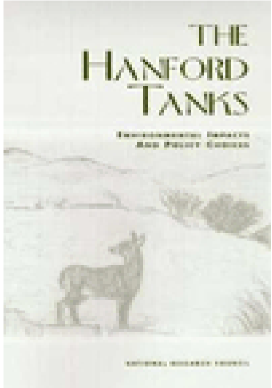

The Hanford Tanks: Environmental Impacts and Policy Choices

Committee on Remediation of Buried and Tank Wastes, Commission on Geosciences, Environment, and Resources, National Research Council

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THE HANFORD TANKS: ENVIRONMENTAL IMPACTS AND POLICY CHOICES

Committee on Remediation of Buried and Tank Wastes
Board on Radioactive Waste Management
Commission on Geosciences, Environment, and Resources
National Research Council

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This report has been reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

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PREFACE

The study described in this report was prepared at the request of the U.S. Department of Energy Office of Waste Management by the Committee on Remediation of Buried and Tank Wastes. The committee has gained a considerable amount of background information on the Hanford Site high-level radioactive waste tanks over the past 4 years of its tenure. We extend our thanks to the many representatives of the Department and its contractors, both from its Washington, D.C., headquarters and from its Richland, Washington, office, who provided timely information, including extensive documentation. We also thank Allen Croft; Oak Ridge National Laboratory, and a member of the National Research Council Subcommittee on Tank Wastes of the Committee on Environmental Management Technologies, who assisted in the analysis and contributed to the preparation of this report.

Thomas M. Leschine
Chairman

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EXECUTIVE SUMMARY

The Hanford Site (also known as the Hanford Reservation) occupies approximately 1,450 km^2 (560 square miles) along the Columbia River in south-central Washington, north of the city of Richland. The site was established by the federal government in 1943 to produce plutonium for nuclear weapons. Currently, the mission of the site, under the responsibility of the U.S. Department of Energy (DOE), is management of wastes generated by the weapons program and remediation of the environment contaminated by that waste. As part of that mission, DOE and the State of Washington Department of Ecology prepared the Hanford Site Tank Waste Remediation System Draft Environmental Impact Statement (DEIS).

The DEIS evaluates alternative strategies for managing and disposing of radioactive, hazardous, and mixed wastes from Hanford underground storage tanks (large single- and double-shell tanks and miscellaneous small tanks), as well as the elements cesium and strontium in capsules currently stored on the site. Within the DEIS are descriptions and analyses of the potential enviromental consequences and the impact on public and worker health and safety related to various alternatives for waste management and remediation of the facilities. These alternatives range from no waste retrieval and treatment actions to extensive retrieval, with varying levels of treatment, and disposal of portions of the treated waste on and off site. The DEIS provides a source of information for decision makers to consider when selecting remediation actions.

At the request of the DOE Office of Waste Management, the Committee on Remediation of Buried and Tank Wastes conducted a general review of the DEIS. Its findings and recommendations are the subject of this report. Selection of a disposition plan for these wastes is a decision of national importance, involving potential environmental and health risks, technical challenges, and costs of tens to hundreds of billions of dollars. The last comprehensive analysis of these issues was completed 10 years ago, and several major changes in plans have occurred since. Therefore, the current reevaluation is timely and prudent. The committee endorses the decision to prepare this new environmental impact statement, and in particular the decision to evaluate a wide range of alternatives not restricted to those encouraged by current regulatory policies.

PRINCIPAL FINDINGS - TANKS

The committee's principal findings identified during this review, as discussed briefly below, are: (1) significant uncertainties exist that limit the ability of DOE to define and characterize disposal alternatives and, hence, to select a final disposal alternative for all of the tanks' wastes; (2) in light of these uncertainties, a phased decision strategy that considers multiple alternatives involving both ex situ and in situ disposal is needed, rather than a phased implementation plan for a single alternative as DOE and the Washington State Department of Ecology propose in the DEIS; and (3) analyses in the final environmental impact statement should be broadened and improved to support such a phased decision strategy.

Uncertainties

Uncertainties, both stated and unstated, concerning the Hanford wastes, the environment, and the remediation processes are found throughout the DEIS. Not enough is known at this time to choose a final, long-term strategy for management of all of the Hanford Site tank wastes. Furthermore, such a decision is neither required nor prudent at this time. Significant uncertainties exist in the areas of technology, costs, performance, regulatory environment, future land use, and health and environmental risks. Among the issues that remain uncertain are:

- effectiveness in practice of technologies to remove and treat waste from tanks,
- costs of operations and off-site waste disposal,
- future policy and regulatory environment,
- characterization of tank wastes,
- relation between tank waste removal, remediation of the surrounding environment, and ultimate land use at the site, and
- long-term risks associated with various alternatives for treating and processing the tank wastes, both in relation to residues left on site and risks transferred off site when processed wastes are moved to a repository.

The scope of the DEIS also has significant limitations. Because the DEIS does not address remediation of the tanks themselves and associated environmental contamination, the alternatives it considers for tank waste remediation are not defined well enough. In addition, the connections between tank remediation alternatives and other cleanup activities at the Hanford Site are not taken into account. Because tank waste remediation alternatives are analyzed and evaluated in isolation from other geographically-related contamination at the Hanford Site, information about risks and costs in the DEIS is difficult to place in a proper perspective.

The DEIS surveyed a wide range of remediation options, including strategies in which tanks with varying contents are treated differently. However, the committee believes that additional alternatives for management of the tank wastes need to be explored in parallel, using a phased decision strategy like the one outlined in this report. Such a strategy would provide flexibility in the event that specific, preferred technologies or management approaches do not perform as anticipated or that innovative waste management and remediation technologies emerge. Among additional options that should be analyzed are (1) in-tank waste stabilization methods that are intermediate between in situ vitrification and filling of the tanks with gravel, (2) subsurface barriers that could contain leakage from tanks, and (3) selective partial removal of wastes from tanks, with subsequent stabilization of residues, using the same range of treatment technologies as in the alternatives involving complete removal of wastes.

When funding is constrained, it is more difficult to devote resources to the continued development of backup options. However, considering the uncertainty in the cost and performance of the technologies required for the preferred alternative, a time period during which funding is constrained is precisely the wrong time to drop work on alternatives that might achieve satisfactory results at a significantly lower cost. Having such alternatives available could allow remediation to proceed expeditiously, even if funding constraints prevent timely implementation of the currently preferred alternative.

The preferred Phased Implementation Alternative presented in the DEIS does not adequately address all of the uncertainties that make it difficult to decide how to complete remediation of the tanks. During Phase 1, cesium and technetium, the most troublesome elements in a vitrifier, are to be removed from the high-level waste that is sent to the pilot vitrification plant, potentially limiting the value of information obtained from the pilot plant operations. This may also delay a decision on the final waste form for these elements. In addition, the plan for this phase does not consider promising ancillary technologies (some of which may already be under development in other parts of the DOE Environmental Management program) such as subsurface containment barriers, other materials and processes for stabilizing wastes left in the tanks, and a range of waste forms for the low-activity materials separated from the wastes removed from the tanks, all of which could play important roles in the remediation approach ultimately selected.

Decisions regarding tank remediation must consider risk, cost, and technical feasibility. Where risks are involved, care should be taken to present a range of potential risks, including expected or most likely estimates as well as the upper-bound estimates presented in the DEIS. While upper-bound estimates may give confidence that actual impacts will not exceed those presented in the DEIS from a worst-case perspective, the inherent uncertainties in risk assessments can distort the comparison of alternatives. This is of particular concern when the upper-bound estimates are derived from a cascade of parameters, each of which was also derived on an upper-bound basis.

While the committee recognizes the utility of quantitative risk assessment in the comparison of remedial alternatives, the limitations of analysis must be underscored. Given the complexity of the Hanford tank farms, many of the potential uncertainties cannot be measured, quantified, or expressed through statistically derived estimates. According to the 1996 National Research Council report *Understanding Risk,* the 1996 U.S. Environmental Protection Agency report *Proposed Guidelines for Carcinogen Risk Assessment,* and a recent draft report by the Commission on Risk Assessment and Risk Management, characterization of risks should be both qualitative and quantitative. In this case, qualitative information should include a range of informed views on the risks and the evidence that supports them, the risk likelihood, and the magnitude of uncertainty. Such evaluations of risk should be based on deliberative scientific processes that clarify the concerns of interested and affected parties to prevent avoidable errors, provide a balanced understanding of the state of knowledge, and ensure broad participation in the decision-making process.

It should be expected that the environmental regulations governing the tank wastes, and the Hanford Site in general, will change over the time during which waste management and environmental remediation occur. DOE should work with the appropriate entities to ensure that future regulatory changes and the future selection of tank remediation approaches are on convergent paths.

Decision Strategy

The preferred alternative for tank remediation that is identified, analyzed, and evaluated in the DEIS is phased implementation of a particular action plan. This alternative includes first a demonstration phase, up to 10 years in duration, during which a portion of the double-shell tank waste would be retrieved, treated, and stored. Using the experience of the demonstration phase, a second phase, lasting approximately 40 years, would complete the task of retrieval, treatment, and storage of the remaining tank wastes.

The committee shares the preference for a phased approach as stated in the DEIS. The committee believes that a phased approach should be a strategy for guiding decision making as information is developed, not merely a plan for implementing decisions made during a single point in time by scaling-up a single, preselected technological approach. Realistically, it is not timely to choose remediation technologies for the less tractable single-shell tanks. The important action now is to select the most promising technologies to be developed, tested, and evaluated for performance. DOE should undertake a program of research, development, and pilot testing and demonstrations to resolve the major process and technical uncertainties concerning single-shell tanks, while pursuing its plans to build a pilot treatment plant for double-shell tank supernatant. In the initial phase of this program, technologies should be selected for evaluation based on technical merit and the environmental consequences, and current regulatory policies should not rule out additional study of otherwise attractive options.

Decisions regarding final disposition of single-shell tank wastes should be deferred until the outcome of this evaluation phase is known. This could take as long as 10 years. The extensive base of information, including what is presented in the DEIS, that is now available for planning should be used to support future decisions. Valuable experience should be gained while retrieving and treating wastes from two single-shell tanks, which the committee understands will be accomplished under the upcoming Hanford Tank Initiative.

This initiative could serve as a good starting point for the DEIS Phase 1 single-shell tank investigation.

A prudent approach to the first phase of the decision-making process requires identification of alternative strategies for the entire remediation process. Each remediation approach selected for analysis should include a plan for research on gaps in technical knowledge, environmental impacts, and other important uncertainties. Results of this research should inform those responsible for making subsequent decisions while scaling up from bench scale, to pilot plant, to full-scale operation. When the applicability and maturity of proposed technologies are uncertain, fallback options should be pursued in parallel. To provide a genuine choice, several phased alternatives should be fully developed for consideration by DOE management, regulators, and the public. Until a range of phased alternatives is compared, it will not be clear whether the one presented in the DEIS will emerge as the best.

PRINCIPAL FINDINGS - CAPSULES AND MISCELLANEOUS TANKS

Concerning the management and disposal of the cesium and strontium capsules and of the miscellaneous underground storage tanks, the committee found that the DEIS lacks enough substantive information for an evaluation of the proposed remediation strategies. Over 99 percent of the tank wastes is in the single-shell and double-shell tanks, and that is where the greatest potential for health and environmental risks exists. However, the extremely high concentration of radioactivity and the nature of the materials in the capsules necessitate a more thorough discussion of their treatment, disposal, and environmental impact. There are serious deficiencies in the attention given to the long-term changes in the chemical and isotopic composition of the cesium and strontium capsules. The large number and wide distribution of the miscellaneous underground storage tanks make a more complete discussion of their management necessary.

RECOMMENDATIONS

1) The proper approach to decision making for tank farm cleanup is to use a phased decision strategy in which some cleanup activities would proceed in the first phase while important information gaps are filled concurrently to define identified remediation alternatives more clearly, and possibly to identify new and better ones. As part of this strategy, periodic independent scientific and technical expert reviews should be conducted so that deficiences may be recognized and midcourse corrections be made in the operational program.
2) A comprehensive strategy of enviromental monitoring and risk surveillance should be an essential component of the phased approach. The goal of this strategy should be to assure that public health and the environment are adequately protected during implementation of the overall remediation program.
3) Plans for building a pilot plant should proceed, but in the context of a phased decision strategy that does not preclude processing of wastes other than the double-shell tank supernatant or producing waste forms other than the glass currently planned.
4) The first phase of such an approach should also include gathering crucial information necessary to support selection from a broad range of well-defined alternatives to be made several years hence. Goals of the first phase should be to (a) reduce uncertainties concerning technology performance, cost, and risks, (b) address policy and regulatory uncertainties, (c) adequately reduce uncertainties associated with the characteristics of wastes inside and outside the tanks, (d) evaluate environmental and public health consequences, (e) explore a range of technology options, as needed, and (f) analyze interrelationships with other site cleanup decisions.
5) The development, testing, and analysis of alternatives during the first phase should continue unconstrained by current regulatory requirements and should examine currently untested technologies.
6) A comprehensive plan should be developed to define the programs for waste management, site-wide remediation, and future land use for the entire Hanford Site.
7) The final environmental impact statement should be as useful as possible to the public and decision makers outside DOE. It should go beyond

merely providing a description of alternatives and a comparative evaluation of their impacts by discussing the critical elements that constituted the basis for the selection of the preferred alternative. In addition, to the extent possible, the relationship between the tank waste remediation alternatives and other contamination and anticipated cleanup actions at the Hanford Site should be analyzed.

1

INTRODUCTION

At the request of the U.S. Department of Energy (DOE) Office of Waste Management (letter of request, Appendix A), the Committee on Remediation of Buried and Tank Wastes (hereafter, the “committee”) conducted a general review and evaluation of the Hanford Site Tank Waste Remediation System (TWRS) Draft Environmental Impact Statement (hereafter, the “DEIS”; U.S. Department of Energy and Washington State Department of Ecology, 1996).

