Tank 19, the walls of Tank 19 were washed with inhibited water from a spray nozzle installed in the center riser. The spray nozzle had pan-and-tilt capability and an operating capacity of 65 gpm at a pressure of 175 psi. This spray wash system was used for washing the waste tank walls from top to bottom and for focused washing in areas with deposits. Approximately 3,200 gallons of additional liquid was added to Tank 19 during this effort and was subsequently transferred to Tank 18. Approximately 100 gallons of insoluble solids could not be removed from the wall and remained on the three stiffener bands (bands that protrude 4 to 5 inches into the tank forming a ledge around the circumference of the waste tank). [WSRC-TR-2000-00311]

Using Flygt Mixer technology, alternative transfer techniques, and waste tank wall cleaning, this initial heel removal campaign reduced the wet solids volume from approximately 33,000 gallons to approximately 15,000 gallons. There is uncertainty associated with this 15,000-gallon volume estimate because it was difficult to discern the depth of solids beneath the 3.3-inch liquid level that remained at the conclusion of Phase 3 removal. The overhead video camera did not provide clear views below the liquid surface. It was assumed that the area under the liquid surface was 75wt% solids (i.e., approximately 2.5 inches). [WSRC-TR-2002-00052, G-CLC-F-00180] Figure 3.1-12 depicts the approximate configuration of the residual waste at the completion of Phase 3 heel removal with Flygt Mixers and prior to the final phase of heel removal (Phase 4). [G-CLC-F-00180]

Because the technology selection for Phase 4 heel removal was performed for both Tanks 18 and 19 at the same time, this phase is discussed in Section 3.3, following discussions on the first three phases of Tank 18 waste removal.

Figure 3.1-12: Tank 19 Residual Material Configuration Following Heel Removal with Flygt Mixers (Phase 3)



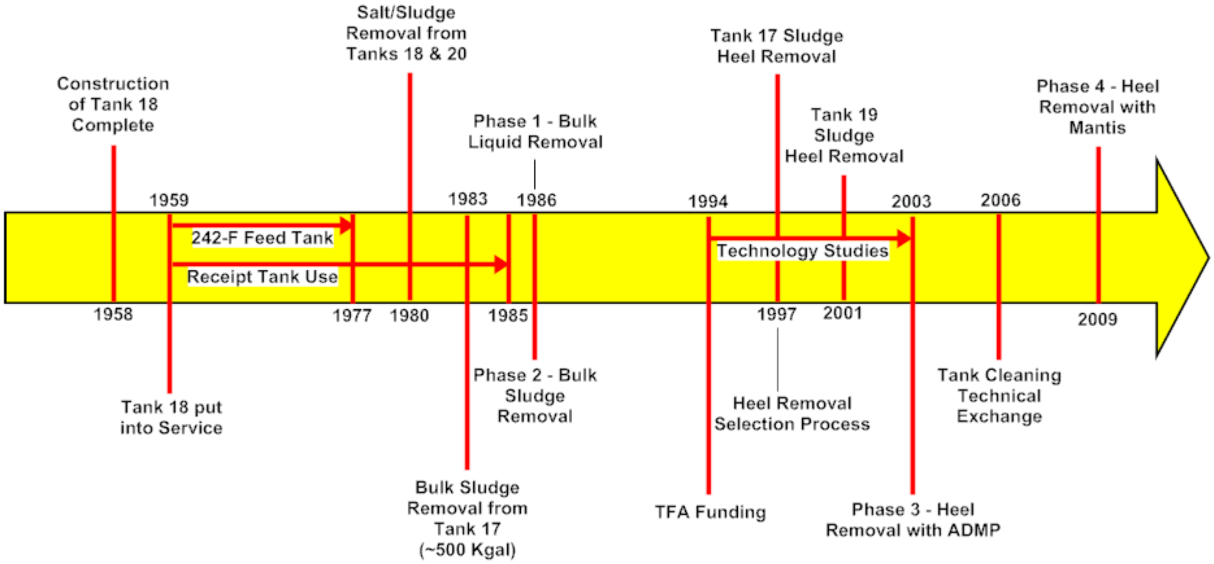
3.2 Tank 18 Waste Removal History

In January 1986, DOE began the waste removal process in Tank 18. [CBU-PIT-2005-00233] Waste removal from Tank 18 was conducted in four phases

- Phase 1: Bulk Liquid Waste Removal
- Phase 2: Bulk Sludge Waste Removal
- Phase 3: Heel Removal with the ADMP
- Phase 4: Heel Removal with Mantis (discussed in Section 3.3)

See Figure 3.2-1 for the Tank 18 historical timeline that includes waste removal activities. The key activities (including the definition of associated terms and phrases) on this timeline will be described in more detail throughout this section.

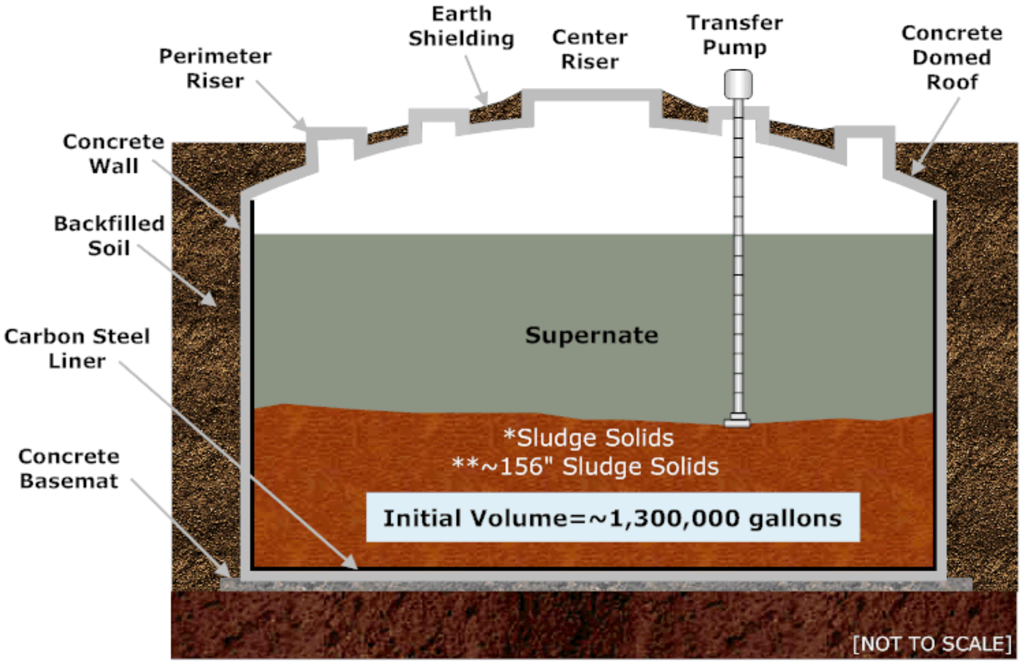
Figure 3.2-1: Tank 18 Historical Timeline



3.2.1 Tank 18 Initial Condition Prior to Waste Removal

Tank 18 was essentially a “hub” tank in that it received and transferred out multiple volumes in support of waste removal activities for other waste tanks. Therefore, the total waste volume in the tank did not remain constant for long periods of time. Prior to beginning the waste removal campaign, the waste level routinely approached the tank nominal capacity of approximately 1.3 million gallons of total waste and therefore this value is used as the baseline volume at the beginning of the waste removal campaign. [WSRC-TR-2004-00284] By the time waste removal activities commenced, approximately 550,000 gallons of this waste was in a wet solids form called sludge (mainly comprised of insoluble metal oxide solids) with their associated interstitial liquid and the remainder was “free-standing” liquid (supernate) (Figure 3.2-2). [CBU-PIT-2005-00233] The source of the sludge in Tank 18 was mainly from its service as a receipt tank for F Canyon waste as described in Section 2.2.1. Some of the sludge waste resulted from waste removal initiatives on Tanks 17, 19, and 20, which transferred waste into Tank 18. Tank 18 continued to serve, in a limited capacity, as a “hub” tank even after the waste removal campaign was initiated. All waste transferred out of Tank 18 was sent into other State-permitted waste tanks.

Figure 3.2-2: Tank 18 Initial Condition Prior to Waste Removal (January 1986)

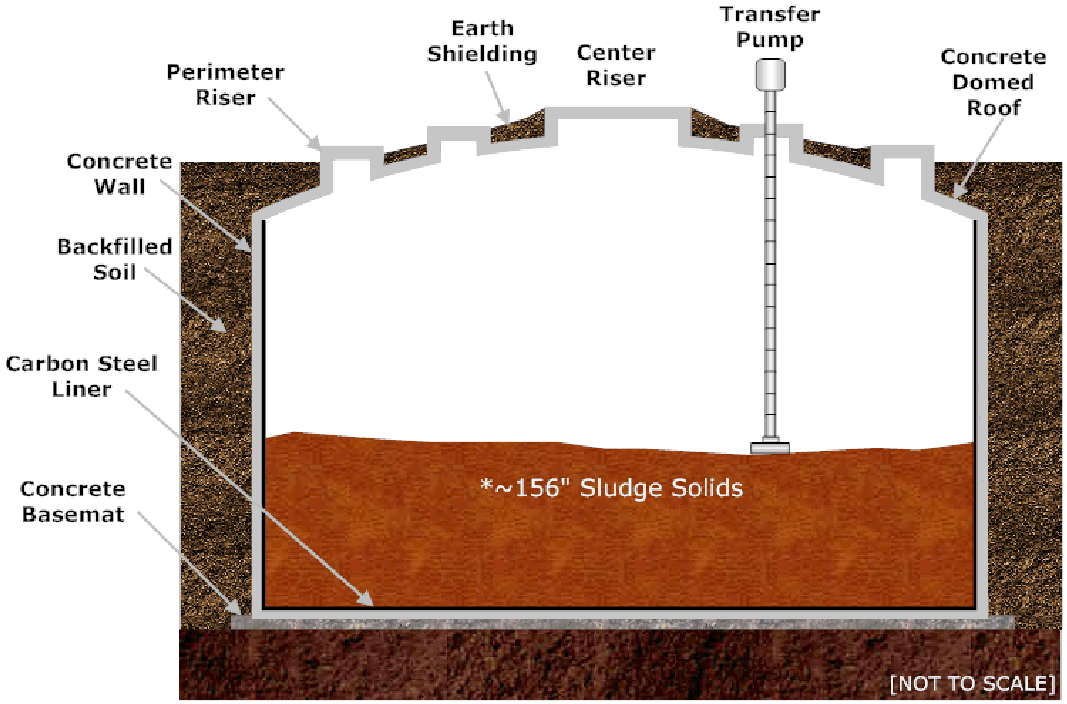


* Sludge solids mainly comprised of insoluble metal hydroxide solids and associated interstitial liquid.
** Indicates approximate average height above the tank bottom.

3.2.2 Phase 1: Bulk Liquid Waste Removal

During this phase, the concentrated liquid wastes, including both “free-standing” liquid (liquid above the sludge) and some interstitial (liquid in the sludge), were removed beginning January 1986 through April 1986. No mixing was needed during this phase and therefore no mixer pump operations were conducted during this phase. A telescoping transfer pump (TTP) was used as the prime mover of this waste stream. A total of 850,000 gallons were removed to provide sufficient space for water additions to support bulk sludge removal. During this time Tank 18 received some salt solution from Tank 20 waste removal efforts. The liquid waste stream was transferred to Tank 26 for future processing/storage in FTF. After the liquid waste was removed, an estimated volume of approximately 550,000 gallons of sludge remained, which contained some “free-standing” and interstitial liquid (Figure 3.2-3). [CBU-PIT-2005-00233] Some historical documentation cites the estimated sludge volume to be approximately 600,000 gallons; however, for conservatism in calculating removal efficiencies, 550,000 gallons is used.

Figure 3.2-3: Tank 18 Phase 1–Following Bulk Liquid Waste Removal (April 1986)



* Indicates approximate average height above the tank bottom.

3.2.3 Phase 2: Bulk Sludge Waste Removal

As discussed in Section 3.1.3, long-shaft mixer pumps (standard mixer pumps) were the baseline mixer technology for bulk waste removal. Additional mixing capabilities were needed to slurry the more difficult-to-remove sludge. During Phase 2, SRS installed three standard mixer pumps (Figure 3.2-4), which required installation of new infrastructure (steel trusses), to prepare Tank 18 for sludge removal. The three standard mixer pumps were mounted on the new supporting truss work. Each standard mixer pump had a 150-hp motor and ran at 2,200 rpm. Each pump had a 45-foot long shaft with cylindrical support columns that were filled with clean water and pressurized to prevent cross contamination between the waste and the top part of the waste tank. Inhibited water or salt solution was added to the waste tank, and the standard mixer pumps exerted a sweeping liquid jet action on the sludge to promote its mixing and allow the particles to be suspended for transferring. In addition to the new mixer pumps, service upgrades were performed on the Tank 18 heating and ventilation system, inhibited water addition system, and bearing water support system. A TTP was used to move the sludge slurry solution out of Tank 18 into other State-permitted waste tanks or treatment facilities in the waste tank farm system. [CBU-PIT-2005-00233, HLW-2002-00025_SUPERSEDED]

To begin the bulk sludge removal process, both supernate and non-radioactive inhibited water were added to the waste tank to improve hydraulic properties and optimize mixing and washing to allow transferring of the sludge slurry. From July 1986 to August 1987, seventeen different sludge slurry transfers combined into four campaigns were executed (Table 3.2-1). The standard mixer pumps were lowered periodically during the transfers as additional sludge was removed. Bulk sludge waste removal operations were stopped in Tank 18 because the sludge solids removal rate decreased and waste tank storage space was not available for receipt of additional sludge slurry transfers from water additions that would have been required for additional campaigns. The spent zeolite resin was not present in Tank 18 during this step of waste removal because the Tank 19 material had not yet been transferred into Tank 18 (discussion in Section 3.1.4).

During the bulk sludge removal phase, approximately 500,000 gallons of sludge were slurried and removed using about 2.19 million gallons of inhibited water/supernate. The final sludge slurry transfer was completed in August 1987 (Figure 3.2-4, Panel 4). [CBU-PIT-2005-00233, HLW-WRE-2001-00008]

Figure 3.2-4: Tank 18 Phase 2 – Bulk Sludge Waste Removal Campaign

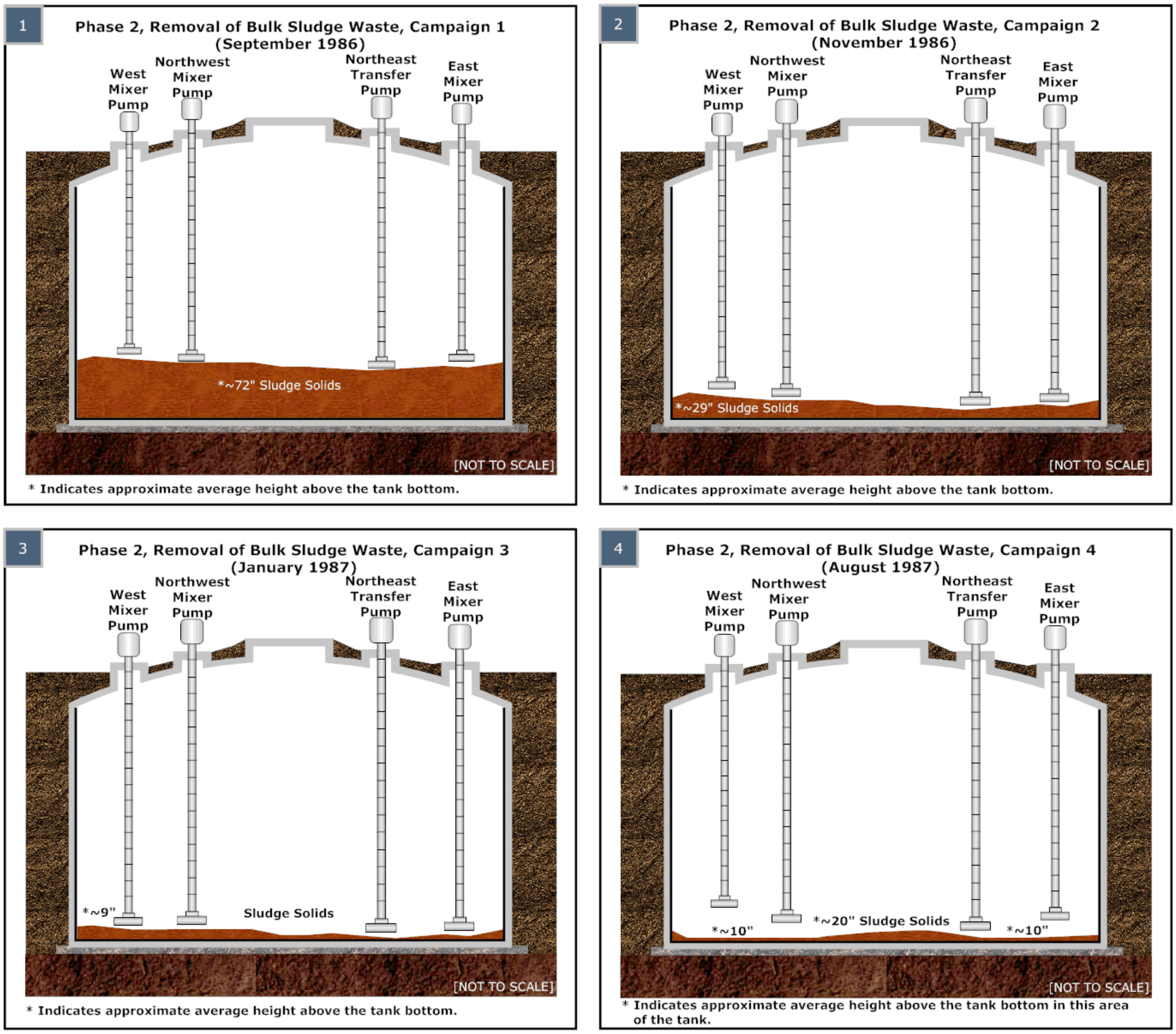


Table 3.2-1: Tank 18 Bulk Sludge Waste Removal Campaigns

Sludge Slurry Transfers (grouped in 4 campaigns)	IW/Supernate Added (gallons)	Sludge Removed* (gallons)	Sludge Slurry Removed (gallons)	Figure 3.2-4
First (transfers 1-5) (Completed September 1986)	1,300,000	295,000	1,300,000	Panel 1
Second (transfers 6-10) (Completed November 1986)	400,000	151,000	700,000	Panel 2
Third (transfers 11-15) (Completed January 1987)	290,000	78,000	420,000	Panel 3
Fourth (transfers 16-17) (Completed August 1987)	200,000	7,000	220,000	Panel 4
Overall Results	**2,190,000**	**500,000**	**2,640,000**	

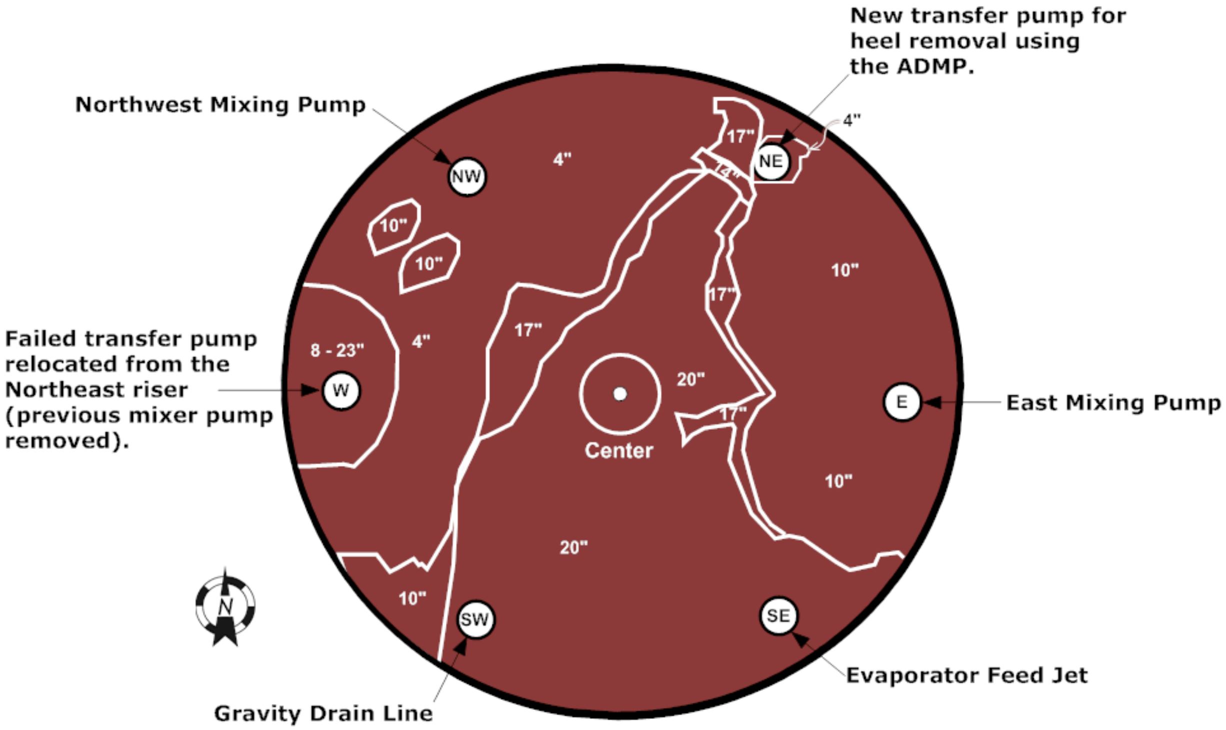
*Volume of sludge removed for each campaign represents estimated volume removed at the time the campaigns were occurring. The overall results do not reflect the total from each campaign. In addition to solids, there was some liquid remaining in the tank.
[CBU-PIT-2005-00233]

3.2.4 Phase 3: Heel Removal with ADMP

3.2.4.1 Tank 18 Conditions Prior to Heel Removal

Based on photographs taken in May 1988, it was estimated that approximately 37,000 gallons of solids remained in Tank 18 at the conclusion of the Bulk Sludge Waste Removal Campaign. [HLW-WRE-2001-00008] An additional 12,500 gallons of insoluble solids were later transferred into Tank 18 from the heel removal operations from Tank 17 and Tank 19. This included approximately 2,500 gallons of spent zeolite resin that were transferred into Tank 18 from Tank 19. Preliminary sludge mapping following bulk sludge removal during Phase 2 indicated solids across the entire tank floor ranging in height from approximately four inches to 20 inches. Several mounds existed with the majority of the material in a connected formation along the centerline of the waste tank (Figure 3.2-5). The shape of these mounds and their locations was attributed to the location of the three standard mixer pumps in the east, northwest and west risers. Due to the solids transferred from Tank 19 to Tank 18 during heel removal using Flygt mixers, it was estimated that a mound with heights of 8 to 23 inches had formed under the Tank 18 west riser. In total, this residual material became known as the heel.

Figure 3.2-5: Tank 18 Heel Map Prior to Heel Removal with the ADMP

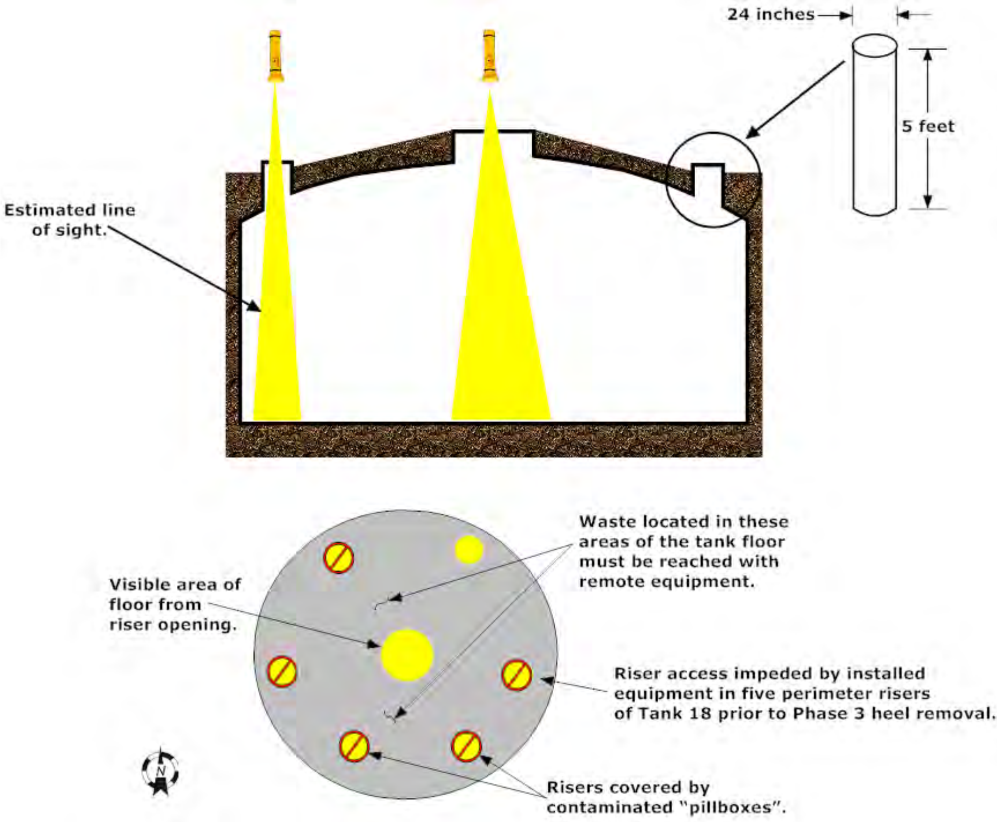


Note: Numbers on the map indicate approximate depth of solids in inches.
[U-ESR-F-00014]

After removal of bulk sludge during Phase 2, Tank 18 remained inactive (except for routine surveillance and maintenance), until June 2000. Requirements and factors impacting technology selection for heel removal included physical configuration of the waste tank, the physical properties of the spent zeolite resin, limited storage space in the waste tank farm system, and occupational radiological exposure risks. [WSRC-RP-2001-00024]

Physical configuration factors impacting selection of the best technology for heel removal in Tank 18 included the carbon steel waste tank construction material, the large size of the waste tank, waste tank floor design, and limited visual and equipment manipulation access in the waste tank interior. The large size of the waste tank (85 feet in diameter by 45 feet high at the top of the domed roof) also influences the types of equipment that can be successfully deployed. In addition to its large size, the floor of the waste tank is essentially level with no designed low spot to collect material for removal. Residual material would collect in areas along the floor dependent on fluid movement within the waste tank. In addition to the waste tank's large size and floor design, the configuration of waste tank risers (access openings) provides very limited access to the waste tank interior. The waste tank has one center riser and six perimeter risers. Each perimeter riser has a nominal diameter of 24 inches. Following bulk sludge removal (Phase 2) in Tank 18, the standard mixer pump was removed from the west riser. In preparation for heel removal using the ADMP, the failed transfer pump in the Tank 18 northeast riser was moved to the Tank 18 west riser to allow access for a new transfer pump to be installed in the Tank 18 northeast riser. In Tank 18, the failed transfer pump, two abandoned standard mixer pumps, an evaporator feed jet and gravity drain line in risers covered by contaminated "pillboxes" were still installed in five of the six perimeter risers. Therefore, these five risers were undesirable locations for heel removal equipment, as replacement of equipment in these risers would result in significant occupational radiation exposure and the generation of additional radiological waste. Riser configuration above the waste tank top limits direct equipment access and allows only a restricted view of the waste tank floor (Figure 3.2-6).

Figure 3.2-6: Diagram of Tank 18 Access Area for Heel Removal Equipment



As discussed in Section 3.1.4, an estimated 13,000 gallons of spent zeolite resin were discharged into Tank 19, and approximately 2,500 gallons of this material were transferred into Tank 18 during waste removal activities from Tank 19. Due to its physical properties (i.e., large particles and fast settling), spent resin is difficult to slurry for removal from a waste tank. [CBU-PIT-2005-00099]

Another factor impacting Tank 18 heel removal technology selection was the availability of waste tank space in FTF and HTF. As discussed in Section 3.1.4 for Tank 19, most of the SRS new-style waste storage tanks (Type III/IIIA tanks with full secondary containment) were already at or near full capacity at the time technology selection for Tank 19 heel removal was being conducted. Because of the lack of available waste tank space, an important criterion for the choice of the heel removal technique was the amount of additional liquid waste that the removal technique would generate.

3.2.4.2 Technology Selection Process for Tank 18 Phase 3 Heel Removal (2001)

3.2.4.2.1 Technology Selection Process

A similar selection process that was used for the selection of the heel removal technology for Tank 19, described in Section 3.1.4, was also used to select a removal technology for the heel in Tank 18. TFA studies conducted since the issuance of the Tank 19 SEE were included in the Tank 18 selection process. This selection process, documented in the Tank 18 SEE, concluded that the ADMP (Figure 3.2-7) was the preferred technology for Tank 18 heel removal. The center-mounted ADMP was selected based on the limited access to the waste tank risers (the center riser was accessible in Tank 18) and previous testing and technical maturity of the ADMP via the TFA effort. As in the case for Tank 19, the selection process rejected chemical cleaning as a heel removal option because of concerns about downstream process impacts (system integration), safety authorization basis impacts, and the effectiveness in removal of spent zeolite resin. [WSRC-RP-2001-00024]

Figure 3.2-7: ADMP Technology

3.2.4.2.2 Selected Technology Testing

After the SEE was concluded, the ADMP was functionally tested at SRS. The ADMP successfully demonstrated its effectiveness with more than 4,200 hours of testing in the SRS test tank using kaolin clay that was significantly more viscous than the expected Tank 18 residual material. The ADMP also had a greater effective cleaning radius than the standard mixer pumps typically used for heel removal and would require only one waste tank entry versus three that were associated with standard heel removal technology (three standard mixer pumps). [M-TR-F-00011]

Computational fluid dynamics modeling was also performed at the Savannah River National Laboratory (SRNL) using kaolin clay as a simulant to the heel material. The modeling predicted that the ADMP was capable of suspending sludge particles throughout the waste tank with the ADMP placed in the center riser and operating at full speed (1,185 rpm). [WSRC-TR-2004-00036]

3.2.4.3 Tank 18 Phase 3 Heel Removal with ADMP Operation and Results

The ADMP was placed in the center riser of the waste tank and attached to structural steel above the waste tank top in September 2002. The pump had a 55-foot long vertical shaft that enabled the suction/discharge nozzles to reach the waste tank bottom. The pump had two discharge nozzles rated at 5,200 gpm each for a total of 10,400 gpm. During heel removal operations, the ADMP, one centrifugal transfer pump, a dewatering pump, and a transfer system completed over 1,000 hours of mixing and six transfers of material out of Tank 18 into Tank 7. [U-ESR-F-00014]

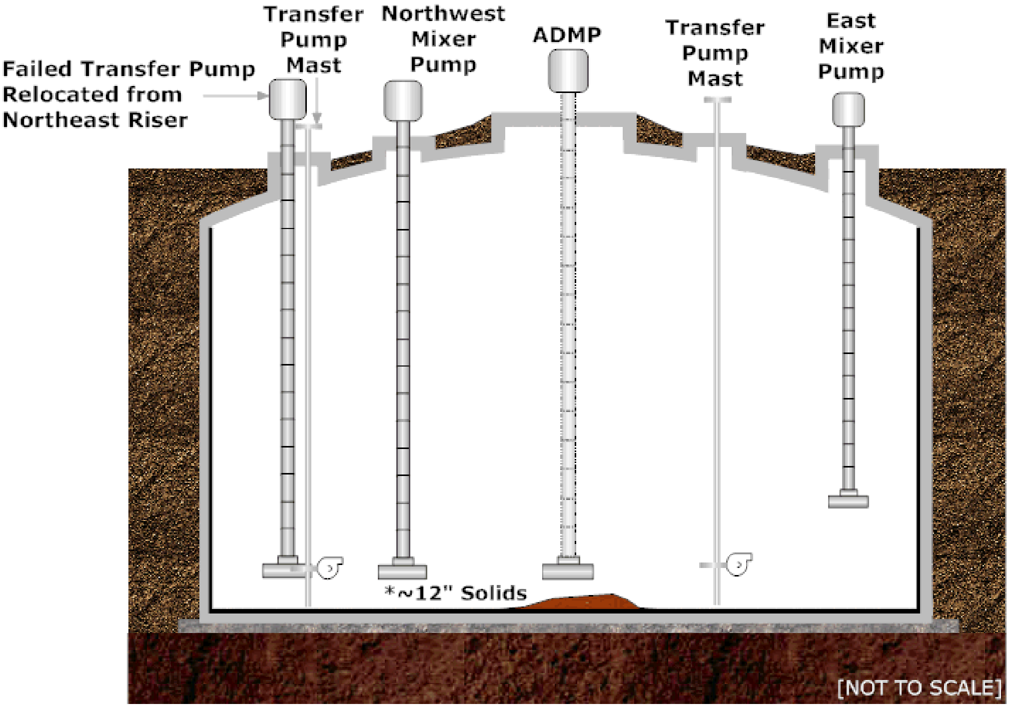
The heel removal strategy consisted of adding well water (total of 800,000 gallons), mixing with the ADMP, and transferring the sludge slurry to Tank 7. The ADMP was turned off when the Tank 18 liquid level reached 43 inches to prevent aerosolization of waste, a radiological release hazard. [WSRC-TR-2004-00036] This sequence of adding well water, mixing, and transferring, continued for six transfers until a point of diminished effectiveness was reached, i.e., waste was no longer being effectively transferred. [CBU-LTS-2003-00158] The amount of solids removed from Tank 18 during transfers was compared with the time of ADMP operation. Comparing the gallons removed per cycle with the time of mixing per cycle indicates that solids removal per hour of mixing decreased significantly in the final three cleaning cycles. [WSRC-TR-2003-00472]

The principal difficulty of Tank 18 heel removal efforts was the removal of a mound near the southwest riser. The southwest mound remained at the completion of the bulk removal campaigns (Phase 1 and Phase 2). The location of the three mixer pumps and their effective cleaning radius had left the southwest area of the waste tank vulnerable to “difficult to remove” undisturbed sludge. Due to interference, the southwest riser was considered inaccessible for heel removal efforts (the evaporator feed jet and gravity drain line in the risers), and therefore no mixer pumps had been installed at this location. There was also a smaller mound remaining in the north region of the waste tank.

