DISTRIBUTION SHEET

To	From	Page 1 of 1
Distribution	DST Retrieval Engineering	Date September 20, 1994
Project Title/Work Order		EDT No. 160549
Tri-Party Agreement Milestone M-45-07A - Complete Evaluation of Subsurface Barrier Feasibility (Summary Report)		ECN No. N/A

Name	MSIN	Text With All Attach.	Text Only	Attach./ Appendix Only	EDT/ECN Only
Westinghouse Hanford Company					
S. E. Ard	R1-08	1			
P. A. Baynes	B1-58	1			
G. D. Bazinet	S4-53	1			
J. M. Cruse	L5-63	6			
L. A. Fort	S4-54	1			
C. E. Grenard	S4-53	1			
M. L. Grygiel	B1-58	1			
K. L. Hampsten	S4-53	5			
D. F. Iwatate	G6-16	1			
W. J. Karwoski	S4-53	1			
G. A. Meyer	S4-54	1			
W. C. Miller	S4-55	1			
E. J. Shen	S4-58	1			
Central Files	L8-04	~~1~~ 2			
OSTI (2)	L8-07	2			
PIMS	S4-53	3			
ICF Kaiser Hanford Company					
C. C. Busacker	E5-14	1			
D. L. Huddleston	G7-21	1			
C. V. Smith	G7-21	1			
Pacific Northwest Laboratories					
A. J. Brothers	K8-10	1			
R. E. Lewis	K6-84	1			
M. E. Peterson	K2-47	1			
J. D. Vick	K7-94	1			
U.S. Department of Energy, Richland Field Office					
R. G. Holt	A5-15	1			
B. L. Nicoll	R3-74	1			
J. E. Rasmussen	A5-15	1			
W. R. Wrzesinski	R3-74	6*			
Ensearch Environmental, Inc.					
B. B. Peters		1			
R. L. Treat		1			
Bovay Northwest, Inc.					
T. J. McLaughlin		1			
J. K. Rouse		1			

* Advance copies provided to W. R. Wrzesinski - 9/22/94.

A-6000-135 (01/93) WEF067

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

DISCLAIMER

SEP 21 1994 (20)

ENGINEERING DATA TRANSMITTAL

1. EDT 160549

2. To: (Receiving Organization) Distribution	3. From: (Originating Organization) DST Retrieval Engineering	4. Related EDT No.: N/A
5. Proj./Prog./Dept./Div.: SSB/DST/TWRS	6. Cog. Engr.: K. L. Hampsten	7. Purchase Order No.: N/A
8. Originator Remarks: Initial issue for public release.		9. Equip./Component No.: N/A
		10. System/Bldg./Facility: N/A
11. Receiver Remarks:		12. Major Assm. Dwg. No.: N/A
		13. Permit/Permit Application No.: N/A
		14. Required Response Date: N/A

15. DATA TRANSMITTED

(A) Item No.	(B) Document/Drawing No.	(C) Sheet No.	(D) Rev. No.	(E) Title or Description of Data Transmitted	(F) Approval Desig-nator	(G) Reason for Trans-mittal	(H) Origi-nator Dispo-sition	(I) Receiv-er Dispo-sition
1	WHC-SD-WM-ES-311		0	Tri-Party Agreement Milestone M-45-07A - Complete Evaluation of Subsurface Barrier Feasibility (Summary Report)	NA	1		

16. KEY

Approval Designator (F)	Reason for Transmittal (G)	Disposition (H) & (I)
E, S, Q, D or N/A (see WHC-CM-3-5, Sec.12.7)	1. Approval 2. Release 3. Information 4. Review 5. Post-Review 6. Dist. (Receipt Acknow. Required)	1. Approved 2. Approved w/comment 3. Disapproved w/comment 4. Reviewed no/comment 5. Reviewed w/comment 6. Receipt acknowledged

17. SIGNATURE/DISTRIBUTION (See Approval Designator for required signatures)

(G) Reason	(H) Disp.	(J) Name	(K) Signature	(L) Date	(M) MSIN	(J) Name	(K) Signature	(L) Date	(M) MSIN	(G) Reason	(H) Disp.
1	1	Cog.Eng. K. L. Hampsten	K L Hampsten	9/20/94							
1	1	Cog. Mgr. G. D. Bazinet	G D Bazinet	9/20/94							

18. J. M. Cruse 9/20/94 Signature of EDT Originator / Date	19. G. D. Bazinet 9/20/94 Authorized Representative for Receiving Organization / Date	20. G. D. Bazinet 9/20/94 Cognizant Manager / Date	21. DOE APPROVAL (if required) Ctrl. No. [] Approved [] Approved w/comments [] Disapproved w/comments

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

RELEASE AUTHORIZATION

Document Number:	WHC-SD-WM-ES-311, Revision 0
Document Title:	Tri-Party Agreement Milestone M-45-07A - Complete Evaluation of Subsurface Barrier Feasibility (Summary Report)
Release Date:	September 21, 1994

* * * * * * * * * * * * *

This document was reviewed following the procedures described in WHC-CM-3-4 and is:

APPROVED FOR PUBLIC RELEASE

* * * * * * * * * * * * *

WHC Information Release Administration Specialist:

M. Boston M. N. Boston 9/21/94

(Signature) (Date)

MASTER

A-6001-400 (07/94) WEF256

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

SUPPORTING DOCUMENT

1. Total Pages	27
2. Title Tri-Party Agreement Milestone M-45-07A - Complete Evaluation of Subsurface Barrier Feasibility (Summary Report)	**3. Number** WHC-SD-WM-ES-311 / **4. Rev No.** 0
5. Key Words Injected materials, frozen soil and desiccant barriers, feasibility study, performance criteria.	**6. Author** Name: J. M. Cruse; Signature: J M Cruse 9/20/94; Organization/Charge Code 8AB00/E24107

7. Abstract

This document provides an overview of the work performed by WHC and its subcontractors in response to Tri-Party Agreement Milestone M-45-07A - "Complete Evaluation of Subsurface Barrier Feasibility" (September 1994). The feasibility study and related work was performed to support a decision by the DOE Richland Operations Office, the Washington State Department of Ecology, and the U.S. Environmental Protection Agency regarding further development of subsurface barrier options for SSTs and whether to proceed with demonstration plans at the Hanford Site (Tri-Party Agreement Milestone M-45-07B).

A summary of the work performed and the conclusions reached is provided along with a list of contacts for technical assistance.

10. RELEASE STAMP

9. Impact Level NA

WHC-SD-WM-ES-311
Revision 0

Tri-Party Agreement Milestone M-45-07A; Complete Evaluation of Subsurface Barrier Feasibility

Summary Report

G. E. Cox
B. B. Peters
R. L. Treat
Enserch Environmental Corporation

G. D. Bazinet
J. M. Cruse
K. L. Hampsten
Westinghouse Hanford Company

Date Published
September 1994

Prepared for the U.S. Department of Energy
Office of Environmental Restoration and
Waste Management

Westinghouse Hanford Company P.O Box 1970
Richland, Washington

Hanford Operations and Engineering Contractor for the
U.S. Department of Energy under Contract DE-AC06-87RL10930

Approved for Public Release

This page intentionally left blank.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF TERMS

DOE	U.S. Department of Energy
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
MEPAS	Multimedia Environmental Pollutant Assessment System
Tri-Party Agreement	Hanford Federal Facility Agreement and Consent Order
TWRS	Tank Waste Remediation System

1.0 INTRODUCTION

The U.S. Department of Energy (DOE) has established the Tank Waste Remediation System (TWRS) program to safely manage and dispose the low-level and high-level radioactive and hazardous wastes currently held in 177 tanks and approximately 1,900 sealed capsules located on the Hanford Site. The remediation of the entire Hanford Site is being conducted under the *Hanford Federal Facility Agreement and Consent Order* (Ecology et al. 1994), otherwise known as the Tri-Party Agreement. The three parties that concluded the agreement are the DOE, the U.S. Environmental Protection Agency (EPA), and the Washington State Department of Ecology (Ecology).

The purpose of the Tri-Party Agreement is to ensure that Hanford Site activities are performed in a manner that protects the public health, welfare, and the environment. The agreement provides a framework and structure for the many different agencies and regulations under which work is performed on the Site, listing responsibilities and attaching scheduled dates of completion for minimum performances (known as milestones).

The Tri-Party Agreement Milestone M-45-07A requires that an assessment of the feasibility of subsurface barriers to support retrieval of tank waste be performed. The activities to meet this milestone have been completed, and are documented herein.

