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# Initial Single-Shell Tank System Performance Assessment for the Hanford Site

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# Initial Single-Shell Tank System Performance Assessment for the Hanford Site

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

Office of River Protection

**P.O. Box 450**
**Richland, Washington 99352**

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Date Published
April 2006

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**Office of River Protection**

**P.O. Box 450**
**Richland, Washington 99352**

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# EXECUTIVE SUMMARY

This *Initial Single-Shell Tank System Performance Assessment for the Hanford Site* (SST PA) presents the analysis of the long-term impacts of residual wastes assumed to remain after retrieval of tank wastes and closure of the SST farms at the U.S. Department of Energy (DOE) Hanford Site. Residual tank waste impacts on groundwater, air resources, and to the inadvertent intruder are shown to be limited and well below most important performance objectives for the reference case used in the analysis. Impacts from grouted tank residuals are first observed in years 4000 to 6000 and peak in years 8000 to 10000. However, past releases to the soil, primarily from past releases during tank farm operations, are shown to have groundwater impacts that are significantly above most performance objectives at the WMA fenceline. These past release impacts are projected to occur rapidly and dissipate by approximately year 2300. Only waste management area (WMA) C does not impact groundwater at levels over performance objectives for the reference case. With implementation of institutional controls for 300 years at the WMA fenceline, all groundwater performance objectives are met through natural attenuation except for two WMAs (i.e., S-SX and T), which meet the groundwater performance objectives at their fenceline boundary in the years 2373 and 2490, respectively.

> *Initial Single-Shell Tank System Performance Assessment for the Hanford Site* provides estimates of the long-term impacts to human health of radioactive and chemical waste left after closure.

The sensitivity analysis of peak impacts indicated that tank waste residual impacts are not sensitive to parameter variability and to the alternative conceptualizations considered. Groundwater impacts from past releases were sensitive to inventory, contaminant-specific distribution coefficient ($K_d$), and infiltration assumptions. Remediation or immobilization of over 90% of key mobile contaminants found in past releases is indicated as necessary to address appropriate groundwater performance objectives at the WMA fenceline. Projections of peak groundwater impacts were estimated to contain a factor of variability of 10 at the time of closure (i.e., a predicted value can be a factor of 10 higher or lower than estimated in the reference case due to features in the system that are inherently variable).

The results of this SST PA support the retrieval of tank wastes and grouting of the SST waste residuals, the institution of interim measures to reduce the impacts of past releases on groundwater, and the examination of potentially more aggressive remedial measures to support the *Resource Conservation and Recovery Act of 1976* (RCRA) Corrective Action process for the protection of groundwater. Where information regarding treatment, management, and disposal of the radioactive source, byproduct material, and/or special nuclear components of mixed waste (as defined by the *Atomic Energy Act of 1954*, as amended) has been incorporated into this document, it is not incorporated for the purpose of regulating the radiation hazards of such components under the authority of Section 70.105 of the *Revised Code of Washington* ("Hazardous Waste Management Act") and its implementing regulations, but is provided for information purposes only.

The SST PA supports key elements of the closure process agreed upon in 2004 by DOE, the Washington State Department of Ecology (Ecology), and the U.S. Environmental Protection Agency (EPA), and documented in Appendix I of the *Hanford Federal Facility Agreement and Consent Order* (Ecology et al. 1989). Closure of the SST and double-shell tank systems is currently planned for year 2032.

## ES1.0 INTRODUCTION

DOE has initiated the process of retrieving, treating, and disposing of waste from the 149 deteriorating SSTs at the Hanford Site. In the years ahead, DOE will remove the bulk of the SST waste and transfer it to facilities for treatment and disposal. High-level waste will be disposed of offsite in a geologic repository, and low-activity mixed waste will be disposed of in state-permitted, onsite facilities as low-level mixed waste. This SST PA incorporates the assumption, without a decision, that after the wastes are removed from the tanks, the SST farm system (also referred to as the SST WMAs) will be closed as a landfill.[1] As part of closure actions, a number of protective measures are planned to ensure safety from future contaminant migration from residual wastes left in each WMA.