During the latter part of the ADMP operations, the walls of Tank 18 were washed with water from nozzles in the east and west ports of the center riser. The spray nozzle had pan-and-tilt capability and an operating capacity of 65 gpm at 175 psi. This spray wash system was used for washing the waste tank walls from top to bottom and for focused washing in areas with deposits, including the stiffener bands (bands that protrude four to five inches into the tank forming a ledge around the circumference of the waste tank). Approximately 2,800 gallons of water were used. Approximately 118 gallons of insoluble solids were left on the stiffener bands and walls. [U-ESR-F-00041]

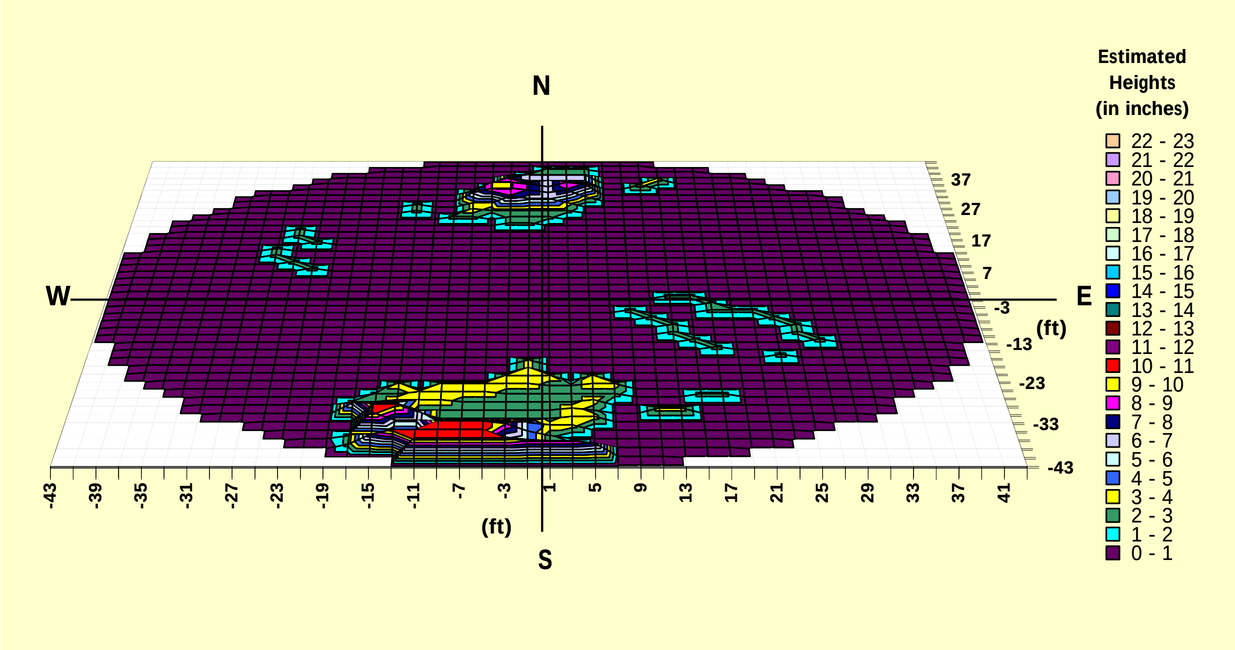
The Phase 3 heel removal campaign reduced the wet solids volume in Tank 18 from approximately 49,500 (37,000 gallons remaining after Phase 2 plus 12,500 gallons of solids that had been transferred from Tank 17 and Tank 19 heel removal) to a then-estimated 4,300 gallons. There was uncertainty associated with this volume estimate of 4,300 gallons because it was based on video inspection where it was difficult to discern the depth of solids beneath the 1.5-inch liquid level. The overhead video camera did not provide clear views below the liquid surface. It was assumed that the area under the liquid surface was 50% solids (i.e. an average solids height of 0.75 inch). [U-CLC-F-00004] Later Phase 4 heel removal efforts and associated final volume determination indicates that this intermediate volume estimate of 4,300 gallons underestimated the volume of solids for the reasons described above. [U-ESR-F-00041] Figure 3.2-8 illustrates the condition of Tank 18 following Phase 3 heel removal. Figure 3.2-9 depicts the approximate configuration of the residual waste at the completion of Phase 3 heel removal with the ADMP and prior to the final phase of heel removal (Phase 4). [U-CLC-F-00004]

Figure 3.2-8: Tank 18 Following Phase 3 – Heel Removal with ADMP (July 2003)



* Indicates maximum height above the tank bottom.

Figure 3.2-9: Tank 18 Residual Material Configuration Following Heel Removal with the ADMP (Phase 3)



[WSRC-TR-2003-00472]

3.3 Tank 18 and 19 Phase 4: Heel Removal with Mantis

3.3.1 Technology Selection

A Tank Cleaning Technical Exchange was conducted in Atlanta, Georgia in March 2006. The technology exchange involved waste tank cleaning experts from across the DOE Complex and from commercial industry. A potentially optimal technology uniquely applicable for removal of additional waste from Tanks 18 and 19 was identified. A procurement scope was developed to evaluate the technical maturity of the equipment for mechanical cleaning of a SRS Type IV waste tank. [LWO-LWE-2007-00210]

The procurement scope for this mechanical cleaning technology was to provide labor, material and services required for the design, fabrication, demonstration, installation and operation of a Mechanical Waste Removal System (MWRS) (including shielding) to remove radioactive waste from the floors of Tanks 18 and 19 and transfer the waste to Tank 7 in FTF. The objective of the MWRS was removal of the remaining waste material from Tanks 18 and 19. To minimize impact on downstream operations, the system needed to include particle size reduction capability (i.e., a grinder) so that the waste particles could be more easily suspended and removed from Tank 7 when further waste removal is performed. The procurement scope included a design requirement that the MWRS be able to operate for twice the period of estimated time required to remove the waste materials from the waste tanks.

These new technologies identified at the Tank Cleaning Technical Exchange were comprised of the following:

- In-tank crawler/robotic arm utilizing air vacuuming as a motive force for waste heel removal
- In-tank crawler/robotic arm utilizing pressurized water eduction for waste heel removal.

An expression of interest was issued to solicit proposals from industries for performing additional heel removal. Once proposals were received from interested companies, they were evaluated based on each company's technical and organizational approach to waste removal, the qualification of their personnel, the amount of resources they could commit and past experience in radioactive waste removal. Forty-nine companies received the expression of interest. Of those, eight responded and four ultimately provided bids. One of the final four withdrew during the bid evaluation process leaving three proposed systems.

A technical review was conducted of the three remaining proposals. All three proposals were similar in technology and organizational approach to performing the heel removal task. Based on a "Best-Value" selection, a three-part subcontract was awarded to TMR Associates, LLC (TMR) of Lakewood, Colorado for their MWRS, which consisted of a robotic crawler called a Mantis. The three-part subcontract included:

- "Proof of Concept" to show the technology's ability to lift material out of Tanks 18 and 19, transfer it above grade to Tank 7 and particle size reduce the transferred waste

- "Full Scale Demonstration" to demonstrate the concept and the technology's ability to lift material out of Tanks 18 and 19, transfer it to Tank 7 and particle size reduce the transferred waste
- Actual Tank 18 and 19 heel removal

Proof of Concept Testing

The "Proof of Concept" demonstration was divided into two separate tests. One test was performed at TMR and demonstrated that the Mantis could remove simulant material from the bottom of a tank and transfer it the height and distance needed to transfer material from Tanks 18 and 19 to Tank 7. The second test was a particle size reduction test performed at the subcontractor's facility. A prototype Mantis based on an existing crawler platform that was used at Hanford Tank Operations in eastern Washington State was used in the demonstration. These tests used clear tubing to simulate the transfer line hose. The use of clear hose demonstrated per visual observation that the flow through the transfer line was three-phase—a combination of air, liquid, and solids. The material flow was not homogenous, but was rather an intermittent flow of liquid, solids, and air based on how the Mantis was operated at any given moment. TMR successfully completed "Proof of Concept" without the identification of any significant issues.

Full Scale Demonstration

The "Full Scale Demonstration" was held at the TMR facility in Lakewood, Colorado on March 11 - 12, 2008. This demonstration was a full-scale test with the actual equipment that ultimately was used for heel removal from Tanks 18 and 19 (Figure 3.3-1). The Mantis used forward/downward spray nozzles to slurry the solids and blades were installed on the front of the crawler to push the waste into piles during testing. The test was successful with a few key deficiencies that required additional modifications to optimize effectiveness of waste removal. TMR was able to demonstrate that the Mantis was able to be deployed, deal with obstacles and break up, and transfer simulant. The pump and control systems all supported operation adequately. The Mantis functioned well at the beginning of each run but debris in the water supply, which had not been adequately flushed prior to the testing, plugged the eductor nozzles. In addition, the dump valve at the bottom of the grinder became obstructed with settled material and required manual intervention to clear. After these and other deficiencies were corrected, a follow-up demonstration was performed on April 7-11, 2008. During the follow-up demonstration, corrections to deficiencies that had been identified in the initial "Full Scale Demonstration" were satisfactorily demonstrated. [LWO-LWE-2008-00185, LWO-LWE-2008-00065]

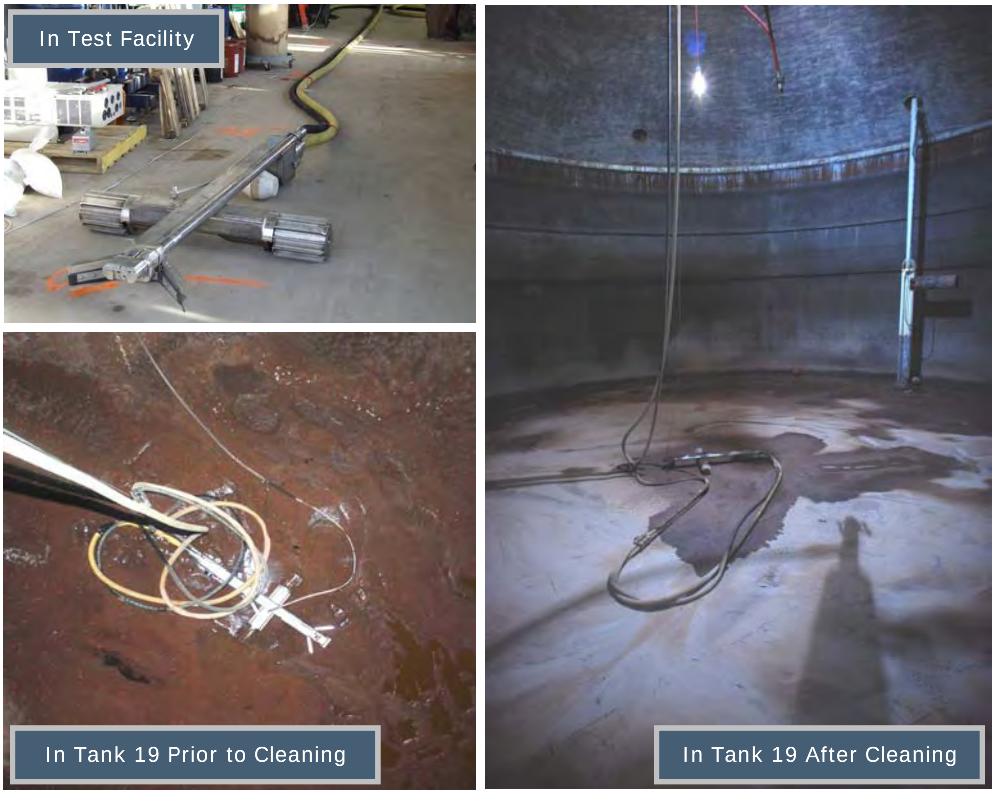
Figure 3.3-1: Full Scale Demonstration Test Waste Tank Operation

After a thorough review of the test results from the “Proof of Concept” and “Full Scale Demonstration”, it was concluded that TMR had successfully met the requirements needed to proceed to actual heel removal in Tanks 18 and 19. A briefing on the status of the Mantis was made to SCDHEC during the Tank Closure Quarterly Update in August, 2008. [SRR-CWDA-2008-00001_Redacted]

TMR Mechanical Waste Removal System Technology Overview

The design for the TMR MWRS technology was finalized for deployment following the “Proof of Concept” and the “Full Scale Demonstration.” The Mantis, shown in the testing facility and in Tank 19 (Figure 3.3-2), consisted of a robotic crawler and an eductor assembly that made up a retrieval system utilizing an UHP water eductor. The eductor operated with a water pressure of approximately 17,500 psi, a flow of 4 to 6 gpm and a discharged airflow of less than or equal to 90 cubic feet per minute into Tank 7. The waste material transfer flow rate caused by the eductor was no greater than two gpm. Based on testing, the predicted operational time to clean the estimated solids was approximately 125 hours for Tank 19 and 36 hours for Tank 18. Based on these estimates, the required design life for the Mantis was established at 250 hours total operation.

Figure 3.3-2: Mantis

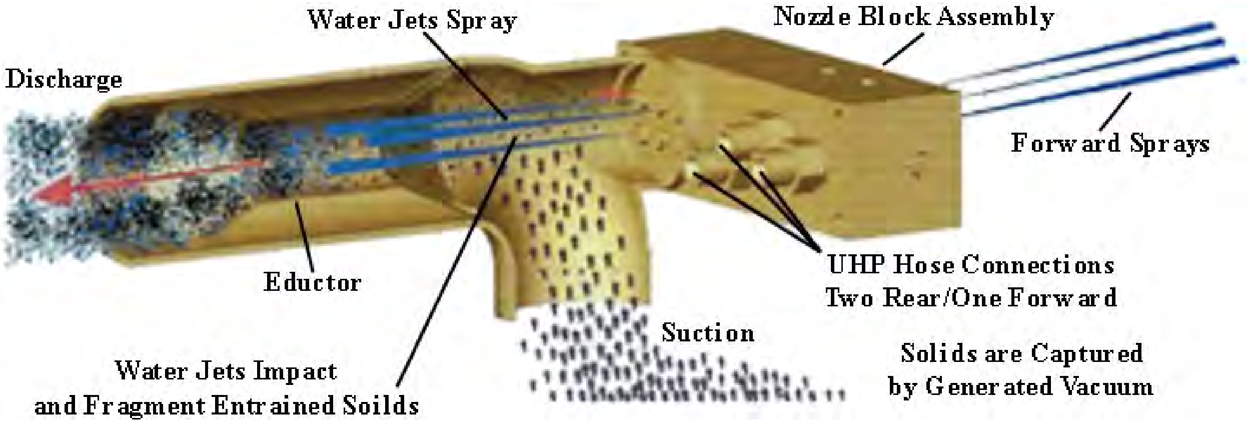


The MWRS consisted of a remotely controlled in-tank Mantis, an umbilical hose containing hydraulic supply lines and the high-pressure water hoses, in-tank waste retrieval hose, UHP water skids, hydraulic pump skid, a minimum 150-kw diesel generator, above ground hose-in-hose transfer lines (HIHTL), waste mixing chamber (WMC) and support structures. Operating controls for the process were installed in a military shipping container called a Container Express (Conex). This Control Conex was continuously manned during the removal process. The Water Treatment Conex contained the process water tank(s) and filters that pre-treated the water supplied to the UHP pump skid. The HIHTL included leak detection, a valve/flush box and heat tracing.

The Mantis was remotely operated within the waste tank by an operator located in the Control Conex. The Mantis had a high-pressure (4,500 psi) hydro-lance at its front that was used to break up waste mounds and an eductor (17,500 psi) used to aspirate waste from the floor of the waste tank. The motive force for the movement of the Mantis was high-pressure hydraulic fluid (oil) operating at 1,750 psi and 6 gpm. The hydraulic system operated the crawler drive wheels, scissor ram, tilt wheel and winch. Operation of the Mantis was monitored using in-tank lighting, cameras and video surveillance equipment. [LWO-LWE-2009-00133]

The eductor (Figure 3.3-3) assembly operated using UHP water flowing through small nozzles and exiting into an eductor. The eductor had a front mounted pickup elbow that was in close proximity with the waste on the bottom of the waste tank. The educted waste traveled through the in-tank waste retrieval hose and up into a tee spool piece (called a Toadstool) located on top of a riser. The eductor discharge hose was a flexible hose that was contained in the Mantis umbilical line. The high-pressure water lines from the UHP pump skids to the Mantis were double walled. The umbilical hose was an elastomer hose that contained the high-pressure water lines and the hydraulic lines inside the waste tank supplying the crawler.

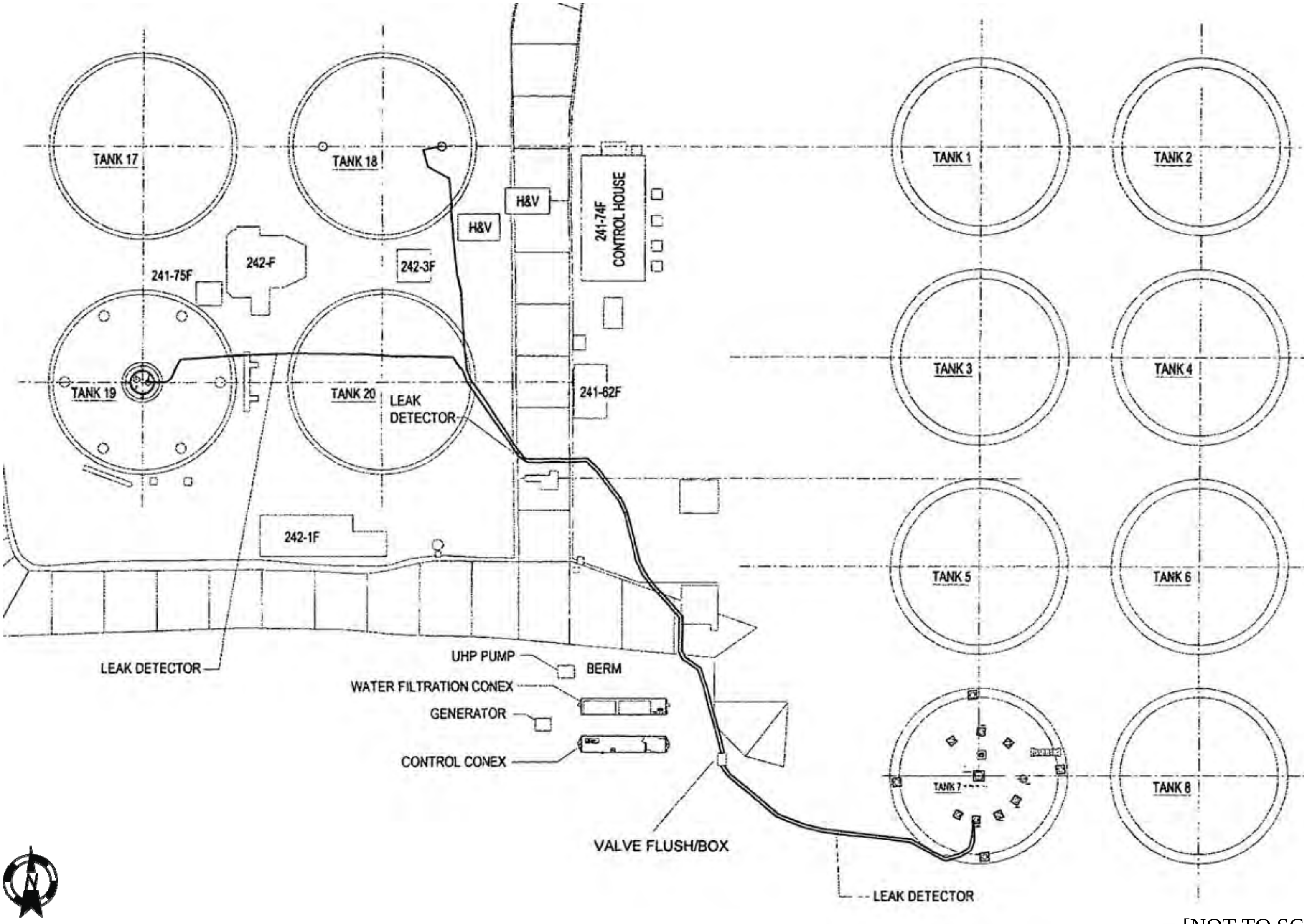
Figure 3.3-3: Mantis Eductor



The Toadstool was the interface between the waste tank riser and mechanical cleaning equipment inside the waste tank. The Toadstool was mounted on top of a riser on the waste tank being cleaned and contained connections for the high-pressure water lines and hydraulic lines. Mounted inside each Toadstool was a winch assembly used to spool out/in the umbilical hose and in-tank waste retrieval line. Each Toadstool contained a mechanical connection on its sidewall for connecting the in-tank waste retrieval hose to the above ground HIHTL.

The MWRS design had an independent above ground transfer line routed from Tanks 18 and 19 to Riser 7 of the receipt waste tank, Tank 7 (Figure 3.3-4). [LWO-LWE-2009-00133] The hose-in-hose design provided full secondary containment. Along the transfer path, leak detection boxes (LDBs) were located at low points to detect any leakage from the primary hose into the secondary hose. Figure 3.3-5 shows the HIHTL during installation at a low point where an LDB will be located. The black primary hose, through which the waste was transferred and the larger exterior hose, which provided secondary containment, can be seen in Figure 3.3.5. Appropriate shielding was installed around the transfer line. The above ground waste transfer lines terminated inside a WMC installed in Riser 7 on the receipt waste tank. The bottom of the WMC extended below the waste tank riser in the vapor space of the receipt waste tank. A valve/flush box was located near Tank 7 to allow flushing/unplugging transfer lines and flushing of the WMC.

Figure 3.3-4: Hose-In-Hose Transfer Route



[NOT TO SCALE]

Figure 3.3-5: LDB Location in Hose-In-Hose Transfer Line During Installation

The WMC (Figure 3.3-6) contained flush water lines, waste lines, thermocouple and particle size reduction equipment (a grinder). The grinder, located in the bottom of the WMC where the transfer lines discharge waste, was designed to grind up and reduce solid waste particles to a particle size of less than 38 microns. The particle size reduction was needed so that the waste particles could be more easily suspended and removed from Tank 7 when further heel removal is performed on that waste tank. The grinder continually re-circulated the waste material until it was light enough for displacement upwards in the WMC. Above the grinder, openings were located in the WMC sidewall that allowed the waste particles, once they became small enough, to float out of the WMC into Tank 7.

Figure 3.3-6: Waste Mixing Chamber

3.3.2 Tank 19 Phase 4 Heel Removal with Mantis

3.3.2.1 Riser Preparation for Mantis Operations

Tank top modifications were required for installation of the Mantis in Tank 19 because of obstructions in all existing risers. The center riser was selected for Mantis installation in Tank 19. Modifications on Tank 19 included removal of an abandoned water tank (which had been used to support earlier phases of waste removal on both Tank 18 and 19) from the structural steel above the center riser (Figure 3.3-7), removal of the existing center riser plug (Figure 3.3-8), and installation of a new center riser cover with a riser designed for installation of the mechanical cleaning equipment and Toadstool (Figure 3.3-9).

Figure 3.3-7: Removal of Water Tank from Tank 19

Figure 3.3-8: Removal of the Existing Tank 19 Center Riser Plug

Figure 3.3-9: New Center Riser Cover Being Lowered onto Tank 19

3.3.2.2 Mantis Operations in Tank 19

The Tank 19 MWRS equipment was installed in Tank 19 center riser in May 2008. A peristaltic sample pump system was installed on the WMC at Tank 7, riser 7 to collect process samples during the Tank 19 Mantis operations. The HIHTL was installed from Tank 19 to Tank 7.

A radiation monitoring system was installed over the temporary shielding on the transfer line from Tank 19 to Tank 7. The system used electronic pocket dosimeters (EPD) equipped with a radio transmitter linked to a computer monitor and logging system. The computer used Thermo Fisher Scientific Viewpoint (Viewpoint) monitoring software. An additional EPD was installed at Tank 19 inside the temporary shielding with the antenna outside the shielding to transmit the signal. This EPD signal was recorded as a means of assessing the solid waste transfer process.

Following a Readiness Assessment, the DOE authorized initiating Tank 19 waste heel removal in November 2008. A camera inspection of Tank 19 was performed prior to initiating heel removal. The MWRS waste transfer operations started on December 4, 2008. [DOE_11-24-2008]

The cleaning operations started in the center of Tank 19. The EPD installed inside the temporary shielding normally showed a relatively low (0.2 mrem/hr) reading due to background radiation from the waste inside Tank 19. The readings for this particular EPD would periodically spike to much higher readings when waste solids were transferred out through the HIHTL (See Section 3.4.5).

To determine the solids content of the material being removed from the waste tank, process samples were taken during cleaning operations. The SRNL initial analysis of the samples showed a nominal weight percent solid. Based on the results, the use of forward/backward sprays was minimized to reduce the rate of additional waste generated during mound removal.

As the heel removal process continued in Tank 19, on December 8, 2008, the rear wheel and swivel arm on the crawler, used to tilt the front of the unit down, failed. The Tank 19 heel removal process was shut down on December 8, 2008 to determine whether repairs could be made to the Mantis.

After extensive work package planning and mockups conducted over a three-month period to ensure repairs could be efficiently implemented while minimizing worker radiation exposure, the rear wheel was replaced with a new wheel and swivel arm assembly on March 6, 2009, allowing the front end to be tilted down for better access to the waste. The MWRS restarted operations for waste heel removal on March 31, 2009.

The heel removal process in Tank 19 continued until April 22, 2009, when it was determined that waste heel removal operations were no longer effective. This determination was based on visual observation and by monitoring diminishing EPD readings from the transfer line radiation monitoring system.

3.3.2.3 Tank 19 Water Lance Operations

Near the end of Mantis operations, additional spray washing of the Tank 19 stiffener bands was performed using a water lance (WL). Tank 19 has three bands of steel angles that were designed to “stiffen” and provide support to the steel waste tank liner. The top angle protrudes four inches from the waste tank wall, while the bottom two angles protrude five inches. Historical photographs of Tank 19 show some solids built up on these stiffener bands. Attempts to remove all of these solids during an earlier spray washing in Phase 3 heel removal were unsuccessful, and approximately 100 gallons remained on the angles. [WSRC-TR-2002-00052]

The WL was designed to concentrate the water spray force on the stiffener bands to remove the visible piles of solid materials. The design of the WL was optimized based on previous testing performed by Augusta Industrial Service, Inc. This testing was performed to develop new water jet/lance designs that could enhance the dispersal of mounds of solid waste for removal from Tank 6 in FTF. This test involved using a trailer-mounted diesel engine driven pump that produced 2,000 psi at 65 gpm. The testing utilized three different water nozzle designs operating at a distance of 5 to 25 feet from piles of soil with high clay content. The clay soil simulates the characteristics of the sludge waste stored in FTF. The three nozzles used during testing were a chisel point nozzle with multiple water jet openings, a 0.375-inch pipe nipple, and a 0.5-inch pipe nipple. The 0.375-inch nozzle caused a rapid gouging of the piles of soil when operated at a distance of 20 feet. [LWO-LWE-2007-00062]

The WL design for Tank 19 mounted the 0.375-inch pipe nipple on a 1-inch diameter high-pressure water hose. The hose was clamped to a 25-foot vertical pipe and to a 10-foot section of pipe connected to the vertical pipe by a hinge. The lower 10-foot pipe section could be raised and lowered by an attached steel cable controlled by a manual winch. The direction of the nozzle was controlled by rotating the entire assembly manually.

The WL was assembled and tested at SRS. The testing used a small section of steel plates to simulate the stiffener bands in the waste tank. Small piles of soil were placed on the horizontal steel plates to simulate the waste material mounds on the Tank 19 stiffener bands. The operating test showed that the water jet would remove the soil from the horizontal surfaces.

The WL was installed in the Tank 19 center riser. The WL heel removal operations utilized approximately 2,250 gallons of high-pressure water. The WL operations were observed by a video camera installed in a second riser port.

The in-tank camera video recordings showed that all of the visible piles of solid waste materials were removed from the stiffener bands. Some of the WL operation was also directed at the dispersal of mounds of solid waste on the waste tank floor in areas beneath installed waste tank equipment that the Mantis could not reach. This was performed to maximize removal of residual tank floor waste by the Mantis.

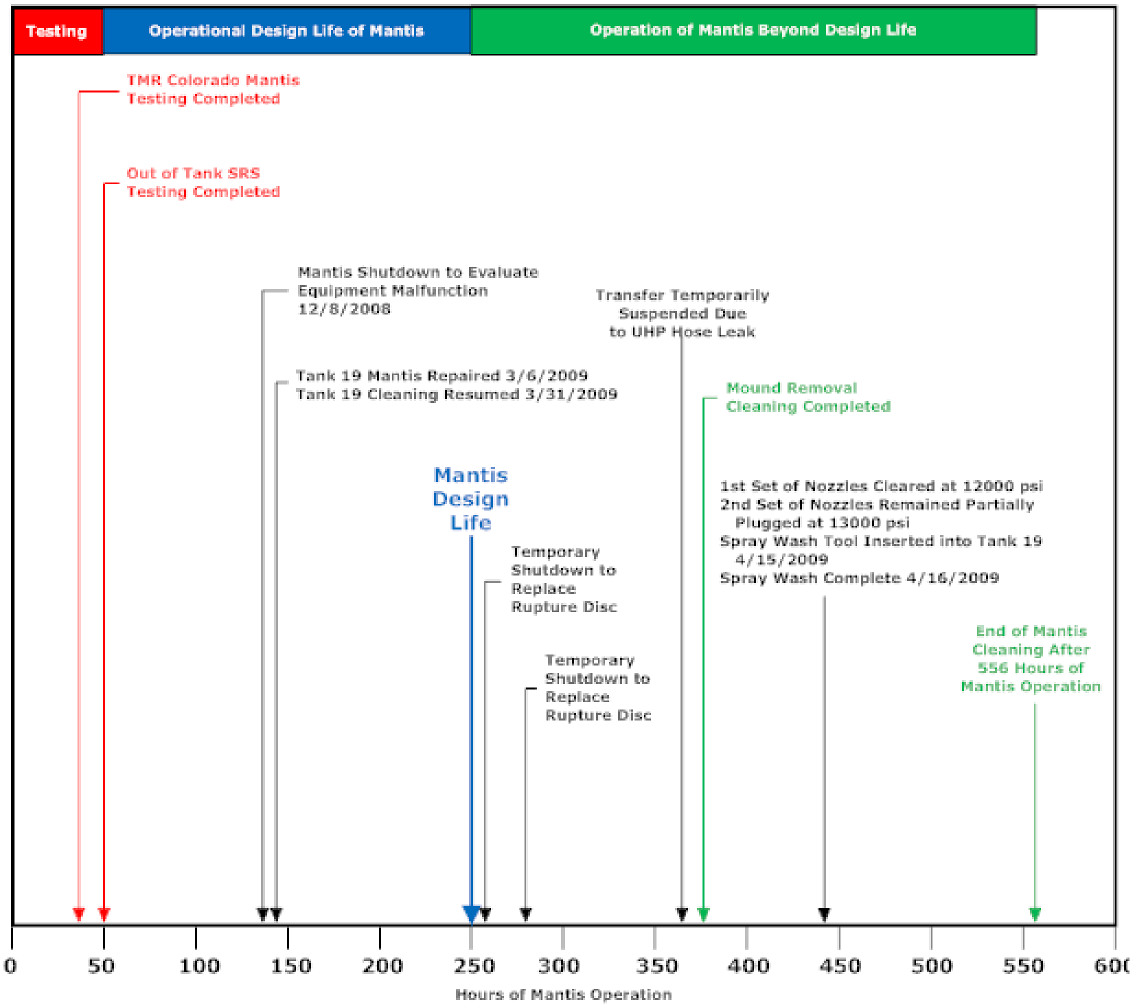
3.3.2.4 Confirmatory Operation of Tank 19 Mantis to Demonstrate Diminished Removal Capability

At the conclusion of Mantis operations on April 22, 2009, the Mantis was operated in predetermined areas to measure the effectiveness of further operations.

The Mantis had operated in the tank for approximately 500 hours creating 140,000 gallons of new waste in the Liquid Waste System. The measurement consisted of monitoring the EPD readings during cleaning in 10 locations in the waste tank. Each location included an area of about 10 feet by 10 feet. The radiation readings for the EPD installed inside of the temporary shielding were recorded during the cleaning operation for each area. The areas were selected to ensure the data was representative of the entire waste tank bottom.

The survey process confirmed that the Mantis had reached the limits for effective removal of solid waste materials. [U-ESR-F-00039] At completion of these effectiveness operational runs, the total operating hours, including time during testing, were approximately 556 hours. The Tank 19 Mantis operational timeline is shown in Figure 3.3-10. During its operation, several repairs were made to the Mantis and to its support system to extend the operational life to maximize additional heel removal. Some of the repairs involved waste tank entry and required extensive evaluation, planning, and mockups to minimize operational exposure. As a result of these efforts, the Mantis was operated over 300 hours beyond its design life. By the end of its operation, the Mantis blade (rubber squeegee device) had become worn and degraded and made additional removal very inefficient (high water to waste ratio) using the installed Mantis. [U-ESR-F-00039]

Figure 3.3-10: Tank 19 Mantis Operational Timeline



3.3.2.5 Tank 19 Waste Removal Summary

Figure 3.3-11 shows the configuration of Tank 19 following Phase 4 heel removal and Figure 3.3-12 depicts the approximate configuration of the residual waste at the completion of Phase 4 heel removal with Mantis. Figure 3.3-13 shows the estimated volume of waste in Tank 19 after each waste removal phase. Of the 1980 starting waste volume of 1.3 million gallons in Tank 19, approximately 2,000 gallons of solids remain inside the waste tank. [U-ESR-F-00042] Approximately 99.8% of the waste volume was removed from Tank 19 in four specific waste removal phases as shown in Table 3.3-1.