The study focused on the decisions facing the nation concerning management of the Hanford Site tank wastes rather than on details of the document. Consistent with the DOE request, the study did not review the extensive data presented in the DEIS, nor did it examine whether the data were properly incorporated into models. The committee assessed the overall approaches of the DEIS, including the means used to identify alternative remediation strategies and evaluate the risks, costs, and technical feasibility of the alternatives. This report addresses the adequacy of the definition of these alternatives; the characterization of the alternatives in terms of risk, environmental impact, and cost; and the path recommended in the DEIS for choosing and implementing a preferred alternative.

The report also provides a broader analysis of the overall approach taken by DOE and the Washington State Department of Ecology in the DEIS, consistent with the statement of task of the committee when it was established in 1992. The committee is charged to provide scientific and technical review and evaluation of the DOE program of remediation of the environment contaminated by buried and tank-contained defense high-level, transuranic, and mixed radioactive wastes, and to address critical generic and specific issues on a broad national (and global) perspective.

The report first gives some brief background information on the DEIS, followed by a discussion of the committee's findings which emphasizes the major concern over uncertainties. The recommendations chapter of this report stresses the phased decision strategy. The last chapter provides some suggestions for the final version of the TWRS Environmental Impact Statement.

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BACKGROUND

The Hanford Site (also known as the Hanford Reservation) occupies approximately 1,450 km^2 (560 square miles) along the Columbia River in south-central Washington, north of the city of Richland. The site was established by the federal government in 1943 to produce plutonium for nuclear weapons. Currently, the mission of the site, under the responsibility of DOE, is management of waste generated by the weapons program and remediation of the environment contaminated by that waste. As part of that mission, DOE and the Washington State Department of Ecology prepared the Hanford Site Tank Waste Remediation System Draft Environmental Impact Statement (DEIS).

The Hanford Site DEIS was prepared under the National Environmental Policy Act (NEPA) and the Washington State Environmental Policy Act. It addresses major changes in the tank waste program that were incorporated by amendments to the Hanford Federal Facility Agreement and Consent Order (hereafter, the “Tri-Party Agreement”) entered into in 1989 by the Washington State Department of Ecology, U.S. Environmental Protection Agency, and U.S. Department of Energy (1994, with latest amendments). This NEPA analysis of a comment made under the Tri-Party Agreement represents a positive development reflecting the national significance of the decisions being proposed.

The DEIS evaluates alternative strategies for managing and disposing of radioactive, hazardous, and mixed wastes from Hanford underground storage tanks (large single- and double-shell tanks and miscellaneous small tanks), as well as cesium and strontium capsules currently stored on the site. The DEIS describes and analyzes the potential enviromental consequences and the projected impact on public and worker health and safety of various alternative approaches to waste management and remediation of the facilities. These alternatives range from no waste retrieval or treatment actions to extensive retrieval, with varying levels of treatment, and disposal of appropriate portions of the treated waste on and off site. The DEIS provides information for decision makers to consider when selecting remediation actions.

THE DRAFT ENVIRONMENTAL IMPACT STATEMENT AND DECISION PROCESS

The January 28, 1994, Notice of Intent to Prepare Hanford Tank Waste Remediation System Environmental Impact Statement (59 FR 4052) states that the DEIS will (1) analyze the adoption of the most recent amendments to the Tri-Party Agreement; (2) supplement the December 1987 Hanford Defense High-Level Transuranic and Tank Wastes Final Environmental Impact Statement (hereafter, the “1987 FEIS”; U.S. Department of Energy, 1987) and the subsequent April 14, 1988, Record of Decision (53 FR 12449); and (3) reflect changes made since the 1988 Record of Decision. An additional purpose of the DEIS is to support the contracting strategy for privatization of tank farm activities (DEIS, p. 3-13).

The Tri-Party Agreement acts as a programmatic document, providing the framework for decision making and prioritization of cleanup at the Hanford Site. It is implemented by a binding, enforceable action plan with milestones that have been accepted by all parties to the agreement. Significant commitments made in the Tri-Party Agreement changed the planning approach chosen in the 1988 Record of Decision which had been based on the 1987 FEIS. Some of these commitments, as referenced in the DEIS, include (1) 99 percent removal of wastes from both single-shell and double-shell tanks, (2) termination of the planned grout project for low-level waste and adoption of a vitrified form, and (3) designation of both single-shell and double-shell tanks for waste retrieval. As far as the committee is aware, the environmental impacts, uncertainties, costs, and alternatives to these commitments were not specifically analyzed prior to the present DEIS.

NATIONAL ENVIRONMENTAL PROTECTION ACT ANALYSIS AFFECTING THE HANFORD SITE

DOE implements its NEPA compliance through regulations found in 10 CFR Part 1021 (NEPA Implementing Procedures), the regulations of the President's Council of Environmental Quality (CEQ; 40 CFR Parts 1500-1508), its own order (DOE Order 5440.1E, 1992, NEPA Compliance Program), and the guidelines presented in *Recommendations for the*

Preparation of Environmental Assessments and Environmental Impact Statements (U.S. Department of Energy, 1993). The DEIS, though presented as a stand-alone document, is only one of a series of enviromental documents analyzing remediation activities at the Hanford Site. A 1995 unpublished DOE briefing document provided to the committee identifies other environmental impact statements, some in preparation or planned, that address DOE activities with the potential to affect remediation of the Hanford Site. A recent DOE publication, *Charting the Course: The Future Use Report* (U.S. Department of Energy, 1996a), makes recommendations for future land uses for 20 DOE sites, including the Hanford Site, and describes plans to prepare the Hanford Remedial Action Environmental Impact Statement for the Hanford Comprehensive Land Use Plan. The 1987 FEIS references eight other relevant environmental impact statements that had already been completed, with the earliest dated 1975.

The DEIS relates most directly to the 1987 FEIS, which led to the 1988 Record of Decision to begin processing the double-shell tank wastes but to defer action on the single-shell tanks. In 1989 a policy shift occurred, and the Tri-Party Agreement was entered into. This agreement gave priority to joint removal and processing of the single-shell and double-shell tank wastes. Preparation of the DEIS, in effect, represents an implementation step of the Tri-Party Agreement.

DESCRIPTION OF WASTE MANAGEMENT FACILITIES

The DEIS addresses the management and disposal of radioactive and mixed wastes stored or to be stored in underground tanks at the Hanford Site. In addition, it addresses the management and disposal of capsules of cesium and strontium, and of waste in miscellaneous underground storage tanks.

Large High-Level Waste Storage Tanks

At the Hanford Site there are approximately 216,000 m^3 (57 million gallons) of waste stored in 177 large tanks, of which 149 are single-shell tanks ranging in capacity from 210 m^3 (55,400 gallons) to 3,800 m^3 (1 million gallons), and 28 are double-shell tanks with capacities ranging from 606 m^3

(160,000 gallons) to 3,800 m^3. The wastes were highly acidic when generated, but they were neutralized with sodium hydroxide or calcium carbonate to permit storage in carbon steel tanks. As a result, most of the chemicals present in the waste precipitated. In the liquid remaining in the tanks, the primary dissolved chemicals are nonradioactive sodium nitrate, nitrite, and hydroxide, with much smaller mounts of other chemicals. Major radioisotopes include ^{137}Cs and ^{90}Sr.

During the years since the tanks were filled, some of the single-shell tanks have failed and leaked. There are presently 67 tanks (all single-shell) known or assumed to have leaked (Hanlon, 1996, p. 1). To forestall further leakage, all single-shell tank contents were processed further to reduce the liquid content as much as possible, given other safety considerations. This resulted in the precipitation of many soluble salts from the oversaturated liquid. There are now four distinct types of material—liquid, saltcake, sludge, and slurry—in at least some of the Hanford tanks (DEIS, Table A.2.1.1):

- Liquid (63,000 m^3) includes the supernatant and drainable interstitial liquid in the tanks, containing substantial amounts of dissolved chemicals, especially sodium salts such as hydroxide and nitrate/nitrite, often near or at their respective solubility limits.
- Saltcake (91,000 m^3) is a crystalline mixture of chemical salts that precipitated when neutralized liquids were concentrated to reduce storage volume or potential waste mobility; in general, it is composed of the same mix of chemicals as is dissolved in the liquid.
- Sludge (54,000 m^3) is a generally viscous, amorphous mixture of relatively insoluble chemicals that precipitated in the tanks as a result of neutralization; iron and aluminum compounds are typically important components, but sludges are usually heterogeneous and contain a wide variety of cations and anions as well as interstitial salt cake or liquid; phosphate ion forms a gelatinous precipitate in the sludge with a variety of cations.
- Slurry (7,700 m^3) epresents tank waste comprising solid, generally crystalline particles suspended in a liquid; most of the solids are alkaline nitrate salts that crystallized in the tanks when liquid wastes were concentrated, but some solids similar to sludges are also present; slurry is found only in double-shell tanks at Hanford.

It is notable that although the radioactive components of the tank wastes represent a small fraction of the total mass of chemicals in the tanks, they nonetheless are the source of a large amount of radioactivity. There are approximately 104 million curies (Ci) in the single-shell tanks and 73 million Ci in the double-shell tanks (DEIS, Table A.2.1.3). The radioisotopes ^{137}Cs (with a half-life of 30 years) and ^{90}Sr (with a half-life of 28.5 years), which account for essentially all of the total radioactivity in both types of tanks, will remain the primary individual contributors to the total radioactivity over the next 150 to 200 years.

Information about the contents of the tanks is based primarily on historical records of transfers of radioactive and chemical wastes from processing facilities, supplemented by recent analyses of samples collected from some of the tanks. The data are suspect on a tank-by-tank basis, but the overall inventory of tank wastes is considered to be more accurate. The total mass of nonradioactive chemical components in the tanks is estimated as approximately 357,000 metric tons (approximately 224,000 metric tons in the single-shell tanks and 133,000 metric tons in the double-shell tanks; DEIS, Table A.2.1.2).

As a result of the various plutonium production processes and tank waste processing methods used at the Hanford Site, the tanks contain a wide variety of minor chemical constituents. Some of these constituents have caused safety concerns apart from the issue of leaking tanks. The most important of these risks are explosions resulting from the presence of unstable chemicals (e.g., ferrocyanides and organic chemicals) or from hydrogen produced by the radiolytic degradation of organic chemicals. One tank has a high heat output and requires the addition of water to maintain an acceptably low temperature. In total, 54 large Hanford Site tanks are on a “watch list” because of safety concerns (Hanlon, 1996, p. 1).

Miscellaneous Underground Storage Tanks

There are approximately 60 so-called miscellaneous underground storage tanks (MUST), with capacities ranging from 3.4 m^3 (900 gallons) to 190 m^3 (50,000 gallons), on the Hanford Site. These tanks were used for a variety of purposes such as settling, processing, and waste transfer. Of these, 40 are now inactive and part of the TWRS project. The total waste volume in these tanks is approximately 400 m^3 (100,000 gallons), a small fraction of the total waste volume in the single-shell and double-shell tanks. The composition of the waste in the MUST is thought to be similar to the waste in the single-shell and double-shell tanks. The design and construction features of the MUST are not described in the DEIS.

Encapsulated Cesium and Strontium

During the 1970s much of the heat-generating radioisotopes of cesium (primarily ^{137}Cs, with a half-life of 30 years) and strontium (primarily ^{90}Sr, with a half-life of 29 years) was removed from the Hanford tank waste to provide for safer storage of the remaining, less radioactive waste. Between 1974 and 1980 this material was purified and encapsulated in double-walled cylindrical containers approximately 7 cm (3 inches) in diameter by 51 cm (20 inches) long. Some of the encapsulated radioisotopes were subsequently recovered for beneficial uses and are not part of the TWRS program. The cesium capsules emit intense penetrating gamma radiation and have been used in beneficial applications such as sterilization of medical equipment. Strontium capsules emit relatively little penetrating radiation and have been used as heat sources.

What remains as a TWRS responsibility are 1,329 capsules of concentrated fused cesium chloride (CsCl) salt and 601 capsules of strontium fluoride (SrF_2) powder. If the materials in the heat-generating capsules could be closely packed, their total volume would be approximately 2 m^3 (DEIS, p. 3-17). As of January 1995, each cesium capsule contains approximately 40,000 Ci of ^{137}Cs (half-life of 30 years) plus an unspecified amount of ^{135}Cs (half-life of 2.3 million years), estimated to be 0.7 Ci; each capsule emits approximately 190 watts (W) of heat. Each strontium capsule contains approximately 39,000 Ci of ^{90}Sr and emits approximately 260 W of heat. The capsules are stored in water pools on the Hanford Site.

