Remediation Technologies Screening Report for the Deep Vadose Zone, Hanford's Central Plateau - 12414

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ABSTRACT

Deep Vadose Zone contamination is a significant issue because it represents a potential source for continued release of contamination to the groundwater and associated receptors. This contamination, which is the result of past waste disposal practices on the Hanford Site Central Plateau, occurs deep in the subsurface and is not easily remediated by typical surface remedies. The Deep Vadose Zone is defined as the sediment below the limit of typical surface-based remedies (such as, excavation or caps), but above the water table. The Central Plateau Deep Vadose Zone begins at a depth of approximately 15 m (50 ft) below ground surface and extends to a depth of approximately 76 m (250 ft) below ground surface. Cleanup of the Deep Vadose Zone is challenging because contamination is difficult to access and expensive to characterize; contaminants occur at different depths and soil types; conventional, surface-based remedies have limited effectiveness; and remedy performance is difficult to predict, test, and monitor. Typically, remedial technologies for Deep Vadose Zone contamination are less developed than for the shallow soil contamination or saturated groundwater contaminants. In addition, few remediation technologies have been tested in the field, and fewer still have been successfully implemented as full remedial actions. These challenges, along with the limited number of potentially applicable remediation technologies, complicate the decision-making process for evaluating and selecting Deep Vadose Zone remedial alternatives.

INTRODUCTION

In an effort to address the challenges in remediating Deep Vadose Zone contamination, potentially applicable remedial technologies were identified and screened to develop a list of promising technologies for further evaluation during the remedial investigation/feasibility study activities. This screening was performed in accordance with U.S. Environmental Protection Agency (EPA) guidance for conducting treatability studies under *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA)[1] (*Guide for Conducting Treatability Studies under CERCLA: Final* [EPA/540/R-92/071a][2]). The EPA guidance document identifies technology pre-screening, conducted early in the planning and scoping phase of the remedial investigation/feasibility study, as an important first step in the identification of potentially applicable remediation technologies and the need for treatability testing. This early screening of technologies for the Deep Vadose Zone (200-DV-1) Operable Unit provides an opportunity to identify promising remediation technologies that require further treatability testing before the feasibility studies or those technologies that are mature enough to be carried forward and evaluated during the feasibility study.

METHOD

Technology pre-screening is an integral part of the CERCLA remediation work planning and scoping process. The purpose of technology pre-screening during development of the 200-DV-1 Operable Unit Work Plan[1] is to identify promising remediation technologies that may need additional testing or evaluation in order to support remedy selection during the subsequent feasibility study. This early screening will allow time for the collection of additional cost/performance information and/or treatability testing so the technologies are ready for evaluation during the subsequent feasibility study. It is during the feasibility study when the viable technologies are combined into a range of remedial alternatives that will be evaluated for remediating the 200-DV-1 Operable Unit waste sites.

The following steps were used to develop and screen the potentially applicable remediation technologies:

1. Frame the problem by developing a preliminary conceptual site model and preparing preliminary remedial action objectives for the 200-DV-1 Operable Unit
2. Identify potentially applicable technologies and gather available information
3. Organize technologies by general response action
4. Identify recent Hanford Site-specific studies or testing related to each technology
5. Pre-screen the technologies to identify viable technologies for evaluation during the feasibility study and potentially viable technologies requiring further investigation and testing during the remedial investigation

Frame the Problem

The 200-DV-1 Operable Unit project will develop the necessary information to select the appropriate approach for remediating a significant number of liquid waste disposal sites associated with past operations on the Hanford Site. The 200-DV-1 Operable Unit includes waste sites consisting of cribs, tile fields, retention ditches, and reverse wells that are located near the T-Farm Complex, S-Farm Complex, and B-Farm Complex (Figure 1). Many of these waste sites received low-level tank waste during past tank farm operations, including in situ tank stabilization and scavenged waste operations. These liquid waste disposal practices were discontinued in 1995. Cribs and tile fields generally received higher quantities of liquid that may affect groundwater; whereas retention ditches typically received lower quantities of liquids that were calculated to theoretically remain in the vadose zone.