Figure 3.3-11: Tank 19 Following Phase 4 Heel Removal with Mantis (April 2009)

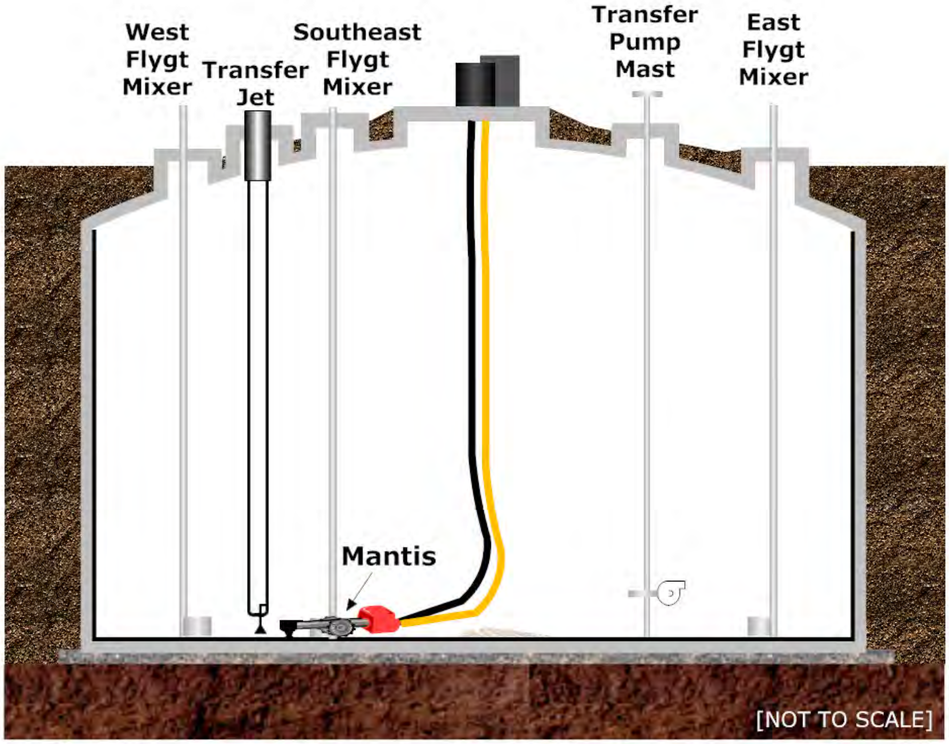


Figure 3.3-12: Tank 19 Residual Material Configuration Following Heel Removal with Mantis (April 2009)

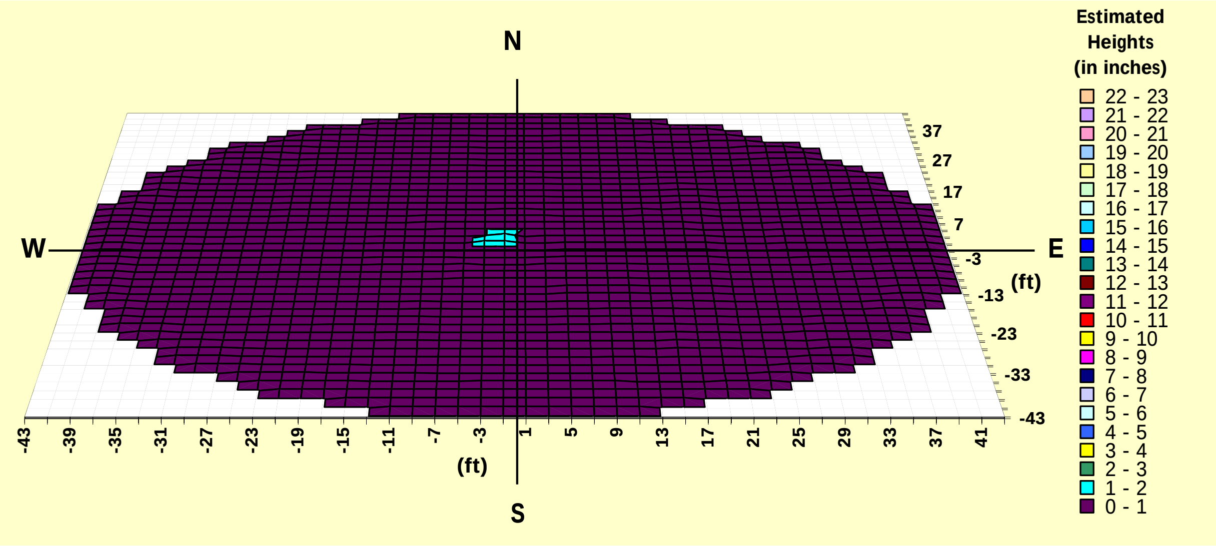


Figure 3.3-13: Tank 19 Waste Volume Reduction

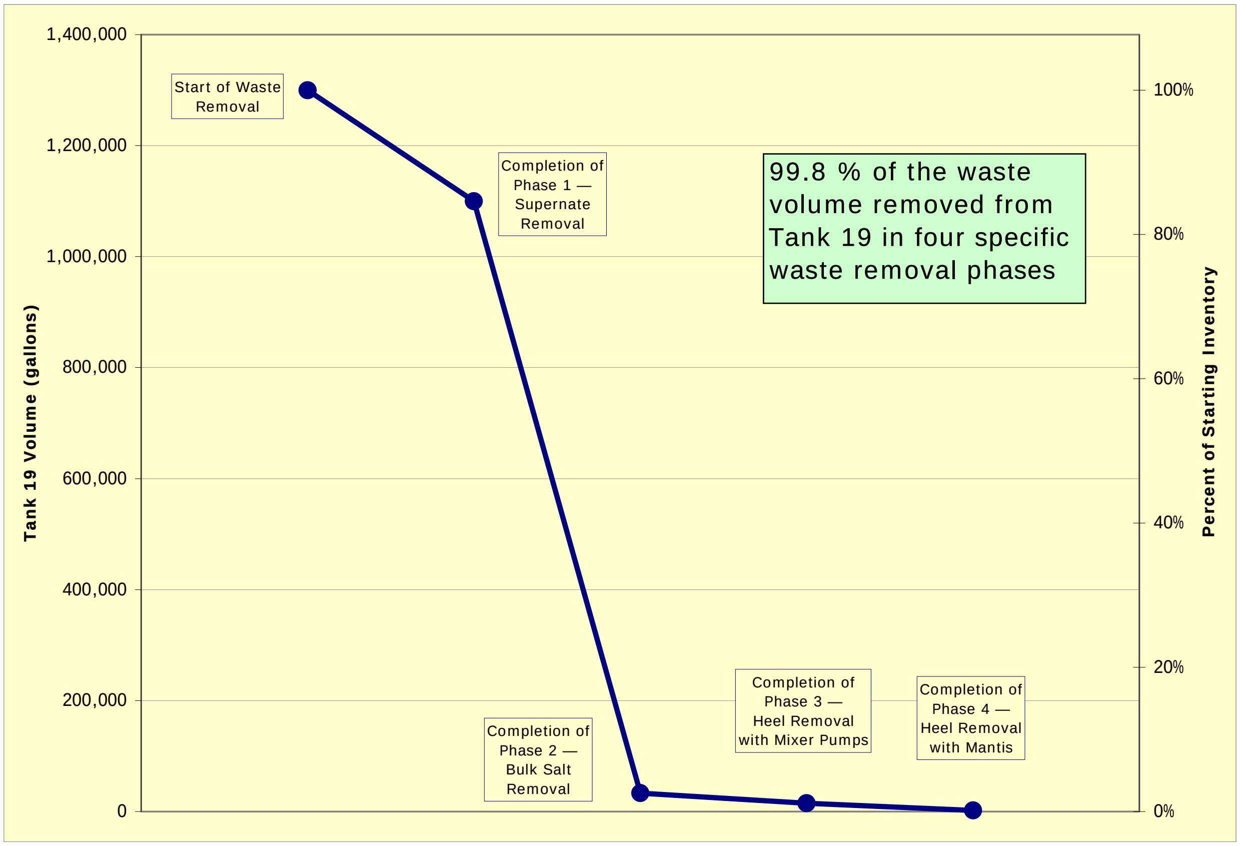


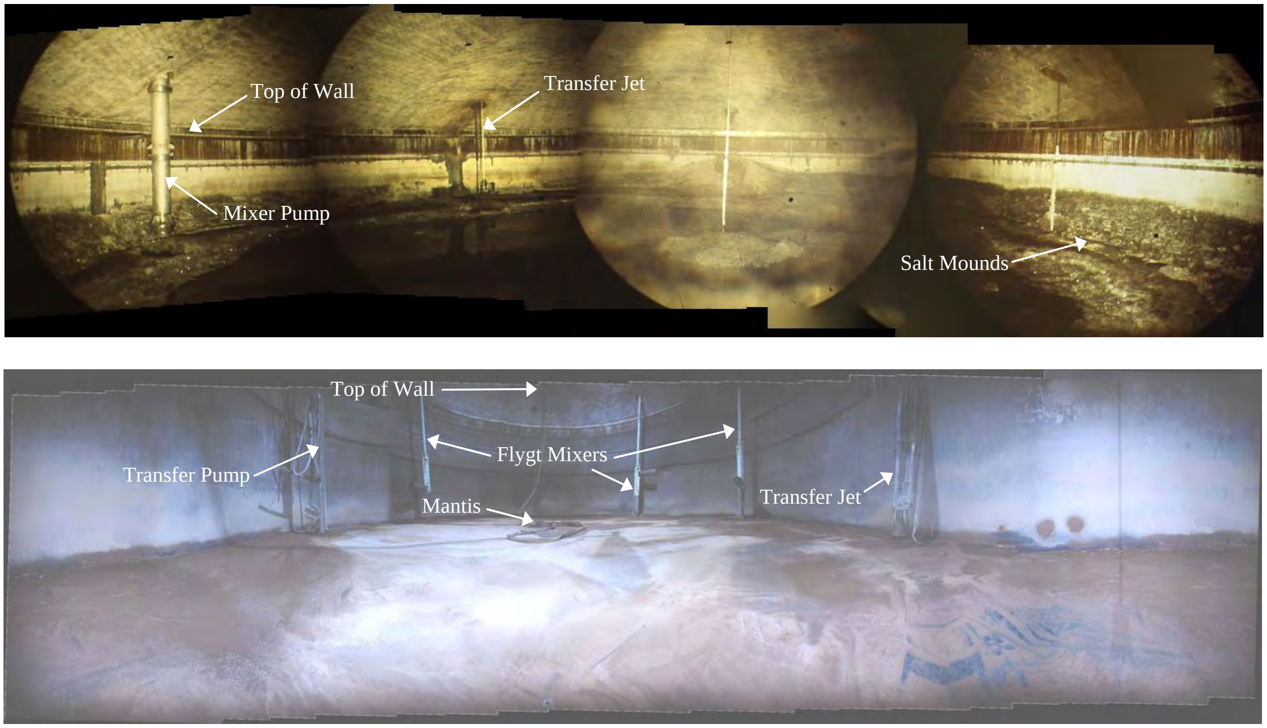
Table 3.3-1: Summary of Results of Waste Removal Activities in Tank 19

Inventory	Waste Tank 19 Waste	
	Approximate Gallons*	Cumulative % Removed
Inventory Prior to Waste Removal	1,300,000	0
Inventory at Completion of Phase 1 Campaign	1,100,000	15.4
Inventory at Completion of Phase 2 Campaign	33,000	97.5
Inventory at Completion of Phase 3 Campaign	15,000	98.8
Inventory at Completion of Phase 4 Campaign	2,000	99.8

* Volumes for Phases 1, 2, and 3 represent approximate volume of wet solids. Other volumes represent total waste volume.
[DPSP-84-17-7, WSRC-TR-2002-00052, U-ESR-F-00042]

Figure 3.3-14 shows Tank 19 early in the waste removal process and at the completion of Phase 4 heel removal operations.

Figure 3.3-14: Tank 19 Following Phase 1 – Bulk Removal of Liquid Waste (top – June 5, 1980) and Following Phase 4 – Heel Removal (bottom – August 8, 2009)



3.3.3 Tank 18 Phase 4 Heel Removal with Mantis

3.3.3.1 Riser Preparation for Mantis Operations

In Tank 18, a new riser, referred to as the new mechanical cleaning riser, was installed on the east side of the waste tank top for installation of the mechanical cleaning equipment and Toadstool. The decision to install a new tank riser was made after determining that the option of removing the ADMP from the center riser would be more costly and result in high worker exposure. A 24-inch diameter opening was core drilled through the reinforced concrete dome of the tank to support installation of the new riser (Figure 3.3-15). The riser installation was completed after extensive work package planning and mockups to minimize worker radiation exposure.

The Tank 18 MWRS equipment was installed in the new mechanical cleaning riser on Tank 18 on January 9, 2009. The HIHTL was installed from Tank 18 to Tank 7. A radiation monitoring system was installed over the temporary shielding on the transfer line from Tank 18 to Tank 7. The system used EPDs equipped with radio transmitters linked to a computer monitor and logging system. The computer used Viewpoint monitoring software. An additional EPD was installed at Tank 18 inside of the temporary shielding with the antenna outside the shielding to transmit the signal. This EPD signal was recorded as a means of assessing the solid waste transfer process.

Figure 3.3-15: Core Drilling of New Mechanical Cleaning Riser in Tank 18

3.3.3.2 Mantis Operations in Tank 18

The DOE authorized initiating Tank 18 waste heel removal on January 29, 2009. A camera inspection of Tank 18 was performed prior to initiating heel removal. The MWRS waste transfer operations started on January 30, 2009.

The cleaning operations started in the northeast quadrant of Tank 18. The EPD installed inside of the temporary shielding normally showed a relatively low (0.8 mrem/hr) background radiation reading from the waste inside of Tank 18. The readings for this particular EPD would periodically spike to higher readings when waste solids transferred out through the HIHTL (See Section 3.4.5).

To reduce the rate of additional waste generated during mound removal, the heel removal process continued in Tank 18 without the use of forward/downward spray water additions. No degradation of performance was noted when the sprays were turned off. Except for the largest mound in the south quadrant of the waste tank, other areas of solids were reduced to a uniform height of about 1 inch by February 7, 2009. On February 8, 2009, the rear wheel on the crawler, used to tilt the front of the unit down, failed. It should be noted that this failure occurred even after redesign efforts had been implemented to strengthen the rear wheel assembly of the Tank 18 Mantis, based on experience with the Tank 19 Mantis. During this period of operations without the spray nozzles operating, the forward/downward spray nozzles became inoperable due to pluggage. After a detailed evaluation of the failed equipment, it was determined that Tank 18 solids in the south quadrant mound were deep enough to allow the crawler to function effectively without tilting the suction head down and without operational spray nozzles.

The heel removal operations continued without forward/downward spray or the ability to tilt the crawler until February 12, 2009. As expected, the effectiveness of the waste solids removal decreased as the height of the remaining mounds was reduced because the mound itself could no longer be used as a backstop to create a localized pool of liquid with a larger weight percent solids content. This technique to optimize operational removal effectiveness had been determined during early Mantis operation in Tank 19. Monitoring of the Viewpoint system showed that the spikes on the EPD inside of the temporary shielding were decreasing in magnitude and occurring less frequently. Operations were suspended to complete the tilt wheel repair.

After technical evaluation of several repair alternatives, an innovative solution of using a shoe assembly versus a replacement wheel was selected for the Mantis repairs. The shoe assembly was installed on February 27, 2009. This increased the length of the control arm to mimic the leverage provided with the original wheel installed on the arm, providing the ability to tilt the forward end of the Mantis down to the remaining solid waste. With this equipment enhancement, the MWRS recovered most of the operational effectiveness, as compared to operations prior to the wheel failure.

The forward/downward spray system was pressurized on March 7, 2009, by a hydrostatic test pump to clear the plugged spray nozzles. This process was successful and the forward spray nozzles were utilized in an effort to optimize the ratio of water added to solids removed from the waste tank.

After the spray nozzles were clear, heel removal operations showed some improvement over the pre-repair operation. The Viewpoint system showed higher rates and additional process samples obtained from both the north and south halves of the waste tank on March 9, 2009, showed higher solids content (approximately 6wt%). The heel removal process in Tank 18 continued until March 13, 2009, when removal effectiveness had diminished. The determination was based on visual observation and by monitoring diminished EPD readings from the transfer line radiation monitoring system.

3.3.3.3 Tank 18 Wall Washing

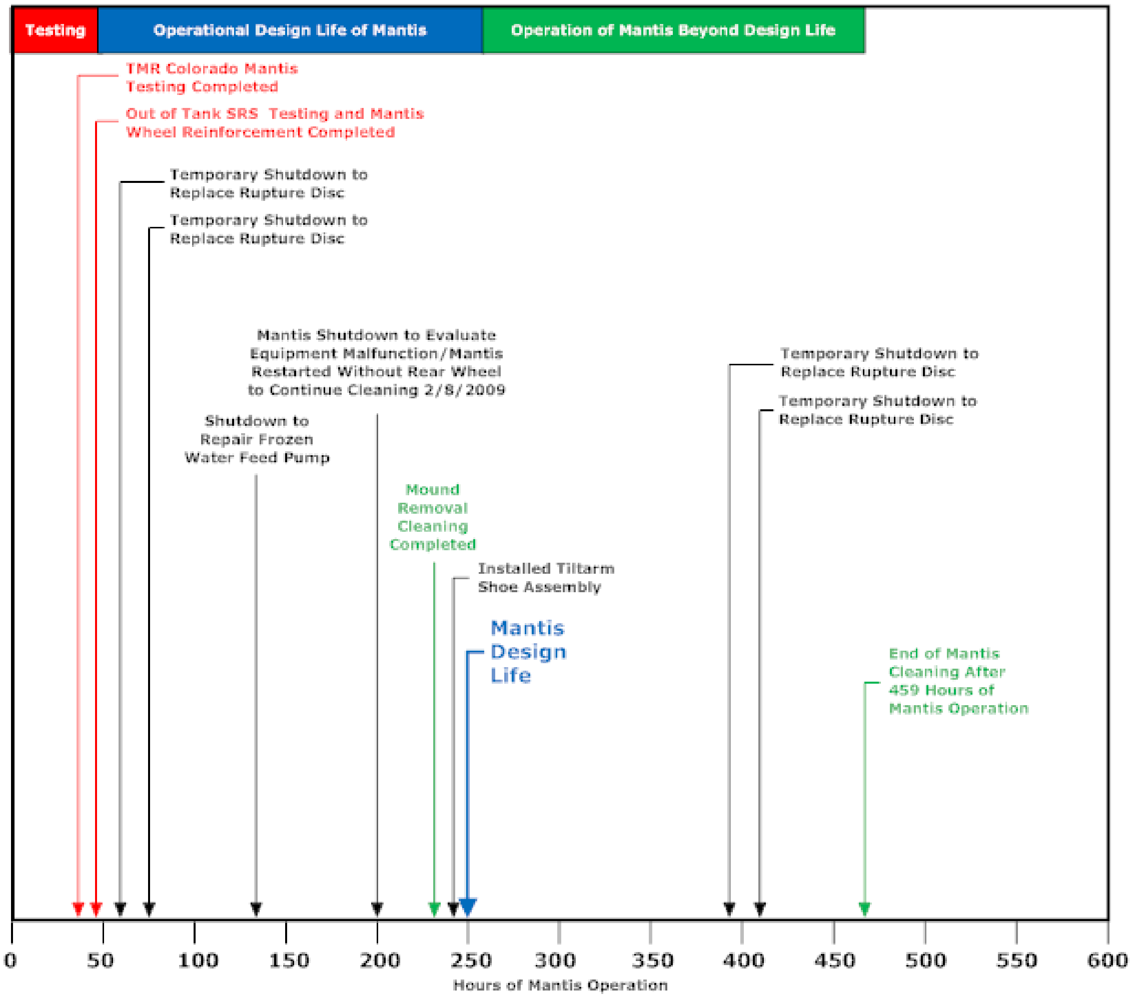
As discussed in Section 3.2.4.3, the walls and stiffener bands in Tank 18 were spray washed with water during Phase 3. This process was not repeated in Phase 4 due to the relatively small amount of solids remaining on the stiffener bands (approximately 8 gallons).

3.3.3.4 Confirmatory Operation of Tank 18 Mantis to Demonstrate Diminished Removal Capability

At the conclusion of Mantis operations on March 13, 2009, the Mantis was operated in predetermined areas to measure the effectiveness of further operations. The Mantis had operated in the tank for approximately 415 hours creating 110,000 gallons of new waste in the Liquid Waste System. The effectiveness measurement consisted of monitoring the EPD readings during cleaning in ten locations in the waste tank. Each location included an area of about 10 feet by 10 feet. The radiation readings for the EPD installed inside of the temporary shielding were recorded during the cleaning operation for each area to define the cleaning effectiveness. The areas were selected to ensure the data was representative of the entirety of the waste tank bottom.

The survey process confirmed that the MWRS had reached the limits for effective removal of solid waste materials. [U-ESR-F-00035] At completion of these effectiveness operational runs, the total operating hours, including during testing, were approximately 459 hours. Figure 3.3-16 shows the Tank 18 Mantis operational timeline. During its operation, several repairs were made to the Mantis and to its support system to extend the operational life to maximize additional heel removal. Some of the repairs involved waste tank entry and required extensive evaluation, planning, and mockups to minimize radiation exposure to workers. As a result of these efforts, the Mantis was operated over 200 hours beyond its design life. By the end of the operational life, the Mantis blade (rubber squeegee device) had become worn and degraded, similar to that noted on the Mantis in Tank 19, and made additional removal very inefficient (high water to waste ratio) using the installed Mantis. [U-ESR-F-00035]

Figure 3.3-16: Tank 18 Mantis Operational Timeline



3.3.3.5 *Tank 18 Waste Removal Summary*

Figure 3.3-17 shows the configuration of Tank 18 following Phase 4 heel removal and Figure 3.3-18 depicts the approximate configuration of the residual waste at the completion of Phase 4 heel removal. [U-ESR-F-00041] Figure 3.3-19 shows the estimated waste volume in Tank

18 after each waste removal phase. Of the starting waste volume of 1.3 million gallons in Tank 18, approximately 4,000 gallons remain inside the waste tank. Approximately 99.7% of the waste volume was removed from Tank 18 in four waste removal phases as shown in Figure 3.3-19 and Table 3.3-2. [CBU-PIT-2005-00240]

Figure 3.3-17: Tank 18 Following Phase 4 Heel Removal with Mantis (April 2009)

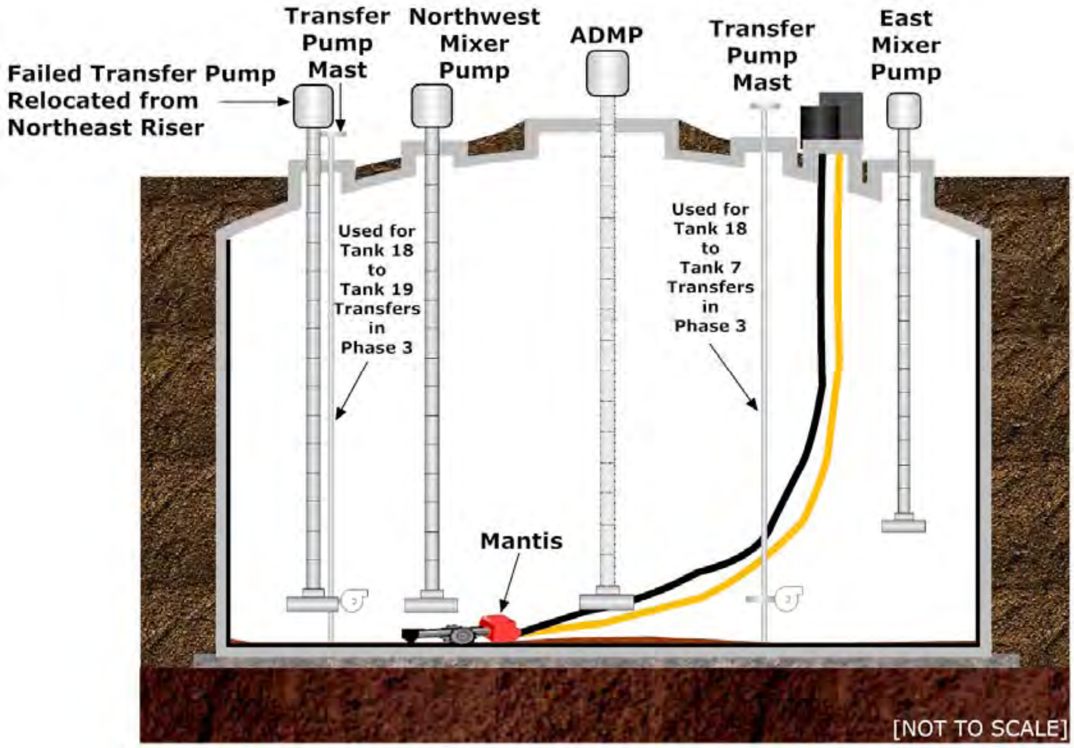


Figure 3.3-18: Tank 18 Residual Material Configuration Following Heel Removal with the Mantis (Phase 4)

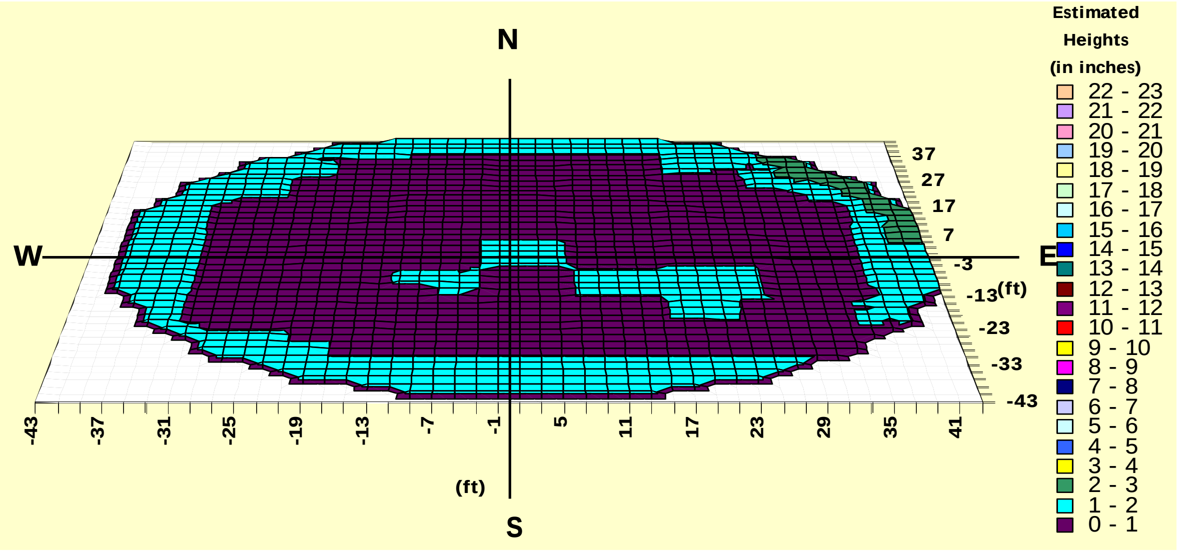


Figure 3.3-19: Tank 18 Waste Volume Reduction

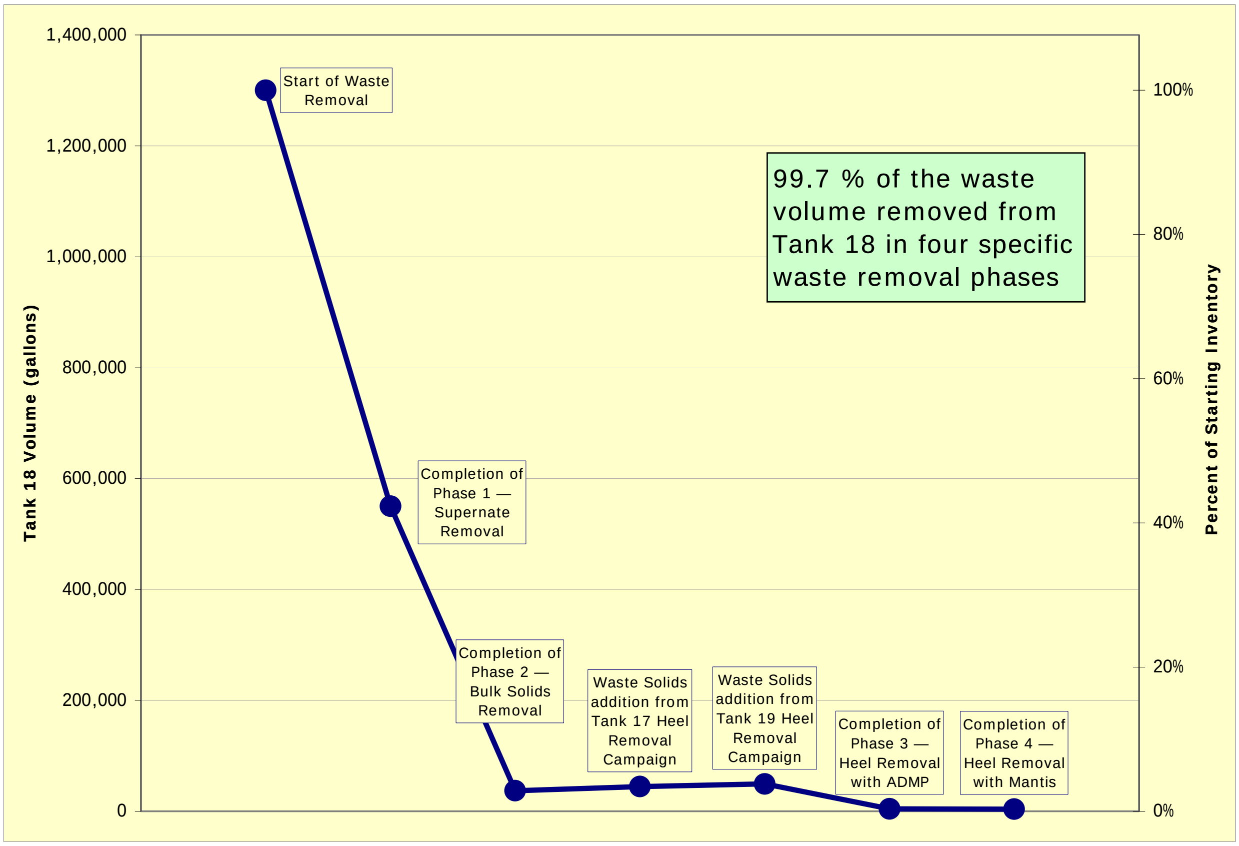


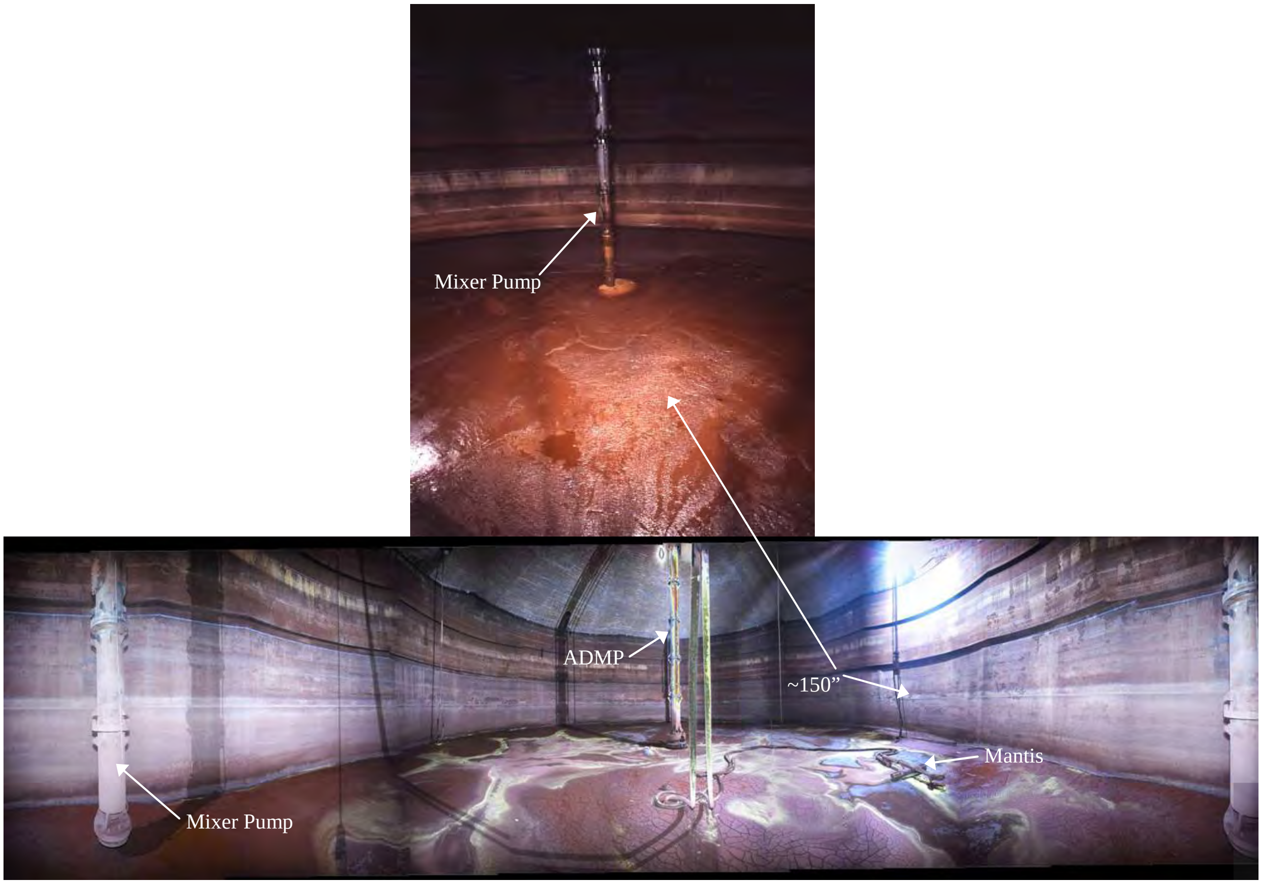
Table 3.3-2: Summary of Results of Waste Removal Activities in Tank 18

Inventory	Tank 18 Waste	
	Approximate Gallons	Cumulative % Removed
Inventory Prior to Waste Removal	1,300,000	0
Inventory at Completion of Phase 1 Campaign	550,000	57.7
Inventory at Completion of Phase 2 Campaign	37,000	97.2
Inventory at Completion of Phase 3 Campaign	4,300*	99.7
Inventory at Completion of Phase 4 Campaign	4,000	99.7

* Inventory following Phase 3 is believed to have been underestimated. See Section 3.2.4.3.

Figure 3.3-20 shows Tank 18 both early in the waste removal process and at the completion of Phase 4 heel removal operations.

Figure 3.3-20: Tank 18 Following Phase 1 – Bulk Waste Removal (top – August 26, 1986) and Following Phase 4 – Heel Removal (bottom – July 21, 2009)



3.4 Basis for Ceasing Mechanical Cleaning Using the Mantis

Heel removal operation using the Mantis was completed on Tanks 18 and 19 as described in Section 3.3. The existing Mantis equipment was determined to have cleaned to the extent of its capability and was no longer effective at removing additional waste. Therefore, its operation was suspended. The following factors, described in the subsections below and applicable to both tanks, were used in making the determination to suspend operations:

- Visual observation of the tank floor indicating significant reduction in residual waste volume
- Technology limitations of Mantis equipment
- Mantis equipment degradation resulted in it being no longer capable of effectively corralling solids for the Mantis to remove
- Significant increase in water addition to solids removal ratio and the associated impact to the Liquid Waste System
- Transfer line radiation trends indicated diminished removal of radioactivity
- Confirmatory operation over ten, 10-foot by 10-foot areas on the tank floor validated diminished removal capability
- Evaluation of a replacement Mantis deployment

3.4.1 Visual Observations

Visual inspections of the tanks indicated that there was a significant reduction in residual material volume resulting from the Mantis operations. Mounds of residual material that had existed prior to heel removal using the Mantis were no longer present. Tank 18 has 4,000 gallons of residual solids (3,900 gallons on the floor and approximately 100 gallons on the wall) while Tank 19 has 2,000 gallons of residual solids on the floor with no appreciable wall scale. Figure 3.4-1 and Figure 3.4-2 show Tanks 18 and 19, respectively, after the completion of Mantis operations.