What Is Not Addressed

The main subject of the DEIS is remediation of the contents of large waste tanks, a number of which are known to have leaked significant portions of their contents to the underlying environment. However, the DEIS does not

Table 1. Summary of Remediation Alternatives for Hanford Waste Tanks and Capsules (after DEIS)

DEIS Alternatives	Remediation Activity[a]			
	Tank Management[b]	Retrieval	Processing	Product Disposition
High-Level Waste Tanks				
No Action	Tank surveillance. Maintain DST^c space in case of a leak	None	None	Left in-place in its present form
Long-Term Management	Above plus replacement of DST^c as needed; build 26 new DST^c in 50 years	None	None	Left in-place in its present form
In Situ Fill and Cap	Evaporate liquid from DST^c waste and return to DST^c. Fill tanks with gravel; cover with multi-layer barriers	Remove pumpable water from DST^c; evaporate and return concentrate to DST^c;	None	Left in-place essentially in its present form
In Situ Vitrification	Evaporate liquid from DST^c. waste and return to DST^c.. Fill with sand and vitrify tank contents in place	Remove pumpable water from DST^c;, evaporate and return concentrate to DST^c	None	Left in-place incorporated into a glass matrix

Ex Situ Vitrification or Calcination; No Separations	Remove all wastes from tanks. Mechanical barriers on tank domes during construction or operations	Retrieve wastes from all tanks to the maximum practical extent	Heat waste plus glass-forming or calcination chemicals to yield HLW^c glass logs or calcined waste	All retrieved waste eventually sent to a repository
Ex Situ Intermediate Separations	As above	As above	Separate LAW^c; from sludge washing, salt cake dissolution, and supernatant. Separate practical amounts of Cs and possibly Sr, Tc, and organics from LAW^c; and combine with HLW^c Vitrify LAW^c and HLW^c.	HLW^c eventually sent to repository. On-site, near-surface disposal of LAW^c
Ex Situ Extensive Separations	As above	As above	Above plus extensive processing to minimize HLW^c volume and yield the lower of Class A LAW^c or ALARA^c	As above
Ex Situ/In Situ Combination	• Higher-risk fraction of tanks managed using Ex Situ/Intermediate Separations alternative • Lower-risk fraction of tanks managed using In Situ Fill and Cap alternative			
Phased Implementation	Any of the above alternatives (except No Action and Long-Term Management) except initial remediation is done on a limited scale to provide the basis for selecting the preferred alternative for the majority of the tanks. Any acceptable waste form for either HLW or LAW			

DEIS Alternatives	Remediation Activity[a]			
	Tank Management[b]	Retrieval	Processing	Product Disposition
Miscellaneous Underground Storage Tanks				
The remediation approach for the Miscellaneous Underground Storage Tanks is stated as being the same as for the larger tanks described above. No additional detail is provided.				
Encapsulated Cesium and Strontium				
No Action	The capsules are stored until 2007 in their current location at which time they are moved to another unspecified facility for continued storage	None	None	None
On-Site Disposal	Storage until repackaging and drywell storage facilities are available	Remove from water pool storage facility	Repackage capsule contents	Emplace capsules in near-surface drywell facility, where they remain forever
Overpack and Ship	Storage until repackaging facility is available	As above	As above	Overpack new capsules and ship to a repository for disposal
Vitrify with Tank Wastes	As above	As above	Remove capsule contents and mix with HLW[c] fraction of tank waste for immobilization	Contents would be sent to repository as part of HLW[c] logs

[a] Except for "No Action" and "Long-Term Management" all tanks are assumed to be closed by covering them with a Hanford barrier.

[b] All alternatives assume a maximum 100 year period after which active management ceases.

[c] Abbreviations: DST (double-shell tanks), HLW (high -level waste), LAW (low-activity waste), ALARA (as low as reasonably achievable)

address remediation of the tanks themselves, waste that cannot be removed from them, or the soil and ground water contaminated by leakage from the tanks. In addition, the DEIS does not address other sites of environmental contamination at the Hanford Site, such as production reactors, cribs, low-level waste disposal sites, and reprocessing facilities. The standards that must be met for tank closure, that is, the process of declaring remediation of the tanks to be complete under applicable federal and state laws, also are not addressed in the DEIS.

DESCRIPTION OF ALTERNATIVES

The DEIS presents and discusses a range of separate alternatives for remediation of the high-level waste tanks, the miscellaneous underground storage tanks, and the encapsulated cesium and strontium. In Table 1 the essential features of the alternatives and implementation sections of the DEIS are summarized. For the reader's convenience, a brief summary from the DEIS of the descriptions and analyses each of the tank waste remediation alternatives is contained in Appendix B.

3

FINDINGS

Many uncertainties exist with respect to implementation of tank remediation alternatives, including those related to technology, cost, performance, regulatory environment, risk, and waste and environmental characterization. These unknowns make it difficult to identify and evaluate the significant environmental impacts with any confidence. Because of these uncertainties, it would be premature for DOE and the State of Washington to commit to any final waste management decision.

In its recommendations, which appear in a subsequent section, the committee presents a framework for a **phased decision strategy** leading to selection of the most acceptable alternative or alternatives, as distinct from a phased implementation of a preselected alternative, to resolve these significant uncertainties.

TECHNOLOGY UNCERTAINTIES

With the exception of the No Action and Long-Term Management Alternatives, the technologies for the tank waste remediation alternatives presented in the DEIS have not been demonstrated for the Hanford tank wastes. Therefore, not only is the effectiveness of the alternatives unknown, but whether they are feasible at all for use with the tank wastes is also largely unknown.

The uniqueness, complexity, and enormous scale of the Hanford tank waste problem make the remediation task unprecedented in DOE's experience. The diversity of the reprocessing and other radioactive waste treatment operations carried out at Hanford has produced a broad spectrum of waste types. These types tend to be grouped into tank farms, each having waste that is greatly different from the others. In addition, the excess alkalinity of the wastes, combined with their chemical complexity, has produced a situation that makes characterization of the tank contents difficult. Without adequate characterization it is difficult to decide among remediation alternatives. In any case, for all of those treatment alternatives that involve removing the wastes from the tanks, a single alternative is unlikely to be suitable for all the different types of waste.

Some of the single-shell tanks contain very refractory solids whose complete removal may be difficult or even impossible without destroying the integrity of the tanks. Most of the single-shell tanks contain sludges that are composed largely of aluminum- or phosphate-containing compounds. Waste removal and transfer operations are likely to alter the physical and chemical natures of these wastes in unknown ways. Dilution of the wastes during sluicing and transfer operations may form colloids and gels, hindering the effectiveness of subsequent process steps. Additional precipitates of unknown physical and chemical composition are likely to form. Removal of the solid cakes could damage the tanks, leading to unacceptable leakage. Conversely, the double-shell tanks contain slurry whose transfer is likely to be relatively easy. However, even in the case of the double-shell tanks the transfer operations may cause changes in any waste whose nature is unknown.

Vitrification of high-level radioactive wastes has been demonstrated for many years on a large scale for well-characterized acid waste feed streams of essentially unvarying composition. However, this is not the case with the Hanford tank wastes for the In-Situ and Ex Situ No Separations Alternatives and is not certain to be the case for the Ex Situ/In Situ Combination, the Ex Situ/In Situ Combination Variation, and the Ex Situ Intermediate Separations Alternatives. In these alternatives, the waste feed to the vitrifier will be alkaline, much larger in quantity than any in previous experience, and of variable composition.

The vitrification operations are certain to be difficult, especially in those alternatives that involve no separations of bulk chemical constituents before vitrification. Radioactive off-gas treatment, particularly in cases involving relatively large amounts of cesium present in the vitrifier, will pose significant technical challenges. Because both cesium and technetium are likely to reach the vitrifier at some point during its operation, it is desirable during operation of the pilot plant to learn how to handle both of these elements in the vitrifier off-gas system.

COST ESTIMATE UNCERTAINTIES

While not necessarily a component of environmental impact assessment, the uncertain and high costs, currently projected at $7 billion to $253 billion in constant dollars, mandate careful review of all of the attributes of the various remediation alternatives. The higher cost estimates for certain alternatives are driven in part by significant uncertainties in waste amount, cost of waste recovery and processing, numbers of waste canisters produced, disposal repository acceptance criteria, and number and timing of repository operations. As an example, estimates of fees at repositories for the ex situ alternatives range from $0.6 billion to $211 billion (DEIS, Vol. One, Sec. 3), a difference of more than 300-fold.

The committee believes that cost uncertainties are even greater than reported in the DEIS. For example, costs of final disposal of high-level waste are used in the DEIS as a major factor in differentiating costs of various alternatives. These costs are estimated on the assumption that the cost of final disposal will be directly proportional to the amount (in volume units) of high-level waste sent to the final repository. This reasoning leads the authors of the DEIS to conclude that extensive separations of the tank waste streams could produce cost savings in the final disposal that counterbalance the cost of the separations.

The assumption that final disposal costs of high-level waste will correlate closely to waste volume is unverified. It is premature to conclude that charges will be based on the volume that is sent to the repository, despite current agreements within DOE. Much of the costs of final disposal stem from fixed costs associated with siting and licensing of the repository and construction of facilities such as shafts and support buildings that are common to all wastes received. The amount of defense waste that will be accepted at the first high-level waste repository is defined in terms of masses of uranium fuel from which the waste was derived. This could mean that the repository will accept a fixed portion of the total Hanford Site inventory of high-level waste, regardless of volume. In that case separation processing that reduces the volume of high-level waste would not change the fraction of the inventory that can be sent to the repository and, therefore, would be unlikely to change the fraction of the fixed costs that will be allocated to defense high-level waste from the Hanford Site.

The committee believes that selection of alternatives should not be predicated strongly on repository costs that are highly uncertain at this stage.

In its projection of costs, DOE does not appear to have been responsive to deficiencies noted in its own report *System Requirements Review, Hanford Tank Waste Remediation System Final Report* (U.S. Department of Energy, 1995). In that report it is suggested that cost estimates for the Tank Waste Remediation System are too uncertain to permit accurate assessment of alternative approaches to meeting performance requirements. Current cost estimates are characterized as “very optimistic” for the many first-of-a-kind systems under consideration (U.S. Department of Energy, 1995, p. v). Privatization of the tank cleanup program further diminishes DOE's ability to predict costs. Because of the many uncertainties about the tank wastes, contracts may have to be repeatedly modified to reflect new information.

There is a potential for enormous cost increases as the program develops. An example of this potential is found in the sensitivity analysis for the Ex Situ Intermediate Separations Alternative. Uncertainties in waste loading parameters are projected to result in a range of $30 billion to $43 billion in total cost, with a repository fee component ranging from $6 billion to $16 billion (DEIS, Table B.8.2.1). The total estimated cost range for each alternative is derived from the input parameters based on best available information, conceptual cost estimates, and engineering judgment. In addition, this range is sensitive to major changes caused by new information on characterization of the wastes, conceptual designs, and assumptions concerning regulatory, land use, and environmental factors (DEIS, pp. B-181). None of the alternatives, even those with high projected costs, include costs for final tank closure, which as discussed below are deferred to a later date and another NEPA review.

PERFORMANCE UNCERTAINTIES

The DOE TWRS *System Requirements Review* came to several conclusions on uncertainties in the performance of the technologies required for tank remediation. The report noted that the “TWRS conceptual architecture relies on numerous first-of-a-kind processes" (U.S. Department of Energy, 1995, p. 2-25). Among the uncertainties and unknowns cited were (1) retrieval of wastes with long-reach mechanical arms that have yet to be developed, (2) pretreatment of wastes by an enhanced sludge-washing process that has yet to be proven in the laboratory, (3) use of sluicing to attain greater than 99 percent waste removal, more complete waste removal than has been required in the past, and (4) immobilization of high-level waste by forming glass in an unproven way in a facility much larger than any existing one.[1]

In addition, the *System Requirements Review* found that the "conceptual architecture is vulnerable to single-point failure of any of the assumed processes" (U.S. Department of Energy, 1995, p. xvi). The proposed architecture was found to be likely to take longer and cost more than currently projected to remediate wastes at the Hanford Site. The Review proposed that:

> . . .Risks should be mitigated by performing laboratory-and bench-scale tests that validate assumptions and substantiate performance expectations for the preferred and *competitive architectures.* [italics added].
>
> A preliminary baseline (technical, cost and schedule) needs to be established with quantified top-level performance requirements that incorporate resolution of key policy issues. *This baseline needs to include schedules for the testing and validation of the assumed solutions, as well as solutions that may be substantially*

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[1] The DOE *System Requirements Review* concluded (U.S. Department of Energy, 1995, p. vii):

Uncertainties are still too great and the variations in the Hanford Site wastes are so significant that there is no assurance a unique, generally applicable process may be found. In order to reduce these uncertainties, the following steps must be taken on a priority basis:

- The wastes must be characterized expeditiously;
- Viable, competitive alternatives for dealing with various types of wastes must be defined;
- These competitive alternatives must be tested following the proven engineering practices that begins at the laboratory scale and progresses to bench and pilot scales; and
- Rigorous trade-off studies using technically defensible criteria at each stage along this path are needed to produce defensible selections of processes for TWRS."

> *better.* [italics added] (U.S. Department of Energy, 1995, p. xvi).

Resolving uncertainty about the effectiveness of processes in removing waste from the tanks, particularly the single-shell tanks, is especially important. The DEIS relies heavily on the combination of sluicing and long-reach arm technology for waste retrieval. Based on its experience with the former at both the Hanford and the Savannah River Sites, however, DOE judged both technologies to be insufficiently developed and tested to the point where they could be recommended confidently for use on the Hanford tanks (U.S. Department of Energy, 1995).

Judgments on performance of the strategies can only be speculative since there is little actual experience with the various suggested technologies. The decision by DOE and the Washington State Department of Ecology to adopt a phased approach for removing and treating the tank wastes is clearly a prudent approach in a situation such as that at the Hanford Site, where there are many uncertainties. A phased decision strategy, as recommended by the committee, allows for process improvements to be made based on experience and provides a credible basis for estimating the performance of future operations.

Recognizing such uncertainties, the preferred alternative in the DEIS involves pilot projects for the processes needed to carry out that alternative at full scale. However, because of uncertainty about the performance of the preferred alternative, it is appropriate to carry some backup alternatives into the pilot phase as well. On this point, the DOE TWRS *System Requirements Review* concluded:

> Key testing programs to obtain performance data do not follow proven engineering practice; they are focused on preferred processes with negligible attention being given to alternatives that might be needed if performance assumptions are not met. (U.S. Department of Energy, 1995, p. iv)

REGULATORY UNCERTAINTIES

Regulatory requirements that will be applied to the tanks and their contents are a significant area of uncertainty. Currently, the Tri-Party Agreement states that the tank wastes are hazardous wastes regulated by the Washington State Department of Ecology under various authorities, including the Resource Conservation and Recovery Act (RCRA). The Tri-Party Agreement references a host of other laws as well, including the State of Washington's Model Toxics Control Act, NEPA, and the Clean Air Act. The role of the U.S. Nuclear Regulatory Commission (USNRC) in this arena may also need to be clarified.

