

APPENDIX F

**COST AND IMPLEMENTABILITY OF
INTERIM MEASURES AND
INTERIM CORRECTIVE MEASURES**

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LIST OF TERMS

ICM	interim corrective measure
WMA	waste management area

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F.1.0 INTRODUCTION

This “Cost And Implementability of Interim Measures and Interim Corrective Measures” appendix describes the interim measures and interim corrective measures (ICMs) that have been evaluated as they relate to the waste management area (WMA) S-SX. Interim measures are initial response actions that can be taken while characterization activities are underway and long-term strategies are being developed to reduce the impacts of tank leaks on groundwater. Interim measures do not require comprehensive evaluation in a corrective measures study. ICMs are response actions having the objective of reducing contaminant migration to groundwater to acceptable regulatory levels and which require a balancing of risk, benefits, and costs.

Interim measure response actions that have been studied are discussed and how these interim measures are being implemented is addressed. Interim measures identified to date focus on actions to minimize infiltration and contaminant migration to groundwater. This appendix also provides estimated costs for implementing the interim measures at WMA S-SX as reflected in *Engineering Report, Single-Shell Tank Farms Interim Measures to Limit Infiltration Through the Vadose Zone* (Anderson 2001).

In general, ICMs involve a substantial commitment of resources, require a more thorough evaluation, and are intended to provide a more permanent solution to the long-term threats posed by a release. For those measures where engineering studies have been performed, results from those studies will be summarized. For other potential ICMs, it is premature to provide a detailed discussion of the associated cost and implementability issues. Detailed evaluation of the ICMs will be undertaken in a corrective measures study, or an accelerated corrective measures study pending results of this field investigation report.

F.2.0 INTERIM MEASURES

The engineering report (Anderson 2001) was prepared to assess potential measures to limit infiltration through the vadose zone at the single-shell tank farms. That study evaluates leaking water lines, wells within the single-shell tank farms, and surface water (both recharge and run-on). Included in this study are a number of interim measures that are ‘good housekeeping’ actions, which should be considered for implementation because they would reduce water infiltration at the tank farms and limit the migration of contamination through the vadose zone. The recommended interim measures include the following:

- Abandoning all active water lines within and near the tank farms
- Decommissioning unfit-for-use wells within the tank farms
- Establishing control measures to prevent water from running onto the tank farm from outside the fence.

These three measures could be implemented without a detailed technical evaluation. Summaries of the work that has been performed in these areas are provided in the following sections.

F.2.1 ABANDONING ACTIVE WATER LINES

Combined, the S and SX tank farms have approximately 1,930 m (6,300 ft) of active water lines that have been abandoned to eliminate persistent leaks and prevent future water line breaks. These lines were mainly installed during original tank farm construction and have exceeded their design life.

F.2.2 DECOMMISSIONING UNFIT-FOR-USE WELLS

Wells that are unfit for use are potential preferential pathways for contaminant migration to reach the groundwater. The engineering report (Anderson 2001) identifies a number of wells in the S and SX tank farms that should be decommissioned.

F.2.3 BERMS

Run-on control consists of berms, ditches, and asphalt curbs constructed outside the water control area to prevent surface water outside the tank farm from flowing on the tank farm areas. The engineering report (Anderson 2001) recommends that, regardless of which interim measures are selected to reduce infiltration within the WMA, run-on control be established to prevent surface water from entering the WMA from outside sources. Run-on controls have been constructed at the S, SX, T, TX, TY, and U tank farms.

F.3.0 INTERIM CORRECTIVE MEASURES

ICMs have the same overall purpose as interim measures. Because of their size, complexity, or impact to operations, a more careful study must be performed before ICMs are implemented. Many potential ICMs have been identified; however, it is recognized that some of these potential ICMs are likely to be implemented sooner than others. Thus, this section describes the two sets of ICMs separately.

F.3.1 IDENTIFICATION OF POTENTIAL NEAR-TERM INTERIM CORRECTIVE MEASURES

The activities that have been undertaken to identify potential ICMs for the WMAs are described below.

- In 1992 an engineering study that evaluated 4 approaches for reducing surface infiltration at the WMAs (Young et al. 1992) was completed. The approaches evaluated were (1) polymer-modified asphalt, (2) fine-soil cover, (3) buildings (structures), and (4) flexible membrane liners. The engineering study concluded that implementation of these approaches for all of the WMAs ranged from \$40 million to \$158 million. Cost and other factors were the reasons that none of the approaches were implemented.
- On May 4 through 6, 1999 an innovative treatment remediation demonstration forum was held in Richland, Washington to discuss techniques for reducing and monitoring infiltration at the single-shell tank farms. The U.S. Department of Energy, Hanford Site contractors and various vendors from throughout the United States and Canada attended. Pacific Northwest National Laboratory summarized this conference in a two-volume report, *Reducing Water Infiltration Around Hanford Tanks* (Molton 1999). Four technical sessions were conducted to discuss (1) moisture monitoring and characterization, (2) structures or buildings to cover the WMAs, (3) surface modifications or covers, and (4) near-surface modifications (barriers and permeability reduction techniques). The forum concluded that existing commercial capabilities could be employed to reduce and monitor infiltration in the WMAs, but that no one technology was appropriate for all seven WMAs. Another conclusion of the forum was that the costs shown in Young, Schroeder, and Carver (1992) were 50% to 80% higher than those reflected by the vendors attending the forum. During the course of the forum a number of U.S. Department of Energy officials and U.S. Department of Energy site subcontractors addressed site-specific constraints that the vendors may not have been taken into account before they submitted their estimated or typical-unit costs.
- In June 2000 the U.S. Department of Energy prepared *Phase 1 RCRA Facility Investigation/Corrective Measures Study Work Plan for Single-Shell Tank Waste Management Areas* (DOE-RL 2000). Section 4.2 of DOE-RL (2000) identifies a number of general response actions, technology and process options associated with each general response action, and screened each option based on effectiveness, ability to implement, worker safety and cost. While the majority of the processes discussed fell into the ICM category, surface caps, overhead structures and run-on and run-off controls, that are considered interim measures, were identified.

