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SGW-34463
Revision 0

# Treatability Studies and Other Focused Investigations: An Initial Planning Basis for the 200-SW-2 Operable Unit Landfills

Prepared for the U.S. Department of Energy Assistant Secretary for Environmental Management

Project Hanford Management Contractor for the U.S. Department of Energy under Contract DE-AC06-96RL13200

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*Richland, Washington*

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# Treatability Studies and Other Focused Investigations: An Initial Planning Basis for the 200-SW-2 Operable Unit Landfills

J. W. Cammann
Fluor Hanford, Inc.

Date Published
March 2008

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## EXECUTIVE SUMMARY

This document provides the initial basis for planning treatability and other focused investigations that may benefit the 200-SW-2 Radioactive Landfills and Dumps Group (200-SW-2) Operable Unit (OU). The following information is provided:

- Overview of the use of treatability investigations to support the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*[1] remedial investigation/feasibility study (RI/FS) process, as prescribed by Environmental Protection Agency (EPA) guidance (EPA/540/R-92/071a, *Guide for Conducting Treatability Studies under CERCLA, Final*[2])
- Discussions of treatability and other focused investigations that may benefit the 200-SW-2 OU RI/FS process
- Rough-order-of-magnitude cost and proposed schedule to support the planning and execution of treatability and other focused investigations for the 200-SW-2 OU.

This initial planning basis supports the development of DOE/RL-2004-60, *200-SW-1 Nonradioactive Landfills and Dumps Group Operable Unit and 200-SW-2 Radioactive Landfills and Dumps Group Operable Unit Remedial Investigation/Feasibility Study Work Plan.*[3]

The need for well planned, conducted, and documented treatability and other focused investigations is driven by uncertainties in effectiveness, implementability, and cost of some characterization and remediation technologies that should be considered during the 200-SW-2 OU RI/FS process. Treatability and other focused investigations provide data to support characterization and remediation technology screening, selection, design, and implementation.

Suggested treatability investigations that address the vadose zone should be considered after a better understanding of the nature and extent of contamination is revealed through the phased remedial investigation approach for the 200-SW-2 OU. Other focused investigations should be initiated during FY 2008 to compile existing information on mature technologies and site conditions in support of the RI/FS process. The focused investigations also provide information to address Washington State Department of Ecology's "Items of Interest" and other areas of potential concern. Technology-specific treatability investigations should be initiated in calendar year 2009 and be based on information obtained from the phased remedial investigation efforts conducted at the 200-SW-2 OU.

This initial planning basis for treatability and other focused investigations will be revised, as needed, to reflect information obtained through the phased remedial investigation of the 200-SW-2 OU. Future revisions will help to ensure needs-driven investments in treatability

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[1] *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*, 42 USC 9601, et seq.

[2] EPA/540/R-92/071a, 1992, *Guide for Conducting Treatability Studies under CERCLA, Final*, Office of Solid Waste and Emergency Response, U.S. Environmental Protection Agency, Washington, D.C.

[3] DOE/RL-2004-60, 2004, *200-SW-1 Nonradioactive Landfills and Dumps Group Operable Unit and 200-SW-2 Radioactive Landfills and Dumps Group Operable Unit Remedial Investigation/Feasibility Study Work Plan*, Draft B, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

investigations required to support completion of the 200-SW-2 OU RI/FS process and development of the Proposed Plan(s) and Record(s) of Decision in a timely manner.

All treatability and other focused investigations preceding the Record of Decision for non-tank farm OUs in the 200 Areas are currently scheduled for completion by December 31, 2011 (the *Hanford Federal Facility Agreement and Consent Order* [Ecology et al., 1989] Milestone M-15-00C); including the feasibility study reports and recommended remedies. Treatability investigations may be warranted after the Record of Decision is issued in support of site-specific remedial designs and subsequent remedial actions. Remedial actions on all non-tank farm OUs are currently scheduled for completion by September 30, 2024 (Tri-Party Agreement Milestone M-16-00).

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## TERMS

| | |
|---|---|
| 200-SW-1 | 200-SW-1 Nonradioactive Landfills and Dumps Group |
| 200-SW-2 | 200-SW-2 Radioactive Landfills and Dumps Group |
| 600 CL | 600 Area Central Landfill |
| AEC | U.S. Atomic Energy Commission |
| ARAR | applicable or relevant and appropriate requirement |
| CERCLA | *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* |
| DOE | U.S. Department of Energy |
| DQO | data quality objective |
| Ecology | Washington State Department of Ecology |
| EMI | electromagnetic induction |
| EPA | U.S. Environmental Protection Agency |
| ET | evapotranspiration |
| FFTF | Fast Flux Test Facility |
| FS | feasibility study |
| GPR | ground-penetrating radar |
| GPS | global positioning system |
| GRA | general response action |
| HEPA | high-efficiency particulate air |
| HPGe | high-purity germanium (detector) |
| Implementation Plan | DOE/RL-98-28, *200 Areas Remedial Investigation/Feasibility Study Implementation Plan – Environmental Restoration Program* |
| INL | Idaho National Laboratory |
| LLMW | low-level mixed waste |
| LLW | low-level waste |
| NRDWL | Nonradioactive Dangerous Waste Landfill |
| OU | operable unit |
| PCB | polychlorinated biphenyl |
| PRG | preliminary remediation goal |
| PUREX | Plutonium-Uranium Extraction (Plant or process) |
| QA/QC | quality assurance/quality control |
| RAO | remedial action objective |
| RCRA | *Resource Conservation and Recovery Act of 1976* |
| RD/RA | remedial design/remedial action |
| RI | remedial investigation |
| RI/FS | remedial investigation/feasibility study |
| RL | U.S. Department of Energy, Richland Operations Office |
| ROD | record of decision |
| RSW | retrievably stored waste |
| RTD | removal, treatment, and disposal |
| SAP | sampling and analysis plan |
| TMF | total magnetic field |
| Tri-Party Agreement | *Hanford Federal Facility Agreement and Consent Order* (Ecology et al., 1989) |

| | |
|---|---|
| TRU | radioactive waste (transuranic) as defined in DOE G 435.1-1, *Implementation Guide for Use with DOE M 435.1-1* |
| TSD | treatment, storage, and/or disposal (unit) |
| VOC | volatile organic compound |
| VPU | vertical pipe unit |

## METRIC CONVERSION CHART

| Into Metric Units | | | Out of Metric Units | | |
|---|---|---|---|---|---|
| *If you know* | *Multiply by* | *To get* | *If you know* | *Multiply by* | *To get* |
| **Length** | | | **Length** | | |
| inches | 25.40 | millimeters | millimeters | 0.0394 | inches |
| inches | 2.54 | centimeters | centimeters | 0.394 | inches |
| feet | 0.305 | meters | meters | 3.281 | feet |
| yards | 0.914 | meters | meters | 1.094 | yards |
| miles (statute) | 1.609 | kilometers | kilometers | 0.621 | miles (statute) |
| **Area** | | | **Area** | | |
| sq. inches | 6.452 | sq. centimeters | sq. centimeters | 0.155 | sq. inches |
| sq. feet | 0.0929 | sq. meters | sq. meters | 10.764 | sq. feet |
| sq. yards | 0.836 | sq. meters | sq. meters | 1.196 | sq. yards |
| sq. miles [a] | 2.591 | sq. kilometers | sq. kilometers | 0.386 | sq. miles |
| ac | 0.405 | hectares | hectares | 2.471 | ac |
| **Mass (weight)** | | | **Mass (weight)** | | |
| ounces (avoir) | 28.349 | grams | grams | 0.0353 | ounces (avoir) |
| pounds | 0.454 | kilograms | kilograms | 2.205 | pounds (avoir) |
| tons (short) | 0.907 | ton (metric) | ton (metric) | 1.102 | tons (short) |
| **Volume** | | | **Volume** | | |
| teaspoons | 5 | milliliters | milliliters | 0.034 | ounces (U.S., liquid) |
| tablespoons | 15 | milliliters | liters | 2.113 | pints |
| ounces (U.S., liquid) | 29.573 | milliliters | liters | 1.057 | quarts (U.S., liquid) |
| cups | 0.24 | liters | liters | 0.264 | gallons (U.S., liquid) |
| pints | 0.473 | liters | cubic meters | 35.315 | cubic feet |
| quarts (U.S., liquid) | 0.946 | liters | cubic meters | 1.308 | cubic yards |
| gallons (U.S., liquid) | 3.785 | liters | | | |
| cubic feet | 0.0283 | cubic meters | | | |
| cubic yards | 0.764 | cubic meters | | | |
| **Temperature** | | | **Temperature** | | |
| Fahrenheit | (°F-32)*5/9 | Centigrade | Centigrade | (°C*9/5)+32 | Fahrenheit |
| **Radioactivity** | | | **Radioactivity** | | |
| picocurie | 37 | millibecquerel | millibecquerel | 0.027 | picocurie |

[a] One square mile = 640 ac.

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# 1.0 INTRODUCTION

The *Hanford Federal Facility Agreement and Consent Order* (Tri-Party Agreement) (Ecology et al., 1989) identifies over 800 soil waste sites (and associated structures) resulting from discharge of liquids and solids to the ground from 200 Areas processing facilities. These soil waste sites are arranged into separate waste groups that contain *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) past-practice operable units (OU); *Resource Conservation and Recovery Act of 1976* (RCRA) past-practice OUs addressed through RCRA corrective action authorities; and RCRA treatment, storage, and/or disposal (TSD) units that will be closed in conjunction with OU activities. Collectively, solid waste landfills have been divided into either past-practice landfills or TSD unit landfills.

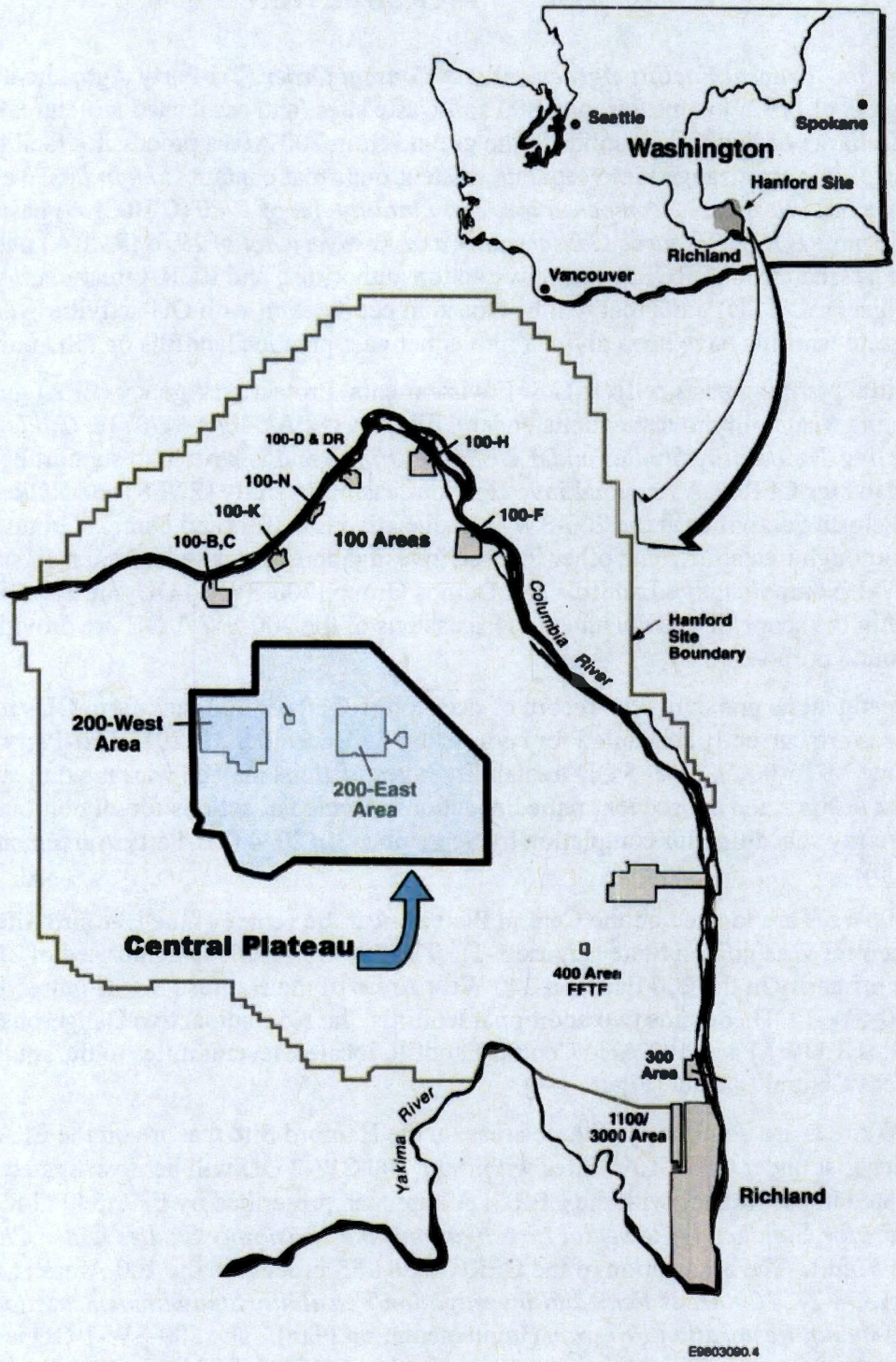
This initial planning basis reflects U.S. Environmental Protection Agency (EPA) guidance for conducting treatability investigations under CERCLA (EPA/540/R-92/071a, *Guide for Conducting Treatability Studies under CERCLA, Final*) and is written to support development of work plans for CERCLA remedial investigation/feasibility study (RI/FS) and RCRA TSD landfill closure activities at the 200-SW-2 Radioactive Landfills and Dumps Group (200-SW-2) OU. Although treatability and other focused investigations discussed herein may support the 200-SW-1 Nonradioactive Landfills and Dumps Group (200-SW-1) OU, the 200-SW-1 OU is not within the scope of this document. Discussions of the 200-SW-1 OU are provided for background purposes only.

All investigations preceding the record of decision (ROD) for non-tank farm OUs in the 200 Areas are currently scheduled for completion by December 31, 2011 (Tri-Party Agreement Milestone M-15-00C). Post-ROD treatability investigations may be warranted in support of remedial designs and subsequent remedial actions. Remedial actions for all non-tank farm OUs are currently scheduled for completion by September 30, 2024 (Tri-Party Agreement Milestone M-16-00).

The 200 Areas are located on the Central Plateau near the center of the Hanford Site in south-central Washington State (Figure 1-1). The 200-SW-2 OU is comprised of 25 landfills located primarily in the 200 East and 200 West Areas of the Hanford Site (Figures 1-2 and 1-3). The 200-SW-1 OU contains two additional landfills, the Nonradioactive Dangerous Waste Landfill (NRDWL) and 600 Area Central Landfill, located several miles to the southeast of the 200 Areas Central Plateau (Figure 1-4).

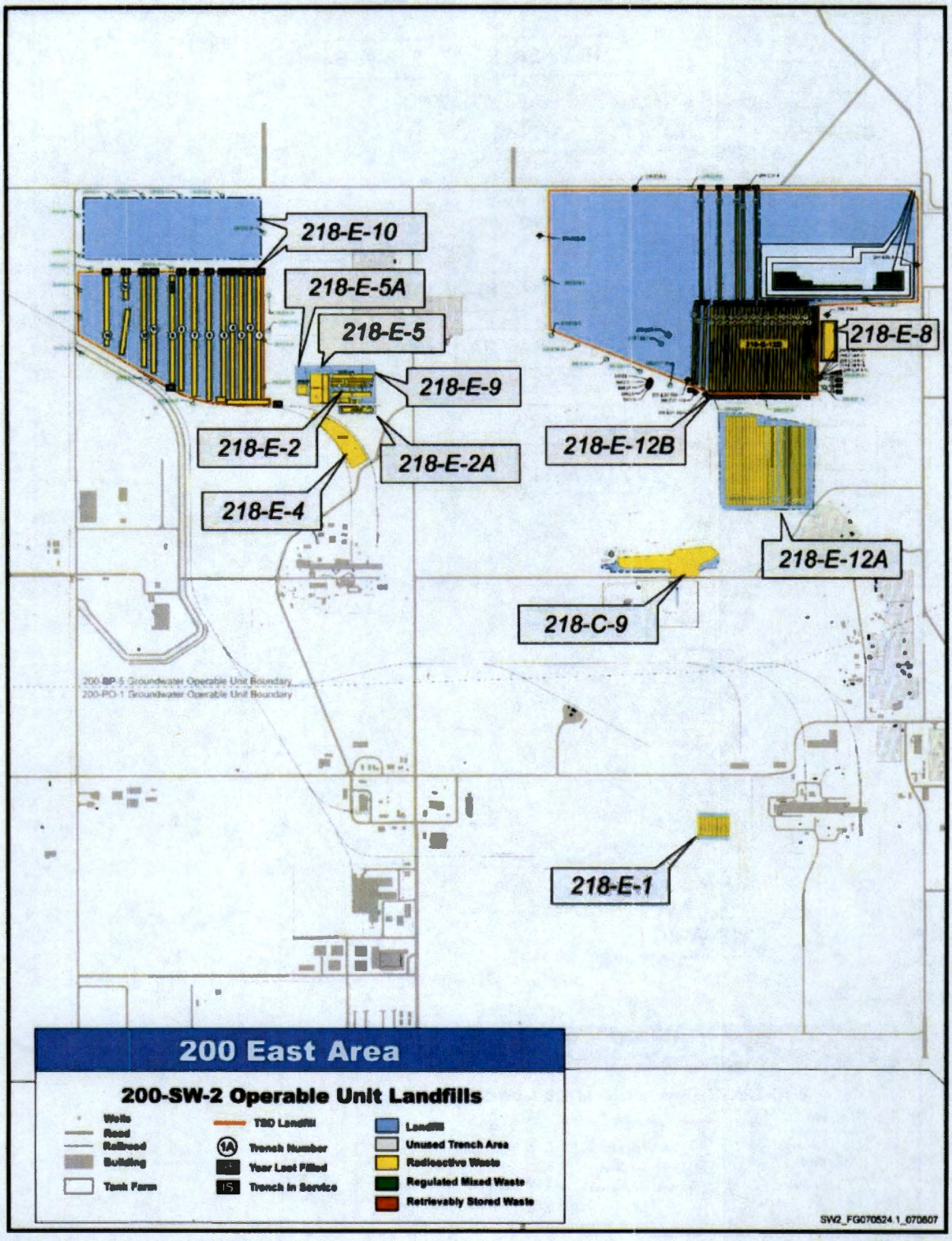
The 200 Areas are within one of three areas on the Hanford Site that are on the EPA National Priorities List under CERCLA. Sites within the 200-SW-2 OU will be investigated and remediated in accordance with the CERCLA approach prescribed by EPA/540/G-89/004, *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA, Interim Final*). The application of the CERCLA RI/FS process in the 200 Areas is described in DOE/RL-98-28, *200 Areas Remedial Investigation/Feasibility Study Implementation Plan – Environmental Restoration Program* (Implementation Plan). The 200-SW-1 OU is proposed for closure outside the CERCLA process as described in DOE/RL-2004-60, Draft B, *200-SW-1 Nonradioactive Landfills and Dumps Group Operable Unit and 200-SW-2 Radioactive Landfills and Dumps Group Operable Unit Remedial Investigation/Feasibility Study Work Plan* (RI/FS Work Plan).

Figure 1-1. Location of the Hanford Site.



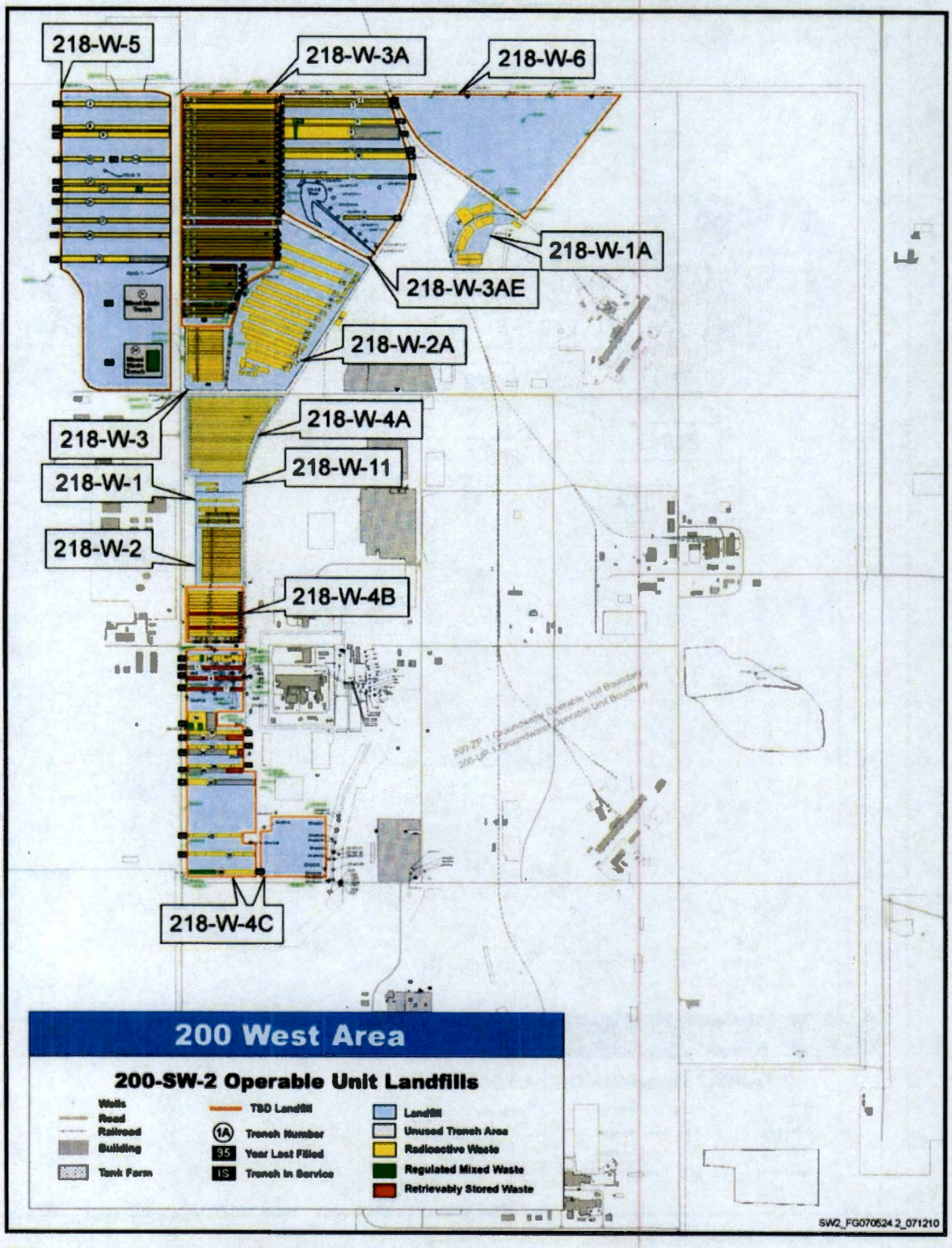

FFTF = Fast Flux Test Facility.

Figure 1-2. Location of 200-SW-2 Operable Unit Landfills in 200 East Area.



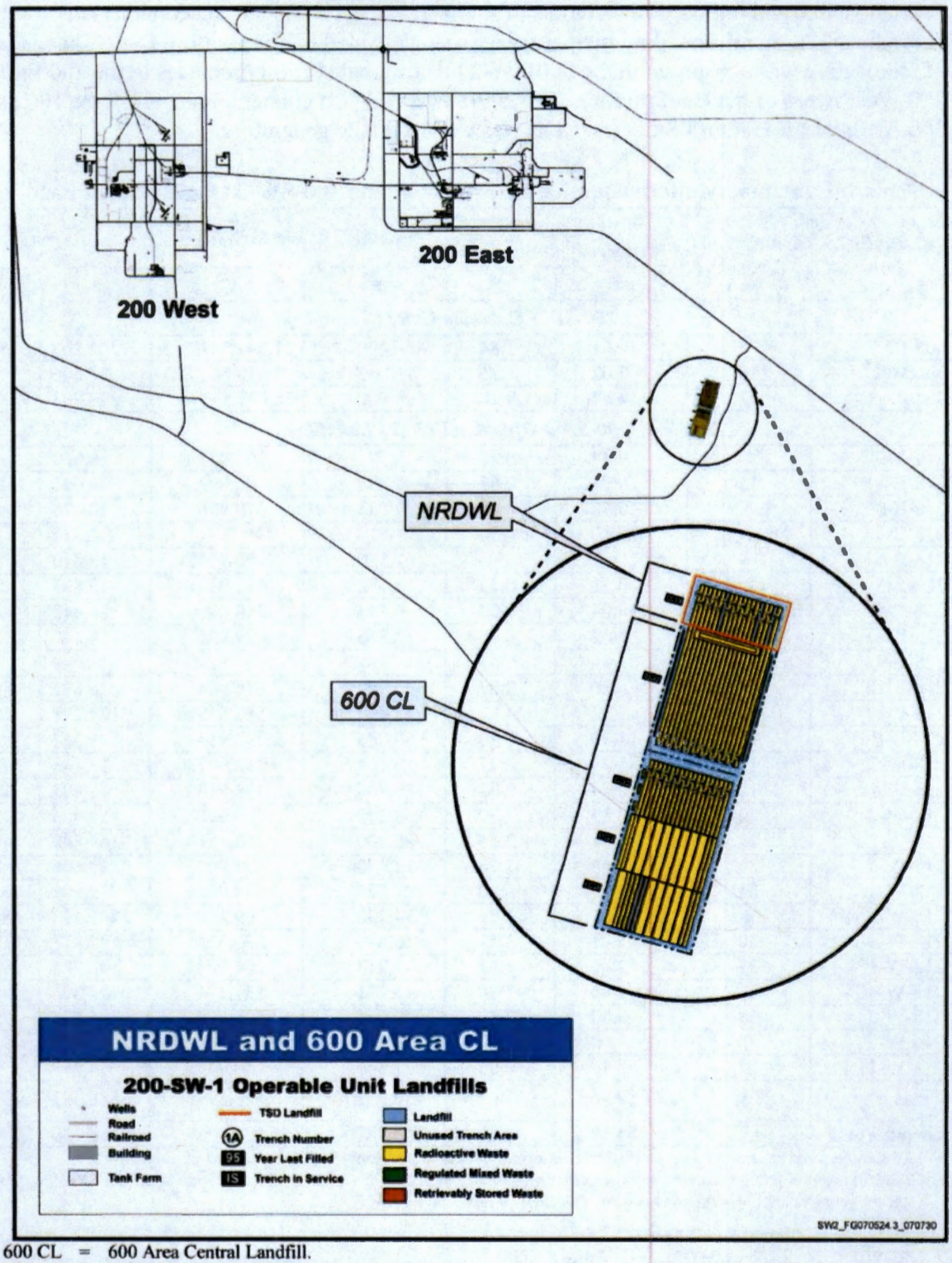

TSD = treatment, storage, and/or disposal.

Figure 1-3. Location of 200-SW-2 Operable Unit Landfills in 200 West Area.




TSD = treatment, storage, and/or disposal.

Figure 1-4. Location of 200-SW-1 Operable Unit Landfills in the 600 Area.




600 CL = 600 Area Central Landfill.
NRDWL = Nonradioactive Dangerous Waste Landfill.
TSD = treatment, storage, and/or disposal.

Based on historical records, the 200-SW-1 and 200-SW-2 OUs contain significant volumes of nonradioactive and radioactive materials (Table 1-1). The 200-SW-1 OU contains only nonradioactive chemical and municipal-type waste generated on the Hanford Site. The majority of radioactive waste disposed in the 200-SW-2 OU originated from processes in the 200 East and 200 West Areas of the Hanford Site. The 200-SW-2 OU also contains waste from the 100 and 300 Areas of the Hanford Site, as well as waste from offsite generators.

Table 1-1. Summary Information for the 200-SW-1 and 200-SW-2 Operable Unit Landfills.

| Landfill Name | Number of Trenches | Total Length of Trenches (Cumulative) | | Volume [a] of Buried Waste | | Area [a] | |
|---|---|---|---|---|---|---|---|
| | | km | mi | $m^3$ | $ft^3$ | $m^2$ | ac |
| ***200-SW-1 Operable Unit (2 Landfills)*** | | | | | | | |
| 600 CL | 75 | 12.61 | 7.84 | 596,000 | 21,047,541 | 241,262 | 59.60 |
| NRDWL[b] | 16 | 2.02 | 1.26 | 141,000 (kg) | 310,851 (lb) | 37,506 | 9.26 |
| **Total** | 91 | 14.63 | 9.10 | 596,000 | 21,047,541 | 278,768 | 68.86 |
| ***200-SW-2 Operable Unit (25 Landfills)*** | | | | | | | |
| 218-C-9 | 1 | 0.44 | 0.27 | 7,573 | 267,421 | 18,060 | 4.46 |
| 218-E-1 | 15 | 0.91 | 0.57 | 3,030 | 106,999 | 9,601 | 2.37 |
| 218-E-2 | 8 | 0.72 | 0.45 | 9,033 | 318,996 | 20,476 | 5.10 |
| 218-E-2A | 1 | 0.10 | 0.06 | -- | -- | 3,714 | 0.92 |
| 218-E-4 | -- | -- | -- | 1,586 | 55,999 | 13,810 | 3.41 |
| 218-E-5 | 2 | 0.21 | 0.13 | 3,172 | 112,018 | 10,893 | 2.69 |
| 218-E-5A | 1 | 0.04 | 0.02 | 6,173 | 218,000 | 4,440 | 1.10 |
| 218-E-8 | 1 | 0.12 | 0.08 | 2,265 | 79,999 | 4,440 | 1.10 |
| 218-E-9 | -- | -- | -- | -- | -- | -- | -- |
| 218-E-10[b] | 14 | 5.26 | 3.27 | 26,900 | 646,964 | 228,895 | 56.56 |
| 218-E-12A | 28 | 7.76 | 4.82 | 15,400 | 543,845 | 121,298 | 29.97 |
| 218-E-12B[b] | 39 | 11.90 | 7.40 | 65,086 | 2,298,453 | 735,362 | 181.71 |
| 218-W-1 | 15 | 1.24 | 0.77 | 7,164 | 252,997 | 33,148 | 8.19 |
| 218-W-1A | 12 | 0.54 | 0.33 | 13,700 | 483,810 | 48,605 | 12.01 |
| 218-W-2 | 20 | 2.85 | 1.77 | 8,240 | 290,996 | 34,455 | 8.51 |
| 218-W-2A | 27 | 4.15 | 2.58 | 26,000 | 918,181 | 164,849 | 40.74 |
| 218-W-3 | 20 | 2.83 | 1.76 | 12,400 | 437,901 | 39,690 | 9.81 |
| 218-W-3A[b] | 61 | 14.25 | 8.86 | 97,528 | 3,444,086 | 219,201 | 54.17 |
| 218-W-3AE[b] | 8 | 2.91 | 1.81 | 34,240 | 1,209,150 | 229,193 | 56.63 |
| 218-W-4A | 30 | 5.01 | 3.11 | 16,886 | 596,323 | 72,811 | 17.99 |
| 218-W-4B[b] | 27 | 2.46 | 1.53 | 7,213 | 254,724 | 40,704 | 10.06 |
| 218-W-4C[b] | 16 | 2.96 | 1.84 | 15,211 | 537,174 | 27,326 | 56.17 |
| 218-W-5 | 13 | 3.90 | 2.42 | 70,961 | 2,505,908 | 385,625 | 95.29 |
| 216-W-6 | 0 | 0 | 0 | 0 | 0 | 207,516 | 51.20 |
| 218-W-11 | 2[c] | 0.12 | 0.08 | 1,160 | 40,949 | 14,279 | 3.53 |
| **Total** | 361 | 69.96 | 43.47 | 450,921 | 15,620,893 | 2,888.391 | 709.10 |
| **Grand Total** | 452 | 84.59 | 52.57 | 1,046,921 | 15,620,893 | 3,167,159 | 777.96 |

[a] All numbers are estimates based on historical information and include only the used portions of the landfills.
[b] Landfill is a permitted treatment, storage, and disposal landfill under the *Resource Conservation and Recovery Act of 1976*.
[c] Recent geophysical investigations suggest that there is only one trench.