2.0 BACKGROUND

A qualitative assessment of risks involving tank waste retrieval was prepared for Hanford Site single-shell tanks (SSTs) with and without subsurface barriers (WHC 1994a). This risk assessment concluded that the use of subsurface barriers could reduce risks if the barriers would support a higher level of retrieval of waste from the tanks. This conclusion led to the creation of Tri-Party Agreement Milestone M-45-07A, to conduct a feasibility study of subsurface barriers.

The Tri-Party Agreement Milestone M-45-07A, Complete Evaluation of Subsurface Barrier Feasibility (due date September 30, 1994) includes a requirement to complete a feasibility study of barriers to accomplish the following:

- Estimate the potential environmental impact of waste storage and retrieval activities without the application of barriers.
- Establish functional requirements of barriers to minimize the impact associated with the waste storage and retrieval activities.
- Evaluate the application of existing subsurface barrier technologies to meet functional requirements of barriers and the potential reduction in environmental

impacts from the application of barriers to SST waste storage and retrieval activities (Ecology et al. 1994).

The feasibility study will support a decision by the DOE Richland Operations Office, Ecology, and the EPA regarding further development of subsurface barrier options for SSTs and whether to proceed with demonstration plans at the Hanford Site. This decision is required by the Tri-Party Agreement as Milestone M-45-07B.

3.0 PERFORMANCE ACTIVITIES

The activities that were performed to complete the requirements of Milestone M-45-07A are discussed in the following sections.

3.1 EVALUATION OF IMPACTS WITHOUT SUBSURFACE BARRIERS

The first objective for the feasibility study called for the evaluation of environmental risks associated with waste storage and retrieval activities without the application of barriers. This evaluation was performed and documented in *Feasibility Study of Tank Leakage Mitigation Using Subsurface Barriers* (WHC 1994b). The risk of contaminant releases into the Hanford Site aquifer was assumed to be the most important risk factor, overshadowing all other risks, including worker safety risks, health risks due to atmospheric releases during installation and operation, and ecological risks. Six alternatives without subsurface barriers were evaluated, including two nonviable alternatives. The nonviable alternatives were: no action, where no action would be taken to remove or treat the wastes in the single-shell tanks; and surface barrier only, where a barrier would be placed over the surface of the tank farm to limit the effect of precipitation on waste movement. These options were used for comparison purposes only because they do nothing to reduce the quantity of contaminants that may leak from the tanks to the groundwater.

Three of the alternatives without subsurface barriers were based on the retrieval of wastes from tanks using three different methods: traditional sluicing, robotic sluicing, and mechanical retrieval. Traditional sluicing is the method historically used to retrieve wastes from Hanford Site SSTs. It uses a large-volume stream of liquid to disperse, dilute, and mobilize sludge (Figure 1). The slurry is then pumped out of the tank to a waste processing system where the supernatant is separated from the sludge. The supernatant is then recycled as sluicing liquid. An early study evaluated hydraulic retrieval (traditional sluicing) of the waste in a SST with respect to the likelihood of tank leaks, gross volumes of potential leaks, and their consequences (Lowe et al. 1993). This study established a leak volume of 40,000 gal as the best estimate of leakage that may occur during traditional sluicing.

Robotic sluicing is a variation of a type of robotic armed-based retrieval systems that were first investigated at the Hanford Site in the mid-1970s. The technology is under development and has not been tested in a Hanford Site SST. An attachment to the end of a robotic arm

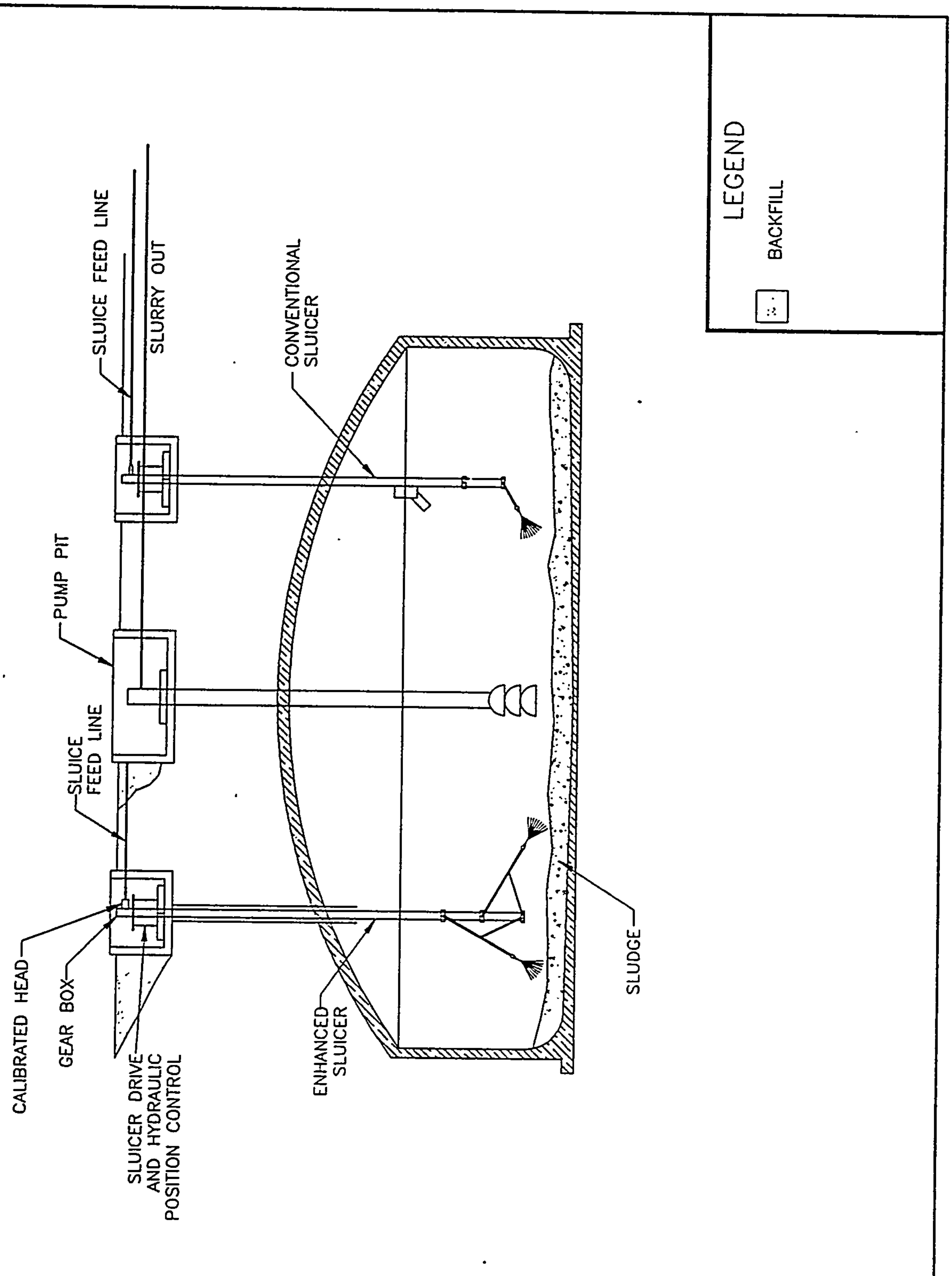

Figure 1. Traditional Sluicing.

called an end effector would use high-pressure water jets to dislodge waste (Figure 2). After the sludge is dislodged, the slurried mixture would be immediately vacuumed through a hose to an air separation system. Following separation, the waste would proceed to a processing system. The degree of leakage from a tank using robotic sluicing for retrieval is expected to be lower than in the case of traditional sluicing due to the reduced height of liquid in the tank.

The mechanical retrieval alternative is designed for the removal of solid waste and debris as opposed to liquids and slurries. It would use a scoop-like end effector affixed to the end of a robotic arm for waste retrieval (Figure 3). The end effector would be capable of mechanically excavating the solid waste in the tank. A jack-hammer end effector may be necessary to break up the rock-like layer of sludge known to exist in some tanks. The excavated waste would be placed by the robotic arm into an in-tank mechanical waste conveyance system and removed from the single-shell tank for further processing. No new leakage would be expected in the case of this retrieval option.

In the above three alternatives, the tanks would be closed in-place as a landfill. This would require adding grout to the empty tanks to physically stabilize them before constructing of a surface barrier over the stabilized tanks. The goal of this closure approach is intended to provide long-term, low-maintenance protection of residual waste from the dispersive effects of environmental processes.