- In April 2001 an engineering report (Anderson 2001) was completed. In addition to evaluating water lines and wells within the WMAs, the report also evaluated surface water both from natural causes and catastrophic events. Alternatives considered in that report include (1) no action, (2) site grading, (3) geo-fabric liners, (4) asphalt concrete paving, (5) building enclosure with asphalt apron, and (6) run-on control. The report recommends that a combination of a building enclosure with asphalt apron and run-on control be implemented. While the building enclosure was not the preferred option (because of the cost) the report concluded that it provided the best operational and technical alternative.

The three potentially viable interim corrective measures selected from among those identified were (1) near-surface barriers, (2) surface barriers, and (3) overhead structures.

F.3.2 NEAR-SURFACE BARRIER

This section describes and evaluates the near-surface barrier option as a near-term ICM, its implementation at WMA S-SX, and costs.

F.3.2.1 Description

The near-surface barrier would consist of an impervious, geo-fabric (geomembrane liner or geosynthetic clay) system over the entire WMA S-SX to direct surface water to the outer boundaries of the tank farm. A run-off collection system consisting of ditches and pipes would be required to route collected surface water to existing drainage routes.

F.3.2.2 Implementation at Waste Management Area S-SX

Implementation of a near-surface barrier would be disruptive to other tank farm activities. The entire area, 18,000 m² (194,000 ft²) at the S tank farm and 20,500 m² (220,000 ft²) at the SX tank farm, would require hand excavation to remove 30 cm (12 in.) of existing soil and subsequent replacement of this soil as a cover over the liner to allow for traffic. The soil would have to be hand excavated because of the tank dome-loading restrictions and the many utilities within the tank farm. Some of these utilities may require support during construction or relocation to a depth below the liner. Installation of the near-surface barrier would require additional time from a typical installation because of the many obstructions protruding above the surface. During the period that the near-surface barrier is required to control surface water, repairs would be required if any tank farm activities required work below the liner.

F.3.2.3 Cost

The estimated costs cited in the engineering report (Anderson 2001) for implementation of a subsurface barrier are \$7.1 million for the S tank farm and \$8.1 million for the SX tank farm.

F.3.2.4 Evaluation Criteria

Tables F.1 and F.2 show decision criteria, weight factors, and score for the near-surface barrier option. For this evaluation, the weight factor was multiplied by one through five to determine the weighted score. A score of one represents little or no impact of the activity to the decision

criterion, and a score of five represents a greatly increased impact of the activity. Note that the weighted factor and decision criteria are the same for all three viable ICMs.

Table F.1. S Tank Farm Near-Surface Barrier Evaluation

Decision Criteria	Weight Factor	Score	Weighted Score	Highest Possible
Safety	5	4	20	25
Regulatory compliance	3	1	3	15
Life cycle cost analysis	2	2	4	10
Tank integrity	5	3	15	25
Future retrieval and processing	4	2	8	20
Schedule	3	3	9	15
Proven technology	3	1	3	15
Maintainability	3	3	9	15
Operability	2	2	4	10
Constructability	3	4	12	15
Decontamination, decommissioning, and disposal	4	3	12	20
Total Weighted Score			99	185

Source: Anderson (2001).

Table F.2. SX Tank Farm Near-Surface Barrier Evaluation

Decision Criteria	Weight Factor	Score	Weighted Score	Highest Possible
Safety	5	4	20	25
Regulatory compliance	3	1	3	15
Life cycle cost analysis	2	2	4	10
Tank integrity	5	3	15	25
Future retrieval and processing	4	2	8	20
Schedule	3	3	9	15
Proven technology	3	1	3	15
Maintainability	3	2	6	15
Operability	2	2	4	10
Constructability	3	3	9	15
Decontamination, decommissioning, and disposal	4	3	12	20
Total Weighted Score			93	185

Source: Anderson (2001).

F.3.3 INTERIM SURFACE BARRIER

This section describes and evaluates the interim surface barrier option as a near-term ICM, its implementation at WMA S-SX, and cost.

F.3.3.1 Description

The only surface barrier evaluated is a 6 cm (2.5 in.) layer of asphalt cement pavement. Surface barriers that were not evaluated, but have been used successfully on other projects include various liquid and solid reagents that are applied and allowed to penetrate the surface materials or are mixed with the surface materials to form a crust. A run-off collection system consisting of ditches and pipes would be required to route collected surface water to existing drainage routes.