600 CL = 600 Area Central Landfill.
NRDWL = Nonradioactive Dangerous Waste Landfill.

Two RCRA TSD units are in the 200-SW-1 and 200-SW-2 OUs. First, the Low-Level Burial Ground TSD unit contains eight landfills in the 200-SW-2 OU. One landfill, 218-W-6, was reserved for future use and never received waste. Other portions of the Low-Level Burial Ground TSD unit never received waste (i.e., the northern part of the 218-E-10 landfill, the western part of the 218-E-12B landfill, and the southeastern part of the 218-W-4C landfill). The remaining seven Low-Level Burial Ground TSD landfills (218-W-3A, 218-W-3AE, 218-W-4B, 218-W-4C, 218-W-5, 218-E-12B, and 218-E-10) were used for radioactive waste disposal. The NRDWL is the second TSD unit. The NRDWL TSD unit is contained in the 200-SW-1 OU and received only nonradioactive waste. The remaining sites in the 200-SW-2 OU are past-practice landfills.

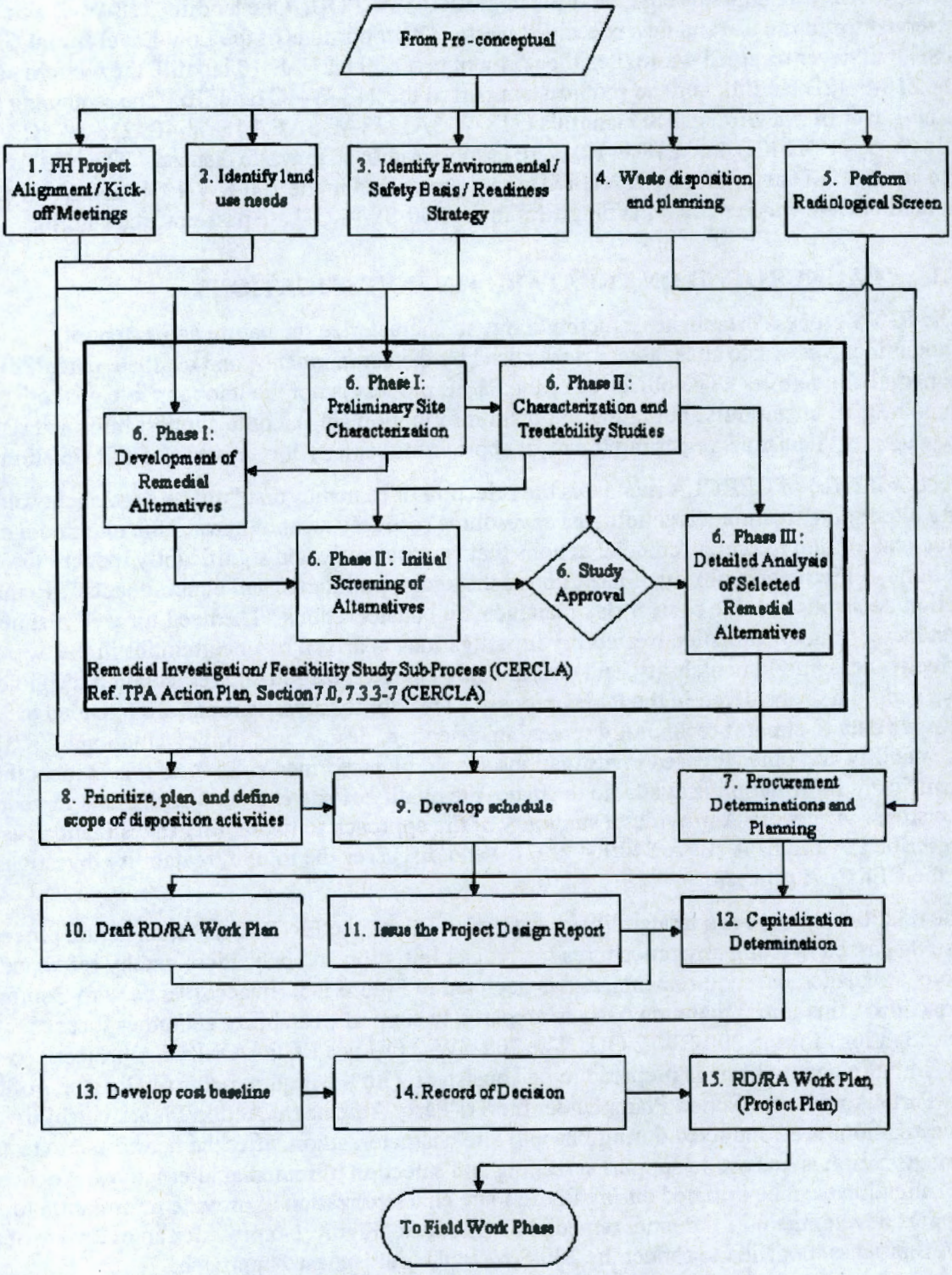
## 1.1 BACKGROUND ON TREATABILITY INVESTIGATIONS

The RI/FS process establishes a methodology to characterize the nature and extent of contaminants at waste sites, assess risks posed by the contaminants, and evaluate potential remedial alternatives. The objective of the RI/FS process is not the unobtainable goal of removing all uncertainty, but rather to obtain information sufficient to support informed risk management decisions regarding the most appropriate remedy for a given site and situation.

Section 121(b) of CERCLA mandates the selection of remedies that "utilize permanent solutions and alternative treatment technologies or resource recovery technologies to the maximum extent practicable" and to prefer remedial actions that "permanently and significantly reduces the volume, toxicity, or mobility of hazardous substances, pollutants, and contaminants." Remedial action decisions involve several risk management considerations. The need for well planned, conducted, and documented treatability investigations is driven by uncertainties in the overall effectiveness, implementability, and cost of some characterization and remediation technologies that should be considered in the RI/FS process. Treatability investigations are intended to provide data to support technology screening, selection, design, and implementation. Treatability and other focused investigations should be performed as soon as it is evident that insufficient information is available to ensure the quality of site characterization and remediation decisions. Appendix A provides a summary of the approach to treatability investigations as prescribed by the EPA (EPA/540/R-92/071a) and discusses the role of treatability investigations in the CERCLA process.

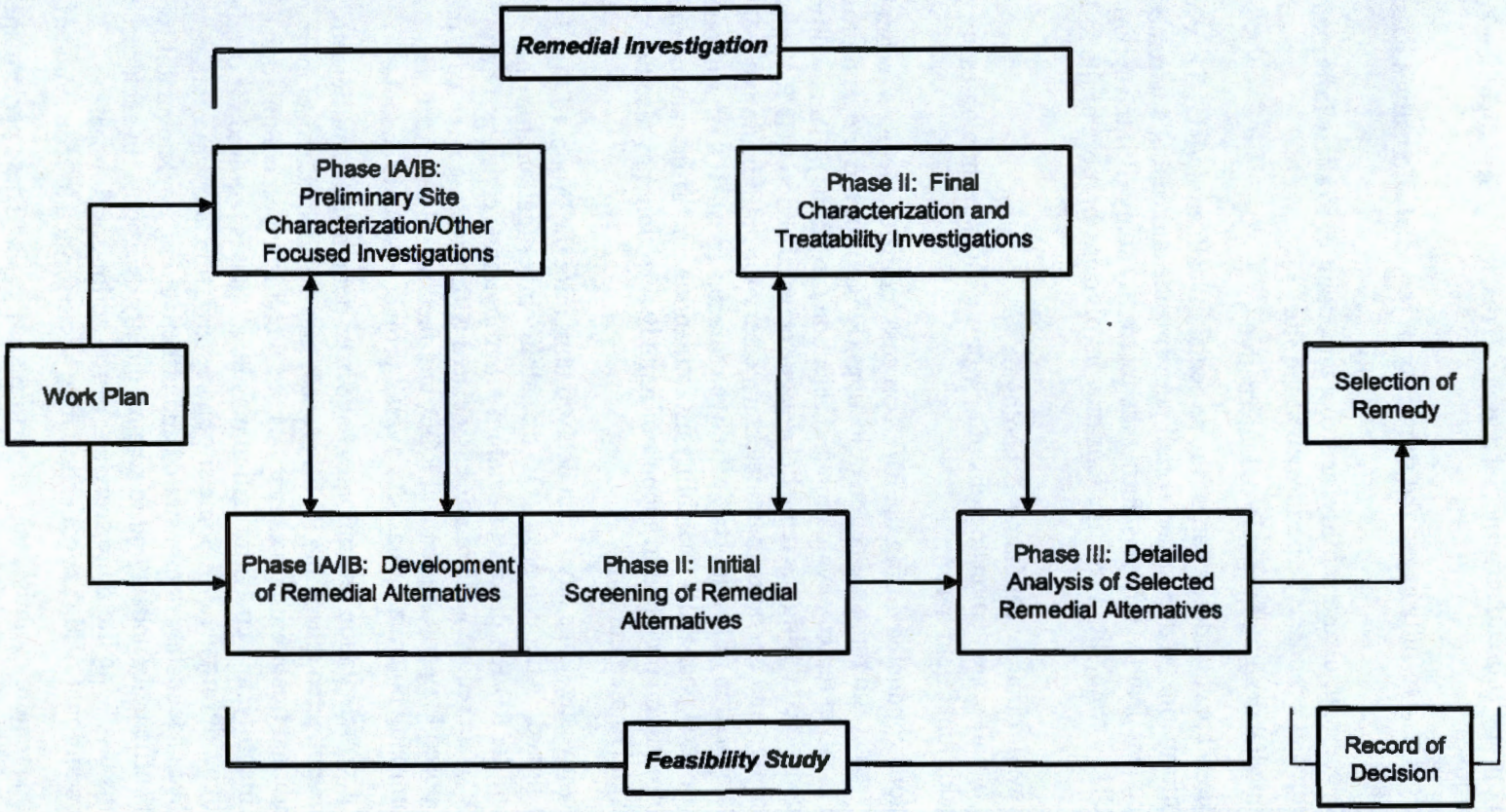
The relationship between treatability investigations and the CERCLA remedial action process is also discussed in Company procedures for project initiation and execution, and by reference the project management requirements, and is depicted in Figure 1-5. In accordance with Company procedures, this initial planning basis is prepared to support treatability and other focused investigations for the 200-SW-2 OU. The 200-SW-2 OU is a RCRA/CERCLA project. As such, this initial planning basis is prepared to be consistent with the requirements of Chapter 7 of the Tri-Party Agreement Action Plan. Under the Tri-Party Agreement Action Plan, treatability investigations are conducted during Phase II site characterization, after the nature and extent of contamination is known, to support screening and selection of remedial alternatives. Focused investigations can be initiated during Phase I site characterization to provide information to support development of potential remedial alternatives. Figure 1-6 provides an overview of the RI/FS process modified to reflect the 200-SW-2 OU multi-phased approach.

Figure 1-5. Typical Hanford Remedial Action Process.




CERCLA = *Comprehensive Environmental Response, Compensation, and Liability Act of 1980.*
RD/RA = remedial design/remedial action.
TPA = Tri-Party Agreement.

Figure 1-6. Overview of the Remedial Investigation/Feasibility Study Process.



Treatability investigations provide valuable site- and technology-specific data necessary to support remedial designs and subsequent remedial actions. Treatability investigations serve the following primary purposes:

- Provide sufficient data to fully assess the suitability of remedial alternatives passing the screening process
- Reduce effectiveness, implementability, and cost uncertainties to allow informed selection of remedial actions to be performed at the site
- Support the remedial design of the selected alternative.

Treatability investigations are considered part of the remedial investigation (RI). They are driven by a need for information to determine overall performance and cost of site remediation technologies for subsequent detailed analysis during the feasibility study (FS) in support of the Proposed Plan and ROD. Treatability investigations may involve one or more of the following major activities:

- Literature surveys for mature candidate technologies
- Bench-, pilot-, or full-scale demonstrations of new or unproven technologies
- Collection of additional field data.

Treatability investigations conducted during the RI/FS process indicate whether a technology can meet expected cleanup goals and remedial action objectives (RAOs) for the site, and provide important information to aid in remedy evaluation and selection (pre-ROD). Treatability investigations can be conducted during the remedial design/remedial action (RD/RA) process to establish site-specific design and operating parameters necessary for optimization of technology performance and implementation of sound, cost-effective remedies (post-ROD). Although the purpose and scope of pre- and post-ROD treatability investigations can differ, they complement one another because information obtained in support of remedy selection may also be used to support remedy design and implementation.

Historically, treatability investigations have been delayed until after the Proposed Plan is issued and the ROD has been signed. Although post-ROD treatability investigations may be appropriate in support of the RD/RA process, treatability investigations conducted during the RI/FS process (pre-ROD) can reduce uncertainties associated with selecting a remedy, provide a sound basis for the Proposed Plan and subsequent ROD, and facilitate site remediation negotiations while minimizing potential impacts to overall project cost and schedule.

Some characterization and remediation technologies have been demonstrated sufficiently and site-specific information collected during the RI/FS process may be adequate to support evaluation without additional treatability investigations. In such instances, compilation of effectiveness, implementability, and cost information may be all that is required for detailed analysis of the technologies during the FS. Some site characterization and remediation technologies have not been adequately demonstrated and effectiveness, implementability, and cost parameters are not sufficiently understood to support quality decisions. In such cases, treatability investigations involving literature searches; bench-, pilot-, or full-scale demonstrations; and/or additional field data collection may be performed to reduce uncertainties.

Treatability investigations require establishment of performance goals. These performance goals typically manifest themselves as applicable or relevant and appropriate requirements (ARAR),

RAO, data quality objectives (DQO), preliminary remediation goals (PRG), and other performance measures that are specified in work plans, sampling and analysis plans (SAP), and other documentation prepared in support of treatability investigations. The performance goals may be reassessed periodically as a result of new information or evolving requirements, treatment train considerations, or other factors to determine suitability following completion of treatability investigations. Pre-ROD treatability investigation goals usually are based on anticipated performance standards that will be established in the ROD. This is because cleanup criteria are typically not finalized until the ROD is signed due to continuing analyses and ARAR determinations. The treatability investigation goals consider the following factors:

- Levels that are protective of human health and the environment (e.g., contact, ingestion, leaching) if remediated waste is left unmanaged or is managed
- Levels that are in compliance with ARARs, including land disposal restrictions
- Levels that ensure a reduction of toxicity, mobility, or volume
- Levels acceptable for delisting the waste
- Levels set by the State or Region for another site with contaminated media having similar characteristics and contaminants.

Furthermore, a goal for remediation technologies to achieve 90 percent or greater reduction in the concentration or mobility of individual contaminants of concern is generally accepted. This goal is intended to complement and be consistent with site-specific, risk-based goals. However, there may be situations where reductions outside this range that achieve health-based or other site-specific remediation goals, may be appropriate and acceptable. Post-ROD treatability investigation goals will reflect those performance standards specified in the ROD.

The proposed schedule for treatability and other focused investigations in presented in Chapter 6 of the 200-SW-1/2 OU RI/FS Work Plan (DOE/RL-2004-60, Draft B). Treatability and/or other focused investigations are proposed for initiation in FY 2008 as discussed herein. All treatability and other focused investigations preceding the ROD for non-tank farm OUs in the 200 Areas are currently scheduled to be completed by December 31, 2011 (Tri-Party Agreement Milestone M-15-00C). Post-ROD treatability investigations may be warranted in support of site-specific remedial designs and subsequent remedial actions. Remedial actions on all non-tank farm OUs are currently scheduled for completion by September 30, 2024 (Tri-Party Agreement Milestone M-16-00).

## 1.2 PHASED REMEDIAL INVESTIGATION/ FEASIBLITY STUDY STRATEGY FOR THE 200-SW-2 OPERABLE UNIT

In FY 2005, the U.S. Department of Energy (DOE), Richland Operations Office (RL) and Washington State Department of Ecology (Ecology) participated in a series of collaborative workshops to discuss the initial draft of the RI/FS Work Plan for the 200-SW-1 and 200-SW-2 OUs (Ecology and DOE, 2005, *200-SW-1 and 200-SW-2 Collaborative Workshops, Agreement, Completion Matrix, and Supporting Documentation, Final Product*). During these workshops, RL and Ecology agreed to a phased characterization approach with an initial phase focused on additional records research, non-intrusive sampling, and waste site boundary

definitions. After the collaborative workshops were completed, over 147,000 burial records and hundreds of reports were compiled and reviewed, and a database was created to capture information that will be used to focus RI/FS activities. This information was then used to support a DQO process for the initial suite of non-intrusive characterization activities. This DQO process (identified within the project as the Phase I-A DQO) resulted in a variety of non-intrusive characterization activities on many of the landfills in the 200-SW-2 OU. These non-intrusive characterization activities included geophysical investigations, radiological surveys, and volatile organic contaminants (VOC) sampling and analysis (D&D-27257, *Data Quality Objectives Summary Report for Nonintrusive Characterization of Bin 3A and Bin 3B Waste Sites in the 200-SW-2 Operable Unit*; D&D-28283, *Sampling and Analysis Instruction for Nonintrusive Characterization of Bin 3A and Bin 3B Waste Sites in the 200-SW-2 Operable Unit*).

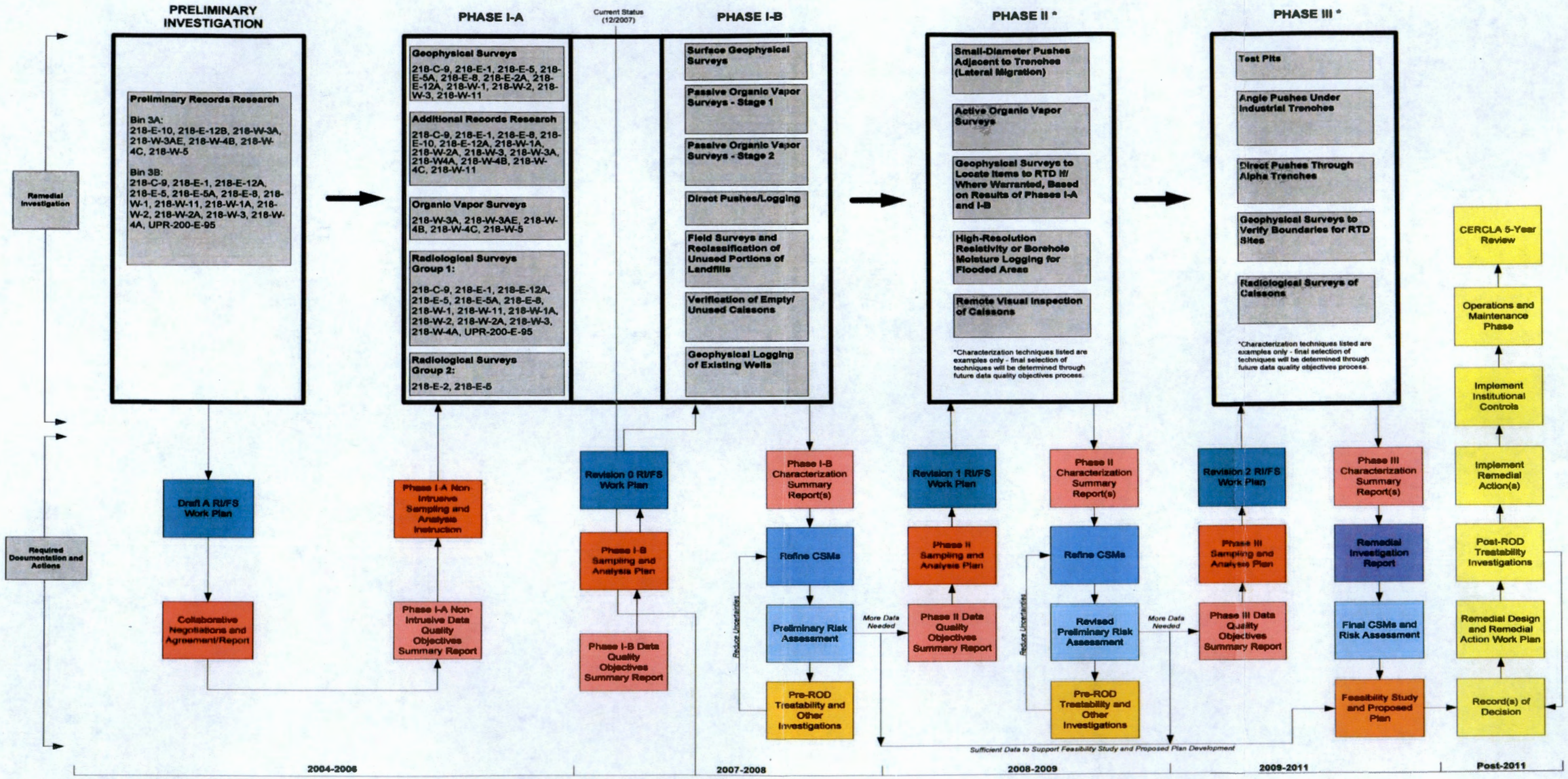
Due to the complexity of the 200-SW-2 OU, a phased RI approach is being employed to support decision making (Figure 1-7). This approach was approved by RL and Ecology and is documented in CCN 0073214, *Path Forward – 200-SW-1/2 RI/FS Work Plan Development, May 15, 2007.*

The Phase I-A characterization activities were completed in FY 2006. A Phase I-B DQO was issued in FY 2008 (SGW-33253, *Data Quality Objectives Summary Report for Phase I-B Characterization of the 200-SW-2 Operable Unit Landfills*) to support the 200-SW-2 OU RI/FS Work Plan. The RI/FS Work Plan and associated SAP provide additional non-intrusive characterization for the 200-SW-2 OU. In addition, limited intrusive characterization outside landfill trench boundaries (i.e., not within the waste) is currently planned using direct push technologies and borehole logging.

Additional DQO processes and site characterization phases will occur following completion of the Phase I-B site characterization activities, as required. Future site characterization phases and associated DQOs and SAPs will focus on progressively more intrusive characterization, as required, to more fully understand the nature and extent of contamination. Information gathered from all phases will be used to support baseline risk assessments, further refine conceptual site models, support treatability investigations, and ultimately select remedial action alternatives in support of the Proposed Plan and subsequent ROD. The phased characterization process for the 200-SW-2 OU is discussed in more detail in the RI/FS Work Plan.

As a better understanding of site conditions and contaminants are acquired through the phased RI, the 200-SW-2 OU project will be better positioned to plan future field activities, including identification of the type and scale of treatability investigations needed in support of selected remedial action alternatives. Treatability investigations should be considered for candidate technologies that have not been sufficiently demonstrated or cannot be adequately evaluated on the basis of available information alone. Necessary treatability investigations should be designed and implemented during the RI, while other field activities are underway. Some treatability investigations are conducted as pre-ROD activities while others tend to be site- and/or technology-specific and are more appropriately conducted after the nature and extent of contamination is better understood and/or post-ROD.

Figure 1-7. Phased Characterization Approach for the 200-SW-2 Operable Unit.




CERCLA = *Comprehensive Environmental Response, Liability, and Compensation Act of 1980*.
CSM = conceptual site model.
RI/FS = remedial investigation/feasibility study.
ROD = record of decision.
RTD = removal, treatment, disposal.

## 1.3 SCOPE AND OBJECTIVES OF THIS INITIAL PLANNING BASIS DOCUMENT

The purpose of this document is to provide the initial basis for planning treatability and other focused investigations that may benefit the 200-SW-2 OU. This document is intended for internal use and is not required under the Tri-Party Agreement. The following information is provided:

- Overview of the use of treatability investigations to support the CERCLA RI/FS process, as prescribed by EPA/540/R-92/071a
- Discussions of treatability and other focused investigations that may benefit the 200-SW-2 OU RI/FS process
- Rough-order-of-magnitude cost and proposed schedule to support the planning and execution of treatability and other focused investigations for the 200-SW-2 OU.

This document supports the RI/FS Work Plan for the 200-SW-2 OU. The primary focus of this treatability investigation document is the 200-SW-2 OU due to its coverage under the CERCLA process. The 200-SW-1 OU is proposed for closure outside the CERCLA process and is beyond the scope of this document.

Several onsite and offsite activities have been completed, are underway, or are planned to address wastes similar to that contained in the 200-SW-2 OU. These activities and experiences are discussed herein and should be leveraged in support of the 200-SW-2 OU RI/FS process. In some cases, it is possible that other onsite and offsite activities may be of limited usefulness and additional treatability investigations may be warranted.

Several treatability investigations are suggested to support detailed analysis of remedial alternatives during the FS by providing additional information regarding the effectiveness, implementability, and/or cost of candidate technologies. In some cases, process options that comprise potential site remediation alternatives (i.e., caps/covers; in situ treatment; retrieve/treat/dispose; etc.) incorporate developed technologies that have a history of use. With a few exceptions, sufficient information regarding the effectiveness, implementability, and cost of candidate characterization and remediation technologies exists based on Hanford Site, other DOE site, and private industry experience to support detailed analysis of remedial alternatives during the FS without additional treatability investigations. However, site-specific treatability investigations of otherwise mature technologies may be advisable to support post-ROD remedial designs by defining operating parameters and specifications, and facilitating remedial action implementation.

Additionally, a number of focused investigations are suggested to obtain information in support of characterization and remediation technology evaluations during the RI/FS process. These focused investigations are discussed herein and tend to be engineering studies of site conditions and/or demonstrated technologies rather than treatability investigations of new or unproven technologies.

## 1.4 PRE-ROD TREATABILITY INVESTIGATIONS

Site characterization and treatability investigations are two major components of the RI to provide sufficient information for detailed analysis of site remediation alternatives during the FS. Given the phased nature of the 200-SW-2 OU RI, additional data needs for evaluating remediation alternatives may be identified as site characterization information is collected and reviewed. Treatability investigations may be required to fill some data gaps. In the absence of data in available technical literature, treatability investigations can provide information regarding the effectiveness, implementability, and cost of technologies needed to evaluate and select among site remediation alternatives in support of the Proposed Plan and subsequent ROD.

The decision to use a bench- versus pilot- or full-scale treatability investigation is affected by a number of factors, including technology maturity, composition of the waste, site-specific conditions, and nature of desired data. For a technology that is well developed and tested, bench-scale treatability investigations may be sufficient to evaluate performance on new waste types. Pilot- or full-scale treatability investigations may be necessary if information needed to operate the technology at full-scale is limited, performance under site-specific conditions is unknown, if there is a need to investigate secondary effects of the process, or if the waste being treated is complex or unique.

During the FS, nine CERCLA evaluation criteria are considered while assessing potential site remediation alternatives. Treatability investigations are structured to provide data required to address selected site remediation technologies with respect to the first seven of the following nine CERCLA evaluation criteria:

- Threshold Criteria
  - Overall protection of human health and the environment
  - Compliance with ARARs
- Balancing Criteria
  - Long-term effectiveness and permanence
  - Reduction of toxicity, mobility, and volume
  - Short-term effectiveness
  - Implementability
  - Cost
- Modifying Criteria
  - State acceptance
  - Community acceptance.

The first two criteria, which relate directly to statutory requirements each remedial alternative must meet, are categorized as threshold criteria. The next five are primary balancing criteria upon which selection of the remedy is based. The final two modifying criteria are addressed in the ROD when comments are received on the RI/FS and Proposed Plan. Figure 1-8 depicts the nine CERCLA evaluation criteria and associated analysis factors.

Pre-ROD treatability investigations may be needed when potentially applicable treatment technologies have no or limited information with respect to the waste types and site conditions of interest. In accordance with EPA guidance, the need to conduct a treatability investigation for

Figure 1-8. Criteria and Analysis Factors for *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* Evaluation.

