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Qualitative Risk Assessment of Subsurface Barriers in Applications Supporting Retrieval of SST Waste

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LIST OF ACRONYMS

DOE	U.S. Department of Energy
HDW-EIS	Hanford Defense Waste Environmental Impact Statement
MEPAS	Multimedia Environmental Pollutant Assessment
NEPA	National Environmental Policy Act
SST	single-shell tank
TWRS-EIS	Tank Waste Remediation System - Environmental Impact Statement
WHC	Westinghouse Hanford Company

1.0 INTRODUCTION

This report provides a brief, qualitative assessment of risks associated with the potential use of impermeable subsurface barriers installed around and beneath Hanford Site single-shell tanks (SSTs) to support the retrieval of wastes from those tanks. These risks are compared to qualitative risks associated with a case in which barriers are not used. A quantitative assessment of costs and risks associated with these two cases will be prepared and documented in a companion report. The companion report will compare quantitatively the costs and risks of several retrieval options with varying parameters, such as effectiveness of retrieval, effectiveness of subsurface barriers, and the use of surface barriers.

For ease of comparison of qualitative risks, a case in which impermeable subsurface barriers are used in conjunction with another technology to remove tank waste is referred to in this report as the Barrier Case. A case in which waste removal technologies are used without employing a subsurface barrier is referred to as the No Barrier Case. The technologies associated with each case are described in the following sections.

1.1 BARRIER CASE TECHNOLOGIES

The primary function of impermeable subsurface barriers in applications to Hanford Site SSTs is to prevent contamination of the environment during waste retrieval from SSTs. An impermeable barrier is one that essentially precludes the release of any contaminated liquids outside the confined area of the barrier. An impermeable barrier may also be useful if installed as a subsurface basin for capturing fluids used to flush leaked contaminants from the soil beneath SSTs. The effectiveness of impermeable subsurface barriers for these applications has not been demonstrated. Various materials capable of creating impermeable barriers are currently under investigation by the U.S. Department of Energy (DOE) (DOE 1993). Candidate barrier materials include ice; cementitious grout; organic polymers (e.g., plastics); thermoviscous fluids (e.g., waxes); and heated flowing air that evaporates water associated with a leak, thereby limiting the depth of penetration of the leak.

Two types of barrier technologies are being considered for use during SST waste removal at the Hanford Site: (1) a stand-off concept that emplaces the barrier forming material some distance away from the tank or tank farm structures and (2) a close-coupled concept that emplaces the barrier forming material directly against the SST structure. The stand-off concept is best suited to containing plumes that have resulted from leaking tanks; the close-coupled concept is best suited to SSTs that have not leaked. Close-coupled barriers may not be suitable where leaks have already occurred because the barrier must be installed in an area of contaminated soil. This may result in unacceptable risks to workers and compromise the ability to clean up the contaminated soil.

The stand-off barrier would be employed to create a basin beneath the plume and could be used in conjunction with soil flushing to clean up the contaminated soil. Soil flushing is a cleanup technology that is well suited to Hanford Site soils. Hanford Site soils exhibit high water percolation rates, a property that would enable a flushing solution to rapidly pass through the soil. The flush solution and the mobilized contaminants it contains could be captured in the stand-off barrier basin, pumped to the surface for treatment, and reused as necessary to achieve relatively fast cleanup of the soil. Based on analyses performed to address public health risks presented in Section 3.1 in this report, it may be shown that a leaked plume equating to more than about 0.1 percent of the present tank contents will require flushing or another form of removal to ensure that drinking water standards are not compromised in groundwater beneath the tank. This is equivalent to a leak of about 5,700 L (1,500 gal) of saturated salt solution. As a relative comparison, leaks of as high as 435,000 L (115,000 gal) have been estimated for Tank 241-T-106 (Routson 1979).

The application of a close-coupled barrier would allow the use of traditional sluicing to retrieve wastes at very high rates from tanks that have not leaked. This type of sluicing has been used successfully in Hanford Site SSTs on several occasions (Rodenhizer 1987). The use of a close-coupled barrier would preclude concerns over causing new leaks in the tank shell during retrieval operations or opening old leaks sealed by fine waste particles. A leak observed during the sluicing of Hanford Tank 241-A-105, for example, was attributed to washing out fines or salt crystals that had sealed an old leak (Nelson 1958).