Closure will be implemented only with regulatory approval as defined by relevant regulatory criteria. The regulatory environment for tank farm closure is complex. At least six major environmental statutes[2] and DOE O 435.1 must be addressed as part of the closure process, which creates redundant, and possibly conflicting, administrative requirements. To address this issue, the *Hanford Federal Facility Agreement and Consent Order* (Ecology et al. 1989) signatories established a single, unified closure process that incorporated the substantive elements of each regulation and DOE O 435.1, with Ecology as the lead regulatory agency. The agreement also established the need for a single performance assessment that will be approved by Ecology and by DOE pursuant to their authorities under RCRA and the *Atomic Energy Act of 1954*, respectively, and to ensure the actions taken for WMA closure will be protective of human health for all contaminants of concern, both radiological and nonradiological. The SST PA will also undergo extensive internal DOE review and be reviewed by the U.S. Nuclear Regulatory Commission under a consultation agreement. Under Appendix I of *Hanford Federal Facility Agreement and Consent Order* (Ecology et al. 1989), Ecology will also seek the involvement of the EPA for the purpose of ensuring the work is consistent with future *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) remedial decisions, and to provide the EPA and DOE a basis to evaluate the need for additional work that might be required if the closure activities were conducted under CERCLA remedial action authority.

Among the purposes of this SST PA for the closure of WMAs are to:

- Estimate the impacts to human health of any residual wastes remaining in the tanks, ancillary equipment, or soil following waste and contaminant removal actions
- Guide the development of WMA closure system designs that are protective of the public, the groundwater, and the Columbia River
- Support waste determinations for any tank waste residuals remaining once waste retrieval has been completed in accordance with *Hanford Federal Facility Agreement and Consent Order* (Ecology et al. 1989).

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[1] This assumption of landfill closure is to provide a point of reference for development of the data presented herein and does not constitute an agency decision selecting landfill closure. That decision can only be made after DOE fulfills its obligations under the *National Environmental Policy Act of 1969*.

[2] *Resource Conservation and Recovery Act of 1976*; *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*; *Atomic Energy Act of 1954*; *Clean Water Act of 1977*; *Safe Drinking Water Act of 1974*; and the Washington State "Hazardous Waste Management Act."

The SST PA supports making risk-informed decisions under multiple closure processes.