F.3.3.2 Implementation at Waste Management Area S-SX

Implementation of a surface barrier would be disruptive to other tank farm activities. The entire area, 18,000 m² (194,000 ft²) at the S tank farm and 20,500 m² (220,000 ft²) at the SX tank farm, would require hand excavation to remove 10 cm (4 in.) of existing gravel cover, which would be taken from the site and disposed of if contaminated or used in the production of the asphalt. The material would have to be hand excavated because of the tank dome-loading restrictions and the many utilities within the tank farm. Some of these utilities may require relocation if they are near the surface following removal of the 10 cm (4 in.) of existing materials. Installation of the surface barrier would also take additional time from typical installations to seal the numerous obstructions protruding above the surface.

Adequate compaction of both the subgrade and the asphalt will not be obtained because of the obstructions within the tank farm and the tank dome-loading restrictions. During the period that the surface barrier is required to control surface water, traffic loading may do substantial damage to the surface barrier. The cost to repair the asphalt barrier using the special fine mix could be excessive.

F.3.3.3 Cost

The estimated costs cited in the engineering report (Anderson 2001) for implementation of a surface barrier are \$3.4 million for the S tank farm and \$3.9 million for the SX tank farm.

F.3.3.4 Evaluation Criteria

Tables F.3 and F.4 show decision criteria, weight factors, and score for the interim surface barrier option. For this evaluation, the weight factor was multiplied by one through five to determine the weighted score. A score of one represents little or no impact of the activity to the decision criterion, while a score of five represents a greatly increased impact of the activity. Note that the weighted factor and decision criteria are the same for all three viable ICMs.

Table F.3. S Tank Farm Interim Surface Barrier Evaluation

Decision Criteria	Weight Factor	Score	Weighted Score	Highest Possible
Safety	5	3	15	25
Regulatory compliance	3	1	3	15
Life cycle cost analysis	2	3	6	10
Tank integrity	5	3	15	25
Future retrieval and processing	4	3	12	20
Schedule	3	3	9	15
Proven technology	3	2	6	15
Maintainability	3	4	12	15
Operability	2	2	4	10
Constructability	3	4	12	15
Decontamination, decommissioning, and disposal	4	4	16	20
Total Weighted Score			110	185

Source: Anderson (2001).

Table F.4. SX Tank Farm Interim Surface Barrier Evaluation

Decision Criteria	Weight Factor	Score	Weighted Score	Highest Possible
Safety	5	3	15	25
Regulatory compliance	3	1	3	15
Life cycle cost analysis	2	3	6	10
Tank integrity	5	3	15	25
Future retrieval and processing	4	3	12	20
Schedule	3	3	9	15
Proven technology	3	2	6	15
Maintainability	3	2	6	15
Operability	2	2	4	10
Constructability	3	3	9	15
Decontamination, decommissioning, and disposal	4	4	16	20
Total Weighted Score			101	185

Source: Anderson (2001).

F.3.4 OVERHEAD STRUCTURE

This section describes and evaluates the overhead structure option as a near-term ICM, its implementation at WMA S-SX, and cost.

F.3.4.1 Description

The overhead structure would consist of an enclosed shelter covering the majority of the surface water control area of the WMA. An asphalt apron would be constructed around the perimeter of the structure to capture surface water and route that water to a run-off collection system.

F.3.4.2 Implementation at Waste Management Area S-SX

Erection of the overhead structure would be more complicated than typical erections because of tank dome-loading limitations. This option may require larger-than-normal cranes for erection of the structure and coverings. To span the entire width of the S or SX tank farm (104 m [340 ft] and 107 m [350 ft], respectively) would limit the weight of equipment that could be attached to the structure (e.g., monorails; lighting; heating, ventilation, and air conditioning). Engineers would have to determine if foundations could be constructed in between the tanks at the S and SX farms to decrease the free span distance and to allow greater auxiliary loading of the structures' supports.

The evaluation of which overhead structure to construct must take into account the free span distances of 104 m (340 ft) and 107 m (350 ft). To provide a structure with this free span, a rigid-framed structure may be required. An evaluation should be made of intermediate supports to be located between the tanks. This would allow the structure to be equipped with accessories that may increase productivity of future tank farm operations (e.g., monorail; lighting; and heating, ventilation, and air conditioning). The use of intermediate supports would also allow the use of enclosure systems other than a rigid-framed structure.

The evaluation of overhead structures should also include recently emerging or advanced technologies, (e.g., a domed structure). This technology is purported to provide greater strengths at less cost than conventional structures.

F.3.4.3 Cost

The estimated costs presented in the engineering report (Anderson 2001) for implementation of a building enclosure with an asphalt apron are \$18.3 million for the S tank farm and \$20.8 million for the SX tank farm. Depending on the closure technology used at WMA S-SX, a confinement facility would be required (DOE-RL 2000). If a confinement facility is not required, production would be increased 30% by working within an enclosure (Anderson 2001). Credit was not given to these items in determination of the costs.

F.3.4.4 Evaluation Criteria

Tables F.5 and F.6 show decision criteria, weight factors, and score for the overhead structure option. For this evaluation the weight factor was multiplied by one through five to determine the weighted score. A score of one represents little or no impact of the activity to the decision

criterion, while a score of five represents a greatly increased impact of the activity. Note that the weighted factor and decision criteria are the same for all three viable ICMs.