A close-coupled barrier constructed of acid-resistant materials may also enable the use of weak acids to clean the tank of residual waste. The potential use of acid is especially important where high temperatures have caused waste at the bottom of tanks to agglomerate into rock-like masses as much as several feet thick. Previous sluicing efforts were unsuccessful in penetrating or eroding such agglomerated wastes. The use of weak acids historically has been viewed at the Hanford Site as a promising means of softening agglomerated waste. After softening the waste, methods such as those used to clean swimming pools may be effective for maximizing removal of the waste from the tanks. Previous use of acids, however, would have rendered the tanks unsuitable for their current use, which is to provide containment of saltcake and sludge. Thus, except for a few limited cases, weak acids were not used in previous sluicing campaigns.

1.2 NO BARRIER CASE TECHNOLOGIES

Three primary options are under consideration at the Hanford Site for the retrieval of wastes from SSTs: traditional sluicing, mechanical mining, and confined sluicing (Boomer et al. 1993). The use of mechanical mining and confined sluicing may limit the head of liquid in the tank sufficiently so that subsurface barriers would not be needed to stop leaks. Mechanical mining employs physical methods that do not use water to retrieve the wastes. Confined sluicing employs a water jet and a pump that are integrated into a single robotic retrieval device. The jet and pump are spaced closely together, which facilitates removal of the sluicing water. Confined sluicing is distinguished from the type of traditional sluicing historically used at the Hanford Site primarily in the level of mobility and spacing of the water jet nozzles and pumps. In traditional sluicing the nozzle and pump intakes are in fixed locations and are typically 9.1 m (30 ft) apart. The objective of confined sluicing is to restrict the dispersal of the sluicing stream to the area around the pump intake. In concept this would enable recovery of the sluicing liquid before it could seep through the tank waste and potentially escape through a leak in the tank shell.

It is estimated that the use of mechanical mining and/or confined sluicing (No Barrier Case) may be successful in recovering up to 99 percent of the waste in SSTs (Boomer 1993). A residue of 1 percent is equivalent to a layer of waste about .8 cm (1/3 in.) thick on the walls and floor of a 3,800,000 L (1,000,000 gal) tank. Traditional sluicing used in combination with weak acids for softening agglomerated sludge, conventional swimming pool cleaning technology, and impermeable barriers to prevent leakage (Barrier Case) may be capable of removing more than 99.9 percent of the waste. These estimated cleanup efficiencies serve as a key basis in the following comparison of risks associated with a Barrier Case and a No Barrier Case.

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2.0 RISK FACTORS

The development and implementation of any technology for retrieval of tank wastes entails numerous risks. Such risks commonly are evaluated through the National Environmental Policy Act (NEPA) process and in planning the subsequent design, construction, and operating phases of a proposed action. At least the following 10 types of risk should be considered in the implementation of a new technology at the Hanford Site.

- **Public health risk** is a measure of the health consequences of exposing the public to contaminated water, air, foodstuffs, and other materials that result from implementing the technology. Public health risk includes short- and long-term risks resulting from routine operations, accidents, and exposure to wastes. This risk may be the most important of the 10 and consequently receives the most discussion in this report. It is also the focus of the companion quantitative risk assessment that is underway to augment the qualitative risk analysis presented in this report.

- **Ecological risk** is a measure of the likelihood and consequences of damage to plants and animals.

- **Worker risk** is a measure of the likelihood and consequences of injury or death to workers as the result of routine exposure to chemicals and radiation and to accidents that occur during construction, maintenance, and operation.

- **Technical risk** is a measure of the probability that an unproven technology will fail to meet functional requirements when fully developed and demonstrated, and the consequences of that failure.

- **Compliance and liability risk** is a measure of the level of future resources necessary to compensate workers and/or the public, and/or to remediate the ecosystem in the event of injury or noncompliance with regulations.

- **Schedule risk** is a measure of the probability and consequences of failure to meet established schedules.

- **Public perception risk** is a measure of the probability of public rejection of the alternative and the resulting consequences.

- **Cultural resource damage risk** is a measure of the probability and consequences of damage to cultural, historical, and religious resources.

- **Natural resource overconsumption risk** is a measure of the likelihood that excessive use of workers, energy, and other limited natural resources will be required, and the consequences of the excessive use.

- **Cost risk** is a measure of the probability and consequences of requiring funding in excess of that for projects of similar priority.

3.0 ASSESSMENT OF RISK

The 10 risk factors described in Section 2.0 were used as a basis for evaluating the Barrier Case and the No Barrier Case. Each case was evaluated qualitatively by separately considering each risk factor. The following measures of risk were used: low, moderately low, moderate, moderately high, and high.