The primary contaminants of potential concern for the Deep Vadose Zone include the mobile and partially mobile contaminants that could affect groundwater. Based upon the review of past waste disposal records and operations reports, the contaminants of potential concern for the Deep Vadose Zone include uranium, Tc-99, I-129, nitrate, chromium, and carbon tetrachloride.

A preliminary conceptual site model was developed for the operable unit that represents the initial understanding of the waste sources, contaminants, affected media, potential pathways, and potential receptors (Figure 2). The conceptual site model approximates the physical setting for both the 200 West and East Areas, which encompass the waste sites within this Operable Unit. The elements depicted in the conceptual site model also assist in the initial identification and screening of potential Deep Vadose Zone remediation technologies. This conceptual site

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[1] The 200-DV-1 Work Plan refers to the 200-DV-1 Operable Unit *Resource Conservation and Recovery Act of 1976* (RCRA)[3] Facility Investigation/Corrective Measures Study and Remedial Investigation/Feasibility Study Work Plan.

model is generic, and does not address site-specific differences beneath the various waste sites, which typically varies with the following:

- Depth of the facility
- Volume of discharge or leak and the quantity of any additional liquid that may have added to or near the original discharge
- Depth to the water table
- Chemical interactions between the waste and soils

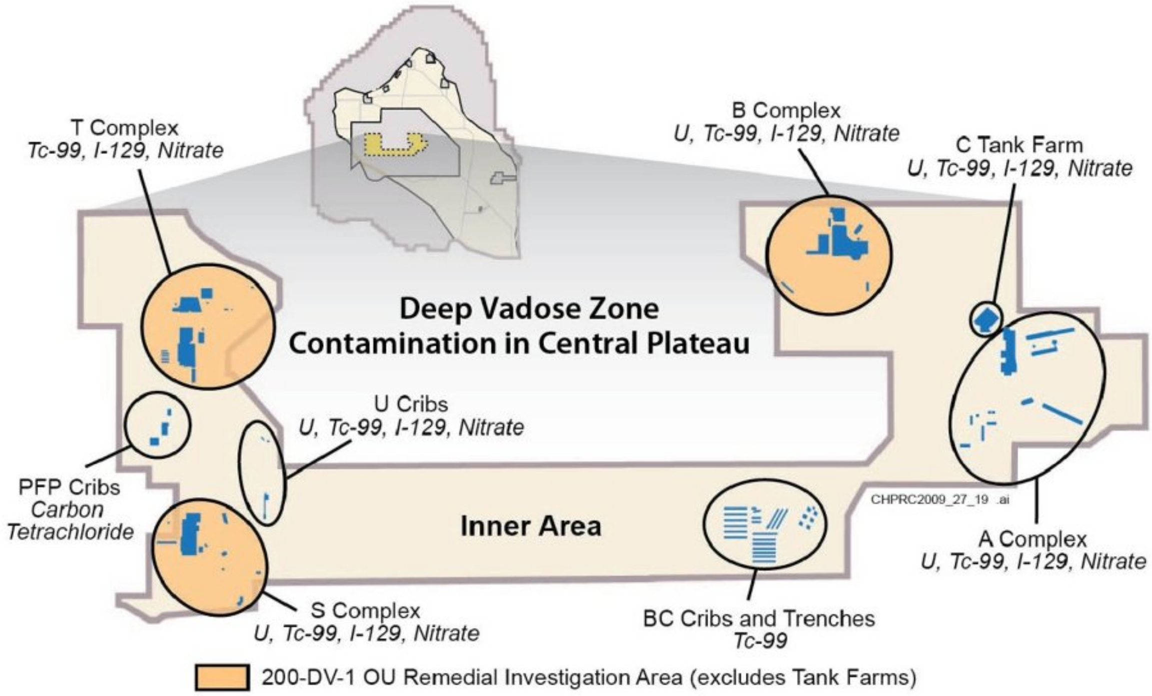

Fig. 1. 200-DV-1 Operable Unit waste sites in the Hanford Central Plateau.