Table F.5. S Tank Farm Overhead Structure Evaluation

Decision Criteria	Weight Factor	Score	Weighted Score	Highest Possible
Safety	5	2	10	25
Regulatory compliance	3	1	3	15
Life cycle cost analysis	2	5	10	10
Tank integrity	5	2	10	25
Future retrieval and processing	4	1	4	20
Schedule	3	2	6	15
Proven technology	3	1	3	15
Maintainability	3	2	6	15
Operability	2	1	2	10
Constructability	3	2	6	15
Decontamination, decommissioning, and disposal	4	4	16	20
Total Weighted Score			76	185

Source: Anderson (2001).

Table F.6. SX Tank Farm Overhead Structure Evaluation

Decision Criteria	Weight Factor	Score	Weighted Score	Highest Possible
Safety	5	2	10	25
Regulatory compliance	3	1	3	15
Life cycle cost analysis	2	5	10	10
Tank integrity	5	2	10	25
Future retrieval and processing	4	1	4	20
Schedule	3	2	6	15
Proven technology	3	1	3	15
Maintainability	3	2	6	15
Operability	2	1	2	10
Constructability	3	2	6	15
Decontamination, decommissioning, and disposal	4	4	16	20
Total Weighted Score			76	185

Note: No credit was given for an estimated 30% productivity improvement for tank farm activities following structure construction or that closure activities may require an enclosure.

Source: Anderson (2001).

F.3.5 NEAR-TERM INTERIM CORRECTIVE MEASURES SUMMARY

This section summarizes the evaluation of the three potential near-term ICMs (near-surface barriers, surface barriers, overhead structures) and provides a comparison of the evaluation criteria and conclusions based on the evaluation. The near-surface barrier, surface barrier, and overhead structures options evaluated presented problems for implementation. Implementation of the near-surface and surface barriers would require extensive hand labor because of tank dome-loading restrictions and numerous obstructions protruding to the surface. Implementation of the overhead structures would require free span distances that may stretch the limits of current technologies involved in construction or would require foundations to be constructed in the area between tanks.

Table F.7 summarizes the estimated costs for each option by tank farm.

Table F.7. Interim Corrective Measures Cost Summary

Option	S Tank Farm Estimated Costs	SX Tank Farm Estimated Costs
Near-surface barriers	\$7,058,000	\$8,123,000
Surface barriers	\$3,373,000	\$3,892,000
Overhead structures	\$18,245,000	\$20,831,000

Table F.8 summarizes the evaluation criteria and weighted scores for the options evaluated for minimizing infiltration at the S and SX tank farms.

Table F.8. Interim Corrective Measures Evaluation Summary

Decision Criteria	Weighted Score S Tank Farm			Weighted Score SX Tank Farm		
	Subsurface Barrier	Surface Barrier	Overhead Structure	Subsurface Barrier	Surface Barrier	Overhead Structure
Safety	20	15	10	20	15	10
Regulatory compliance	3	3	3	3	3	3
Life cycle cost analysis	4	6	10	4	6	10
Tank integrity	15	15	10	15	15	10
Future retrieval and processing	8	12	4	8	12	4
Schedule	9	9	6	9	9	6
Proven technology	3	6	3	3	6	3
Maintainability	9	12	6	6	6	6
Operability	4	4	2	4	4	2
Constructability	12	12	6	9	9	6
Decontamination, decommissioning, and disposal	12	16	16	12	16	16
Total Weighted Score	99	110	76	93	101	76

Source: Anderson (2001).

WMA = waste management area.

Any of the three potential near-term ICMs could be implemented to reduce infiltration at WMA S-SX. The cost versus benefits (i.e., reduction in contaminant concentrations in the groundwater) of implementing any of the interim measures should be considered because sufficient time may have elapsed between when the leaks occurred and the present to effectively reduce the contaminant concentrations in the groundwater. Additionally implementing ICMs may divert funding from other tank waste remediation activities such as waste retrieval.

The evaluation of options in Anderson (2001) resulted in a recommendation to implement the overhead structure. This recommendation is based on the summary of the evaluation criteria that ranked the overhead structure lowest for both S and SX tank farms. The weighted scores presented are subjective and represent a best-estimate effort to account for the relative importance of the different evaluation criteria presented. The estimated cost for the overhead structure is considerably higher than the other options evaluated and this variation is not well captured in the weighted ranking. Anderson (2001) did not provide credit for an estimated 30% productivity gain for tank farm operations within the enclosure or that enclosure would be required for certain tank farm closure alternatives.

F.3.6 ADDITIONAL POTENTIAL INTERIM CORRECTIVE MEASURES

This section identifies additional potential ICMs for consideration at WMA S-SX. These ICMs generally involve a greater commitment of resources than the ICMs discussed in Section F.3.5 and require a more thorough site-specific evaluation prior to selecting an ICM for implementation at WMA S-SX. Any evaluation of ICMs must include consideration of continued storage of waste in the tanks and future plans to retrieve waste from the tanks as well as cost versus benefits of the technologies in terms of reducing groundwater impacts. If warranted, detailed evaluation of ICMs for WMA S-SX would be conducted in a corrective measures study.