## THRESHOLD CRITERIA

**Overall Protection of Human Health and the Environment**

- How alternative provides human health and environmental protection

**Compliance with ARARs**

- Compliance with chemical specific ARARs
- Compliance with action specific ARARs
- Compliance with location specific ARARs
- Compliance with other criteria, advisories, and guidance

## BALANCING CRITERIA

**Long-Term Effectiveness and Permanence**

- Magnitude of residual risk
- Adequacy and reliability of controls

**Reduction of Toxicity, Mobility, or Volume through Treatment**

- Treatment process used and materials treated
- Amount of hazardous material destroyed or treated
- Degree of expected reductions in toxicity, mobility, and volume
- Degree to which treatment is irreversible
- Type and Quantity of residuals remaining after treatment

**Short-Term Effectiveness**

- Protection of community during remedial action
- Protection of workers during remedial action
- Environmental impacts
- Time until remedial action response objectives are achieved

**Implementability**

- Constructability and operability of technology
- Reliability of technology
- Ease of additional remedial actions, if necessary
- Ability to monitor effectiveness of remedy
- Ability of obtain approvals from other agencies
- Coordination with other agencies
- Availability of TSD services and capacity
- Availability of equipment and specialists
- Availability of prospective technologies

**Cost**

- Capital cost
- Operating and maintenance cost
- Present worth cost

## MODIFYING CRITERIA

**State Acceptance***

**Community Acceptance***

* These criteria are assessed following comment on the RI/FS report and the Proposed Plan

ARAR = applicable or relevant and appropriate requirement.
RI/FS = remedial investigation/feasibility study.
TSD = treatment, storage, and/or disposal (unit).

any part of a remediation alternative is a management decision. In addition to the technical considerations, certain non-technical management decision factors must be considered. These factors typically include the expected level of State and community acceptance of a proposed alternative; time constraints on the completion of the RI/FS process; preparation of the Proposed Plan and signing of the ROD; and the discovery of new site, waste, or remediation technology information.

If existing data are adequate for evaluation and selection of remedial alternatives (i.e., sufficient to perform a detailed analysis against the CERCLA evaluation criteria), then a treatability investigation may not be required. Otherwise, treatability investigations may be performed to generate data needed to conduct detailed analysis of alternatives during the FS. The need for pre-ROD treatability investigations is a project risk management decision in which the cost and time required to conduct treatability investigations are weighed against the risks inherent in selection of site remediation technologies.

## 1.5 POST-ROD TREATABILITY INVESTIGATIONS

Although a substantial amount of data on the selected remedy may be available from the RI/FS process, treatability investigations may be necessary to support the RD/RA (i.e., remedial design report and remedial action work plan) following the signing of the ROD. Post-ROD or RD/RA treatability investigations provide detailed design, cost, and performance data to optimize site remediation processes and implement full-scale remediation systems at specific sites. In the process of designing and implementing a remedy, RD/RA treatability investigations can be used to:

- Verify that the selected technology can be implemented and achieve ROD goals
- Pre-qualify and select among multiple vendors and processes within the prescribed remedy
- Implement the most appropriate remedy prescribed in a Contingency ROD involving multiple remedies
- Optimize design and operating conditions
- Support preparation of detailed design specifications and design of treatment trains
- Improve cost estimates.

In general, a single remedy is typically selected in the ROD. However, due to the complexity of wastes sites at Hanford, multiple remedies are possible in the ROD. Remedies are often identified as a technology class or family (e.g., solidification/stabilization) rather than a specific process option (e.g., grouting or vitrification). Selection of a technology class affords flexibility during the remedial design to procure the most cost-effective vendor and process. There are situations where additional flexibility in the ROD may be required to ensure implementation of the most appropriate technology for a site. In these cases, the selected remedy may be accompanied by a proven contingency remedy as in a Contingency ROD. The Contingency ROD option was developed for two purposes:

- Promote the use of innovative technologies
- Allow different technologies offering comparable performance to be carried through to remedial design.

Although treatability investigations of an innovative technology could be conducted during the FS to support remedy selection, it may not be feasible to conduct sufficient demonstrations to address major uncertainties associated with implementation of the technology. This situation, however, should not cause the innovative technology to be screened out during the detailed analysis of alternatives. If the potential performance of an innovative technology indicates the technology would provide the best balance of tradeoffs from among the options considered despite its uncertainties, CERCLA Section 121(b)(2) provides support for selecting such a technology in the ROD. Implementation of the technology, however, may be contingent upon the results of post-ROD treatability investigations. If two different technologies for treatment of the same contaminant/matrix emerge from the FS process and each offers comparable performance with respect to the five primary balancing criteria, one of the alternatives may be named in the ROD as the selected remedy and the other as the contingency remedy. Based on the results of post-ROD treatability investigations, the most appropriate remedy can then be identified and implemented.

If technical data available from the RI/FS process are insufficient for design of the remedy, a post-ROD treatability investigation may be necessary to support development of detailed design specifications. Post-ROD treatability investigations can also be performed to support the design of treatment trains. Treatability investigations of a single unit operation can assist in identifying characteristics of the treated material that may need to be taken into consideration in the design of subsequent units. A treatability investigation of the entire site remediation train can then provide data to confirm compliance with ARARs and cleanup criteria outlined in the ROD.

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# 2.0 INITIAL TREATABILITY AND OTHER FOCUSED INVESTIGATIONS FOR THE 200-SW-2 OPERABLE UNIT

## 2.1 OVERVIEW

The purpose of the FS is to identify and evaluate alternatives for waste site remediation in support of the Proposed Plan and subsequent ROD. Treatability and other focused investigations can be conducted to fill data gaps with information required to reduce uncertainties and support better decision making and more cost-effective site remediation. The FS has several steps in support of remedial alternatives identification and evaluation including:

- Define RAOs (including ARARs)
- Identify general response actions (GRAs) to satisfy RAOs
- Identify potential technologies and process options associated with each GRA
- Screen process options to select a representative process for each type of technology based on its effectiveness, implementability, and cost
- Assemble viable technologies into alternatives representing a full range of options including, but not limited to, retrieval, treatment, and disposal; in situ treatment; and in situ isolation and stabilization. Options for no-action and/or monitored natural attenuation are also considered.

In some cases, the various process options comprising candidate remedial alternatives are fully developed and have a history of use at the Hanford Site or elsewhere (EPA/402/R-96/017, *Technology Screening Guide for Radioactively Contaminated Sites*). With a few exceptions, sufficient information exists regarding process options and associated remedial alternatives to support detailed analysis during the FS without additional treatability investigations. However, site-specific treatability investigations may be required to support the remedial design and remedial action by defining operating parameters following the signing of the ROD.

### 2.1.1 200 Area Remedial Investigation/Feasibility Study Implementation Plan

The Implementation Plan (DOE/RL-98-28) contains a preliminary evaluation of RAOs, GRAs, and potential technologies and process options to support identification of viable remedial action alternatives for contaminated soil and buried solid waste in the 200 Areas of the Hanford Site; including the 200-SW-2 OU. These RAOs, GRAs, and potential alternatives provide a basis for refinement and detailed evaluations during preparation of the FS. In general, waste site characterization data can be limited and historical records can be incomplete. Consequently, remedial alternatives discussed in the Implementation Plan tend to be general and cover a wide range of potential actions to reflect the diversity of possible waste conditions.

Remedial alternatives are developed based on classes of compounds rather than specific contaminants. One important consideration in the identification of remedial alternatives is that radionuclides, heavy metals, and some inorganic compounds cannot be destroyed. Rather, these compounds must be physically removed, immobilized, contained, isolated, or chemically

converted to less mobile or less toxic forms. Organic compounds, on the other hand, can be destroyed, but may represent a much smaller portion of the overall contamination.

Alternatives may require refinements or modifications based on site characterization data collected during the RI. The Implementation Plan identifies preliminary technology-specific and site-specific information needs to complete detailed analysis of potential alternatives during the FS. These information needs can be satisfied by conducting treatability investigations of selected technologies. Recommendations regarding the feasibility of some technologies may change as a result of treatability investigation results and consideration of site-specific conditions discovered during the RI.

### 2.1.2 Preliminary Remedial Action Objectives

The RAOs are general descriptions of remedial action expectations in order to be protective of human health and the environment. When necessary, treatability investigations can be conducted to demonstrate a technologies ability to meet established RAOs. The RAOs are typically defined, during the FS process, with as much specificity as possible and usually include the following considerations:

- Medium of concern
- Types of contaminants
- Possible exposure pathways
- Potential receptors
- Levels of residual contaminants that may remain following remediation (i.e., contaminant levels that are below cleanup standards or below a range of levels for different exposure routes).

The RAOs provide a basis for evaluating the capability of remedial alternatives to achieve compliance with ARARs and/or intended levels of risk protection for human health or the environment. The RAOs identified in the Implementation Plan are general and preliminary. They are intended as a guide for developing specific RAOs during the FS process in support of 200-SW-2 OU remediation and may be revised or modified as a result of new information derived from site characterization activities conducted during the RI.

Preliminary RAOs are typically used to develop remedial action alternatives that are focused on reducing potential hazards of contamination and satisfying ARARs. The Implementation Plan identified the following preliminary RAOs:

- Prevent or mitigate risk to human and ecological receptors associated with ingestion, dermal contact, inhalation, and external exposure to contaminants that exceed ARARs or a risk of $10^{-4}$ to $10^{-6}$
- Prevent or mitigate the migration of contaminants to groundwater such that no further groundwater degradation occurs
- Prevent or mitigate the migration of contaminants to groundwater and through groundwater so contaminants do not reach the Columbia River at levels that exceed ARARs or a risk of $10^{-4}$ to $10^{-6}$
- Prevent plants and animals from creating a migration pathway for the contaminants

- Prevent or mitigate risk to workers performing remedial actions
- Provide conditions suitable for proposed future land use
- Prevent destruction of significant cultural resources and sensitive wildlife habitat; minimize disruption of cultural resources and wildlife habitat; prevent adverse impacts to cultural resources and threatened or endangered species.

The primary media of concern for the 200-SW-2 OU are soil and solid waste potentially contaminated with radioactive and chemical constituents. The primary radioactive contaminants of potential concern include americium, carbon, cesium, cobalt, europium, tritium, nickel, plutonium, samarium, strontium, technetium, thorium, and uranium. Nonradioactive hazardous chemical contaminants of potential concern include a variety of metals, inorganics, VOCs, semi-VOCs, and petroleum compounds (Implementation Plan).

Transuranic waste was retrievably stored in portions of the 200-SW-2 OU for subsequent retrieval under the M-91 Project. The remainder of the radioactive material is low-level waste (LLW), some of which contains alpha-emitting radionuclides. The LLW is primarily paper, plastic, wood, protective clothing, concrete rubble, activated metal, and contaminated equipment.

Based on historical disposal records, no bulk liquids are disposed in the 200-SW-2 OU. Small volumes of liquid were disposed after stabilization on absorbent materials and containerization. Although small portions of the 200-SW-2 OU reportedly had standing water following a rapid snow melt over frozen ground in the late 1970's, there is currently no evidence to suggest that the 200-SW-2 OU has contributed to groundwater contamination on the Hanford Site although the possibility may exist. The various phases of RI will provide a better understanding of the nature and extent of contamination beneath trenches in the 200-SW-2 OU. Although some trenches in the 200-SW-2 OU may have received VOCs, many landfills are situated in areas where regional groundwater and vadose zone plumes of VOCs are known to exist from past operation of waste water disposal to underground cribs. Data collected through the various phases of RI in the 200-SW-2 OU may help to differentiate the sources of VOCs.

### 2.1.3 Preliminary Remediation Goals

Preliminary remediation goals (PRGs) are numeric representations of the RAOs. The PRGs represent cleanup levels that are identified for applicable contaminants and exposure pathways based on anticipated future land use, the conceptual exposure model, and the RAOs. The PRGs are used to define unacceptable risk posed by specific contaminants to identify contaminants that are most likely risk drivers (i.e., contaminants of concern). The PRGs provide target cleanup goals for use during remedial design and provide guidance during remediation. The PRGs are based on acceptable levels of human health and ecological risk, ARARs, points of compliance, remediation timeframes, and other guidance.

Preliminary RAOs identified in the Implementation Plan are designed to protect human and ecological receptors from exposure to contaminants and may be achieved by meeting PRGs based on the following standards, as applicable:

- DOE, EPA, and Ecology supported radionuclide soil cleanup standard of 15 mrem/yr above background radiation levels
- The State of Washington's Model Toxics Control Act standards for nonradioactive contaminants.

The RAOs designed to ensure no further degradation of groundwater and protection of the Columbia River may be achieved by meeting PRGs based on the following, as applicable:

- Maximum contaminant levels promulgated under the Safe Drinking Water Act
- State of Washington's Drinking Water Standards or alternate concentration limits established where groundwater restoration is shown to be impracticable
- The State of Washington's Model Toxics Control Act standards for nonradioactive contaminants
- Ambient Water Quality Criteria developed under the Clean Water Act
- State of Washington's Surface Water Quality Standards.

The above PRGs, identified in the Implementation Plan, are initial goals based on standards derived from existing ARARs. The PRGs will be reevaluated to reflect ARARs that are current when the 200-SW-2 OU FS is written. Future characterization data may indicate that the initial PRGs are inappropriate. As site characterization data become available through the RI, the PRGs will be evaluated in the FS and modified, as appropriate.

### 2.1.4 Preliminary General Response Actions

Preliminary GRAs represent broad classes of remedial actions that are intended to satisfy the RAOs. The GRAs are intended to cover the range of options from "no action" to complete remediation. The GRAs are also referred to as likely response scenarios. The alternatives and remediation technologies identified in the Implementation Plan were associated with the following preliminary GRAs. These GRAs will be refined and modified, as needed, during preparation of the 200-SW-2 OU FS. Section 2.2.3 identifies likely response scenarios established more recently through the collaborative workshops between RL and Ecology.

- No-action
- Institutional control
- Containment
- Removal, treatment, and disposal
- Ex situ treatment
- In situ treatment (including natural attenuation)

"***No Action***" is included for evaluations in accordance with the provisions of the *National Environmental Policy Act* and *National Contingency Plan* to provide a baseline for comparison with other response actions. The no action alternative may be appropriate for some sources of contamination if risks are acceptable to natural resources or humans, and contaminant-specific ARARs are not exceeded.

"***Institutional Controls***" involve the use of physical barriers (fences) and access restrictions (property deeds) to reduce or eliminate exposure to contamination. Institutional controls can also include groundwater, vadose zone, surface soil, biotic, and/or air monitoring.

"***Containment***" includes physical measures to restrict accessibility to waste or the migration of contaminants from in-place waste disposal. Containment technologies include the use of engineered surface barriers (i.e., caps/covers) and vertical subsurface barriers (e.g., slurry walls, grout curtains, etc.) as physical and hydraulic barriers to control the downward or lateral

migration of contaminants due to water infiltration; plant, animal, and human intrusion; and wind/water erosion.

"***Removal, Treatment, and Disposal***" involves the excavation of contaminated material for disposal in a regulatory compliant facility. Depending on the nature of the waste removed (e.g., radioactivity levels, hazardous waste classification, etc.) ex situ treatment of the waste may be performed prior to disposal, if necessary. Treatment of contaminated material can be performed in situ or ex situ and typically involves the use of biological, thermal, physical, or chemical technologies.

"***Ex Situ Treatment***" involves the above ground treatment of soil and debris after it has been excavated. Typical treatment options include biological land farming, thermal processing, soil washing, and solidification and/or stabilization.

"***In Situ Treatment***" is distinguishable from ex situ treatment in its ability to attain RAOs without removing wastes. The final waste form generally remains in place. This feature can be an advantage when exposure or worker safety during excavation would be significant or when excavation is considered technically impractical (e.g., deep vadose zone contamination). Examples of in situ waste treatment techniques include in situ vitrification, in situ grouting, soil vapor extraction, and in situ bio-treatment. Treatment technologies must often be pilot tested before they can be applied due to site-specific conditions (e.g., site hydrology, geology, geochemistry, etc.) affecting the effectiveness and implementability of the technology.

Although natural attenuation is not actually a technology, it can be addressed as an in situ treatment process. Natural attenuation encompasses natural subsurface processes or contaminant characteristics that can effectively reduce contaminant toxicity, mobility or volume. Natural attenuation processes include radioactive decay, biodegradation, biological stabilization, volatilization, dispersion, dilution, chemical or biological stabilization, transformation or destruction, and sorption.

## 2.2 TECHNOLOGY PRESCREENING IN SUPPORT OF THE 200-SW-2 OPERABLE UNIT REMEDIAL INVESTIGATION/FEASIBILITY STUDY

### 2.2.1 General

The three primary strategies used separately or in conjunction to remediate most sites include:

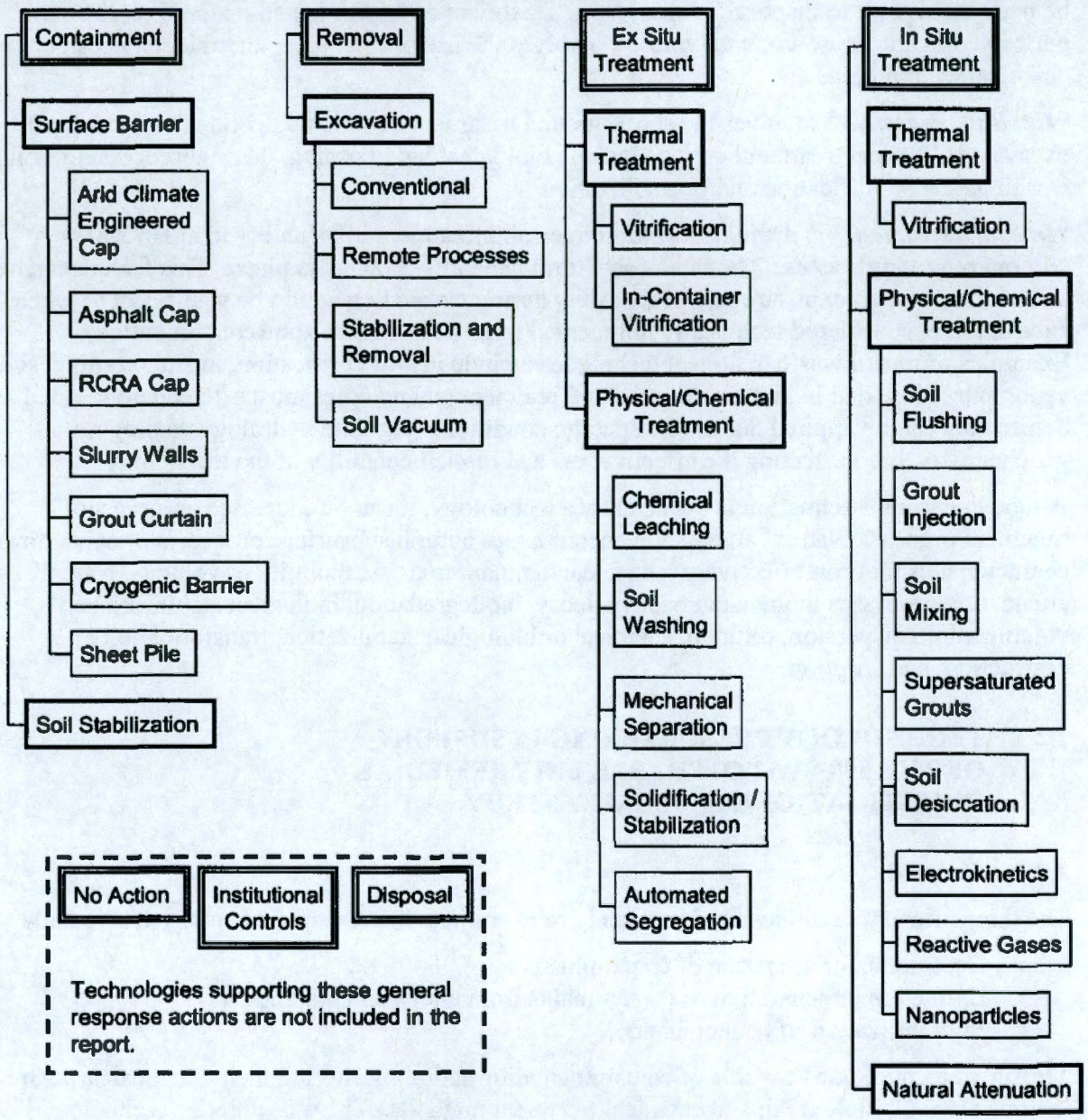
- Destruction or alteration of contaminants
- Extraction or separation of contaminants from environmental media
- Immobilization of contaminants.

Treatment technologies capable of contaminant destruction by altering their chemical structure include thermal, biological, and chemical treatment methods. These destruction technologies can be applied to contaminated media either in situ or ex situ (following removal). Figure 2-1 depicts a typical organization of treatment and immobilization technologies.

Treatment technologies commonly used for extraction and separation of contaminants from soil include thermal desorption, soil flushing/washing, solvent extraction, and soil vapor extraction. These extraction/separation technologies can be applied to contaminated media either in situ or

ex situ (following removal). Selection and integration of technologies should consider effective contaminant transport mechanisms to arrive at the most effective treatment scheme.

Figure 2-1. Organization of Typical Treatment and Immobilization Technology Options.




PNNL-16105, *Technology Survey to Support Revision to the Remedial Investigation/Feasibility Study Work Plan for the 200-SW-2 Operable Unit at the U.S. Department of Energy's Hanford Site.*

For example, more air than water can be moved through soil. Therefore, for a volatile contaminant in soil that is relatively insoluble in water, soil-vapor extraction would be a more efficient separation technology than soil flushing or washing.

Immobilization technologies include stabilization, solidification, and containment technologies. The long-term effectiveness of immobilization technologies requires periodic maintenance. Immobilization technologies are often proposed for remediating sites contaminated by radionuclides, metals, or other inorganic species.

### 2.2.2 200-SW-2 Operable Unit Technology Prescreening

The management of contaminated soil and buried solid waste in the 200 Areas is described in the Implementation Plan. Appendix D of the Implementation Plan provides an initial screening to identify potentially viable remediation technologies. The appendix also identifies additional technology-specific and site-specific information needs to support detailed analysis of site remediation alternatives. In most cases, the process options comprising the technology alternatives were found to be fully developed with a history of use at the Hanford Site or elsewhere. With a few exceptions, sufficient information regarding effectiveness, implementability, and cost exists to support detailed analysis of potential remediation alternatives in the FS. However, site-specific treatability investigations may be required post-ROD to support the remedial design and implementation of the remedial action.

A technology survey was conducted (PNNL-16105, *Technology Survey to Support Revision to the Remedial Investigation/Feasibility Study Work Plan for the 200-SW-2 Operable Unit at the U.S. Department of Energy's Hanford Site*) to support revision of the 200-SW-2 OU RI/FS Work Plan and address, in part, comments documented in the collaborative agreement between RL and Ecology. A full range of remediation and characterization technologies were evaluated to support revision of the RI/FS Work Plan, identification of DQOs, preparation of work plans and SAPs, and identify the potential need for treatability and other focused investigations in support of the 200-SW-2 OU FS.

The technology survey also served to update and expand remediation technology evaluations conducted in the Implementation Plan. Primary areas of technology expansion included methods for containment, removal, ex situ treatment, and in situ treatment. Information was assembled to update the descriptions of potential remediation technologies and support the technology basis for likely response scenarios. Information for each technology is presented with respect to maturity, effectiveness, implementability, and cost. The need for possible treatability investigations for several supporting technologies in the areas of retrieve, treat, dispose; in situ stabilization; and in situ contaminant extraction were identified. The updated remediation technology information considered site remediation activities being conducted in the 100, 300, and 600 Areas of the Hanford Site, which are being addressed separately through other projects.

The technology survey also addressed potentially applicable characterization technologies. Eight categories of information relevant to the characterization of the 200-SW-2 OU were addressed:

- Distribution of debris and physical boundaries of landfill trenches (intrusive and non-intrusive)
- Distribution of heavy metals/inorganic compounds (intrusive and non-intrusive)
- Distribution of organic compounds (intrusive and non-intrusive)
- Lateral distribution of radionuclides (intrusive and non-intrusive)

- Vertical distribution of radionuclides (intrusive only)
- Identification of transuranic radionuclides (intrusive and non-intrusive)
- Enabling technologies (analytical)
- Enabling technologies (subsurface access).

Discussions are provided with respect to the advantages, disadvantages, limitations, uncertainties, maturity, and relative cost of potentially viable characterization technologies. Remediation and characterization technology experts from Pacific Northwest National Laboratory, Idaho National Laboratory, and Oak Ridge National Laboratory provided technical review and input to the technology survey efforts. In general, technologies exist through private industry and other DOE sites to address the 200-SW-2 OU characterization needs with respect to the above mentioned attributes. While many intrusive and non-intrusive characterization methods are commercially available, some are emerging technologies that have been successfully deployed on a limited basis.

The initial phase (Phase I-A) of the 200-SW-2 OU investigation focused on non-intrusive methods including geophysical surveys, surface radiation monitoring, and VOC sampling and analysis during FY 2006. The next phase of investigations (Phase I-B) is planned to begin in FY 2008. Phase I-B continues the non-intrusive methods with the addition of limited intrusive methods (i.e., direct push technologies) to provide information regarding site geology, soil moisture content, and the presence/absence of contamination at direct push locations near the center of 200-SW-2 OU landfills and in areas known to have received excess moisture (i.e., rapid snow melt and surface ponds). The waste will not be penetrated. The Phase I-A and Phase I-B investigations are intended to provide data necessary to focus future phase intrusive investigations aimed at better definition of the nature and extent of contamination in the 200-SW-2 OU. The results of intrusive characterization will also support needs-driven treatability investigations.

### 2.2.3 Likely Response Scenarios for the 200-SW-2 Operable Unit

Likely response scenarios provide a basis for identifying potentially viable remedial alternatives and associated technologies. Formal development and evaluation of likely response scenarios and associated remedial alternatives for the 200-SW-2 OU will occur during preparation of the FS. Due to the heterogeneity of the landfill waste, multiple likely response scenarios may be applicable. The following potential likely response scenarios were identified in the Implementation Plan:

- No action
- Institutional controls
- Engineered surface barriers with or without vertical subsurface barriers
- Excavation and disposal with or without ex situ treatment
- Excavation, ex situ treatment, and geologic disposal of soil with transuranics
- In situ grouting or stabilization of soil
- In situ vitrification of soil
- In situ vapor extraction of VOCs
- Monitored natural attenuation.

More recently, the collaborative workshops between RL and Ecology (CCN 0073214) identified the following likely response scenarios as being potentially applicable to the 200-SW-2 OU:

- Excavation, treatment (as necessary), and disposal of waste from within individual burial grounds
- Excavation, treatment (as necessary), and disposal of waste from within portions of individual burial grounds
- Capping of individual burial grounds
- In situ treatment (e.g., vitrification, grouting) of portions of individual burial grounds
- Some combination of the above
- No action with continued monitoring (maintain existing soil cover/natural attenuation).

Table 2-1 provides a composite listing of potential likely response scenarios presented in the technology survey report for the 200-SW-2 OU based on the Implementation Plan and collaborative workshops. Also included are potential site remediation technologies and indications of whether treatability investigations are suggested to collect information regarding effectiveness, implementability, or cost to support detailed evaluation of remedial alternatives during the 200-SW-2 OU FS. The need for treatability investigations and approach to collecting performance and cost information are discussed further in Sections 2.3 and 2.4. Section 2.5 discusses other focused investigations to collect information in support of the FS. Appendix B of this document provides information regarding the effectiveness, implementability, and relative cost of remediation technologies for which treatability investigations are suggested. Appendix C of this document provides typical data needs in support of suggested treatability investigations for immobilization and in situ treatment. Actual data needs will be delineated in DQOs, work plans, SAPs, and other documents prepared in support of individual treatability investigations.

Table 2-1. Likely Response Scenarios and Suggested Treatability Investigations. (2 Pages)

| Likely Response Scenario | Supporting Technologies | Treatability Investigation Suggested* |
|---|---|---|
| ***Technologies Applicable Within a Landfill*** | | |
| Surface and Subsurface Barriers | Arid climate engineered barrier | No |
| | Asphalt, concrete, cement-type cap | Yes (E) |
| | RCRA cap | No |
| | Slurry walls | No |
| | Grout curtains | No |
| | Dynamic compaction | No |
| Retrieve, Treat, Dispose (RTD) for all or portions of an individual landfill | Conventional | No |
| | Remote processes | No |
| | Stabilization and retrieval | Yes (E,I,C) |
| | Soil vacuum | No |
| | Vitrification | No |

Table 2-1. Likely Response Scenarios and Suggested Treatability Investigations. (2 Pages)

| Likely Response Scenario | Supporting Technologies | Treatability Investigation Suggested* |
|---|---|---|
| | In-container vitrification | No |
| | Soil Washing | No |
| | Mechanical separation | No |
| | Solidification/stabilization | No |
| | Automated segregation based on rad | No |
| In situ solidification and stabilization for all or portions of an individual landfill | Vitrification | No |
| | Grout injection | Yes (E) |
| | Soil mixing | Yes (E) |
| ***Technologies Applicable in the Vadose Zone Beneath a Landfill*** | | |
| In situ solidification and stabilization | Grout injection | Yes (E) |
| | Supersaturated grouts | Yes (E) |
| | Soil desiccation | Yes (E) |
| | Reactive gases | Yes (E) |
| | Nanoparticles | Yes (E,I,C) |
| Contaminant extraction | Soil flushing | Yes (E) |
| | Electrokinetics | Yes (E) |
| Natural attenuation | Monitored natural attenuation | No |

*Additional information may be needed to support the FS in the area of effectiveness (E), implementability (I), or cost (C). Some technologies not listed as requiring treatability investigations may still need site-specific design information as part of the RD/RA activities following determination of the ROD and selection of the technology.

PNNL-16105, *Technology Survey to Support Revision to the Remedial Investigation/Feasibility Study Work Plan for the 200-SW-2 Operable Unit at the U.S. Department of Energy's Hanford Site.*

RD/RA = remedial design and remedial action.
RCRA = *Resource Conservation and Recovery Act of 1976.*
ROD = record of decision.

Following completion of the RI/FS process, the results of the detailed alternatives analysis and risk management judgments provide the basis and rationale for selecting the preferred alternative(s). Once a preferred alternative is selected, then a Proposed Plan is prepared to support the ROD. Once a ROD is issued, additional treatability investigations may be conducted to support the remedial design and subsequent remedial action. Furthermore, if new technologies emerge during the RI/FS process, they may be considered, as appropriate. If additional treatability investigations are deemed necessary to support evaluation of new or emerging technologies, then work plans, DQOs, SAPs, health and safety plans, and other supporting documentation will be prepared or updated at that time.

The technology survey evaluated potential remediation technologies applicable (1) within a landfill, and (2) within the vadose zone beneath a landfill. Sections 2.3 to 2.5 describe suggested treatability and other focused investigations. Detailed performance requirements for each

treatability investigation will be developed in the future as documentation is prepared in accordance with the *Approach to Treatability Investigations,* discussed in Appendix A. Technologies not requiring treatability investigations were identified as such because they are mature and sufficient information exists regarding effectiveness, implementability, and cost to support detailed analysis during the 200-SW-2 OU FS.