Clean-closure was the fourth alternative evaluated without subsurface barriers. To achieve clean-closure, traditional sluicing would be employed to recover most of the tank waste. Following sluicing, all residual contamination in the tank, tank structures, and soil would be retrieved using mechanical methods (Figure 4). Most of the contaminants of concern would be removed from the retrieved materials and either destroyed or treated and disposed of at a Federal high-level waste repository. The excavated site would be backfilled with clean soil after verifying that cleanup limits were achieved. Clean-closure would eliminate the need for grout stabilization and a surface barrier at the tank waste site. Washed soil and debris from tank removal and treatment operations would be disposed in a new landfill at the Hanford Site. The landfill would constitute a small source of risk.

A summary of the technical features of each of the six alternatives without subsurface barriers is provided in Table 1.

A quantitative assessment of overall costs and health risks associated with these alternatives and alternatives that include subsurface barriers was prepared and documented in WHC (1994b). The report contains first approximations of carcinogenic risk and noncarcinogenic hazards to the maximally exposed individual for 30,000 years. Risks were estimated using the Multimedia Environmental Pollutant Assessment System (MEPAS) computer code. This code includes a one-dimensional model capable of projecting radiological and chemical risks and hazards through the groundwater and other pathways. Only the groundwater pathway was analyzed because the purpose of subsurface barriers is to prevent or limit future contamination of the groundwater. The cost and risk analyses of SSTs without subsurface

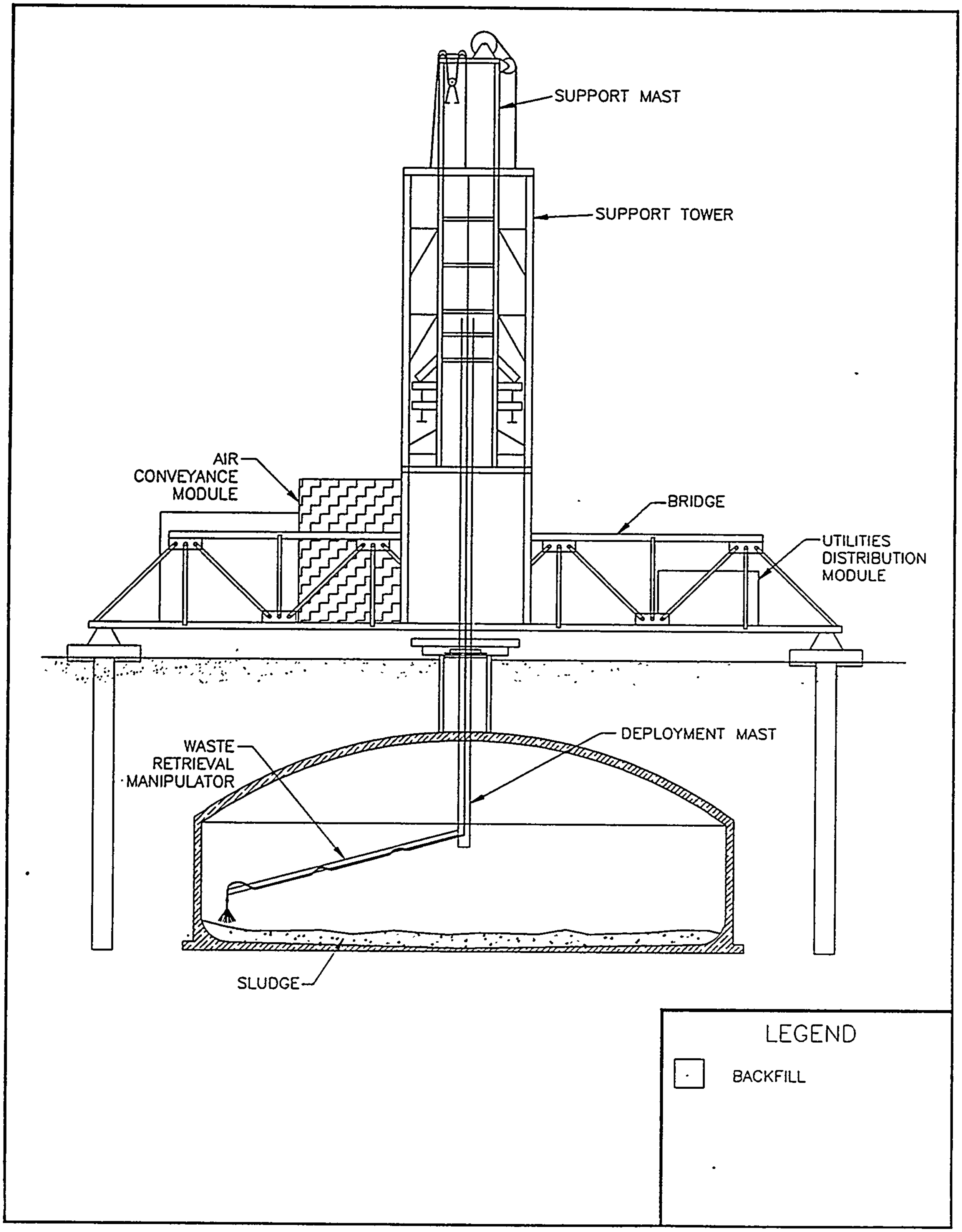

Figure 2. Robotic Sluicing.

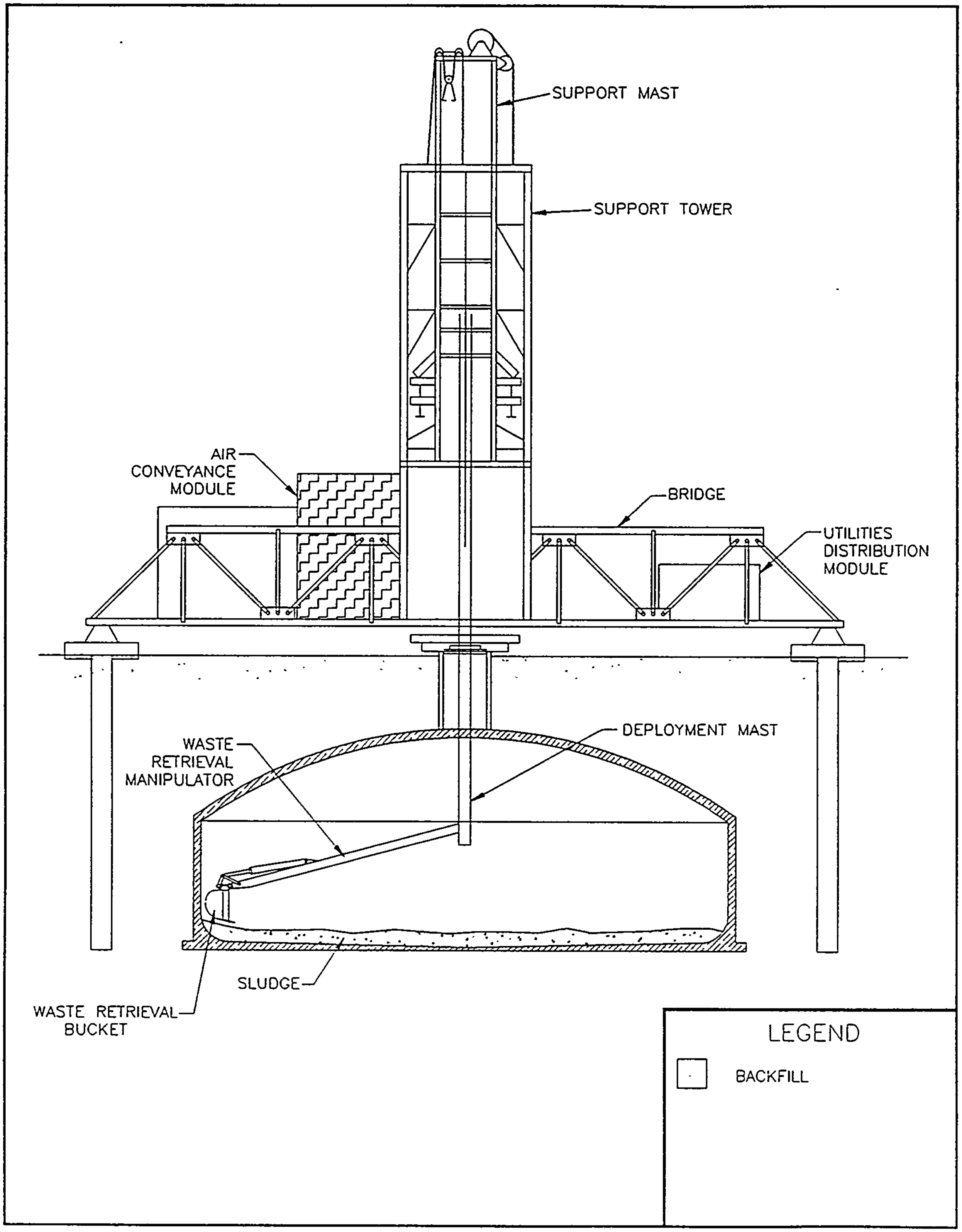

Figure 3. Mechanical Retrieval.