Figure 3.4-1: Tank 18 after Completion of Mantis Operations (July 2009) (View from New Mechanical Cleaning Riser Looking North)

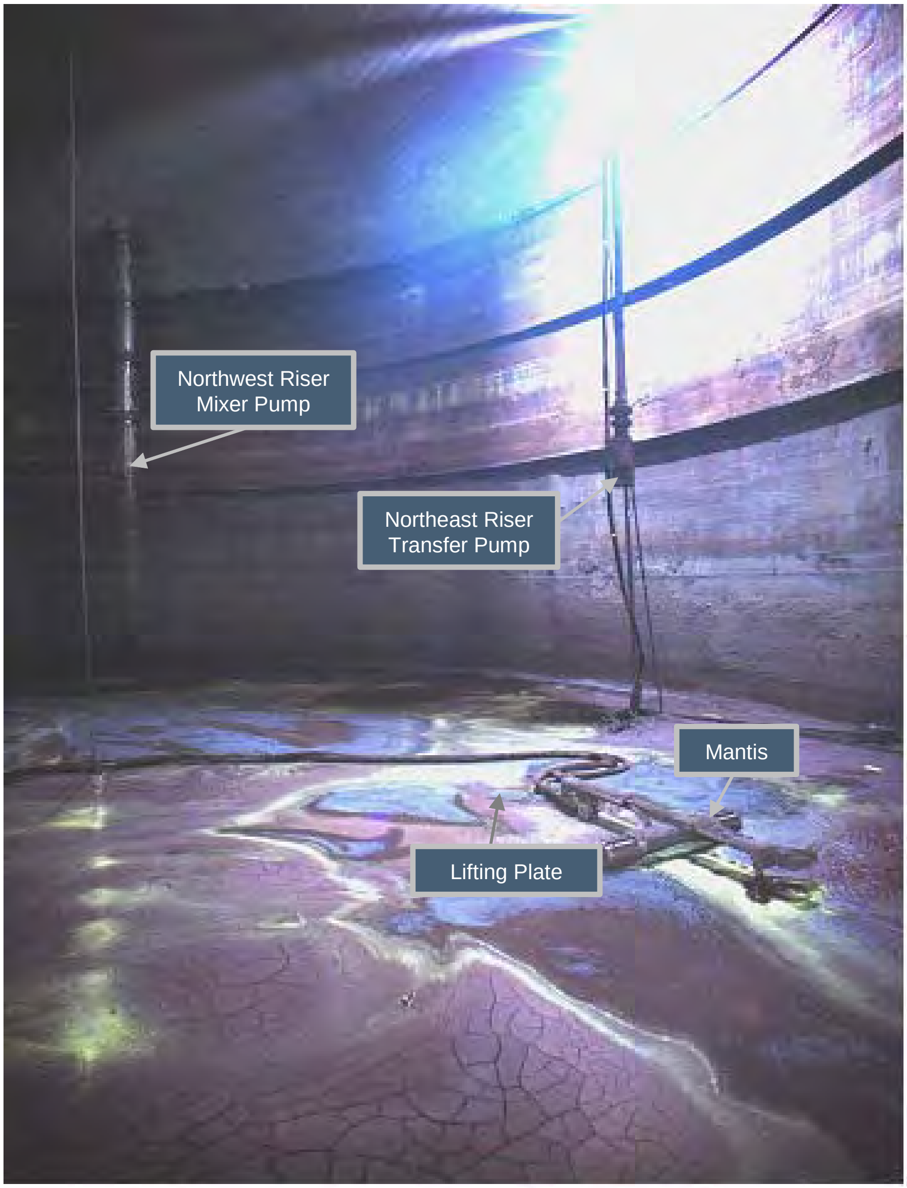
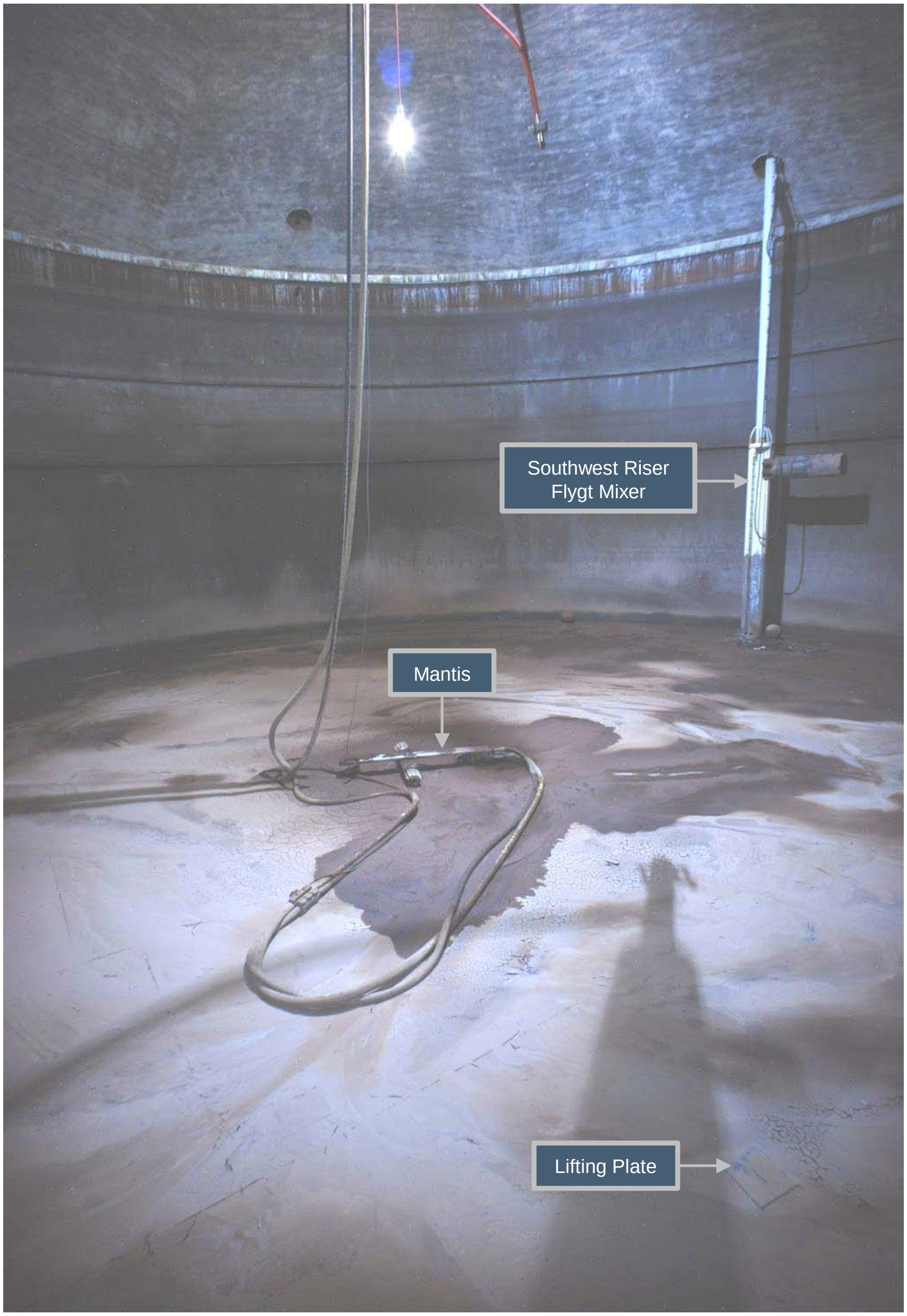


**Figure 3.4-2: Tank 19 after Completion of Mantis Operations (August 2009)
(View from Northeast Riser Looking South)**

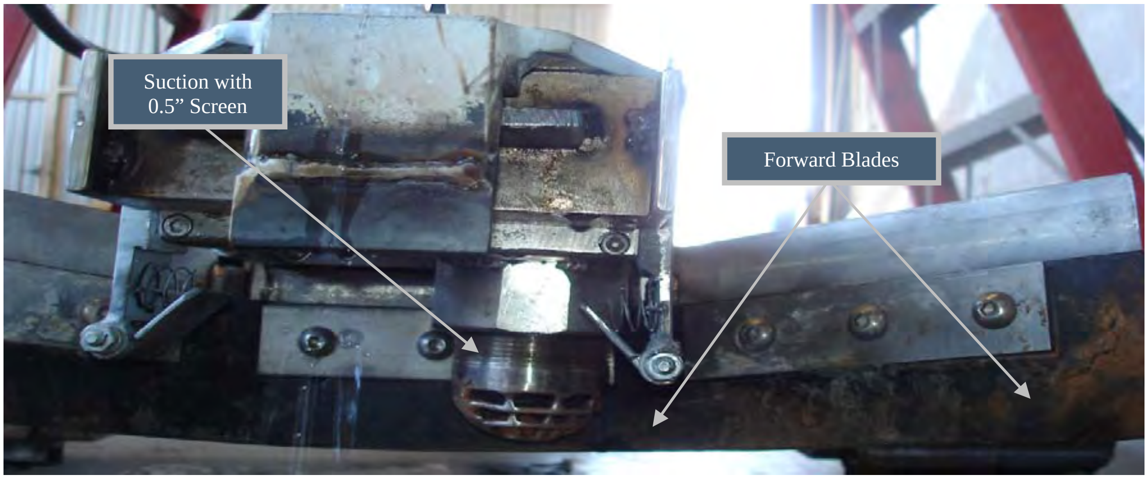


3.4.2 Technology Limitations of Mantis Equipment

Based on lessons-learned from previous heel removal operations, the suction head on the Mantis for Tanks 18 and 19 was designed with a screen to prevent debris (e.g., steel tapes, nuts, bolts) from being sucked up into the Mantis discharge piping and clogging the suction inlet or damaging the eductor.

The installation of the screen resulted in a 0.5-inch air gap between the bottom of the waste tank and the Mantis suction inlet. This air gap limited the Mantis ability to remove waste below the 0.5-inch level in the tank. To remove the waste effectively, this suction head configuration depended on the use of the forward blades (rubber squeegee devices), located just behind the suction head, to corral or pile the waste up into the suction head. The suction head and blade configuration are shown in Figure 3.4-3. The forward blades were most effective in corralling the waste in areas of the tank floor with mounds. The effectiveness of the forward blades was diminished in areas of the tank floor with thin layers of waste due to the interference by physical obstacles (primarily lifting plates) in the tank. The floor of each Type IV tank has sixty-nine 1-foot by 1-foot by 0.5-inch high lifting plates, which are remnants of tank construction (arrayed in a grid pattern across the floor). These physical features interfered with the blade's ability to push the material and also contributed to deterioration of the blades after extended operations.

Figure 3.4-3: Mantis Suction Head Screen and Blades



3.4.3 Mantis Equipment Degradation

At the completion of Phase 4 heel removal, the total Mantis operating time was 459 hours and 556 hours for Tanks 18 and 19, respectively. During its operation, several repairs were made to the Mantis and its supporting equipment for both Tanks 18 and 19 to extend its operational life and to maximize additional heel removal. For example, after approximately four days of operation the rear wheel of the Mantis in Tank 19 failed. Extensive work package planning and mockups were conducted over a three-month period to ensure repairs involving waste tank entry could be efficiently implemented while minimizing worker radiation exposure. Based on the lessons learned from Tank 19, the Tank 18 Mantis was redesigned before being deployed to strengthen the wheel assembly. Even with this redesign, the wheel assembly on the Tank 18 Mantis failed after nine days of operation. As described in Section 3.3.3.1, an innovative in-tank repair was implemented which recovered most of the operational effectiveness, as compared to operations prior to the wheel failure, by increasing the length of the control arm to mimic the leverage provided with the original wheel on the tilt-arm assembly. As a result of the efforts, the Mantis was operated for over twice its design life (i.e., 250 hours) in Tank 19 and almost twice its design life in Tank 18.

Even with equipment repairs to extend operational life, the existing Mantis equipment eventually was no longer effective in removing additional waste at the low residual levels remaining in the tank. After extended operations, the forward blades eventually wore to the point that they were no longer effectively corralling the waste in front of the suction head and the Mantis removal efficiency was significantly impacted. In addition, after Tank 18 Mantis repair completion and during its further operation, it was determined that the full capability of the tilt-arm assembly to reach the 0.5-inch level in the tank was not realized. Therefore, the effectiveness of the Tank 18 Mantis at low residual levels in the tank was even more impacted.

3.4.4 Impacts on Tank Space and the Liquid Waste System

Through experience gained during Mantis operations it was learned that solids removal effectiveness could be optimized by operating the Mantis such that the mounds were used as a “backstop” to help corral the waste thus increasing the solids content in the discharge stream to Tank 7. During Mantis operations in the tank, it was determined that the hoses attached to the Mantis could actually be used to help corral the waste into mounds. By the end of Mantis operations, the remaining material in Tanks 18 and 19 was no longer contained in mounds or able to be corralled into mounds, but was spread in a thin layer on the bottom of the tank. As a result, the water efficiency (gallons of waste removed per gallon water used) during continued Mantis operations was steadily decreasing. It should be noted that water used for operation of the Mantis was added at nearly a constant rate regardless of the amount of waste removed. The increased water-to-waste ratio issue was also compounded by the deterioration of the forward blades on the Mantis and the degradation of the eductor system. At the start of Mantis operations, it was estimated that a combined total of approximately 150,000 gallons of waste, consisting of existing tank solids and water added for removal, would be generated in completing solids removal from both Tanks 18 and 19. [LWO-CES-2007-00002] At the time Mantis operation was suspended, approximately 250,000 gallons of waste (110,000 gallons from Tank 18 and 140,000 gallons from Tank 19) had been generated. [U-ESR-F-00039, U-ESR-F-00035] The increase of waste actually generated versus planned was a result of the combination of a decreased heel removal efficiency and the fact that the Mantis was operated longer than originally planned in both Tank 18 and 19 (Section 3.4.3).

The greatest impact of this increased waste generation was that available space in Tank 7 (the receipt tank for Mantis removal operations for both Tank 18 and 19) was being depleted by the additional waste being created by extended Mantis operations. Tank 7, a Type I tank, was being used as the receipt tank for waste generated by Mantis operations because of its geographic proximity and because there was insufficient tank operating space existing in FTF Type III/IIIA tanks to support receiving the expected waste generated from Mantis operations. At the completion of Mantis operations on April 23, 2009, there was less than 25,000 gallons of receipt space remaining in Tank 7. [N-ESR-G-00001, Rev. 470] Based on its operational history, it was expected that continued operation of a Mantis would add approximately 8,000 gallons per day of new waste to the tank farm system [U-ESR-F-00039]. Therefore, existing Tank 7 receipt space when Mantis operations were suspended would only support an additional 3 to 4 days of Mantis operations.

In addition, when Tanks 18 and 19 Mantis operations were suspended and continued heel removal was being evaluated, Sludge Batch 6 was in the process of being prepared for feed to the DWPF. Sludge Batch 6 preparation involved removing bulk sludge from Tanks 4 and 7 in FTF, and Tank 12 in HTF (Type I tanks) into Tank 51 (a Type III/IIIA tank used for sludge batch preparation), thereby significantly reducing the risk associated with the sludge stored in these Type I tanks. [SRR-LWP-2009-00001] The subsequent Sludge Batch 6 washing operation in Tank 51 required both the 2F and the 3H evaporators to process the additional washwater (>1 million gallons) generated by washing the sludge to meet DWPF feed specifications. At that time, additional load on the evaporators resulting from waste generated from additional Tanks 18 and 19 cleaning would have delayed the preparation of Sludge Batch 6, potentially causing a feed break and subsequent shut down of DWPF. It would have also had the effect of delaying sludge removal efforts for the preparation of Sludge Batch 7, which removed additional sludge from Tank 4 and also includes sludge in Tank 7 that originated from Tanks 5 and 6 (Type I tanks) heel removal. [SRR-LWP-2009-00001]

In addition to supporting Tanks 18 and 19 cleaning, Tank 7 is also the “hub” tank supporting tank cleaning initiatives in Tanks 5 and 6 and bulk sludge removal initiatives for Tank 4. That is, most, if not all, of the transfers associated with these activities also go into Tank 7 before being moved on to their final tank destination. Due to the unique transfer line configuration in FTF, this overall integration of waste transfers and equipment usage is a closely monitored process to maximize efficient use of all resources associated with risk reduction activities in FTF. For example, additional cleaning efforts in Tanks 18 and 19 would have continued to occupy Tank 7 thereby precluding a planned transfer from Tank 7 to Tank 51 needed to maintain the Sludge Batch 6 schedule. In addition, it would have delayed chemical cleaning in Tank 5 resulting in a subsequent delay in Tank 6 heel removal because these two tanks utilize some of the same equipment to perform heel removal. Therefore, any delay in cleaning of Tank 5 would cause a delay in the cleaning of Tank 6.

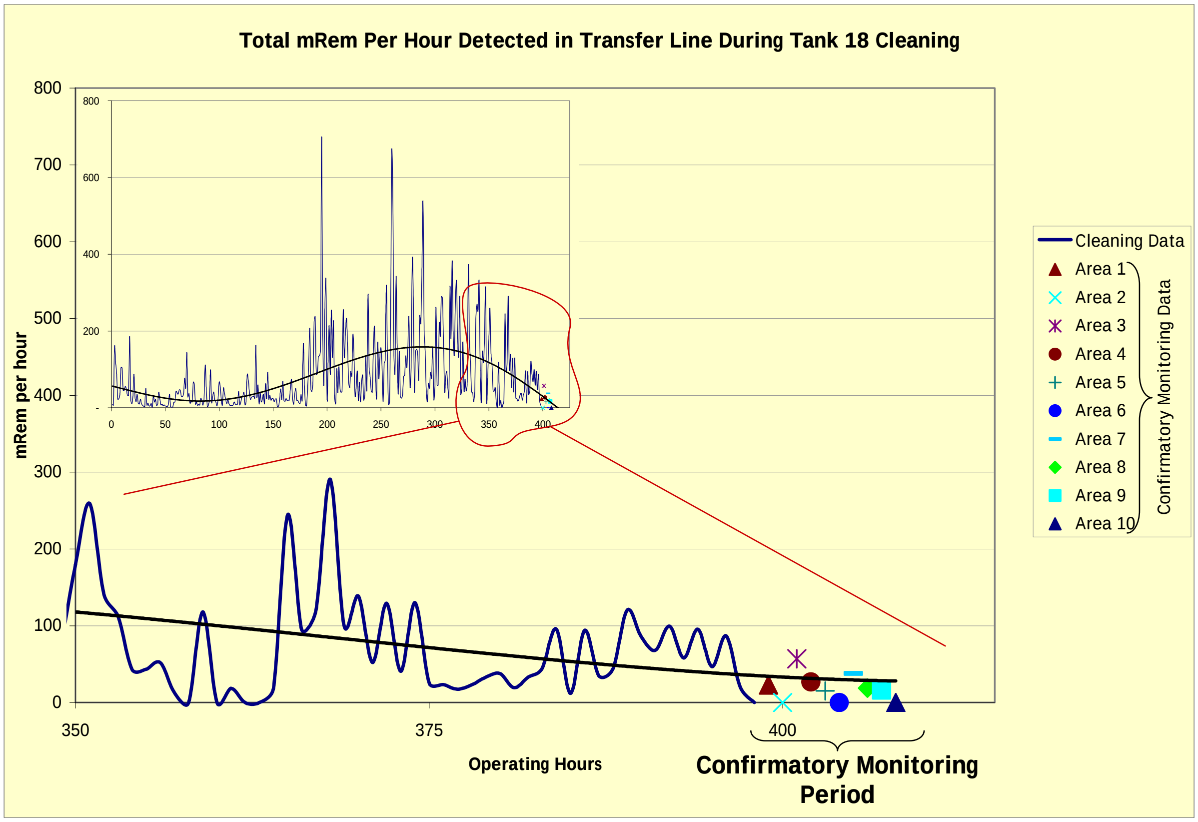
From an overall Liquid Waste System risk-informed perspective, it is important to ensure that continuation of sludge feed to DWPF be maintained. This must be taken into consideration when priority decisions are made involving conflicting uses of a key Liquid Waste System facility such as Tank 7, which is integral to supporting both sludge waste removal, needed to maintain stabilization of tank waste at DWPF and heel removal activities supporting RFS of waste tanks.

3.4.5 Diminished Transfer Line Radiation Trends and Confirmatory Operation

As discussed in Section 3.3.2.2 and 3.3.3.1, a radiation monitoring system was installed on the inside and outside of the transfer line shielding from both Tanks 18 and 19 to assess the solid waste transfer process and measure the effectiveness of Mantis operations. The system used EPDs equipped with a radio transmitter linked to a computer monitor and logging system. The radiation monitoring system was used to assess solids waste transfer progress over the life of the Mantis operations.

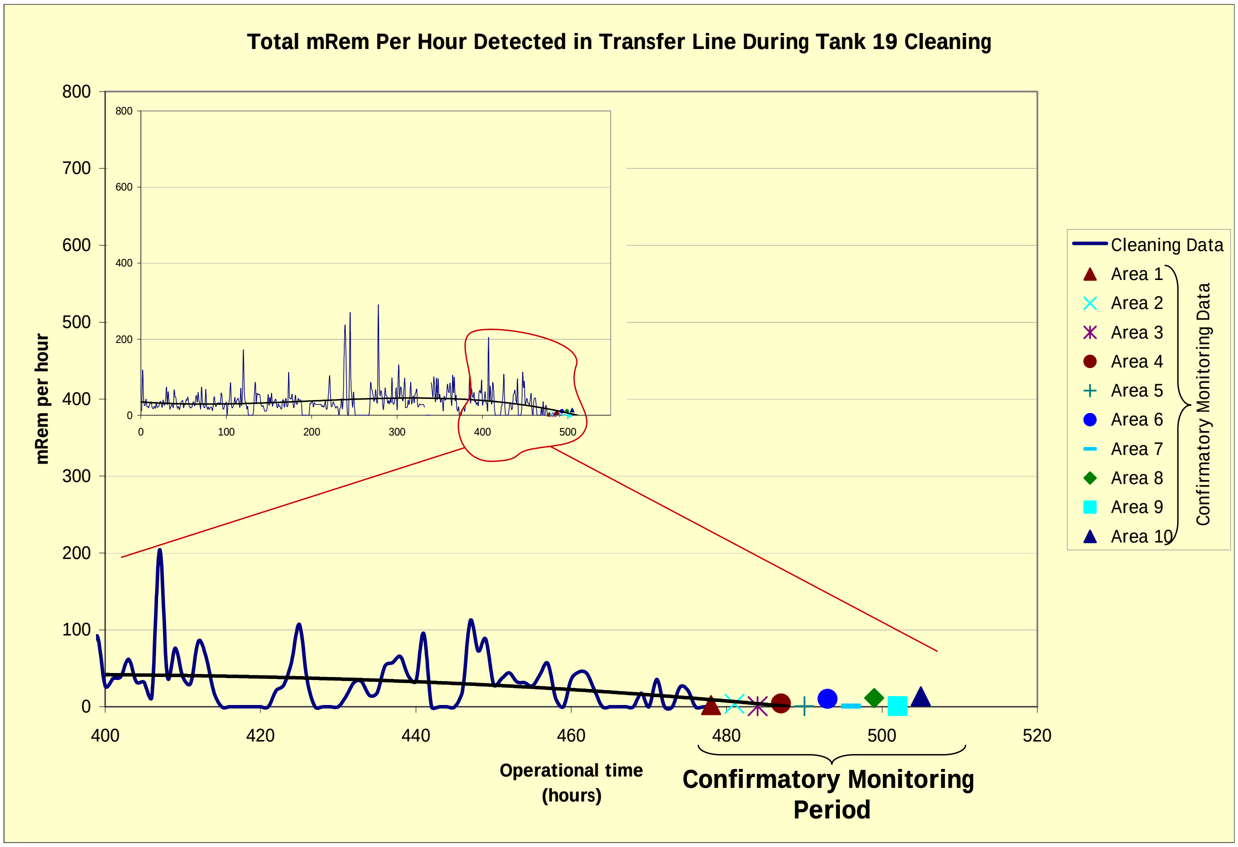
At the conclusion of Mantis operations in Tank 18 on March 13, 2009, the Mantis was operated in predetermined areas to measure the effectiveness of further operations. The effectiveness consisted of evaluating radiation monitoring during the cleaning of ten locations in the tank. Each location was an area of about 10 feet by 10 feet. These areas were selected to ensure the data was representative of the entire tank bottom. The results of this confirmatory monitoring can be seen in Figure 3.4-4, which shows that the Tank 18 Mantis had reached diminished effectiveness for removal of solid waste materials. [U-ESR-F-00035]

Figure 3.4-4: Radiation Monitor Data for Tank 18 Mechanical Cleaning



In similar fashion, at the conclusion of Mantis operations of Tank 19 on April 22, 2009, the Mantis was operated in ten areas to measure the effectiveness of further operations. The results of this confirmatory monitoring for Tank 19 can be seen in Figure 3.4-5 which shows that the Tank 19 Mantis had also reached diminished effectiveness for removal of solid waste materials. [U-ESR-F-00039]

Figure 3.4-5: Radiation Monitor Data for Tank 19 Mechanical Cleaning



3.4.6 Evaluation of a Replacement Mantis Deployment

In both Tanks 18 and 19, when it was determined that the existing Mantis was no longer effectively removing additional waste from the tank, an evaluation of the installation of a replacement Mantis of the same design in one or both tanks was performed. The following was determined from these evaluations. [U-ESR-F-00035, U-ESR-F-00039]

- As described in Section 3.4.2, because of design limitations associated with the Mantis suction screen impeding its ability to vacuum solids below ½ inch, additional solids removal was expected to be minimal. The results of the confirmatory Mantis operational runs described in Section 3.4.5, showing minimal additional heel removal, support this conclusion.
- The estimated cost of removing the existing Mantis and associated riser support equipment and replacing them with similar equipment was estimated at approximately $2.8M per tank and would take up to a year to implement. This estimate assumed that the existing above-grade HIHTL could still be used. [U-ESR-F-00035]
- The estimated worker dose for replacement Mantis installation ranged from 250 person-mrem to 1,200 person-mrem per tank assuming that the existing above-grade HIHTL could still be used. [U-ESR-F-00035]

- Because the remaining material was spread out evenly across the tank bottom rather than in mounds, the water efficiency (gallons of waste removed per gallon of water used) was expected to be low even with a new Mantis. This additional waste generated would be detrimental to the Liquid Waste System management as described in Section 3.4.4.

Therefore, as discussed previously, continued operation with the existing Tank 18 or Tank 19 Mantis was no longer effective at removing additional waste and would be detrimental to the Liquid Waste System. In addition, the purchase, installation, and operation of a replacement Mantis would not result in a substantial gain in removal efficiency because of design limitations described earlier. In accordance with Section 6.2 of the FTF GCP, DOE concluded that waste removal activities were sufficiently complete to provide reasonable assurance that proceeding to the sampling and analysis phase would demonstrate that RFS criteria will be met.

3.4.7 Agreement to Proceed with Sampling and Analysis

Per the requirements of the FFA, DOE briefed officials of EPA on September 24, 2009 and SCDHEC on October 1, 2009 on the results of the Mantis cleaning of Tanks 18 and 19. [SRR-CWDA-2009-00030]

The briefing demonstrated that:

- The Mantis technology has been effective in Tanks 18 and 19 and had reached the extent of this technology to remove significant additional waste.
- Over 99% of the waste and the associated hazardous constituents and radionuclides in these waste tanks have been removed.
- A qualitative assessment of additional options indicate that additional waste removal was not practical.
- A qualitative assessment indicates that 10 Code of Federal Regulations (CFR) 61, Subpart C performance objectives would be met.

DOE followed up the presentation with a Request for Concurrence to Proceed to Sample and Analysis Phase of the Tank Closure Process for Tanks 18 and 19. [WDPD-10-02]

Agreement was reached between the three agencies that waste removal efforts could cease and DOE could proceed with the sampling and analysis phase of the project. SCDHEC and EPA submitted letters to DOE stating:

> *"…based upon the qualitative information provided, there is reasonable assurance that it is appropriate to enter the sampling and analysis phase of the closure process for Tanks 18 and 19. Full sampling and analysis of the residuals in support of the Closure Module for these tanks will be needed before a final decision can be made by the Department regarding completion of waste removal operations for Tanks l8 and 19."* [DHEC_11-02-2009]
>
> and

> *“Based on the provided information, EPA concurs with DOE's request to cease waste removal activities in Tanks 18 and 19 and proceed with the sampling and analysis phase of the project.”* [EPA_11-02-2009]

4.0 RESIDUAL WASTE CHARACTERIZATION

DOE has characterized the residual material that remains in Tanks 18 and 19 today in order to support updated fate and transport predictions in the PA using actual inventories from Tanks 18 and 19, and to provide reasonable assurance of achieving the FTF GCP performance objectives. The characterization of the residuals and the projections of long-term performance prepared through the FTF PA models predict fate and transport over time of constituents that remain in the tanks. This characterization is not meant to demonstrate compliance with the GCP performance objectives but rather determines the source term for modeling purposes to predict if reasonable assurance exists that the GCP performance objectives will be met throughout the evaluation period.

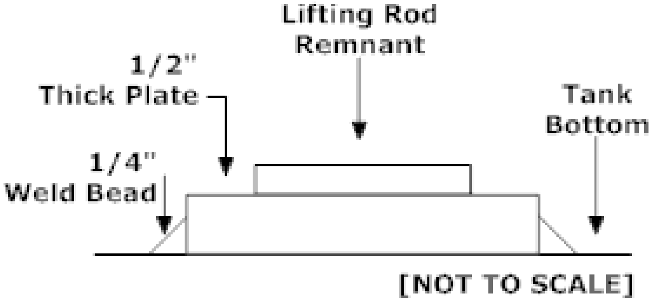
The residual material that remains in the waste tanks upon removal from service must be representatively sampled and characterized to evaluate the long-term hazards of closure and to verify that the assessment of performance remains valid. To provide support and defensibility to the characterization data used in this CM, DOE has prepared the Data Quality Summary Report and reference documents for the Tanks 18 and 19 sampling and analysis. [SRR-CWDA-2011-00150] It compiles and summarizes sampling and characterization information and reports, and presents data quality components of the laboratory sample analyses, the results of a limited data validation study, and a Data Quality Assessment. Several of the key attributes associated with residual waste characterization are described in more detail in the following sections.

4.1 Residual Volume Determination

Material mapping is a method for determining the volume of residuals inside of a waste tank. This method relies on photographic images to capture the relative depth of material across a waste tank floor in relation to known landmarks. These depths can then be plotted over the waste tank floor area to determine the volume. During the various waste removal campaigns intermediate mapping was performed to better understand the relative volume and location of the waste within Tank 18 or Tank 19. Typically, this intermediate mapping was performed with significant liquid remaining in the tank resulting in significant uncertainty in the volume estimates. In addition, intermediate mapping was typically performed using lower-resolution video cameras. Following Mantis operations, over 140 high-definition photographs were taken of the interior of Tank 18 and over 175 high-definition photographs were taken of the interior of Tank 19 at various locations and elevations inside the waste tanks for the purpose of final waste mapping and final volume determination. These high-definition photographs were taken after the tanks had been allowed to dry. The pictures were inspected by a team of professionals experienced in waste tank mapping.

The floor of a Type IV waste tank has 69 1-foot by 1-foot by 0.5-inch high lifting plates arrayed in a grid pattern across the floor. Each plate has a 0.25-inch weld bead affixing it to the floor and the remnant of where the lifting rod attached to the top of the plate during waste tank construction (Figure 4.1-1). These lifting plates were used as key landmarks for material mapping.

Figure 4.1-1: Lifting Plate Elevation View

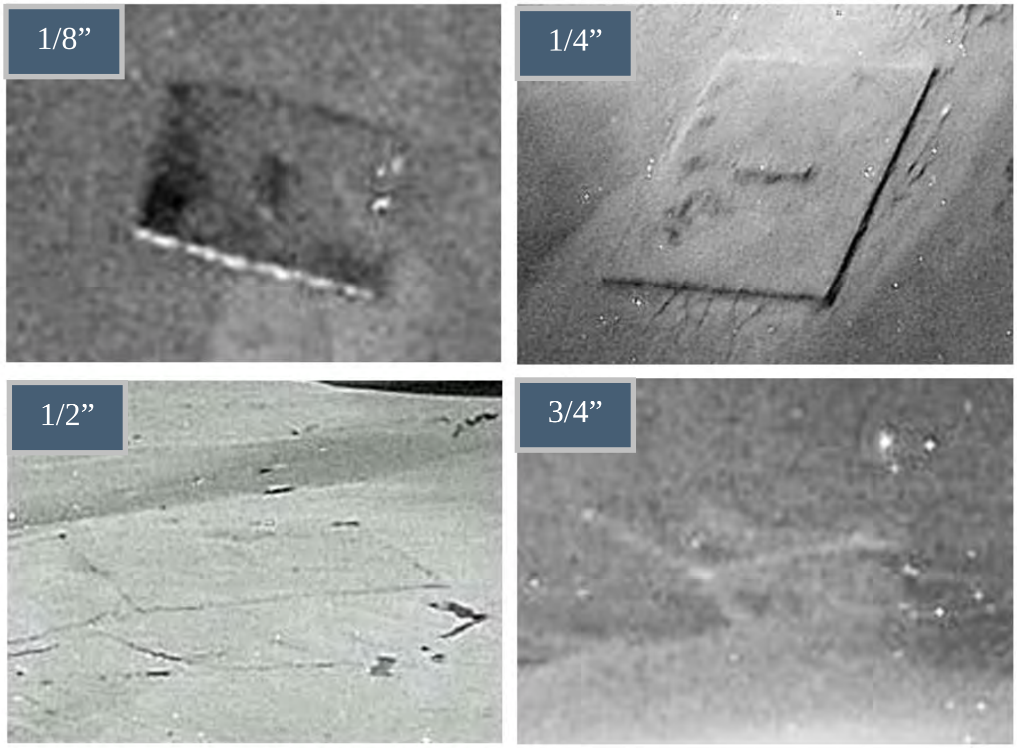


The evaluation team used a widescreen high definition monitor and picture enhancement software to adjust color, contrast and brightness to provide the best views possible. Twenty lifting plates in Tank 18 and 34 lifting plates in Tank 19 could be observed at the completion of the Phase 4 heel removal with the Mantis and the criteria in Table 4.1-1 were used to assign depths of residual solids. Figure 4.1-2 shows examples of the lifting plates and the depth of material surrounding them. The depths of the regions surrounding the lifting plates were determined and plotted onto a gridded map of the tank floor. Figures 4.1-3 and 4.1-4 show maps of Tanks 19 and 18 respectively after Phase 4 of heel removal. [U-ESR-F-00041, U-ESR-F-00042]

Table 4.1-1: Material Depth Criteria

Depth (Inches)	Criteria
1/8	Dusting of solids evident with some clean steel floor visible.
1/4	Sides of lifting plate visible. Solids are mostly well below the top of lifting plate.
1/2	The shape of the lifting plate is clearly visible but the material appears to be the same depth as the top of the lifting plate.
3/4	Shape of lifting plate can be discerned through solids.