## 2.3 TECHNOLOGIES APPLICABLE WITHIN A LANDFILL

### 2.3.1 Surface and Subsurface Barriers

Surface barriers (also referred to as caps and/or covers) involve covering waste in-place to reduce or eliminate exposure pathways. Because contaminated media are not removed or treated, there is a residual risk of exposure over the long-term due to surface barrier disturbance. If surface barriers remain undisturbed, then they can protect human health and the environment by putting a physical separation between the contaminated waste and the surface. Additionally, properly designed surface barriers can control water infiltration; plant, animal, and inadvertent human intrusion (when coupled with administrative controls); and wind/water erosion thereby providing a mechanism for controlling contaminant migration from the disposal site.

Surface barriers may be designed as temporary or final site remediation measures. Temporary surface barriers are typically of a mono-layer design and are installed before final closure to control water infiltration and minimize generation of leachate until an alternative remedy is selected. Temporary surface barriers are also used to minimize water infiltration while the underlying waste mass is undergoing settling. A more stable base will thus be provided for a final surface barrier, if selected as the remedy, thereby reducing the cost of post-closure maintenance and ensuring long-term stability and performance. Surface barriers designed as final site remediation measures are typically of a multi-layer design utilizing the concept of engineered graded soil filters to create capillary breaks within the barrier profile to store incipient moisture in fine-textured soil layers for recycle to the atmosphere by evaporation and plant transpiration. Multi-layer surface barrier designs can also incorporate low permeability materials (e.g., asphalt, geomembranes, etc.) deeper in the profile to further reduce the likelihood of water infiltration into the waste site and control the emanation of soil vapors. Variations in overall thickness and surface treatments are also incorporated to control biointrusion and erosion.

The most significant advantages of surface barriers are the ease of application, maturity of the technology, and reliability when properly designed, installed, and maintained. Surface barriers do not directly lessen the toxicity, mobility, or volume of hazardous wastes, but they can mitigate contaminant migration. Surface barriers are most effective where the underlying waste is above the water table in the vadose zone. In some cases, surface barriers can be used in conjunction with vertical walls (i.e., subsurface barriers) to minimize the potential for contaminant migration by controlling both advective and diffusive flow of liquids. The effective life of surface and subsurface barriers can be extended by long-term inspection and periodic maintenance activities.

Industry experience suggests that the most effective mono-layer caps for areas receiving high annual precipitation are composed of concrete or bituminous asphalt. Research in arid/semi-arid areas of the nation has demonstrated the effectiveness of mono-layer fine soil covers or evapotranspiration (ET) covers. Mono-layer caps form a surface barrier between the waste site and the environment and can effectively reduce leaching through the waste site and into an

underlying aquifer. Existing data demonstrate that concrete and fluid-applied asphalt caps can provide extremely low hydraulic conductivities ($<1x10^{-11}$ cm/s). On-going laboratory research and natural analog studies indicate that asphalt may have the robust properties necessary for a service life approaching 1000 years under certain conditions. The technology survey identified the possible need for treatability investigations to determine the effectiveness of asphalt, concrete, or cement mono-layer surface barriers. Investment in treatability investigations of mono-layer caps is not recommended at this time for the 200-SW-2 OU. A mono-layer cover demonstration using polyurea/polyurethane was installed during 2007 at the Hanford Site as an interim remedial measure at the 241-T Tank Farm. Information regarding the effectiveness, implementability, and cost of this cap should be compiled for evaluation during the 200-SW-2 OU FS. Furthermore, extensive information exists regarding the performance and cost of asphalt mono-layers from the road paving industry. Also, the Hanford Protective Barrier Prototype, constructed in 200 East Area over the 216-B-57 crib, incorporates a fluid-applied asphalt mono-layer in the barrier profile. Performance data has been collected since the Hanford Protective Barrier Prototype was constructed in FY 1994.

The RCRA Subtitle C multi-layered surface barrier is a baseline design that is suggested for use in RCRA hazardous waste applications. These surface barriers generally consist of an upper vegetative (topsoil) layer, a drainage layer, and a low permeability layer which consists of a synthetic liner over 2 feet of compacted clay. Compacted clay liners are effective if they retain prescribed moisture contents, but are susceptible to cracking if clay materials are allowed to desiccate. As a result, alternate surface barrier designs are being considered for arid/semi-arid environments like the Hanford Site (e.g., ET covers). Extensive experience exists with respect to surface barrier design, construction, performance, and costs. Side-by-side comparisons of conventional RCRA Subtitle C surface barriers with alternative barrier designs have been conducted by the DOE, Department of Defense, and others (SAND98-1988, *Construction Costs of Six Landfill Cover Designs*; Bolen, et al., 2001, *Alternative Cover Assessment Program: Phase III Report*; Albright, et al., 2002, *Alternative Cover Assessment Program: Phase I Report*; ITRC, 2003, *Technical and Regulatory Guidance for Design, Installation, and Monitoring of Alternative Final Landfill Covers*). The results of this work should be reviewed for incorporation into the FS. If surface barriers are selected as part of a ROD, then soil borrow sites of sufficient quantity and quality will need to be identified and approved for access.

Subsurface barrier technologies (e.g., slurry walls, grout curtains, etc.) are considered mature and are used routinely in support of geotechnical engineering applications. Information regarding the effectiveness, implementability, and cost are available in support of the FS. Therefore, pre-ROD treatability investigations related to surface and subsurface barriers are not recommended at this time. Post-ROD treatability investigations may be required to optimize the design and implementation of subsurface barriers if they are selected for application in the ROD.

### 2.3.2 Waste Stabilization and Retrieval

Technologies for the stabilization and subsequent retrieval of materials placed in the 200-SW-2 OU will require detailed analysis during the FS. Some of the landfill trenches have relatively poor and incomplete waste disposal records. Furthermore, the waste in most of the 200-SW-2 OU is heterogeneous and most packaging was designed primarily for safe transport to the landfills, with little regard for long-term durability and post-burial integrity. Early

radioactive waste was packaged in wooden or cardboard boxes (primarily cardboard boxes), 55-gallon drums, and steel containers prior to placement in the trenches.

The types of solid waste generated and disposed in the 200-SW-2 OU ranges from large pieces of contaminated process equipment to small tools, rags, and other miscellaneous items. Portions of some landfill trenches contain contaminated soil and tumbleweeds. The waste is considered dry for the most part. However, records show that small amounts of liquid waste, sealed in containers with stabilizers and absorbents, were placed in some landfill trenches. Small amounts of highly radioactive wastes from laboratory operations were typically packaged in 1-gallon and 5-gallon cans prior to disposal in underground caissons and vertical pipe units (VPUs) that exist within a few of the landfill trenches.

Low-level radioactive waste and waste containing transuranic materials were not segregated prior to 1970. In 1970, the U.S. Atomic Energy Commission (AEC) defined transuranic waste (DOE G 435.1-1, *Implementation Guide for Use with DOE M 435.1-1*, Chapter 3, "Transuranic Waste Requirements") (TRU) as a separate category and required the waste to be segregated and retrievably stored. In 1973, DOE established a 10 nCi/g lower limit for TRU. In 1982, the lower limit for TRU was increased to 100 nCi/g. The equipment required to assay waste containing TRU materials against the 100 nCi/g lower limit was not available at Hanford until 1985. Consequently, portions of the waste placed in the 200-SW-2 OU between 1970 and 1985 may not meet the current definition of TRU and could be subject to different remediation considerations.

Similar technical challenges associated with waste stabilization and retrieval will be addressed by the 618-7/10/11 landfills remediation project at the Hanford Site (EPA/ROD/R10-01/119, *Declaration of the Interim Record of Decision for the 300-FF-2 Operable Unit*) and the Radioactive Waste Management Complex at the Idaho National Laboratory. Furthermore, Hanford's M-91 Project is currently removing retrievably stored TRU from 200 West Area landfills and 200 East Area landfills in the future. Experiences with solid waste stabilization, retrieval, treatment, and disposal gained through these and other projects should be leveraged with respect to effectiveness, implementability, and cost in support of the 200-SW-2 OU FS. Numerous retrieve, treat, and dispose technologies were evaluated during the technology survey and determined to have sufficient information regarding effectiveness, implementability, and cost for detailed analysis during the FS. These technologies included conventional and remote retrieval processes, soil vacuum systems, in-container vitrification, soil washing, mechanical separation, solidification/stabilization, and automated segregation based on radioactivity.

A combination of laboratory and pilot-scale treatability investigations may be required to demonstrate methods for ex situ treatment of excavated contaminated soils. The specifications for the treatability investigations depend upon the nature of the contaminants and will not be known until intrusive activities within and/or beneath landfill trenches are conducted during Phase II and III activities in the 200-SW-2 OU. Treatability investigations involving ex situ treatment of excavated contaminated materials, if warranted, may be more appropriately conducted post-ROD in support of the remedial design in the event this remedial alternative is selected.

### 2.3.3 In Situ Solidification/Stabilization

In situ solidification/stabilization technologies can reduce the mobility of hazardous and radioactive contaminants in the environment through both physical and chemical processes. The target contaminant group for in situ solidification/stabilization is generally inorganics (including radionuclides). Stabilization seeks to trap contaminants within the host medium (i.e., the soil, equipment, and/or building materials) by inducing chemical reactions between stabilizing agents and contaminants, thus reducing their leachability and mobility. Chemical stabilization agents include thermoplastic polymers (asphalt bitumen, paraffin, polyethylene), thermosetting polymers (vinyl ester monomers, urea formaldehyde, epoxy polymers), and other proprietary additives. Chemical grouts can also be used as stabilization agents. In situ solidification encapsulates the waste in a monolithic solid of high-structural integrity. Solidification does not involve chemical interaction between the contaminants and the solidification agents, but are bonded mechanically instead.

Solidification and stabilization techniques are often used together (e.g., incorporation of calcium hydroxyapatite in amended grout formulations to reduce the mobility of technetium and other mobile radionuclides of concern). The intent of solidification and stabilization processes is to limit the spread of radioactive material and other contaminants by trapping them within the monolithic solid. While the contaminants would not be removed and would remain radioactive and/or hazardous, the mobility of the contaminants would be eliminated or greatly reduced.

Solidification and stabilization has been implemented full-scale and may be employed in situ or ex situ. In situ techniques typically use auger and injector head systems to apply agents within soils. Ex situ techniques differ because the processes involve excavation of materials and machine-mixing with solidifying agents instead of injecting the agents into the materials in-place. Ex situ processes require disposal of the resultant materials. In situ and ex situ techniques can be used alone or combined with other treatment and disposal methods to yield a product or material suitable for land disposal. Both techniques have been used as final and interim remedial measures in private industry applications.

Work has been completed at Hanford and the Idaho National Laboratory to demonstrate in situ methods for solidification/stabilization of solid wastes using simultaneous dynamic compaction and grout injection techniques (Phillips, et.al., 1992, *Development, Testing, and Demonstration of Geotechnical Equipment, and Cement Based Void-Fill Encapsulant Materials for Stabilization and Isolation of Radioactive and Hazardous Waste Disposal Structures*; WHC-SA-1928-FP, *Co-Disposal of Mixed Waste Materials;* WHC-SA-1935-FP, *Environmental Restoration Waste Materials Co-Disposal*; WHC-SA-2101-FP, *Subsurface Barrier Design Alternatives for Confinement and Controlled Advection Flow*; INEEL/EXT-02-00851, *Operable Unit 7-13/14 In Situ Grouting Treatability Studies Bench-Scale Testing*). The combined process of dynamic compaction and grout injection induces liquefaction in the soil/waste matrix resulting in enhanced mixing and formation of a solid monolith. The technology survey suggested that treatability investigations may be needed to evaluate the effectiveness of in situ grout injection and soil mixing. However, sufficient information exists with respect to the effectiveness, implementability, and cost of in situ grout injection and soil mixing for detailed evaluation during the FS. Post-ROD treatability investigations may be required if in situ solidification/stabilization is included in the ROD in order to accommodate site-specific conditions. Some factors may limit the implementability and effectiveness of in situ

solidification/stabilization technologies and would be considered during post-ROD treatability investigations, if selected as a remedy. These factors include the following:

- Depth of contaminants may limit some types of application processes
- Some processes result in a significant increase in volume (up to double the original volume)
- Certain wastes can be incompatible with solidification/stabilization processes
- Reagent delivery and effective mixing are more difficult than for ex situ applications
- Like all in situ treatments, confirmatory sampling can be more difficult than for ex situ treatments.

In situ vitrification was evaluated during the technology survey process and was determined to have sufficient information regarding effectiveness, implementability, and cost for detailed analysis during the FS process. In situ vitrification can destroy or remove organics and immobilize most inorganics in contaminated soils, sludge, or other materials. The process has been tested on a broad range of VOC and semi-VOCs, other organics including dioxins and polychlorinated biphenyls, and on most priority pollutant metals and radionuclides. Potential over-pressurization caused by contact of molten material with sealed VOCs and loosely packed combustibles has been identified as a concern when considering application of in situ vitrification to buried solid wastes. This concern should be addressed in post-ROD treatability investigations, if in situ vitrification is selected as a remedy.

## 2.4 TECHNOLOGIES APPLICABLE WITHIN THE VADOSE ZONE BENEATH LANDFILLS

The technology survey (PNNL-16105) suggested treatability investigations in each technology area applicable to the vadose zone beneath the 200-SW-2 OU to gain better understanding of the effectiveness, implementability, and cost in support of the FS. For in situ stabilization, the technologies included grout injection, supersaturated grouts, soil desiccation, reactive gases, and nanoparticles. For contaminant extraction, the technologies included soil flushing and electrokinetics. These technologies are discussed further in the following sections.

Based on historical records, wastes disposed in the 200-SW-2 OU are mostly dry. The small volume of liquids disposed in the landfill trenches were stabilized onto sorbent material and containerized. Portions of four landfills had standing water in the past due to rapid snow melt or seepage from a nearby liquid drainage ditch. Characterization efforts planned during Phase I-B of the RI using direct push techniques and borehole logging will collect information to better understand the nature and extent of vadose zone moisture and possible contamination as a result of standing water in affected landfills. Possible treatability investigations related to contaminant plumes beneath landfills should be coordinated with a better understanding of the nature and extent of radioactive and/or hazardous chemical contamination revealed through intrusive site investigation activities proposed for the 200-SW-2 OU beginning in FY 2009. There is little need to invest in vadose zone treatability investigations if vadose zone contamination does not exist beneath waste trenches in the 200-SW-2 OU or is not likely to exist in the future.

### 2.4.1 In Situ Solidification/Stabilization

Previous discussions regarding solidification and stabilization within landfills using grout injection and soil mixing are applicable in the vadose zone beneath landfills. In addition, several other physical and chemical methods were identified during the technology survey and are potentially applicable in the vadose zone beneath landfills to reduce the mobility of radionuclides and other hazardous materials. These technologies involve the use of supersaturated grouts, soil desiccation, reactive gases, and nanoparticles.

#### 2.4.1.1 Supersaturated Grouts

Supersaturated grouts are based on using crystallization or precipitation processes for targeted sealing and immobilization of wastes. Solutions are prepared and used as grouts that are supersaturated in slightly soluble sulfates or carbonates. The solutions are temporary stable due to added precipitation inhibitors. Mineral formation takes place when supersaturated grouts encounter soil and rock formations creating in-situ immobilization or sealing. In contrast to natural water, the chemical concentrations of the supersaturated grout solutions are much higher resulting in faster and more effective mineral formation in treated areas.

One advantage of mineral forming solutions is that they can penetrate soil or rock formations with low permeability. In order to grout a soil formation with a suspension, it is necessary that the average particle size of suspended solids is three times smaller than the diameter of the flow paths. Otherwise the suspension cannot effectively penetrate into the flow paths. The suspended solids are filtered out forming a filter cake and penetration is impossible. The method of sealing or immobilization by crystallization or precipitation uses clear solutions with properties similar to natural groundwater. Soils which cannot be penetrated and grouted with conventional systems can typically be treated with supersaturated grouts.

Immobilization is achieved by naturally occurring minerals and no dangerous or toxic compounds are brought into the treated formation. There are many possibilities to direct the precipitation and immobilization or sealing process. In all cases, the preparation of the supersaturated grout solution is simple and can be realized under field conditions typical of the Hanford Site.

#### 2.4.1.2 Soil Desiccation

Soil desiccation can be a form of in situ barrier to subsurface flow of moisture and contamination. In principle, soil desiccation involves establishment of an air flow regime in the vadose zone directly beneath the solid waste landfill. The act of moving air through vadose zone soils desiccates the soils by evaporating available moisture. It has an added benefit of removing VOCs (e.g., carbon tetrachloride) in a manner similar to soil vapor extraction methods for subsequent treatment. Once the soils are desiccated, any moisture reaching the area tends to be held tightly unless and until the water-holding capacity of the soil is exceeded. The effectiveness of soil desiccation methods may require a long-term commitment to maintenance and operating costs associated with air blower systems.

#### 2.4.1.3 Reactive Gases

Reactive gas treatment is a technology that is applicable for treatment of contaminated vadose zone soils. In this technology, a series of wells are used to treat a contaminated area of the vadose zone to destroy or immobilize contaminants by introducing reactive gases into the zone

of contamination. Several successful field deployments of this technology have been conducted for immobilizing chromate contaminated soils using low concentrations of hydrogen sulfide gas. Pilot testing of hydrogen sulfide gas injection into the vadose zone has demonstrated roughly 70 percent reduction of hexavalent chromium to levels below cleanup standards. Reactive gases such as ozone have been used for oxidizable organic contaminants, such as hydrocarbons, certain chlorinated hydrocarbons, pesticides, and explosives. Some reactive gases (e.g., hydrogen sulfide) are toxic and must be handled with proper safety precautions.

#### 2.4.1.4 Nanoparticles

Environmental applications of metallic iron have gained acceptance due to low costs and absence of known toxicity induced by the iron. Metallic iron in the form of packed bed reactors and in situ permeable reactive barriers has been in wide use. One of the most promising new innovations involves microscopic iron particles known as nanoparticles (Zhang, 2003, *Nanoscale Iron Particles for Environmental Remediation: An Overview*). Nanoparticles are between 1 and 100 nanometers in diameter, which is about ten to a thousand times smaller than most bacteria. At that scale, they can move through microscopic flow channels in soil and rock, reaching and destroying contaminants that larger particles cannot.

Iron nanoparticles have been shown to effectively breakdown carbon tetrachloride and TCE into harmless byproducts. Iron nanoparticles plus visible light or sunlight have been shown to convert mobile hexavalent chromium into insoluble trivalent chromium. Recent laboratory research has established nanoscale iron particles as effective reductants and catalysts for a wide variety of common environmental contaminants including chlorinated organic compounds and metal ions. Furthermore, almost all halogenated hydrocarbons can be reduced to benign hydrocarbons. Iron-based materials have been successful in transforming many other contaminants including anions, heavy metals, and radionuclides.

### 2.4.2 Contaminant Extraction

The technology survey identified two in situ contaminant extraction methods for possible treatability investigations. These methods included soil flushing and electrokinetics.

#### 2.4.2.1 Soil Flushing

In situ soil flushing involves the extraction of contaminants from soil with water or other suitable aqueous solutions. Soil flushing is accomplished by passing the extraction fluid through in-place soils using an injection or infiltration process. Extraction fluids are typically recovered and recycled. Soil flushing differs from soil washing in that the former is an in situ process while the latter is typically performed ex situ on retrieved soils.

Soil flushing operations can be enhanced through the use of cosolvents. Cosolvent flushing involves injecting a solvent mixture (e.g., water plus a miscible organic solvent) into the vadose zone to extract organic contaminants. Cosolvent flushing can be applied to soils to dissolve either the source of contamination or the contaminant plume emanating from it. The cosolvent mixture is normally injected upgradient of the contaminated area and the solvent, with dissolved contaminants, is extracted downgradient for above ground treatment.

Recovered soil flushing fluids with the desorbed contaminants may need treatment to meet appropriate discharge standards prior to recycle or disposal. To the maximum extent practical,

recovered soil flushing fluids should be reused in the flushing process. The separation of surfactants from recovered soil flushing fluid and capability for reuse in the process is a major cost saving factor in soil flushing. Treatment of the recovered soil flushing fluid results in process sludges and residual solids that must be appropriately treated before disposal. Air emissions of volatile contaminants from recovered soil flushing fluids should be collected and treated, as appropriate, to meet applicable regulatory standards. Residual soil flushing additives in the soil may be a concern and should be evaluated on a site-specific basis.

The target contaminant group for soil flushing is inorganics including radioactive contaminants. The technology can be used to treat VOCs, semi-VOCs, fuels, and pesticides, but it may be less cost-effective than alternative technologies for these contaminant groups and should be evaluated accordingly. The addition of environmentally compatible surfactants may be used to increase the effective solubility of some organic compounds; however, the soil flushing solution may alter the physical/chemical properties of the soil system and should be evaluated. The technology offers the potential for recovery of metals and can mobilize a wide range of organic and inorganic contaminants from coarse-grained soils typical of the Hanford Site.

Factors that may limit the applicability and effectiveness of the soil flushing process include:

- Low permeability or heterogeneous soils are difficult to treat
- Surfactants can adhere to soil and reduce effective soil porosity
- Reactions of flushing fluids with soil can reduce contaminant mobility and subsequent extraction
- The potential of flushing the contaminant beyond the capture zone and the introduction of surfactants to the subsurface can be a concern; the technology should be used where flushed contaminants and soil flushing fluid can be contained and recaptured
- Above ground separation and treatment costs for recovered soil flushing fluids can drive the economics of the process.

#### 2.4.2.2 Electrokinetics

The principle of electrokinetic remediation relies upon application of a low-intensity direct current through the soil between ceramic electrodes that are divided into a cathode array and an anode array. This mobilizes charged species, causing ions and water to move toward the electrodes. Metal ions, ammonium ions, and positively charged organic compounds move toward the cathode. Anions and negatively charged organic compounds move toward the anode. The current creates an acid front at the anode and a base front at the cathode. Generation of acidic conditions can help to mobilize sorbed metal contaminants for transport to the collection system at the cathode.

Two approaches can be taken during electrokinetic remediation: enhanced removal and treatment without removal. Enhanced removal is achieved by electrokinetic transport of contaminants toward the polarized electrodes to concentrate the contaminants for subsequent removal and ex-situ treatment. Removal of contaminants at the electrode may be accomplished by several means including electroplating at the electrode, precipitation or co-precipitation at the electrode, pumping of water near the electrode, or complexing with ion exchange resins. Enhanced removal is widely used for remediation of soils contaminated with metals.

Treatment without removal is achieved by electro-osmotic transport of contaminants through treatment zones placed between electrodes. The polarity of the electrodes is reversed periodically, which reverses the direction of the contaminant flow back and forth through a treatment zone. The frequency with which electrode polarity is reversed is determined by the rate of transport of contaminants through the soil. This approach can be used on in-situ remediation of soils contaminated with organic species.

Targeted contaminants for electrokinetics are heavy metals, anions, and polar organics in soil. Electrokinetics can be effective at contaminant concentrations ranging from a few parts per million (ppm) to tens of thousands of ppm. Electrokinetics is most applicable in low permeability soils. Such soils are typically saturated and partially saturated clays and silt-clay lenses that are not readily drained (e.g., silt lenses in the Hanford Formation).

Factors that may limit the applicability and effectiveness of the electrokinetic process include:

- Effectiveness is sharply reduced for wastes with a moisture content of less than 10 percent; maximum effectiveness occurs if the moisture content is between 14 and 18 percent
- The presence of buried metallic or insulating material can induce variability in the electrical conductivity of the soil, therefore, the natural geologic spatial variability should be delineated; deposits that exhibit very high electrical conductivity can cause the technique to be inefficient
- Inert electrodes, such as carbon, graphite, or platinum, must be used so that no residue will be introduced into the treated soil mass; metallic electrodes may dissolve as a result of electrolysis and introduce corrosive products into the soil mass
- Electrokinetics is most effective in clays because of the negative surface charge of clay particles; however, the surface charge of the clay is altered by changes in the pH of the pore fluid and the adsorption of contaminants; extreme pH at the electrodes and reduction-oxidation changes induced by the process electrode reactions many inhibit effectiveness, although acidic conditions (i.e., low pH) may help to remove metals
- Oxidation/reduction reactions can form undesirable products (e.g., chlorine gas).

## 2.5 OTHER FOCUSED INVESTIGATIONS

In addition to the aforementioned technology-based treatability investigations, other focused investigations are suggested to provide information needed in support of the overall RI/FS process for the 200-SW-2 OU. This information tends to be site-specific in nature, but has general applicability to all solid waste landfills where similar conditions exist. For the most part, these focused investigations involve research and compilation of information from available databases, similar projects, and available literature. The results of focused investigations will provide information to support refinement of conceptual site models, likely response scenarios, possible treatability investigations, and remedial alternatives evaluated during the FS. Furthermore, some focused investigations will provide information important to planning site characterization activities within the 200-SW-2 OU.

During one of the Phase I-A DQO workshops, Ecology noted a desire to verify, through historical records research and nonintrusive investigations, the ability to identify and locate objects on the

"items of interest" list that was provided to RL during the 200-SW-2 OU collaborative discussions. An agreement was reached that, in part, requested RL to summarize the items of interest based on waste form and to focus on logic to support decisions on the items of interest. This list was included in the Phase I-A DQO summary report and was evaluated through a data-gap analysis to determine those items that could be located using nonintrusive survey techniques. Section 4 of the 200-SW-2 OU RI/FS Work Plan provides a detailed discussion of the Ecology items of interest. Appendix D provides a cross-walk between suggested focused investigations and Ecology's items of interest.

The following is a discussion of focused investigations suggested in support of the 200-SW-2 OU RI/FS process. As site characterization information is obtained through the RI, the need for focused investigations may be expanded in response to newly identified information needs and there may be a need for additional pre- and/or post-ROD technology-based treatability investigations. This initial planning basis for treatability and other focused investigations for the 200-SW-2 OU will be revised, as needed, to reflect current needs.

### 2.5.1 Locations of Large Burial Boxes/Equipment – Areas of Potential Subsidence

The industrial solid waste landfills received radioactive waste packaged in large wooden or concrete boxes and contain large inventories of mixed fission products with high dose rates. In general, the industrial solid waste landfills were restricted to burial of large pieces of failed or obsolete equipment from chemical processing facilities in the 200 Areas, although some items came from decommissioned nuclear reactors in the 100 Areas. These large burial boxes can have high internal void volumes and are susceptible to degradation and collapse under the weight of soil overburden. Portions of some solid waste landfills currently have access and load restrictions due to concerns over past subsidence and the possibility for future events.

During detailed evaluations of surface barrier alternatives in the FS, it will be important to understand where landfill areas susceptible to subsidence are located so corrective actions can be considered to provide a stable substrate for surface barrier construction. In the case of solid waste landfills with high internal void volumes, subsidence control measures may need to be considered as an integral part of surface barrier alternatives. The potential for subsidence raises concerns with respect to worker safety during site characterization and remediation actions. Furthermore, subsidence under a surface barrier can disrupt critical construction material layering sequences (e.g., engineered graded filters) and compromise the functionality of the barrier with respect to intended design features (e.g., water infiltration control, biointrusion control, erosion control, etc.). Surface depressions can serve to collect and concentrate meteoric water over areas where critical layers may have been disrupted as a result of subsidence thereby increasing the potential for water infiltration into the waste site. These and other surface barrier performance concerns are a few of the reasons for the current interest in mono-fill ET barriers and their limited self-healing capabilities. Stabilization of internal void volumes in large waste disposal containers may also be desirable in support of other alternatives (e.g., stabilization and retrieval) evaluated during the FS.

Information regarding the location of large burial boxes and equipment can be obtained from interviews with solid waste landfill personnel, review of waste disposal records, and review of available geophysical survey reports. To date, geophysical surveys (ground penetrating

radar [GPR], electromagnetic induction [EMI], and total magnetic field [TMF]) have been conducted on all but two of the industrial landfills (218-E-2 and 218-E-9). Geophysical surveys have also been conducted on all but one of the dry waste alpha landfills (218-W-4A) and one of the construction landfills (218-E-4). Geophysical surveys have not been conducted on any of the TSD landfills due to the number and quality of burial records. Additional geophysical surveys are planned during Phase I-B site investigations during FY 2008. Geophysical surveys of landfill trenches with good burial records (i.e., TSD unit landfills) can be used to ground-truth the methods and facilitate interpretation of data collected from poorly documented landfills.

Techniques for core drilling and filling containers with stabilizing materials are commercially available. Information regarding the effectiveness, implementability, and cost are available in support of detailed analyses of remediation alternatives during the FS.

### 2.5.2 Cost of Waste Retrieval and Barrier Construction

Two of the likely response scenarios for remediation of the 200-SW-2 OU that will be evaluated during the FS involve stabilization and retrieval of waste and in-place disposal of waste using surface barriers. This activity involves the compilation of cost information associated with the retrieval of buried solid waste and construction of surface barriers for evaluation during the FS.

The DOE-Complex is acquiring experience in the removal of retrievably stored TRU at the Idaho National Laboratory, Hanford Site, and elsewhere. Costs associated with the removal of waste from the Idaho National Laboratory Radioactive Waste Management Complex (Operable Unit 7-13/14), and Hanford's 218-W-4C solid waste landfill (M-91 Project) and 618-7/10/11 landfills provide insights in support of the evaluation of remedial alternatives involving retrieval of waste during the FS. These costs should be researched and compiled for consideration during the FS.

Similarly, the DOE-complex and private industry has considerable experience in the design, construction, and evaluation of a variety of engineered surface barrier designs ranging from conventional RCRA Subtitle C and D barriers to alternative engineered barrier designs like the Hanford Protective Barrier, Modified RCRA Subtitle C Barrier, and mono-fill ET barrier. The DOE-complex has collected surface barrier performance and cost information from Sandia's Alternative Landfill Cover Demonstration Project, Hanford's Protective Barrier Development Program, Idaho's Engineered Barrier Test Facility, and other efforts. This information should be researched and compiled for consideration during the FS.