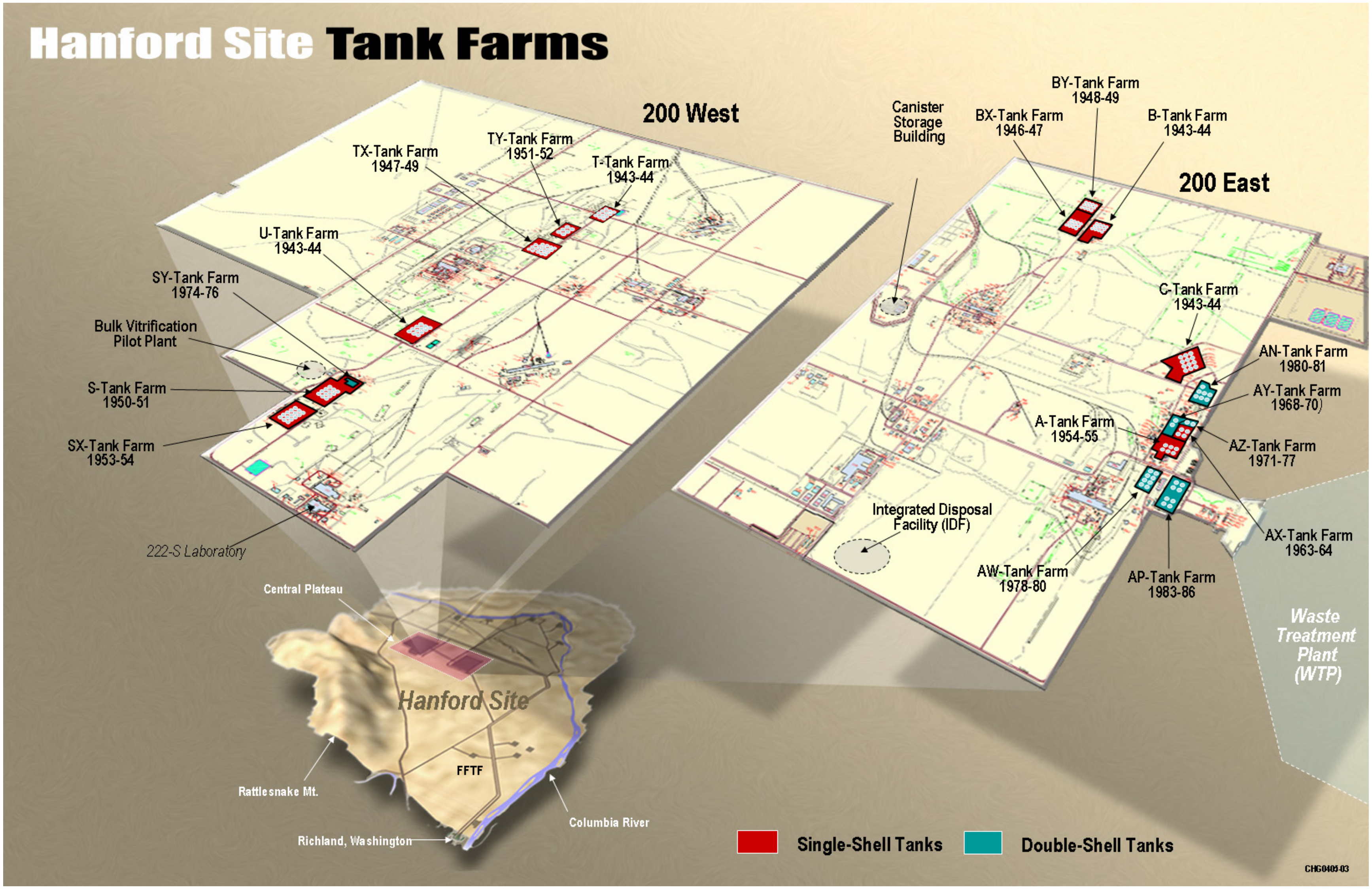
The scope of this SST PA includes estimating possible impacts of wastes remaining in the environment and residuals left in the tank system after closure, estimating possible releases to the air of radioactive gases from tank waste residuals after closure, and estimating possible impacts to an inadvertent intruder who unknowingly contacts contaminated materials left within the waste site after closure. Current WMA closure plans call for an approximately 15-foot thick surface barrier to infiltration to be constructed over the WMAs and surrounding environs. This barrier effectively eliminates the need to further consider impacts to human health through a direct contact pathway.

## ES2.0 SINGLE-SHELL TANK WASTE MANAGEMENT AREA OVERVIEW

The 149 Hanford Site SSTs are distributed among 12 groups called tank farms that are located on the Central Plateau in the Hanford Site 200 East and 200 West Areas. The SST farm system is large and varied and comprises underground waste storage tanks, pipelines, waste transfer lines, water lines, diversion boxes, and other facilities and equipment. To support compliance with hazardous waste regulations, the 12 SST farms, shown in red on Figure ES-1, have been further grouped into seven WMAs: A-AX, B-BX-BY, C, S-SX, T, TX-TY, and U.