Figure 4.1-2: Examples of Lifting Plate Depths



*** Inches reflect estimated depth of waste.**

Figure 4.1-3: Tank 19 Residual Material Configuration (April 2009)

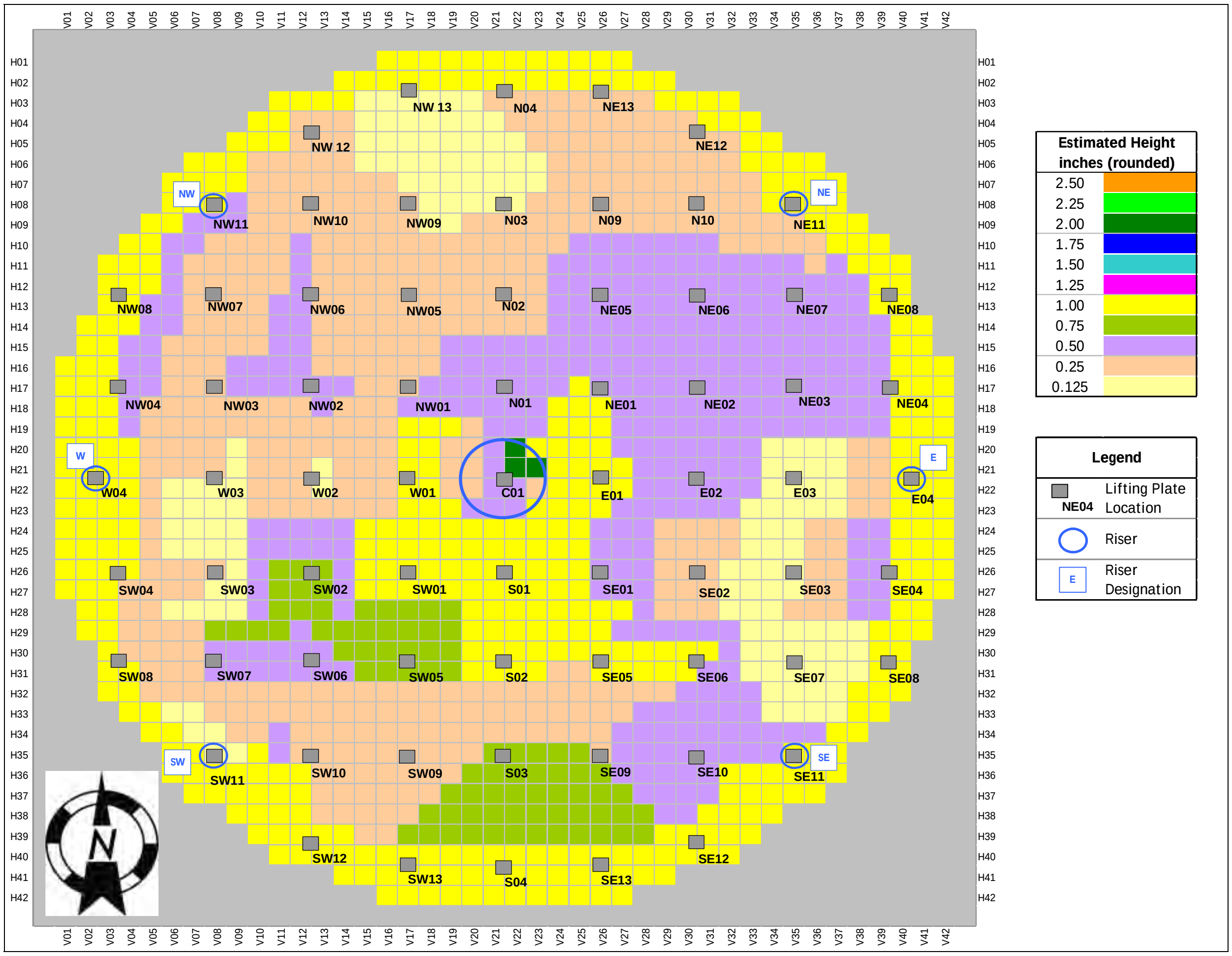
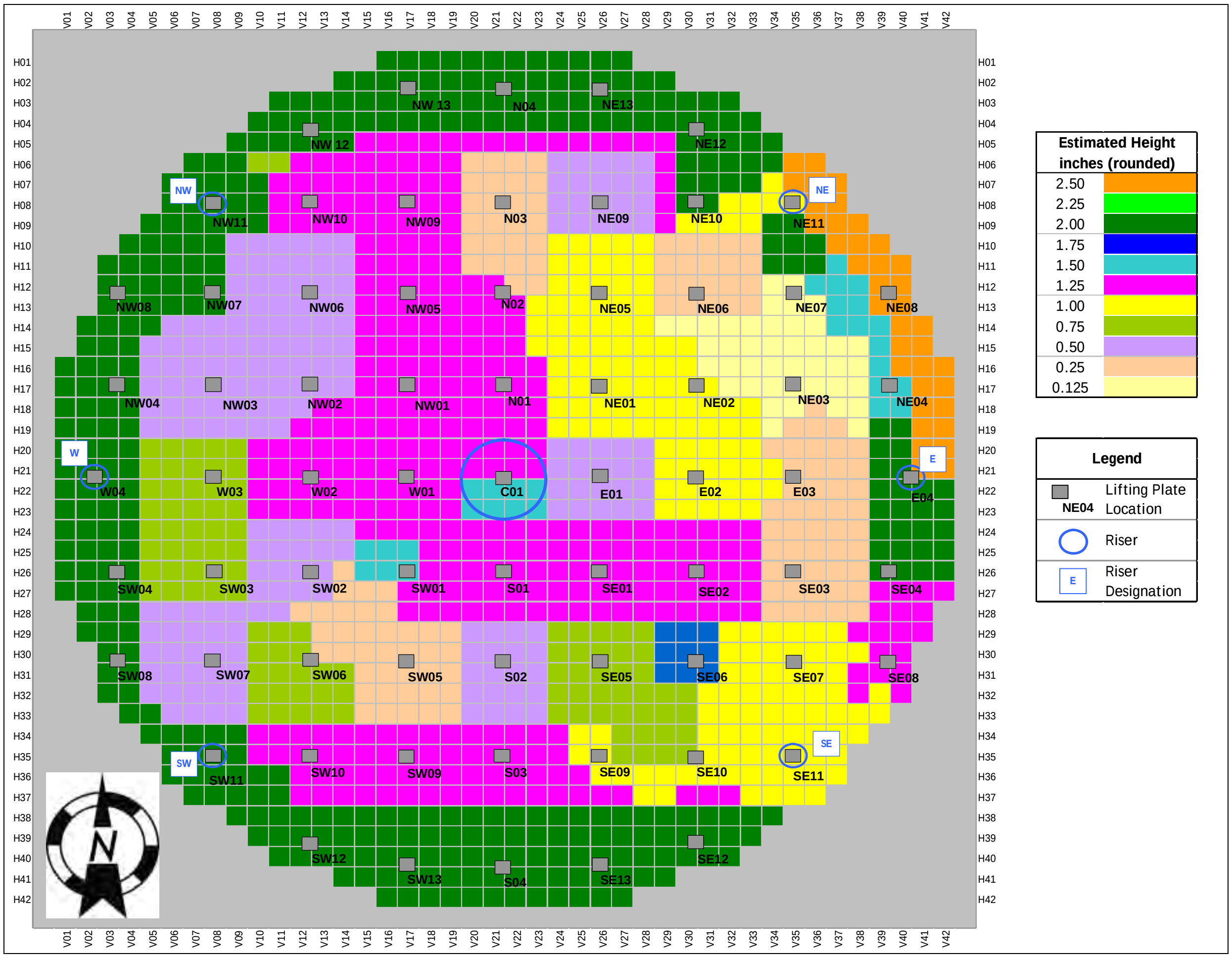


Figure 4.1-4: Tank 18 Residual Material Configuration (April 2009)



As many of the lifting plates were not visible, additional data was collected to support volume determination. Because physical dimensions (i.e., height of wheel treads) of the Mantis were known, it was determined that the Mantis itself could be used as a landmark to determine the depth of residuals in areas where the lifting plates could not be seen. In early September 2009, the Mantis was successfully used in surveying the central, northeastern, eastern and southeastern regions of Tank 18. For each depth measurement in these regions, the Mantis' wheels were confirmed to be in contact with the bare waste tank floor to ensure accurate measurement. However, due to a loss in traction caused by material building up inside the Mantis' wheels and drag weight of hose and tether system the Mantis was unable to reach the other regions inside of Tank 18. To approximate the material depths in other regions the corresponding depths in the surveyed areas were analyzed and their weighted mean values were applied. [U-ESR-F-00041]

In addition to the residual material resting on the floor of Tank 18, there is also material remaining on the waste tank stiffener bands and on the tank wall surfaces. The volume of the material resting on the stiffener bands was determined to be about eight gallons based on analysis of digital photographs. The depths and areas covered by the material on the vertical surfaces of the walls were also determined using digital photographs. Previous video in 2002, following wall washing in Phase 3, did not reveal the scale on the vertical surface and it was not discovered until the digital mapping photographs were used. The material on the lower regions of the wall (above the lower weld located 27 inches above the floor) was determined to be 0.1875 inch thick. For volume determination purposes, a 3-foot wide band around the entire circumference of the waste tank represents the tank wall surface area covered by this material. Material on the wall was determined to be 0.25 inch thick at other various elevations of the waste tank wall. The volume of material on the vertical surface of the Tank 18 wall was determined to be 110 gallons. [U-ESR-F-00041]

The material volume for Tank 18 was determined to be 3,900 gallons using the material mapping technique. [U-ESR-F-00041] With the addition of the residue volume on the stiffener bands and vertical surfaces, the total residue volume of Tank 18 was determined to be 4,000 gallons.

Based on Tank 18 experience it was expected that the Mantis inside of Tank 19 would face similar limitations. It was predicted that the range of travel for the Tank 19 Mantis would exclude the possibility of gathering data from the outer regions of the waste tank and actual operations showed that only a portion of the central region could be surveyed. Digital photographs taken on August 8, 2009 were used to assess the depths of residual solids in regions where plates were not discernable. Analysis of the photographs showed little to no evidence of material height changes inside of the regions not surveyed. In addition, the appearance of waste tank floor welds across some of these regions demonstrates that a material height estimate of one inch would be conservative. Material mapping in Tank 19 determined a total volume of residue at 2,000 gallons. The digital photographs of Tank 19 showed no appreciable material on either the vertical surfaces or stiffening bands of the walls. [U-ESR-F-00042]

4.2 Residual Waste Sampling

4.2.1 Representative Characterization

Working with statistical experts in the Applied Computational Engineering and Statistics Group in the SRNL, a basis was developed for the number of locations and quantity of residual samples required to characterize the residuals sufficiently. The sampling strategy used the tank history and waste removal knowledge as a guide when developing the sampling basis. It was anticipated that the residual material could be characterized as one population (similar concentrations throughout the tank) based on previous sample results. Following heel removal activities, this sampling strategy was evaluated to determine the appropriate number of samples to collect and the appropriate sample locations to provide representative characterizations of Tanks 18 and 19 and to validate the similarities in residual material. The evaluation concluded that six sample locations would be necessary to characterize the residual material. It was recommended that an additional two samples be obtained as archive samples to provide contingency. The sample locations were specified based on the configuration of the residual material on the tank floors. [SRNL-STI-2009-00782, SRNL-STI-2009-00779] The samples were floor scrape samples. The technique for obtaining the samples is described in Section 4.2.2. Sampling activities and sample handling are conducted in accordance with the SRR SW11.1-SAMPLE Manual. Procedures outlined in the Sample Manual include those for obtaining samples, packaging, transporting and tracking (i.e., chain of custody).

Subsequent statistical analysis of the results validated the similarity of material throughout the tank, thereby allowing the material to be characterized as one population (Section 4.3).

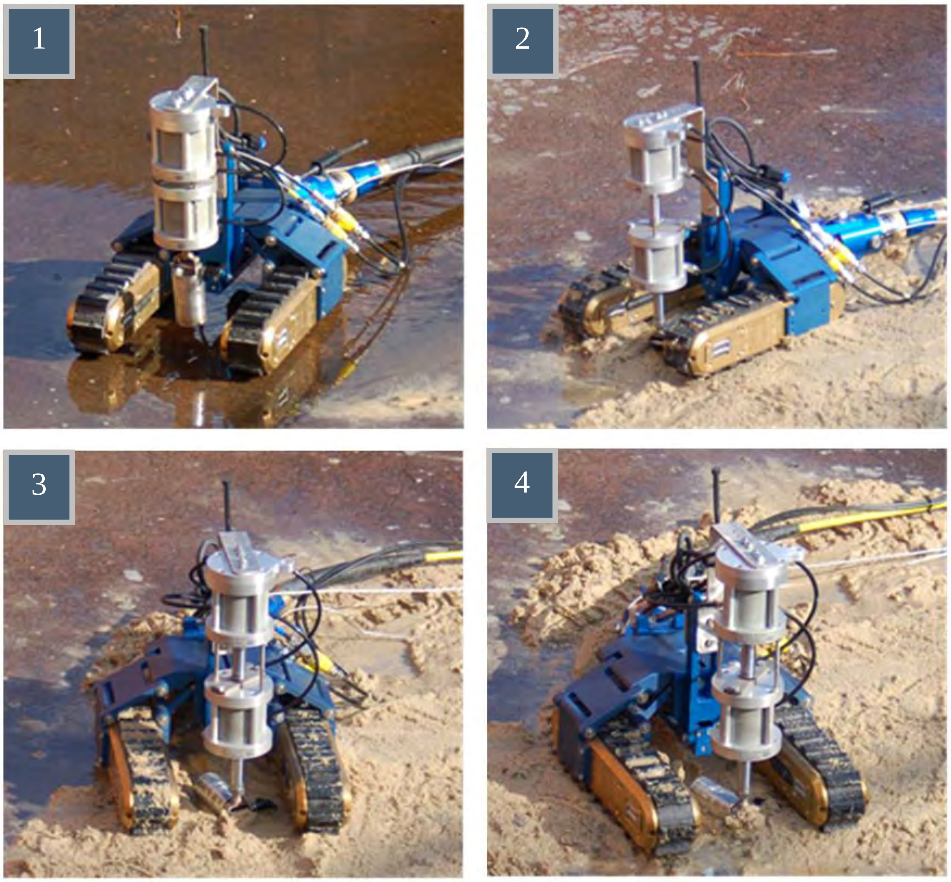
4.2.2 Floor Sampling Technique

Due to limited availability of riser access for collecting samples to characterize the residual material in the tanks, a task team was formed to develop a mobile sampling tool. The team created a design based on modifications to the VersaTrax™ 150 robotic platform (VT 150) that was developed primarily for internal video inspection of commercial piping systems. The VT 150 has an anodized aluminum chassis, which is radiation hardened to 100,000 rem, and can be used underwater and in soil and debris situations.

The VT 150 was modified by replacing the video camera and lighting equipment with a pneumatic sampling device. The sampling device consisted of a dual pneumatic cylinder with a pinned connection located on the shaft of the cylinder for sample cup attachment. The pneumatic cylinders were operated with air supplied by air lines that are strapped to a tether. A winch and steel cable was used to hoist the robotic sample crawler, instead of the supplied tether, for simplicity of operation and because the tether was the weakest component of the VT 150 system. The modifications reduced the robotic sample crawler's overall dimensions, allowing entry into a 24-inch diameter riser.

Between January 5, 2010, and February 4, 2010, the residual waste on the Tank 18 and Tank 19 floors was sampled at the designated locations using the modified robotic crawler-sampling device. Figure 4.2-1 provides photographs taken during mock-up testing of the device. The crawler was lowered to the waste tank floor (Panel 1) and then driven to the sample location. Upon arrival at the sample location, several scrape samples were taken while moving the robotic crawler forward or backward and lowering the sample cup (Panels 2 and 3). Once the sample cup was filled (Panel 4), the crawler was driven to a location under the riser where it was hoisted to the waste tank top. A new sample cup was attached and the process was repeated. [SRR-LWE-2010-00059]

Figure 4.2-1: Waste Tank Floor Sampling Process During Mock-Up Testing

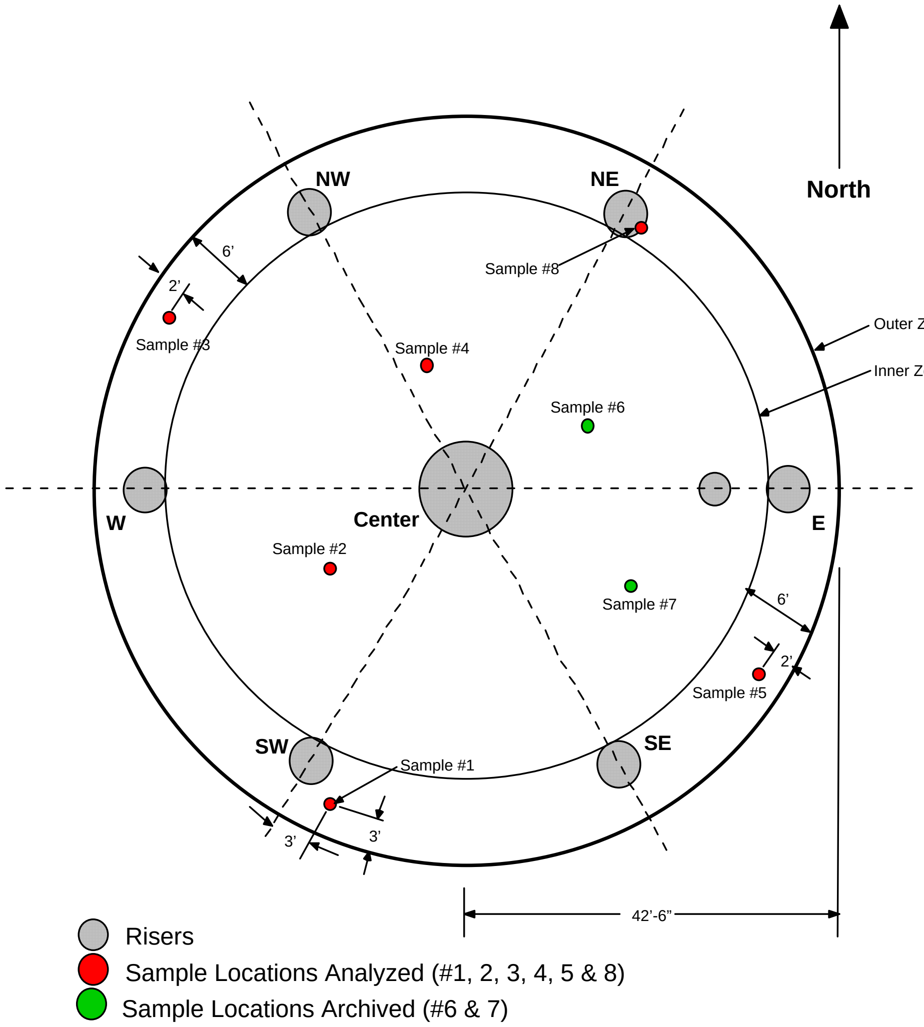


4.2.3 Tank 18 Residual Waste Sampling

4.2.3.1 Tank 18 Floor Sampling

Eight discrete samples were taken for analysis to characterize the residual material. Tank 18 was artificially partitioned into six 60-degree sectors with an outer zone area and inner zone area as shown in Figure 4.2-2. The Tank 18 solids were approximately equally divided between the outer and inner zones. The Tank 18 samples were obtained from each sector to ensure different tank regions were represented. Two samples were archived for possible analysis at a later time, one sample from the northern half of the tank and the other from the southern half. Approximately 70 grams of solids was required per sample location to perform the required analyses. [SRNL-STI-2010-00386]

Figure 4.2-2: Tank 18 Floor Sample Locations



4.2.3.2 Tank 18 Wall Sampling

The tank wall material was sampled to validate previous estimates of the corrosion film material composition. Inspection of the waste tank wall with high quality digital cameras for sampling activities found residual material, referred to as scale, adhered to the wall in addition to the corrosion material expected. The scale build up covered only a portion of the wall, whereas the corrosion film was assumed to cover the entire wall surface. Samples were collected of these two material types. Two samples of the Tank 18 wall corrosion products and one sample of wall scale were collected in September 2009. The two wall corrosion samples were obtained by drilling into, but not through, the carbon steel tank wall at two locations approximately 17 feet above the tank floor and capturing the drill cuttings on filter pads. The scale sample was collected at five locations approximately 6 to 7 feet above the tank floor. The corrosion film samples were analyzed by SRNL to determine the activity per unit area of the tank wall. The scale samples were analyzed on a concentration per mass basis and the results were compared to the results of the floor samples. Since the concentrations between the scale and floor samples were comparable, the floor sample concentrations statistics (see Section 4.3) were used to determine the scale inventory. Additional details of the sampling and analysis are presented in the respective characterization reports. [SRNS-STI-2009-00416, SRNL-STI-2009-00802]

For the film characterization, the concentration of material was measured in the film samples and applied uniformly across the entire surface area of the wall. The characterization of the material used the collected sample surface area to determine the contamination per area units. This characterization was then projected around the entire wall surface area to determine the wall corrosion film inventory. The scale build up concentrations were multiplied by the estimated scale volume (110 gallons) to determine the scale inventory. [SRR-CWDA-2010-00117]

4.2.4 Tank 19 Residual Waste Sampling

4.2.4.1 Tank 19 Floor Sampling

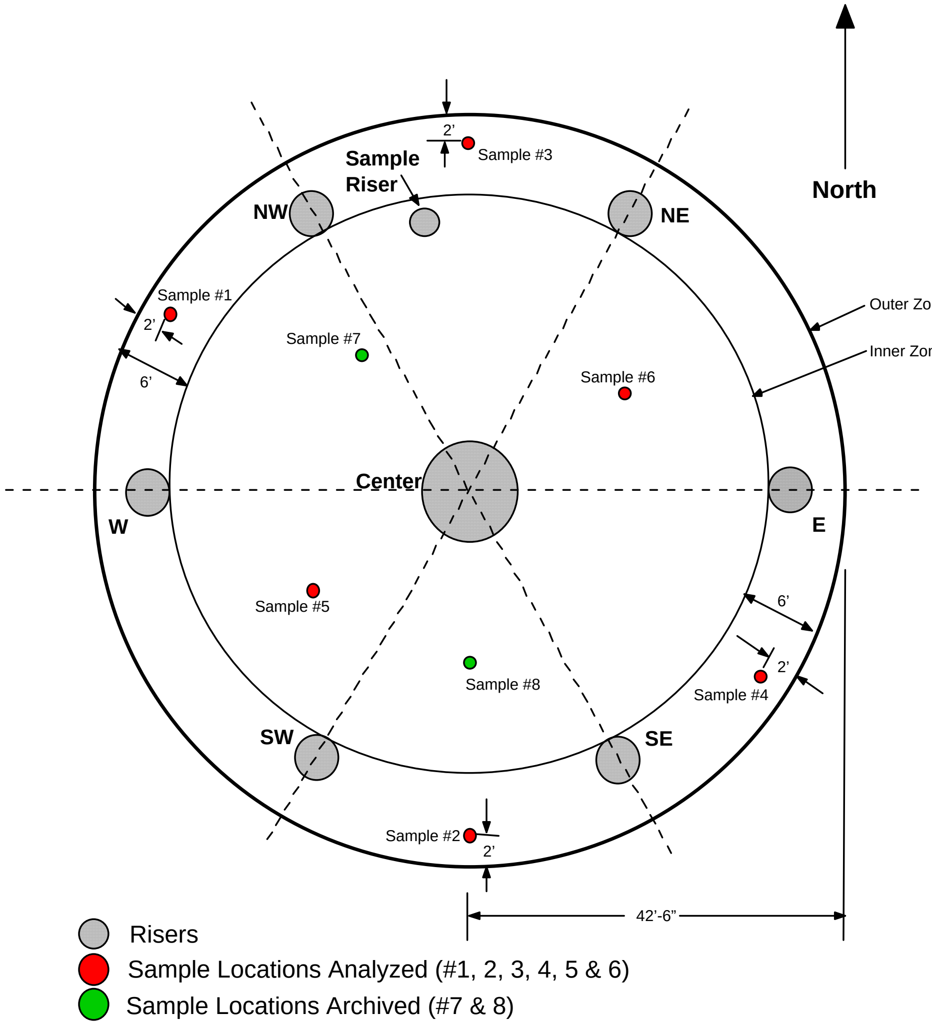
Eight discrete samples were taken for analysis to determine the residual material's characterization. Tank 19 was artificially partitioned into six 60-degree sectors with an outer zone area and inner zone area as shown in Figure 4.2-3. [SRNL-STI-2010-00439] The Tank 19 solids are approximately equally divided between the outer and inner zones. The Tank 19 samples were obtained from each sector to ensure different waste tank regions were represented. Two samples were archived for possible analysis at a later time. Approximately 70 grams of sample solids was required per sample location to perform the required analyses.

4.2.4.2 Tank 19 Wall Sampling

The tank wall material was sampled to validate previous estimates of the corrosion film material composition. Inspection of the waste tank wall with high quality digital cameras for sampling activities found corrosion material as expected but no appreciable scale, as had been seen in Tank 18. Therefore, samples were only collected of the corrosion film. The corrosion film was assumed to cover the entire wall surface. Two samples of the Tank 19 wall were collected in October 7, 2009. An upper tank sample was collected in an area above a line 7.1 feet above the tank floor and a lower tank sample was collected in an area below the 7.1 foot elevation line. [SRNS-STI-2009-00416, SRNL-STI-2009-00779]

For the film characterization, the concentration of material was measured in the film samples and multiplied across the entire surface area of the wall (Section 4.3). The characterization of the material used the collected sample surface area to determine the contamination per area units. This characterization was then projected around the entire wall surface area to determine the wall film inventory. [SRNL-STI-2009-00799, SRR-CWDA-2010-00118]

Figure 4.2-3: Tank 19 Floor Sample Locations



4.3 Characterization of Waste Tank Residual Materials

4.3.1 Derivation of Constituents of Concern

Chemical and radiological constituents in the waste tanks are well known from tracking waste data based on sample analysis, process histories, composition studies and theoretical relationships. The most current listing of the chemical and radiological constituents found in tank waste is documented in *Information on the Radiological and Chemical Characterization of the Savannah River Site Tank Waste As of July 5, 2011* (SRR-LWE-2011-00201), which includes constituents that were received into the FTF or HTF over the facility history as well as any constituents that could have formed in the tank sludge, salt or supernate phases. The referenced report was used to determine the list of chemical constituents in the tank residues. The inventories reported in the referenced document are best available information or estimate values used to support liquid waste management safety and operational decisions. Because this information is used for safety purposes (e.g., nuclear criticality evaluations, corrosion evaluations), the estimates are approximate and may over or underestimate the actual inventories (i.e., may be conservative, but not reflective of actual lower or higher inventories).

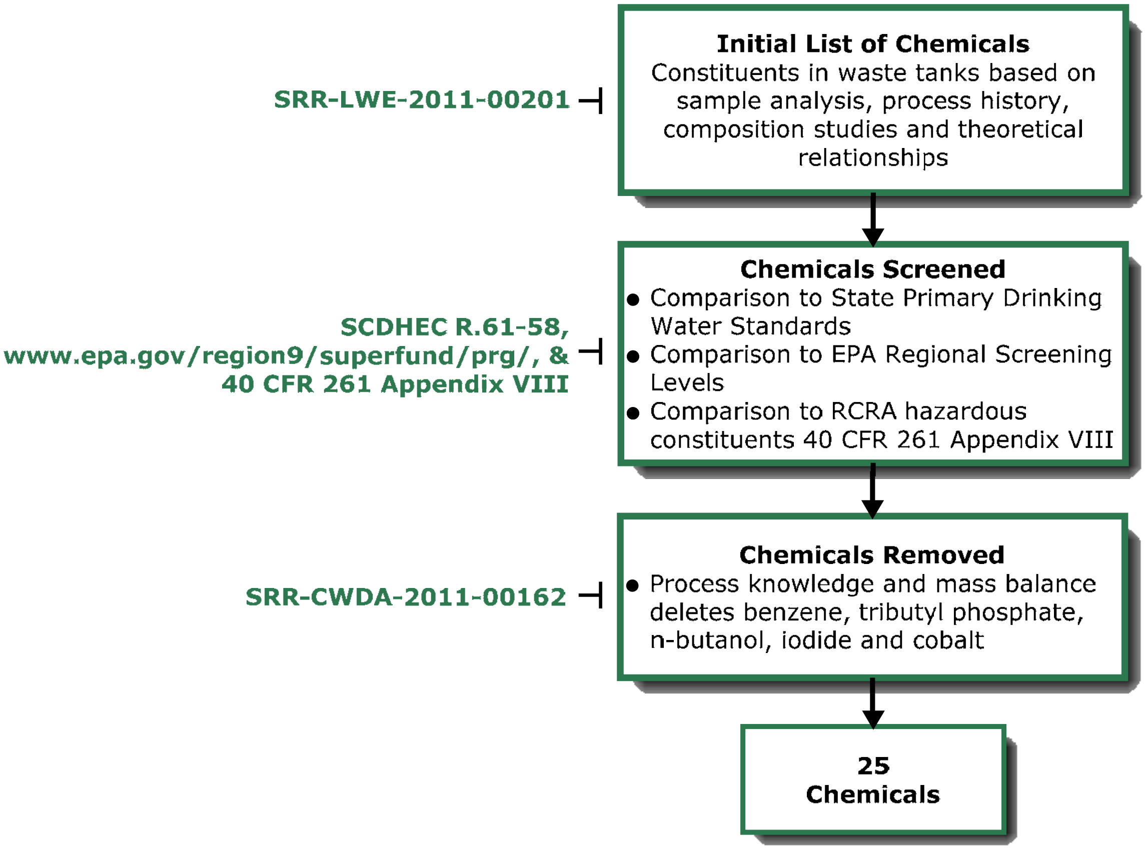
From the overall Tank Farm waste constituent list, chemical constituents of interest were identified through a screening process using EPA Regional Screening Levels (RSL) (http://www.epa.gov/region9/superfund/prg/), MCLs from the State Primary Drinking Water Regulations for inorganic contaminants specified in SCDHEC R.61-58, and hazardous constituents from 40 CFR 261 Appendix VIII. The list of chemical constituents that were expected to be present in the waste tanks was compared to the list of chemicals that had RSLs, MCLs or hazardous characteristics and if any of the tank farm chemicals were found on any of the lists, the chemical was added to the list of chemicals of interest.

From this list, it was determined which constituents could be present in Tanks 18 and 19. Tributyl phosphate, benzene, n-butanol, cobalt and iodide were removed based on process knowledge and confirmed using mass balance of analysis results. The result of this overall screening process yielded a list of 25 chemical constituents that will have an inventory determined based on analysis and/or process knowledge, which are shown in Table 4.3-1 and illustrated in Figure 4.3-1. [SRR-CWDA-2011-00162]

Table 4.3-1: Chemical Analyte List for Tank 18 and 19 Samples

Chemicals		
Aluminum	Fluoride	Phosphate
Arsenic	Iron	Selenium
Antimony	Lead	Silver
Barium	Manganese	Strontium
Boron	Mercury	Sulfate
Cadmium	Molybdenum	Uranium
Chloride	Nickel	Zinc
Chromium	Nitrate	
Copper	Nitrite	

Figure 4.3-1: Chemicals of Interest Determination for Tank 18 and 19

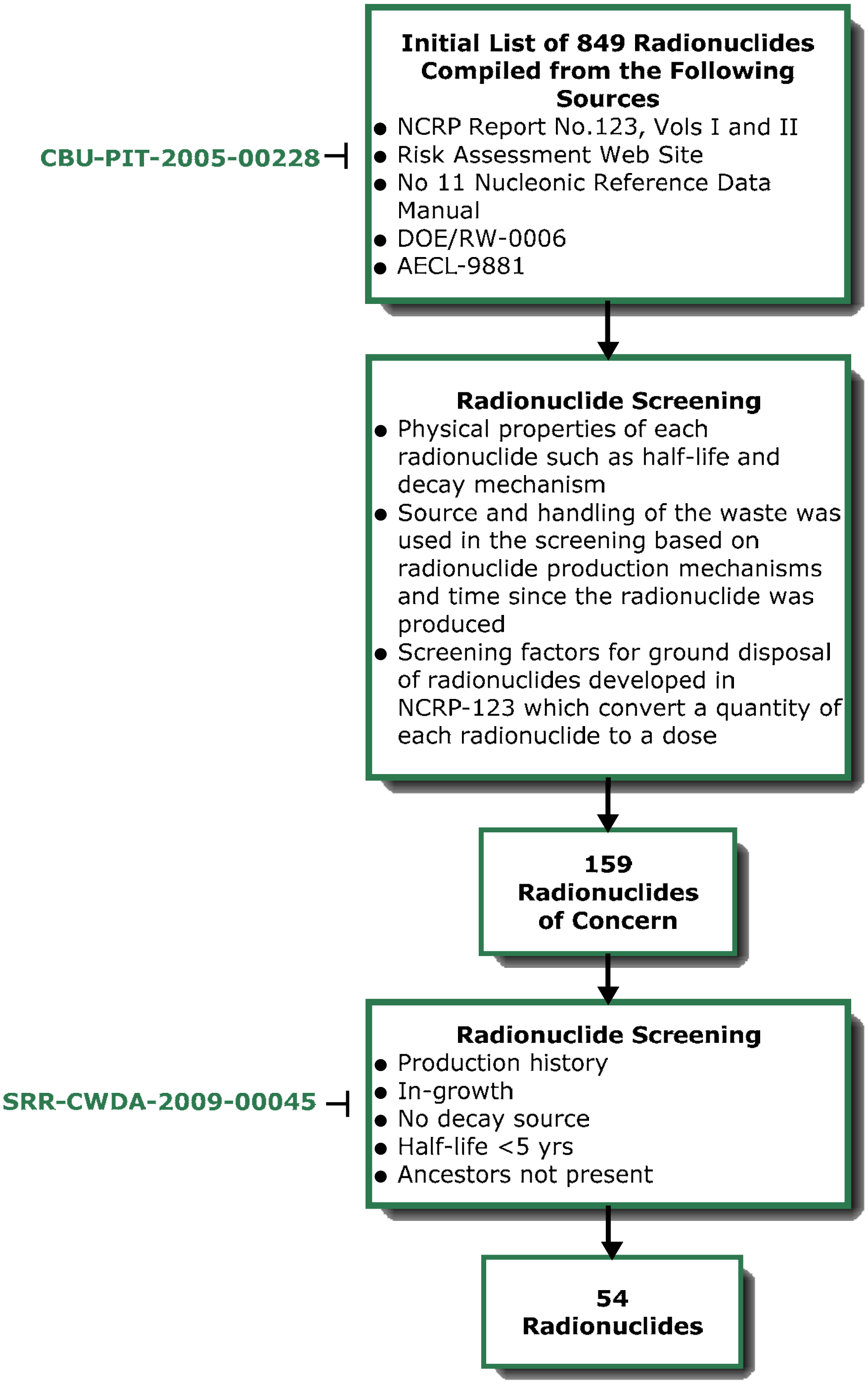


The screening process to determine potential radionuclide contaminants is described in Section 5.1 of the FTF GCP. [LWO-RIP-2009-00009] The radionuclide analytes include potential contaminants that have been present in the waste tanks as well as any radionuclide daughters that may be present. SRS performed a screening of radionuclides by initially evaluating 849 radionuclides. Of the original 849 radionuclides, 159 remained on the list and 690 were excluded from further consideration for various reasons (e.g., short half life, no FTF applicable production history, low risk) as explained in *Savannah River Site High-Level Waste Tank Farm Closure, Radionuclide Screening Process (First-Level), Development and Application* [CBU-PIT-2005-00228] Additional screening was performed for the remaining 159 isotopes in Section 4.2.1.3 (Evaluation of Remaining Radionuclides) of the FTF PA based on the presence/absence of parent radionuclides and the expectation of waste tank inventory. The result of these two screening processes yielded a list of 54 radionuclides that would be included in the characterization which are shown in Table 4.3-2 and illustrated in Figure 4.3-2. Screening criteria used in this evaluation are described in CBU-PIT-2005-00228 and in the FTF PA. [SRS-REG-2007-00002]

Table 4.3-2: Radiological Analyte List for Tank 18 and 19 Samples

Radionuclides			
Ac-227	Co-60	Pd-107	Sr-90
Al-26	Cs-135	Pt-193	Tc-99
Am-241	Cs-137	Pu-238	Th-229
Am-242m	Eu-152	Pu-239	Th-230
Am-243	Eu-154	Pu-240	U-232
Ba-137m	H-3	Pu-241	U-233
C-14	I-129	Pu-242	U-234
Cf-249	K-40	Pu-244	U-235
Cl-36	Nb-93m	Ra-226	U-236
Cm-243	Nb-94	Sb-126	U-238
Cm-244	Ni-59	Sb-126m	Y-90
Cm-245	Ni-63	Se-79	Zr-93
Cm-247	Np-237	Sm-151	
Cm-248	Pa-231	Sn-126	

Figure 4.3-2: Radionuclides of Interest Determination for Tank 18 and 19



Based on the screening processes used for chemical and radiological constituents described above, the tank waste residual samples described in Section 4.2 were analyzed to quantify the constituents listed in Table 4.3-1 and 4.3-2. [SRNL-STI-2010-00386, SRNL-STI-2010-00439, SRNL-STI-2009-00802, SRNL-STI-2009-00799].