3.1 PUBLIC HEALTH RISK

Westinghouse Hanford Company (WHC) recently evaluated certain public health risks associated with residues in SSTs in a draft report that has not yet been approved for release to the public (Schmittroth et al. 1993). The assessment was based on the assumption that drinking water standards must be met at wells 100 m downgradient of six individual SST tank farms. Contaminants originating in the SST residues could reach the wells as a consequence of leaching and advection by percolating groundwaters. Such water recharges at very slow rates because of the desert environment at the Hanford Site. The travel time of water between the ground surface and the water table may vary over nearly two orders of magnitude depending on conditions at the surface (DOE 1987). If the surface is highly porous (e.g., gravelly sand) and no deep-rooted plants are present, the travel time may be about 100 years. If a well-established system of deep-rooted plants in fine-grained soils exists, travel times may exceed 1,000 years. The application of a well-designed surface barrier may also result in travel times of 1,000 years or longer. A surface barrier under development at the Hanford Site appears capable of achieving this level of performance (Gee et al. 1993).

The WHC evaluation of the public health risks associated with residues in SSTs was conducted using the Multimedia Environmental Pollutant Assessment code System (MEPAS) developed by Pacific Northwest Laboratory (Buck et al. 1989 and Droppo et al. 1989). Contaminants included 17 radionuclides and 13 chemicals shown in the Hanford Defense Waste Environmental Impact Statement (DOE 1987) as potentially significant contributors to risk. Risks were evaluated for each of six tank farms as functions of time, distribution coefficient, and recharge rates. This evaluation showed that more than 99 percent of the SST waste must be removed and a functioning plant system or surface barrier must be employed continuously for thousands of years to satisfy drinking water limits in groundwater beneath four of the six tank farms considered. The evaluation did not consider that other sources of contaminants exist (e.g., burial grounds, cribs, and processing facilities). Nor did the evaluation consider that certain tank farms will be in alignment relative to the direction of groundwater flow. Thus, contaminants released from several aligned sources may be additive with respect to estimating concentrations in the drinking water. The additive effects of combined sources should be considered to establish cleanup levels for individual sources. Thus, more rigorous cleanout of the tanks may be required to meet drinking water ndards than currently is planned. A tank waste retrieval system comprising subsurface ba s, traditional sluicing, weak acid dissolution, and swimming pool cleaning technology (the

Barrier Case) may prove successful in achieving waste recoveries of more than 99.9 percent. If so, releases from tanks cleaned to this level may not cause drinking water limits to be exceeded, even in the case of additive sources.

Public health risk also arises from consumption of foodstuffs irrigated with contaminated well water and inadvertent intrusion by humans into the closed tanks (e.g., by well drilling). These scenarios were evaluated in the Hanford Defense Waste Environmental Impact Statement (HDW-EIS) (DOE 1987) and may be revisited in the planned Tank Waste Remediation System Environmental Impact Statement (TWRS-EIS). The higher levels of residual waste likely in the No Barrier Case would result in higher public health risks for both the irrigation and intrusion scenarios.

Additional public health risks are postulated through accidents that may occur during the installation, maintenance, and operation of the retrieval systems. The potential for spreading contamination to the air during installation of the retrieval system may be greater in the No Barrier Case. This is because the mechanical retrieval systems described by Boomer (1993) require cutting a large hole in the top of the tank to insert retrieval system components. In most tanks the Barrier Case can employ existing sluice and pump pits and, thus, requires fewer and smaller holes. The No Barrier case is also likely to require removal of a greater amount of equipment presently in the tanks that would interfere with the movement of the robotic arm but not interfere with traditional sluicing. The Barrier Case requires installation of barrier-forming materials around tanks, which introduces mechanical risks not attendant to the No Barrier Case, however, current barrier concepts entail emplacement of these materials in clean or nearly clean soil. Thus, the level of airborne contamination created during the barrier installation phase is expected to be low.

The physically taxing nature of mechanical mining (No Barrier Case) is likely to result in significantly greater maintenance than is likely to occur in the case of traditional sluicing (Barrier Case). Confined sluicing (No Barrier Case) is also likely to entail a higher level of maintenance because of the higher complexity of the equipment. The relatively high frequency and difficulty of removing and reinstalling mechanical mining equipment and confined sluicing equipment equates to higher risks of airborne contamination.

Human health risks associated with operations may be somewhat higher in the Barrier Case, which employs traditional sluicing. Sluicing creates mists that will be drawn into the tank's offgas system. Virtually all mists and entrained particles will be captured by the offgas system. However, small amounts of tritium will evaporate from the mists and exit the offgas system to the atmosphere. Tritium will also be released by similar mechanisms in the No Barrier Case. The levels of entrained mists, particles, and tritium released in the two cases may be nearly equal depending on design of the offgas systems and the input energies required to achieve waste retrieval by the various technologies.