F.3.6.1 Interim Corrective Measure Technologies for Soil Contamination

This section describes the ICM technologies for soil contamination that are described in the Phase 1 RFI/CMS work plan (DOE-RL 2000) and in *Feasibility Study of Tank Leakage Mitigation Using Subsurface Barriers* (Treat et al. 1995).

F.3.6.1.1 Containment Technologies. Containment technologies use physical measures to isolate and reduce the horizontal and vertical movement of contaminants.

Grout Walls. Grout walls are formed by either injecting grout under pressure directly into the soil matrix (permeation grouting) or in conjunction with drilling (jet grouting) at regularly spaced intervals to form a continuous low-permeability barrier. Grout walls could be installed either vertically or directionally in an effort to create a barrier underneath the contaminant plume in the soil (DOE-RL 2000). A large number of boreholes would be required to construct a barrier. A grout containment barrier was previously evaluated for the AX tank farm as a means to contain potential retrieval leakage (Norman 1999). In the AX tank farm study, grout injection borings were directionally drilled beneath the tanks on approximately 1.5 m (5 ft) centers. Installation of a horizontal grout blanket beneath the four tanks in the AX tank farm was estimated to cost approximately \$200 million. One of the issues identified with this technology

was the difficulty in verifying the integrity of the grout barrier. Grout walls are potentially applicable at WMA S-SX; however, the contamination has reached the groundwater and the ability to implement this technology and determine its effectiveness are of concern and would require further evaluation.

Cryogenic Barrier. Cryogenic (or freeze-wall) barriers are formed by recirculating chilled brine or other refrigerants through an array of closely spaced wells or freeze pipes. As the soil surrounding and between these wells or freeze pipes cools and freezes, the water in the voids freezes and expands. The freezing and expanding water effectively creates an impermeable barrier. Cryogenic barriers may be applicable at WMA S-SX although it is unclear if the technology would perform as planned if it were necessary to inject supplemental water into the highly transmissive soils of the Hanford Site. In addition, maintenance of a cryogenic barrier requires a long-term commitment of resources. Contamination has reached the groundwater, and the ability to implement this technology and determine its effectiveness is of concern and would require further evaluation.

Dynamic Compaction. Dynamic compaction is used to densify the soil; compact buried solid waste; and reduce the void spaces in the soil, which can reduce the hydraulic conductivity of the soil and the mobility of contaminants. This process is accomplished by dropping a heavy weight onto the ground surface. This technology is commonly used in coordination with caps; it would have limited application in the tank farm area because of the graveled surface and the potential tank dome-loading during the compaction process.

Circulating Air Barriers. The circulating air barrier technology would create a dry zone under the area of confinement through which no liquids could penetrate until a critical liquid saturation was exceeded. For most sediments at the Hanford Site, critical saturation is on the order of 5% to 25%. The water under the tanks is essentially immobile and, if kept at or below the critical saturation value, would remain immobile. Circulating air barrier technology injects dry air from an array of either vertical or horizontal wells. The air is forced through porous soils to extraction wells, vaporizing water in the process. Circulating air barrier technology is applicable at WMA S-SX although no large-scale field tests have been performed.

Radio Frequency Desiccating Subsurface Barriers. A radio frequency heating process can be used for the formation of an active desiccating barrier underneath underground storage tanks. Electrodes are installed in the soil between the source of the contamination and groundwater using horizontal drilling techniques. The radio frequency energy applied to the electrodes heats a 2 to 3 m (6 to 10 ft) thick layer of soil to temperatures above 100 °C (212 °F) to evaporate the moisture. Electrodes are perforated and maintained under vacuum to remove the steam and volatile organics for aboveground treatment and disposal. Radio frequency desiccating subsurface barriers may be applicable at WMA S-SX although the concept has not been tested at the Hanford Site.

Close-Coupled Injected Chemical Barriers. Unlike the concept of subsurface barriers installed at some depth below the tanks or below a containment plume as discussed previously for grout walls and cryogenic barriers, close-coupled injected chemical barriers are formed against the sides and bottom of an individual underground storage tank. It is unlikely that the close-coupled chemical barrier concept would be applicable at WMA S-SX because of the

problems of induced stresses on the tanks and the inability of installing a conical jet grout shell given the confining limitations among the Hanford Site underground storage tanks. In addition, the concept has not been tested outside of the laboratory.

Induced Liquefaction Barriers. Induced liquefaction is a close-coupled subsurface barrier option that combines the concepts of sheet metal piling to create a vertical barrier with caisson-drilled horizontal jet grouting. Although this technology may be applicable at WMA S-SX, no full-scale application of this technology for waste management or environmental restoration purposes is known.

F.3.6.1.2 Removal Technologies. Removal technologies include the excavation of contaminated soils or buried solid waste. After removal, the soil and debris may require ex situ treatment to meet disposal requirements or to reduce waste volume. Removal technologies could be considered for localized areas in the tank farms where leaks occurred from piping or diversion boxes at near-surface to mid-depth. Removal would not likely be effective for capturing the mobile contaminants because of the relatively high recharge rate in the tank farms and the elapsed time since the leaks occurred.