The SSTs currently contain approximately 30 million gallons of radioactive and hazardous waste. The waste currently in the SSTs includes approximately 81 million curies of radioactive material. Two to four million curies of tank waste residual will remain after retrieval is complete. The waste currently in the tanks largely consists of sludge and saltcake. Most of the free liquids have evaporated or have been successfully transferred to newer and structurally stable double-shell tanks through the interim stabilization program. The total volume liquid lost through leaks occurring during past tank operations is estimated to range between 0.5 to 1 million gallons.

Figure ES-1. Facilities in the 200 East and 200 West Areas



## ES3.0 DEFENSE IN DEPTH APPROACH TO CLOSURE

DOE will employ a defense in depth approach for its WMA closures using a risk and uncertainty mitigation philosophy developed by the U.S. Nuclear Regulatory Commission that has proven effective in other venues. Key elements of the defense in depth philosophy are the use of multiple barriers (both natural and engineered) to isolate waste in the disposal environment and the establishment of institutional controls to prevent or limit human access to the waste. The use of multiple barriers improves confidence in the adequacy of closure actions by mitigating intrinsic uncertainties associated with any single barrier. With this approach, even if one or more parts of the system fail or function at a less effective level than projected, overall system performance remains at sufficiently protective levels.

Multiple barriers provide protection to the public from waste left after closure.

To close the WMAs, three barriers that implement the defense in depth philosophy are anticipated including two engineered barriers (i.e., the surface cover and the grouted tank structure) and a natural barrier (i.e., the vadose zone). The barrier functions vary depending on which of the three primary pathways[3] are being considered. For the groundwater pathway, all the barriers impede water movement in the subsurface and two of the barriers (grouted tank structure and vadose zone) react with contaminants to retard their migration through the subsurface. For the air pathway, the grouted tank structure and surface cover provide distance between waste and receptor, and resistance to vapor migration. For the intruder pathway, the engineered barriers deter intrusion over an assumed time interval, but have no function following intrusion. The vadose zone has no function in the air pathway or the intruder pathway.

The application of defense in depth principles in the SST PA also provides insights into the design of WMA closure, the extent and type of characterization needed of the geologic system, and the approach to conducting an analysis of the performance of the proposed closure system. The SST PA analysis specifically evaluates the characteristics of barriers and other site features that influence contaminant migration by the various pathways. In this manner, the functionality of the barriers, both individually and as part of the total system, are directly evaluated. Both expected performance (called a reference case analysis) and sensitivity to variability in input parameters are quantified (sensitivity case analysis). Finally, the SST PA analysis must consider plausible barrier failure modes or underperformance and evaluate their impacts on total system performance.

Knowing this information, analysts can then assist the engineers and scientists responsible for WMA closure design to appropriately address those components and assumptions that are most important to success by reducing their associated uncertainties through additional characterization and/or development of compensating design features. Quality assurance, performance confirmation, and model verification are additional activities that enhance confidence in the long-term total system performance.

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[3] The groundwater migration pathway represents movement of infiltrating water through the waste form, its percolation through the vadose zone, and its mixing and transport by groundwater. The air migration pathway begins in the waste form and represents the volatilization of gases and their movement to the atmosphere. The intruder pathway represents human intrusion into the waste form and subsequent exhumation and spreading of the waste form onto the land surface.

## ES4.0 CONTAMINANT EXPOSURE SCENARIOS AND EXPOSURE PATHWAYS

This SST PA evaluates three contaminant migration pathways (i.e., groundwater, air, and intruder) that can lead to human exposure through a variety of scenarios. Contaminant exposure scenarios are defined as sequences of human activities that establish levels of interaction with the waste found in air, water, and soil. Human interaction with the waste generally occurs through a variety of exposure pathways such as direct human contact (e.g., contamination of skin), ingestion or inhalation (which enable contaminants to enter the body), or exposure to radiation (potentially important only for the first few hundred years until cesium-137 decays to inconsequential levels). Exposure scenarios are selected that represent plausible land use activities that could occur near a closed facility, and can be analyzed to provide exposure estimates that are comparable with regulatory criteria. Implicit in the assumptions of these scenarios is the idea that waste quantities should be sufficiently limited and isolated to permit safe land use with these activities. Exposure scenarios evaluated represent a range of possible exposure pathways. The scenarios include the residential farmer, site resident, and the industrial user.