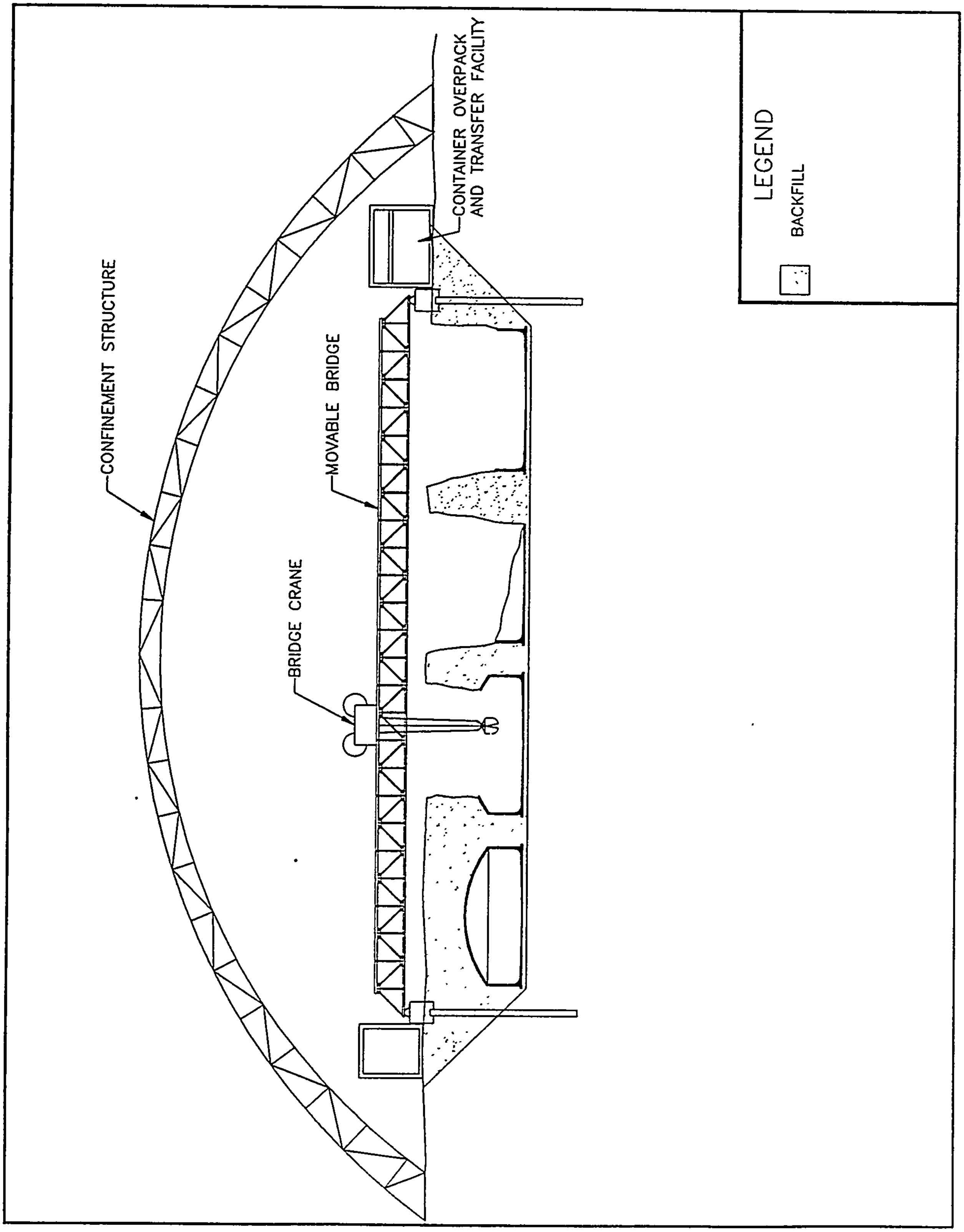

Figure 4. Confined Tank Demolition and Mining System (Clean-Closure Alternative).

Table 1. Summary of Alternatives Without Subsurface Barriers.

Alternative	Waste Retrieval Type	Assumed Tank Waste Retrieval Effectiveness	Subsurface Barrier Type	Old Leaks Flushed?	New Leaks Flushed?	Tanks Stabilized?	Surface Barrier Used?
No Action	None	0%	None	No	No	No	No
Surface Barrier Only	None	0%	None	No	No	No	Yes
Traditional Sluicing (Baseline)	Traditional sluicing	99%	None	No	No	Yes	Yes
Robotic Sluicing	Robotic sluicing	99.9%	None	No	No	Yes	Yes
Mechanical Retrieval	Mechanical retrieval	95%	None	No	No	Yes	Yes
Clean-Closure w/o Subsurface Barrier	Traditional sluicing	100%	None	No	No	Not Applicable	No

Table 2. Summary of Overall Costs and Projected Risks to the Maximally Exposed Individual Using Contaminated Groundwater (Without Subsurface Barriers).

Alternative	Total Net Present Worth Costs (in millions of dollars)	Incremental Carcinogenic Risk[a]	Hazard Index[b]
No Action	0	1.5E-01	2.8E+03
Surface Barrier Only	6	3.7E-04	8.6E+00
Traditional Sluicing (Baseline)	107	1.1E-05	2.4E-01
Robotic Sluicing	316	2.5E-06	5.7E-02
Mechanical Retrieval	244	2.1E-05	4.9E-01
Clean-Closure w/o Subsurface Barrier	1965	1.1E-07	2.4E-03

(a) An incremental carcinogenic risk range of 10^{-4} to 10^{-6} is normally specified for cleanup of hazardous waste sites.
(b) A hazard index of less than 1 is normally specified.

barriers is summarized in Table 2. The costs and risks shown in Table 2 are based on the following key assumptions:

- Costs are based on remediation of a hypothetical tank farm consisting of 12, 1-million gallon tanks, each containing the average quantity and composition of waste in all 149 SSTs.
- Risks are based on the maximally exposed individual who uses well water obtained immediately downgradient of the closed hypothetical tank farm. The well is used to provide drinking water and irrigation of a five-acre farm. Risk includes exposure through consumption of foodstuffs raised on the farm.

3.2 ESTABLISH FUNCTIONAL REQUIREMENTS

Functional requirements were established and documented in *Functions and Requirements for Single-Shell Tank Leakage Mitigation* (Cruse 1994). A function is defined as what a system or subsystem must accomplish to satisfy the overall mission; a requirement is a qualitative or quantitative statement of how well a function must be performed. Within TWRS, requirements may be one of two types: constraints and performance requirements. Constraints are imposed upon the function by the external environment (e.g., Ecology, U.S. Congress). Performance requirements are imposed upon the function by the TWRS program itself and therefore may be traded with respect to other performance requirements to optimize overall performance.

A functional hierarchy was created based on the constraints and performance requirements identified (Figure 5). The functional hierarchy applies to mitigative actions to be taken regarding belowground leaks from SST containment boundaries and the resulting soil contamination.

One of the major constraints driving the functions and requirements for subsurface barriers is the potentially applicable regulatory requirements that may impact full-scale construction and operation of these underground barrier systems. An analysis of the regulatory requirements was performed and documented in *Regulatory Analysis for the Use of Underground Barriers at the Hanford Site Tank Farms* (WHC 1994c). In addition to the potentially applicable regulatory requirements, this document provided a discussion of factors that should be considered throughout the barrier selection process, including disposition of secondary waste and potential impacts on final closure of the SSTs.