4.3.2 Sample Analysis

The SRNL performed the waste tank residuals characterization sample analyses under *Tank 18 and 19 Additional Closure Sample Analysis* (HLE-TTR-2009-120) and the *Task Technical Quality Assurance Plan for the Characterization of Additional Tank 18F and 19F Floor Samples* (SRNL-RP-2010-00084).

Because of the complex matrices and relatively high sample radioactivity, SRNL Analytical Development used their analytical procedure, supplemented as necessary by Research and Development (R&D) directions to prepare and analyze these samples. The existing procedures are written with general guidelines with regard to instrument calibration and quality control protocols. As needed, new or modified preparation methods in the form of R&D directions, were developed to achieve the low target detection limits requested in the Technical Task Request (TTR).

For most of the analytes, samples were divided into three aliquots, digested, and the resulting solutions were analyzed for the requested constituents. For a few constituents, it was recognized that reaching the target detection limits was going to be challenging and thus, new or modified analytical methods and/or additional sample material were required to approach these target detection limit values. Special emphasis was placed on achieving these target detection limits for at least one sample location. In addition, there was a second set of constituents where the analysis was aimed at confirming analyte absence (at least down to low concentrations). These analyses were also expected to be challenging. Only one replicate per sample was performed for these analytes. The analytical results for these single analyses were applied to that tank's residuals.

For the majority of the analytical methods, specific sample batch preparation instructions were provided with R&D directions, which are essentially customized sets of instructions for the preparation of a sample batch and the associated quality control measurements for that sample batch (blank, blank spike, serial dilution, internal standard, tracer, etc.). These R&D directions were provided to the staff members that prepared and analyzed the sample batch, and they were filed in lab notebooks and/or the data packages as records. In addition, each analytical instrument had a Measurement Control Plan document that provided broad guidelines for the calibration and quality control associated with instrument operation as well as a history file that contained calibration and maintenance records.

The analytical procedures and quality assurance/quality control measures used for the Tank 18 and 19 sample analyses are summarized in the final analysis reports. [SRNL-STI-2010-00386, SRNL-STI-2010-00439, SRNL-STI-2009-00802, SRNL-STI-2009-00799] The data was determined sufficient to define fully the waste tank residuals.

4.3.3 Statistical Evaluation of Results

A statistical study of sampling results was performed providing the ability to characterize the waste tank as homogeneous. The study showed that a comparison of the range of relative standard deviations to the mean fell within a three sigma limit. Figure 4.3-3 shows the relative standard deviation for each sample taken from Tank 18 and Figure 4.3-4 shows the relative standard deviation for each sample taken from Tank 19. The purpose of these figures is to demonstrate the strong statistical agreement of the results from all samples as data points. Each data point was calculated by subtracting the average and dividing by the standard deviation. The data proves to be consistent since all fit within a range of plus or minus three standard deviations as shown Figures 4.3-3 and 4.3-4. This is also important because it provides confidence that the number of samples analyzed was sufficient to characterize the residual material on the floor. [SRR-CWDA-2010-00117, SRR-CWDA-2010-00118]

Figure 4.3-3: Relative Standard Deviations for the Tank 18 Sample Results

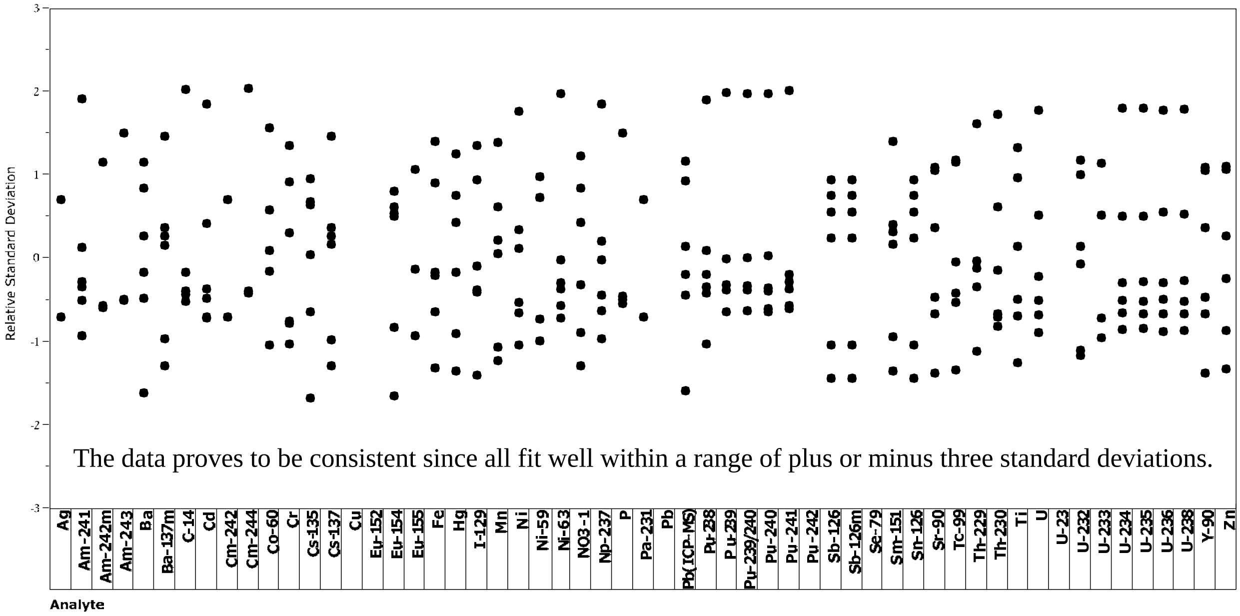
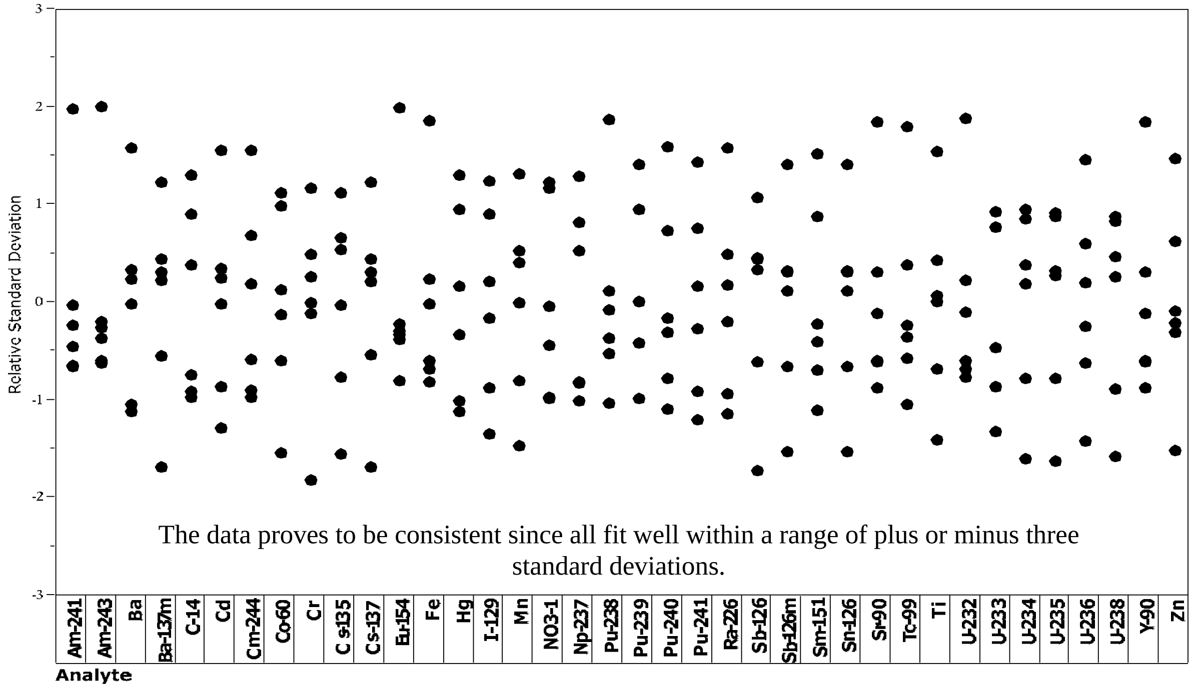


Figure 4.3-4: Relative Standard Deviations for the Tank 19 Sample Results



The data proves to be consistent since all fit well within a range of plus or minus three standard deviations.

This study proceeded to determine the averages, standard deviations, and upper 95% confidence limits for those constituents where sample analyses provide measured results. This included constituents where the sample results were mixed with measured values and detection limits. For these constituents, only the measured values were used to calculate the statistics, which conservatively increased the confidence limits. The 95% upper confidence limits were used to determine the best-estimate inventory. Since only the measured values were used to determine the statistical parameters, in some cases the amount of measured results was limited to a small number. The statistical analysis of this subset was affected by the limited number of sample results and resulted in increasing the variance and the 95% confidence limit significantly.

There were some constituents that were not within the detection limits of the analytical instrumentation in any of the samples and results were therefore classified as the detection limits of the instrumentation. In this case, no statistical analysis was performed. The analysis of constituents with very low concentrations reached the limits of the analytical equipment and process. Based on many factors, such as interference from other radionuclides, the reported detection limit can differ between sample analyses. For the best-estimate characterization, the lowest detection limit reached was chosen as the concentration for the waste tank. [SRR-CWDA-2010-00117, SRR-CWDA-2010-00118]

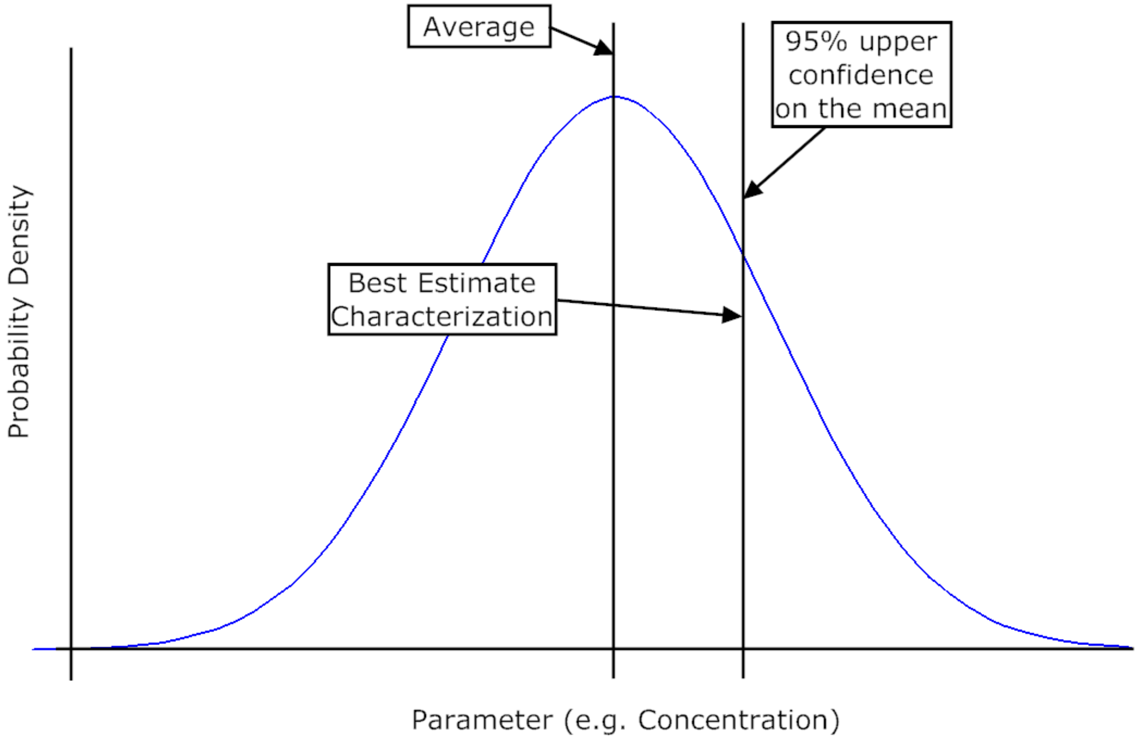
4.3.4 Quantification of Residual Contaminants

The methodology used to develop the residual characterization summed the inventory from separate areas (e.g., floor, wall) of the waste tank. The inventory for each area was determined by taking the material concentration and multiplying it by the corresponding volume (or surface area). This process was repeated for each constituent (radionuclides and chemicals).

The residual material concentrations were determined from the sample analyses. A statistical study was performed for evaluation of the sample analyses to determine the average concentrations. To account for the uncertainty associated with the sampling methods and analyses, conservatism was added to the average values to determine the 95% upper confidence on the mean value. These higher values were used to determine the residual inventory, which was labeled the "Best Estimate" characterization.

Figure 4.3-5 illustrates the level of conservatism and the approach used in the characterization. [SRR-CWDA-2010-00117, SRR-CWDA-2010-00118]

Figure 4.3-5: Illustration of Various Levels of Conservatism



Using the Best Estimate values, the inventories for each of the separate areas was determined and then summed for the total residual inventory for both Tanks 18 and 19. These Best Estimate characterizations were used for modeling the fate and transport of the hazardous chemical constituents and radionuclides. A more in-depth description of the methodology and determination of the Tank 18 and 19 residual inventories are provided in the *Tank 18 Residual Characterization Report* and the *Tank 19 Residual Characterization Report* for all of the analytes. Chemical contaminant inventories are presented in Table 4.3-3 and radiological contaminant inventories are presented in Table 4.3-4. [SRR-CWDA-2010-00117, SRR-CWDA-2010-00118] Additional information can be found in the *Tank 18/Tank 19 Special Analysis for the Performance Assessment for the F-Tank Farm at the Savannah River Site*. [SRR-CWDA-2010-00124]

Table 4.3-3: Residual Chemical Inventories for Tanks 18 and 19

Constituent	Tank 18 (kg)	Tank 19 (kg)
Aluminum	3.6E+03	1.3E+03
Antimony	8.8E+00	3.5E+00
Arsenic	8.5E-02	2.9E-02
Barium	5.4E+00	8.0E+00
Boron	6.7E+00	1.6E+00
Cadmium	1.6E+02	1.2E+00
Chloride	1.0E+01	2.0E+00
Chromium	1.2E+01	3.0E+00
Copper	1.8E+00	5.0E-01
Fluoride	8.3E+00	1.5E+01
Iron	1.9E+03	4.0E+02
Lead	1.2E+01	3.5E+00
Manganese	2.4E+02	1.6E+01
Mercury	1.7E+01	3.8E+00
Molybdenum	5.5E+00	1.1E+00
Nickel	2.4E+01	2.3E+00
Nitrate	8.2E+00	1.7E+02
Nitrite	9.6E+00	8.8E+01
Phosphate	3.3E+00	1.4E+00
Selenium	1.7E-01	8.8E-03
Silver	4.5E+00	7.1E-01
Strontium	4.2E+00	1.6E+00
Sulfate	7.2E+00	3.7E+01
Uranium	9.0E+02	1.6E+01
Zinc	3.9E+00	6.9E-01

[SRR-CWDA-2010-00117, SRR-CWDA-2010-00118]

Table 4.3-4: Residual Radiological Inventories for Tanks 18 and 19

Radionuclide	Tank 18 Actual Curies	Tank 19 Actual Curies	Radionuclide	Tank 18 Actual Curies	Tank 19 Actual Curies
Ac-227	1.5E-04	9.6E-06	Pa-231	4.6E-02	6.9E-05
Al-26	1.9E-04	3.8E-05	Pd-107	1.2E-01	2.0E-01
Am-241	1.6E+02	2.6E+00	Pt-193	3.6E-03	1.5E-03
Am-242m	3.8E-02	2.5E-04	Pu-238	1.3E+03	3.4E+00
Am-243	2.3E+00	6.8E-03	Pu-239	2.8E+02	4.0E+00
Ba-137m	8.7E+03	4.0E+03	Pu-240	6.5E+01	9.8E-01
C-14	9.0E-01	4.1E+00	Pu-241	2.7E+02	3.9E+00
Cf-249	2.3E-03	5.2E-04	Pu-242	2.7E-02	1.7E-03
Cl-36	2.8E-04	9.1E-05	Pu-244	6.2E-06	5.3E-06
Cm-243	1.8E-02	1.7E-03	Ra-226	3.4E-03	4.1E-03
Cm-244	9.8E+01	2.7E-01	Sb-126	1.8E-03	4.7E-04
Cm-245	1.2E-02	1.6E-03	Sb-126m	1.3E-02	3.3E-03
Cm-247	2.1E-06	1.3E-06	Se-79	4.8E-04	4.6E-04
Cm-248	9.5E-05	5.8E-05	Sm-151	3.7E+01	1.5E-01
Co-60	3.2E-01	1.2E-02	Sn-126	1.3E-02	3.3E-03
Cs-135	3.0E-02	5.4E-02	Sr-90	2.5E+03	6.9E+00
Cs-137	9.2E+03	4.2E+03	Tc-99	9.0E-01	3.8E-01
Eu-152	4.7E-03	1.7E-04	Th-229	8.9E-04	2.0E-04
Eu-154	2.1E-01	3.8E-03	Th-230	2.1E-03	1.1E-04
H-3	8.0E-03	2.5E-03	U-232	6.9E-04	9.5E-05
I-129	2.7E-04	2.2E-04	U-233	4.0E-02	4.3E-03
K-40	1.6E-02	1.0E-03	U-234	3.1E-01	4.8E-03
Nb-93m	8.6E-02	1.8E-02	U-235	1.1E-02	1.7E-04
Nb-94	5.5E-04	1.0E-04	U-236	1.2E-02	2.5E-04
Ni-59	3.3E-01	3.5E-04	U-238	2.8E-01	5.4E-03
Ni-63	1.6E+01	1.3E-02	Y-90	2.5E+03	6.9E+00
Np-237	1.9E-01	1.5E-03	Zr-93	8.6E-02	1.8E-02

[SRR-CWDA-2010-00117, SRR-CWDA-2010-00118]

5.0 PERFORMANCE EVALUATION

The FTF PA (SRS-REG-2007-00002) was prepared to support closure of the FTF underground radioactive waste tanks and ancillary structures. The purpose of the FTF PA modeling of contaminant release from within waste tanks that have been removed from service is to evaluate the potential impact on human health and the environment. Therefore the assumed quantity of contaminants is the starting point of this process. A methodical approach was used to construct estimates of FTF waste tank closure inventories to be used in PA modeling. This approach considered current tank inventories, uncertainties in the effectiveness of tank cleaning technologies, laboratory detection limits, decay products and half-lives of radionuclides. The initial FTF inventory projection is provided in *F-Tank Farm Closure Inventory for use in Performance Assessment Modeling.* [SRR-CWDA-2009-00045]

The PA provided the technical basis and results to be used to predict residual contaminant status over time. An Integrated Conceptual Model (ICM) was prepared for the PA to evaluate the performance of the FTF during the 10,000-year period following RFS of all waste tanks and ancillary structures. This ICM is used to evaluate the migration of contaminants from the FTF. The ICM comprises three related conceptual flow models that represent the FTF and the environmental media through which contaminants may migrate: 1) closure cap model, 2) vadose zone model, and 3) saturated zone model.

The ICM simulates the release of radiological and chemical contaminants from the underground waste tanks and the associated ancillary structures in the FTF as well as the migration of the contaminants through soil and groundwater. An independent conceptual waste release model was used to simulate the release of stabilized contaminants from the stabilized waste tanks, based on various chemical phases in the waste tank controlling solubility and thereby affecting the timing and rate of release of the residual inventory. The ICM also considers the integrity of the waste tank steel liners and cementitious barriers in waste tank modeling. In the ICM, steel liner failure triggers contaminant release from the waste tanks. After failure, the carbon steel liner is assumed to be absent, or otherwise not a hindrance to flow, conservatively modeling a spike of material releasing from the tanks. The flow into and out of the stabilized residual material is impacted by the material properties of the waste tank cementitious materials. The expected degradation rate and timing for the waste tank cementitious materials is modeled in the ICM. The ICM also simulates the effect of the cementitious materials and soil on contaminant transport.

As part of the Tank 18 and Tank 19 RFS process, actual residual inventories have been determined for Tank 18 and Tank 19. [SRR-CWDA-2010-00117, SRR-CWDA-2010-00118] The actual residual inventories from Tanks 17, 18, 19 and 20, along with the informed inventory estimates for the remainder of the waste tanks and ancillary equipment in FTF were evaluated in a Special Analysis (SA) to predict the impact of the closure actions. [SRR-CWDA-2010-00124] The FTF Conceptual Model was not changed for the SA, only the Tank 18 and Tank 19 actual residual inventories at closure were updated.

The FTF PA provided technical information at different points of assessment that can be utilized in the subsequent decision documents. The FTF PA provided groundwater radionuclide concentrations at one meter, 100 meters, and exposure points at the two seeplines approximately

1,600 meters from FTF. The groundwater concentrations are provided for each of the three aquifers as a part of the FTF groundwater modeling. The FTF PA also provides groundwater concentrations for various chemical contaminants. The SA simply documents the updated peak radionuclide and chemical concentrations reflecting the replacement of the Tank 18 and Tank 19 estimated inventories in the ICM with actual inventories.

It should be noted that the peak concentrations calculated in the FTF PA and SA are associated with specific locations and times. Since there are multiple unique and independent inventory sources modeled, there is significant temporal and spatial complexity inherent in the modeling system. Removal of any one inventory source may reduce the concentrations (including the peak concentration where applicable) associated with that source, but the overall FTF peak concentrations will not necessarily be reduced by a corresponding amount. The overall FTF concentrations will merely shift to a different location and time. Due to this, completely removing the entire inventory from a single source (e.g., Tank 18) would not necessarily result in an equivalent corresponding concentration reduction, since another waste source (e.g., one of the other waste tanks) would then replace the affected source as the primary contributor to the peak concentration.

Performance objectives applied to FTF waste tank system RFS for groundwater concentrations are as follows:

1) The SCDHEC Primary Drinking Water Regulations for radionuclides (i.e., 4 mrem/yr beta-gamma dose and 15 pCi/L total alpha concentration, and 5 pCi/L total Ra-228 + Ra-226)
2) The SCDHEC Primary Drinking Water Regulation for nonradiological inorganic constituents

[SCDHEC R.61-58]

These performance objectives are used only in the PA process to provide reasonable assurance that during the interim period from tank grouting to final FFA corrective/remedial actions, it can be concluded that groundwater concentrations derived from residual contamination in the tanks and ancillary structures will be within the MCLs. The SCDHEC Primary Drinking Water MCLs are listed in Table 5.1-1. [SCDHEC R.61-58]

5.1 Performance Evaluation Modeling Results

The DOE modeled the groundwater impacts of closing Tanks 18 and 19 using actual inventories from Tanks 17, 18, 19, and 20 and estimated inventories at closure for the tanks that have not completed cleaning. The results of the constituents modeled in the SA are presented along with the MCLs established in SCDHEC drinking water regulations in Table 5.1-1. [SCDHEC R.61-58] In all cases, the results demonstrate that the respective peak concentrations or peak doses remain below the MCL value during the 10,000-year assessment period following closure. Due to the presumed location of a potential closure cap following final closure activities in FTF, the point of assessment was 100 meters from the outer-most edge of the tanks in FTF (i.e., line of demarcation enclosing the FTF waste tanks). The results presented in this section are from the base-case modeling. They are the results from the SA that represent the best estimate or most likely scenario for fate and transport modeling

Table 5.1-1: Modeling Results at the Assessment Point

Constituent	Units	MCL[a]	Peak Groundwater Concentration at FTF Perimeter
Nonradiological			
Antimony	µg/L	6	1.4E-12
Arsenic	µg/L	10	2.5E-03
Barium	µg/L	2,000	4.0E-01
Cadmium	µg/L	5	3.7E+00
Chromium[b]	µg/L	100	5.2E-01
Copper	µg/L	1,300	5.3E-01
Fluoride	µg/L	4,000	1.0E+01
Iron	µg/L	300	2.8E+00
Lead	µg/L	15	2.0E-10
Manganese	µg/L	50	4.1E+01
Mercury	µg/L	2	1.7E-06
Nickel	µg/L	100	6.3E-01
NO_2 + NO_3 (as N)	µg/L	10,000	1.2E+02
Selenium	µg/L	50	8.4E-10
Silver	µg/L	100	9.1E-01
Uranium	µg/L	30	1.7E-03
Zinc	µg/L	5,000	5.3E-01
Radiological			
Beta-gamma dose	mrem/yr	4	1.6
Alpha concentration	pCi/L	15	7.8
Total Ra-226 + Ra-228	pCi/L	5	3.1

[a] [SCDHEC R.61-58]

[b] Total chromium (chromium III and VI)

Maximum Tanks 18 and 19 impacts may occur at times different from the time of maximum FTF impacts. Maximum Tanks 18 and 19 impacts are expected to remain below GCP performance objectives over the next 10,000 years. The peak concentrations for cadmium and manganese, for example, are determined by selecting the highest single concentration of these elements at 100 meters from FTF at any point in the 10,000 years following FTF closure. Both cadmium and manganese were identified as the only two nonradiological Contaminant Migration Constituents of Concern (CMCOC) in the FTF GCP and, as shown in Table 5.1-1, peak concentration values are below the MCL value with the peak cadmium concentration at 74% of the MCL and the peak manganese concentration at 82% of the MCL. The peak cadmium concentration occurs approximately 7,300 years following closure and the peak manganese concentration occurs approximately 5,200 years following closure of the FTF. Since this occurs prior to the release of contaminants from the Type I and III/IIIA tanks in the base-case modeling, the contributing sources are the Type IV tanks and the ancillary structures. [SRR-CWDA-2010-00124, Appendix A]

To determine peak alpha concentration, the sum of the concentrations of alpha emitting isotopes, with the exception of uranium and radon, is determined for each year. The peak alpha concentration in the groundwater at the assessment point occurs approximately 6,000 years following closure of the FTF. The primary contributors are Np-237, Pa-231 and Ra-226. The peak total radium concentration occurs 10,000 years following closure of the FTF. Since this occurs prior to the release of contaminants from the Type I and III/IIIA tanks in the base-case modeling, the contributing sources are the Type IV tanks and the ancillary structures, with Tank 18 being the primary source contributing 91%. [SRR-CWDA-2010-00124, Appendix A]

The peak beta-gamma dose is calculated by comparing the concentration of individual beta and gamma emitters over a 10,000-year period to the derived concentrations of these isotopes that would produce a 4 mrem/yr dose from the EPA *Derived Concentrations (pCi/l) of Beta and Photon Emitters in Drinking Water*. **[www.epa.gov/ogwdw/radionuclides/pdfs/guide_radionuclides_table-betaphotonemitters.pdf]** The derived concentrations were calculated using Federal Guidance Report No. 13, *Cancer Risk Coefficients for Environmental Exposure to Radionuclides* (EPA-402-R-99-001), which provides numerical factors for estimating the risk of cancer from low-level exposure to radionuclides. The sum of the fractions of significant beta-gamma emitting isotopes are determined for each year. If the highest sum of the fractions is less than 1.0, the resultant beta-gamma dose is expected to be below the MCL value. After analysis of the significant beta or gamma contributors to the dose, the peak sum of fractions was determined to be 0.41 and the dose was calculated to be 1.6 mrem/yr (0.41 x 4 mrem/yr). The peak beta-gamma dose at the assessment point occurs approximately 4,200 years following closure of the FTF. The primary contributors are C-14, I-129, Nb-93m, Ni-59, and Tc-99. Since this peak dose occurs prior to the release of contaminants from the Type I and III/IIIA tanks in the base-case modeling, the contributing sources are the Type IV tanks and the ancillary structures, with Tank 18 being the primary source contributing 91%. [SRR-CWDA-2010-00124, Appendix B]

MCLs represent the maximum levels of contaminants that can be present in drinking water directly from a free-flowing tap (e.g., kitchen sink faucet). In developing MCL values, the EPA must consider:

> *(a) incremental costs and benefits associated with a range of MCL values, (b) health effects to the general population and sensitive sub-populations, and (c) any increased health risk to the general population that may occur as a result of the new MCL. EPA may adjust the MCL for particular class or group of systems to a level that "maximizes health risk reduction benefits at a cost that is justified by the benefits.*

[http://water.epa.gov/lawsregs/rulesregs/regulatingcontaminants/basicinformation.cfm]

In the establishment of the MCLs, the associated costs and benefits have been considered. Comprehensive modeling, including uncertainty analysis and sensitivity analysis, has demonstrated reasonable assurance that groundwater concentrations derived from residual contamination in the tanks, including the residual inventory in Tank 18 and Tank 19 will be within the MCLs during the next 10,000 years. Therefore, it may be concluded that there is reasonable assurance that, at the time of final FFA corrective/remedial actions, groundwater concentrations will be within the MCLs.

5.2 Assessment Evaluation

The *SRS Long Range Comprehensive Plan* is based on the following premises: [PIT-MISC-0041]:

- The SRS will be owned and controlled by the federal government in perpetuity
- The property will be used only for industrial purposes
- Site boundaries will remain unchanged
- Residential use will not be allowed onsite

In light of these restrictions, a scenario in which a future hypothetical member of the public establishes a residence directly on the FTF and obtains drinking water from the underlying water table aquifer is extremely unlikely. A more credible, although still highly unlikely, location for the future member of the public to be exposed to the groundwater below the FTF would be at the Upper Three Runs (UTR) seepline or the Fourmile Branch seepline located at least one mile from the FTF. In 1997, the CMs associated with the RFS of Tank 17 and Tank 20 were developed by DOE, approved by SCDHEC and utilized the Fourmile Branch seepline as the point of assessment.

The SA, as described in Section 5.0, provides reasonable assurance that groundwater concentrations derived from residual contamination in the tanks and ancillary structures will be within the MCL values and provides even greater assurance that human health and the environment will continue to be protected after waste tank systems have been removed from service. [SRR-CWDA-2010-00124]

6.0 ASSESSMENT OF THE IMPACT OF DEPLOYING ADDITIONAL REMOVAL TECHNOLOGY

An evaluation has been completed to determine if it is useful (i.e., that the costs, such as monetary costs, delays in higher risk reducing activities, or occupational exposure of site workers to hazardous or potentially hazardous materials including radioactive materials, outweigh the potential benefits associated with further waste removal) to develop and deploy another cleaning technology assuming such a technology could be identified and safely deployed. This cost-benefit analysis considered a broad range of costs including resultant schedule impacts on other on-going cleaning activities and waste disposition activities, and also the current state of waste removal capabilities and technologies. As described below, the analysis shows that the relatively insignificant benefits of removing additional waste from Tank 18 or Tank 19, even a large fraction of the remaining waste if such removal was possible, do not support the costs of implementation or the impacts to on-going and future risk-reduction activities associated with waste removal and stabilization.

6.1 Analysis of Potential Cleaning Technologies

DOE has developed a robust process to assess the technical readiness of new technologies as described in DOE Guide 413.3-4, *U.S. Department of Energy Technology Readiness Assessment Guide*. The process evaluates technology maturity using the Technology Readiness Level scale that was pioneered by the National Aeronautics and Space Administration in the 1980’s. It is through this process that DOE is able to validate that technologies have reached a level of maturity ensuring a high probability of success before they are fully funded and deployed.

There are three broad categories of cleaning technologies that can be deployed for residual heel removal activities in FTF. These include mechanical solids removal, chemical solids removal and vacuum technologies. The following subsections describe the available technologies and their viability for removing additional waste from Tank 18 or Tank 19.

6.1.1 Mechanical Cleaning Technologies

As described in Section 3, initial mechanical cleaning heel removal activities were accomplished in Tank 18 and Tank 19 using an ADMP and Flygt Mixers, respectively. These mechanical cleaning technologies reached diminished effectiveness in their respective tanks and are not viable technologies for additional removal of residuals.

Since suspension of waste removal activities in Tank 18 and Tank 19, the next generation of mixing pumps, submersible mixing pumps (SMPs), have been successfully deployed in Tank 5 and Tank 6, two Type I waste storage tanks in FTF. As with the Flygt Mixers and the ADMP, the SMPs are designed to create vigorous mixing in a tank for the purpose of suspending solids into a slurry that can then be pumped out to another waste tank. In the case of Tank 18 and Tank 19, the receipt tank for this material would be Tank 7.

The SMPs have proven to be very robust and capable pumps but have inherent design features that limit application in Tank 18 or Tank 19. The following summarizes these features:

- A design for placement of the SMPs currently does not exist for a Type IV tank. Although such a design could be developed, such an activity would delay the deployment of the SMPs into a Type IV tank six months. Currently, there are no "spare" SMPs available for deployment in Tank 18 or Tank 19 so new pumps would need to be procured, fabricated and tested prior to installation. The duration from procurement initiation through deployment is twelve to 18 months based on recent experience.
- As was seen in Tank 5 and Tank 6 cleaning, the placement of the SMPs is critical due to the formation of "limited mixing zones" where solids accumulate. Testing outside of a waste tank has indicated an effective cleaning radius (ECR) up to 50 feet at their maximum operating speed. Placement of a single SMP in the center riser of the 85-foot diameter tank would be at the outer range of the theoretical ECR and would likely result in minimal removal and the mounding of solids along the outer wall of the tank. Also, due to the domed roof on Type IV tanks, the SMP would require redesign to extend the 45 feet from the riser to the tank floor. Due to the close proximity of the outer risers to the wall, two limited mixing zones would be present if two SMPs were utilized and a single limited mixing zone would be present if a third SMP were used. A total of four SMPs would be required to fully eliminate the limited mixing zones within the tank. The use of the SMPs to further remove the residuals in Tank 18 or Tank 19 would result in delays in waste removal activities in other tanks as the SMPs and the associated infrastructure necessary to run them would be diverted away from bulk waste removal or heel removal activities in other waste tanks.
- Due to the inability of the ADMP and Flygt Mixers installed in Tanks 18 and 19, respectively, for heel removal to suspend or maintain the heavier, rapidly settling spent zeolite resin in suspension, solids removal efficiency significantly decreased as the liquid level in the tank approached or exceeded the lower operating limit of the mixer(s). This resulted in preferential removal of the light solids (both sludge and salts) leaving the heavier solids in the tanks. [PNNL-12093, WSRC-TR-2004-00036] Due to the vigorous mixing associated with the SMPs, certain liquid levels must be maintained during their use for safety and contamination control reasons. Experience has shown that the pumps must be shut down when the liquid level approaches 30 inches and that the pumps cannot run at their maximum mixing capability below 60 inches. With the particle-size characteristics of the residuals remaining in the tanks, it is unlikely that significant additional waste removal would occur using SMPs due to the need to shut down the mixing in the tank at a liquid level of 30 inches and associated fast-settling nature of the remaining residuals.