Environmental rules are often written in general terms that leave a substantial amount of discretion to regulatory agencies. Industrial companies commonly engage in informal negotiation with regulators over detailed implementation of the rules. In addition, waivers of specific rules are frequently available when it can be shown that the underlying aim of the requirement can be achieved in a different way, or when the cost of compliance is excessive. Such flexibility is most important and most frequently used with unusual materials and processes that are unlike those that were envisaged when the rules were written. Regulation of the Hanford tanks under Environmental Protection Agency (EPA) rules written for ordinary chemical wastes is such a case. Furthermore, environmental regulations change over time. It is difficult to know what rules will apply to treatment and disposal processes some decades in the future, and it is important for those involved with the Hanford Site cleanup to ensure that the processes under development and any relevant regulatory changes are on convergent paths. The committee notes that the Hanford Tri-Party Agreement has been amended through negotiation four times since it was entered into in 1989; a fifth amendment is currently being negotiated.

There are several important areas in which the DEIS contains restrictive interpretations of rules that are ambiguous, takes insufficient account of regulators' flexibility in dealing with unusual situations like the Hanford tanks, or neglects the likelihood that environmental rules will change over time. For example, the DEIS concludes that many alternatives that leave waste in the tanks would violate the land disposal restrictions under RCRA (DEIS, pp. 3-47 and 3-92). This conclusion is premature.

Under the land disposal restrictions, EPA defines treatment standards for particular waste streams from particular industries. These standards are based on existing technologies and practices whose costs are not prohibitive. The EPA standard for high-level waste treatment as expressed for specified technologies (40 CFR Part 268.42) appears to assume that the waste is from commercial reactors because it requires vitrification in a plant regulated by the USNRC. A treatment standard for single-shell tank high-level waste that required dewatering and tank stabilization with gravel or other stabilizers would appear to be consistent with the EPA philosophy in setting land disposal restrictions for other industries. The DEIS should not prejudge this regulatory decision.

The DEIS states that waste recovered in the ex situ/in situ option would require USNRC licensing for disposal in a geologic repository. However, implementing this option would also result in the creation of residues from the high-level and low-activity waste vitrifiers and residues in the form of the “heel” left behind in the tanks following waste removal. The committee believes these residues would be novel enough that the regulatory regime would be unique and require a special determination.

In other areas, the DEIS relies on favorable interpretations of regulations. Several of these were noted in the DOE TWRS *System Requirements Review* (U.S. Department of Energy, 1995).[2] What constitutes “incidental waste” [waste originating from nuclear fuel

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[2] “. . .To avoid wasteful expenditures of money and resources on the design of an unacceptable system, policy-level decisions are needed urgently to validate several assumptions including the following:

- The low-level waste fraction separated from the waste in single-shell tanks, miscellaneous underground storage tanks and catch tanks, and placed in near surface vaults will be accepted by the U.S. Nuclear Regulatory Commission as incidental waste not subject to their regulatory jurisdiction;
- Any residual material left in the tanks after practical retrieval operations will be suitable for in situ tank closure, i.e., how clean is clean;
- The transuranic waste can be blended with high-level waste for disposal in the geologic repository if it is determined that separation of some, or all, of the in-tank transuranic waste for disposal at the Waste Isolation Pilot Plant is more costly or presents significant safety or environmental hazards;
- The projected volumes of immobilized high-level waste in the selected size canisters will, in fact, be accepted for the geologic repository, and that the expected and bounding fees for permanent disposal of waste will be established expeditiously; and
- Multiple, nonconforming glass compositions, significantly different than Defense Waste Processing Facility and West Valley Project borosilicate glass, are to be pursued despite risks that regulators might not accept one or more of these glasses.” (U.S. Department of Energy, 1995, pp. xii-xiii)

processing that is not defined as high-level waste (DEIS, p. G-11)] may prove critical to decisions on both waste treatment and tank closure. The exact requirements of the regulations that will apply to the Hanford Site waste treatment and disposal activities are as yet unknown. Furthermore, DOE and the public have significant opportunities to influence the regulations through negotiation with regulators in an arena that includes public participation. It seems likely that what makes environmental, technical, and economic sense will have more influence on future rules than predictions based on the wording of the current rules, even though DOE needs to be mindful of the current regulatory environment.

The DEIS needs to expressly recognize the dynamic nature of decision making with respect to the tank wastes by providing review and revision approximately every 5 years as allowed by 10 CFR Part 1021. Given the large scale of the Hanford Site environmental remediation, it is prudent to review periodically total costs, total risks, and cumulative and indirect environmental impacts for the entire Hanford Site environmental remediation, and for the TWRS program specifically, in a public process.

UNCERTAINTIES IN TANK AND ENVIRONMENTAL CHARACTERIZATION

An important component of a long-term commitment to remediating the single-shell tanks at the Hanford Site is an adequate understanding of the nature of the present contents in the tanks and the extent to which the soil and ground water beneath the tank farms have been contaminated. Characterization should continue until such an understanding has been obtained.

In the 200 Areas of the Hanford Site where the tank farms are located, the waste in the tanks (approximately 177 million Ci) and the cesium and strontium capsules (173.5 million Ci) account for approximately 90 percent of the 391 million Ci of the total inventory (DEIS, p. 1-5). Another 1.4 million Ci is estimated to have been released or leaked to the ground. Approximately 4.9 million Ci has been disposed of in solid waste burial grounds, and 2.6 million Ci is stored in solids or contained in irradiated fuel storage. The DEIS addresses only the management and disposal of tank wastes and part of the inventory of cesium and strontium capsules. Other waste disposal activities in or near the Hanford Site 200 Areas that are not addressed in the DEIS include (1) site waste from the environmental restoration program (to be disposed of in the Environmental Restoration Disposal Facility), (2) commercial low-level waste disposed of at the U.S. Ecology site, and (3) submarine reactor compartments.

Recent monitoring in the vadose zone beneath a single-shell tank revealed ^{137}Cs at the bottom of a 125-foot (38-m) well (Rust Geotech, 1996). This finding does not appear to be consistent with what is otherwise known about cesium mobility in the subsurface environment surrounding the tanks. The source of this radionuclide may be a tank, or it may have come from other past disposals in cribs or directly into the ground. The cesium may have been carried down the well during drilling, entered the hole through faulty casing, or migrated along some other preferred path. In another recent finding the State of Washington Department of Ecology noted contamination by ^{99}Tc of the ground water under a tank farm, citing evidence leading to the conclusion that this radionuclide came from the tanks (Leja, 1996). More discoveries are possible as tank and environmental characterization studies proceed, and it is unclear at this point what implications they may have for the conduct of the remediation program.

The committee understands that a first step in characterizing single-shell tank conditions under the new Hanford Tanks Initiative (U.S. Department of Energy, 1996b) will be to investigate two single-shell tanks: tank AX-104, reported in 1977 to be a leaker and now mostly empty of liquids primarily due to pumping; and tank C-106, which has a high heat generation problem. Removal of material from tank AX-104 is to be done mechanically and will provide data on the effectiveness of this approach. Presumably, hydraulic sluicing of an almost empty but formerly leaking tank would not be desirable or practical and will not be attempted.

HEALTH RISK UNCERTAINTIES

In the DEIS, analyses of health risk effects are divided into two time periods: short-term impacts during remediation and during the post-remediation monitoring and maintenance period, assumed to be a 100-year administrative control period; and potential long-term impacts beginning after the 100-year administrative control period and continuing for 10,000 years into the future. Short-term potential health effects would result from occupational nonradiological accidents, occupational radiological exposure during operations and waste transportation, radiological and chemical accidents, and transportation accidents from deliveries of materials and supplies to the site (DEIS, p. S-22). The primary potential long-term impacts are ground water contamination, health effects associated with consumption of the ground water, and potential health effects resulting from post-remediation intruders and accidents (DEIS, p. S-25).

Presentation of Key Risk Parameters and Health Impact Projections

Several key parameters directly affect the calculation of potential health effects, including the range of variation in source and source term, exposure parameters, risk coefficients and hazards indices, size and temporal distribution of populations at risk (both workers and public), and degree of conservatism in health risk calculation methodologies. Many of these parameters have been selected on an upper-bound rather than expected value basis to provide conservative projections of potential health effects. In some instances, cascading of conservatively-derived parameters has produced conservative estimates that may not reflect meaningful values. Examples of such cascading found in the DEIS include the calculation of probability of risks from radiological and toxicological accidents (DEIS, pp. E-27 through E-28) and the treatment of a sample accident scenario involving a mispositioned jumper (short connecting pipe) (DEIS, pp. E-247 through E-248).

Estimates of potential health effects, both short- and long-term, for each of the remediation alternatives are scattered throughout the DEIS volumes, making comparison difficult. Risks are frequently presented as individual health effect probabilities without reference to time frame or size of population at risk (DEIS, Table 5.14.1). The expected values of these health effects projections and their uncertainties are either not displayed or are difficult to locate within the DEIS.

Use of Guidance on Collective Dose

The estimates of latent health effects in the DEIS are based on collective dose multiplied by risk coefficients and, for chemicals, exposure multiplied by hazard coefficients. While the National Council on Radiation Protection and Measurements (NCRP; 1995) and the International Commission on Radiological Protection (ICRP; 1991) have provided guidance on the use of such methodology for estimating exposure to radiation, both groups recognize that collective dose can be used to derive an estimate of collective or total health detriment from radiation exposure only under limited conditions.[3] More explicit guidance is given by NCRP with respect to the use of collective dose to determine societal risk from future exposures to long-lived environmental radioactive contaminants.[4]

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[3] ". . .However, the legitimate applications of collective dose must include clearly defined boundary conditions for the time, locations and pathways of exposure, as well as characteristics of the exposed populations. The uncertainties must not only be stated, but should be used to determine the extent to which the collective dose can be used as a surrogate for risk.

When the combined uncertainties in the exposed population, e.g., size, those related to characteristics, exposure pathways and individual doses, result in a collective dose with a relative uncertainty of more than an order of magnitude, neither estimates of collective dose nor estimates of collective risk are adequate for making decisions." (National Council on Radiation Protection and Measurements, 1995, p. 48)

[4] "Neither population size and characteristics nor environmental exposure pathways for most radioactive elements are predictable with any degree of confidence for more than a few generations into the future. . . Consequently, there can be no meaningful calculation of collective or individual doses for populations far in the future. For this reason, collective dose projected more than a few generations into the future should not be used as a basis for estimating societal risk or for limitation or practices, although such projections may have some utility for other purposes.

The most reasonable risk assessment that can be made for such situations is to calculate potential individual doses for a range of scenarios in order to: (1) evaluate protective measures and (2) to try to place some boundaries on estimates of future individual risks. For the few very long-lived radionuclides that are metabolically regulated in the body and more or less uniformly distributed within the biosphere (e.g., ^{14}C and ^{129}I), future average individual doses may be estimated from total quantities in the environment even though there could be no valid estimate of collective dose because of the lack of knowledge regarding future populations and their demographics." (National Council on Radiation Protection and Measurements, 1995, pp. 57-58)

The DEIS derivations of potential long-term health risks from collective dose estimates have gone beyond what the NCRP guidance suggests is appropriate. Adverse health effects have been projected for 10,000 years, rather than the few generations recommended by NCRP, with significant uncertainties concerning sources, pathways of exposure, and characteristics of future populations at risk. The NCRP admonitions concerning the use of collective dose as a risk surrogate should be recognized in the risk projections. Moreover, all estimates of exposures that could lead to future adverse health effects were calculated on an upper-bound basis in the DEIS rather than on the basis of expected values.[5] In keeping with the NCRP guidance and to facilitate a more meaningful comparison of alternatives, both the expected value and range of health risk estimates, as well as the upper-bound values, should be provided when possible for each remediation alternative. To provide a public health context for the estimates, statistics on the background cancer rates and occupational risks to workers and the general population should be presented.

Risk Assessment for Comparison of Alternatives

The risk estimates for occupational accidents given in the DEIS appear to be within average experience, taking into account the size of the populations at risk and the period of time for remedial actions. Summaries in the DEIS of potential long-term health effects of each of the remediation alternatives all present post-remediation potential cancer incidences and fatalities from exposures out to 10,000 years. It is not clear whether these estimates are calculated from radiation exposures or combinations of radiation and chemical exposures. Unavoidably, the uncertainties

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[5] For example, in the DEIS (p. S-23):

"…a bounding approach to estimating accident consequences was taken in the EIS. Conservative estimates were made for the type and amount of contaminants that would be released and how they would be transported in the atmosphere to expose both workers and the public. Therefore, the health effects calculated provide an upper bound for the health effects that could occur."

Also, in the DEIS (p. D-297):

"The summation of cancer risk across pathways or for multiple pathways makes the total cancer risk more conservative. This is because each slope factor for each chemical carcinogen is an upper 95th percentile estimate and such probability distributions are not strictly additive."

associated with these estimates are high (DEIS, p. 5-150) because assumptions must be made concerning data on sources, transport, dose-response relationships, hypothetical land use, population distributions, and receptor behavior. The risk estimates thus derived should reflect the NCRP guidance noted previously. The uncertainty in the risk values for certain receptors increases as time into the future increases.

It is important to recognize that risk to human health, especially to workers on the site, increases significantly as the degree of remediation and its complexity are increased. Ultimately there are trade-offs between occupational risks, completeness of in situ remediation, export of wastes with concomitant risk during transportation, and uncertainties about risks at an external site.

While the committee recognizes the utility of quantitative risk assessment in the comparison of remedial alternatives, the limitations of analysis must be underscored. Given the complexities of the tank farms, many of the potential uncertainties cannot be measured, quantified, or expressed through statistically derived values. Therefore, the characteristics of risks and their ranges must go beyond a synthesis of statistical estimates. Characterization of risks should be both qualitative and quantitative. Qualitative information should include a range of informed views about the risks and the evidence that supports them, the risk likelihood, and the magnitude of uncertainty (U.S. Environmental Protection Agency, 1996; Commission on Risk Assessment and Risk Management, 1996).