Prior to and concurrent with the determination of the functions and requirements for SST leakage mitigation, a mission analysis was prepared to determine the program objectives and evaluate the feasibility and risks associated with achieving those objectives (Lowe and Cruse 1994). Lowe and Cruse (1994) provides a consistent basis for subsequent

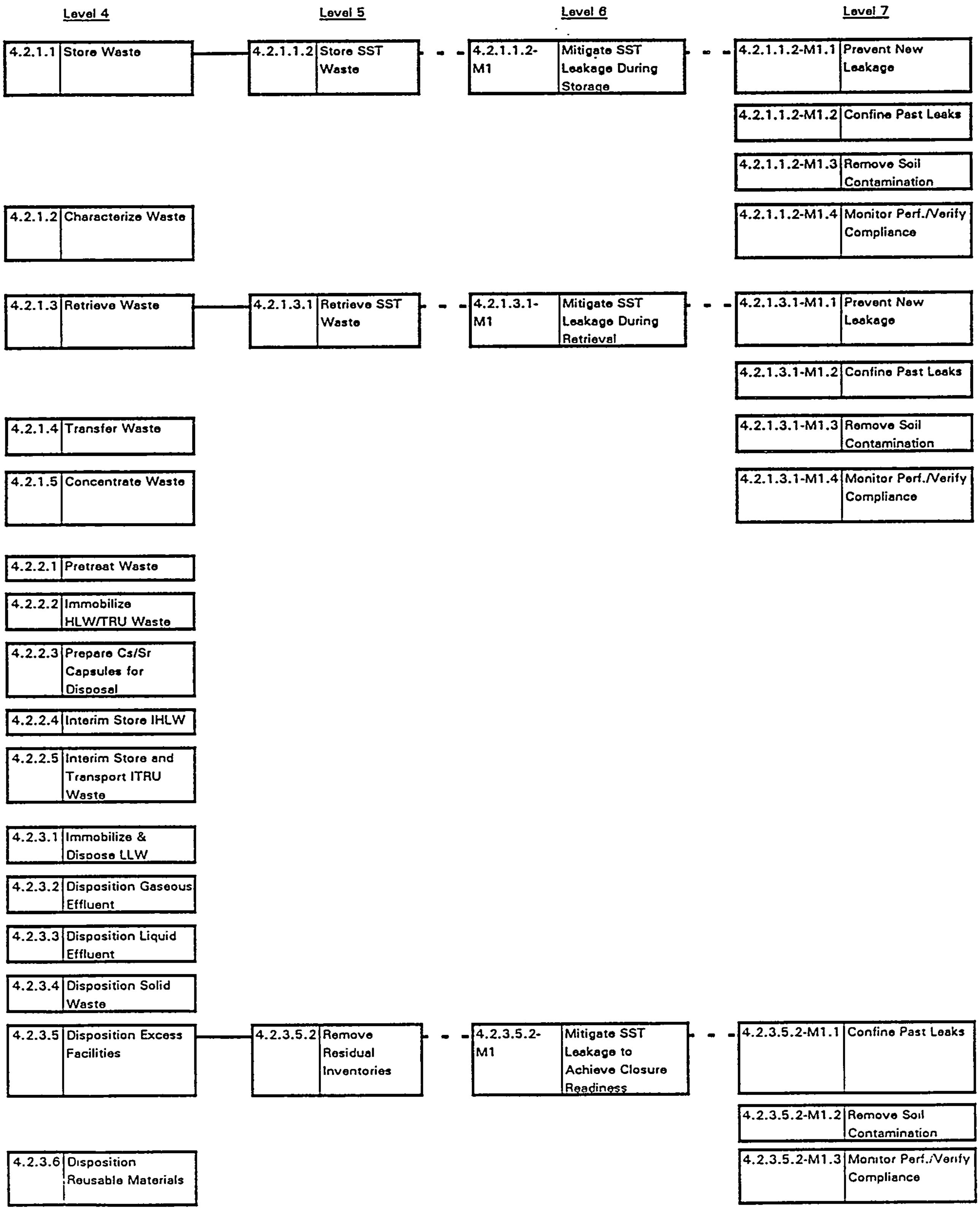

Figure 5. Single-Shell Tank Leakage Mitigation Function Hierarchy.

system engineering work (e.g., functional analysis, requirements definition, parametric analysis) and can also be updated as required throughout the systems engineering process to reflect programmatic decisions.

3.3 EVALUATE APPLICATION OF SUBSURFACE BARRIERS

Due to the risk that the large volumes of water used in the sluicing process may cause leakage of waste through cracks in the tanks, subsurface barriers that could contain waste released during sluicing were evaluated. A number of studies and working meetings have taken place in an effort to identify potentially applicable subsurface barrier systems for SST waste retrieval applications and to determine the best approach to develop them (Bovay Northwest 1992; LATA 1992). As a result of these activities, three types of subsurface barrier systems have emerged for further consideration: (1) chemical grout barriers, (2) freeze wall barriers, and (3) desiccant barriers. These barrier concepts may be installed in either close-coupled (against the tank structure) or standoff (with a soil layer between the tank and barrier) configurations. A later study performed by Kaiser Engineers Hanford estimated the cost and effectiveness of three subsurface barrier designs for Tank 241-C-106, an SST at the Hanford Site (KEH 1993). These studies were used as starting points for the general evaluation of the applicability of subsurface barriers to support retrieval of waste from SSTs.

The evaluation of subsurface barrier applications and their environmental impacts can be found in WHC (1994b). Twenty-four subsurface barrier concepts were investigated, and the concepts were divided into a group of 13 viable and 11 nonviable options. The rationale behind the viability decision for each concept is also provided in WHC (1994b). In general, less viable concepts would generate large amounts of contaminated spoils and/or were deemed impractical for use around Hanford Site tanks or tank farms.

The 13 viable subsurface barrier concepts were categorized by the overall method of confinement presented by the option. Ten concepts employed standoff barriers and three employed close-coupled barriers. Each of the close-coupled alternatives involves injection of chemical grout into the soil next to the tank to create a barrier that encompasses the tank walls and bottom (Figure 6). One option calls for "flushing" the soil prior to the injection of the barrier-forming chemicals. Flushing would be used to remove as many contaminants as possible prior to the creation of the close-coupled barrier.

Some of the standoff barrier alternatives utilized the same chemicals proposed for the close-coupled option, but instead of injecting the chemicals to form a barrier in contact with the tanks, the chemicals would form a box (Figure 7) or a V-shaped barrier basin (Figure 8) that would serve to prevent leaks from reaching the water table. One standoff option utilizes a freeze-wall barrier formed from ice instead of chemicals. Freeze pipes would be installed in a V-shaped configuration around and beneath the tanks, and internal pipes would be installed in each freeze pipe. Refrigerated coolant would be pumped down the inside pipe and