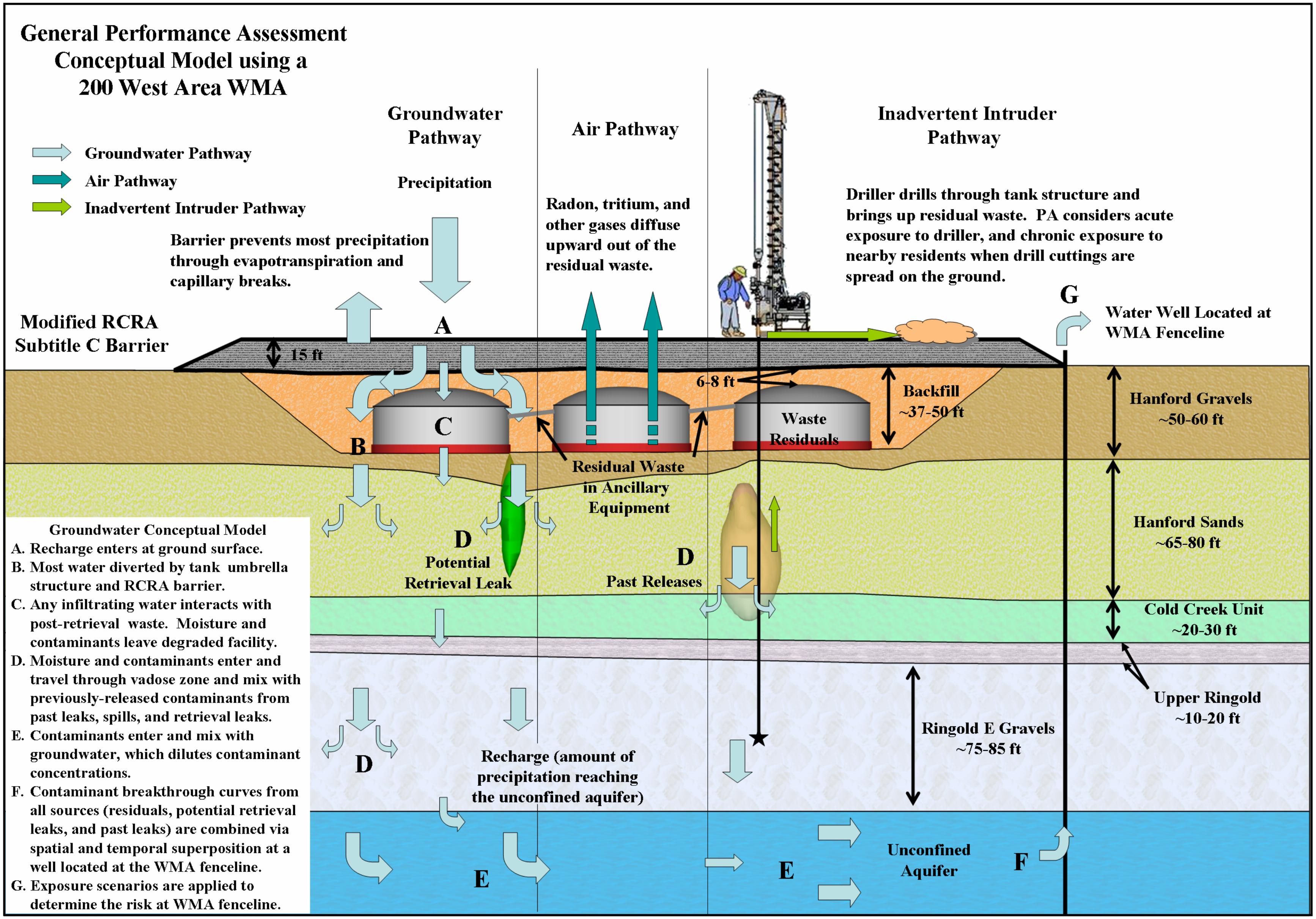
The selection of scenarios discussed above implies knowledge of waste disposal in the area. Human exposure scenarios are also evaluated with the inadvertent intruder pathway in which knowledge of the location of the disposal site is assumed to be lost. These scenarios include a suburban resident with a garden, rural pasture, and commercial farming. The rural pasture scenario is considered part of the reference case, while the suburban resident and commercial farmer are considered in the sensitivity analysis. The intruder pathway is specific to the regulatory environment for the disposal of low-level radioactive waste (DOE O 435.1) and is not typically seen in environmental remediation investigations.