The practice of maximizing risk by upper-bounding of the parameters inevitably leads to biased decision making when comparing alternatives. As noted in a recent report of the National Research Council:

> Organizations responsible for characterizing risks should plan to blend analysis with deliberative processes that clarify the concerns of interested and affected parties, help prevent avoidable errors, offer a balanced and nuanced understanding of the state of knowledge, and ensure adequately broad participation for a given risk decision. (National Research Council, 1996a, p. 72)

Both expected values and ranges of risk estimates and their uncertainties should also be provided, and limitations on the assessment of long-term societal risks acknowledged. In addition, as noted in the DOE guidance for NEPA:

> Analyses generally should be based on realistic exposure conditions. Where conservative assumptions (i.e., those that tend to overstate the risk) are made, describe the degree of conservatism, and characterize the "average" or "possible" exposure conditions if possible. (U.S. Department of Energy, 1993, p. 21)

Intruder Scenario Estimates

The DEIS projects a high probability of significant risk to the waste site intruder over the long-term of 1-in-1, making it a major component of projected long-term risk. It projects 5.5 intrusions into single-shell tanks and 0.58 (or 1) intrusion into double-shell tanks over the 10,000 year period (DEIS, Table D.7.5.1). Significant uncertainties in intruder risk result from the way in which certain factors have been selected to produce a maximum or upper-bound risk estimate. For example, the amount of radioactivity to which the intruder is exposed is based on the tank inventory in the year 2095. No correction is applied for radioactive decay over the remainder of the 10,000-year period, although the anticipated 5.5 intrusions may be expected to be randomly distributed over that time period.

Moreover, the representative waste tank source area used for the analysis (called source area "3EDS" in the DEIS and made up of three adjacent double-shell tank farms, AN, AZ, and AY) has the highest radioactive inventory (in total curies of ^{137}Cs) of the eight aggregated tank source areas used (DEIS, Table A.2.1.8). These tank farms were combined as source areas for the purpose of ground water modeling, based on tank contents (inventory), tank proximity, and ground water flow direction. The inventories from individual tank farms were combined to create the waste inventory for each source area (DEIS, p. A-2). Selection of a double-shell tank source area with the highest combined inventory of ^{137}Cs highlights the conservatism of the approach used in the DEIS to estimate risks associated with the intruder scenario, especially as it is applied to the single-shell tanks, and reinforces the need to provide both expected values and upper-bound estimates of risk.

Dose-Response Estimates

The uncertainties of long-term risk projections were recognized in previous reports of the National Research Council:

> The uncertainty, especially regarding human intrusion into a repository over a 10,000-year time span, is such that “it is not possible to make scientifically supportable predictions of the probability” of such an intrusion (National Research Council, 1995:11 [*1995a, p. 11*]). (National Research Council, 1996a, p. 107)

In the DEIS, estimates of risk based on upper-bound assumptions do not represent expected values or reflect changing conditions over the 10,000-year period.[6] For example, the 1-in-1 risk of latent cancer fatality given to a waste site intruder (DEIS, Table S.7.4) would apply only to the post-drilling resident. The total inventory of the eight aggregated tank sources ranges from 20.8 Ci to 1,030 Ci, with an arithmetic mean of 326 Ci (DEIS, Table D.7.1.1). Adjusting for source term and radioactive decay, the expected values for dose estimates for the intruder scenario must be lower by one or two orders of magnitude or more over time. A more realistic approach is needed, and both expected values and ranges of risk should be provided subject to uncertainties noted above. Similar considerations apply to other groups evaluated for the period following the 100-year administrative control period.

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[6] Under the No Action, Long-Term Management, and In Situ Fill and Cap Alternatives, which are stated to convey the greatest risks, the probability of a latent cancer fatality was calculated to be 8.52E-03 for the driller, and 2.96E+00 for the post-drilling resident (DEIS, Table D.7.4.2.). The dose-to-risk conversion factors used for cancer fatality are 4.00E-04 for the well driller and 5.00E-04 for the post-driller resident (DEIS, Section D.7.4). By dividing the estimated probabilities by the pertinent risk coefficients, the calculated doses are 21.3 rem to the driller (received over 40 hours) and 5,920 rem to the post-driller resident (received over 70-year lifetime), or an average of 84.5 rem per year.

UNCERTAINTIES ABOUT REMEDIATION OF RESIDUAL CONTAMINATION

Under RCRA a hazardous waste management unit must be "closed" after it is no longer used. Such an end point may be accomplished either by "clean closure," which requires removal of all detectable contamination and is not a realistic option for the Hanford tanks, or "closure as a landfill," which requires stabilization and capping to limit waste migration, followed by long-term monitoring. The term "closure" refers to a legal determination by regulators that an acceptable technical job of remediation has been accomplished. As applied to the Hanford tanks, closure requires remediating the tank wastes, as well as the tanks, ancillary equipment, and contaminated soil and ground water. In common usage, "closure" sometimes refers only to the legal determination and sometimes to the remediation activities as well.

Conceptually, the Washington State Department of Ecology and DOE have divided the technical work of remediating the Hanford tanks into two parts. One part, removal, treatment, and disposal of the wastes in the tanks, is the subject of the DEIS. The second part, remediation of the tanks themselves, waste that cannot be removed from the tanks, waste from deliberate discharges, and environmental contamination that is associated with the tanks, is outside the scope of the DEIS and will be addressed separately in the future.

This division artificially limits the alternatives available. For one, the option of deliberately leaving some waste in tanks is precluded. Furthermore, decisions on waste in the tanks are interrelated with decisions regarding the tanks themselves, associated equipment, and soil and ground water contaminated by past leaks and deliberate discharges.

For example, some of the tank retrieval activities are projected to lead to further leakage of tank contents. The retrieval of single-shell tank waste under each of the ex situ alternatives was assumed to result in the release of approximately 15,000 liters (4,000 gallons) of material from each single-shell tank to the soil surrounding it during retrieval operations (DEIS, p. B-176). No leakage was assumed to occur from the double-shell tanks during retrieval operations. For the single-shell tanks, the total release from the 149 tanks would be 2.3 million liters (600,000 gallons).

The single-shell tank radionuclide inventory of 104 million Ci is contained in approximately 140 million liters (36 million gallons) of waste. Discounting any dilution during the waste slurrying process, retrieval of the single-shell tank wastes could result in the release of an additional 1.7 million Ci of radioactivity to the surrounding soil, an amount on the same order of magnitude as the 1.4 million Ci already estimated to have been released or leaked to the soil in the 200 Areas. This leakage is explicitly excluded from the scope of the DEIS (p. 5-12).

It is not at all evident how a preferred tank waste retrieval and treatment remediation alternative can be selected rationally without simultaneously considering what is to be done with the contamination left behind. Some of the decisions to be made concerning disposal of tank waste will limit future decisions on what to do about the tanks themselves and any unremoved wastes. The DEIS provides little information on this subject. For purposes of analysis, it assumes that the tanks will be covered with a multilayer cap, the Hanford Barrier (DEIS, Figure S.6.2), except in the No Action and Long-Term Management Alternatives, which essentially maintain the present tank farm status.

The DEIS confuses these issues in its choice of terminology. The word "closure" is used to describe both the second part of the remediation (the tanks and waste left in the ground) and the final legal determination that both parts of the cleanup have been concluded satisfactorily. DOE and the Washington State Department of Ecology state that they intend to develop a plan for closure, defined in this way, at a later date. No timetable is given, but waste treatment operations that must precede closure are not projected to end before the years 2009 to 2028 for the various alternatives (DEIS, Tables 3.7.1 and B.11.0.1). Indeed, this schedule seems optimistic in view of the new technologies, construction and operations activities, and resources required.

TRANSFER OF RISK TO OFF-SITE POPULATIONS

Risks that may be transferred to off-site populations by transfer of waste from the Hanford Site to repositories, while not a component of this DEIS (p. S-16), are an important part of the risks of the various remediation alternatives and should be considered when the alternatives are compared. For example, in the in situ alternatives, all radioactive wastes remain in the 200 Area tank farms and convey their risks to the public and the environment from those locations. In the Ex Situ/In Situ Combination Alternative, appropriate tanks would be selected so that 90 percent of the contaminants that contribute to long-term risk would be disposed of ex situ while only 50 percent of the waste would be retrieved (DEIS, pp. 3-86 to 3-88). Thus, only 10 percent of the projected long-term risk would remain on site, while most of the risk would be transferred to transportation of the retrieved wastes and to an off-site geologic repository.

For all other ex situ alternatives, tank waste would be separated into low-activity waste and high-level waste fractions. The high-level waste fraction, varying in volume according to the degree of separation applied, would be immobilized by vitrification or some other solidification process and sent to a geologic repository for off-site disposal. All of the long-term risk from high-level waste would be transferred to transportation of the wastes and to the repository site. The radioactivities estimated for wastes left in place are within the 10- to 15-millirem limits prescribed in 40 CFR Part 191 for repository doses.

Basing health and environmental risk estimates solely on on-site source terms results in inconsistencies and gives an inappropriate basis for comparing various remediation alternatives. In other environmental impact statements DOE has prepared comparative analyses of risks for alternatives involving waste disposal on and off site, including transportation risks. Such a comparison need not require elaborate analysis; for example, risks from final repositories could be assumed to equal the risk targets set in the EPA regulations. Such a comparison for 200 Area wastes could provide insight as to levels of acceptable risk. The appropriate portions of this off-site risk should be allocated to each of the pertinent alternatives in the DEIS.

FUTURE LAND USE UNCERTAINTIES AND EFFECT ON ALTERNATIVES

Future land use is a critical factor for making decisions concerning tank waste at the Hanford Site. The DEIS defers discussion of future land use of the site. The absence of a comprehensive land use plan and analysis creates the possibility that proposed tank decisions may involve the application of cleanup standards that are not consistent with intended uses of the 200 Areas or other portions of the site. The ability of DOE to make final cleanup decisions anywhere on the site is thus limited. Although difficult to accomplish, development of a plan detailing future land uses and analyzing their implications for cleanup would be extremely useful.

Land use is closely related to risk assessment. EPA guidance on land use of Superfund sites should be cited and considered when developing exposure scenarios (U.S. Environmental Protection Agency, 1995). Future land uses may be restrictive, unrestrictive, or conditioned in specific ways.

The DOE report *Charting the Course: The Future Use Report* (U.S. Department of Energy, 1996a) describes efforts by the Hanford Future Site Uses Working Group to develop a Hanford Remedial Action Environmental Impact Statement and Comprehensive Land Use Plan. Such a document could meet the need for a broader context for decision making discussed above. This potentially significant effort is not referenced in the DEIS, however. The numerous commitments that have been made in the Tri-Party Agreement to specific timetables for elements of the cleanup have rendered coordination of environmental documentation for the Hanford Site difficult, a problem exemplified by the limited discussion in the DEIS of land use consequences of TWRS cleanup alternatives.

CAPSULES AND MISCELLANEOUS TANKS

There is little substantive discussion in the DEIS of the management and disposal of the cesium and strontium capsules and of the miscellaneous underground storage tanks. To be sure, more than 99 percent of the tank wastes is in the single- and double-shell tanks, where the greatest potential for health risks exists. However, the high concentration of radioactivity and the nature of the materials in the capsules warrant a more thorough discussion of their treatment, disposal, and environmental impact. Additionally, the large number and wide distribution of the miscellaneous underground storage tanks make a more complete discussion of their management necessary.

Cesium and Strontium Capsules

Although the DEIS describes the capsules and discusses their treatment and disposal, it is not clear that adequate attention has been given to the changes in chemical and isotopic composition that will occur over time. The capsule remediation alternative is missing important information. The No Action and Onsite Disposal Alternatives would leave a large amount of both ^{137}Cs (half-life of 30 years) and ^{135}Cs (half-life of 2.3 million years) in a near-surface disposal facility. Even though the hazard of the long-lived radionuclide will persist well beyond the 100-year institutional control period assumed in the DEIS, the risk to intruders or the general public from other release mechanisms is unspecified.

Cesium Capsules

The situation with the cesium is more complex than that considered in the DEIS. Table 2 provides the cesium isotope composition as a function of decay time. It is important to note that approximately 5 percent by weight of the capsule contents is long-lived ^{135}Cs and that approximately 40 percent of the capsule is composed of elements other than cesium. The ^{135}Cs activity will exceed that of the ^{137}Cs after approximately 560 years. The times required for the cesium capsule

Table 2. Isotopic Composition of Hanford Reservation Cesium Capsules (after A.G. Croff, personal communication)

Isotope	Half-life, years	Decay Time after Encapsulation								
		November 20, 1981			100 Years			300 Years		
		g/Mg	(Ci/g)[a,b]	%	g/Mg	(Ci/g)	%	g/Mg	(Ci/g)	%
Cs-133	Stable	300,000	(0)	30 (0)	300,000	(0)	30 (0)	300,000	(0)	30 (0)
Cs-134	2.062	23	(0.03)	0.002 (0.1)	0	(0)	0 (0)	0	(0)	0 (0)
Cs-135	2.3 x 10^{6}	50,000	(6x10^{-5})[c]	5 (3 x 10^{-4})	50,000	(6x10^{-5})	5 (3x10^{-3})	50,000	(6x10^{-5})	5 (0.24)
Cs-136	3.6 x 10^{-2}	0	(0)	0 (0)	0	(0)	0 (0)	0	(0)	0 (0)
Cs-137	30.17	256,000	(22)	25.5 (99.9)	25,700	(2.3)	2.6 (100)	280	(0.025)	0.03 (99.8)

Isotope	Concentration in Encapsulated Material,[d] Ci/m^3	Class A		Class B		Class C	
		Limit,[e] Ci/m^3	Time to reach limit, years	Limit, Ci/m^3	Time to reach limit, years	Limit, Ci/m^3	Time to reach limit, years
Cs-135	166	80 (est.)	3.2 x 10^{6}	80 (est.)	3.2 x 10^{6}	800 (FEIS)	0
Cs-137	6 x 10^{7}	1	775	44	610	4600	410

[a] Basis is a 1Mg of encapsulated material as of 11/20/81 per personal communication from J. D'Ambrosia to A.G. Croff on May 30, 1996.