### 2.5.3 Caisson and Vertical Pipe Unit Characterization and Remediation Techniques

Caissons and vertical pipe units (VPU) were used for disposal of hot cell waste or high plutonium-bearing waste in the 218-W-4A and 218-W-4B solid waste landfills. Up to six of the caissons in the 218-W-4A solid waste landfill are constructed from welded 55-gallons drums (vertical, 5 drums high); two other VPUs may also exist in the 218-W-4A landfill. The caissons in the 218-W-4B solid waste landfill are constructed from metal pipe or concrete structures with offset dump chutes to minimize radiation exposure. Waste packages disposed to caissons and VPUs were allowed to fall freely which often resulted in damage, and at times, rupture of the packages. There are several caissons in the 218-W-4A and 218-W-4B solid waste landfills that were never used according to historical records and require verification.

The Hanford Site has initiated work addressing the retrieval of VPUs in support of 618-7/10/11 solid waste landfills remediation. A cold test facility was constructed in October 2004 with four buried simulated VPUs. Four full-scale retrieval tests were successfully conducted in July/August 2005 using a vibratory hammer to drive a 42-inch diameter casing and over-core the VPUs followed by removal. Experience from these tests led to the development of a cost-effective method for VPU retrieval, including injection of grout into the bottom of the casing to create a grout plug to stabilize the soil and retain the core to support intact removal of VPUs. Additional work has been completed at the Hanford Site to evaluate techniques for in situ stabilization and isolation of caissons and VPUs using grout injection techniques.

Additionally, direct push technologies have been used at the Hanford Site in support of characterizing soils at a variety of waste sites including underground storage tanks, ponds, ditches, cribs, and pipelines. These direct push technologies can be used to characterize soils surrounding caissons and VPUs. Also, commercially available remote visual inspection technologies have been used to inspect tanks, cribs, pipelines, and other confined spaces onsite. These remote visual inspection technologies can be used to interrogate the caissons and VPUs. Finally, a variety of radiation and VOC detection equipment is commercially available and can be deployed to characterize contaminant levels within caissons and VPUs.

A focused investigation should be performed involving the compilation of information germane to the characterization and remediation of caissons and VPUs in support of the RI/FS process. Particular emphasis should be placed on the effectiveness, implementability, and cost of commercially available and recently demonstrated technologies for consideration during the FS.

### 2.5.4 Location of Non-Retrievably Stored Spent Fuel in the 200-SW-2 Operable Unit

Before the first spent fuels were received in the solid waste landfills around 1973, approval was given to handle these materials in the same manner as TRU (WHC-EP-0912, *The History of the 200 Area Burial Ground Facilities*). The wastes were to be packaged and stored in the solid waste landfills to meet future retrieval requirements so materials could be removed, processed, and sent to the national geologic repository.

Since 1974, a variety of irradiated fuels from research and development activities has been placed in retrievable storage. This includes spent fuel and irradiated scrap from test reactors and the Fast Flux Test Facility. Many of the spent fuel containers are in retrievable storage trenches in the 218-W-4C solid waste landfill, which is outside the scope of the 200-SW-2 OU, and is being addressed through separate efforts (M-91 Project).

According to available disposal records, one test reactor fuel element is buried in Trench 6 (left side end of trench) of the 218-W-4A solid waste landfill. This fuel element was placed in the landfill trench on September 20, 1963 and had a surface reading of 500 R/hr at that time. Also, records indicate the disposal of 12 tons of irradiated fuel in Trench 12 of the 218-E-10 solid waste landfill. There are several hundred references in available records documenting the disposal of irradiated metal scrap.

Given the potential amount of spent fuel in the 200-SW-2 OU based on historical disposal records, an activity involving the compilation of information addressing the location of non-retrievably stored spent fuel should be conducted. Information on activities associated with the

retrieval of spent fuel from the 618-7/10/11 solid waste burial grounds, M-91 solid waste retrieval project, and other applicable sources is available for compilation in support of the FS.

### 2.5.5 Direct Push Technology Through or Near Waste Trenches

Direct push technologies (e.g., cone penetrometers, Geoprobe[4], Eurodrill[5] hydraulic hammer, etc.) are commercially available and have been successfully demonstrated at the Hanford Site in support of site characterization activities at liquid waste storage and disposal facilities. It is reasonable to believe that direct push technologies will be equally effective in support of solid waste landfill characterization. However, nuclear safety documentation requirements for application of direct push technologies in solid waste landfills must be identified and met. In particular, possible direct pushes through the waste may be problematic given the desire to not breach intact waste containers and the potential to encounter shock-sensitive wastes. An advantage of direct push techniques over conventional drilling operations is the elimination of contaminated drill cuttings being brought to the surface. Direct push techniques can be equipped with a variety of probes to support in-situ characterization of the subsurface with vertical or angle pushes. These include, but are not limited to:

- Vapor probes to detect and collect soil gas samples
- Down-hole cameras to allow visual inspection of subsurface conditions
- Probes to measure soil moisture content
- Lysimeter probes to collect subsurface liquid samples
- Tensiometer probes to measure subsurface movement of moisture
- Multi-instrument probes for deployment of gross and spectral gamma, passive neutron, and other radionuclide and hazardous chemical detectors
- Dual-wall probes for soil sampling.

Potential activities associated with direct push technology deployment through waste trenches will involve investigation of nuclear safety documentation requirements to ensure that proper safety documentation exists to provide adequate protection of human health and the environment. Following completion of necessary safety documentation, several opportunities for direct push technology demonstrations may exist in support of the RI/FS process.

The initial phase (Phase I-B) of direct push technology deployment includes a total of about 40 direct pushes adjacent to waste trenches in the 200-SW-2 OU currently planned during FY 2008. The purpose of the direct pushes is to gain experience using the technology in support of landfill characterization and to obtain information regarding the site geology, soil moisture content, and the presence/absence of contamination at the direct push locations. This information will be used to refine the conceptual site models and provide future direction for direct push soil logging and sampling operations aimed at acquiring a better understanding of the nature and extent of contamination during later site investigation phases.

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[4] Geoprobe is a registered trademark of Kejr, Inc., Salina, Kansas.

[5] Eurodrill is owned by Colcrete Eurodrill, Derbyshire, United Kingdom.

A direct push characterization well is planned near the center of each landfill within the 200-SW-2 OU, between the waste trenches. Historical records indicate that four of the landfills were subject to temporary events resulting in standing water (rapid snow melt and seepage from a wastewater ditch). Four additional direct push characterization wells are planned in each of these landfills, but not through the waste itself. The goal of the direct pushes is to reach a maximum depth of 100 feet or until refusal, and determine the potential impact of the standing water on soil moisture content and potential contaminant migration.

### 2.5.6 Acid Soaked Material Trenches

Thirteen of the 28 trenches in the 218-E-12A solid waste landfill are documented as containing acid-soaked material (e.g., laboratory rags, absorbents, etc.). Anecdotal evidence suggests it was common practice for Nuclear Chemical Operators to soak rags in nitric acid and use them to decontaminate glove boxes in Plutonium-Uranium Extraction Plant (PUREX) process cells. The cotton rags, contaminated with plutonium and nitric acid, were quickly disposed into the 218-E-12A landfill trenches because they posed a fire hazard. The acid soaked rags were not containerized into 55-gallon drums due to concerns over possible generation and containment of explosive gases.

A geophysical survey of the 218-E-12A solid waste landfill (and other areas of the 200-SW-2 OU) was conducted during June 2006. The geophysical techniques included GPR, EMI, and TMF. All of the trenches containing acid soaked material are documented as being in the eastern half of the 218-E-12A solid waste landfill. The waste trenches are documented as 5 feet or 12 feet wide and are likely to be relatively shallow given the natural angle of repose in Hanford soils (roughly 1:1). There were no geophysical features identified in the data (i.e., excavation boundaries or notable changes in soil characteristics) that are typically associated with a waste trench.

Based on geophysical survey results, there are a few anomalies in the eastern half of the 218-E-12A solid waste landfill that appear to fall within a trench due to their linear nature, however, they may also be scattered debris unrelated to a trench. If there were concentrations of metallic objects in the acid soaked material trenches, then they would have been identified with the geophysical methods. Since no concentrations of metallic objects were detected, this suggests that debris buried in these waste trenches is non-metallic.

The sediments of the Hanford Formation geologic unit typically have low organic carbon content and low-to-moderate cation exchange capacity. The sediments have a slightly basic pH ranging from roughly 7.7 to 8.2. Small amounts of calcium carbonate (calcite) are common and can act as a weak buffer. The sediments have the capacity to adsorb most contaminants from solution. The amount of adsorption is a function of many factors, including mineral surface area and type, contaminant type (speciation) and concentration, overall solution concentration, pH, reduction potential (Eh), and reaction rates for the controlling adsorption, precipitation, dissolution, and hydrolysis reactions. Some contaminants do not adsorb (i.e., soluble anions such as nitrate, chromate, and pertechnitate) and move through the unsaturated vadose zone along with the bulk solution. Acidic solutions can also mobilize some contaminants that are otherwise relatively immobile in soils (e.g., plutonium).

Future investigations, including interviews with knowledgeable site personnel, are suggested for the acid soaked material trenches to determine the presence of acid contaminated soils. If acid contaminated soils exist, then potential impacts on the mobility of other contaminants (e.g., plutonium) should be determined in support of the RI/FS process. Direct push technology with dual-wall push rod can be utilized to obtain soil samples beneath the waste trenches to evaluate the nature and extent of acid and other contamination. Also, nuclear probes discussed in Section 2.5.9.6 may be deployed for in situ characterization of plutonium, if sufficient quantities exist.

### 2.5.7 Vadose Zone Characterization and Monitoring

Vadose zone characterization and monitoring is essential for several major environmental remediation needs, including:

- An assessment of the inventory, distribution, and movement of contaminants
- Development of improved predictive methods for liquid flow and contaminant transport in support of risk and performance assessments
- Selection and design of remediation systems
- Verifying long-term performance of remediation systems to ensure adequate protection of human health and the environment.

Vadose zone characterization and monitoring is intended to address concerns related to potential release of contaminants into the vadose zone and obtain data to design site remediation systems and verify their performance over time. Development of cost-effective remediation plans and post-closure monitoring of contaminated sites requires understanding of the inventory, distribution, and movement of contaminants in the vadose zone. One of the challenges associated with vadose zone characterization and monitoring is the determination of preferential flow paths (i.e., clastic dikes, caliche layers, etc.) and potential impacts of anisotropic soil properties on contaminant fate and transport. These impacts can be enhanced by episodic infiltration of meteoric water (e.g., rapid snow melt) and other sources of liquids (e.g., lateral seepage from ponds, ditches, and cribs along confining geologic layers).

A number of point-type direct push probes can be used to monitor liquid flow and contaminant transport in the vadose zone including tensiometers, time domain reflectometry (TDR) probes, suction lysimeters, and thermistors. Additionally, geophysical imaging methods such as seismic surveys, time-domain and frequency-domain EMI, GPR, 3-D electrical resistivity tomography, and other methods can be effective in monitoring liquid flow and contaminant transport in the vadose zone. The Hanford Site has extensive experience in the use of soil science and geophysical measuring devices, and is gaining experience in the use of electrical resistivity methods to monitor contaminant fate and transport in the vadose zone around and beneath waste sites.

The sediments beneath the 200-SW-2 OU are heterogeneous (i.e., unconsolidated sand, silts, and gravels). In heterogeneous sediments, point-type direct push probes may or may not intersect single flow paths that can cause preferential flow in the vadose zone. This situation is further exacerbated by anisotropic soil properties typical of Hanford Site sediments. Geophysical

imaging methods can complement point-type direct push measurements by providing a geo-spatially distributed view of subsurface conditions.

Post-closure monitoring will be required at virtually all remediated sites where contaminants remain isolated and stabilized in-place. The standard practice is to monitor groundwater for contaminants of concern. This approach can be less desirable at sites with relatively deep groundwater tables. By the time contaminants are detected in the groundwater, it is possible that significant vadose zone contamination may have occurred. Monitoring the near-field vadose zone of remediated sites can provide earlier possible detection of contaminant releases and the ability to proactively implement corrective actions before the groundwater can be impacted.

Vadose zone hydrogeology has a pronounced impact on contaminant fate and transport. Investigations are suggested to identify current vadose zone characterization and monitoring strategies, and technologies in support of the RI/FS process. Furthermore, numerous vadose zone and groundwater monitoring wells exist around the solid waste landfills. Some wells have been logged with geophysical instruments and geologist logs exist with site geology information recorded every five feet or change in lithology during well construction. This information should be reviewed and site-specific geologic cross-sections should be prepared for each solid waste landfill to support the RI/FS process. Additional gross/spectral gamma, passive neutron, and active neutron moisture logging of a select number of existing groundwater monitoring wells is proposed during Phase I-B site characterization activities at the 200-SW-2 OU to determine site stratigraphy, soil moisture content, and the presence/absence of mobile contaminants. Also, two dry wells were drilled to a depth of 25-30 feet through the wastes in or around Trench #2 of the 218-W-3A landfill (299-W10-179) and Trench #8 of the 218-W-4B landfill (299-W15-207). These dry wells were drilled and core sampled in 1978 using a tripod drilling method. The 3-inch casings were grouted around the top and plugged in the bottom. These dry wells should be investigated for possible logging with active neutron moisture, passive neutron, and gross/spectral gamma tools.

Surface topography can have an impact on moisture distribution and potential contaminant migration in the underlying vadose zone. Topographic lows can provide areas that collect runoff during adverse weather conditions (e.g., heavy snowfall followed by rapid snow melt). Ponding of surface water can increase the amount of moisture available for recharge into underlying soils. Topographic lows may also be an indication of areas within landfills that have subsided due to biodegradation or collapse of the buried waste. Numerous techniques exist to monitor surface topography. These include, but are not limited to, photogrammetry, global positioning system (GPS) surveys, and LIDAR methods. Photogrammetry involves the use of aerial photographs taken in a planned sequence along parallel flight lines and from a predetermined height above a datum, such as sea level. The GPS surveys, also called mobile mapping surveys, are executed using a vehicle equipped with a GPS receiver that sends data to a computer for processing real-time position and height (also referred to as real-time kinematic surveys). The LIDAR (Light Detection and Ranging) method involves distance measurement using laser light and it's return after reflection as a measure of distance. It is suggested that topographic surveys methods be explored and executed to establish a baseline for surface topography at the 200-SW-2 OU landfills, and help to focus site characterization efforts. Topographic information exists from photogrammetric surveys conducted in 1996. This information should be used as an initial starting point to understand surface topography at the landfills. Surface topography

measurement capabilities may also have applications to post-closure monitoring in the event a surface cap or cover is selected as the site remedy.

### 2.5.8 Waste Compaction Methods and Other In Situ Stabilization/Solidification

The 200-SW-2 OU contains biodegradable materials and burial containers with high internal void volumes as previously discussed in Section 2.5.1. These conditions can give rise to subsidence under the weight of the soil overburden. Subsidence events have occurred in some solid waste burial trenches with resultant concerns over worker safety and the potential spread of contamination. Load and access restrictions (i.e., no walk/no drive zones) have been imposed in some portions of the 200-SW-2 OU in an attempt to mitigate subsidence events, protect workers, and minimize the potential spread of contamination. As previously mentioned, when evaluating surface barrier alternatives during the RI/FS process it is important to construct surface barriers over a stable substrate to maintain the integrity of engineered soil layers and other barrier design features critical to the control of water infiltration, bio-intrusion, and wind/water erosion. Waste container stability will also be an issue to ensure the safety of potential retrieval operations.

Many waste compaction methods are commercially available and have been demonstrated by various DOE Site contractors over the years. These methods range from waste consolidation by falling masses to simultaneous dynamic compaction and grout injection using vibratory hammers. The falling masses can induce collapse of burial containers and subsidence of the soil overburden. Subsidence craters are then filled with clean soil and compacted. Simultaneous dynamic compaction and grout injection uses vibratory hammers to collapse waste disposal containers while injecting grout. This process induces liquefaction in the soil/grout matrix that can effectively fill voids.

Focused investigations are suggested to identify current methods and associated costs for compaction and other in situ stabilization/solidification methods for solid waste landfills in support of the RI/FS process.

### 2.5.9 In Situ Detection of Transuranics

From the 1940s through the 1970s, radioactive materials containing alpha-emitting radionuclides were disposed by shallow land burial at Hanford and elsewhere in the DOE-complex. The AEC first identified TRU as a separate category of radioactive waste in 1970. In 1973, the AEC further defined TRU as containing transuranic alpha-emitting radionuclides in concentrations greater than 10 nCi/g. This waste was believed to warrant more stringent handling and disposal considerations than LLW because of potential hazards associated with increased concentrations of long-lived, alpha-emitting radionuclides. The DOE revised the definition of TRU in 1982, increasing the lower limit of transuranic alpha-emitting radionuclides with half-lives greater than 20 years from 10 nCi/g to 100 nCi/g.

According to the "Immediate Action Directive" issued by AEC in 1970, all TRU generated after 1970 was to be segregated from LLW and placed in retrievable storage pending shipment to and disposal in an approved geologic repository. Some waste managed by shallow land burial or placed in retrievable storage between 1970 and 1982 as TRU may not meet the current definition of TRU (i.e., contains alpha-emitting radionuclides with half-lives greater than 20 years in

concentrations greater than 100 nCi/g). Methods to perform in situ detection of TRU could be beneficial to the 200-SW-2 OU project.

Several technologies for the in situ characterization of TRU and other elements have been used successfully at DOE and DOD sites across the nation (ITRC, 2006, *Real-Time Measurement of Radionuclides in Soil: Technology and Case Studies*) and should be investigated in support of the 200-SW-2 OU RI/FS process. The following is a brief description of potentially applicable technologies and techniques.

#### 2.5.9.1 Xenon Gas

The spontaneous fission of plutonium and other transuranic isotopes produces xenon, an inert rare gas. Stable xenon isotopes are also produced during fission in nuclear reactors. The xenon isotopic composition is altered from atmospheric levels by spontaneous fission of transuranic isotopes or by the presence of non-separated fissionable material (e.g., irradiated fuel). Numerical modeling under generalized solid waste landfill conditions indicates radioxenon isotopes will diffuse away from the waste and may be found in the soil cover and adjacent to the burial ground at levels many orders of magnitude above the instrument detection limit (PNNL-14617, *Evaluation of Xenon Gas Detection as a Means for Identifying Buried Transuranic Waste at the Radioactive Waste Management Complex, Idaho National Environmental and Engineering Laboratory*; Dresel, 2006, "Sampling and Analysis of Rare Gas Isotopes for In Situ Delineation of Buried Transuranic and Tritium Waste").

The use of radioactive and stable xenon isotopes is a minimally invasive method for in situ characterization of transuranic wastes through soil-gas sampling and analysis. The technique is based on collecting soil gas samples from the vicinity of the waste and analyzing the xenon isotopes in the gas. The method is analogous to the well established methods of soil gas sampling for VOCs and can use similar equipment.

#### 2.5.9.2 Copper Foils

Copper-63 (in copper metal) can be activated by neutrons emitted from transuranic sources to Copper-64. The neutrons are produced by spontaneous fission and by alpha-neutron reactions. Copper, in the form of pipes, rods, plates, or foils is positioned in the subsurface near the zone of interest using direct push methods. After a period of 24-hours, the copper is retrieved and analyzed by gamma coincidence counting methods. The neutron activation of copper has been used to measure transuranics in soils down to background levels.

#### 2.5.9.3 Helium-3 Neutron Detectors

Helium-3 filled neutron detectors are typically used for oil and mineral exploration to detect neutrons in boreholes to determine formation properties (e.g., moisture levels). These gas-filled neutron detectors can be deployed in drilled boreholes or within the rods of a direct push method. A neutron count rate significantly above background is an indicator of the possible presence of transuranic material nearby. The detector is sensitive to neutron sources within a radius of roughly 1.6 feet.

#### 2.5.9.4 Gamma Ray Detectors

Down-hole gamma ray detectors can be deployed to determine the location of buried waste that emits gamma radiation. The simplest gamma ray detectors measure the number of gamma rays, but not the individual energies. Sodium iodide detectors are typically used for these gross gamma

measurements. Advanced detectors are available that provide spectral measurements to determine gamma ray energies and associated radionuclides. Advanced detectors using cryogenically cooled, high-purity germanium (HPGe) detectors are available and provide enhanced spectral quality. Sodium iodide, cesium iodide, and bismuth-germanate spectral detectors also exist but have lower resolution of gamma energy peaks than the HPGe detectors.

#### 2.5.9.5 Americium-241 Surrogate

Gamma emitting surrogates can also be used to determine the activity level of some alpha emitters. At Rocky Flats, plutonium was the contaminant of greatest concern requiring an efficient method for measurement. Plutonium, however, is a weak gamma emitter and its gamma emissions are generally undetectable at the low activity levels typical of cleanup goals. Alpha spectrometry results normally take a week. This is typically too long a period of time to support efficient and timely decision making. Consequently, Plutonium-239 activity levels in contaminated soils were determined by measuring Americium-241 gamma emissions as a surrogate thereby providing real-time measurement of plutonium activity levels.

#### 2.5.9.6 Nuclear Probes for Mapping Transuranics and Volatile Organic Contaminants in Soils

DOE-sponsored research has been underway for several years to develop and demonstrate nuclear probes for mapping transuranic and chlorinated VOC concentrations in the subsurface. Two nuclear probes have been the focus of the research; prompt fission neutron and pulsed neutron-gamma tools. These tools were adapted from the oil field exploration industry for use at DOE facilities.

The prompt fission neutron tool is capable of accurate plutonium concentration determinations to <10 nCi/gm using five minute station measurements through 0.5-inch steel casing. The tool has a diameter of 4.25-inches and a length of 7 feet. The maximum depth is 40-feet with the current cable configuration for the tool. Logs generated by the tool produce a contour map of fissionable material and spontaneous neutron emitters. The prompt fission neutron is configured with two detectors, and therefore data from the scans can be used to determine the approximate distance from the source to the probe-hole.

The pulsed neutron-gamma tool measures thermal decay time from which a neutron cross-section is derived which is a linear function of chlorine concentrations. The tool is capable of measuring chlorine concentrations from 16 ppm carbon tetrachloride to 43 percent by weight. The tool has a diameter of 3.9-inches and a length of 11-feet. The maximum depth is 40-feet with the current cable configuration for the tool. The pulsed neutron-gamma uses ratios of gamma-ray intensities from a specific element to estimate the distance to the source from the probe-hole.

### 2.5.10 Soil Vacuum Removal Methods

The control of radioactive contamination during solid waste retrieval operations can be substantially improved and maintained "as low as reasonably achievable" by using high-efficiency particulate air (HEPA) filtered vacuum cleaners to remove potentially contaminated soil. Effective use of these engineered controls can capture particulate contamination at the source, thereby minimizing its spread. The HEPA filtered soil vacuum systems also have application around shock-sensitive waste (e.g., picric acid). In addition to improved worker

comfort and efficiency, reductions in the use of respiratory protection equipment, decontamination time, and waste generation may be realized in some environments.

The HEPA filtered vacuum cleaners are designed to collect radioactive debris and concentrate it in 55-gallon drums. The HEPA filtered vacuum cleaners come in several shapes and sizes and may be either electrically or pneumatically operated. A typical vacuum cleaner contains a HEPA filter, a bag or container for collecting debris, and a vacuum cleaner hose. Debris vacuumed into the hose is deposited in the container. The air passes through the container and may be drawn through an additional prefilter, prior to the HEPA filter, before passing through the fan motor.

The HEPA filtered vacuum cleaners can be truck-mounted or skid-mounted for portability. Some models are fully automated and capable of remote operations (e.g., MOOSE[6]). The Hanford Site currently uses the Guzzler[7]. This truck-mounted, HEPA filtered, vacuum system enables excavation of contaminated soils by the vacuum process rather than manually using shovels to avoid hazards.

Investigations into the use of soil vacuuming methods should be conducted to provide information regarding effectiveness, implementability, and cost in support of detailed analysis during the RI/FS process. Also, much information currently exists with respect to remotely operated equipment for hazardous waste site characterization and remediation to ensure personnel safety (Boissiere, et al., 2005, *Remote Systems for Hazardous Waste Site Remediation and Characterization*).

### 2.5.11 Herbicides and Pesticides

The Hanford *Radiation Area Reduction* and *Interim Stabilization* projects have been involved with surface stabilization of landfills for decades. Surface stabilization activities typically involved placing an initial layer of radiologically clean soil over landfill areas followed by revegetation with shallow-rooted perennial grasses and the application of time release herbicides (picloram, dicamba, and 2,4-D amine plus a polymer). A rodent deterrent (sucrose octa-acetate) was also applied. The time release herbicides were augmented by annual surface applications of selective herbicides to minimize the occurrence of undesirable deep rooting plants. A focused investigation of herbicide and pesticide use at the 200-SW-2 OU landfills is suggested. Landfill burial records and other project activity reports should also be reviewed for possible disposal of herbicide and pesticide residues and/or containers (SD-RE-PRS-001, *Annual Stabilization Progress Review and Status Report* – Fiscal year 1981).

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[6] MOOSE is a trademark of Pentek, Inc., Coraopolis, Pennsylvania.

[7] Guzzler is a trademark of Guzzler Manufacturing, Inc. (a subsidiary of Federal Signal Corporation), Streator, Illinois.

# 3.0 COST AND PROPOSED SCHEDULE FOR TREATABILITY AND OTHER FOCUSED INVESTIGATIONS

Appendix A discusses the three tiers of treatability investigations (remedy screening, remedy selection, RD/RA). Many cost elements are applicable to all tiers of treatability investigations, however, some increase from one tier to another with increasing scale and quality assurance/quality control (QA/QC) requirements. Some cost elements are only applicable to a particular tier (e.g., vendor equipment rental and site preparation in RD/RA). Analytical costs apply to all tiers and can have significant impact on total project costs. Transportation and disposal of residuals are also important elements that must be budgeted in all treatability investigations. Figure 3-1 identifies the general applicability of cost elements to the various treatability investigation tiers.

Since the RI/FS process for the 200-SW-2 OU is currently in its initial stages, suggested treatability investigations fall into the realm of either the remedy screening or remedy selection tiers. The RD/RA tier is typically conducted post-ROD to support remedy design and implementation. Discussions of the cost and duration of RD/RA treatability investigations are included below for completeness.

## 3.1 REMEDY SCREENING

The duration and cost of remedy screening treatability investigations depend on the type and maturity of the technology under investigation, and the number of parameters being considered. Remedy screening tends to be the least costly and time consuming of the three tiers because of the relatively simple equipment used, small number of laboratory test samples and replicates, less stringent QA/QC, and minimal reporting requirements. Remedy screening can typically be conducted over several days to a week at a cost of roughly $10,000 to $50,000. The duration does not include sample analysis or data validation as the time to complete these can be laboratory specific. Also, the time required for treatability investigation planning and reporting is not included. The cost, however, does include these items.

## 3.2 REMEDY SELECTION

The duration and cost for remedy selection treatability investigations are dependent upon the type of technology under investigation, the types of analyses performed, and the level of QA/QC implemented. Higher levels of QA/QC and pilot- to full-scale demonstrations are typically required in support of technology selection decisions during the FS. The duration of remedy selection treatability investigations is typically on the order of weeks to months and does not include the time required for sample analysis, data validation, planning, and reporting. Depending upon the scale, complexity, and level of QA/QC required remedy selection treatability investigations can be performed at a cost between $50,000 and $250,000.

Figure 3-1. Applicability of Cost Elements to Treatability Study Tiers.

| Cost Element | Treatability Study Tier | | |
|---|---|---|---|
| | Remedy Screening | Remedy Selection | RD/RA |
| Labor | ● | ● | ● |
| Testing Equipment | ◒ | ● | ● |
| Vendor Equipment Rental | ○ | ○ | ● |
| Field Instrumentation and Monitors | ○ | ○ | ● |
| Reagents | ◒ | ◒ | ● |
| Site Preparation | ○ | ○ | ● |
| Utilities | ○ | ◒ | ● |
| Mobilization/ Demobilization | ○ | ◒ | ● |
| Permitting and Regulatory | ◒ | ◒ | ● |
| Health and Safety | ● | ● | ● |
| Sample Transportation | ◒ | ◒ | ● |
| Analytical Services | ● | ● | ● |
| Air Emission Treatment | ○ | ◒ | ● |
| Effluent Treatment | ○ | ◒ | ● |
| Decontamination of Equipment | ○ | ◒ | ● |
| Residual Transportation | ◒ | ◒ | ● |
| Residual Treatment/ Disposal | ◒ | ◒ | ● |

○ Not applicable and/or no cost incurred.

◒ May be applicable and/or intermediate cost incurred.

● Applicable and/or high cost incurred.

RD/RA = remedial design/remedial action.

## 3.3 REMEDIAL DESIGN AND REMEDIAL ACTION

The duration and cost for RD/RA treatability investigations are significantly higher than remedy screening or remedy selection because of the potentially significant mobilization and demobilization requirements associated with full-scale systems and onsite operations and maintenance. Like remedy selection, the duration and cost of RD/RA treatability investigations depends on the type of technology, types of analyses, and level of QA/QC required. RD/RA treatability investigations are typically conducted over a period of weeks to months. This is the time required for actual testing and does not include the time for mobilization, construction, acceptance testing, or demobilization since these activities are technology- and site-specific. The time for sample analysis, data validation, planning, and reporting are also not included. Most RD/RA treatability investigations can be performed at a cost between $250,000 and $1,000,000. Prequalification treatability investigations following the signing of the ROD can be an exception to these duration and cost estimates because the investigations are typically performed at the vendors' cost in anticipation of winning the contract award for performing the work.

## 3.4 FOCUSED INVESTIGATIONS

Several focused investigations are suggested to collect available information in support of alternatives analysis during the FS as discussed in Section 2.5. These focused investigations can be conducted in parallel and will require approximately one to two months each at a cost of roughly $15,000 to $25,000 per investigation. Some focused investigations (e.g., surface topography surveys) require field work and the cost may approach $50,000 for the 200-SW-2 OU landfill sites.

Figure 3-2 provides a rough order of magnitude cost estimate for treatability investigations by tier including sample analysis, data validation, planning, and reporting. Figure 3-3 provides a typical schedule for the performance of treatability investigations by tier; including the various documentation required to support the investigations. If treatability investigations are being conducted on new or emerging technologies, then multiple tiers of investigation may be required. If so, the timeline is sequential for the applicable tiers. Figure 3-4 provides a summary of the general cost and proposed schedule for suggested treatability investigations and other focused investigations.