The evaluation of pertinent regulations also identified media-specific (i.e., air and groundwater) criteria or performance objectives that may be used for remediation goals. The SST PA uses these criteria as appropriate to the media and contaminant.

## ES5.0 MODEL METHODOLOGY

A conceptual model for each contaminant migration pathway was developed for each WMA, incorporating all available and relevant site-specific data. For groundwater pathways, much of these data have been collected under the RCRA Corrective Action process conducted by the DOE Office of River Protection. Figure ES-2 presents a schematic of a typical conceptualization for a generalized WMA. The scientific conceptualization includes the dominant processes controlling the mobilization and transport of contamination. In keeping with the defense in depth safety philosophy, a reference case for each contaminant migration pathway was defined. The reference case reflects the set of parameters and engineering assumptions that can represent the likely performance of the closed WMA. A concurrent examination of the expected range of values for each parameter helps define the expected performance range of each barrier or feature. To estimate the robustness of the selected set of barriers, alternative conceptualizations are also analyzed using variations on the reference case design to establish the level of performance degradation that might occur. This degradation might represent an overestimate in the performance of a barrier, an error in the geologic conceptualization of the system, or a future event that cannot be reasonably contemplated at this time. Poor system performance noted through either the sensitivity analysis or the alternative conceptualization analysis (i.e., “what if” analysis) indicates a need for an improved understanding of the system and/or a design change.

**Figure ES-2. General Performance Assessment Conceptual Model**



Groundwater Conceptual Model

A. Recharge enters at ground surface.

B. Most water diverted by tank umbrella structure and RCRA barrier.

C. Any infiltrating water interacts with post-retrieval waste. Moisture and contaminants leave degraded facility.

D. Moisture and contaminants enter and travel through vadose zone and mix with previously-released contaminants from past leaks, spills, and retrieval leaks.

E. Contaminants enter and mix with groundwater, which dilutes contaminant concentrations.

F. Contaminant breakthrough curves from all sources (residuals, potential retrieval leaks, and past leaks) are combined via spatial and temporal superposition at a well located at the WMA fenceline.

G. Exposure scenarios are applied to determine the risk at WMA fenceline.

*The geology shown in the figure is specific to the 200 West Area.*

Certain features and assumptions are common to the development of each SST WMA model. These refer primarily to the reference case and include:

- Retrieval of tank waste to meet *Hanford Federal Facility Agreement and Consent Order* (Ecology et al. 1989) minimum goals
- Industrial land use following site closure
- Simulation of over 47 radiological and 60 chemical contaminants
- Following waste retrieval, any remaining contamination within the SSTs and the tanks themselves are stabilized with grout to reduce waste/water contact and surface subsidence.