Based on the above discussions, no existing mechanical cleaning technology is considered to be a viable candidate for removing additional waste inventories from Tanks 18 and 19.

6.1.2 Chemical Cleaning Technologies

Bulk oxalic acid (BOA) represents the mature chemical cleaning technology that has been successfully demonstrated at the SRS. The BOA cleaning was recently deployed as the chemical heel removal method in Tanks 5 and 6 in 2008 and 2009, respectively. In each waste tank, the majority of the waste tank floor was left with a relatively thin waste layer coupled with some small mounds of material. Following oxalic cleaning campaigns, Tank 5 had an estimated 3,300 gallons of waste and Tank 6 had an estimated 3,600 gallons of solids remaining. [SRR-CWDA-2010-00150] For residual sludge inventories containing appreciable quantities of spent zeolite resin, however, limited success using BOA has been realized. In 1985, a bulk oxalic flowsheet was used to remove solids from Tank 24, a Type IV tank in HTF. Tank 24, like Tank 18 and Tank 19, contained significant quantities of spent zeolite resin loaded with radioactive cesium. Removal effectiveness of the spent zeolite resin was much lower than expected due to the chemical changes to the resins over time in the high caustic environment. [DPST-85-782-TL]

In addition, BOA cleaning has some potentially detrimental downstream impacts to the Liquid Waste System. As an example, using OA to clean a waste tank with an approximate 5,000-gallon sludge heel will result in the creation of approximately 51,000 kilograms of sodium oxalates in the feed to the DWPF and approximately 500,000 gallons of salt waste because of washing required to remove the oxalates from the DWPF feed. In the case of Tank 18, with 4,000 gallons of residual solids, an estimated 41,000 kilograms of sodium oxalates would form resulting in an additional 400,000 gallons of wash water utilized to prepare DWPF feed. These quantities of oxalates result in:

- Additional wash cycles to the DWPF sludge batch feed preparation
- An increased likelihood of feed breaks to the DWPF
- Significant volumes of feed to salt waste treatment processes such that the construction of additional Saltstone Disposition Facility disposal cells would be required
- Extension of the operating life requirements for the entire Liquid Waste System [SRR-STI-2010-00015]

The oxalates are also anticipated to create evaporator foaming and scaling problems, which would in turn, impact the rate at which tank space is recovered through evaporation. [LWO-SPT-2008-00033]

Enhanced chemical cleaning (ECC), which is in the preliminary design stage, is a process that is being explored to minimize the downstream impacts introduced by the BOA flowsheet. As currently envisioned, the ECC process will use dilute OA to dissolve or facilitate suspension of residual waste solids and clean the tank internals. The oxalates in the resulting acid stream are then destroyed using ozone. [SRR-STI-2010-00015] The dissolved metals, and associated radionuclides precipitate out and are transferred to a Type III or IIIA waste tank. Consequently, the ECC concept minimizes the impacts of using OA for residual heel removal, and potentially permits additional cleaning opportunities. [LWO-SPT-2008-00033]

Due to the adverse downstream impacts associated with BOA cleaning and its relative ineffectiveness in removing spent zeolite resin, BOA has been eliminated from further consideration. ECC, which is in the developmental stage and is not ready for deployment, also would not be a viable candidate for removing additional waste inventories from Tanks 18 and 19 as prioritizing the deployment of ECC in Tanks 18 and 19 would delay the waste removal and tank closure activities for other old-style tanks, many of which have a history of leakage from the primary tanks.

6.1.3 Vacuum Cleaning Technology

As discussed extensively earlier in Section 3, the prototypical Mantises initially deployed in Tanks 18 and 19 reached diminished effectiveness due, in combination, to design limitations for removal of thin layers of waste from the tank bottom and degradation of equipment parts due to the abrasive nature of the high-pressure water sprays that create the vacuum and the waste passing through the unit. Repair of the equipment to improve degraded removal efficiency is not an option due to the integral nature of the eductor and spray nozzles within the device and the associated high occupational exposure that would result from such “hands-on” maintenance activities.

However, lessons learned from the Mantis operations identified potential design improvements/upgrades (e.g., redesigned rubber squeegee device, suction head, drive mechanism, strainer, etc.), which could potentially result in removing some additional fraction of waste inventories from the tanks. Consequently, an upgraded Mantis could potentially be used for removing additional waste from Tanks 18 and 19; however, it is not possible to predict the removal effectiveness that would be realized by developing/deploying an upgraded Mantis device. As described above, the development process for a revised Mantis would be consistent with DOE Guide 413.3-4, and the upgraded device would not be deployed until its technology maturity was fully developed through simulant testing in a non-hazardous environment.

Based on cost estimates recently developed for future cleaning activities in HTF Type IV waste tanks where heel removal is planned to be accomplished using the Mantis technology, development and deployment of an upgraded Mantis, transfer line and associated sampling for Tank 18 or Tank 19 would cost approximately $8.0M. See Table 6.1-1 below for details. [90012101 Tank 21 Closure]

Table 6.1-1: Estimated Project Cost Summary for the Development/Deployment of an Upgraded Mantis in Each Tank

Description	Estimated Cost $k
Engineered Equipment	$4,050
Water Wash Tool	183
Transfer Line	523
Mantis Installation	119
Construction Equipment & Material	261
Demobilization	198
Execution	178
Sampler Crawler	42
Total Support Cost [a]	1,246
Sampling Support	1,267
Total Estimated Project Cost	**$8,067**

[a] The Total Support Cost includes costs for support provided by Design, Design Authority, Operations, Engineering, Maintenance, Craft, Training, Procedures, Environmental Compliance Authority, Radcon, Camera Crew, and Generator Certification Official personnel.

The development, design, testing and deployment duration for a Mantis with upgraded features is estimated to be at least two years. This is comparable to the timeframe required to design, test and deploy the first Mantises in Tank 18 and Tank 19. [LWO-CES-2006-00006, U-ESR-F-00041, U-ESR-F-00042] The operational time is estimated to be another three months before supplemental cleaning operations are completed. This would impact the ability to meet the respective FFA RFS commitments and potentially impact funding and FFA commitments for subsequent waste tanks scheduled to undergo RFS.

Deploying an upgraded Mantis in Tanks 18 and 19 would have an adverse impact on the already critical tank space in the Liquid Waste System and hinder cleaning activities in the remaining Type I tanks in FTF by tying up common infrastructure including transfer lines, diversion boxes and Tank 7, the hub tank for waste removal activities in the old-style tanks in FTF. These actions could further adversely impact the timely preparation of feed for the DWPF, resulting in a slow-down of operations or a feed break requiring shutdown of the facility. Considering the widespread dispersion of the residual waste in Tanks 18 and 19, an upgraded Mantis, if deployed, would have significantly diminished removal efficiency as related to the quantity of waste removed versus the amount of water required to remove the residual waste (i.e., gallons of waste removed per gallons of new waste created in the receipt tank). Individual operation of an upgraded Mantis could add approximately 8,000 gallons/day of water to the Liquid Waste System. As evaporator staging space is limited, water generation associated with continued waste removal operations in Tanks 18 and 19 would impact waste removal and tank closure operations, and could result in delays to preparation of Sludge Batch 7B and Sludge Batch 8, and a potential feed break at DWPF.

The negative consequences and costs of deploying an upgraded Mantis, combined with the anticipated inefficient removal of additional residuals from either Tank 18 or Tank 19, do not justify additional use of vacuum technology.

6.2 Estimated Dose Reduction

In the FTF PA, Revision 1, informed estimates were made on the ultimate inventory that would remain in Tank 18 and Tank 19 at the time of FTF closure. [SRS-REG-2007-00002] As described in Section 4, extensive residual volume determination, and sampling and analysis were performed to characterize the Tank 18 and Tank 19 residuals. [SRR-CWDA-2010-00117, SRR-CWDA-2010-00118] A SA was performed and documented to evaluate the impact of the final residual inventory remaining in both Tank 18 and Tank 19. The SA utilizes the same deterministic (PORFLOW) and probabilistic (GoldSim) conceptual models that were developed for the FTF PA. [SRR-CWDA-2010-00124] For FTF tanks that have been cleaned and fully characterized (i.e., Tanks 17, 18, 19, and 20), the actual final residual inventory was used in the fate and transport modeling. For the remaining waste tanks and ancillary equipment, the same informed estimates of final inventories as were originally used in the PA were utilized in the model.

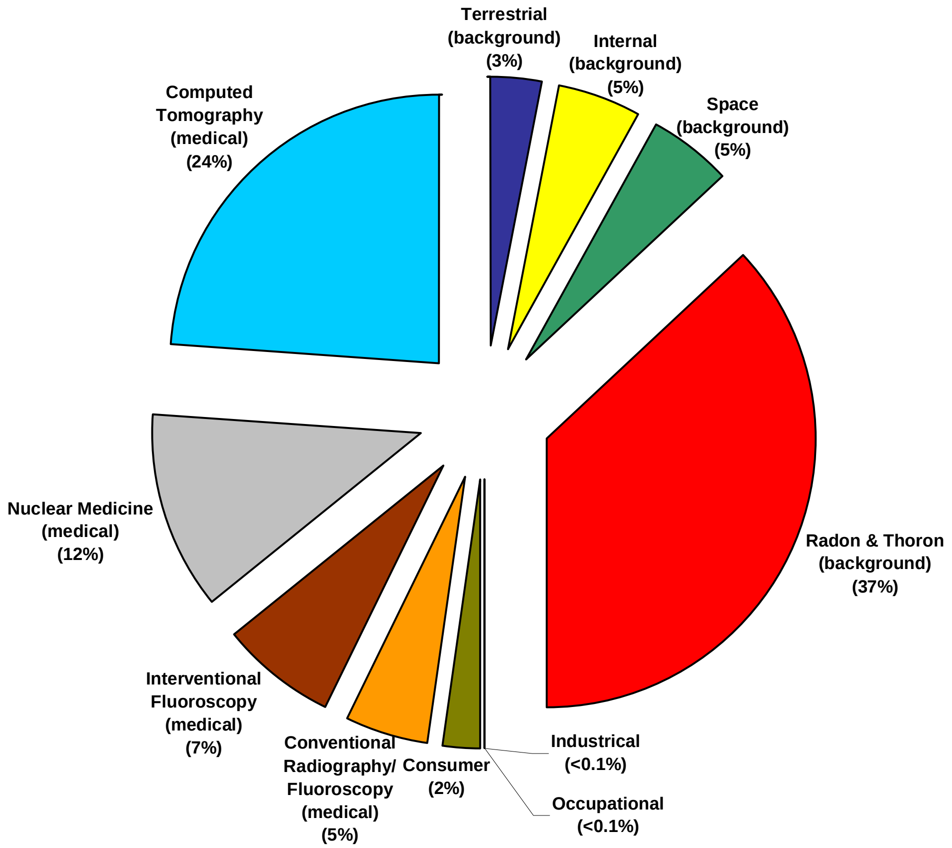
As discussed in Section 5 and shown in Table 5.1-1, with the actual Tank 18 and Tank 19 inventories, the projected peak groundwater concentrations at the assessment point remain below the MCLs for the 10,000-year assessment period despite the use of reasonably conservative modeling assumptions. This analysis provides reasonable assurance that the groundwater contaminant concentrations derived from residual contamination in the tanks and ancillary structures removed from service, including the current inventory of residuals in Tank 18 and Tank 19, will be within the MCLs. Therefore, it may be concluded that further residual removal is not technically practicable from an engineering perspective.

Although not under the scope of the FTF GCP, but to put into perspective the radiological dose impacts, the results of the SA also determined that the peak all-pathways radiological dose to a member of the public living at 100 meters from the FTF boundary at any point in time for the next 10,000 years is 3.4 mrem/yr. Tank 18 contributes approximately 3 mrem to the peak dose or about 91% of the total annual peak dose. Tank 19 contributes less than 0.1 mrem to the annual peak dose. [SRR-CWDA-2010-00124] It should be noted that the peak all-pathways dose cannot be directly compared to the gross beta-gamma MCL value shown in Table 5.1-1 (i.e., 4 mrem/yr) nor to the value calculated for comparison purposes versus the gross beta-gamma MCL (i.e., 1.6 mrem/yr). The MCL was derived to establish acceptable concentrations in drinking water. The assumptions used to calculate this MCL value differ from those used to calculate an all-pathways peak dose. For example, the MCL calculations utilized dose conversion factors associated with International Commission on Radiological Protection (ICRP)-72 that were developed in the 1950’s when knowledge of the biological effects on humans from various radionuclides was limited. The all-pathways dose determined in the SA utilized dose conversion factors associated with ICRP-72, reflecting the current state of knowledge on human health effects. In addition, while the MCL is only assessing hazards associated with drinking water, the all-pathways dose considers much broader resident scenarios involving drinking and showering with water from a contaminated well but also using the contaminated water to grow livestock and crops that are consumed by the hypothetical individual. The FTF PA provides a detailed description of the pathways for exposure associated with the all-pathways dose.

To determine the potential risk reduction from removing additional residual waste, it was assumed that some unidentified technology such as an upgraded Mantis could be developed and deployed in Tank 18 and Tank 19 that could remove 50% of the existing residual waste. Based on this assumption, an evaluation was performed using the FTF GoldSim computer model. A discussion of the GoldSim FTF model and the individual parameters in the model is provided in the FTF PA. [SRS-REG-2007-00002] A peak dose was determined with the final Tank 18 and Tank 19 inventories at closure using the GoldSim FTF model Base Case input parameters and Base Case configuration. The model was then run with 50% of the Tank 18 and Tank 19 inventories at closure to evaluate the change in peak dose from the potential inventory reduction. The peak year dose in 10,000 years with the 50% reduction in Ci is approximately 55% of the base case peak dose. It should be noted that the base case peak dose in GoldSim could differ slightly from the PORFLOW FTF model peak dose due to the inherent characteristics of the two models, as discussed in Section 5.6.2 of the FTF PA. [SRS-REG-2007-00002] However, the magnitude and timing of the peak doses are similar such that valid sensitivity trends can be analyzed using the GoldSim FTF model. Therefore, the potential expected reduction in dose from a 50% reduction in the residual waste curies from Tanks 18 and 19 would only be approximately 1.3 mrem/yr.

All human beings are exposed to sources of ionizing radiation that include naturally occurring and man-made sources. To put this estimated reduction of 1.3 mrem/yr to a member of the public living 100 meters from the closed FTF in perspective, on average, a person living in the United States receives approximately the same annual radiation dose of 620 mrem/yr. Figure 6.2-1 provides a breakdown of this exposure.

Figure 6.2-1: Major Sources of Radiation Exposure Near SRS



The major source of radiation exposure to an average member of the public in the Central Savannah River Area is attributed to naturally occurring radiation (311 mrem/yr) and medical exposure (300 mrem/yr). This naturally occurring radiation is often referred to as natural background radiation and includes dose from background radon and its decay products (228 mrem/yr), cosmic radiation (33 mrem/yr), internal radionuclides occurring naturally in the body (29 mrem/yr), and natural radioactive material in the ground (21 mrem/yr). The dominant medical sources include dose from computed tomography (147 mrem/yr), nuclear medicine (77 mrem/yr), and radiography/fluoroscopy (77 mrem/yr). The remainder of the dose is from consumer products (13 mrem/yr), industrial/ educational/research activities (<1 mrem/yr), and occupational exposure (<1 mrem/yr). [NCRP-160]

With the current inventory of residuals in Tank 18 and Tank 19, the all-pathways peak dose (i.e., the highest single year dose in the 10,000 years following closure of FTF) is estimated to be less than 4 mrem. [SRR-CWDA-2010-00124] This peak dose is less than two percent of the naturally occurring background radiation in this area, and less than one percent when considering all sources of radiation exposure to the average person living in the United States.

6.3 Assessment Conclusion

Based on this evaluation of technology capability, schedule and quantified cost/benefit analysis, deployment of additional waste removal technology would not be practicable for the following reasons:

Technology Evaluation Summary

- No new practicable technology has been identified that has reached a level of maturity for deployment to remove a significant additional concentration of constituents of concern from Tank 18 or Tank 19. The three broad categories of cleaning technologies (i.e., mechanical, chemical and vacuum) which have been used at SRS were evaluated for viability in removing additional waste.
    - SMPs, the latest in mechanical cleaning technology, have been effective in subsequent tanks (i.e., Tanks 5 and 6) but are not attractive for Tanks 18 or 19 for the following reasons.
        - Design for the installation in a Type IV tank does not exist and the estimated duration from procurement to deployment is 12 to 18 months.
        - With the particle-size characteristics of the residuals remaining in Tanks 18 and 19 it is unlikely that significant additional waste removal would result from using SMPs due to the need to shut down the mixing in the tank at a liquid level of 30 inches and associated fast-settling nature of the remaining residuals.
        - The use of the SMPs to further remove the residuals in Tank 18 or Tank 19 would result in delays in significant risk reduction activities through waste removal in other tanks as the SMPs and the associated infrastructure necessary to run them would be diverted away from bulk waste removal or heel removal activities in other waste tanks.
    - Due to the adverse downstream impacts associated with BOA cleaning, the current baseline chemical cleaning technology and its relative ineffectiveness in removing spent zeolite resin, BOA has been eliminated from further consideration. ECC, which is in the developmental stage and is not ready for deployment, also would not be a viable candidate for removing additional waste inventories from Tanks 18 and 19 as prioritizing the deployment of ECC in Tanks 18 and 19 would delay the waste removal and tank closure activities for other old-style tanks, many of which have a history of leakage from the primary tanks into the secondary containment structures.
    - The prototypical Mantises, a vacuum cleaning technology, deployed in Tanks 18 and 19 reached diminished effectiveness due, in combination, to design limitation for removal of thin layers of waste from the tank bottom and degradation of equipment parts due to the high-pressure sprays that create the vacuum and the waste passing through the unit.

Cost/Benefit Analysis Summary

- Though no new practicable technology was identified in the technology evaluation, a cost/benefit analysis was performed to determine the potential risk reduction from removing additional residual waste from Tanks 18 and 19. As input to the analysis, it was assumed that an upgraded Mantis could be developed and deployed in Tank 18 and

Tank 19 that could remove 50% of the existing residual waste. The upgraded Mantis was selected for the evaluation because it was considered to have the highest likelihood of success in removing additional residual waste, it could be deployed in the least amount of time, and it would be the least costly technology alternative to implement.

- The development, design, testing and deployment duration for an upgraded Mantis is estimated to be at least two years.
- Based on cost estimates recently developed for future cleaning activities in HTF Type IV waste tanks where heel removal is planned to be accomplished using the Mantis technology, development and deployment of an upgraded Mantis, transfer line and associated sampling for Tank 18 or Tank 19 would cost approximately $8.0M. [90012101 Tank 21 Closure]
- Deploying an upgraded Mantis in Tanks 18 and 19 would have an adverse impact on the already critical tank space in the Liquid Waste System and hinder cleaning activities in the remaining Type I tanks in FTF by tying up common infrastructure including transfer lines, diversion boxes and Tank 7, the hub tank for waste removal activities in the old-style tanks in FTF.
- Deploying an upgraded Mantis in Tanks 18 and 19 would result in additional worker exposure ranging from 250 person-mrem to 1,200 person-mrem. [U-ESR-F-00035]
- Assuming that an upgraded Mantis could remove 50% of the remaining solids in Tanks 18 and 19, the potential expected reduction in dose from a 50% reduction in the residual waste curies from Tanks 18 and 19 in any year over a period of the next 10,000 years would only be approximately 1.3 mrem/yr to a member of the public living 100 meters from the closed FTF. [SRR-CWDA-2010-00124]
- To put this estimated reduction of 1.3 mrem/yr in perspective, on average, a person living in the United States receives approximately the same annual radiation dose of 620 mrem each year. [NCRP-160]

Therefore, even if a technology could be identified and deployed, the relatively insignificant reduction of risk associated with further removal of residuals from Tank 18 or Tank 19 does not justify the associated additional costs including the resulting delays in other risk-reducing activities in the Liquid Waste System. Therefore, it may be concluded that further residual removal is not technically practicable from an engineering perspective.

7.0 WASTE TANK SYSTEM ISOLATION PROCESS AND STABILIZATION STRATEGY

This section summarizes the planned waste tank system isolation process and subsequent stabilization strategy to be implemented on Tanks 18 and 19 after waste removal is complete. In particular, the following attributes will be described.

- Waste tank system isolation process and final configuration of the waste tank system
- Description of structures and equipment that are part of this RFS activity including any equipment that will remain in Tank 18 or Tank 19 at the time of RFS
- Stabilization strategy including type and characteristics of fill material (i.e., grout), as appropriate

7.1 Waste Tank System Isolation Process

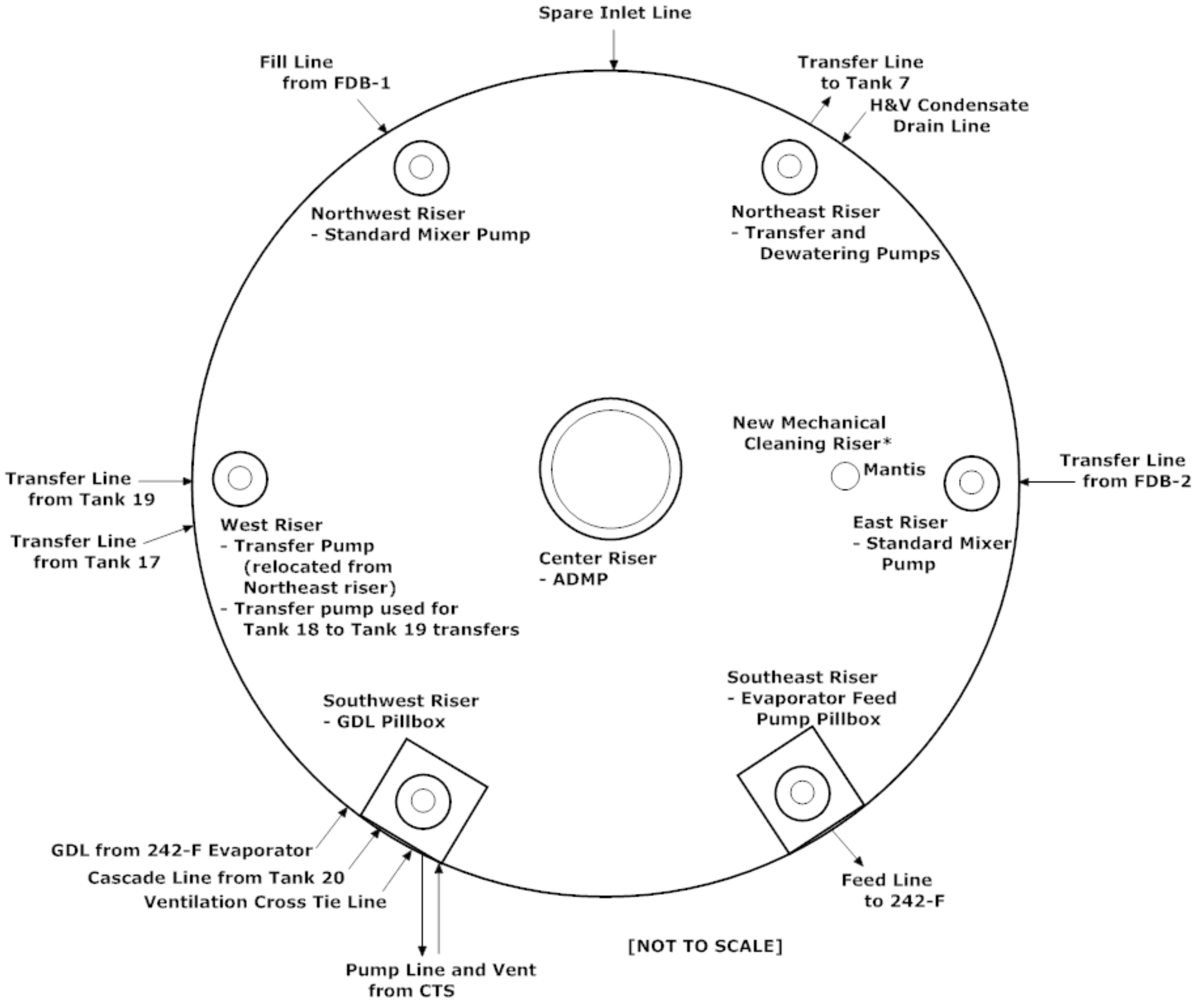
The isolation processes for Tanks 18 and 19 will isolate each waste tank from the FTF Waste Transfer System (WTS) and the FTF support systems. Implementation of the process consists of identification and isolation of transfer lines, drain lines, water, air, and steam supply lines, ventilation lines, power and instrumentation lines and all other penetrations into or out of the waste tank. Isolation of these systems will be performed at the electrical control rooms for electrical services and instrumentation and at the system supply headers located off the waste tank top for mechanical systems. Where practical, accessible piping and conduit will be removed creating physical break from the waste tank. Other pipes will be plugged or capped to isolate them from the FTF transfer line system. Isolating all systems from the waste tank will render the waste tank closed to waste processing activities. [M-CTP-F-00003, M-CTP-F-00004]

7.1.1 Tank 18 System Isolation

As a waste tank is filled with grout, grout material will flow into the abandoned waste tank and riser penetrations, thereby sealing and effectively isolating the abandoned lines. This will eliminate the risk of transferring waste into or out of the waste tank through the abandoned lines. Though the grout will seal the abandoned lines at the waste tank penetrations, there are no current plans to fill the abandoned FTF transfer lines exterior to the waste tank with grout. The waste transfer lines were modeled in the FTF PA with no grout and the results predicted compliance with the required performance objectives. [SRS-REG-2007-00002] Since any residual waste would be on the interior wall of the transfer lines and the leach rate would not be significantly influenced by grouting of the transfer line, then there is no environmental benefit to grouting these small diameter (3 or 4-inch) transfer lines. In addition, due to the small diameter of the transfer piping there is no long-term subsidence issue requiring stabilization of the lines. Additional details on the isolation plans of the Tank 18 systems from the FTF WTS and support systems can be found in the Tank 18 Closure Isolation Plan. [M-CTP-F-00003] The isolation plans will continue to be updated, as new information is made available from field walkdowns and tank inspections.

The thirteen Tank 18 transfer line wall or riser penetrations to be isolated during the Tank 18 RFS are shown on Figure 7.1-1 and are described in Table 7.1-1.

Figure 7.1-1: Tank 18 Riser and Transfer Line Locations



* The mechanical cleaning riser is a 24-inch diameter opening that was installed for mechanical cleaning equipment.

Table 7.1-1: Tank 18 Penetrations

Line Description	Line Size	Location
Spare Inlet Line	3-inch inner diameter (ID)	Penetrates the waste tank north wall and is approximately 33 feet above the waste tank bottom.
Cascade/Transfer Line from Tank 20	4-inch ID with 6-inch outer diameter (OD) jacket	Penetrates the waste tank southwest wall and is approximately 33 feet above the waste tank bottom. The pipe extends into the waste tank approximately 3 feet.
Gravity Drain Line (GDL) / Vent from the 242-F Evaporator	1.5-inch ID core, with a 3-inch OD jacket	Penetrates the waste tank southwest riser and is approximately 43 feet above the waste tank bottom.
Vent from Concentrate Transfer System (CTS)	3-inch ID, 4-inch OD jacket	This vent from CTS Nozzle 13 penetrates the southwest riser and is approximately 43 feet above the waste tank bottom.
Pump Line from CTS	1.5-inch ID, 3-inch OD jacket	This line from CTS Nozzle 14 penetrates the waste tank southwest riser and is approximately 43 feet above the waste tank bottom.
Ventilation Cross Tie Line	4- inch ID, 6-inch OD jacket diameter	This line extends from the northwest riser of Tank 20, penetrates the southwest riser of Tank 18 and is approximately 36.5 feet above the waste tank bottom.
Heating and Ventilation Condensate Drain Line to Northeast Riser	2-inch ID	This line runs from the portable H&V unit to the northeast riser of Tank 18. The drain penetrates the earth berm above the waste tank, descends a few feet, makes a right turn, and penetrates the northeast riser approximately 39 feet above the waste tank bottom. The LDB-10 overflow for the jacketed transfer line to Tank 7 ties in to this drain line just before it penetrates the northeast riser
Transfer Line from Tank 19	3-inch ID, 4-inch OD jacket	This line penetrates the West Riser and is approximately 38 feet above the waste tank floor.
Transfer Line from Tank 17	3-inch ID, 4-inch OD jacket	This line from Tank 17 penetrates the West Riser and is approximately 38 feet above the waste tank floor.
Transfer Line from Tank 18 Northeast Riser to Tank 7	3-inch ID, 4-inch OD jacket	This line penetrates the Northeast Riser and runs to Tank 7. The transfer line is approximately 43 feet above the waste tank bottom.
Feed Line to 242-F Evaporator	3-inch ID, 6-inch OD jacket	This line penetrates the Southeast Riser approximately 42 feet above the waste tank bottom and runs to 242-F Evaporator Nozzle 13.
Transfer Line from FTF Diversion Box (FDB)-2 Nozzle 33	3-inch ID, 4-inch OD jacket	This line runs from FDB-2 Nozzle 33 to the East Riser at approximately 43.5 feet above the waste tank bottom.
Fill Line from FDB-1	3-inch ID	This line from FDB-1 Nozzle 28 penetrates the Northwest wall of Tank 18. The fill line penetrates the riser approximately 33.5 feet above the waste tank bottom.

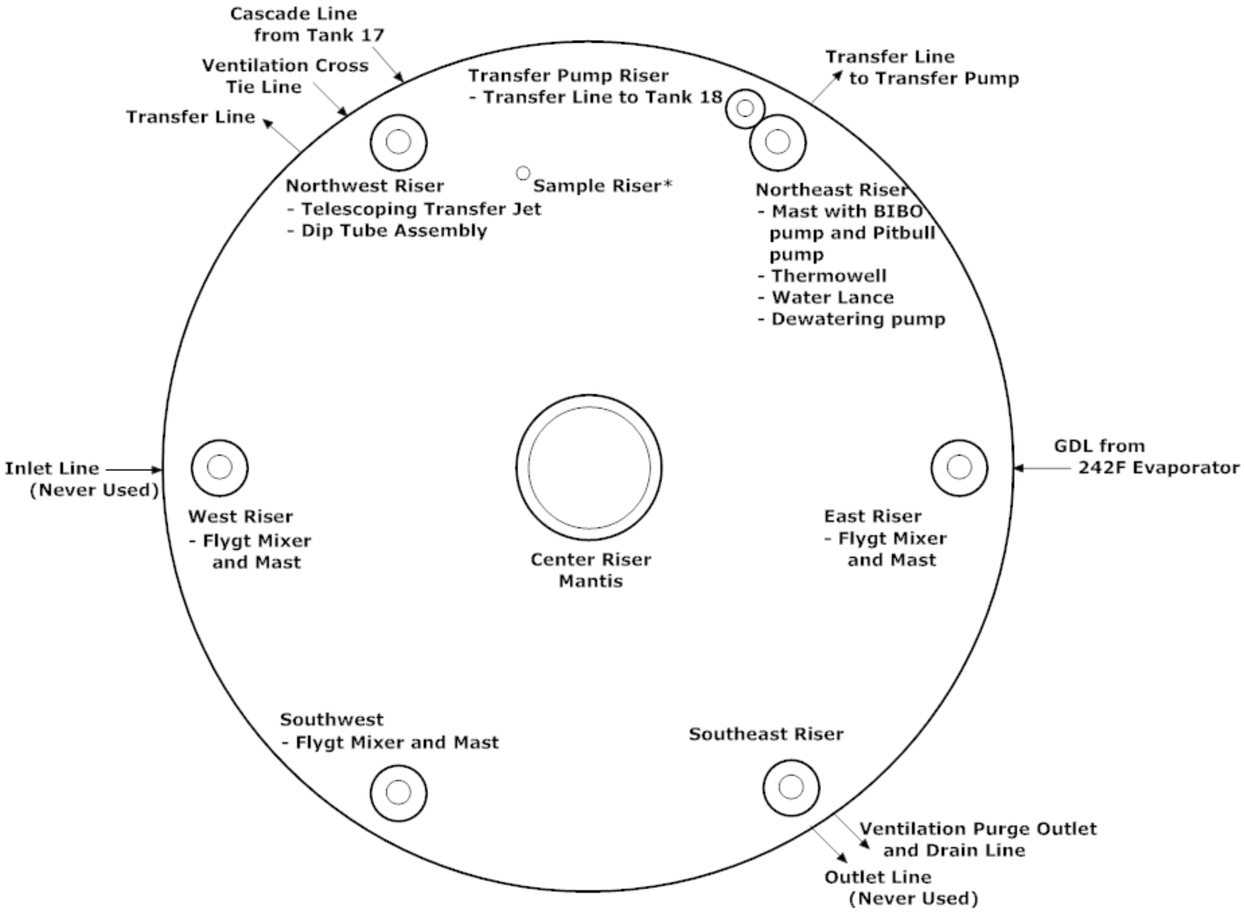
[M-CTP-F-00003]

7.1.2 Tank 19 System Isolation

Tank 19 isolation activities will be performed in the same manner as described in Section 7.1.1 for Tank 18. Additional details on the isolation plans of the Tank 19 systems from the FTF WTS and support systems can be found in the *Tank 19 Closure Isolation Plan.* [M-CTP-F-00004] The isolation plans will continue to be updated, as new information is made available from field walkdowns and tank inspections.

The eight Tank 19 transfer line wall or riser penetrations to be isolated during the Tank 19 RFS are shown in Figure 7.1-2 and are described in Table 7.1-2.

Figure 7.1-2: Tank 19 Risers and Piping Locations



* The sample riser is a 10-inch diameter opening that was core-drilled in the tank roof for sampling access following Phase 3 heel removal with Flygt mixers.