[b] An additional approx. 200,000 g/Mg of the encapsulated material is chlorine. The remaining approx. 200,000 g/Mg is not specified and is presumed to be inert. Density is assumed to that of pure CsC1: 2.77 g/cm^3.

[c] Equivalent to 60,000 nCi/g of encapsulated material.

[d] Time at which Cs-137 activity declines so that it equals Cs-135 activity: 560 years.

[e] Class C value taken from FEIS underlying 10CFR61. Class A and B limits assumed to be 10% of Class C.

NOTE: Cs-135 decays by beta emission (E_{max}= 0.205 MeV) with no accompanying gamma emission. Its ingestion toxicity is about 14% of that of Cs-137.

contents to reach the low-level waste Class A, B, and C concentrations that are generally acceptable for various types of near-surface disposal, based on 10 CFR Part 61, are given in the lower portion of Table 2. While these limits are not directly applicable to DOE operations, they are indicative of the long times over which the cesium capsules remain a potential risk.

Of particular relevance, the capsules will be intensely radioactive for hundreds of years because of the presence of ^{137}Cs, and they will remain hazardous for millions of years because of the presence of ^{135}Cs, with an activity of approximately 60,000 nCi/g during the first million years. The capsules are Class C low-level waste for approximately 410 years because of the ^{137}Cs alone, and they are estimated to remain in such a classification for a few millions of years because of the ^{135}Cs.

There is no indication in the DEIS that the longer-term (beyond 100 years) hazard from the ^{137}Cs or ^{135}Cs in the capsules was considered in characterizing the impacts of cesium capsule management alternatives. The committee believes it is necessary to include this consideration, especially when characterizing alternatives that involve leaving the capsules on the Hanford Site.

The non-cesium components of the capsules should also be considered in assessing the performance of cesium capsule management alternatives. Of the 40 percent of the capsule contents that is not cesium, approximately half is chlorine (as chloride) initially associated with cesium. The rest is composed of stable barium resulting from the decay of the cesium, and an assortment of incidental chemicals that accompanied the CsCl during its recovery. Some trace radionuclides are also to be expected but are not identified. The amount and composition of incidental species is poorly characterized and can vary from several percent to approximately 15 percent. It is composed of elements such as sodium, potassium, barium (present in the Hanford tanks when the cesium was recovered), iron, and nickel.

An additional complicating feature is that the decay of monovalent cesium results in the production of divalent barium. Because the amount of chlorine combined with the radioactive cesium is only one-half of that needed to balance the divalent barium produced by the decay of cesium, it it is likely that the more noble impurity elements present in the capsules will be reduced by the barium. Any unreacted barium will be present as metallic barium, which is likely to persist over a long time period. The change in chemical species is also likely to cause volume changes of unknown direction and magnitude that may become important. The identity and impact of these other elements on the long-term integrity of the cesium capsules, which must be taken into account in assessing the impacts of the various alternatives, have not been addressed in the DEIS.

Strontium Capsules

Strontium-90, which is divalent, decays with a 28.5-year half-life to stable ^{90}Zr, which is normally tetravalent. It is not clear what the effect of the resultant deficiency of fluoride ion will be on the stability of the capsules. There will be a significant change in chemical composition as the transmutation from strontium fluoride to zirconium fluoride (and presumably to uncombined zirconium metal) takes place. Additionally, there is the potential for a net increase in the volume of the capsule contents. In the DEIS there is no discussion of the potential effects of these changes on the integrity of the capsules and, thus, the risk associated with capsule disposition. In contrast to the situation with the long-lived ^{135}Cs, the changes are not a long-term issue in the strontium capsules. In approximately 830 years the concentration of ^{90}Sr in the capsules would be less than the low-level waste Class A level of 0.04 Ci/m^3.

Miscellaneous Underground Storage Tanks

There is too little discussion of the miscellaneous underground storage tanks in the DEIS for a meaningful analysis of their proposed treatment and management and an evaluation of the adequacy of the alternatives in this application. In the DEIS, it is assumed that the same general approach will be used for these tanks as for the single-shell and double-shell tanks.

4

RECOMMENDATIONS

RECOMMENDED APPROACH

Phasing

The committee concludes that not enough is currently known to support any final decision on tank farm cleanup. Major uncertainties exist in the areas of technology, costs, performance, regulatory environment, future land use, and health and environmental risks. Among the issues that remain uncertain are:

- effectiveness and feasibility in practice of technologies to remove and treat waste from tanks,
- costs of operations and off-site waste disposal,
- future policy and regulatory environment for managing waste at the Hanford Site,
- characterization of tank wastes, and
- relationship between tank waste removal, remediation of the surrounding environment, and ultimate land use at the site.

These are in agreement with DOE's own conclusion in its *Systems Requirements Review* (U.S. Department of Energy, 1995). The analysis in the DEIS reveals that there are crucial gaps in the scientific and technical knowledge that make it imprudent to decide now on a multidecade plan. Furthermore, there is no need to make such a sweeping decision now.

In view of such uncertainties, the committee recommends that the proper approach to decision making for tank cleanup is a phased decision strategy in which some cleanup activities would proceed in the first phase, while the important information gaps are filled, in parallel, by focused research, technology and engineering development, and pilot-test and demonstration programs. The major programmatic decisions in such a phased decision strategy should be deferred, possibly for as long as 10 years, while the information needed to provide a more complete basis for sound decisions is developed. Such a phased decision strategy is compatible with the view, expressed in other National Research Council reports, that the DOE environmental remediation activities throughout the DOE Defense Waste Complex should be viewed as an experimental program rather than a straightforward cleanup effort (National Research Council, 1995b, 1996b).

The committee applauds the choice by the U.S. Department of Energy and the Washington State Department of Ecology of a phased approach as the preferred option in the DEIS. However, the phased option in the DEIS is narrowly drawn, representing two stages of scale-up of a single selected technological approach. In the phased approach described in the DEIS, the first phase is more like a demonstration project in which two pilot plants provide operating experience that will allow optimization of the relevant processes associated with a single technology before the construction of full-scale facilities. In the phased decision strategy recommended in this report, the first phase should provide information about backup technologies and overall strategies to leave open the option of selecting a different alternative for full-scale operation.

The phased decision strategy involves moving forward on two tracks. Concerning the supernatant in the double-shell tanks, uncertainties regarding characterization, removal, and treatment technology are much less significant than for other wastes in both the single- and double-shell tanks. The committee concurs with the view expressed in the DEIS that a pilot treatment plant should be built now, and it recommends that such a plant be part of Phase 1 of the phased decision strategy. However, the committee is not aware of an adequate analysis to support the choice of glass in the DEIS (and the Tri-Party Agreement) over grout, the previous solidifier, as the low-level waste form to be produced by this plant, and it believes that the choice of waste form to be produced by this plant should be reevaluated based on present knowledge before plans for the pilot plant are made final.

As for the other tank wastes, the first phase should be used to gather all of the crucial information necessary to support a selection from among a range of alternatives several years hence. In the first phase, DOE should explore technical options and overall strategies that may be realistically considered candidates for a role in the long-range tank cleanup effort. For each such option explored, the gaps in technical knowledge should be identified and analyzed. In the committee's view the first phase should be dedicated to providing the technical data on required processes and analyses of costs and impacts needed to support informed decisions.

After the first phase in the strategy recommended by the committee, DOE and the State of Washington would supplement the final TWRS Environmental Impact Statement and issue a new record of decision selecting a preferred alternative based on the new information and understanding of the feasibility and impacts of several alternative strategies developed during the first phase. The reality is that a multidecade commitment to a particular course of action for remediating all of the Hanford tanks cannot be made at this time. Unlike a record of decision to implement a typical RCRA closure or Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) remediation action for a site, whatever course is chosen now cannot be implemented very quickly, and changes will have to be made as circumstances warrant. The preferred option, estimated to cost as much as $42 billion, represents a significant commitment of national resources. A program of this magnitude will undoubtedly be subject to intense scrutiny as it is implemented and will be subject to “midcourse corrections” based on experience and external policy changes (e.g., possible changes in the controlling environmental laws and regulations).

A comprehensive strategy of environmental monitoring and risk surveillance should be an essential component of the phased approach. The goal of this strategy should be to assure that public health and the environment are adequately protected during implementation of the overall remediation program.

The phased decision strategy is similar to the CERCLA process for remediation, which involves a sequence of (1) treatability studies on the remediation target, (2) a record of decision that establishes the preferred remediation approach based on the results of the treatability studies, and then (3) large-scale remediation using this preferred approach. This strategy is being used to remediate underground waste storage tanks at Oak Ridge National Laboratory (U.S. Department of Energy, 1994).

In making this recommendation, the committee concurs fully with the conclusion of the DOE *System Requirements Review* (U.S. Department of Energy, 1995).[7] That review recommended a similar course of action, involving development of a baseline and testing of both the baseline and backups (U.S. Department of Energy, 1995).[8]

Range of Alternatives to Consider

The committee recommends that DOE and the Washington State Department of Ecology not restrict their decision to choosing one among the nine alternatives identified in the DEIS. Such a restriction will limit the range of alternatives by driving the decision inexorably toward the phased alternative currently described in the DEIS because this is the only alternative that benefits from phasing. The best decisions will result if DOE compares a range of different phased alternatives and chooses the best one.

The DOE TWRS *System Requirements Review* observed the need for development of better alternatives.[9] The committee agrees with the conclusion that in the absence of substantive data, estimates of the cost and performance of first-of-a-kind alternatives "are so uncertain that they can

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[7] "The evaluation of the conceptual architecture for TWRS must not be confined to the assumed processes. As noted in the Tri-Party Agreement, 'Options may be identified which have the potential to significantly improve the tank waste disposal strategy. A systems engineering approach will be used to define and evaluate the options.'" (U.S. Department of Energy, 1995, p. vii)

[8] "2.1.2.5 Recommendation: Approve a preliminary baseline that defines the technical configuration, the alternatives to be concurrently tested and evaluated, the assumptions that must be tested, the schedules for all critical activities, and the cost estimate and their (sic) appropriate contingencies" (U.S. Department of Energy, 1995, p. 2-5)

[9] "In general, when alternatives have been considered for meeting requirements of a TWRS function, these alternatives have been bounding or otherwise limiting. Some use has been made of synthesized alternatives… No systematic approach integrated over TWRS has been defined to consider intermediate alternatives synthesized from the better features of the limiting alternatives." (U.S. Department of Energy, 1995, p. 2-25)

only be used for crude screening of alternatives to define limited sets of alternatives for further testing" (U.S. Department of Energy, 1995, p. 2-26). It is not possible at this stage to support a conclusion that any alternative is clearly preferable, and the current emphasis should be placed on identifying a set of alternatives that are worthy of further technical exploration. The DOE should use its existing understanding of the uncertainties to identify a reasonable set of alternatives for examination that, taken together, provide confidence that workable and environmentally acceptable options will be available when the time comes to commit to full-scale remediation.

Backup approaches are needed because the technologies projected to meet current requirements might not work or might cost far more than anticipated. Costly options designed to meet regulatory requirements may fail to provide significant additional health benefits or environmental protection, thereby focusing attention on the need for regulatory change. Further, if funding for the Hanford Site cleanup is constrained, as it almost surely will be in an era of increasingly tight federal budgets, it will become more important to be able to optimize the cost/risk reduction ratio across the entire site.

DOE should develop fallback options and promising alternatives that might achieve most of the projected benefits of current options at a substantially reduced cost. For example, the additional $14 billion cost of the preferred Phased Implementation Alternative compared to the Ex Situ/In Situ Combination Alternative (DEIS, Table S.7.6) reduces the projected long-term health effects from 88 to 15 fatalities (DEIS, Table S.7.3). Although, as pointed out earlier in this report, the values of costs and risks in the DEIS are uncertain, one could calculate from the above a projected cost-per-avoided-cancer-fatality of nearly $200 million, an exceedingly large number, especially given the speculative and highly conservative nature of the health risk estimates in the DEIS. At the very least, this suggests that improved versions of the ex situ/in situ alternatives are worth further development and evaluation.

When funding is constrained, it is more difficult to devote resources to continued development of backup options. However, considering the great uncertainty in the cost and performance of the technologies required for the preferred alternative, the period during which funding is constrained is precisely the wrong time to drop work on alternatives that might achieve satisfactory results at a significantly lower cost. Having such alternatives available could allow remediation to proceed expeditiously, even if funding constraints prevent timely implementation of the currently preferred alternative.

Summary

A phased decision process is inevitable, and the decisions concerning what to do in the second phase will necessarily be driven by what has been learned and accomplished in the first phase. DOE and the Washington State Department of Ecology should deliberately adopt a phased decision strategy that recognizes the uncertainties affecting the TWRS effort at this time and is aimed at reducing the uncertainties and keeping options open so that a more informed choice among better-defined alternatives is possible later. This involves pursuing a wide enough range of phased alternatives to provide adequate confidence that at least one workable option will be available for full-scale deployment in the second phase. Indeed, a single alternative will probably not be applicable to all of the tanks.

THE FIRST PHASE

The first phase should include gathering the information needed to support a broad programmatic decision concerning disposition of the tank wastes and to implement the decision. As discussed earlier, important uncertainties are found in several key areas; cost and performance of necessary technologies, regulatory requirements, characteristics of the tank contents and the environment, and analysis of health and safety risks associated with the alternatives.

The first phase should have the following goals:

- reduce uncertainties about technology, performance, cost, and risks;
- address policy and regulatory uncertainties;

- reduce uncertainties associated with the characteristics of the waste inside and outside of the tanks;
- explore a broader range of technologies; and
- analyze interrelationships with other site cleanup decisions.