Modeling of the groundwater pathway assumes:

- Site-specific simulation information developed for WMA C in the 200 East Area is extrapolated to other WMAs in the 200 East Area and, similarly, WMA S-SX simulation information is extrapolated to the remaining WMAs in the 200 West Area using WMA-specific inventory.
- A 10,000-year period was selected for evaluation due to the long time it may take for any discernable impacts to be observed in the environment. This is consistent with U.S. Nuclear Regulatory Commission guidance (NRC 2000).
- A surface barrier to infiltration is placed over the WMA at closure and is assumed to perform at its design specifications for 500 years following closure, and then to perform in a degraded manner until the end of the simulation.
- Three sources of contamination remain in the ancillary equipment: past releases, grouted tank residuals, and residual contamination.

Modeling of the air migration pathway uses a bounding analysis due to the low impacts associated with the volatilization of radioactive gases.

The inadvertent intruder pathway assumes intentional drilling through the tank and the residual waste form and the subsequent spreading of the exhumed waste form over the immediate area, ignoring both institutional and engineered controls left in place after closure. Assumptions describing this pathway include:

- Institutional controls are assumed to deter intrusion into the waste form for 500 years after closure (until year 2532). This time of evaluation is consistent with U.S. Nuclear Regulatory Commission guidance (NRC 2000) and past performance assessments at the Hanford Site (Wood et al. 1995a, 1996; Mann et al. 2001).
- Intrusion occurs by drilling through the surface barrier, remaining tank structure, and the grouted tank waste. The tank waste residuals are approximately 50 feet below ground surface. A portion of the waste is brought to the surface in drill cuttings.
- Impacts from past releases are also considered in addition to impacts from exhumed tank residual waste, where appropriate.

Modeling of the reference case inadvertent intruder scenario assumes:

- Exposure occurs to a person while participating in the operation of drilling through the tank waste residuals and contamination from past releases underlying the tank. It is assumed this receptor is exposed to these waste residuals exhumed during the drilling for 40 hours over 5 days.
- In addition, exposure also occurs according to a second scenario defined to emulate a rural lifestyle. Exposure is assumed to occur over a period of 50 years.

## ES6.0 CONCLUSIONS

The SST PA presents a comprehensive analysis of human health impacts associated with the retrieval of tank wastes and closure of WMAs located on the Hanford Site. Table ES-1 presents a summary of the estimated impacts to groundwater after closure from each WMA. A stark contrast exists between projected impacts from past releases and those from grouted tank waste residuals. The upper half of Table ES-1 indicates that the impacts of tank waste residuals on groundwater are below all performance objectives considered. In many cases, these impacts are over 10 times below a performance objective. Impacts from grouted tank residuals are first observed in years 4000 to 6000 and peak in years 8000 to 10000. The lower half of Table ES-1 presents the impacts to groundwater at the WMA fenceline for past releases. As noted, impacts from past releases indicate a decidedly different conclusion. With the exception of WMA C, past groundwater release impacts exceed at least two maximum contaminant levels (i.e., technetium-99 and beta-photon) for every WMA by over a factor of 10. The chromium performance objective is also exceeded for each WMA, except for WMA C. Potentially significant remedial actions may be necessary for those WMAs shown as greater than 10 times above groundwater performance objectives. Groundwater impacts from past releases are projected to peak in less than 100 years and decline to levels less than the performance objectives approximately 300 years after closure for most WMAs at the WMA fenceline.

> Groundwater impacts from tank waste residuals after closure are at levels protective of human health; impacts from past releases are above important performance objectives for every WMA except WMA C.

At closure, this SST PA concludes that estimates of peak contaminant concentrations would likely have a variability on the order of a factor of 10 (i.e., an estimated peak impact could be a factor of 10 higher or lower than that calculated in the reference case due to the natural and non-reducible variability of the system). A similar estimate of cumulative variability based on a probabilistic uncertainty analysis is documented in DOE-RL (1999) and corroborates the estimate of variability provided here.

Impacts to human health resulting from the air release of volatile radionuclides from the grouted tank residuals were found to be well below air performance objectives, as were estimates of human health impacts for an intruder exposed to the residual tank waste and past releases (assumed to occur 500 years after closure).