Based on the analyses above, the two cases were scored regarding the level of human health risk as follows:

Public Health Risk Evaluation

Barrier Case:	moderately low
No Barrier Case:	moderate

3.2 ECOLOGICAL RISK

Leachate that arises from residual waste in SSTs eventually will reach the groundwater and then flow downgradient to the Columbia River. Fish, mammals, and plants that use the Columbia River will be exposed to contaminants that originated in the leachate.

Similarly, airborne contamination released during installation, maintenance, and operation can injure plants and animals. Higher waterborne and airborne releases may be more probable in the No Barrier Case as discussed in Section 3.1. Although the sensitivity of various plants and animals to chemical and radionuclide exposure varies, it is generally accepted that higher exposure results in more harm. Because the overall public health exposure is likely to be higher in the No Barrier Case, the ecological exposure is also expected to be higher.

Based on the analysis above, the two cases were scored regarding ecological risk as follows:

Ecological Risk Evaluation

Barrier Case:	moderately low
No Barrier Case:	moderate

3.3 WORKER RISK

Worker risk arises from exposure to radiation, chemicals, and industrial hazards. Industrial hazards include high pressure, high temperature, and mechanical hazards such as pinch points and puncture sources. A higher degree of radiation exposure is likely in the No Barrier Case. This is because of the higher level of contact maintenance and handling accidents expected to result from the mechanically complex design of robots and mining devices. The higher level of contact maintenance will also present opportunities for injury because of various mechanical hazards involved.

The Barrier Case presents difficult installation challenges, however, especially in the installation of the horizontal component of a close-coupled barrier. The Barrier Case may require the installation of large, vertical, encased holes or trenches next to individual tanks or tank farm. Small-diameter holes may then be drilled horizontally from the base of the vertical holes to provide conduit" for emplacing materials to form horizontal barriers. This latter step may be relatively hazardous, although similar horizontal drilling was safely conducted in all six tanks in A Tank Farm and in 10 tanks in SX Tank Farm (Raymond and Shdo 1966). Horizontal holes were drilled under these tanks to permit insertion of instruments to monitor radiation plumes resulting from leaks. The higher level of maintenance-related risks in the No Barrier Case appears to be approximately equal to the higher level of risks associated with barrier installation in the Barrier Case.

Based on the above analyses, the two cases were scored regarding worker risk as follows:

Worker Risk Evaluation

Barrier Case:	moderate
No Barrier Case:	moderate

3.4 TECHNICAL RISK

Both cases feature significant technical risks. Retrieval must be accomplished within confined spaces in a corrosive, highly radioactive, and mechanically challenging environment. There is little question that retrieval systems can be designed to remove the bulk of the waste successfully, based on the past success of traditional sluicing. Whether enough of the waste (more than 99 percent) can be removed by mechanical mining and/or confined sluicing methods and whether the equipment is sufficiently robust to avoid excessive maintenance and associated costs and worker safety risks are issues that must be resolved through technology demonstrations and analyses. Confined sluicing reduces the risk of insufficient removal relative to that of mechanical mining (except where extremely tough agglomerated sludges exist) but increases the risk of excessive leakage of liquid waste through holes in the tanks. The Barrier Case (traditional sluicing, etc.) relies on two unproven technologies: an impermeable barrier and the ability of weak acids to soften and dissolve agglomerated sludge. Both technologies must be successful for the Barrier Case to be viable.

Based on the above analysis, the two cases were scored regarding technical risk as follows:

Technical Risk Evaluation

Barrier Case:	high
No Barrier Case:	high

3.5 COMPLIANCE AND LIABILITY RISK

The use of either mechanical mining or confined sluicing without barriers (the No Barrier Case) is likely to leave more residual waste in the tanks than will a successful application of the Barrier Case. Higher long-term risks to the public and the ecology would result, as well as higher risks that the level of cleanup achieved would not be in compliance with regulatory limits. Worker risks will be approximately equal, as concluded in Section 3.3. The higher level of residual waste expected in the No Barrier Case increases the risk that additional remedial measures will be required in the future to protect the public and the ecology, and ensure compliance with regulations.