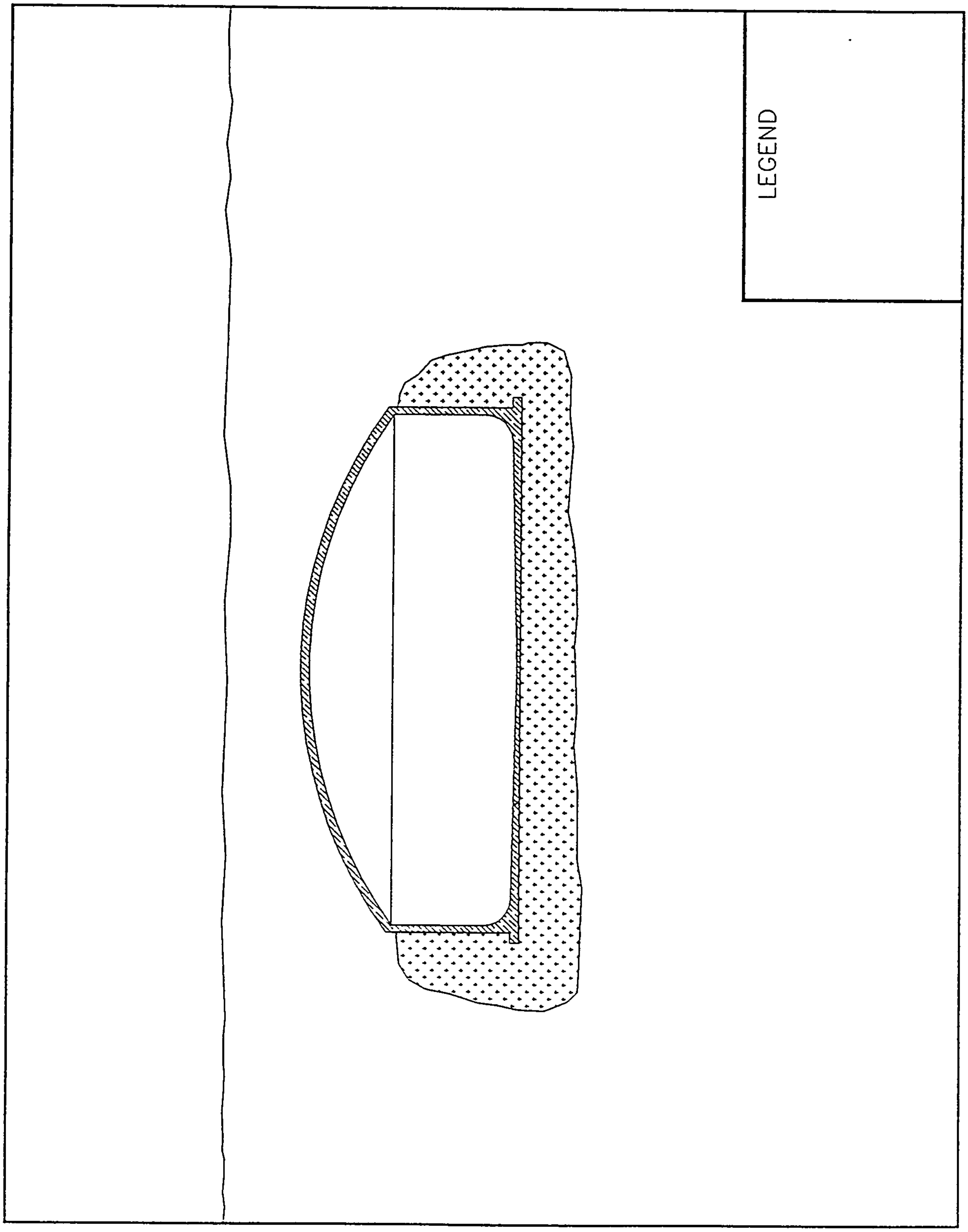

Figure 6. Close-Coupled Chemical Barrier.

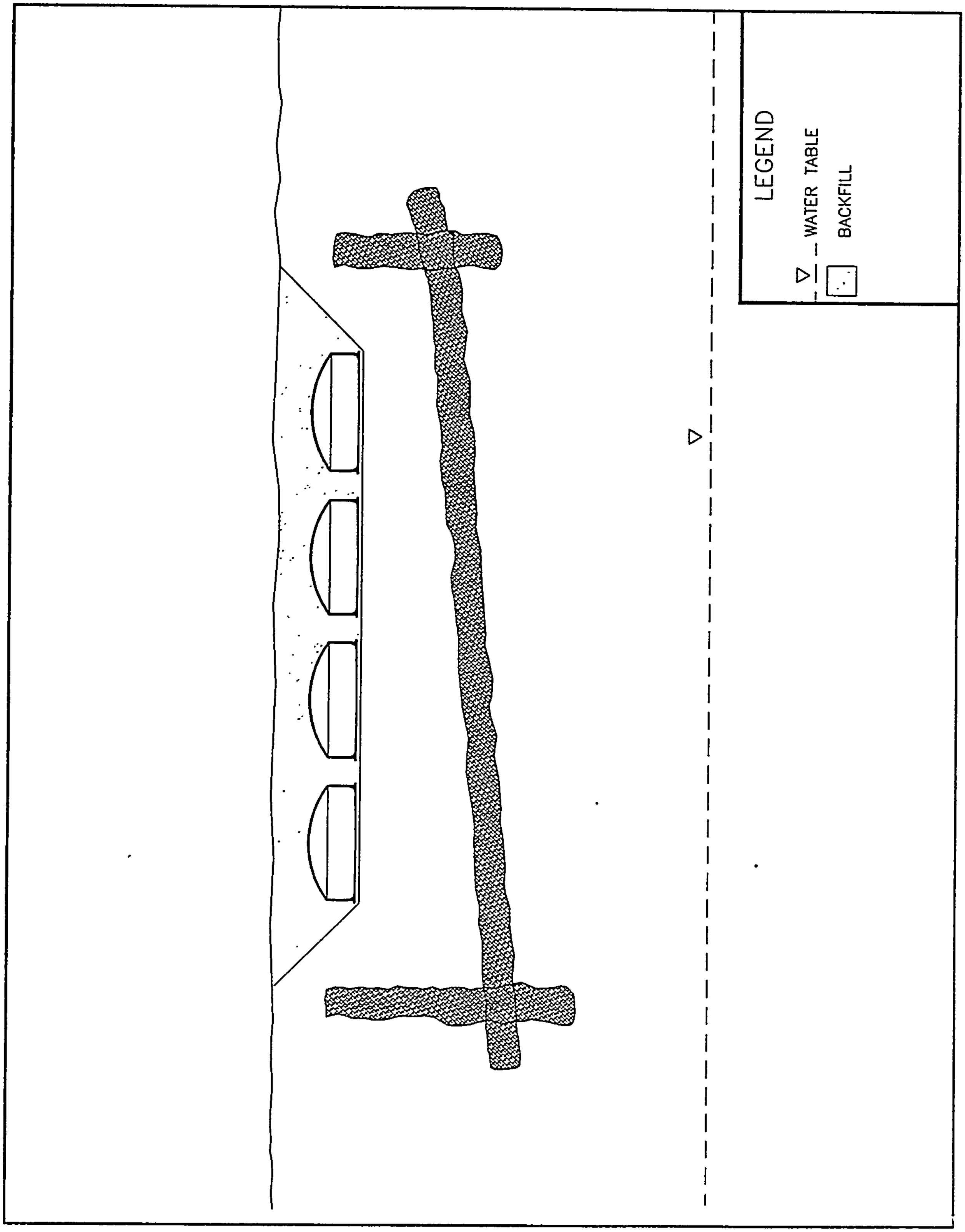

Figure 7. Box-Shaped Chemical Barrier.

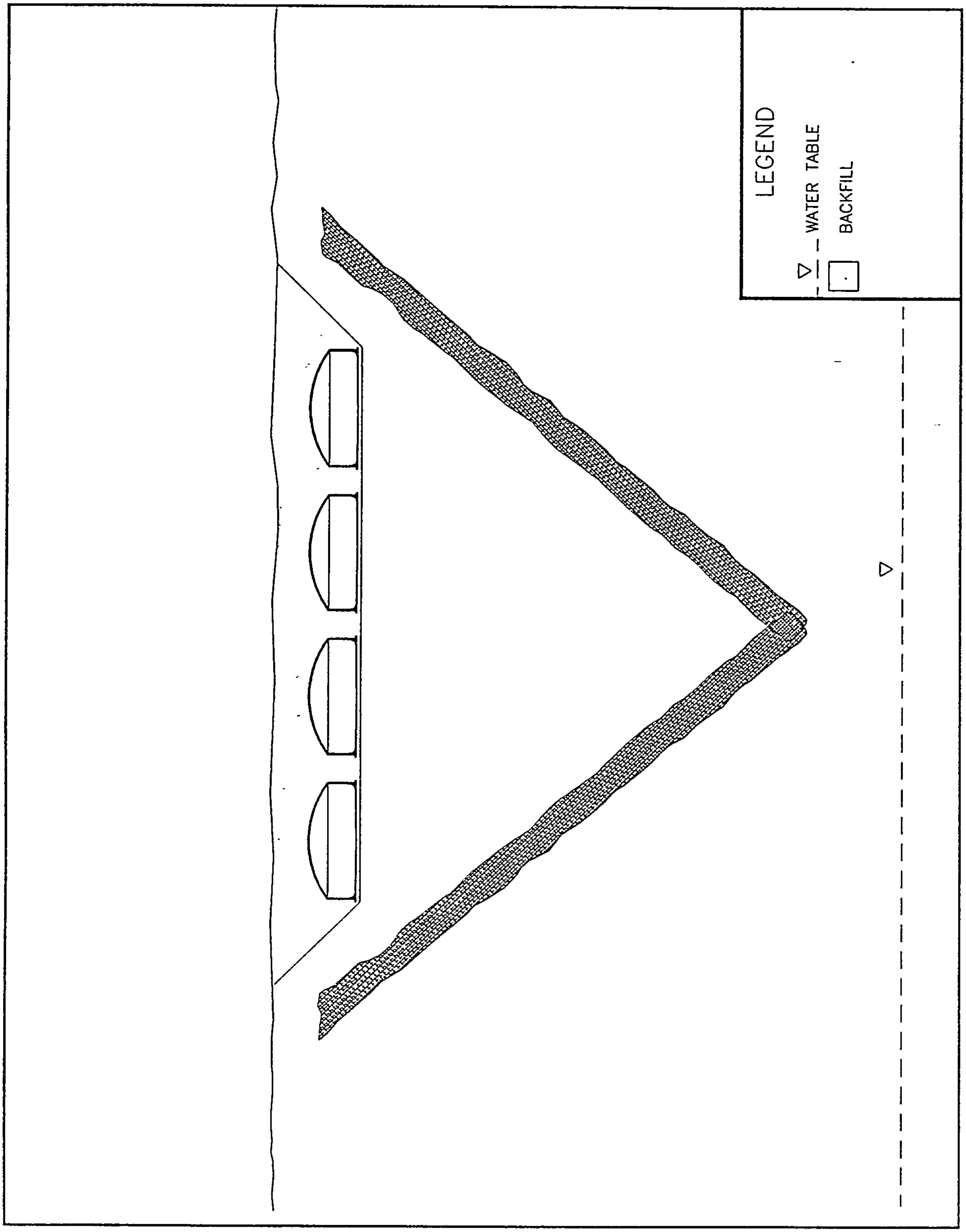

Figure 8. V-Shaped Chemical or Freeze Wall Barrier.

returned through the annulus. The addition of water to the soil may be required in this option in case the natural water content of the soil is insufficient to form an effective barrier.