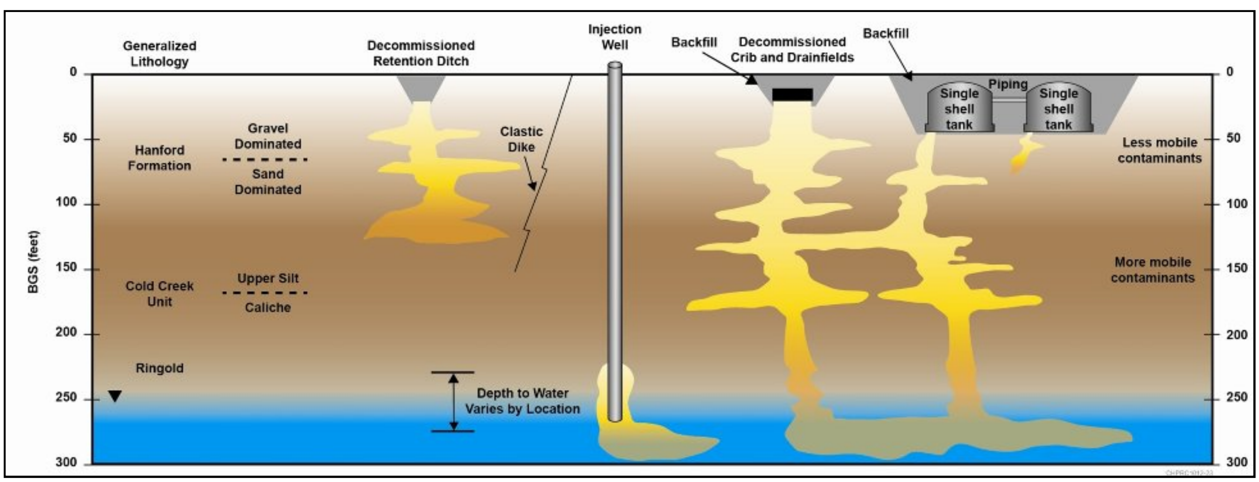

Fig. 2. Preliminary conceptual site model for the 200-DV-1 Operable Unit.

Technology Screening under CERCLA[1]

Technology screening is an integral part of the CERCLA[1] remediation process. Per EPA guidance, technology pre-screening and treatability study scoping may occur during work plan development to support both remedy screening treatability studies and remedy selection (Figure 3). For this project, the technology screening was initiated before submittal of the work plan because of the recognized difficulties in effectively remediating soils in the Deep Vadose Zone using readily available technologies.