Table 7.1-2: Tank 19 Penetrations

Line Description	Line Size	Location
Inlet Line (never used)	3-inch ID	Penetrates the west waste tank wall and is approximately 33 feet above the waste tank bottom.
Cascade Line from Tank 17	4-inch ID, 6-in OD jacket	Penetrates the northwest waste tank wall, and is approximately 33 feet above the waste tank bottom.
GDL from the 242-F Evaporator	3-inch ID core, 6-inch jacket	This line penetrates the east riser and is approximately 38 feet above the waste tank bottom.
Ventilation Cross Tie Line	6-inch ID	This line extends from the Tank 19 northwest riser (330° riser coordinate) to the southwest riser of Tank 17 and is approximately 38 feet above the waste tank bottom.
Waste Tank Transfer Line	3-inch ID	This line is the discharge line from the Tank 19 transfer jet. It runs from the northwest riser to the transfer pump opening and is approximately 40 feet above the waste tank bottom.
Ventilation Purge Outlet and Drain Line	6-inch ID ventilation pipe and a 2-inch ID drain pipe	The lines extend from the southeast riser to the purge exhaust equipment.
Waste Tank Transfer Line to Transfer Pump Riser	3-inch ID	This line is located in the transfer pump riser located near the northeast riser. It runs from Tank 19 to Tank 18 and is approximately 40 feet above the waste tank bottom.
Outlet Line (never used)	4-inch diameter	This line is in the southeast of the waste tank and is approximately 33 feet above the waste tank bottom.

[M-CTP-F-00004]

7.2 Structures and Equipment Involved with RFS

For both Tanks 18 and 19, waste tank top modifications will be made to accommodate waste tank grouting and riser capping activities. Riser capping will be performed to isolate risers and structures protruding from a riser. After external motors, piping, electrical, and instrumentation commodities have been removed from the riser, a grout form will be built around and over the riser and remaining structures will be encapsulated with grout. Post-grout modifications will remove the remaining structural steel trusses, mechanical and electrical piping/conduit, instrumentation and power cables/wiring, raceways, motors, and any other remaining equipment from the waste tank top footprint. The waste tank top will be free of all mechanical, structural, and electrical commodities. Only the grouted riser caps will remain within the footprint of the waste tank's tank top.

Each waste tank riser will be filled with grout through the lower sections of each riser. Additional details on the isolation of the waste tank mechanical, electrical, equipment, and piping systems from service are presented in the *Tank 18 Closure Isolation Plan* [M-CTP-F-

00003] and the *Tank 19 Closure Isolation Plan.* [M-CTP-F-00004] The isolation plans will continue to be updated, as new information is made available from field walkdowns and tank inspections.

Several large pieces of equipment used in supporting waste removal and heel removal from the tank will be entombed in place with grout and connected to the risers in which they are located, as part of the RFS process for both Tanks 18 and 19. Equipment planned to be entombed in the grout as part of the RFS process for Tanks 18 and 19 are included in Table 7.2-1 and 7.2-2, respectively. [M-CTP-F-00003, M-CTP-F-00004] Internal space in this equipment will be filled with grout or other fill material to the extent practical to minimize void space, as the waste tank is filled.

Table 7.2-1: Equipment to Remain in Tank 18

Equipment	Grout Plan	Location
ADMP	Grout interior space	Suspended from Center Riser
Transfer pump (used for Tank 18 to Tank 7 transfers)	Grout discharge pipe	Suspended from Northeast Riser
Transfer pump (relocated from Northeast Riser)	Grout interior space	Suspended from West Riser
Two standard mixer pumps	Grout interior space	Suspended from East and Northwest Risers
Dewatering pump	Not accessible to grout. Minimal void space	On tank floor below Northeast Riser
Transfer pump (used for Tank 18 to Tank 19 transfers)	Discharge pipe is in the tank below riser, so not accessible for grouting. Bulk fill grout expected to flow into pipe.	Suspended from West Riser
Evaporator feed pump	Grout pipe and hose and eductor. Pump entombed pillbox above riser	Eductor suspended from Southeast Riser, hose dropped to floor
Robotic crawler used for sampling after heel removal using the ADMP	Not accessible to grout. Minimal void space	On tank floor below Center Riser
Sampling mast used for sampling after heel removal using the ADMP	Grout interior space	Extends from Northeast Riser with the arm resting on the floor below the riser.
Mantis	Not accessible to grout. Minimal void space	On tank floor below New Mechanical Cleaning Riser

Table 7.2-2: Equipment to Remain in Tank 19

Equipment	Grout Plan	Location
Transfer Jet	Grout interior space	Suspended from Northwest Riser
Thermowell	Grout interior space	On tank floor below Northeast Riser
Level Instrumentation (Dip Tube Assembly)	Grout interior space	Suspended from Northwest Riser
Transfer pumps (BIBO, Dewatering, and Pitbull)	Disconnect flexible discharge hoses. Not accessible to grout	On tank floor below Northeast Riser
Three Flygt Mixers	No void space to grout.	Suspended from East, West, and Southwest Risers
Mantis	Disconnect flexible discharge hoses. Not accessible to grout	On tank floor below Center Riser

7.3 Stabilization Strategy

7.3.1 Waste Tank Grouting Selection

In May 2002, DOE issued an Environmental Impact Statement (EIS) on waste tank cleaning and stabilization alternatives. [DOE-EIS-0303] The DOE studied five alternatives:

- Empty, clean and fill with grout
- Empty, clean and fill waste tank with sand
- Empty, clean and fill waste tank with saltstone
- Clean and remove waste tanks
- No action

The EIS concluded the Fill with Grout option was preferred. The DOE also issued a Record of Decision selecting the Fill with Grout alternative for SRS waste tank closure. [DOE-EIS-0303 ROD]

Evaluations described in the EIS showed the Fill with Grout alternative to be the best approach to minimize human health and safety risks associated with closure of the waste tanks. [DOE-EIS-0303] This alternative offers several advantages over the other alternatives evaluated such as:

- Provides greater long-term stability of the waste tanks and their stabilized contaminants than the sand-fill approach;
- Provides for retaining radionuclides within the waste tanks by use of reducing agents in a fashion that the sand-fill would not;
- Avoids the technical complexities and additional worker radiation exposure that the fill-with-saltstone approach would entail;

- Produces smaller impacts due to radiological contaminant transport than the sand- and saltstone-fill alternatives;
- Avoids the excessive personnel radiation exposure, and provides greater occupational safety impact that would be associated with the clean and remove alternative. [DOE-EIS-0303]

Cementitious materials are often used to stabilize radioactive wastes. Grout has been one of the most commonly used materials for solidifying and stabilizing radioactive wastes, and the technology is at a mature stage of development. [ISBN: 0-309-59313-1] The purpose of this stabilization is to maintain waste tank structure and minimize water infiltration over an extended period of time, thereby impeding release of stabilized contaminants into the environment. Grout is a mixture of primarily cement and water proportioned to produce a pourable consistency. Studies have focused on improving grout production and batching, grout flow, measurement of the effective diffusion coefficients in reducing fill grout and measurement of hydraulic properties. [WSRC-STI-2007-00369]

Filling a cleaned waste tank with grout prevents the walls and ceiling from possible collapse thereby providing long-term stability. The grout fill also helps to reduce water intrusion into the waste tank over time. Reducing the amount of water entering a closed waste tank retards the migration of residual materials from the waste tank to the environment. Testing has demonstrated that the chemical and physical characteristics of the grout formula used at SRS retards the movement of chemical constituents. [WSRC-TR-97-0102]

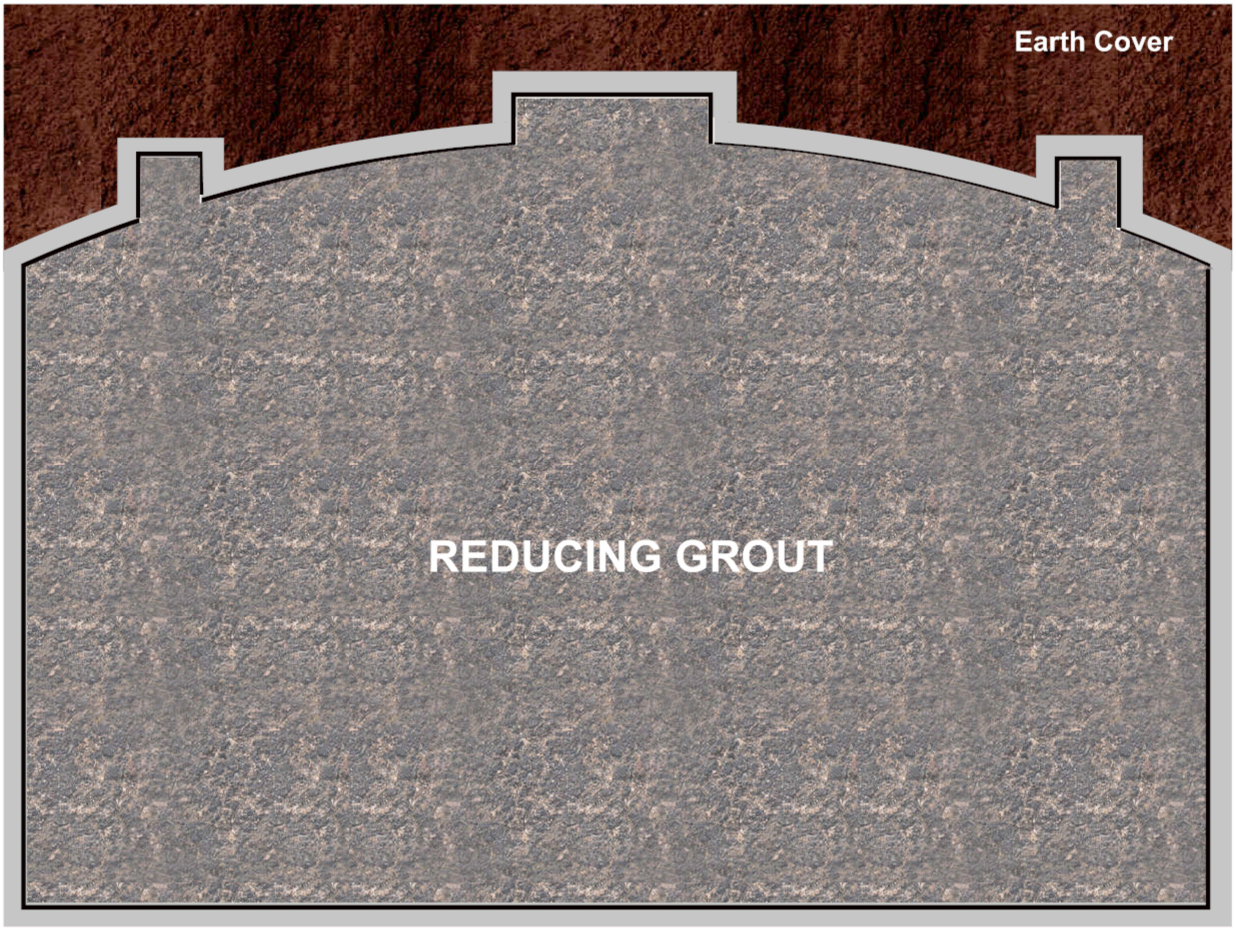
The fill grout that will be used has reducing properties (i.e., low redox or E_h) which minimize the mobility of the chemicals after closure. All grout formulas are alkaline because grout is a cement-based material that naturally has a high pH. This alkalinity is compatible with the carbon steel materials of construction of the waste tank. Grout has a high compressive strength and low permeability, which enhances its ability to limit the migration of contaminants after closure. The grout formulas are also designed to promote flowability, thereby enabling a near level placement within the waste tank. [SRS-REG-2007-00002]

7.3.2 Waste Tank Grouting Plan

Independent testing determined that certain formulas of grout provide a superior protection for any stabilized contaminant that might remain in the waste tank. [WSRC-STI-2007-00369]

For Type IV waste tanks, placement of the grout can be through risers in each quadrant of the waste tank and/or the center riser. [WSRC-RP-2005-01684] Figure 7.3-1 illustrates the typical grouted configuration for Tanks 18 and 19 (shown with potential earthen cover).

Figure 7.3-1: Typical Tank 18 and 19 Grout Configuration



Reducing grout will be used to fill the entire volume of Tanks 18 and 19 Reducing grout is composed primarily of cement, sand, water, fly ash, slag, silica fume, and other additives. The reducing grout mix must be flowable, pumpable, and self-leveling to minimize void space formation.

A grout formula that meets the requirements shown in Table 7.3-1 will be to prevent a hypothetical future member of the public from drilling into the waste tank.

Most grout types consist of two major states, cured and fresh. [WSRC-STI-2007-00369] The major requirements for cured properties of grout include compressive strength, effective diffusion coefficient, hydraulic conductivity, porosity, dry bulk density, and Young's Modulus. The fresh grout properties include flow, bleed water generation, set time, air content, and wet unit weight (density). [WSRC-STI-2007-00641] The quality control of the grout production will be included as part of the grout procurement specification (C-SPP-F-00055). Table 7.3-1 outlines some of the key requirements for grout that will be used to support RFS. [SRR-LWE-2010-00318]

Table 7.3-1: Mechanical and Chemical Requirements for Grout Material

Properties	**Engineering Requirements**	**Test**
I. Fresh Properties (Suggested to Meet Tank Grout Strategy)		
Slump-Flow (inches)	24 +/- 4	ASTM C-1611
Air Content (vol %)	< 8 %	ASTM C-231
Unit Weight (lbs/cu ft)	132 +/- 2	ASTM C-138
Set Time (hr.)	< 24	ASTM C-403
Bleed Water (vol %)	< 0.5% after 24 hr.	ASTM C-232
Max temperature after placement (°C)	65	SRNL Adiabatic Cal.
Slurry pH	>12.4	SRNL Method
II. Cured Properties from PA		
Hydraulic Conductivity (cm/sec)	<3.6E-08	ASTM D-5084
Compressive Strength (psi)	> 2,000 at 90 days	ASTM C-39/C-39M
Porosity (volume %)	< 26.6	ASTM C642
Dry Bulk Density (g/cm^3)	1.81	ASTM C642
Particle Density (g/cm^3)	2.51	SRNL
Effective Diffusion Coefficient (cm^2/sec)	8.00E-07	SRNL
Water Retention and van Genuchten Parameters to characterize unsaturated moisture transport	Van Genuchten Parameters same as parameters used in FTF PA	ASTM D-6836 Parameters calculated from water retention results
High Reducing Capacity (negative Eh)	> 210 lbs slag/yd^3	Grout QC
High Alkalinity (based on Ca(OH)2 and Calcium leaching / carbonation)	> 75 lbs of Portland cement/yd^3	Grout QC

[SRR-LWE-2010-00318]

The waste tank risers will be modified as needed to permit grout to be placed into the waste tank. Video cameras will be used during the grout pouring process to monitor for potential void space formations. To completely fill the tank risers with grout, an alternate grout mix that does not affect the tank modeling but is easier to mix and pump from a smaller system may be utilized. The alternative mix will also not have an effect on the bulk reducing grout. Once the risers are filled, they are capped with the reducing grout mix. Provisions will be made to provide delivery points into the waste tank, to manage air displacement, to address bleed water build-up, and to handle any waste tank top overflow. The waste tank will be ventilated until after grouting is complete. Since the commencement of waste tank grouting requires approval of this CM, final grouted tank configuration will be reported in the Final Configuration Report for Tanks 18 and 19.

8.0 MAINTENANCE AND MONITORING PLANS

The FFA establishes requirements for the prevention and mitigation of releases or threats of releases at or from the FTF, and any needed remediation of soils and groundwater when all FTF waste tanks have been removed from service. Because not all waste tank systems will be removed from service at the same time, there will be an interim period where some systems remain operational, while others are removed from service. [WSRC-OS-94-42]

Following stabilization of Tanks 18 and 19, they will become subject to the maintenance and monitoring requirements of an Interim Record of Decision/RCRA Permit Modification. They will then be removed from the Permit #17,424-IW. In the interim period following RFS until any needed final FFA corrective/remedial actions, Tanks 18 and 19 will be subject to the following maintenance and monitoring requirements.

- Historically,groundwater monitoring has been performed in accordance with the current SRS programs that have been conducted inside and around FTF since the 1970's, as requested by SCDHEC in support of Permit #17,424-IW (DHEC_01-25-1993). Upon approval, the *F-Area Tank Farm Groundwater Monitoring Plan*, (SRNS-RP-2011-00995) will be used for groundwater monitoring. The analysis of groundwater samples will be performed by a laboratory certified for applicable parameters in accordance with SCDHEC Regulation 61-81, *State Environmental Laboratory Certification Program*. Results have been and will continue to be reported annually to SCDHEC and EPA.
- Conduct annual visual inspections of the area surrounding the waste tank(s) and perform maintenance actions as appropriate. The grout is the primary barrier to contaminant release. The grout, where visible, will be inspected for significant cracking. The stormwater system will be maintained to ensure that any possible infiltration through grout is minimized. Inspections will commence within one year of grout stabilization and will be performed annually. Deficiencies will be corrected as soon as practical and will be documented by procedure. Within 30 days of detection, DOE will notify SCDHEC of any significant cracking of the grout or degradation of the stormwater system and will establish a schedule to complete necessary maintenance activities. Inspection records will be maintained until all tanks have been removed from service and the FTF OU is closed.
- Provide access controls for on-site workers via the Site Use Program, Site Clearance Program, work control, worker training, worker briefing of health and safety requirements and identification signs located at the waste unit boundaries.
- Notify the EPA and SCDHEC in advance of any changes in land use.
- Provide access controls against trespassers as consistent with the 2000 RCRA Part B Permit Renewal Application, Volume I, Section F.1, which describes the security procedures and equipment, 24-hour surveillance system, artificial or natural barriers, control entry systems, and warning signs in place at the SRS boundary. [WSRC-IM-98-30]

9.0 CONCLUSION

Bulk waste and heel removal activities undertaken in Tanks 18 and 19 were successful in removing over 99% of the waste inventory from each waste tank. For mechanical cleaning, the volume removal is directly proportional to the contaminant removal. Summaries of the results of bulk waste and heel removal campaigns conducted in Tanks 18 and 19 are provided in Figures 9.0-1 and 9.0-2, respectively.

Figure 9.0-1: Tank 18 Waste Volume Reduction

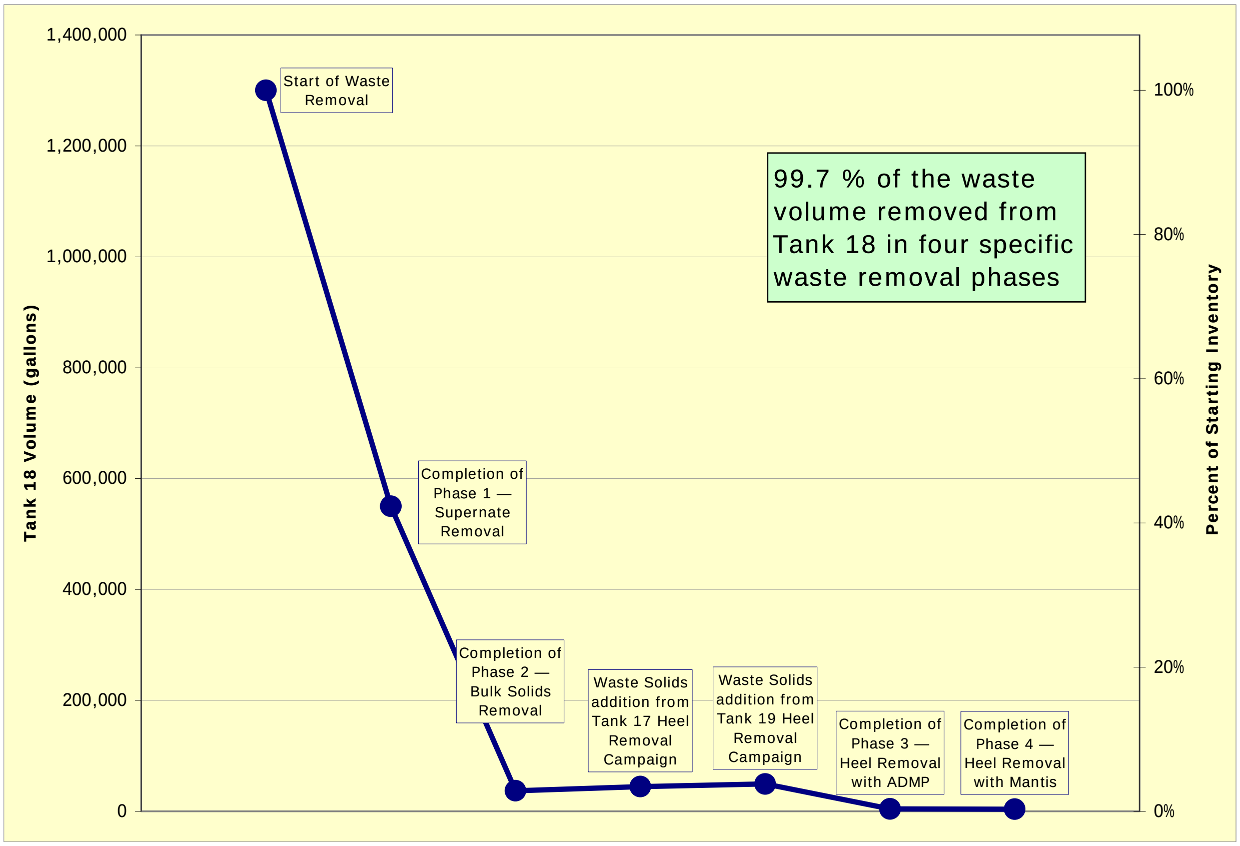
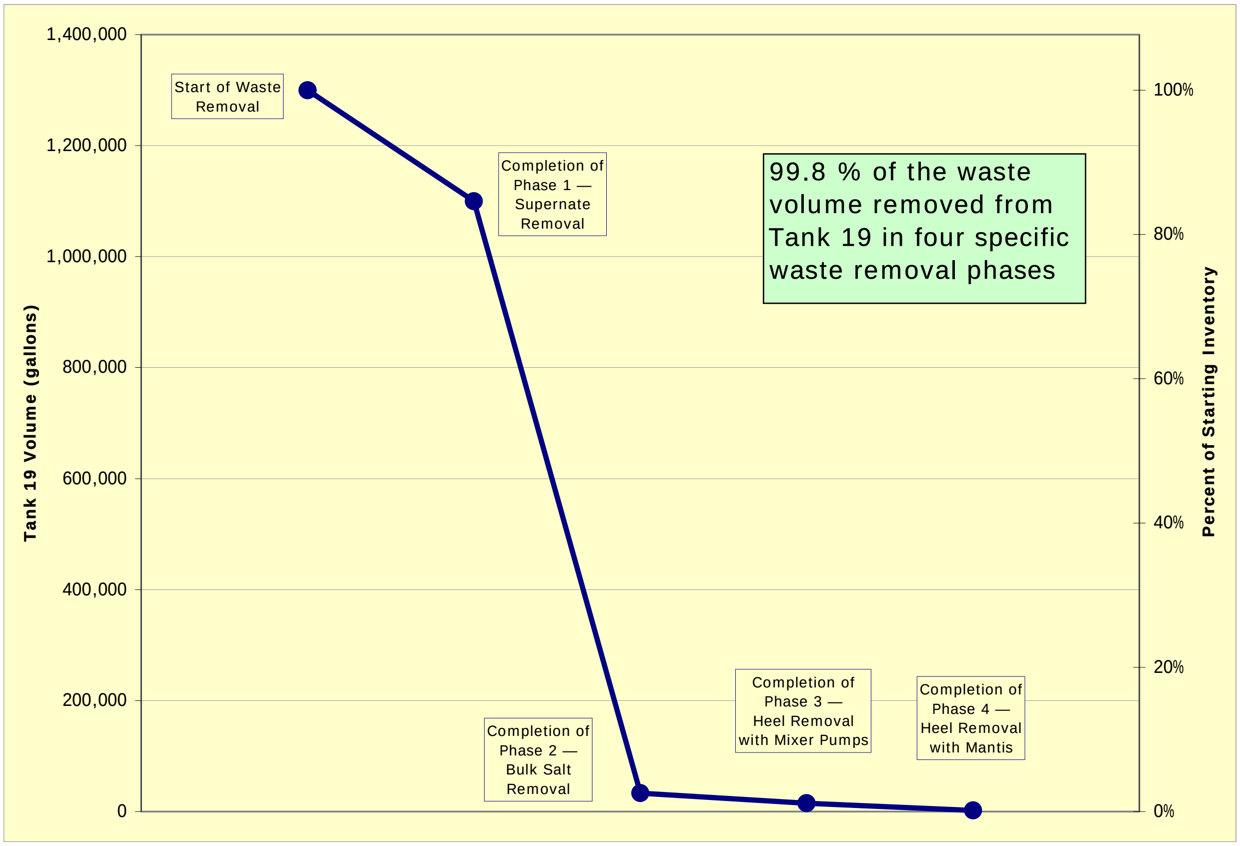


Figure 9.0-2: Tank 19 Waste Volume Reduction

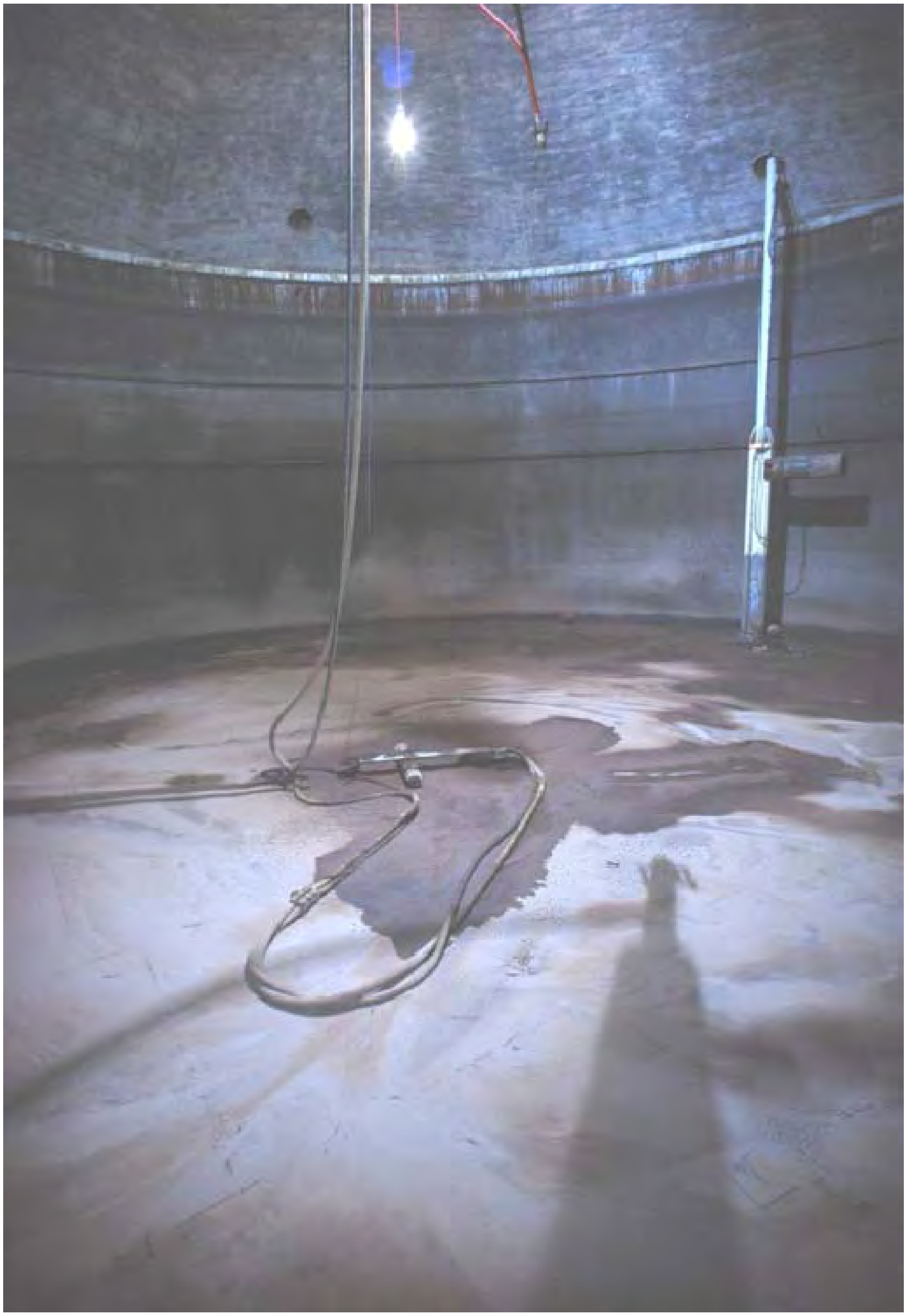


Based on the information discussed within this CM, DOE has determined that further waste removal efforts are not technically practicable from an engineering perspective for both Tanks 18 and 19. This determination is based on the following factors

- Visual Observation – Visual inspections of the tanks indicated that there was a significant reduction in residual material volume resulting from the Mantis operations. Figure 9.0-3 and Figure 9.0-4 show Tanks 18 and 19, respectively, after the completion of Mantis operations (Section 3.4.1).

Figure 9.0-3: Tank 18 after Completion of Mantis Operations

Figure 9.0-4: Tank 19 after Completion of Mantis Operations



- Mantis Technology Limitations – Design requirements and tank obstacles limited the removal of waste once there were no longer mounds and the waste existed in a thin layer on the tank floor (Section 3.4.2).
- Mantis Equipment Degradation – Even with equipment repairs to extend operational life, the existing Mantis equipment eventually was no longer effective in removing additional waste at the low residual levels remaining in the tank (Section 3.4.3).
- Liquid Waste System Impacts – Continued Mantis operation for further cleaning of either Tank 18 or 19 would impact other risk reduction activities associated with removing sludge from Type I tanks for stabilization at DWPF (Section 3.4.4).
- Diminished Removal of Waste as Indicated by Transfer Line Radiation Trends and Confirmatory Mantis Operation – The radiation monitoring system installed on the transfer system from both Tanks 18 and 19 to assess the solid waste transfer process indicated a trend of diminished effectiveness of Mantis operations. Further evaluation was performed to confirm that continued heel removal was no longer effective by conducting radiation monitoring while cleaning selected floor surface areas (Section 3.4.5).
- Analysis of Deploying an Additional Waste Removal Technology – An analysis of deploying another cleaning technology was performed that demonstrated that it was not technically practicable from an engineering perspective to continue with active waste removal activities. The analysis included such things as technology capabilities, schedule impacts and a quantified cost summary, risks and benefit analysis (Section 6.0). The evaluation concluded that:
    - No new practicable technology has been identified that has reached a level of maturity for deployment to remove a significant additional concentration of constituents of concern from Tank 18 or Tank 19.
    - Development and deployment of an upgraded Mantis, transfer line and associated sampling for Tank 18 or Tank 19 would cost approximately $8.0M. [90012101 Tank 21 Closure]
    - If an upgraded Mantis could remove 50% of the remaining solids in Tanks 18 and 19, the potential expected reduction in dose from a 50% reduction in the residual waste curies from Tanks 18 and 19 would only be approximately 1.3 mrem/yr to a member of the public living 100 meters from the closed FTF. [SRR-CWDA-2010-00124]
- Performance Assessment Impacts – Tanks 18 and 19 have been sampled to determine actual inventories of residual material and updating the inventory inputs into the fate and transport model used in the FTF PA. Updating the fate and transport model with the actual inventories shows no significant impact to human health and the environment (Section 5.0).
- Isolation Strategy – The isolation strategy demonstrates that Tanks 18 and 19 will be isolated from the remainder of the FTF Waste Transfer System and the FTF support systems, rendering them closed to any future waste processing activities (Sections 7.1 and 7.2).
- Stabilization – DOE has evaluated stabilization alternatives in the EIS (DOE-EIS-0303) and has determined that the “Fill with Grout” alternative is the best approach to minimize human health and safety risks associated with RFS of the waste tanks (Section 7.3).

- Maintenance and Monitoring – DOE will monitor groundwater, conduct visual inspections, and control access to the FTF during the interim period between RFS of Tanks 18 and 19 until final closure of the FTF OU (Section 8.0).

Based on these factors, DOE has determined that residual material has been removed from Tanks 18 and 19 to the extent practicable from an engineering perspective and is ready to proceed to isolation and stabilization activities summarized in Section 7.0. DOE has determined that the above analysis demonstrates that the proposed RFS configuration is protective of human health and the environment and that the closure actions will continue to be supportive of meeting the applicable performance standards for the closure of the FTF OU.

The DOE has determined that all FTF GCP requirements have been met to proceed with removing Tanks 18 and 19 from service and is ready to stabilize the tanks with grout. Approval of this CM by SCDHEC signifies State acceptance of the proposed DOE RFS of Tanks 18 and 19, State concurrence that waste removal activities for Tanks 18 and 19 can cease, and authorization to stabilize the waste tanks and the residual contaminants under Permit #17,424-IW. [DHEC_01-25-1993] In accordance with the FFA, EPA will provide concurrence that waste removal activities may cease. Following stabilization, DOE will submit a Final Configuration Report for Tanks 18 and 19 to SCDHEC with certification that the RFS activities have been performed in accordance with the FTF GCP and this CM.

Based on the information provided in this CM and supporting documents, it may be concluded that (1) there is reasonable assurance that, at the time of final FFA corrective/remedial actions, groundwater concentrations derived from residual contamination in the tanks and ancillary structures will be within the MCLs and (2) further residual removal is not technically practicable from an engineering perspective.

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APPENDIX A: WASTE TANK SYSTEM TRACKING

Future closure of the waste tanks and ancillary structures will be conducted in such a way that structures will be included in CMs when determined that it is practical to remove the structures from service simultaneously with the waste tanks and there is no longer a need for the ancillary structures to manage waste in tanks that are still in service. The ancillary structures to be closed as part of the FTF are listed in Table A-1. As CMs are developed and approved, Table A-1 will be updated to include the document number and date of RFS for each of the ancillary structures listed in Permit #17,424-IW (DHEC_01-25-1993) to ensure that all tanks and ancillary structures have been addressed.

Table A-1: FTF Waste Systems Tracking

Waste Tank System	CM Document Number	Date of RFS
Tank 1		
Tank 2		
Tank 3		
Tank 4		
Tank 5		
Tank 6		
Tank 7		
Tank 8		
Tank 17	PIT-MISC-0004	12/15/1997
Tank 18	SRS-CWDA-2010-00003	
Tank 19	SRS-CWDA-2010-00003	
Tank 20	PIT-MISC-0002	7/31/1997
Tank 25		
Tank 26		
Tank 27		
Tank 28		
Tank 33		
Tank 34		
Tank 44		
Tank 45		
Tank 46		
Tank 47		

Table A-1: FTF Waste Systems Tracking (Continued)

Waste Tank System	CM Document Number	Date of RFS
242-F Evaporator Vessel		
Mercury Collection Tank		
Cesium Removal Column Pump Tank		
Overheads Tank, North		
Overheads Tank, South		
242-3F Concentrate Transfer System		
242-16F Evaporator Pot		
Mercury Collection Tank		
Cesium Removal Column Pump Tank		
Overheads Tank, North		
Overheads Tank, South		
FPT-1 and FPP-1		
FPT-2 and FPP-2		
FPT-3 and FPP-3		
FDB-1		
FDB-2		
FDB-3		
FDB-4		
FDB-5		
FDB-6		
F-Area Catch Tank		