The last standoff barrier alternative evaluated was a type of desiccant barrier (circulating air barrier) that would use the circulation of warm dry air through the soil to remove moisture (Figure 9). This alternative would rely on evaporation of water from the soil, thereby limiting the ability of a leak to migrate through the vadose zone.

Clean-closure using a close-coupled chemical barrier was the last subsurface barrier option evaluated. Where the other subsurface barrier alternatives would close the tank waste sites as landfills in-place by using grout stabilization and a surface barrier, clean-closure would remove all contaminated tank structures and soils following retrieval of wastes from the tanks. The use of the subsurface barrier in the clean-closure alternative would limit the depth of leakage into the soil and the volume of contaminated soil requiring excavation and treatment.

These subsurface barrier technologies and other supporting technologies were combined selectively into eight alternatives for evaluation. The alternatives were chosen to enable evaluation of a representative range of different types of subsurface barriers, retrieval methods, soil flushing methods, and the use of tank stabilization and surface barriers as parts of an overall tank cleanout and closure strategy. The primary features of each alternative are summarized in Table 3.

A quantitative assessment of overall costs and risks associated with barrier versus non-barrier options was prepared in WHC 1994b. First approximations of carcinogenic risk and noncarcinogenic hazards to the maximally exposed individual for 30,000 years were estimated using the MEPAS computer code. Overall costs and results of the risk analysis of alternatives that include subsurface barriers is contained in Table 4. Table 4 includes the results of Table 2 to facilitate comparison of alternatives with and without subsurface barriers.

4.0 CONCLUSIONS

The activities described in the previous sections served as the basis for the following conclusions regarding the three objectives of Tri-Party Agreement Milestone M-45-07A:

- Taking no action would result in risks approximately three orders of magnitude higher than the assumed upper limit (10^{-4}) of the target risk range.
- Taking no action other than capping a tank farm with a surface barrier capable of limiting recharge to 0.05 cm/yr (0.02 in/yr) may result in acceptable risks for some tanks, but only if collapse of the tank domes could be prevented.

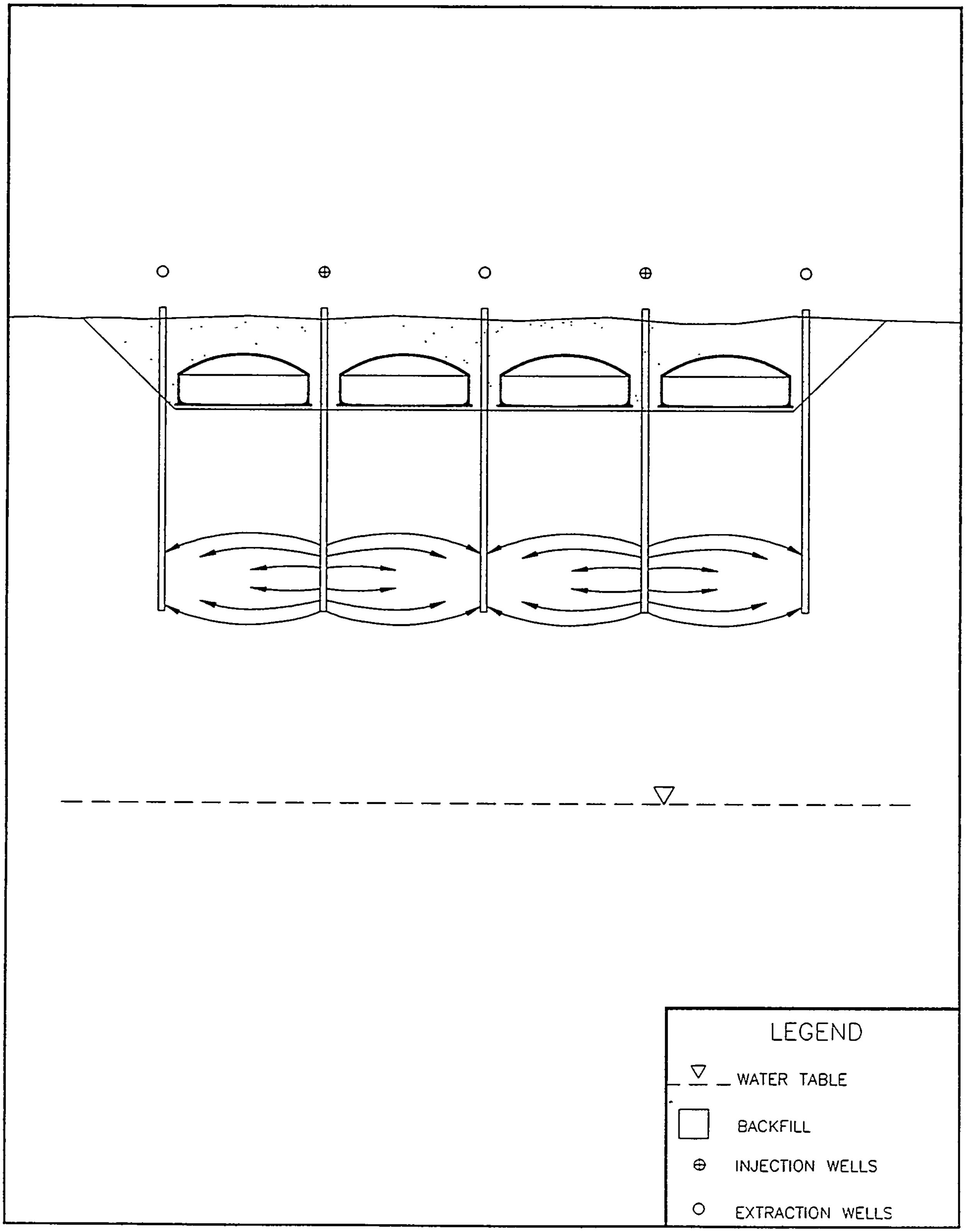

Figure 9. Circulating Air Barrier.

Table 3. Summary of Alternatives With Subsurface Barriers.

Alternative	Waste Retrieval Type	Assumed Tank Waste Retrieval Effectiveness	Subsurface Barrier Type	Old Leaks Flushed?	New Leaks Flushed?	Tanks Stabilized?	Surface Barrier Used?
Close-Coupled Chemical Barrier with Flushing	Traditional sluicing	99%	Close-coupled	Yes	Not Applicable	Yes	Yes
Close-Coupled Chemical Barrier w/o Flushing	Traditional sluicing	99%	40% None 60% Close-Coupled	No	No	Yes	Yes
Modified Close-Coupled Chemical Barrier w/o Flushing	Traditional sluicing	99%	Vertical Close-Coupled	No	No	Yes	Yes
Box-Shaped Chemical Barrier	Traditional sluicing	99%	Box-shaped chemical	Yes	Yes	Yes	Yes
V-Shaped Chemical Barrier	Traditional sluicing	99%	V-shaped chemical	Yes	Yes	Yes	Yes
V-Shaped Freeze Wall Barrier	Traditional sluicing	99%	V-shaped freeze wall	Yes	Yes	Yes	Yes
Circulating Air Barrier	Traditional sluicing	99%	Circulating air	Yes	Yes	Yes	Yes
Clean-Closure with Close-Coupled Chemical Barrier	Traditional sluicing	100%	40% None 60% Close-Coupled	No	No	Not Applicable	No

Table 4. Summary of Overall Costs and Projected Risks to the Maximally Exposed Individual Using Contaminated Groundwater (With and Without Subsurface Barriers).