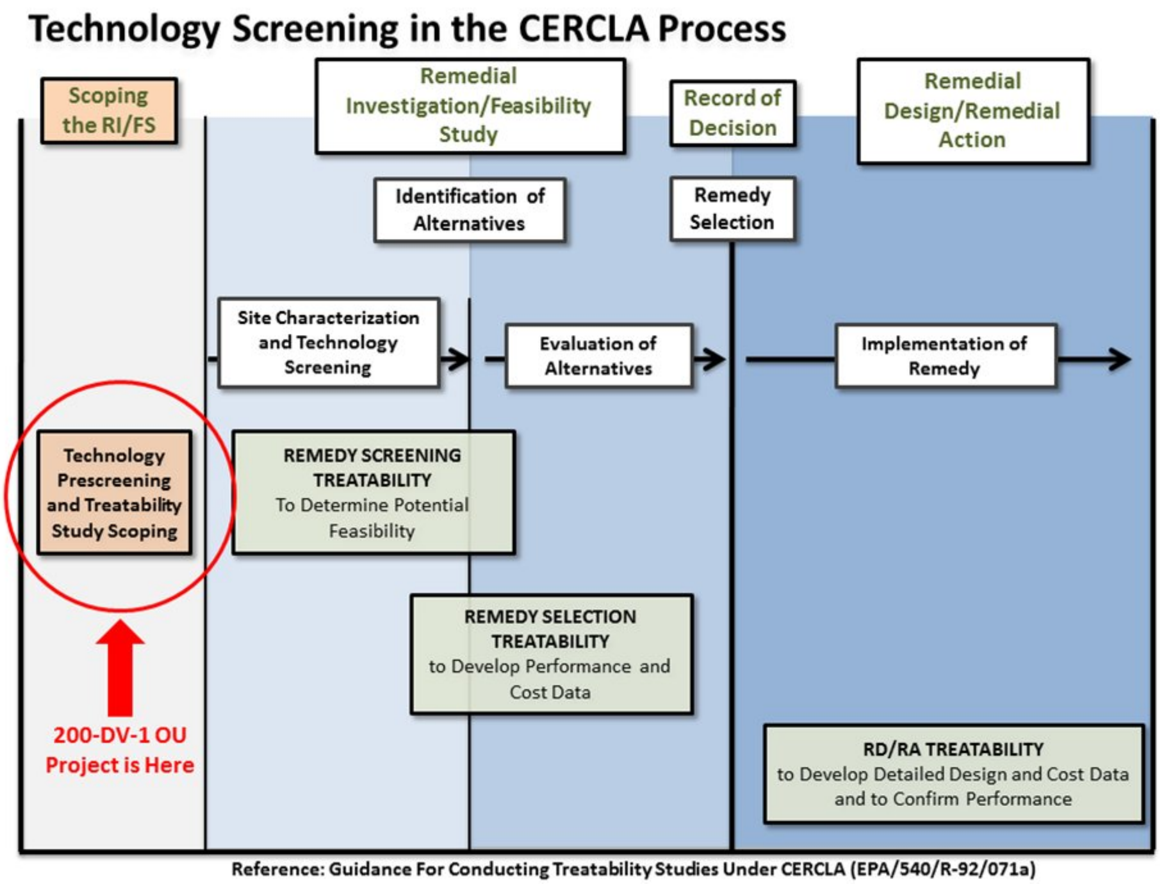

Fig. 3. Technology screening in the CERCLA[1] process.

The objectives for technology pre-screening conducted during the remedial investigation/ feasibility study scoping stage differ from the objectives used for the selection of remedial alternatives conducted during the feasibility study. In the feasibility study, technology screening is conducted to narrow down the number of viable technologies, from which remedial alternatives are assembled and evaluated with respect to their effectiveness, implementability, and cost. In contrast, technology screening conducted during the initial remedial investigation/feasibility study scoping is focused primarily on identifying potentially applicable technologies that may require further evaluation so they will be available during the feasibility study. Technologies that have been demonstrated or proven as viable in remediating Deep Vadose Zone contamination and do not require additional evaluation or testing during RI activities will be carried forward to the feasibility study.

The pre-screening of technologies during work plan development provide an opportunity to consider a broad range of potentially applicable technologies. Pre-screening aids in identifying potentially applicable technologies that have not been fully field tested or tested in the specific conditions found at the Hanford Site. These technologies may not otherwise have been considered during the technology screening and remedial alternative evaluations conducted as part of the "routine" CERCLA[1] remedial alternative selection process. The pre-screening allows for the following:

- Promising technologies to be identified
- Site-specific data to be collected in the remedial investigation/feasibility study work plan to help in their evaluation
- Field studies to be planned and implemented, if necessary, to validate their effectiveness and support a timely cleanup schedule

Identify Potentially Applicable Technologies

Technologies have been identified as part of previous work on the vadose zone at the Hanford Site, such as the *Deep Vadose Zone Treatability Test Plan for the Hanford Central Plateau* (DOE/RL-2007-56)[4]. This technology study and others were used as the starting point for identifying technologies for this effort. Additional resources were used to augment the list of potentially applicable technologies, which include the following:

- Remediation approaches from similar sites across the country
- Research and development (R&D) activities performed within the U.S. Department of Energy (DOE) and U.S. Department of Defense
- Past and current technology research and development (R&D) occurring at the Hanford Site
- Solicited input from DOE, EPA, the Washington State Department of Ecology, and stakeholders

This effort identified 59 potentially applicable technologies for remediating contamination in the Deep Vadose Zone (Table I). To aid in future evaluation during the feasibility study, this list of technologies is sorted by the typical CERCLA[1] General Response Actions (containment, removal, ex situ treatment and disposal, and in situ treatment), which resulted in 7 containment technologies, 18 removal technologies, 8 ex situ treatment and disposal technologies, and 26 in situ treatment technologies.