Based on the above analyses, the two cases were scored regarding liability risk as follows:

<u>Compliance and Liability Risk Evaluation</u>

Barriers Case:	moderately low
No Barrier Case:	moderate

3.6 SCHEDULE RISK

Technologies associated with mechanical mining and confined sluicing (No Barrier Case), and impermeable barriers and weak acid treatment (Barrier Case) are unproven. The development of each of these technologies poses unique and difficult technical challenges. Development will require a high level of commitment of management, engineering, and financial resources. Other priorities will be competing for these same resources. The time to complete development of each of these technologies is estimated to be about the same.

Based on the above analyses, the two cases were scored regarding schedule risk as follows:

<u>Schedule Risk Evaluation</u>

Barrier Case:	high
No Barrier Case:	high

3.7 PUBLIC PERCEPTION RISK

Alternatives that result in a higher risk to the public and the ecology are less likely to be viewed as favorably by the public. The option of emplacing a barrier around a tank or a tank farm in an attempt to minimize the spread of contamination, even if it is not completely successful, is likely to receive the support of the public and the regulatory agencies.

Based on the above analyses, the two cases were scored regarding public perception risk as follows:

Public Perception Risk Evaluation

Barrier Case:	moderately low
No Barrier Case:	moderate

3.8 CULTURAL RESOURCE DAMAGE RISK

The Yakima Indian Nation views the Hanford Site as a sacred area, and has taken the position that the Hanford Site be restored to conditions that existed before the Hanford mission began. The Hanford Site has relatively less cultural value to other stakeholders. The Arid Lands Ecology and Hanford Reach areas are important to a relatively small population of stakeholders other than Native Americans. It is unlikely that the Barrier Case or the No Barrier Case would have or be viewed by Native Americans and other stakeholders as having significantly different impacts on cultural resources.

Based on the above analyses, the two cases were scored regarding cultural resource damage risk as follows:

Cultural Resource Damage Risk Evaluation

Barrier Case:	moderately low
No Barrier Case:	moderately low

3.9 NATURAL RESOURCE OVERCONSUMPTION RISK

Neither case is likely to result in excessive consumption of limited natural resources. The two cases were scored on natural resource over-consumption risk as follows:

Natural Resource Over-consumption Risk

Barrier Case:	low
No Barrier Case:	low

3.10 COST RISK

Both cases are likely to incur relatively high developmental costs. Costs of installation and waste retrieval using either case are expected to be very high, but probably not excessive relative to the costs required to address other Hanford Site and national priorities. Boomer et al. (1993) estimated life-cycle costs for retrieval using a mechanical arm (the No Barrier

Case) and retrieval using sluicing with subsurface barriers (the Barriers Case). The life-cycle costs reported by Boomer were $4.0 billion and $3.7 billion, respectively. The two cases were scored on cost risk as follows:

<u>Cost Risk Evaluation</u>

Barrier Case:	moderately high
No Barrier Case:	moderately high

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4.0 SUMMARY AND CONCLUSIONS

A summary of the evaluation of risks posed by the Barrier Case and the No Barrier Case is presented in Table 4-1.

Table 4-1. Barrier (B) vs. No Barrier (NB) Risks.

RISK FACTORS	LOW	MODERATELY LOW	MODERATE	MODERATELY HIGH	HIGH
Public Health		B	NB		
Ecological		B	NB		
Worker			B NB		
Technical					B NB
Compliance and Liability		B	NB		
Schedule					B NB
Public Perception		B	NB		
Cultural Resource Damage		B NB			
Natural Resource Overconsumption	B NB				
Cost				B NB	

The table shows that six of the 10 risk factors were considered equal for the Barrier and No Barrier Cases. Risks associated with public health, the ecology, liability, and public perception were considered lower for the Barrier Case. The lower risks evaluated for each of these four factors is strongly dependent on the prediction that lower levels of residual wastes in tanks will result if the technologies associated with the Barrier Case can be successfully developed and implemented.

It is noteworthy that technical and scheduling risks are considered high for both cases. Overall technical and schedular risks would be mitigated by continuing the study and development of the technologies associated with both cases in parallel. Thus, the failure to develop one technology successfully would not cause the failure of the overall Hanford Site mission associated with SST waste retrieval, which includes waste pretreatment, vitrification, storage, and disposal. Continuation of the study, development and demonstration of mechanical mining, modified sluicing, impermeable subsurface barriers, and weak acid softening of agglomerated sludge appears to be a prudent approach to ensuring the success of the overall tank waste retrieval system. Study and development should focus on the weakest areas of the technologies. This approach will help ensure that technologies with major flaws are identified at the earliest time. Technology study and development should cease once it is clear that major weaknesses cannot be overcome.

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