F.3.6.1.3 In Situ Treatment Technologies. In situ treatment technologies are oriented at treating the contamination in place to either extract the contaminants of concern or to stabilize and isolate contaminated soil to prevent migration to the groundwater.

Electrokinetic Separation. Electrokinetic separation can be used for organics, inorganics, and radioactive contaminants. This technology involves applying an electrical potential across the contaminated zone by using electrodes placed in the ground. Remediation by electrokinetics is based on the migration of water and ions in an electrical field. The application of electrokinetic separation at the tank farms may be limited since water is required to move ions between electrodes. Application in unsaturated soils may require water addition that could cause unwanted migration of contaminants.

In Situ Biodegradation. In situ biodegradation relies on microbial transformation of organic contaminants. Biodegradation is effective on organic contaminants but is not effective on radionuclides or inorganics. Therefore, this technology would have limited application in the tank farm area.

Solidification. Solidification can be used for organics, inorganics, and radiological contaminants. This process involves drilling holes to the desired depth, then injecting the solidification and stabilization agents into the soil with high-pressure pumps. Variations of solidification include jet injection and shallow-soil mixing. Jet injection involves drilling a small-diameter hole using a downward jet of air or water then pumping the solidification agent out laterally through jets located near the bottom of the drill pipe. Shallow-soil mixing is performed using a crane-mounted auger head to mix the soil and solidification agent. Solidification methods are potentially applicable at WMA S-SX. Access to contaminants beneath the tanks would be difficult and would require directional drilling or angle drilling. Solidification requires an understanding of the location and distribution of contaminants. Stabilization of large plumes extending from the base of the tank to the groundwater would

require a substantial commitment of time and resources. Solidification technologies would serve to delay the migration of contaminants to the groundwater.

Grout Injection. Grout is injected into the soil matrix, encapsulating the contaminants. The injection process produces a monolithic block that can be left in place or excavated for disposal elsewhere. Although grout injection is applicable at WMA S-SX, if the encapsulated contaminants are left in place future use of the site may be limited. Grouting contaminated soils deep in the vadose zone beneath the tanks would be an issue.

Deep Soil Mixing. Deep soil mixing is performed using large augers and injector-head systems to inject and mix solidifying agents into contaminated soil. Although deep soil mixing is applicable at WMA S-SX, if the encapsulated contaminants are left in place future use of the site may be limited. Using this technology to mix contaminated soil deep in the vadose zone directly beneath or adjacent to the tanks would be problematic.

Vitrification. Vitrification can be used for organics, heavy metals, and radionuclides. In situ vitrification involves the application of an electrical current to the soil to bring it to a temperature sufficient to melt the soil (1400 to 2000 °C [2552 to 3632 °F]). The process forms a stable, vitrified mass when cooled, chemically incorporates most inorganics including heavy metals and radionuclides, and destroys or removes all organic contaminants. In situ vitrification is probably not applicable at WMA S-SX because process depths are limited and the technology has very limited (extremely unlikely) potential for use in tank farms or near tanks that are storing waste.

Soil Flushing. Soil flushing can be used for organics, inorganics, and radioactive contaminants. In situ soil flushing involves the extraction of contaminants from the soil by injecting an extractant or elute (e.g., water or some other suitable solvent) through the contaminated soils. The extraction fluids solubilize or elute the contaminant from the soil. The resultant solution must be recovered through extraction wells and treated at the surface by a treatment system (e.g., ion-exchange system). Soil flushing is potentially applicable at WMA S-SX.

Soil Vapor Extraction. The soil vapor extraction process induces airflow through the soil matrix with an applied vacuum that facilitates the mass transfer of adsorbed, dissolved, or free phases of the contaminant to the vapor phase. Because soil vapor extraction is best used for volatile organic compounds and fuels, it would have limited application in the tank farm area.

Monitored Natural Attenuation. Monitored natural attenuation relies on natural processes to lower contaminant concentrations through physical, chemical, or other biological processes that, “under favorable conditions, act without human intervention to reduce the mass, toxicity, mobility, volume, or concentration of contaminants” (EPA 1999) until cleanup levels are met. Although natural attenuation methods may be readily implemented, significant action or commitment of resources (e.g., personnel to conduct sampling and perform analytical work, construction activity, and loss of land use) may be required.

F.3.6.1.4 Ex Situ Treatment Technologies. Ex situ technologies would be used in conjunction with removal technologies as discussed in Section F.3.6.1.2. Ex situ treatment technologies would have potential application for near-surface spills and leaks but would not have application for tank leaks near tanks used for storage of high-level waste. Ex situ treatment of contaminated

soils would likely require excavation by hand to remove contaminated soils within the tank farms. Worker exposures associated with hand excavation of soils contaminated from concentrated tank or transfer line leakage would be prohibitive. Additionally, an enclosure structure would also likely be required to reduce the potential for airborne contamination during excavation. Remote removal techniques are possible but would require research and development prior to being considered for deployment in the tank farms.

Biodegradation. Ex situ biodegradation is essentially the same as in situ biodegradation, except that the soil is excavated and placed in a system or pile where treatment is applied (DOE-RL 2000). Biodegradation is effective on organic contaminants, but is not effective on radionuclides or inorganics. Therefore, this technology would have limited application in the tank farm area.