Gather Supporting Information

Once the list of technologies was developed, available information was collected for each technology and described in a fact sheet. The technology fact sheets provide general explanations of each technology, including state of development, contaminants treated, examples of applications or testing of the technology (if applicable), and the effectiveness and limitations for deployment of the technology at the Hanford Site. The information used to complete the fact sheets was collected from a number of document sources, which are listed at the end of each fact sheet, as well as from discussions with experts in the industry.

Table I. List of Potential Remediation Technologies for the Deep Vadose Zone.

Containment Technologies	Removal Technologies	Ex Situ Treatment and Disposal Technologies	In Situ Treatment Technologies
• Asphalt/ Concrete Cap • Modified RCRA[3] Subtitle C Barrier • Hanford Barrier • Vegetative Cap (Evapo-transpiration Cap/Cover) • Jet Grouting* • Permeation Grouting (Molten Wax Injection) • Soil Freezing	• Deep Excavation with Sloping and/or Benching (Open Pit Mining) • Deep Excavation using Dragline Excavators • Deep Excavation using Drilling and Soil Replacement • Deep Excavation using Sheet-piling or Sheet Pile Walls • Deep Excavation using Soldier Pile and Lagging Wall • Deep Excavation using Diaphragm Walls • Deep Excavation using Soil Nail Walls • Deep Excavation using Secant/Tangent Pile Walls • Deep Excavation using Caissons • Deep Excavation using Jet Grout Walls • Deep Excavation using Deep Mixed Walls • Deep Excavation using Reinforced Concrete Walls • Deep Excavation using Cofferdams • Deep Excavation using Tunneling • Perched Water Removal • Porewater Extraction • Soil Flushing—Vadose Zone with Water and Chemical Enhanced • In Situ U Recovery	• Ex Situ Vitrification • Solidification/ Stabilization • Soil Washing • Soil Sorting/ Screening • Backfill Treated Soil • Onsite Landfill • Offsite Landfill/ Repository • Molecular Sieves	• In Situ Vitrification • In Situ Thermal Desorption • Gas-phase Delivery of Reactant, Sequestering Agent, etc. • Foam Delivery of Reactant, Sequestering Agent, etc. • Shear Thinning Fluid Injection • Jet Grouting • Injection/Extraction Wells (Horizontal) • Injection/Extraction Wells (Vertical) • Surface/Subsurface Infiltration of Reactant, Sequestering Agent, etc. • Deep Soil Mixing • Chemical Oxidation • Soil Vapor Extraction • Biological Reductive Dechlorination • Electrokinetic Mobilization and Recovery • Hybrid Electrokinetic Delivery of Treatment Chemicals • Sodium Dithionite • Sulfide Salts and Minerals • Ferrous Iron Reduction • Gaseous Reduction • Gaseous Ammonia • Phosphate Sequestration (Apatite) • Carbonate Sequestration • Soil Desiccation • In Situ Biological Reduction • Monitored Natural Attenuation • Nanoparticle Treatment

* Jet grouting for containment is very similar to the jet grouting for in situ treatment, differing primarily by the reagent type.