Uncertainties About Technology, Performance, Cost, and Risks

The phased option in the DEIS focuses only on pilot-scale tests for waste retrieval, separations, and vitrification activities using waste from double-shell tanks. The first phase should include activities to acquire more information about the methods for removal of wastes from the single-shell tanks to meet the 99 percent removal objective for full-scale operation in the second phase. The committee concurs with DOE's earlier recommendation that the TWRS program should “determine the methods of waste removal that will meet requirements for the extent of tank decontamination and other requirements such as allowable leakage to the ground” (U.S. Department of Energy, 1995, p. viii). The committee also concurs with the DOE recommendation for early sluicing demonstrations of representative waste to obtain performance data on retrieval of “hard pan” material using past-practice sluicing and/or enhanced sluicing (U.S. Department of Energy, 1995, p. xiv).

The recently announced Hanford Tank Initiative appears to be designed to address these and other issues associated with removal of waste from the single-shell tanks to the double-shell tanks and the ultimate closure process for the evacuated tanks after as much waste as possible has been removed (U.S. Department of Energy, 1996b). This effort will attempt to take two single-shell tanks, one low-risk tank and one presenting substantial safety risks, all the way from removal of the waste through closure. The process, which will involve close interaction with a range of stakeholder groups, will provide a better basis of information for the second phase retrieval activities. The committee endorses the decision by DOE and the Washington State Department of Ecology to undertake an effort of this type and recommends that the effort be included in the final Hanford TWRS environmental impact statement as an important part of the first-phase activities. This is consistent with NEPA requirements.

It should be noted that useful testing of alternatives need not be limited to the Hanford Site; the TWRS program should also take into account the results of related work at other DOE sites. For example, the experience of vitrifying high-level waste streams at the Defense Waste Processing Plant at the Savannah River Site, S.C., and at the West Valley (N.Y.) Demonstration Project, as well as the experience of several foreign countries, should provide useful input to the decision about full-scale vitrification at the Hanford Site. Valuable information on the scientific and technological aspects and operational experience of vitrification was presented at an international workshop conducted by the National Research Council, May 13-15, 1996, in Washington, D.C.

Policy and Regulatory Uncertainties

There is a need for ongoing coordination and discussion among DOE, the Washington State Department of Ecology, and other regulatory agencies to address and resolve regulatory and policy uncertainties. The magnitude of the proposed action requires prudent consideration of potential regulatory changes. This should include long-term interactions with the DOE Office of Civilian Radioactive Waste Management and USNRC to resolve issues concerning the acceptability of high-level waste from Hanford tanks for off-site disposal. As noted earlier, what constitutes “incidental waste” may prove critical to decisions on both waste treatment and tank closure. The committee understands that the objective of the developing Hanford Tank Initiative is to help reduce the uncertainty about the regulatory requirements for waste left in the tanks by attempting to develop a legally acceptable tank closure process. Suggestions for other initiatives to reduce regulatory uncertainties are needed. For example, DOE might petition EPA for an alternative disposal standard for waste left in the tanks, under 40 CFR Part 191.

Uncertainties About Characteristics of Wastes Inside and Outside the Tanks

Adequate characterization of the tank wastes and surrounding contaminated environment will be required for processing of waste that is removed for treatment and for in situ disposition of wastes not removed from the tanks (either by choice or by necessity). A better understanding of what has already leaked and how rapidly it is moving toward the ground water is needed for assessing risks. Significant uncertainty currently exists concerning the sources and migration paths of cesium and technetium that have been found at some depth beneath the tank farms. Leakage from the tanks caused by sluicing, as well as the risk associated with waste left in the tanks, must be analyzed during the first phase in the context of the overall risks. The mechanisms and rates of migration of cesium and other radionuclides originating from the tank farms and from other waste disposal facilities at the Hanford Site also need to be better understood.

Range of Technologies

DOE and the Washington State Department of Ecology are to be commended for considering in the DEIS technologies that do not or may not meet current regulatory requirements. The development, testing, and analysis of technology alternatives during the first phase should continue unconstrained. The committee has identified several technology options that were not included in any of the DEIS alternatives and recommends that they be considered for inclusion in the first phase.

Consideration of the use of appropriately designed subsurface barriers (vertical and subsurface horizontal) could be an integral part of many of the alternative approaches evaluated in the final environmental impact statement. Such barriers could not only contain releases to the subsurface during sluicing operations, but they could also provide an effective containment of the tanks when the radioactive contents cannot be completely removed, as is the case for many of the DEIS alternatives. Thus, pilot studies on barriers are desirable in the first phase in the search for promising methods of containment (National Research Council, 1996c).

Another key issue in isolating the single-shell tanks at the Hanford Site is the manner in which the wastes remaining in the tanks are stabilized. Several alternatives in the DEIS state that the tanks would be filled with gravel, either with or without the retrieval of tank contents, depending on the alternative. While gravel may be effective in keeping the tanks from collapsing, it would do little to reduce the possibility of human intrusion or to supplement the effectiveness of the Hanford barrier to reduce the infiltration of precipitation.

Other approaches for stabilizing tanks should be evaluated in a broadened first phase through appropriately designed bench, pilot, and demonstration studies. For example, the residue left after retrieval, or the contents without retrieval, could be covered with large cobbles that would impede drilling into the radioactive residue. Furthermore, the voids in such a very coarse sediment mass could be filled with bentonite clay, which may result in further resistance and perhaps minimize infiltration of precipitation.

The final environmental impact statement should consider additional options that appear worthy of further examination, including:

- Use of a stabilization and protection technology for the in situ residuals left in the tanks that is intermediate between the less effective gravel fill and the more complex (and less feasible) in situ vitrification. While the two extreme cases presented in the DEIS may bound the impacts from wastes left in the tanks, they may give a very distorted picture of what is reasonably achievable.
- Removal options of less than 99 percent to examine more thoroughly the tradeoffs between cost and risk reduction in removing the last fraction of the waste residue. Such an examination might be applied during the Hanford Tank Initiative.
- A deferred-action option in which tanks containing significant quantities of relatively short-lived radionuclides (90Sr and 137Cs) would be stabilized and contained by temporary physical barriers for perhaps 100 to 150 years to allow them to decay by an order of magnitude before remediation is undertaken.

Interrelationships with Other Hanford Site Cleanup Decisions

It is particularly important that the first tank cleanup phase be used to assess the interactions and interdependencies among the remediation actions described in this DEIS and the other related waste management and environmental remediation activities at the Hanford Site.

For example, a decision to proceed with any full-scale remediation effort for the tanks must be based on a much better understanding of the relationship between the remediation of tank wastes and remediation of the tanks themselves and of associated contamination than is presented in this DEIS. DOE and the Washington State Department of Ecology should not make a final decision on a remediation approach for the tanks without considering the ultimate disposition of the tanks and associated contamination, but they should proceed with the first phase to gather the necessary information. The DOE TWRS System Requirements Review clearly recognizes the problems that could potentially result from a lack of integration of waste retrieval, decontamination, and final closure of the tanks (U.S. Department of Energy, 1995, pp. 2-22 to 2-23).

While the necessary technology development activities are underway, DOE should prepare a comprehensive plan for site-wide cleanup and future land use to provide the needed context for decisions concerning specific projects such as environmental remediation of the tanks and related contaminated soils and ground water. To the extent that the Tri-Party Agreement is the programmatic environmental management framework, it should be subject to a systematic analysis of costs and impacts that takes into account the interrelationships among component projects on a site-wide basis.

In its 1994 letter report to DOE (National Research Council, 1994), the committee stressed the importance of considering the tank remediation actions in a broader context. Based on its review of the DEIS, the committee believes that these comments continue to be valid. In this context, the attempt in the DOE Hanford Tank Initiative to address closure issues on an accelerated basis is a welcome step forward. [10]

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[10] "The Committee believes that the operational definition of the overall tank-remediation system is seriously deficient. Specifically, the current Hanford tank-remediation system, as embodied in the actions and milestones in the Tentative TPA [tri-party agreement], concentrates mainly on wastes currently in the tanks. Only limited consideration is given to the leaked wastes and past-practice units, the physical tanks themselves (as distinct from their contents), and the ultimate fate of the products of the various remediation processes, including any repository to which the waste components are destined. The Committee believes that unless systematic consideration is given to the entire tank-remediation program from now to the completion of all remediation, the analysis of broad program options will inevitably be inadequate, leading to distorted or perhaps erroneous input to decision-makers. For example, the technical approach to remediating the problem of the wastes that have leaked from some of the tanks should be developed together with the technical approach to remediating the tank contents and the tanks themselves. These are linked issues, not separate ones, and the best overall solution may not be the "best" for any one of the elements taken singly." (National Research Council, 1994, pp. 2-3)

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SUGGESTIONS FOR CLARIFYING THE FINAL ENVIRONMENTAL IMPACT STATEMENT

The committee recognizes that an environmental impact statement has a specific legal function and purpose—to ensure that the environmental impacts of a range of reasonable alternatives have been considered by the decision makers before selecting a course of action. There is no requirement that the alternative with the lowest environmental impacts be chosen, as other considerations not addressed in the environmental impact statement can legitimately affect the decision. The environmental impact statement is simply one important input to the decision process.

Nonetheless, for many outside of the decision-making agencies, the environmental impact statement is the principal (or only) document available to provide insights into and an understanding of the decision-making process. To be most useful to those trying to understand the basis for agency decisions, more is required than simply a description of the alternatives and a detailed analysis of a wide range of impacts for each. A discussion of the meaning of the impact analysis is particularly useful in an environmental impact statement. The DEIS falls somewhat short in this regard.

A section in the final environmental impact statement summary presenting the key findings and insights from the impact analysis would be helpful to the interested reader. For example, buried within the text of the DEIS is the observation that the impacts are determined primarily by two variables: the fraction of wastes retrieved from the tanks and the degree of separations into low-activity waste and high-level waste fractions. This point should be highlighted for the reader. In addition, it would be useful to prepare a summary of potential short-term health effects for the alternatives which are currently spread throughout many tables in the DEIS.

waste left in the tanks even in the ex situ options, in which 99 percent of the wastes are to be removed. This suggests that it might be cost-effective to focus future resources on methods to better protect the residuals in the tank from infiltration of water and human intrusion rather than on better immobilization techniques for low-level waste. Another insight that can be gleaned from the impact analysis presented in the DEIS is that the incremental cost of going from the ex situ/in situ option to the preferred option (on the order of $14 billion) represents a cost per avoided statistical death of nearly $200 million. These and other such insights should be clearly presented in the final environmental impact statement, rather than being left to the industrious reader to discover.

The final environmental impact statement should rely less on conservative, upper-bound estimates of the impacts of the alternatives. While such estimates can provide confidence that the actual impacts will not exceed those presented in the DEIS, they can significantly distort the comparisons among options. To avoid distortion of the comparisons, the final environmental impact statement should, to the extent possible, present expected values and ranges of risks for the quantitative impacts in addition to upper-bound estimates.

The analysis should also give more details about the levels of existing contamination in the soil and ground water under the tanks and estimates of long-term impacts of such contamination under baseline conditions. The DEIS notes that ground water protection standards are already exceeded for a number of radionuclides of interest, but it does not provide quantitative information. The reader would obtain a better perspective on the risk potential of the various TWRS options if the final environmental impact statement showed what the situation is now and what the long-term risks would be if the tanks and their contents were removed entirely.

The cost estimates in the final environmental impact statement would be more useful for purposes of comparison among alternatives if they were expressed as unit treatment costs (with costs for all processing steps included for each alternative). Capital costs should be annualized and incorporated into the treatment costs in a clearly defined way. All cost elements should be expressed in terms of the same base year, using the same assumptions about future economic growth and inflation. Such annualized cost estimates are especially important in light of DOE's privatization initiative, which dictates the deferment of payment until a waste form is produced. The assumptions underlying the generation of cost estimates in the DEIS are generally not stated, making it difficult to determine what values are being compared and whether they have the same basis. While the numbers are estimates, as noted elsewhere in this report, it is not clear that the DEIS cost estimates follow the dictates of good economic analysis noted in the Systems Requirements Review (U.S. Department of Energy, 1995).

Finally, as noted earlier in this report, because of the dynamic nature of decision making with respect to the management and remediation of the tank wastes, a review by independent scientific and technical experts and an update of all the factors that are pertinent to the decisions should be conducted approximately every 5 years, as allowed by 10 CFR Part 1021. Given the large scale of the Hanford Site environmental remediation, it is prudent to review costs, risks, and environmental impacts for environmental remediation of the entire Hanford Site, including the TWRS program, in a periodic public process.