Soil Washing. Soil washing is a process that applies to coarse-grained soils contaminated with a wide variety of metal, radionuclide, and organic contaminants. This process uses a wash solution (e.g., water) to remove soil contaminants by dissolving or suspending the contaminants in solution or concentrating them through particle size separation, gravity separation, and attrition scrubbing. The wash solution requires treatment to remove the contaminants that have been washed and desorbed from the soil. Although soil washing could be applicable at WMA S-SX, there are significant safety and contamination control issues associated with excavation of the more contaminated soils beneath the tanks, particularly while the tanks are still storing waste.

Solidification and Stabilization. Solidification and stabilization uses admixtures to encapsulate excavated soil and render inert various hazardous substances. This process is targeted at metals, radionuclides, and other organics. Stabilizing agents include cement, asphalt, and polymeric materials. Solidification and stabilization is applicable at WMA S-SX.

Thermal Desorption. Thermal desorption uses relatively low-temperature heat (150 to 425 °C [302 to 842 °F]) to volatilize organic contaminants from soil. A carrier gas or vacuum is used to collect and transport the volatilized organics to a gas-treatment system. Thermal desorption is only effective on organics, and it would have limited applicability at WMA S-SX.

Encapsulation. Encapsulation is accomplished by fixing individual particles in a solid matrix as discussed in “Solidification and Stabilization” or by enclosing a quantity of waste in an inert jacket or container. Encapsulation of contaminated soils is potentially applicable at WMA S-SX excluding the issues associated with excavation of the contaminated soils.

F.3.6.2 Interim Corrective Measure Technologies for Groundwater Contamination

This section describes the ICMs for groundwater contamination that are defined in the Phase 1 RFI/CMS work plan (DOE-RL 2000) and in *Feasibility Study of Tank Leakage Mitigation Using Subsurface Barriers* (Treat et al. 1995).

F.3.6.2.1 Hydraulic Containment: Extraction Wells. Hydraulic containment involves placement of extraction wells close along a line or surrounding an area, and pumping the groundwater to form depression zones, thereby creating a barrier to the passage of groundwater

and contaminants contained in the groundwater. The extracted groundwater may require treatment to remove the contaminants.

Hydraulic containment using extraction wells is applicable at WMA S-SX. However, this may not make sense within the context of other waste sites in the 200 Areas, and the potential exists for extracting contamination from nearby cribs and environmental restoration disposal sites.

F.3.6.2.2 Impermeable Barriers. Impermeable barriers are solid walls that are placed into the subsurface to retard the movement of groundwater. Groundwater flowing toward a barrier will divert away from and eventually flow around the barrier. A barrier could be supplemented with extraction wells at the ends of the barrier to prevent mobile contaminants from migrating around the barrier.

Sheet-Pile Barrier. Sheet-pile barriers are constructed by driving interlocking sheet-piles into the ground with either vibratory or impact pile drivers. This barrier would need to be coupled with a horizontal barrier to form a complete barrier envelope. Sheet-pile barriers were tested in the 100-N Area of the Hanford Site and were unsuccessful. The piling was destroyed after penetrating to a depth of 9.2 m (30 ft). Based on the depth to groundwater, installation of a sheet-pile barrier at WMA S-SX would not be possible.

Cryogenic (Freeze-Wall) Barrier. A cryogenic or freeze-wall barrier is formed using two methods. A closed-loop system recirculates chilled brine or other refrigerants through an array of closely spaced wells or pipes, freezing and expanding the water in the soil voids surrounding the freeze pipes. An open loop system involves the injection of liquid nitrogen into the ground through perforated well casings. Cryogenic barriers may be applicable at WMA S-SX. Maintenance of a cryogenic barrier requires a long-term commitment of resources.

Chemical Jet Grout Encapsulation. Chemical jet grout encapsulation uses primarily high-pressure jet grouting to form columns of grouted soil via directionally drilled wells. Standard grouts such as portland cements or bentonite clays are used. More exotic grouts could be used for enhanced set times and better compatibility with Hanford soils. Chemical jet grout encapsulation is applicable at WMA S-SX.

Jet Grout Curtains. Jet grout curtain placement is similar to grout encapsulation described above, except that both vertical and horizontal wells, rather than directionally drilled wells, are used for injection. Jet grout curtain technology is applicable to WMA S-SX.

Permeation Chemical Grouting. Permeation chemical grouting is similar to jet grouting except that lower pressures are used for injection. Permeation chemical grouts could be injected using both vertical and horizontal wells. Permeation chemical grouting is applicable at WMA S-SX, although performance is highly dependent upon the properties of the grouting material used and the properties of the soil.

Wax Emulsion Permeation Grouting. A mineral wax-bentonite emulsion, called ‘Montan’ wax, has been developed for grouting applications. Montan wax grout consists of a stable emulsion of Montan wax, water, and a surfactant. Once inside the soil matrix, the wax particles begin to aggregate and move through void spaces until they bridge an opening and become fixed. Bridging the openings between pores reduces the permeability of the soil. Wax emulsion

permeation tests have been conducted at the Hanford Site and have shown that soil hydraulic conductivity can be reduced by two to three orders of magnitude.