RESULTS

The 59 potentially applicable remediation technologies were screened following the process depicted in Figure 4. Information collected on each of the remediation technologies were evaluated with respect to being able to deploy the technology for remediation of the Deep Vadose Zone within the next 3 to 5 years. Based on this evaluation, the technologies were placed into one of four general bins. Brief descriptions of the different bins are as follows:

- **Technologies that are fully developed and need no additional work.** These technologies are known to be viable for remediating Deep Vadose Zone contamination and need no additional data to support remedial alternative evaluation during the feasibility study.
- **Technologies that are fully developed, but would benefit from additional cost or performance information.** These technologies are known to be viable for remediating Deep Vadose Zone contamination, but need additional cost or performance information to support further evaluation of the technologies as part of remedial alternatives. Typically, additional design and performance information is needed to help support an evaluation of implementability, effectiveness, and/or cost analysis during the feasibility study.
- **Technologies that require further development to prove.** These are innovative or emerging technologies that may be worthy of additional development and testing to support application for Deep Vadose Zone contamination.
- **Technologies for no further evaluation.** These technologies are clearly not applicable to the Deep Vadose Zone applications or will not be ready in time to support the 200-DV-1 Operable Unit time frame.

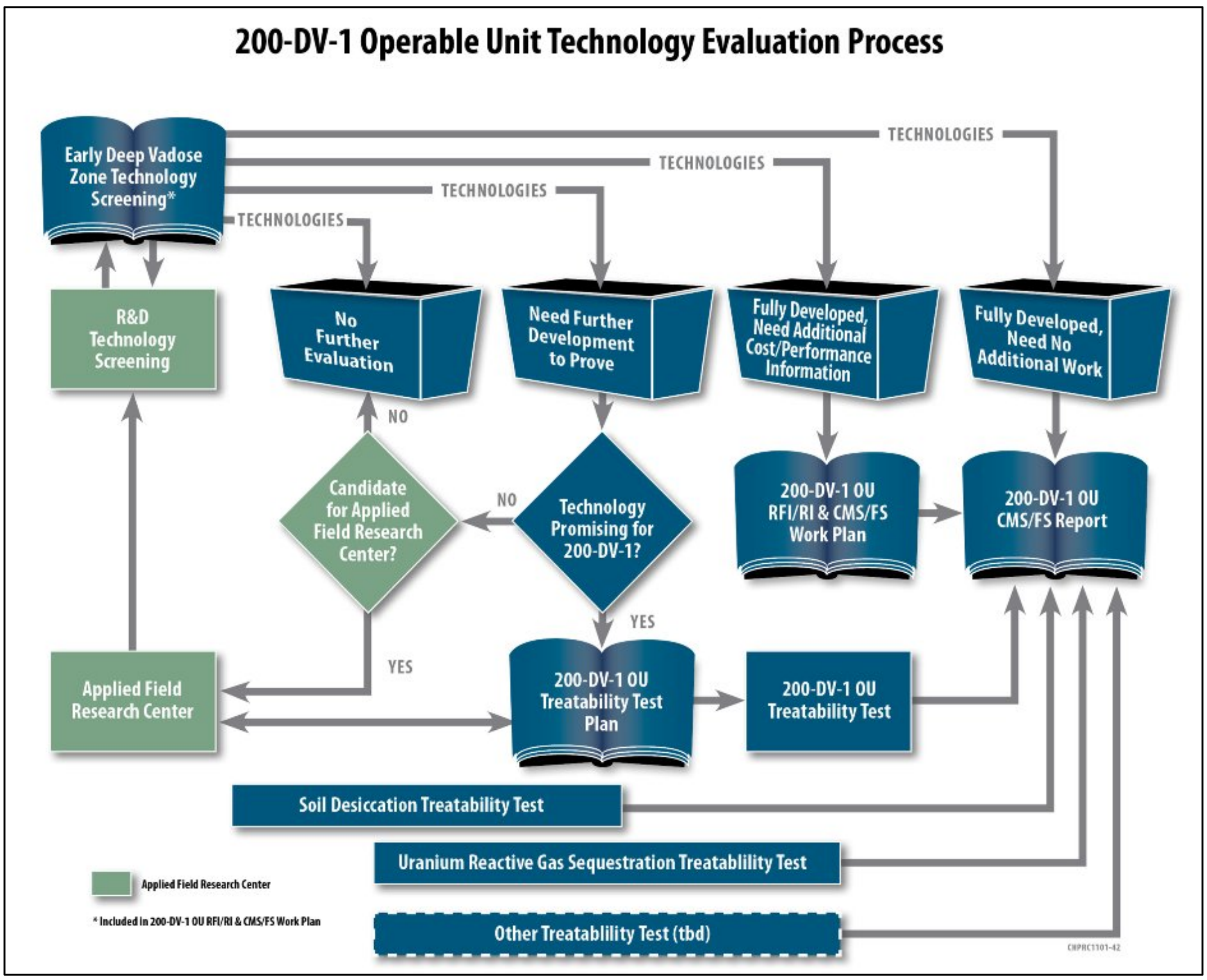

Fig. 4. 200-DV-1 Operable Unit technology evaluation process.

Based upon these definitions, 11 technologies were considered ready for evaluation in the feasibility study. These technologies primarily consist of commonly used remediation methods such as soil vapor extraction, perched water removal, or landfill disposal.

Fourty-three (43) potentially applicable technologies were identified as requiring additional testing or investigation to determine whether they should be considered further in the selection of a remedial alternative for the 200-DV-1 Operable Unit. Twenty-one (21) technologies were considered viable, but would benefit from the collection of additional information on remedy performance and/or implementation cost prior to evaluation in the feasibility study. The technologies in this category primarily include a variety of containment/barrier methods and deep excavation techniques for contaminant removal. Twenty-two (22) technologies were identified that require additional treatability testing, either laboratory or field, to support adequate evaluation during the feasibility study. These technologies are primarily associated with in situ treatment methods (from soil flushing through sequestration) and include a variety of different delivery techniques to get the reagents to the contamination.