Figure 3-2. Rough Order of Magnitude Costs for Treatability Investigations by Tier.

| Activity | Remedy Screening Treatability Investigations ($K) [Pre-ROD] | Remedy Selection Treatability Investigations ($K) [Pre-ROD] | Remedial Design/Remedial Action Treatability Investigations ($K) [Post-ROD] | Duration (Weeks) | Cost Basis* |
|---|---|---|---|---|---|
| Prepare Data Quality Objective | 60.0 | 60.0 | 60.0 | 10 | 400 hrs of subcontract support at $105/hr; 200 hrs of support at $85/hr |
| Prepare Statement Of Work | 7.0 | 7.0 | 7.0 | 2 | 80 hrs of support at $85/hr; includes preparation, review, and contract award |
| Prepare Work Plan | 14.0 | 14.0 | 14.0 | 4 | 160 hrs of support at $85/hr; includes preparation, review, and release |
| Prepare Sampling and Analysis Plan | 14.0 | 14.0 | 14.0 | 4 | 160 hrs of support at $85/hr; includes preparation, review, and release |
| Prepare Health and Safety Plan | 14.0 | 14.0 | 14.0 | 4 | 160 hrs of support at $85/hr; includes preparation, review, and release |
| Conduct Treatability Investigation | 50.0 | 250.0 | 1,000.0 | Based on Tier | Cost based on EPA guidance (upper range); includes residual waste management; remedy screening duration is days; remedy selection duration is days to weeks; RD/RA duration is weeks to months |
| Data Analysis and Interpretation | 7.0 | 7.0 | 7.0 | 2 | 80 hrs of support at $85/hr |
| Report Preparation/Review/Issuance | 20.0 | 20.0 | 20.0 | 5 | 200 hrs support at $85/hr |
| **SUBTOTAL** | 186.0 | 386.0 | 1,136.0 | | |
| **CONTINGENCY, 30%**** | 55.8 | 115.8 | 340.8 | | |
| **ESTIMATED TOTAL***** | 241.8 | 501.8 | 1,476.8 | | |

* Costs are rounded for simplicity of estimate.

** Contingency reflects preliminary stage and generic nature of estimate; estimate must be refined based on specific technologies once selected.

*** Costs for treatability investigations based on EPA/540/R-92/071a; other costs based on Hanford Site experience.

EPA/540/R-92/071a, *Guide for Conducting Treatability Studies under CERCLA, Final.*

Figure 3-3. Generic Schedule for Treatability Investigation Activities.

| Activity/Task* | Span in Weeks | Months from Project Start | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| ***Supporting Project Documentation*** | | | | | | | | | | | | | |
| **Prepare Data Quality Objective** | 10 | | | | | | | | | | | | |
| **Prepare Statement of Work** | 2 | | | | | | | | | | | | |
| **Prepare Work Plan** | 4 | | | | | | | | | | | | |
| **Prepare Sampling/Analysis Plan** | 4 | | | | | | | | | | | | |
| **Prepare Health/Safety Plan** | 4 | | | | | | | | | | | | |
| ***Treatability Investigation Tiers*** | | | | | | | | | | | | | |
| **Conduct Treatability Investigation** | | | | | | | | | | | | | |
| ***Remedy Screening [Pre-ROD]*** | | | | | | | | | | | | | |
| Conduct Treatability Investigation | 6 | | | | | | | | | | | | |
| Data Analysis/Interpretation | 2 | | | | | | | | | | | | |
| Prepare/Review/Issue Report | 4 | | | | | | | | | | | | |
| ***Remedy Selection [Pre-ROD]*** | | | | | | | | | | | | | |
| Conduct Treatability Investigation | 12 | | | | | | | | | | | | |
| Data Analysis/Interpretation | 2 | | | | | | | | | | | | |
| Prepare/Review/Issue Report | 6 | | | | | | | | | | | | |
| ***Remedial Design/Action [Post-ROD]*** | | | | | | | | | | | | | |
| Conduct Treatability Investigation | 20 | | | | | | | | | | | | |
| Data Analysis/Interpretation | 4 | | | | | | | | | | | | |
| Prepare/Review/Issue Report | 8 | | | | | | | | | | | | |

* Major tasks in treatability investigation protocol; community relations activities and regulatory compliance occur throughout the process.

** New or emerging technologies may require multiple tiers of treatability investigation. In such cases, schedule timelines would be sequential.

Generic schedule based on EPA/540/R-92/071a, Guide for Conducting Treatability Studies under CERCLA, Final.

Figure 3-4. Potential Pre-Record of Decision Treatability and Other Focused Investigations.

| Potential Pre-Record of Decision (ROD) Treatability and Other Focused Investigations [5] | Investigation Scale | Estimated Cost $K [3] | FY 2008 $K | FY 2009 $K | FY 2010 $K | FY 2011 $K [4] | FY 2012 $K Post-ROD |
|---|---|---|---|---|---|---|---|
| **LIKELY RESPONSE SCENARIOS** | | | | | | | |
| 1. Retrieval, treatment and disposal of waste from within individual burial grounds | | | | | | | |
| 2. Retrieval, treatment, and disposal of waste from within portions of individual burial grounds | | | | | | | |
| 3. Capping of individual burial grounds | | | | | | | |
| 4. In-situ treatment (e.g., vitrification/grouting) of portions of individual burial grounds | | | | | | | |
| 5. Some combination of the above | | | | | | | |
| **PRE-ROD (FY 2008 through FY 2011)** | | | | | | | |
| **TREATABILITY AND FOCUSED INVESTIGATIONS FOR EXCAVATION, TREATMENT, AND DISPOSAL (portion or entire burial ground)** | | | | | | | |
| 1. Location of non-retrievably stored spent fuel | Document [2] | | 20 | | | | |
| 2. Soil vacuum removal methods | Document | | 20 | | | | |
| 3. ***Waste stabilization and retrieval [1]*** | Pilot/Full | 50-500 | | 500 | | | |
| **TREATABILITY AND FOCUSED INVESTIGATIONS FOR CAPPING OF INDIVIDUAL BURIAL GROUNDS** | | | | | | | |
| 1. Waste compaction methods | Document | | 20 | | | | |
| 2. ***Surface barriers - asphalt, concrete, cement-type cap designs and performance*** | Document | | 20 | | | | |
| **TREATABILITY AND FOCUSED INVESTIGATIONS FOR IN-SITU TREATMENT [6]** | | | | | | | |
| 1. Stabilization/solidification | Document | | 20 | | | | |
| 2. ***Supersaturated grouts*** | Pilot/Full | 50-500 | | 500 | | | |
| 3. ***Grout injection*** | Pilot/Full | 50-500 | | | 500 | | |
| 4. ***Soil mixing*** | Pilot/Full | 50-500 | | | 500 | | |
| 5. ***Soil desiccation*** | Bench/Pilot | 50-250 | | | | 250 | |
| 6. ***Reactive gases*** | Bench/Pilot | 50-250 | | | | 250 | |
| 7. ***Nanoparticles*** | Bench/Pilot | 50-250 | | | | 250 | |
| 8. ***Soil flushing*** | Bench/Pilot | 50-250 | | | | 250 | |
| 9. ***Electrokinetics*** | Bench/Pilot | 50-250 | | | | 250 | |
| **FOCUSED INVESTIGATIONS SUPPORTIVE OF MULTIPLE LIKELY RESPONSE SCENARIOS** | | | | | | | |
| 1. Location of large burial boxes/equipment | Document | | 20 | | | | |
| 2. Cost of waste retrieval and barrier construction | Document | | 20 | | | | |
| 3. Caisson and vertical pipe unit characterization and remediation techniques | Document | | 20 | | | | |
| 4. Direct push technology through or near waste trenches | Document | | 20 | | | | |
| 5. Acid soaked material trenches | Document | | 20 | | | | |
| 6. Vadose zone characterization and monitoring; including topographic surveying | Document | | 50 | | | | |
| 7. In situ detection of transuranics [7] | Field Support | | 10 | | | | |
| 8. Herbicides and pesticides | Document | | 10 | | | | |
| **PRE-ROD SUBTOTAL** | | | 270 | 1000 | 1000 | 1250 | |
| **POST-ROD (Beyond FY 2011)** | | | | | | | |
| 1. Treatability investigation required to support remedial design/remedial action implementation | Full | 250-1,500 | | | | | 250-1,500 |
| **POST-ROD SUBTOTAL** | | | | | | | |

**NOTES**

1. Items in ***bold italics*** reflect treatability investigations suggested by Truex, et.al., "Technology Survey to Support Revision to the Remedial Investigation/Feasibility Study (RI/FS) Work Plan for 200-SW-2," PNNL-16105;
2. "Document" refers to a literature search to extract pertinent information from other on-going projects (e.g., M-91 retrieval, 618-7/10/11 burial ground retrieval, etc.) or past work on the Hanford Site and elsewhere.
3. Costs reflect Environmental Protection Agency (EPA) experience with bench/pilot/full scale treatability investigations plus costs for data quality objectives, work plans, sampling and analysis plans, health and safety plans, and data analysis/interpretation/reporting.
4. Assume completion of the RI/FS process for all operable units by December 31, 2011 (Tri-Party Agreement M-15-00) followed by appropriate post-ROD treatability investigations (if necessary) to support the remedial design and remedial action.
5. Per EPA guidance the protocol for conducting treatability investigations include: establishing data quality objectives, identifying sources, issuing work assignments, preparing work plans, preparing sampling and analysis plans, conducting community relations, complying with regulatory requirements, executing the investigations, analyzing and interpreting the data, and reporting the results in support of the feasibility study. Likely response scenarios from "Collaborative Agreement". See note #3 regarding costs.
6. Treatability investigations involving in situ treatment of vadose zone soils contingent upon results of the remedial investigation and the nature and extent of contaminant plumes beneath landfill trenches.
7. From Small-Business Innovative Research Project #DE-FG02-04ER83902, "Nuclear Probes for Mapping TRU and VOC Concentrations in the Subsurface," University of Connecticut and Applied Physics and Measurements, Inc.; cost leveraging

# 4.0 CONCLUSIONS

In many cases, the various process options comprising candidate remedial alternatives are fully developed and have a history of use at the Hanford Site and elsewhere. With few exceptions, sufficient information exists on process options and associated remedial alternatives to support detailed analysis during the FS without additional treatability investigations. However, site-specific treatability investigations may be required to support the remedial design and remedial action by defining operating parameters and equipment specifications following the signing of the ROD.

Based on the remediation technology pre-screening conducted in the Implementation Plan and subsequent technology survey, treatability investigations were suggested for the technologies summarized in Table 4-1 to provide information regarding effectiveness, implementability, and/or cost in support of the FS.

Table 4-1. Treatability Information for Candidate Technologies and Likely Response Scenarios.

| Likely Response Scenario | Supporting Technology | Treatability Information | Level of Maturity |
|---|---|---|---|
| ***Applicable Within a Landfill*** | | | |
| Surface barrier | asphalt/concrete/cement type cap | effectiveness | mature |
| RTD of all or portion of landfill | stabilization/retrieval | effectiveness, implementability, cost | mature |
| In situ stabilization of all or portion of landfill | grout injection<br>soil mixing | effectiveness<br>effectiveness | mature<br>mature |
| ***Applicable Within the Vadose Zone Beneath a Landfill*** | | | |
| In situ stabilization | grout injection<br>supersaturated grouts<br>soil desiccation<br>reactive gases<br>nanoparticles | effectiveness<br>effectiveness<br>effectiveness<br>effectiveness<br>effectiveness, implementability, cost | developmental<br>developmental<br>developmental<br>developmental<br>experimental |
| Contaminant extraction | soil flushing<br>electrokinetics | effectiveness<br>effectiveness | mature<br>developmental |

The technologies "Applicable within a Landfill" are mature and have been demonstrated at Hanford, other DOE Sites, and elsewhere. For the most part, information regarding the implementability and cost of these technologies is available. However, the effectiveness of these technologies under Hanford Site conditions is generally not fully known and subject to existing 200-SW-2 OU waste conditions and configurations.

Treatability investigations have been completed, are underway, or are planned for technologies "Applicable within a Landfill." These treatability investigations should be leveraged to obtain information regarding effectiveness, implementability, and cost in support of alternatives analyses in the 200-SW-2 OU FS. For example, a Hanford Protective Surface Barrier Prototype was constructed over the 216-B-57 crib in 200 East Area. This prototype surface barrier incorporates a fluidized asphalt layer within its profile. Surface barrier performance data has

been collected since completion of construction in 1994. Furthermore, a treatability investigation of a polyurethane mono-layer surface cover was initiated over the 241-T tank farm in 200 West Area during FY 2007. Finally, alternative surface barrier treatability investigations have been conducted at other DOE Sites and elsewhere.

Experience with the retrieval, treatment, and disposal of radioactive solid wastes in support of the interim action ROD for the 618-7/10/11 landfills in the 300 Area, ongoing retrievably stored TRU retrievals conducted by the M-91 Project, and treatability investigations conducted in support of solid waste landfill remediation efforts at the INL provide effectiveness, implementability, and cost information for the FS. Other treatability investigations performed at Hanford under subcontract provide information regarding the retrieval of solid waste caissons and VPUs.

In situ stabilization/solidification of solid waste landfill trenches has been demonstrated at INL using simultaneous dynamic compaction (vibratory hammer) and grout injection. The process induces liquefaction in the soil/waste matrix enhancing grout flow into interstitial voids thereby creating a solid monolithic structure.

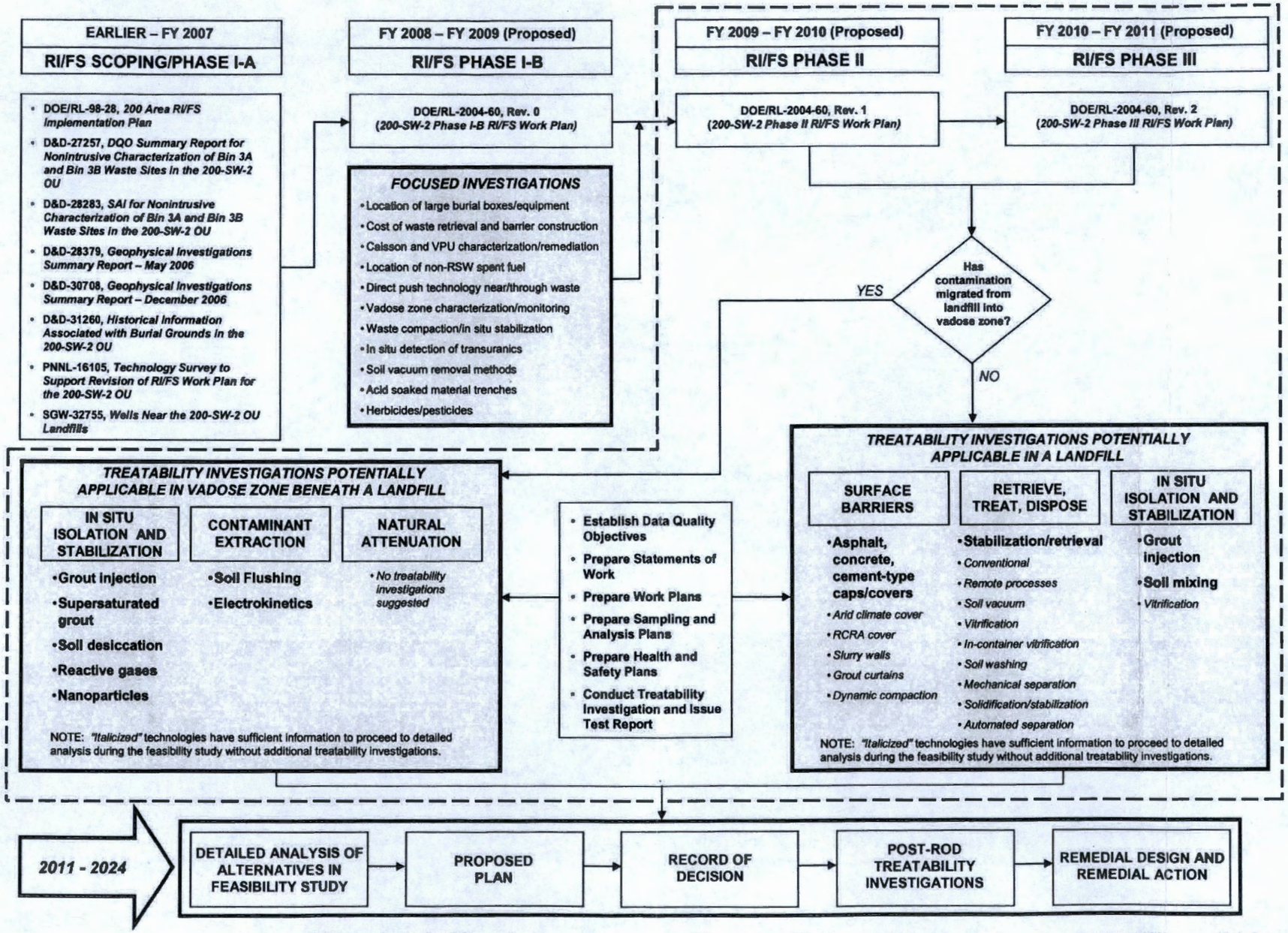
The technologies "Applicable within the Vadose Zone beneath a Landfill" tend to be more developmental or experimental in nature. In general, information regarding the implementability and cost of these technologies is available. The effectiveness of these technologies under Hanford Site conditions is not fully known and subject to site-specific geology and nature and extent of vadose zone contamination. Given the need to better understand site-specific geology, the presence/absence of contamination in the vadose zone, and ongoing efforts to collect data through a phased RI to better understand the 200-SW-2 OU conditions, investments in vadose zone treatability investigations should be delayed into FY 2009.

Fiscal year 2008 activities should be devoted primarily to other focused investigations discussed in Section 2.5. These activities include a number of literature reviews and historical information compilation tasks, and provide information required in support of detailed alternative analyses during the 200-SW-2 OU FS process. A treatability investigation of nuclear probes developed through a DOE-sponsored SBIR grant for in situ characterization of transuranics and chlorinated volatile organics is also suggested for FY 2008 to support future intrusive characterization efforts (Phase II and III).

Beginning in FY 2009, treatability investigations applicable within a landfill (i.e., surface barriers, RTD methods, and in situ isolation/stabilization techniques) should be considered in support of the 200-SW-2 OU FS. Available information regarding surface barriers, RTD methods, and in situ isolation/stabilization techniques should be leveraged to the maximum extent possible in satisfying treatability investigation needs.

Treatability investigations applicable within the vadose zone beneath landfills should be considered in FY 2010 and beyond after a more thorough understanding of the nature and extent of vadose zone contamination is acquired through intrusive characterization activities planned in the 200-SW-2 OU. If vadose zone contamination is not discovered, then suggested treatability investigations beneath landfills may not be needed. Figure 4-1 shows the relationship between suggested treatability and other focused investigations and major documents generated during the CERCLA process.

Figure 4-1. Relationship between Treatability and Other Focused Investigations and Major Documents in the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* Process.




DQO = data quality objective.
FY = fiscal year.
RI/FS = remedial investigation/feasibility study.
RSW = retrievably stored waste.
OU = operable unit.
RCRA = *Resource Conservation and Recovery Act of 1976.*
VPU = vertical pipe unit.

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# APPENDIX A

# APPROACH TO TREATABILITY INVESTIGATIONS

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# APPENDIX A

## A.0 APPROACH TO TREATABILITY INVESTIGATIONS

Treatability investigations are comprised of literature searches and/or laboratory and field demonstrations designed to provide critical data needed to evaluate and implement cost-effective remediation technologies at waste sites. A three-tiered approach to treatability investigations (i.e., remedy screening, remedy selection, and remedial design and remedial action [RD/RA]) typically follows an initial pre-screening of technologies and scoping of suggested treatability investigations requiring laboratory or field demonstrations. Figure A-1 provides a flow diagram representing the three-tiered approach to treatability investigations. Figure A-2 provides a depiction of the role of treatability investigations in the RI/FS process.

## A.1 TECHNOLOGY PRE-SCREENING AND TREATABILITY INVESTIGATION SCOPING

Technology prescreening is conducted to identify potential remediation technologies and the need for treatability investigations. The prescreening criteria of effectiveness, implementability, and cost are typically applied to technologies without consideration of site-specific variables. Site-specific variables are considered following the remedial investigation (RI) during detailed analyses of the technologies in the feasibility study (FS).

***"Effectiveness"*** deals with (1) the technologies ability to address areas or volumes of contaminated media while meeting remedial action objectives (RAO) and associated requirements (e.g., applicable or relevant and appropriate requirements [ARAR]); (2) the potential impacts on human health and environment during construction and implementation; and (3) how proven and reliable the technologies are with respect to contaminants. This criterion also focuses on the ability of technologies to treat a contaminant type (i.e., organics, inorganics, metals, radionuclides, etc.) rather than specific contaminants (i.e., nitrate, cyanide, chromium, plutonium, etc.).

***"Implementability"*** emphasizes the institutional aspects of technology deployment. These aspects include the ability to obtain necessary permits; availability of treatment, storage, and/or disposal (unit) services; availability of skilled work force and necessary equipment. This criterion considers the technologies maturity and overall developmental status.

***"Cost"*** deals with the capital and operating costs for technology deployment. Costs associated with technologies are typically evaluated as being high, medium, or low relative to other technologies under consideration.

Technology prescreening and treatability investigation scoping includes searching technology literature and treatability databases; consulting with technology experts; determining data needs; identifying potential treatability investigation sources or contractors; and identifying preliminary data quality objectives (DQO), RAOs, and site remediation goals. Section 2.0 discusses technology prescreening conducted to date; including suggested treatability investigations.

Following pre-screening of potentially applicable technologies and identification of the possible need for treatability investigations, a three-tiered process is implemented as discussed below. Table A-1 provides a comparative summary of the three tiers based on actual experiences of the EPA.

Figure A-1. Flow Diagram for the Tiered Approach to Treatability Investigations.

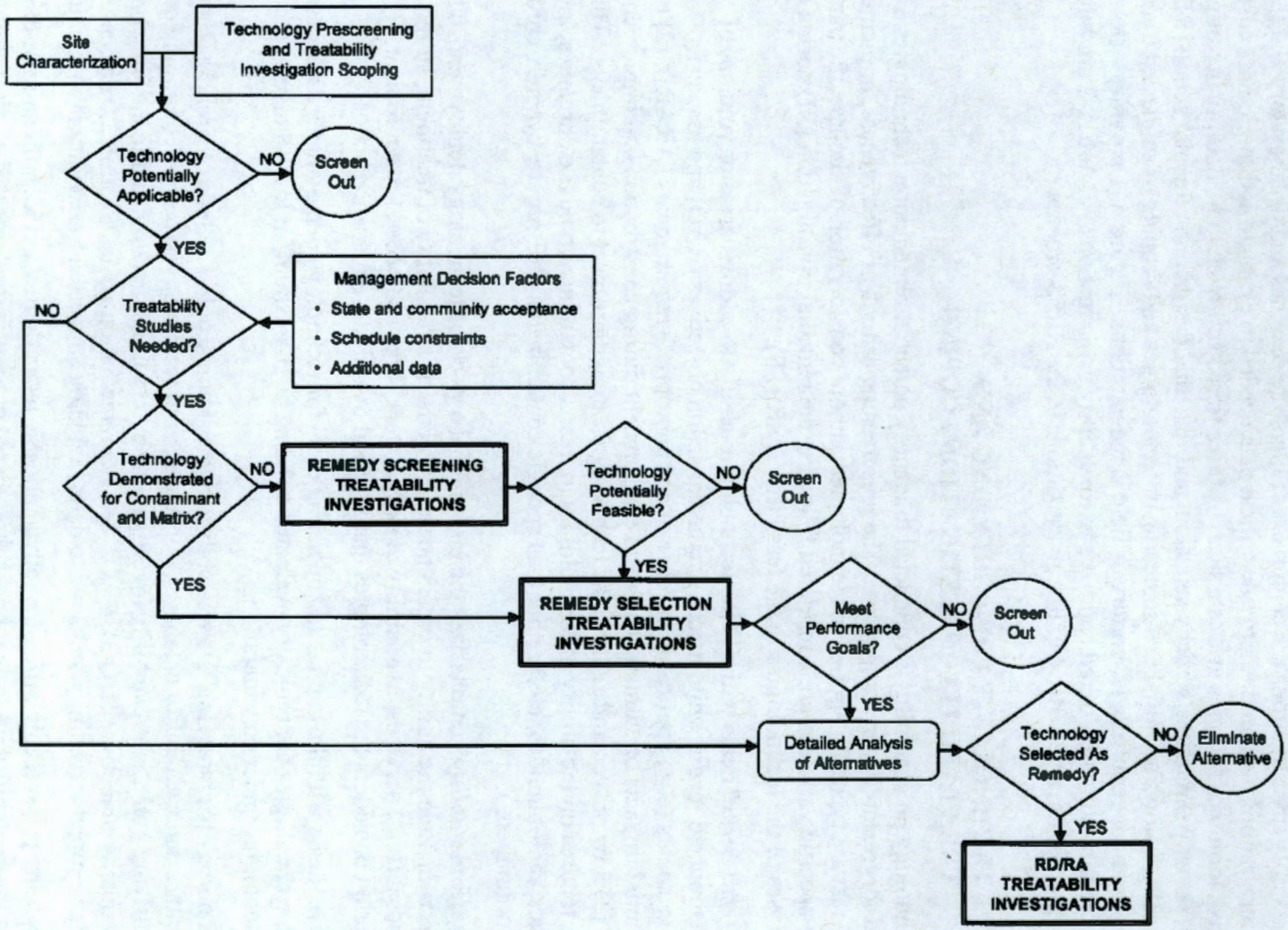
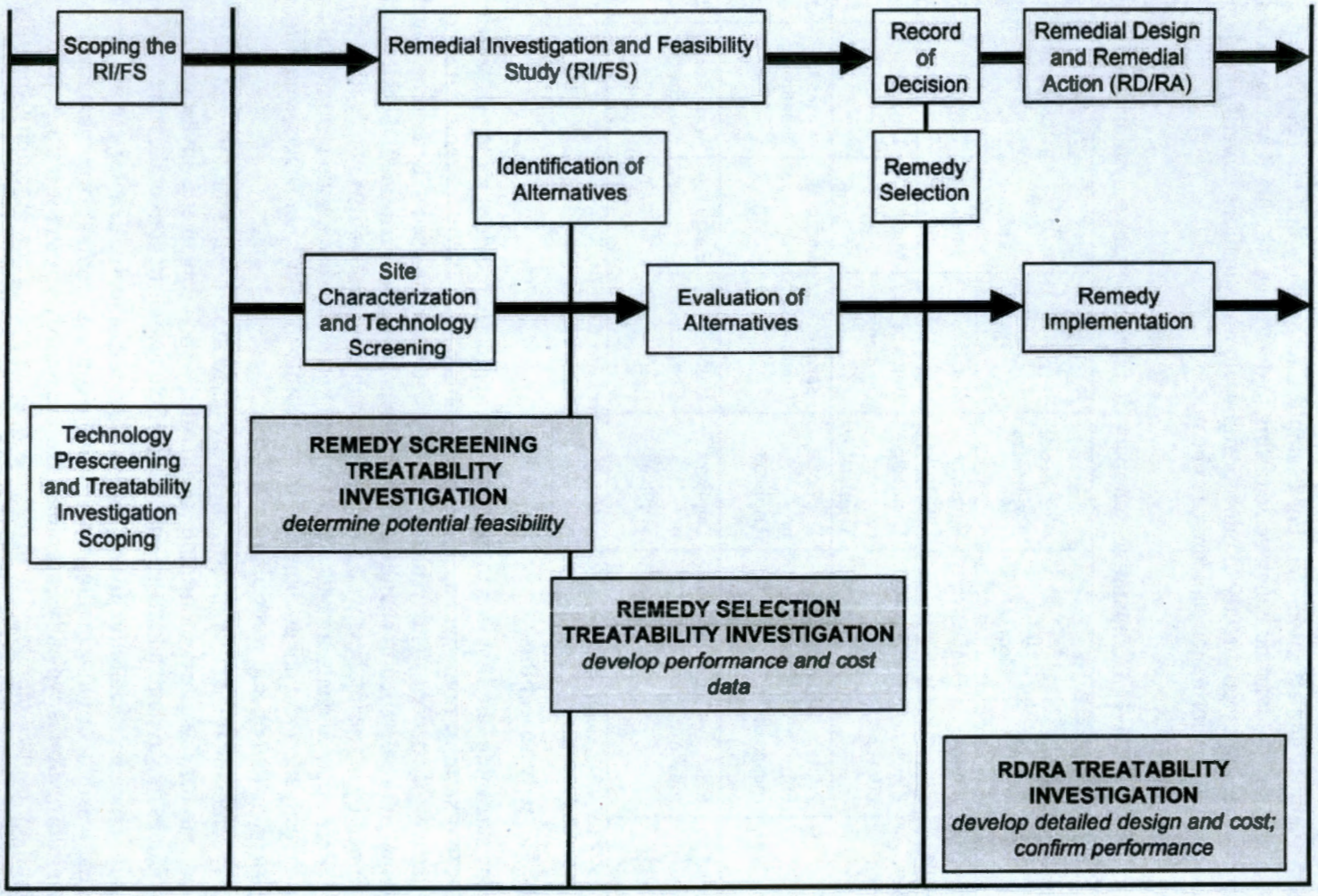


Figure A-2. Role of Treatability Investigations in the Remedial Investigation/Feasibility Study and Remedial Design/Remedial Action Process.



In general, waste treatment technologies are evaluated first at the bench-scale and progress through pilot- and full-scale treatability investigations. However, a technology may be tested at the appropriate scale based on its maturity and consideration of site-specific factors affecting implementability and effectiveness. For example, a technology that has been investigated extensively may not warrant bench-scale testing to determine whether it has the potential to work. Rather, it may go directly to pilot- or full-scale investigations to verify implementability and that overall performance standards can be met.