Silica, Silicate Permeation Grouting. Sodium silicate permeation grouting uses a silicate-based chemical grout with favorable characteristics that can be controlled by altering the formulation of the grout. By altering the proportions of the components of sodium silicate grout, the set time and grout viscosity can be controlled. Colloidal silica is also being explored for use in forming subsurface barriers at the Hanford Site. Colloidal silica is a colloidal suspension with gelling properties. Tests using Hanford soils have been performed on sodium silicate grouts and colloidal silica, and have shown that soil hydraulic conductivity can be reduced by three to four orders of magnitude. This technology is potentially applicable at WMA S-SX.

Polymer Permeation Grouting. Polymer permeation grouting employs an injected liquid monomer or resin that converts to a polymer (in place) to form a concrete-like monolithic barrier. Polymer-forming chemicals could be injected into the ground using the same methods for emplacing cement slurry walls. Although some polymer grouts (e.g., furfuryl alcohol) are chemically incompatible with Hanford Site soils, polymer permeation grouting is applicable at WMA S-SX.

Formed-in-Place Horizontal Grout Barriers. Placement of formed-in-place horizontal grout barriers involves the use of a proprietary technology to generate a barrier slab of uniform thickness between guide wires placed by horizontal drilling methods. The technology uses high-pressure jets mounted on a reciprocation machine tool. The grout slurry sprayed through the jets disrupts and mixes soils to a mortar-like consistency between the guide pipes. The machine tool passes through this semi-liquid material as the hardware is pulled along the guide wires, forming a uniform barrier behind it. Adjacent panels would be placed at the edge of the previous panel (before it hardens totally), overlapping the previous panel to some extent to form an extended slab. Formed-in-place horizontal grout barriers may be applicable at WMA S-SX although the technology has never been incorporated at full scale.

Concepts Not Considered Feasible for the Hanford Site. The following concepts are not considered feasible for Hanford Site underground storage tank applications and are listed here for completeness only:

- Soil fracturing
- Longwall mining
- Modified sulfur cement
- Sequestering agents
- Reactive barriers
- Impermeable coatings
- Microtunneling
- In situ vitrification barriers
- Soil saw
- Deep soil mixing
- Slurry walls
- Soil-mixed walls.

F.3.6.2.3 In Situ Treatment Technologies. In situ treatment technologies are oriented at treating the contamination in place to either selectively extract contaminants or to stabilize and isolate contaminants from migrating in the groundwater.

Adsorption-Type Treatment Barrier. Permeable treatment beds and barriers are constructed by excavating a trench and backfilling it with a mixture of soil and adsorbents. The bed is placed downgradient of the contaminated plume. As the natural groundwater flow carries the contaminants through the bed, the contaminants that the barrier is designed to remove are adsorbed onto the bed. Adsorption-type treatment barriers would have limited applicability to WMA S-SX due to the depth of soil that would have to be excavated to reach groundwater.

Phosphate Precipitation Barrier. Phosphate compounds are used in these barriers to precipitate heavy metals (e.g., strontium-90) in the soil matrix. This technology is in the developmental stages and its applicability to WMA S-SX is not known.

Soil Flushing. Soil flushing is described in Section F.3.6.1.3. This technology is considered innovative and was considered for remediating a deep (21.4 m [70.2 ft]) aquifer (DOE-RL 1997). Use of the soil flushing technology requires mounding of the water table over a relatively large area.

Monitored Natural Attenuation. Monitored natural attenuation relies on natural processes to lower contaminant concentrations through physical, chemical, and other biological processes that, "under favorable conditions, act without human intervention to reduce the mass, toxicity, mobility, volume, or concentration of contaminants" (EPA 1999) until cleanup levels are met. Although natural attenuation methods may be readily implemented, significant action or commitment of resources (e.g., personnel to conduct sampling and perform analytical work, construction activity, and loss of land use) may be required. Monitored natural attenuation would have limited applicability at WMA S-SX for the long-lived mobile radionuclides.

F.3.6.2.4 Ex Situ Treatment Technologies. Ex situ treatment technologies are used to remove contaminants from groundwater after the groundwater has been pumped to the surface. Ex situ treatment technologies that are potentially applicable at WMA S-SX are noted below.

Precipitation Technology. Precipitation technology is used to remove metals and radionuclides from water by precipitation.

Membrane Technology. Membranes can be considered for the treatment of radionuclides (e.g., strontium-90). The membrane adsorbs the contaminant. This technology is in the developmental stage.

Ion-exchange Technology. Ion-exchange technology removes ions from solution by adsorption on a solid medium, typically an ion-exchange resin bed or column. As the groundwater is passed through the resin, ionic species in the groundwater exchange with ions on the resin and are adsorbed onto the surface of the resin.

Wet Air Oxidation. Wet air oxidation is based on a liquid-phase reaction between organics in the wastewater and compressed air. This process is used for the treatment of organics and may have limited applicability at WMA S-SX.

Activated Carbon. When contaminated wastewater is passed over activated carbon beds, organic hydrocarbon contaminants are absorbed onto the carbon. This process is used for the treatment of organics and may have limited applicability at WMA S-SX.

Tritium Treatment Technologies. The most successful treatment systems for tritium treatment and separation are gaseous phase applications as used in commercial nuclear power operations. Technologies being considered or being used for tritium are a combination of electrolysis and catalytic exchange, bithermal catalytic exchange, and membrane separation.

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