Finally, five technologies were identified for no further evaluation at this time. These technologies are either not applicable to the contaminants of concern or will not be ready for full-scale implementation in the near-term. To help advance some of these technologies, additional research and development activities may be performed by other organizations, such as the Applied Field Research Initiative. The Applied Field Research Initiative, which is funded by DOE, provides the framework for a coordinated and integrated research and technology development strategy to increase understanding of and develop remedial technologies for the Deep Vadose Zone. If the Applied Field Research Initiative deems that the technology may be potentially useful for Deep Vadose Zone applications following research and development, it will be given higher priority for additional research and development. If the technology is not expected to be applicable or useful for Deep Vadose Zone applications, it will be given a lower priority and dropped from consideration for further work associated with the Deep Vadose Zone.

DISCUSSION

An evaluation of the ongoing or recently completed work at the Hanford Site was performed to help facilitate decisions on planning and scoping additional work activities, including treatability studies that could be performed during the 200-DV-1 Operable Unit RCRA[3] Facility Investigation/Remedial Investigation. This effort only addressed the technologies that were placed into the “Need Additional Cost/Performance Information” and “Need Further Development to Prove” bins. A significant amount of work has been completed in the application of various technologies for the remediation of the Deep Vadose Zone. By understanding the existing Hanford Site-specific information on these technologies, additional work can be identified and prioritized to support the 200-DV-1 Operable Unit. The recent Hanford Site-specific work for the technologies that “Need Additional Cost/Performance Information” or “Need Further Development to Prove” are provided in Tables II and III, respectively.

As shown in Table II, field demonstrations have been completed or are underway for the technologies that include infiltration control barriers, deep excavation–sloping and benching, and ex situ soil sorting/screening. Information collected from these Hanford Site-specific projects will provide a good basis for evaluation of remedial alternatives during the feasibility study. Reports have been written for 11 of the technologies with respect to Deep Vadose Zone remediation. Only three technologies (dragline excavators, tunneling, and cofferdams) have not been evaluated during a previous Hanford Site-specific study.

As shown in Table III, field demonstrations have been completed or are underway for the technologies that include soil desiccation, gaseous ammonia injection, in situ vitrification, porewater extraction, and horizontal well drilling. The results from these tests will be used to support the evaluation of remedial alternatives during the feasibility study. Laboratory studies have been completed on the technologies that include phosphate sequestration (apatite), gaseous reduction, and use of calcium polysulfide. The results from these laboratory studies will be reviewed to determine whether field treatability testing is warranted. Reports have been written on eight of the technologies with respect to Deep Vadose Zone remediation. Only two technologies (electrokinetic mobilization/recovery and deep soil mixing) have not been evaluated during a previous Hanford Site-specific study.