Table A-1. Comparative Summary of Treatability Investigations by Tier.

| Tier | Study Scale | Type of Data Generated | Number of Replicates | Typical Process Type | Waste Stream Volume | Time Required (Test Only) | Rough Order of Magnitude Cost ($K) |
|---|---|---|---|---|---|---|---|
| Remedy Screening | Bench | Qualitative | Single or Duplicate | Batch | Small | Days | 10 to 50 |
| Remedy Selection | Bench or Pilot | Quantitative | Duplicate or Triplicate | Batch or Continuous | Medium | Days to Weeks | 50 to 100 |
| | Pilot or Full (onsite or offsite) | Quantitative | Duplicate or Triplicate | Batch or Continuous | Large | Weeks to Months | 50 to 250 |
| Remedial Design/ Remedial Action | Full (onsite) | Quantitative | Duplicate or Triplicate | Batch or Continuous | Large | Weeks to Months | 250 to 1,000 |

EPA/540/R-92/071a, *Guide for Conducting Treatability Studies under CERCLA, Final.*

### A.1.1 Remedy Screening

Remedy screening, the first step in the three-tier approach, provides gross performance data needed to determine potential feasibility of a treatment technology for remediating contaminants and matrices of concern. The results of remedy screening are used to determine whether additional, more-detailed treatability investigations should be performed. Feasibility is determined by assessing how well a technology achieves treatability investigation performance goals. Performance goals are based on available knowledge of cleanup criteria and are set prior to the investigation and are documented in treatability investigation DQOs, sampling and analysis plans (SAP), and work plans.

Remedy screening treatability investigations are performed in the laboratory and are limited in size and scope to bench-scale demonstrations with off-the-shelf equipment. Investigations of some technologies may require additional small-scale field demonstrations at the remedy screening tier.

Remedy screening treatability investigations provide qualitative data for use in assessing potential feasibility of a technology for treating a contaminant/matrix combination. No cost or design information is typically generated. During remedy screening, a single indicator contaminant is often monitored to determine whether a reduction in toxicity, mobility, or volume is occurring as waste is treated. Remedy screening generally involves batch testing and the use of small-volume samples of the waste or an acceptable surrogate.

The nature of remedy screening (i.e., simple equipment, small number of test samples and replicates, less-stringent quality assurance/quality control (QA/QC) requirements, and minimum reporting requirements) makes it the least costly and time-consuming of the three treatability investigation tiers. Cost and time savings are increased by limiting sampling and analysis objectives to address only indicator contaminants that are representative of the families of chemicals and/or radionuclides present and their concentrations.

### A.1.2 Remedy Selection

Remedy selection is the second step in the three-tier approach. A remedy selection treatability investigation is designed to verify whether a process option can meet cleanup criteria and at what cost. The purpose of this tier is to generate performance and cost data necessary for remedy evaluation in the detailed analysis of alternatives during the FS. Results of remedy selection treatability investigations allow for estimating costs associated with full-scale implementation of the alternative within an accuracy of roughly +50/-30 percent, as required for the RI/FS process. Remedy selection treatability investigations are initiated during the pre-ROD site characterization and technology screening activities, and continue through the evaluation of alternatives during the FS.

Remedy selection treatability investigations are performed in the laboratory or field with bench-, pilot-, or full-scale equipment. Equipment should be designed to simulate the basic operations of the full-scale treatment process.

Remedy selection treatability investigations provide quantitative data for use in determining whether a technology can meet cleanup criteria and at what cost. The operational and performance information resulting from remedy selection investigations are used to estimate full-scale treatment costs and schedules, and to assess the technology against the RI/FS evaluation criteria. Because the data generated at this tier will be used for remedy selection in the Proposed Plan and ROD, moderately to highly stringent levels of QA/QC are required.

Remedy selection treatability investigations may be conducted as either batch or continuous processes. Waste stream sample volumes should be adequate to simulate full-scale operations. The higher cost and longer time requirements of remedy selection treatability investigations compared with remedy screening are directly related to the need for stringent QA/QC and the greater number of samples and replicates to be analyzed.

### A.1.3 Remedial Design/Remedial Action (RD/RA)

The final step in the three-tier approach involves treatability investigations to support RD/RA activities. The purpose of a RD/RA treatability investigation is to generate the detailed design, cost, and performance data necessary to optimize and implement the selected remedy.

RD/RA treatability investigations are conducted after the ROD has been signed. These investigations are performed to:

- Select among multiple vendors and processes within a prescribed remedy (pre-qualification)
- Implement the most appropriate remedies prescribed in a Contingency ROD
- Support detailed design specifications and the design of treatment trains for specific sites.

Most RD/RA treatability investigations are performed in the field with pilot- or full-scale equipment. Some prequalification treatability investigations may be performed in the laboratory; however, the system should closely approximate the proposed full-scale operations. Remedial design/remedial action treatability investigations provide the detailed, quantitative design and cost data required to optimize critical parameters and to implement the selected remedy in accordance with the provisions of the ROD.

Remedial design/remedial action treatability investigations usually require duplicate or triplicate sample replication. The data generated at this tier are used to design and optimize the process; therefore, stringent levels of QA/QC are required.

Remedial design/remedial action treatability investigations may be conducted as either batch or continuous processes, depending on the operation of the full-scale system. Waste stream sample throughput and volume should achieve levels projected for full-scale operations. Because of the potentially significant mobilization requirements associated with any onsite operation, RD/RA treatability investigations are significantly more time consuming and costly than pre-ROD treatability investigations.

## A.2 PROTOCOL FOR CONDUCTING TREATABILITY INVESTIGATIONS

Some treatability investigations involve relatively simple literature research to compile data regarding the effectiveness, implementability, and cost of mature, demonstrated technologies. Bench-, pilot-, and full-scale treatability investigations for new or unproven technologies are performed in a systematic fashion to ensure that the data generated can support remedy selection and implementation. The protocol for conducting treatability investigations includes:

- Establishing DQOs
- Identifying sources for treatability investigations
- Issuing work assignments
- Preparing work plans
- Preparing sampling and analysis plans
- Preparing health and safety plans
- Conducting community relations activities
- Complying with regulatory requirements
- Executing the study
- Analyzing and interpreting the data
- Reporting the results.

### A.2.1 Establishing Data Quality Objectives

DQOs are qualitative and quantitative statements that specify the type, quality, and quantity of data required in support of decisions concerning remedy selection and implementation. The end use of collected treatability investigation data will determine the appropriate DQOs. The DQO process (EPA/600/R-96/055, *Guidance for the Data Quality Objectives Process*) provides a systematic procedure for defining the criteria that data collection should satisfy. The data collection design addresses when to collect samples, where to collect samples, how to collect samples, the tolerable level of decision errors, and the quantity of samples to collect. Table A-2 provides a cross-walk between the DQO process and a typical Quality Assurance Project Plan.

### A.2.2 Identifying Sources for Treatability Investigations

Once the decision to conduct a treatability investigation has been made and the scope of the project has been defined, the project manager must identify a qualified contractor or technology vendor with the requisite technical capabilities and experience to perform the work. Treatability investigations can be performed in-house or via established contracting/procurement mechanisms. The project manager must perform the necessary acquisition planning; including preparation of procurement specifications to ensure that qualified contractors and technology vendors are acquired.

### A.2.3 Issuing the Work Assignment

The work assignment is a contractual document that outlines the scope of work to be provided by the contractor (i.e., Statement of Work). It presents the rationale for conducting the investigation, identifies the waste stream and technologies to be investigated, specifies the tier(s) of investigation required, and defines QA/QC requirements.

### A.2.4 Preparing the Work Plan

Treatability investigations must be carefully planned to ensure that the data generated are useful for evaluating the effectiveness, implementability, and cost of a technology. The work plan, which is prepared when the work assignment is in place, sets forth the proposed technical approach for completing the tasks outlined in the work assignment and the level of QA/QC rigor required to ensure the defensibility of the treatability investigation results. It also assigns responsibilities and establishes the project schedule and costs.

Treatability investigation work plans will be submitted by DOE to the lead regulatory agency when the investigation is related to a specific operable unit per the RI/FS work plan. All treatability investigation work plans shall be assigned to an operable unit for which a lead regulatory agency has been identified. The lead regulatory agency shall determine on a case-by-case basis whether a treatability investigation work plan is a primary document or a secondary document (see Section 9.1 of the Tri-Party Agreement Action Plan) during development of the applicable RI/FS (or RFI/CMS) work plan.

The work plan will identify technology-specific performance goals based on ARARs and the use of national consensus standards. Also, applicable constraints (e.g., radiological and hazardous chemical exposures, air release limits, waste acceptance criteria, etc.) should be addressed in the work plan and be reflected in the HASP and other appropriate documents.

### A.2.5 Preparing the Sampling and Analysis Plan

An SAP is required for all field and test activities conducted to support a treatability investigation. The purpose of the SAP is to ensure samples obtained for characterization and testing are representative and the quality of analytical data generated is known and satisfies DQO requirements. The SAP addresses field sampling, waste characterization, and sampling and analysis of treated wastes and residuals from the testing apparatus or treatment unit.

Table A-2. Cross-Walk Between Quality Assurance Project Plan and Data Quality Objective. (2 Pages)

| Quality Assurance Project Plan Elements | Requirements | DQO Overlap |
|---|---|---|
| **PROJECT MANAGEMENT** | | |
| A1 Title and Approval Sheet | Title and approval sheet. | N/A |
| A2 Table of Contents | Document control format. | N/A |
| A3 Distribution List | Distribution list for the QA Project Plan revisions and final guidance. | Step 1: State the Problem |
| A4 Project/Task Organization | Identify individuals or organizations participating in the project and discuss their roles, responsibilities and organization. | Step 1: State the Problem |
| A5 Problem Definition/Background | 1) State the specific problem to be solved or the decision to be made.<br>2) Identify the decision maker and the principal customer for the results. | Step 1: State the Problem<br>Step 2: Identify the Decision |
| A6 Project/Task Description | 1) Hypothesis test,<br>2) Expected measurements,<br>3) ARARs or other appropriate standards,<br>4) Assessment tools (technical audits),<br>5) Work schedule and required reports. | Step 1: State the Problem<br>Step 2: Identify the Decision<br>Step 3: Identify the Inputs to the Decision<br>Step 6: Specify Limits on Decision Errors |
| A7 Quality Objectives and Criteria | Decision(s), population parameter of interest, action level, summary statistics and acceptable limits on decision errors. Also, scope of the project (domain or geographical locale). | Step 4: Define the Boundaries<br>Step 5: Develop a Decision Rule<br>Step 6: Specify Limits on Decision Errors |
| A8 Special Training/Certification | Identify special training that personnel will need. | N/A |
| A9 Documents and Records | Itemize the information and records that must be included in a data report package, including report format and requirements for storage, etc. | Step 3: Identify the Inputs to the Decision<br>Step 7: Optimize the Design for Obtaining Data |
| **DATA GENERATION AND ACQUISITION** | | |
| B1 Sampling Process Design (Experimental Design) | Outline the experimental design, including sampling design and rationale, sampling frequencies, matrices, and measurement parameter of interest. | Step 5: Develop a Decision Rule<br>Step 7: Optimize the Design for Obtaining Data |
| B2 Sampling Methods | Sample collection method and approach. | Step 7: Optimize the Design for Obtaining Data |
| B3 Sample Handling and Custody | Describe the provisions for sample labeling, shipment, chain-of-custody forms, procedures for transferring and maintaining custody of samples. | N/A |
| B4 Analytical Methods | Identify analytical method(s) and equipment for the study, including method performance requirements. | Step 3: Identify the Inputs to the Decision<br>Step 7: Optimize the Design for Obtaining Data |

Table A-2. Cross-Walk Between Quality Assurance Project Plan and Data Quality Objective. (2 Pages)

| Quality Assurance Project Plan Elements | Requirements | DQO Overlap |
|---|---|---|
| B5 Quality Control | Describe quality control procedures that should be associated with each sampling and measurement technique. List required checks and corrective action procedures. | Step 3: Identify the Inputs to the Decision |
| B6 Instrument/Equipment Testing, Inspection, and Maintenance | Discuss how inspection and acceptance testing, including the use of QC samples, must be performed to ensure their intended use as specified by the design. | Step 3: Identify the Inputs to the Decision |
| B7 Instrument/Equipment Calibration and Frequency | Identify tools, gauges and instruments, and other sampling or measurement devices that need calibration. Describe how the calibration should be done. | Step 3: Identify the Inputs to the Decision |
| B8 Inspection/Acceptance of Supplies and Consumables | Define how and by whom the sampling supplies and other consumables will be accepted for use in the project. | N/A |
| B9 Non-direct Measurements | Define the criteria for the use of non-measurement data, such as data that come from databases or literature. | Step 1: State the Problem<br>Step 7: Optimize the Design for Obtaining Data |
| B10 Data Management | Outline the data management scheme including the path and storage of the data and the data record-keeping system. Identify all data handling equipment and procedures that will be used to process, compile, and analyze the data. | Step 3: Identify the Inputs to the Decision<br>Step 7: Optimize the Design for Obtaining Data |
| **ASSESSMENT AND OVERSIGHT** | | |
| C1 Assessments and Response Actions | Describe the assessment activities needed for this project. | Step 7: Optimize the Design for Obtaining Data |
| C2 Reports to Management | Identify the frequency, content, and distribution of reports issued to keep management informed. | N/A |
| **DATA VALIDATION AND USABILITY** | | |
| D1 Data Review, Verification, and Validation | State the criteria used to accept or reject the data based on quality. | Step 7: Optimize the Design for Obtaining Data |
| D2 Verification and Validation Methods | Describe the process to be used for verifying and validating data, including the chain-of-custody for data throughout the lifetime of the project. | Step 3: Identify the Inputs to the Decision |
| D3 Reconciliation With User Requirements | Describe how results will be evaluated to determine if performance criteria have been satisfied. | Step 7: Optimize the Design for Obtaining Data |

ARAR = applicable or relevant and appropriate requirement.
DQO = data quality objective.
N/A = not applicable.
QA = quality assurance.
QC = quality control.

### A.2.6 Preparing the Health and Safety Plan

A project-specific health and safety plan (HASP) is required for all treatability investigations conducted onsite or at offsite laboratories or testing facilities permitted under RCRA; including research, development, and demonstration facilities. The HASP describes the work to be performed in the field and in the laboratory, identifies the possible physical and chemical hazards associated with each phase of field and laboratory operations, and prescribes appropriate protective measures to minimize worker exposure and risk.

Given the radioactive nature of wastes in the 200-SW-2 Radioactive Landfills and Dumps Group (200-SW-2) Operable Unit (OU), the HASP should also address nuclear and radiation safety, waste management, occupational safety and health, safeguards and security, risk assessment, and other applicable areas as described in Company procedures for project initiation and execution, and DOE O 435.1, *Radioactive Waste Management.*

### A.2.7 Conducting Community Relations Activities

Community relations activities provide interested persons an opportunity to comment on and participate in decisions concerning site actions, including the performance of treatability investigations. From the beginning of the RI/FS process, a description of the treatability investigation activities that will be performed in support of the FS should be included in the discussion on how the alternatives will be delineated for the particular site.

### A.2.8 Complying with Regulatory Requirements

Treatability investigations involving Superfund wastes are subject to various requirements under CERCLA and RCRA. The applicability of these requirements depends on whether the treatability investigations are conducted onsite or at an offsite laboratory or testing facility. Also, investigation derived waste must be handled in accordance with applicable Hanford-specific implementing agreements and procedures.

Onsite treatability investigations under CERCLA may be conducted without Federal, State, or local permits [40 CFR 300.400(e)(1), "National Oil And Hazardous Substances Pollution Contingency Plan Subpart E—Hazardous Substance Response,]; however, such investigations must comply with ARARs under Federal and State environmental laws to the extent practicable or justify a waiver under CERCLA Section 121(d)(4).

Section 121(d)(3) of CERCLA generally states that offsite facilities that receive CERCLA wastes must:

- Operate in compliance with applicable Federal and State laws
- Control relevant releases of hazardous substances to the environment
- Get lead regulatory agency approval for offsite disposal of wastes.

Off-site treatability investigations under CERCLA must be conducted under appropriate Federal or State permits or authorization and other legal requirements.

### A.2.9 Executing the Investigation

Execution of the treatability investigation begins after the project manager has approved the work plan and other supporting documents. Steps include collecting a sample of the waste for characterization and investigation, conducting the investigation, and collecting and analyzing samples of the treated waste and residuals.

### A.2.10 Analyzing and Interpreting the Data

Upon completion of a treatability investigation, the data must be compiled and analyzed. The first goal of data analysis is to determine/verify the quality of the data collected. All data should be checked to assess precision, accuracy, and completeness as specified in DQOs, work plans, SAPs, and other testing support documentation.

Interpretation of treatability investigation data must be based on the test objectives established prior to testing. The purpose of a pre-ROD treatability investigation is to provide the data needed for a detailed analysis of alternatives against the CERCLA evaluation criteria and ultimately the selection of a remedial action that can achieve site cleanup goals and objectives. The results of a treatability investigation should enable evaluation of all treatment alternatives on an equal basis during the detailed analysis of alternatives in the FS.

As opposed to pre-ROD treatability investigations, no clearly defined criteria exist on which to base the interpretation of post-ROD RD/RA treatability investigation results. The purpose of a RD/RA treatability investigation is to generate site-specific, detailed design, cost, and performance data. These data are then used to:

- Prequalify vendors and processes within the prescribed remedy;
- Implement the most appropriate of the remedies prescribed in a Contingency ROD.

Post-ROD treatability investigation results are also used to support the preparation of detailed design specifications and the design of treatment trains.

### A.2.11 Reporting the Results

The final step in conducting a treatability investigation is reporting the results. Complete and accurate reporting is critical, as decisions about remedial alternatives will be based partly on the outcome of the treatability investigations. Besides assisting in the selection and implementation of the remedy, the performance of treatability investigations will increase the existing body of scientific knowledge about treatment technologies with respect to their effectiveness, implementability, and cost.

Upon completion of the treatability investigation, DOE shall submit a treatability investigation report to the lead regulatory agency, documenting the findings of the investigation and applicability to the remedial action project. The treatability investigation report is a secondary document (see Section 9.1 of the Tri-Party Agreement Action Plan).

## REFERENCES

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*Resource Conservation and Recovery Act of 1976*, 42 USC 6901, et seq.

# APPENDIX B

# TREATABILITY INVESTIGATION INFORMATION SUPPORTING TECHNOLOGIES AND ASSOCIATED LIKELY RESPONSE SCENARIOS

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# APPENDIX B

Table B-1. Treatability Investigation Information for Supporting Technologies and Associated Likely Response Scenarios. (10 Pages)

| Process Option | Description/Maturity | Effectiveness | Implementability | Relative Cost |
|---|---|---|---|---|
| **APPLICABLE WITHIN A BURIAL GROUND** | | | | |
| **Simple Surface Barriers**<br><br>Single-layered surface barriers (soil, asphalt, concrete, geomembrane type covers) | A single-layered surface barrier consists of a designed thickness of a single type of material, which could include soil, concrete, asphalt, or geomembrane.<br><br>• Soil cover: A mono-fill soil layer composed of silt-loam or silty-sand with low hydraulic conductivity and high moisture storage capacity. Soil would be compacted to provide consistency and achieve desired performance. Soil surface would be vegetated to control water infiltration by evaporation and plant transpiration (i.e., ET Barrier).<br>• Concrete cover: A reinforced concrete slab placed over a prepared sub-grade above contaminated material. Concrete could be considered a barrier to | A single-layered surface barrier can be effective at achieving the project remedial action objectives. In arid/semi-arid environments mono-fill ET soil barriers have been shown to effectively store moisture for recycle to the atmosphere by evaporation and plant transpiration thereby preventing water infiltration into waste sites. Mono-fill soil barriers can also be self-healing during subsidence events. Clay layers should be avoided under arid/semi-arid site conditions due to the desiccation and cracking that can occur. Other single-layered surface barriers generally are not durable over the long term and can fail as a result of subsidence events. Concrete and asphalt covers can crack with differential settlement of the sub-grade; asphalt covers and geomembranes require periodic replacement. | A single-layered surface barrier can be technically and administratively implemented. The various types of single-layered surface barriers are routinely used and the necessary materials are available. Mono-fill ET barriers have been designed, constructed, and tested. A single-layer polyurethane barrier test is planned in the 241-T tank farm during FY 2007. The single-layer barrier will be sprayed onto the surface and cover an area of 60,000 square feet to a thickness of about 0.5 inches. An engineered fill of 2-3 feet will be placed prior to single-layer barrier construction to achieve the desired surface slope for drainage. The asphalt and concrete paving industries have extensive experience implementing these materials. | Capital cost is expected to be low to medium relative to other multi-layer surface barrier options. However, operating costs are expected to be higher because simple surface barriers require routine maintenance and, in some cases, periodic replacement (e.g., asphalt, concrete, or geomembranes). |

Table B-1. Treatability Investigation Information for Supporting Technologies and Associated Likely Response Scenarios. (10 Pages)

| Process Option | Description/Maturity | Effectiveness | Implementability | Relative Cost |
|---|---|---|---|---|
| | prevent direct access to waste. Engineering controls could reduce potential for cracking and increase effective life of the cover.<br>• Asphalt cover: An asphalt pavement placed over a prepared sub-grade above contaminated material. Asphalt is commonly used to control water infiltration.<br>• Geomembrane: Flexible, polymeric plastic sheeting. Geomembranes are commercially available synthetic materials that are used to prevent surface water infiltration. The effective life of geosynthetics materials exposed to weather generally does not exceed 20 years.<br><br>**Maturity:** Mature technology. Tested and deployed. | | | |
| **RTD all or portions of a burial ground**<br><br>Stabilization and retrieval | Some wastes that could be candidates for full or partial retrieval were buried in waste containers that have degraded | Highly concentrated copolymer emulsions have been shown to have exceptional performance in | Commercially available soil stabilizers work quickly and are inexpensive. There are three primary ways to use soil | Capital and operating costs are expected to be high relative to in situ treatment options due to the cost for |

Table B-1. Treatability Investigation Information for Supporting Technologies and Associated Likely Response Scenarios. (10 Pages)

| Process Option | Description/Maturity | Effectiveness | Implementability | Relative Cost |
|---|---|---|---|---|
| | over the past 4-5 decades. Early waste packaging was intended more for transport of waste to the burial trenches rather than long-term performance. Stabilization of wastes with a chemical binding agent prior to retrieval may be required to facilitate waste retrieval, control dust, and minimize airborne hazards associated with degraded waste containers.<br><br>**Maturity:** Demonstrated technology. Some information is available from limited treatability investigations. The effectiveness, implementability, and cost for stabilization/retrieval technologies are not fully developed and warrant additional consideration. | stabilizing soils and debris by forming strong yet flexible three-dimensional bonds between soil and aggregate particles. Copolymer emulsions are designed to be extremely durable and resistant to water, sun, alkaline, and daily use. Copolymer emulsions can be diluted with water and work their way down into the soil to maximize penetration depth and minimize dust. | stabilizers to improve soil. One method is to strengthen existing soil, which enhances its load-bearing capacity. Other soil stabilizers are used to control dust by preventing it or eliminating it altogether. Finally, waterproofing soil stabilizers assist in preserving the natural or constructed strength of the soil by protecting the surface from water. Treatability testing results addressing stabilization and retrieval are available from the 618-10/11 burial ground retrieval efforts, M-91 TRU retrieval efforts, and INL buried waste retrieval efforts. | waste retrieval, treatment, and disposal. |
| **<u>In Situ Stabilization of all or portions of a burial ground</u>**<br><br>Grout Injection | High-pressure in situ grouting (ISG) uses the energy of a high-pressure grout jet to disrupt buried waste and mix it into an impermeable waste form. Because the waste, | High-pressure ISG has been shown to be effective for in situ stabilization of heterogeneous buried solid waste in unconsolidated silt, sand, and gravel soil. Tests | High-pressure ISG waste stabilization is technically implementable with commercially available equipment. Engineering and administrative controls would | Capital and operating costs are expected to be low to medium relative to other in situ treatment options. |

Table B-1. Treatability Investigation Information for Supporting Technologies and Associated Likely Response Scenarios. (10 Pages)

| Process Option | Description/Maturity | Effectiveness | Implementability | Relative Cost |
|---|---|---|---|---|
| | interstitial soil, and grout are physically mixed, effectiveness of ISG is not limited by variations in soil permeability. ISG methods can be combined with dynamic compaction using vibratory hammers to enhanced grout flow into void spaces by inducing liquefaction.<br><br>**Maturity:** Mature technology. Relevant demonstrations of grout injection have been conducted at Hanford and Idaho National Laboratory. The ability to implement and associated costs are generally known. Effectiveness is not fully known and warrants additional consideration. | of hydraulic conductivity of simulated waste stabilized by high-pressure ISG at INL showed more than two orders of magnitude less hydraulic conductivity than for unstabilized waste and is comparable to permeability requirements for engineered clay liners used in construction of hazardous waste landfills. Cementitious grouts, both commercially available and nonproprietary, and paraffin-based thermoplastic grouts have been evaluated for stabilization of waste forms containing transuranic isotopes and other radionuclides at INL. Chemical buffering provided by cementitious grouts may reduce the solubility of some radionuclides.<br><br>Evaluations of long-term durability of paraffin-based and cementitious grouts suggest that they should be effective for in situ stabilization of waste for at least 1,000 years. Tests of simultaneous dynamic compaction and grout | be required for application at radioactive waste sites. Preliminary documented safety analysis of high-pressure ISG for use at INL concluded that ISG could be safely implemented with no additional technical safety requirements beyond those required for the pressurized subsystems of the grout injection rig. High-pressure ISG using paraffin-based grout was shown to be implementable at INL. Cement-based grouts may not be applicable to in situ treatment of some waste forms (e.g., organic sludge, nitrate salts) due to impacts on set time and strength.<br><br>Jet grouting pumps and drill rigs used in conventional civil engineering practice are readily adaptable for emplacing thermoplastic (e.g., paraffin-based) or cementitious grouts suitable for in situ stabilization. | |

Table B-1. Treatability Investigation Information for Supporting Technologies and Associated Likely Response Scenarios. (10 Pages)

| Process Option | Description/Maturity | Effectiveness | Implementability | Relative Cost |
|---|---|---|---|---|
| | | injection at the Hanford Site showed that liquefaction was induced in the soil/waste matrix enhancing void filling capabilities and creating solid waste/soil monoliths. | | |
| Soil Mixing | In situ enhanced soil mixing uses a crane-suspended auger to disrupt contaminated soil and mix soil with reagents for in situ treatment. In situ soil mixing has been used for in-place stabilization of contaminated soil using cementitious grout. It also has been used to improve in situ vapor extraction and in situ chemical oxidation.<br><br>**Maturity:** Mature technology. Ability to implement and associated costs are generally known. Effectiveness is not fully known and warrants additional consideration. | In situ enhanced soil mixing has been proven effective at sites where contaminants are associated with soil but is not applicable at sites that contain highly contaminated heterogeneous debris, large metal objects, or cement stabilized waste forms. | Enhanced in situ soil mixing is not technically implementable at the Hanford Site solid waste burial grounds, unless wastes are retrieved and any contaminated soil remaining requires in situ treatment. | Capital and operating costs are expected to be medium relative to other in situ treatment options. |
| **APPLICABLE IN THE VADOZE ZONE BENEATH A BURIAL GROUND**<br><br>**<u>In Situ Stabilization</u>**<br><br>Grout Injection | See grout injection above. | See grout injection above. | See grout injection above. | See grout injection above. |

Table B-1. Treatability Investigation Information for Supporting Technologies and Associated Likely Response Scenarios. (10 Pages)

| Process Option | Description/Maturity | Effectiveness | Implementability | Relative Cost |
|---|---|---|---|---|
| Supersaturated Grouts | Supersaturated grouts are based on using crystallization or precipitation processes for targeted sealing and immobilization of wastes. Solutions are prepared and used as grouts that are supersaturated in slightly soluble sulfates or carbonates. The solutions are temporary stable due to added precipitation inhibitors. Mineral formation takes place when supersaturated grouts encounter soil and rock formations resulting in an in-situ immobilization or sealing. In contrast to natural water, the chemical concentrations of the supersaturated grout solutions are much higher resulting in faster and more effective mineral formation in the treated areas.<br><br>**Maturity:** Developmental stage. Ability to implement and associated costs generally known. Effectiveness is not fully known and warrants additional consideration. | One advantage of mineral forming solutions is that they can penetrate soil or rock formations with low permeability. In order to grout a soil formation with a suspension, it is necessary that the average particle size of suspended solids is three times smaller than the diameter of the flow paths. Otherwise the suspension can not effectively penetrate into the flow paths. The suspended solids are filtered out forming a filter cake and penetration is impossible. The method of sealing or immobilization by crystallization or precipitation uses clear solutions with properties similar to natural groundwater. Soils which cannot be penetrated and grouted with conventional systems can typically be treated with supersaturated grouts. | Immobilization is achieved by naturally occurring minerals and no dangerous or toxic compounds are brought into the treated formation. There are many possibilities to direct the precipitation and immobilization or sealing process. In all cases, the preparation of the supersaturated grout solution is simple and can be realized under field conditions without problems. | Capital and operating costs are expected to be medium relative to other in situ treatment options. |
| Soil Desiccation (dry barrier) | A dry barrier is a layer of geologic material dried by air flow. Water that is | The principal design challenge for a dry barrier containment system is related | Dry barriers, as compared to capillary barriers, permit less downward movement of | Cost for a dry barrier system depends upon the existing cover design (e.g., is there |