ABBREVIATIONS

ALARA	as low as reasonably achievable
CEQ	Council on Environmental Quality
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
DEIS	Draft Environment Impact Statement for Hanford Tank Waste Remediation System, 1996
DOE	U.S. Department of Energy
DST	double-shell tank
EDTA	ethylene diamine tetracetic acid
EIS	environmental impact statement
EPA	U.S. Environmental Protection Agency
FEIS	Final Environmental Impact Statement for disposal of Hanford Defense High-Level, Transuranic and Tank Wastes, 1987
FR	Federal Register
HEPA	high-efficiency particulate air [filters]
HLW	high-level waste
ICRP	International Commission on Radiological Protection
LAW	low-activity waste
MUST	miscellaneous underground storage tanks
NCRP	National Council on Radiation Protection and Measurements
NEPA	National Environmental Protection Act
NOx	oxides of nitrogen
NRC	National Research Council
PUREX	plutonium uranium extraction
RCRA	Resource Conservation and Recovery Act
SOx	oxides of sulfur
SST	single-shell tank
TPA	Tri-Party Agreement (Hanford Site)
TRUEX	transuranium extraction
TWRS	Tank Waste Remediation System (Hanford Site)
USNRC	U.S. Nuclear Regulatory Commission

UNITS OF MEASURE

Ci (nCi)	curie (nanocurie = 10^{-9} curies)
cm	centimeter
g (Mg)	gram (megagram)
km	kilometer (km^2 = square kilometer)
m	meter (m^3 = cubic meters; 1 m^3 = 264 gallons U.S.)
W (MW)	watt (MW = megawatt)

CHEMICAL ELEMENTS

Ba	barium (^{137}Ba isotope)
C	carbon (^{14}C isotope)
Cl	chlorine
Cs	cesium (^{133}Cs, ^{134}Cs, ^{135} Cs, ^{136}Cs, and ^{137}Cs isotopes)
Cu	copper
F	fluorine
I	iodine (^{129}I isotope)
Sr	strontium (^{90}Sr isotope)
Tc	technetium (^{99}Tc isotope)
Zr	zirconium (^{90}Zr isotope)

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APPENDIX A

REQUEST FOR STUDY

Department of Energy
Washington, DC 20585
MAR 0 4 1996

Dr. Michael Kavanaugh
Board on Radioactive Waste Management
National Research Council 2001 Wisconsin Avenue, N.W. 456 Harris Building
Washington, D.C. 20007

Dear Dr. Kavanaugh:

The purpose of this letter is to provide information on the Hanford Tank Waste Environmental Impact Statement (EIS), and request comments on this document from the National Research Council (NRC) Committee on Remediation of Buried and Tank Waste (the Committee).

The EIS will evaluate the environmental impacts of a broad range of options for addressing the waste in the Hanford tanks. Much of the information contained in the EIS will be based on environmental sampling data, Department of Energy's understanding of tank contents, and models which predict the movement of tank waste into and through the environment.

Our objective in requesting the NRC to review the EIS is for this knowledgeable group to aid in identifying significant inconsistencies, over-simplifications, or errors. We believe this is an appropriate task for the Committee because over the past three years the Committee has become familiar with: (1) the Hanford geology and hydrology and other wastes on the site, (2) the objectives of the Tank Waste Remediation System (TWRS) program and specific programmatic documentation, and (3) the concerns of stakeholders, including the State of Washington and the Environmental Protection Agency, and the commitments contained in the Tri-Party Agreement. Knowledge of all of these factors is key because the EIS will be used as the basis for future Hanford tank waste management decisions.

The EIS will include several hundred pages of data and calculations. A number of technical consultants and experts will be reviewing the EIS to ensure the data was correctly incorporated into the models, the results were correctly interpreted, and uncertainties identified. We welcome any comments in these areas the Committee (or its individual members) may care to offer.

We expect to provide the TWRS EIS to NRC by mid-March, and would like your review completed by July 31, 1996.

We hope you will be able to participate in reviewing this document. If you have any questions, please contact John Lehr at 301-903-8621.

Sincerely,

Eugene C Schmitt

for

Stephen P. Cowan
Deputy Assistant Secretary for Waste Management
Environmental Management

cc:
Dr. Carl Anderson, NRC

APPENDIX B

DESCRIPTION OF ALTERNATIVES

The following is a brief description and analysis of the alternatives based on information from the DEIS. It was prepared and is included here as a convenience to the reader of this report.

NO ACTION

This alternative calls for management of the tank farms consistent with current waste management programs, with monitoring for only 100 years to provide a consistent basis for assessing health and environmental impacts. Spare double-shell tank space is to be maintained in the event of a tank leak. The alternative does not comply with either federal or state requirements for storing hazardous or high-level waste, now or in the future. Discussion of it in the DEIS is treated as a pro forma requirement.

LONG-TERM MANAGEMENT

The tank farms would be managed consistent with current waste management programs, with monitoring for only 100 years to provide a consistent basis for assessing health and environmental impacts. The double-shell tanks would be replaced with 26 new ones as needed, presumably at the end of the existing tank design life of approximately 50 years. Approximately 1 percent of the waste would be left in the abandoned double-shell tanks, around which a permanent marker would be emplaced. This alternative does not comply with either federal or state requirements for storing hazardous or high-level waste, now or in the future. After 100 years, the tank wastes would be in the same unacceptable long-term disposal condition they are in today.

IN SITU FILL AND CAP

All pumpable liquids would be evaporated from double-shell tanks, with the concentrate being returned to the tanks. The condensates would be routed to the Hanford Site 200 Area Effluent Treatment Facility, where all effluents would meet discharge limits. The single-shell and double-shell tanks would be filled with gravel and covered by caps (Hanford Barriers) over each tank farm, marked with surface and subsurface markers. Institutional control of the buried tanks would terminate after 100 years. Each tank would need to be characterized to determine that the concentrated residues are safe, i.e., not explosive or otherwise likely to present a hazard at some future time. The alternative, representing a low-cost approach to managing the tank waste, does not comply with either federal or state requirements for storing hazardous or high-level wastes, now or in the future.

IN SITU VITRIFICATION

All pumpable liquids from double-shell tanks would be evaporated, and the concentrates would be returned to the tanks. The condensate would be routed to the Hanford Site 200 Area Effluent Treatment Facility, where effluents would be treated to meet currently applicable discharge limits. The tank dome space would be filled with sand, and the waste plus the sand would be melted by joule heating with graphite electrodes to 1,450 to 1,600°C to produce a vitreous mass (each in situ vitrification melter would require approximately 160 MW). Thermally unstable solids in the waste (nitrates/nitrates, organic compounds, ferrocyanides, etc.) would decompose during the melting, producing off-gases, and volatile materials would vaporize. Four in situ vitrification units would be on site, with at least two operating at all times. A thermal oxidizer would be provided to complete organic compound destruction. A tank farm confinement facility would be constructed over an entire tank farm for containment during treatment operations. Movable-wall buffer areas would provide a safe operating area. Shielding for personnel would be provided. An off-gas system consisting of water scrubbing, high-efficiency particulate air (HEPA) filtration, charcoal bed sorption, and electrostatic precipitation is to be provided.

Caps (Hanford Barriers) would be constructed over the tank farms. The variability of waste composition among tank farms (and among tanks) dictates the need for specific knowledge of tank waste composition and of the safety implications of that information. Fluxing additives may be required to achieve proper melting. Inspection and sampling of the final waste form may be difficult. If treatment of hazardous wastes can be demonstrated to be adequate, the vitrified wastes might meet RCRA land disposal requirements. However, the near-surface disposal would not meet DOE Order 5820.2A, requiring disposal of readily retrievable high-level waste in a geologic repository.

EX SITU/IN SITU COMBINATION

The ex situ/in situ alternative is intended to bound the impacts from a combination of a wide range of alternatives, including treatment of some tanks by the in situ and capping alternative and some by the ex situ alternatives. It presents a concept of recognizing that different tanks should be treated differently, depending upon their specific attributes. In the version evaluated in the DEIS, approximately one-half of the tanks would be treated ex situ, based on an evaluation of treatment alternative on a tank-by-tank basis. The retrieved wastes would be treated according to the ex situ intermediate treatment alternative, while the tanks with wastes not retrieved would be treated according to the in situ fill and cap alternative. Selection of tanks for treatment would require extensive characterization. The in situ tanks would not meet RCRA land disposal requirements for hazardous waste or the DOE policy of readily retrievable high-level waste in a geologic repository.

EX SITU/IN SITU COMBINATION VARIATION

This alternative is similar to the ex situ/in situ combination alternative, differing in that it allows for a judicious selection of the tanks by focusing treatment on the biggest contributors to long-term risk (^{99}Tc, ^{14}C, ^{129}I, and ^{238}U), while limiting the volume of waste to be processed.

Approximately 23 tanks would be processed instead of 70 tanks, as in the ex situ/in situ combination alternative. Two treatment facilities would be constructed for ex situ treatment; one would be for combined separation and treatment of low-activity waste, and the other would be a high-level waste treatment facility. Selection of tanks to treat would depend on results of future characterization of the tanks. Waste contained in the tanks left for in situ treatment would follow the in situ fill and cap alternative. The benefit foreseen for this alternative is that up to 85 percent of the greatest contributors to long-term risk would be disposed of ex situ, while only approximately 26 percent of the waste would need to be retrieved and treated. The implementation aspects are the same as those for the phased implementation alternative and the in situ fill and cap alternative. This approach deals with many of the limitations of availability of funding and, at the same time, addresses the real risks associated with the tanks. (However, it may be found that many of the tanks that must be emptied to get 85 percent of the long-term risk isotopes out would be among the most difficult to empty.)

EX SITU NO SEPARATIONS

All wastes under this alternative would be handled as high-level waste, and there would be no separations. Otherwise, this alternative is similar to the ex situ intermediate separations alternative. Wastes would either be vitrified or calcined. The primary matrix of calcination would be sodium carbonate, resulting in a finely divided powder that must be compacted to produce dense pellets or briquets. Off-gas treatment would be the same as for any vitrification alternative. This alternative produces a large volume of high-level waste and meets all applicable regulations for disposal of radioactive, hazardous, and mixed wastes, assuming they are all contained in the final waste form. However, the final waste forms may not meet geologic disposal waste acceptance criteria.

EX SITU INTERMEDIATE SEPARATIONS

As much of the waste as practicable would be removed from the tanks and separated into high-level and low-activity (low-level) waste fractions. Slurry pumping would be used to extract wastes from the double-shell tanks. Hydraulic sluicing plus hydraulic arm retrieval would be used to remove the single-shell tank wastes, crush chunks as necessary, and transfer slurries to interim storage in double-shell tanks or directly to a pretreatment facility. Sludge washing, enhanced sludge washing, solid/liquid separation, and ion exchange would be used to produce high-level and low-level waste streams. Solutions of salts from washing would be sent to ion exchange to remove cesium and then to a low-activity waste vitrification facility for concentration, mixing with glass formers, and vitrification. Additional liquid processing may be necessary to remove certain radionuclides (e.g., technetium and strontium) as well as organic compounds from the low-activity waste to meet on-site disposal requirements. The sludge remaining after washing, along with the separated cesium, would be sent to the high-level waste vitrifier, where it would be mixed with glass formers and vitrified. The vitrified off-gas systems would consist of water scrubbing, HEPA filtration, cupric oxide (CuO) bed sorption for oxides of sulfur (SOx), and catalytic reduction of oxides of nitrogen (NOx). The vitrified low-activity waste in the form of cullets would be mixed with a matrix material and put into large containers for near-surface, retrievable disposal on the Hanford Site. A cap (Hanford Barrier) would be put over the low-activity waste, and markers would be installed; controls would be terminated after 100 years. Vitrified high-level waste would be put in temporary storage in an aboveground interim facility on the Hanford Site. The low-activity waste form requirements have not been defined, and selection of vitrifiers has not been made. In addition, many mechanical features of this alternative have not been demonstrated.

EX SITU EXTENSIVE SEPARATIONS

This alternative is similar to the ex situ intermediate separations alternative, but with additional, extensive separations to remove components of the high-level sludge from recovered tank wastes. The goals are to minimize the number of high-level waste canisters and produce low-activity waste that meets USNRC low-level waste Class A standards or as low as reasonably achievable (ALARA), whichever is lower. Processing operations to separate elements such as uranium, plutonium, neptunium, thorium, americium, lanthanide elements, cesium, strontium, and technetium would be used. The separations include sludge washing, caustic and acid leaching, solvent extraction, and ion exchange. Destruction of organic compounds and ferrocyanides would be carried out by wet air oxidation by holding the liquid at 325°C and 2,000 psi in the presence of oxygen for 1 hour. Plutonium/uranium extraction (PUREX) followed by transuranic extraction (TRUEX) would be used to remove residual americium, trivalent lanthanides, and bismuth. Bismuth would be stripped with sodium and ethylene diamine tetracetic acid (EDTA), and the lanthanides and americium with dilute nitric acid. Americium would then be separated from the lanthanide elements by cation exchange. Raffinate from this step would be processed by displacement ion exchange. The TRUEX raffinate containing cesium, strontium, and technetium would be processed by crown ether extraction to remove strontium. The cesium in the raffinate would be isolated by adsorption on an ammonium phosphomolybdate column and dissolved in caustic. Final concentration of cesium would be by ion exchange on a resorcinol-formaldehyde column. The subsequently eluted cesium would be sent to high-level waste processing and treatment. Any cesium, or plutonium carried over into the cesium stream, would be sorbed on silicotitanate. Technetium in the raffinate from the crown ether extraction would go to a strong base ion exchanger for removal as the pertechnetate ion. Technetium, strontium, plutonium, and cesium would all go to the high-level waste. Bulk chemicals such as water, nitric acid and sodium hydroxide would be recovered and recycled. Excess caustic would go with the low-activity waste. Chromium would be processed in a step to reduce it to trivalent chromium, which precipitates as the hydroxide and is removed by centrifugation, and sent to a separate waste processing step as a mixed waste. Concentrated sodium nitrate and aluminum nitrate solutions may be purified by crystallization. Subsequent operations would parallel those for the ex situ intermediate alternative operations. Processing equipment would be decontaminated for on-site disposal in a low-activity waste burial ground. Processing facilities are decontaminated and entombed in place.

PHASED IMPLEMENTATION

The phased implementation alternative assumes tank waste remediation in two steps, or phases. The first phase (Phase 1 in the DEIS) entails operation for up to 10 years (1997 to 2007) of two low-level waste separation and vitrification facilities, one of which would also include high-level waste vitrification. Approximately 20 million gallons (76 million liters) of tank waste would be processed. Wastes would be stored pending availability of both an on-site storage facility and a geologic repository. The second phase (Phase 2 in the DEIS) upgrades the facilities in Phase 1 and uses them for another 10 years. In addition, a full-scale low-level waste separation and immobilization facility and a high-level vitrification facility would be built. All wastes (99 percent) would be removed from both single-shell and double-shell tanks. Sludge washing, caustic leaching, ion exchange, and other separations "as required" would be used to separate the tank wastes into high-level and low-activity wastes. High-level waste would go to a geologic repository; low-activity waste would go to near-surface storage on site.