Table II. Technologies that Need Additional Cost/Performance Information.

Technology or Method	Hanford Site-Specific Studies			
	None	Report	Laboratory Studies	Field Demonstration
Infiltration Control Barrier (Asphalt/ Concrete Cap, Modified RCRC[3] Subtitle C Barrier, Hanford Barrier, Vegetative/Evapotranspiration Cap)—4 technologies				●
Jet Grouting*		●		
Deep Excavation—Sloping and Benching				●
Deep Excavation—Drilling and Soil Replacement		●		
Deep Excavation—Dragline Excavators	●			
Deep Excavation—Tunneling	●			
Deep Excavation—Reinforced Concrete Walls		●		
Deep Excavation—Secant/Tangent Pile Walls		●		
Deep Excavation—Soldier Pile Walls		●		
Deep Excavation—Diaphragm Walls		●		
Soil Sorting/ Screening				●
Deep Excavation—Soil Nail Walls		●		
Deep Excavation—Jet Grout Walls		●		
Deep Excavation—Caissons		●		
Deep Excavation—Cofferdams	●			
Deep Excavation—Deep Mixed Walls		●		
Deep Excavation—Sheet Pile Walls		●		
Soil Freezing		●		

Note: Further information on these technologies is available in the documents identified in the reference section.

* Jet grouting as identified under Containment Technologies.

Table III. Technologies that Need Further Development to Prove.

Technology or Method	Hanford Site-Specific Studies			
	None	Report	Laboratory Study	Field Demonstration
Soil Flushing—Vadose Zone		●		
Phosphate Sequestration (apatite)			●	
Soil Desiccation				●
Gaseous Ammonia				●
In Situ Vitrification				●
In Situ Thermal Desorption		●		
Injection/Extraction Wells (Horizontal)				●
Porewater Extraction				●
Sodium Dithionite		●		
Gaseous Reduction			●	
Sulfide Salts and Minerals (Calcium Polysulfide)			●	
Biological Reductive Dechlorination		●		
Ferrous Iron Reduction		●		
In Situ Biological Reduction		●		
Permeation Grouting (Molten Wax Injection)		●		
In Situ Uranium Recovery		●		
Electrokinetic Mobilization and Recovery	●			
Gas-phase Delivery			●	
Surface/Subsurface Infiltration				
Deep Soil Mixing	●			
Foam Delivery			●	
Jet Grouting		●		
Soil Wicking		●		

Note: Further information on these technologies is available in the documents identified in the reference section.

CONCLUSIONS

The Deep Vadose Zone remediation technologies pre-screening involved a comprehensive review of potentially applicable technologies for remediating Deep Vadose Zone contamination in the Hanford Site's Central Plateau. The list of remediation technologies was developed from previous Hanford Site studies, science and technology databases, as well as other cleanup projects across the country that have similar conditions. The list of remediation technologies was shared with the public and stakeholders to provide an opportunity to identify additional technologies. From these efforts, 59 technologies that may support future remediation of the Deep Vadose Zone were identified.

The initial list of 59 potential technologies were then screened in order to identify viable or potentially viable technologies whose implementation would benefit from further investigation and evaluation during the remedial investigation/feasibility study activities. This approach eliminated five technologies from further consideration because they either would not be ready to support remediation within the next 3 to 5 years or were not applicable for Deep Vadose Zone remediation. Eleven (11) technologies were identified as viable, requiring no further testing or investigation during the RCRA[3] Facility Investigation/Remedial Investigation activities. The remaining 43 potentially applicable technologies were identified as requiring additional testing or investigation to determine whether they should be considered further in the selection of a remedial alternative for the 200-DV-1 Operable Unit. The results of this pre-screening effort will be used to plan and scope the appropriate field investigation, treatability study, and feasibility study tasks during development of the 200-DV-1 Operable Unit Work Plan.

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