Table B-1. Treatability Investigation Information for Supporting Technologies and Associated Likely Response Scenarios. (10 Pages)

| Process Option | Description/Maturity | Effectiveness | Implementability | Relative Cost |
|---|---|---|---|---|
| | evaporated from within the cover system by air flow is less likely to become leachate. To create a dry barrier, air flows into a layer within the cover where it accumulates water vapor as it passes through the layer and then emerges as moist air. As covers typically include multiple, laterally continuous layers with contrasts in material properties, air flow is channeled through relatively coarse, air-permeable layers. Active and passive systems are possible, with the active systems using blowers and fans to move air through a high air-permeable layer.<br><br>**Maturity:** Developmental stage. Effectiveness and implementability generally not fully known. Cost is generally known. | to the air flow rates required to remove downward moving water. After water moves from the overlying fine layer to the coarse layer, it moves relatively quickly through the coarse layer into the underlying waste. This breakthrough happens periodically when the cover system has been subjected to sustained precipitation.<br>To intercept all of the water moving through the coarse layer, the air flow rate must be relatively great. These high air flow rates can only be accomplished with active systems using high output, high energy consumption blowers. | meteoric water and potential waste products when used in semi-arid to arid climates typical of the Hanford Site. As compared to compacted soil barriers, dry barriers are prone to fewer problems related to desiccation and are also initially less costly than multi-component covers. A drawback to dry barriers is the need for a continuously operating system to keep the soil dry. | already a coarse layer suitable for air flow). Electricity costs amount to approximately 90% of an active system's operational cost. A passive system has no appreciable operating costs, however, soil layers must be conducive to natural air flow. |
| Reactive Gases | In situ chemical treatment can be useful, especially for redox sensitive inorganic constituents. A primary obstacle to the application of the in situ chemical treatment approach to soils is the identification of a means of introducing and effectively | Laboratory test results indicate that hydrogen sulfide can provide effective treatment of soils contaminated with Cr(VI). Immobilization of >90%of chromium was routinely achieved under treatment conditions. Test results also | The testing results indicate that delivery of a hydrogen sulfide gas mixture to a contaminated soil waste site can be effective in immobilization of hexavalent chromium. Soil treatment could be undertaken by injection of the gas mixture in a central borehole. A system | Capital and operating costs are expected to be medium relative to other in situ treatment options. |

Table B-1. Treatability Investigation Information for Supporting Technologies and Associated Likely Response Scenarios. (10 Pages)

| Process Option | Description/Maturity | Effectiveness | Implementability | Relative Cost |
|---|---|---|---|---|
| | dispersing the treatment agent in unsaturated soil media. The use of chemically-reactive gas mixtures is an alternative that offers the advantage of ease of introduction and control during treatment, and removal of the unreacted agent from the soil after remediation is completed.<br><br>**Maturity:** Developmental stage. Effectiveness is not fully known. Ability to implement and associated costs are generally known. | suggest that the treatment process is irreversible and not strongly influenced by soil chemistry. The technology is developmental and has focused primarily on immobilization of hexavalent chromium. Due to the poisonous nature of some reactive gasses, extreme caution must be exercised to ensure their safe use. | of withdrawal wells located at the periphery of the site would permit removal of excess agent and provide control of the movement of the gas through the site. An impermeable cover could also be placed over the site to minimize the escape of treatment gas to the atmosphere. The treatment gas would be recirculated through the soil in a multi-pass approach until the treatment process reached completion. | |
| Nanoparticles | A nanoparticle is a microscopic particle with at least one dimension less than 100 nm. Injection of nanoparticles of reactive agents (e.g., iron) in saturated soil has been shown to facilitate the remediation of chlorinated organic contaminants.<br><br>**Maturity:** Experimental stage. Effectiveness, implementability, and cost are generally not fully known. | Research has shown that nanoscale iron particles are very effective for the transformation and detoxification of a wide variety of environmental contaminants, such as chlorinated organic solvents, organochlorine pesticides, and PCBs. Modified iron nanoparticles, such as catalyzed and supported nanoparticles have been synthesized to further enhance the speed and efficiency of remediation. | Two factors contribute to the nanoparticles' capabilities as an extremely versatile remediation tool. First, their small particle sizes (1–100 nm). In comparison, a typical bacterial cell has a diameter of 1 μm (1000 nm). Nanoparticles can be transported effectively by the flow of groundwater. Due to this, the nanoparticle/water slurry can be injected under pressure and/or by gravity into the contaminated plume where treatment is needed. The nanoparticles can remain in suspension for extended periods to establish an in situ treatment zone. | Capital and operating costs are expected to be medium relative to other in situ treatment options. |

Table B-1. Treatability Investigation Information for Supporting Technologies and Associated Likely Response Scenarios. (10 Pages)

| Process Option | Description/Maturity | Effectiveness | Implementability | Relative Cost |
|---|---|---|---|---|
| **Contaminant Extraction** | | | | |
| Soil Flushing | Water or water containing additives to enhance contaminant solubility is applied to soil. Contaminants are leached from soil for collection and treatment. Because of difficulties in solution recovery, extracting contaminants by flushing soil or debris with aqueous solutions is performed ex situ. For in situ applications, flushing solutions are removed using extraction wells or subsurface drains. Soil flushing solutions can incorporate miscible organic solvents for removal of organic and inorganic contaminants. | Though soil flushing is effective for contaminant removal in ex situ applications, it is not effective for in situ treatment of buried solid waste. The heterogeneous nature of the waste and surrounding soil could make it difficult to recover flushing solutions. Unrecovered solutions might carry contaminants beyond the capture zone and deeper into the underlying vadose zone. Furthermore, a significant portion of target contaminants may be in containers that are intact and not available to flushing solutions. | In situ soil flushing is not technically implementable in the solid waste burial grounds. | Capital and operating costs are expected to be medium relative to other in situ treatment options. |
| | **Maturity:** Mature technology. Ability to implement and associated cost is generally known. Effectiveness is not fully known and warrants additional consideration. | | | |
| Electrokinetics | Electrokinetic remediation is used to remove inorganic cations from contaminated soil. A low-level direct current is applied to the | Though in situ electrokinetic remediation has proved to be effective in fine-grained soil, it has not been demonstrated at a buried waste site | In situ electrokinetic remediation is not a mature in situ treatment method for heterogeneous buried waste and would not be | Capital and operating costs are expected to be moderate relative to other in situ treatment process options. |

Table B-1. Treatability Investigation Information for Supporting Technologies and Associated Likely Response Scenarios. (10 Pages)

| Process Option | Description/Maturity | Effectiveness | Implementability | Relative Cost |
|---|---|---|---|---|
| | contamination zone using fluid-filled electrodes. Ionic species, including heavy metal contaminants, migrate within the soil matrix and are collected in the electrolytes within the electrodes.<br><br>**Maturity:** Developmental stage. Effectiveness, implementability, and cost are not fully known. | containing large amounts of metallic waste. Furthermore, its ability to maintain adequate current densities without adding water to the unsaturated soil has not been demonstrated. | implementable at the solid waste burial grounds without further development. | |

INL = Idaho National Laboratory.
PCB = polychlorinated biphenyl.

# APPENDIX C

## TYPICAL DATA REQUIRED TO SUPPORT SUGGESTED TREATABILILTY INVESTIGATIONS

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# APPENDIX C

## TECHNOLOGY-SPECIFIC CHARACTERIZATION PARAMETERS

Tables C-1 and C-2 contain typical data needs specific to immobilization and in situ treatment technologies suggested for treatability investigations. Generally, these are the types of data needs that must be established in support of treatability investigations conducted on the corresponding technology. Additional parameters may be required due to site-specific conditions and should be specified in data quality objectives, work plans, sampling and analysis plans, and other documentation prepared in support of the treatability investigations. Each table is divided by technology, waste matrix, parameter, and purpose of analysis.

Table C-1. Waste Characterization For Immobilization. (2 Pages)

| Treatment Technology | Matrix | Parameter | Purpose and Comments |
|---|---|---|---|
| Stabilization/Solidification | Soils/Sludges | **Physical:** | |
| | | Description of Materials | Determine waste handling methods (e.g., crusher, shredder, removal equipment) |
| | | Particle Size Analysis | Determine surface area available for binder contact and leaching |
| | | Moisture Content | Determine amount of waste to add/remove during the stabilization/solidification mixing process |
| | | Density Testing | Evaluate changes in density between untreated and treated waste; determine volume increase |
| | | Weight Ratio Additives to Waste | Determine effects of dilution due to volume increases |
| | | **Chemical:** | |
| | | Total Organic Content | Determine reagent requirements |
| | | pH | Evaluate changes in leaching as function of pH between treated and untreated waste |
| | | Alkalinity | Evaluate changes in leaching as function of pH between treated and untreated waste |
| | | Interfering Compounds | Evaluate viability of stabilization/solidification process; interfering compounds impede fixation reactions, cause adverse chemical reactions, generate excessive heat; interfering compounds vary with the type of stabilization/Solidification |
| | | Indicator Compounds | Evaluate performance |
| | | Leach Testing | |
| | | - TCLP | Evaluate performance based on regulatory test |
| | | - TCLP-Water | Evaluate performance under natural conditions |

Table C-1. Waste Characterization For Immobilization. (2 Pages)

| Treatment Technology | Matrix | Parameter | Purpose and Comments |
|---|---|---|---|
| | | Heat of Hydration | Measure temperature changes during mixing. |
| | | Total Waste Analysis | Evaluate performance |
| Vitrification | Soils/Sludges | **Physical:**<br>Depth of Contamination and Water Table | Technology applied in unsaturated soils |
| | | Soil Permeability | Dewatering of saturated soils may be possible; technology is applied in unsaturated soils. |
| | | Metal Content of Waste Materials; Placement of Metal Within Waste | Greater than 5 to 15% by weight interferes with process (may ignite) |
| | | Rubble Content of Waste | Greater than 10 to 20% by weight interferes with process |
| | | Void Volumes | Large, individual voids (greater than 150 $ft^3$) impede process and may cause subsidence |
| | | Moisture Content | Determine power requirements |
| | | Particle Size Analysis | Determine surface area available for binder contact and leaching |
| | | **Chemical:**<br>Leach Testing | Evaluate performance |
| | | Total Waste Analysis | Evaluate performance |

Table C-2. Waste Characterization For In Situ Treatment. (2 Pages)

| Treatment Technology | Matrix | Parameter | Purpose and Comments |
|---|---|---|---|
| Vapor Extraction<br>- Vacuum Extraction<br>- Steam Enhanced<br>- Hot Air Enhanced | Soils/Sludges | **Physical:**<br>Vapor Pressure of Contaminants | Estimate ease of volatilization |
| | | Soil Permeability, Porosity, Particle Sizes | Determine if soil matrix will allow adequate air and fluid movement |
| | | Depth of Contamination and Water Table | Determine relative distance; technology applicable in vadose zone |
| Solidification and Stabilization<br>- Pozzolanic<br>- Polymerization<br>- Precipitation | Soils/Sludges | **Physical:**<br>Presence of Subsurface Barriers (Drums, Large Objects, Debris, Geology) | Assess feasibility of adequately delivering and mixing the solidification and stabilization agents |
| | | Depth to First Confining Layer | Determine required depth of treatment |
| Soil Flushing<br>- Steam/Hot Water<br>- Surfactant<br>- Solvent | Soils/Sludges | **Physical:**<br>Presence of Subsurface Barriers (Drums, Large Objects, Debris, Geology) | Assess feasibility of adequately delivering the flushing solutions |
| | | Hydraulic Conductivity | Assess permeability of soils |
| | | Vadose Zone Moisture Content | Calculate pore volume to determine rate of treatment |
| | | Soil/Water Partition Coefficient | Assess removal efficiency; correlate field/theoretical calculations |
| | | Octanol/Water Partition Coefficient | Assess removal efficiency; correlate field/theoretical calculations |
| | | Cation Exchange Capacity | Evaluate potential for contaminant flushing |
| | | Soil Alkalinity | Estimate likelihood of precipitation |

Table C-2. Waste Characterization For In Situ Treatment. (2 Pages)

| Treatment Technology | Matrix | Parameter | Purpose and Comments |
|---|---|---|---|
| | | **Chemical:**<br>Major Cations/Anions Present in Soil | Estimate likelihood of precipitation; estimate potential for plugging |
| Vitrification | Soils/Sludges | **Physical:**<br>Depth of Contamination/Water Table | Technology is applied in vadose zone |
| Electrokinetics | Soils/Sludges | **Physical:**<br>Hydraulic Conductivity | Technology applied in zones of low hydraulic conductivity |
| | | Depth to Water Table | Technology applied in saturated soils |
| | | **Chemical:**<br>Presence of Soluble Metal Contaminants | Technology applicable to soluble metals; not organics and insolubles |
| Microbial Degradation<br>- Aerobic<br>- Anaerobic | Soils/Sludges | **Physical:**<br>Permeability of soil | Determine ability to deliver nutrients/oxygen to matrix; allow movement of microbes |
| | | **Chemical/Biological:**<br>Contaminant Concentration and Toxicity | Determine viability of microbial population in contaminated zone |
| Adsorption | Soils/Sludges | **Physical:**<br>Depth of Contamination/Water Table | Technology applicable in vadose zone |
| | | Horizontal Hydraulic Flow Rate | Determine if groundwater will come in contact with adsorbent |

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# APPENDIX D

# CROSS-WALK BETWEEN ECOLOGY'S ITEMS OF INTEREST AND FOCUSED INVESTIGATIONS

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# APPENDIX D

Table D-1. Cross-Walk Between Items of Interest and Focused Investigations. (9 Pages)

| Items of Interest | Proposed Focused Investigations and Where They Support the Items of Interest | Potential Waste Sites | Comments |
|---|---|---|---|
| High-dose-rate lab-packed liquid waste | • Caisson and Vertical Pipe Unit Characterization and Remediation Techniques<br>• Cost of Waste Retrieval and Barrier Construction<br>• Direct Push Technology Near Waste Trenches<br>• Vadose Zone Characterization and Monitoring | 218-W-4A<br>218-W-4B | • High dose rate lab packed liquid waste was typically disposed of in caissons. |
| Remote-handled low-level waste (RH-LLW) | • Locations of Large Burial Boxes/Equipment – Potential Areas for Subsidence<br>• Cost of Waste Retrieval and Barrier Construction<br>• Direct Push Technology Near Waste Trenches<br>• Vadose Zone Characterization and Monitoring | 218-W-5<br>218-W-4C<br>218-W-4B<br>218-W-3AE<br>218-W-3A<br>218-W-2A<br>218-E-12B<br>218-E-10 | • *Solid Waste Information and Tracking System* database (SWITS) records show locations and numbers of containers with RH-LLW. |
| Caissons used to receive remote-handled high-dose-rate and transuranic waste(TRU)* | • Caisson and Vertical Pipe Unit Characterization and Remediation Techniques<br>• Cost of Waste Retrieval and Barrier Construction<br>• Direct Push Technology Near Waste Trenches<br>• Vadose Zone Characterization and Monitoring | 218-W-4A<br>218-W-4B | • Good records and drawings for these caissons. |

Table D-1. Cross-Walk Between Items of Interest and Focused Investigations. (9 Pages)

| Items of Interest | Proposed Focused Investigations and Where They Support the Items of Interest | Potential Waste Sites | Comments |
|---|---|---|---|
| Suspect caisson locations | • Caisson and Vertical Pipe Unit Characterization and Remediation Techniques<br>• Cost of Waste Retrieval and Barrier Construction<br>• Direct Push Technology Near Waste Trenches<br>• Vadose Zone Characterization and Monitoring | 218-W-4A | • Two suspect caissons thought to be located between trenches 17, 18, and 19.<br>• Caisson presence likely can be verified via interviews with cognizant workers.<br>• Geophysical investigation of 218-W-4A landfill planned during Phase I-B characterization activities for 200-SW-2 Operable Unit (OU). |
| Burial boxes containing RH-LLW and contact-handled low-level waste (CH-LLW) | • Locations of Large Burial Boxes/Equipment – Potential Areas for Subsidence<br>• Cost of Waste Retrieval and Barrier Construction<br>• Direct Push Technology Near Waste Trenches<br>• Vadose Zone Characterization and Monitoring<br>• Waste Compaction Methods and Other In Situ Stabilization Needs | 218-C-9<br>218-E-5<br>218-E-5<br>218-E-10<br>218-E-12<br>218-E-12B<br>218-W-2<br>218-W-3<br>218-W-3A<br>218-W-3AE<br>218-W-4A<br>218-W-4B<br>218-W-4C | • Good records exist for 218-C-9, 218-E-10, 218-E-12B, 218-W-3A, 218-W-3AE, 218-W-4A, 218-W-4B, and 218-W-4C.<br>• 218-E-5, 218-E-5A, 218-E-12A, 218-W-2A, and 218-W-3 records are not as good.<br>• Recommend further records research for 218-C-9, 218-E-10, 218-E-12B, 218-W-3A, 218-W-3AE, 218-W-4A, 218-W-4B, and 218-W-4C to determine locations of boxes.<br>• Recommend correlation of 2005 geophysics with existing records to determine location of boxes in 218-E-5, 218-E-5A, 218-W-2A, and 218-W-3.<br>• Recommend geophysical survey for 218-E-12A. |
| Areas of highly contaminated tumbleweeds | • Direct Push Technology Near Waste Trenches | 218-E-12B<br>218-E-3A<br>218-E-8 | • Historical records show areas that have had contaminated tumbleweeds growing on the surface in the past.<br>• Historical records show several sites that contain buried contaminated tumbleweeds.<br>• Mobile Surface Contamination Monitor is routinely used to locate contaminated biological items on the surface of the burial grounds.<br>• Areas of highly contaminated tumbleweeds should be considered in formulating the approach to Phase II intrusive characterization in support of the 200-SW-2 OU. |

Table D-1. Cross-Walk Between Items of Interest and Focused Investigations. (9 Pages)

| Items of Interest | Proposed Focused Investigations and Where They Support the Items of Interest | Potential Waste Sites | Comments |
|---|---|---|---|
| Fuel-element clips and spacers | • Location of Non-Retrievably Stored Spent Fuel in the 200-SW-2 OU<br>• Cost of Waste Retrieval and Barrier Construction<br>• Direct Push Technology Near Waste Trenches<br>• Vadose Zone Characterization and Monitoring | 218-E-10<br>218-W-3AE<br>218-W-5 | • All burial grounds listed have good records.<br>• Historical records provide location data for several burials that list fuel element clips and spacers on the disposal records.<br>• Historical-records research to date indicates that fuel clips and spacers were disposed of in burial containers other than caissons. |
| Irradiated fuel elements | • Location of Non-Retrievably Stored Spent Fuel in the 200-SW-2 OU<br>• Cost of Waste Retrieval and Barrier Construction<br>• Direct Push Technology Near Waste Trenches<br>• Vadose Zone Characterization and Monitoring | 218-E-10<br>218-W-3A<br>218-W-3AE<br>218-W-4A<br>218-W-4B<br>218-W-4C | • All burial grounds listed have good records.<br>• Historical records indicate potential for irradiated fuel elements to be disposed of in burial grounds other than 218-W-3A and 218-W-4A, as noted in the SWITS.<br>• Additional records research to be performed to map the locations of irradiated fuel elements in burial grounds. |
| 10 large concrete burial boxes of soil from S Tank Farm | • Locations of Large Burial Boxes/Equipment – Potential Areas for Subsidence<br>• Cost of Waste Retrieval and Barrier Construction<br>• Direct Push Technology Near Waste Trenches<br>• Vadose Zone Characterization and Monitoring<br>• Waste Compaction Methods and Other In Situ Stabilization Needs | 218-W-3A | • Historical records show where the boxes are located in the burial ground. |

Table D-1. Cross-Walk Between Items of Interest and Focused Investigations. (9 Pages)

| Items of Interest | Proposed Focused Investigations and Where They Support the Items of Interest | Potential Waste Sites | Comments |
|---|---|---|---|
| Reactor-fuel waste | • Location of Non-Retrievably Stored Spent Fuel in the 200-SW-2 OU<br>• Cost of Waste Retrieval and Barrier Construction<br>• Direct Push Technology Near Waste Trenches<br>• Vadose Zone Characterization and Monitoring | 218-W-3AE<br>218-W-4B<br>218-W-4C<br>218-W-5 | • All burial grounds listed have good records.<br>• Historical records show locations of buried reactor-fuel debris in these waste sites. |
| Drums of test reactor and isotope fuel waste | No focused investigations planned at this time. Being addressed by the M-91 Project. | 218-W-4C | • Historical records provide location information for this waste.<br>• This waste is TRU and is therefore out of scope.<br>• Being addressed by M-91 Project. |
| Areas of the burial grounds that were flooded with standing water | • Direct Push Technology Near Waste Trenches<br>• Vadose Zone Characterization and Monitoring | 218-W-3A<br>218-W-4B<br>218-W-4C | • Addressed through direct pushes planned during Phase I-B site characterization for 200-SW-2 OU. |
| Pond disposal area, 216-T-4B Pond | • Direct Push Technology Near Waste Trenches<br>• Vadose Zone Characterization and Monitoring | 218-W-3AE | • Addressed through direct pushes planned during Phase I-B site characterization for 200-SW-2 OU. |
| Suspect TRU or CH-TRU in treatment, storage, and/or disposal (TSD) units | • In Situ Detection of Transuranics and Chlorinated volatile organic compounds (VOC)<br>• Cost of Waste Retrieval and Barrier Construction<br>• Direct Push Technology Near Waste Trenches<br>• Vadose Zone Characterization and Monitoring | 218-E-12B<br>218-W-3A<br>218-W-3AE<br>218-W-4B<br>218-W-4C | • Nuclear probes developed through a DOE-Headquarters Small Business Innovative Research grant to Applied Physics and Measurements, Inc. planned for demonstration at Hanford during Spring of 2008.<br>• Nuclear probes capable of in situ detection of transuranics and chlorinated VOCs. |

Table D-1. Cross-Walk Between Items of Interest and Focused Investigations. (9 Pages)

| Items of Interest | Proposed Focused Investigations and Where They Support the Items of Interest | Potential Waste Sites | Comments |
|---|---|---|---|
| Pre-1970s suspect TRU | • In Situ Detection of Transuranics and Chlorinated VOCs<br>• Cost of Waste Retrieval and Barrier Construction<br>• Direct Push Technology Near Waste Trenches<br>• Vadose Zone Characterization and Monitoring | 218-E-5<br>218-E-10<br>218-E-12B<br>218-W-1<br>218-W-2<br>218-W-3<br>218-W-3<br>218-W-4<br>218-W-4B | • Nuclear probes developed through a DOE-Headquarters Small Business Innovative Research grant to Applied Physics and Measurements, Inc. planned for demonstration at Hanford during Spring of 2008.<br>• Nuclear probes capable of in situ detection of transuranics and chlorinated VOCs. |
| D-2 Column from PUREX K Cell | • Locations of Large Burial Boxes/Equipment – Potential Areas for Subsidence<br>• Cost of Waste Retrieval and Barrier Construction<br>• Direct Push Technology Near Waste Trenches<br>• Vadose Zone Characterization and Monitoring<br>• Waste Compaction Methods and Other In Situ Stabilization Needs | 218-E-5A | • Geophysics performed in 2005, and historical records show likely location for the D-2 Column. |
| Shallow buried waste | No focused investigations planned at this time. Can be addressed with existing geophysical survey methods. | 218-W-1<br>218-W-2<br>218-W-4A | • 218-W-1 and 218-W-2 have poor records and geophysical surveys were conducted during Phase I-A site characterization.<br>• 218-W-4A has good records and is planned for geophysical investigations during Phase I-B site characterization.<br>• Addressed through geophysical surveys using ground-penetrating radar (GPR), electromagnetic induction (EMI), and total magnetic field (TMF) during Phase I-A and Phase I-B site characterization activities for the 200-SW-2 OU. |

Table D-1. Cross-Walk Between Items of Interest and Focused Investigations. (9 Pages)

| Items of Interest | Proposed Focused Investigations and Where They Support the Items of Interest | Potential Waste Sites | Comments |
|---|---|---|---|
| Rotten wooden boxes | • Cost of Waste Retrieval and Barrier Construction<br>• Direct Push Technology Near Waste Trenches<br>• Vadose Zone Characterization and Monitoring | 218-W-1A | • Wood boxes were used in nearly all burial grounds. |
| Drywells, vertical pipes | • Caisson and Vertical Pipe Unit Characterization and Remediation Techniques<br>• Cost of Waste Retrieval and Barrier Construction<br>• Direct Push Technology Near Waste Trenches<br>• Vadose Zone Characterization and Monitoring | 218-W-4A | • Locations of six drywells have been verified through drawings and historical-records research.<br>• Addressed through geophysical surveys using GPR, EMI, and TMF planned during Phase I-B site characterization activities for the 200-SW-2 OU. |
| High-activity Plutonium Finishing Plant waste | • In Situ Detection of Transuranics and Chlorinated VOCs<br>• Cost of Waste Retrieval and Barrier Construction<br>• Direct Push Technology Near Waste Trenches<br>• Vadose Zone Characterization and Monitoring | 218-W-4A | • Drawing H-2-32487 indicates the location of high-activity waste; however, the generator is listed as the 325 Building, not the Plutonium Finishing Plant.<br>• Nonintrusive radiological surveys may help to locate high-activity waste; however, the potential for success is diminished, based on the amount of shielding provided by the overburden, container, packaging, etc. |
| Acid-soaked waste trenches | • Acid Soaked Material Trenches<br>• Cost of Waste Retrieval and Barrier Construction<br>• Direct Push Technology Near Waste Trenches<br>• Vadose Zone Characterization and Monitoring | 218-E-12A | • Geophysical surveys conducted on 218-E-12A in FY06 (D&D-30708). |

Table D-1. Cross-Walk Between Items of Interest and Focused Investigations. (9 Pages)

| Items of Interest | Proposed Focused Investigations and Where They Support the Items of Interest | Potential Waste Sites | Comments |
|---|---|---|---|
| Cell cover blocks | • Cost of Waste Retrieval and Barrier Construction | 218-E-10<br>218-W-2A<br>218-W-3A | • Locations of cover blocks are shown on drawings.<br>• Geophysical survey conducted on 218-W-2A in FY05 (D&D-28379).<br>• 218-E-10 and 218-W-3A are TSD landfills with relatively good burial records and coordinates for waste burials. |
| Potential organic waste | • In Situ Detection of Transuranics and Chlorinated VOCs<br>• Cost of Waste Retrieval and Barrier Construction<br>• Direct Push Technology Near Waste Trenches<br>• Vadose Zone Characterization and Monitoring | 218-E-10<br>218-E-12B<br>218-W-2<br>218-W-3<br>218-W-3AE<br>218-W-4A<br>218-W-4B<br>218-W-4C<br>218-W-5 | • 218-E-10, 218-E-12B, 218-W-3AE, 218-W-4B, 218-W-4C, and 218-W-5 are TSD landfills with relatively good burial records and coordinates for waste burials.<br>• Phase I-B Work Plan for 200-SW-2 OU proposes additional passive soil gas surveys in 218-W-3, 218-W-3AE, 218-W-4B, and 218-W-5 where high concentrations of organic vapors were detected during Phase I-A characterization activities in FY06.<br>• Phase I-B Work Plan for 200-SW-2 OU proposes initial passive soil gas surveys in 218-E-1, 218-E-2A, 218-E-5, 218-E-5A, 218-E-8, 218-E-12A, 218-W-1, 218-W-1A, 218-W-2, 218-W-2A, 218-W-3, and 218-W-11 where strong metallic signatures were detected during Phase I-A geophysical surveys. |
| Potential liquid waste containing tritium | • Cost of Waste Retrieval and Barrier Construction<br>• Direct Push Technology Near Waste Trenches<br>• Vadose Zone Characterization and Monitoring | 218-E-10<br>218-W-3A<br>218-W-4B | • Records indicate that a small volume of liquid waste was buried in 218-W-4B, usually in the form of tritium contained in metal cylinders or plutonium liquid waste.<br>• Liquid waste was typically small in volume, containerized, and stabilized with absorbents. |

Table D-1. Cross-Walk Between Items of Interest and Focused Investigations. (9 Pages)

| Items of Interest | Proposed Focused Investigations and Where They Support the Items of Interest | Potential Waste Sites | Comments |
|---|---|---|---|
| Large tanks | • Locations of Large Burial Boxes/Equipment – Potential Areas for Subsidence<br>• Cost of Waste Retrieval and Barrier Construction<br>• Direct Push Technology Near Waste Trenches<br>• Vadose Zone Characterization and Monitoring<br>• Waste Compaction Methods and Other In Situ Stabilization Needs | 218-W-3AE | • Burial ground is a TSD unit. TSD units generally have more detailed records associated with the burials.<br>• Locations of tanks can be determined from historical records and drawings. |
| Pre-August 1987 laboratory waste | • Cost of Waste Retrieval and Barrier Construction<br>• Direct Push Technology Near Waste Trenches<br>• Vadose Zone Characterization and Monitoring | 218-E-5<br>218-E-12B<br>218-E-12<br>218-W-2<br>218-W-3<br>218-W-3A<br>218-W-3AE<br>218-W-4A<br>218-W-4B<br>218-W-4C<br>218-W-5 | • Records indicate the numbers of containers by generator for each burial ground.<br>• Because laboratory waste may contain liquid organics, passive organic-vapor surveys may be effective in determining locations of this waste.<br>• Phase I-B Work Plan for 200-SW-2 OU proposes additional passive soil gas surveys in 218-W-3, 218-W-3AE, 218-W-4B, and 218-W-5 where high concentrations of organic vapors were detected during Phase I-A characterization activities in FY06.<br>• Phase I-B Work Plan for 200-SW-2 OU proposes initial passive soil gas surveys in 218-E-1, 218-E-2A, 218-E-5, 218-E-5A, 218-E-8, 218-E-12A, 218-W-1, 218-W-1A, 218-W-2, 218-W-2A, 218-W-3, and 218-W-11 where strong metallic signatures were detected during Phase I-A geophysical surveys. |

Table D-1. Cross-Walk Between Items of Interest and Focused Investigations. (9 Pages)

| Items of Interest | Proposed Focused Investigations and Where They Support the Items of Interest | Potential Waste Sites | Comments |
|---|---|---|---|
| Mixed LLW disposal pre-1987 | • Cost of Waste Retrieval and Barrier Construction<br>• Direct Push Technology Near Waste Trenches<br>• Vadose Zone Characterization and Monitoring | 218-E-10<br>218-E-12B<br>218-W-3A<br>218-W-3AE<br>218-W-4B<br>218-W-4C<br>218-W-5 | • These are the TSD landfills and have relatively good burial records and coordinates for waste burials. |
| Z Plant Burning Pit Waste | No focused investigations planned at this time. Being addressed by the M-91 Project. | 218-W-4C | • This site was a disposal area for combustible nonradioactive office and laboratory waste and chemicals. The source and inventory of chemicals are not known. The burn pit is reported to have received 2,000 $m^3$ (70,000 $ft^3$) of waste for burning, plus less than 1,000 $m^3$ (35,000 $ft^3$) of chemicals.<br>• The site is associated with retrievably stored TRU and is not in the scope of the 200-SW-2 OU project. |

* TRU Radioactive waste as defined in DOE G 435.1-1, *Implementation Guide for Use with DOE M 435.1-1.*

## REFERENCES

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