Alternative	Total Net Present Worth Costs (in millions of dollars)	Incremental Carcinogenic Risk[a]	Hazard Index[b]
1. No Action	0	1.5E-01	2.8E+03
2. Surface Barrier Only	6	3.7E-04	8.6E+00
3. Traditional Sluicing (Baseline)	107	1.1E-05	2.4E-01
4. Robotic Sluicing	316	2.5E-06	5.7E-02
5. Mechanical Retrieval	244	2.1E-05	4.9E-01
6. Close-Coupled Barrier with Flushing	742	5.2E-06	1.2E-01
7. Close-Coupled Barrier w/o Flushing	293	7.0E-06	1.6E-01
8. Modified Close-Coupled Barrier w/o Flushing	265	8.0E-06	1.8E-01
9. Box-Shaped Chemical Barrier	727	4.9E-06	1.1E-01
10. V-Shaped Chemical Barrier	857	4.9E-06	1.1E-01
11. V-Shaped Freeze Wall Barrier	937	4.8E-06	1.1E-01
12. Circulating Air Barrier	702	5.1E-06	1.2E-01
13. Clean-Closure w/o Subsurface Barrier	1965	1.1E-07	2.4E-03
14. Clean-Closure with Barrier	1962	6.3E-08	1.4E-03

(a) An incremental carcinogenic risk range of 10^{-4} to 10^{-6} is normally specified for cleanup of hazardous waste sites.
(b) A hazardous index of less than 1 is normally specified.

Note: Shading denotes alternative without subsurface barrier.

- The use of either traditional sluicing (assumed capable of achieving 99% tank waste retrieval), robotic sluicing (99.9% retrieval), or mechanical retrieval (95% retrieval), in combination with stabilizing the structure of emptied tanks and using a surface barrier, appears potentially capable of attaining the target risk range for most tanks.

- The retrieval of all tank waste, including tank structures and contaminated soil to effect clean-closure, would likely result in bettering the risk range. The landfill created to contain washed, retrieved soil and debris from the tank farm would represent a new, but relatively small source of risk.

- The clean-closure alternatives would be about as cost-effective as other tank waste retrieval alternatives assuming that all recovered contaminants of environmental concern would be destroyed or treated and disposed offsite in a Federal repository, and assuming that benefit can be represented as a ratio of initial risk to achieved risk. If benefit is represented by the difference in these risks, the cost-benefit is two to eight times lower than for the other retrieval alternatives.

- Functional requirements have been established in a companion document, *Functions and Requirements for Single-Shell Tank Leakage Mitigation* (Cruse 1994). All functional requirements potentially can be satisfied using any of the subsurface barrier options evaluated.

- The use of any of the subsurface barrier concepts (chemical, freeze wall, and circulating air in close-coupled and standoff configurations) in general applications to tank farms would result in a relatively small incremental reduction in the risk level achievable using baseline technologies. (Baseline technologies include traditional sluicing, emptied-tank stabilization, and surface barriers.)

- The use of a close-coupled barrier to support clean-closure activities may be cost-effective in comparison to the clean-closure alternative without a barrier because it would limit the volume and reduce the cost of contaminated soil requiring excavation and treatment, while reducing risk.

- Except for the clean-closure application, cost-effectiveness of subsurface barrier technologies is essentially equal and relatively low. The cost-effectiveness of the subsurface barriers, calculated by the method most favorable to subsurface barriers, is about 0.0001 times that of surface barriers, and 0.01 times that of the set of baseline technologies.

- Uncertainty in the performance of subsurface barriers is high, but because the impact of subsurface barriers on risk and cost-effectiveness is very low, even best-case assumptions of subsurface barrier performance have a relatively small effect on improving overall risk and cost-effectiveness of SST disposal options.

- More conservative assumptions could easily lead to order of magnitude or higher projections of risk, thereby potentially rendering some alternatives without subsurface barriers incapable of achieving the target risk range. In the event a conservative analysis is required by the decision makers as a basis for establishing cleanup requirements, the use of subsurface barriers may be necessary to reduce risks sufficiently to satisfy all conditions of a closure permit.

These conclusions were based on the ability of subsurface barriers to reduce risk and improve cost-effectiveness in general-use applications to tank farms. A broader set of values beside risk and cost-effectiveness should be considered. Conclusions presented here may be modified as a result. Investigation of the merits of selective applications of subsurface barriers should also be made, i.e., (1) to tanks that have exhibited high leakage rates during previous operations, (2) where highly conductive soils exist, potentially promoting high leakage rates, and (3) to support cleanup of the most contaminated soils by enabling soil flushing without driving contaminants to the groundwater.

5.0 TECHNICAL ASSISTANCE

The feasibility study for subsurface barriers was performed by Westinghouse Hanford Company and its subcontractors Enserch Environmental Corporation; Bovay Northwest, Inc.; and Battelle Pacific Northwest Laboratory. The names and contact information for the technical team are listed below:

Westinghouse Hanford Company
- G.D. (Jerry) Bazinet, 509/376-3059, Program Manager
- J.M. (Jon) Cruse, 509/372-1024, Team Leader, Functions and Requirements
- L.A. (Les) Fort, 509/372-0385, Waste Retrieval Program
- K.L. (Ken) Hampsten, 509/376-3127, Program Lead
- S.S. (Steve) Lowe, 509/376-2023, Mission Analysis

Advanced Systems Technology, Inc.
- T.J. (Tom) McLaughlin (formerly with Bovay Northwest, Inc.), 509/375-1938, Concepts Definition

Battelle Pacific Northwest Laboratory
- A.J. (Alan) Brothers, 509/372-4227, Decision Analysis

Bechtel Hanford Inc.
- K.A. (Kevin) Lindsay (formerly with Westinghouse Hanford Company), 509/375-4640, Geology
- E.H. (Ed) Smith (formerly with Westinghouse Hanford Company), 509/375-4640, Regulatory Assessment

Bovay Northwest, Inc.
S.L. (Sara) Lindberg, 509/946-6220, Project Support
J.K. (Jim) Rouse, 509/946-6220, Concepts Definition

Enserch Environmental Corporation (formerly Ebasco Environmental, A Division of Ebasco Services Incorporated)
W.D. (Dave) McCormack, 206/451-4617, Risk Assessment
R.L. (Russ) Treat, 509/372-5812, Risk Assessment
T. (Tina) Trenkler, 206/451-4616, Risk Assessment
M.F. (Fliegle) Walters, 509/372-5800, Cost Estimating

University of Southern California
Richard John, 213/740-4012, Decision Analysis

6.0 REFERENCES

Cruse, J.M., 1994, *Functions and Requirements for Single-Shell Tank Leakage Mitigation*, WHC-SD-WM-FRD-019, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

Ecology, EPA, and DOE, 1994, *Hanford Federal Facility Agreement and Consent Order, Fourth Amendment, January 1994*, Washington State Department of Ecology, U.S. Environmental Protection Agency, and the U.S. Department of Energy, Olympia, Washington.

KEH, 1993, *Engineering Study for Subsurface Barriers*, ER3547ES, Kaiser Engineers Hanford Company, Richland, Washington.

Lowe, S.S., W.C. Carlos, J.J. Irwin, R. Khaleel, N.W. Kline, J.D. Ludowise, R.M. Marusich, and P.D. Rittman, 1993, *Engineering Study of Tank Leaks Related to Hydraulic Retrieval of Sludge from Tank 241-C-106*, WHC-SD-WM-ES-218, Rev. 1, Westinghouse Hanford Company, Richland, Washington.

Lowe, S.S. and J.M. Cruse, 1994, *Mission Analysis Report for Single-Shell Tank Leakage Mitigation*, WHC-SD-WM-MAR-001, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

WHC, 1994a, *Qualitative Risk Assessment of Subsurface Barriers in Applications Supporting Retrieval of SST Waste*, WHC-SD-WM-RA-010, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

WHC, 1994b, *Feasibility Study of Tank Leakage Mitigation Using Subsurface Barriers*, WHC-SD-WM-ES-300, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

WHC, 1994c, *Regulatory Analysis for the Use of Underground Barriers at the Hanford Site Tank Farms*, WHC-SD-EN-RD-010, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

Bovay Northwest Inc., 1992, *Interim Subsurface Barrier Technologies Workshop Report*, prepared for WHC under Contract No. MDR-SVV-274303, Bovay Project No. 1842-001, Richland, Washington.

LATA, 1992, *Single-Shell Tank Barrier Technologies Assessment*, prepared for WHC under Contract No. MGM-SVV-032915, Task 19, Los Alamos Technical Associates, Richland, Washington.