## Table ES-1. Estimated Reference Case Groundwater Impacts at the Waste Management Area Fenceline

| Performance Objective | Maximum Contaminant Level[a] | | | | Exposure Scenarios[b] | | |
|---|---|---|---|---|---|---|---|
| | Beta-Photon 4 mrem/yr | Tc-99 900 pCi/L | I-129 1 pCi/L | Cr 0.10 mg/L | All-Pathways Farmer 15 mrem | Radiological ILCR Industrial 1.0E-4 to 1.0E-5 | WAC 173-340 Hazard Index Method B 1.0 |
| ***WMA*** | ***Tank Residuals*** | | | | | | |
| S-SX | 🔷 | 🔷 | 🔷 | ◇ | 🔷 | 🔷 | ◇ |
| T | 🔷 | 🔷 | 🔷 | 🔷 | 🔷 | 🔷 | 🔷 |
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| TX-TY | 🔴 | 🔴 | ◇ | 🟡 | 🔷 | ◇ | ◇ |
| U | 🔴 | 🔴 | 🔷 | 🟡 | 🔷 | ◇ | ◇ |
| C | ◇ | ◇ | 🔷 | ◇ | 🔷 | ◇ | ◇ |
| B-BX-BY | 🔴 | 🔴 | 🔷 | 🟡 | 🔷 | ◇ | ◇ |
| A-AX | 🔴 | 🔴 | 🔷 | 🟡 | 🔷 | ◇ | ◇ |

| Below Performance Objective: | | Above Performance Objective: | |
|---|---|---|---|
| 🔷 | Greater than a factor of 10 | 🔴 | Greater than a factor of 10 |
| ◇ | Less than a factor of 10 | 🟡 | Less than a factor of 10 |

[a] Evaluated from year 2000 to 12032.

[b] Evaluated from year 2332 to 12032.

ILCR = incremental lifetime cancer risk

The sensitivity and "what if" analyses divided the model parameters and assumptions into three categories: 1) changes in recharge, 2) changes in source term characteristics (e.g., inventory, release mechanism, initial location, vadose zone retardation), and 3) changes in hydrologic parameters. The recharge category addressed those elements of the defense in depth associated with the surface barrier cover function. The contaminant source term characteristics cases examined the impacts of changes in the contaminant source inventory and release. The source term characteristics category addressed those elements of the defense in depth associated with the grouted tank structure function. The surface barrier cover function and grouted tank structure function are the engineered components of the system. The hydrology category addressed those elements of the defense in depth associated with the vadose zone function. The sensitivity of peak groundwater impact to the expected range of each parameter controlling the performance of a barrier was completed. Additionally, an evaluation of several "what if" cases was conducted to evaluate the capability of the system to perform under alternatives or "what if" analyses not included in the reference case. A complete presentation of the results of the sensitivity and "what if" analyses is found in Section 4.11.

In accordance with the defense in depth safety philosophy, a multiple barrier system was used to control the groundwater impacts of residual contamination left in place after closure of each WMA. To isolate the effect of individual barriers on total system performance, parameters controlling the performance of each barrier were simultaneously degraded causing each barrier to significantly underperform. Peak groundwater impacts from the underperformance cases were then compared against the reference case and a ratio of peak impacts from each case was calculated. The value of the ratio is indicative of the level of overall system loss of performance due to the underperformance of the respective barrier. For mobile contaminants in tank residuals, the results of this analysis indicated that system groundwater performance degraded by factors of 1.75, 7.85, and 1.24 due to underperformance of the surface barrier, the grouted tank structure, and the vadose zone, respectively, for WMA C. Underperformance of the entire engineered system in WMA C (i.e., surface barrier and grouted tank structure) yielded an underperformance ratio as high as 13.77. The effect of each barrier on WMA S-SX was similar to results shown for WMA C. Moderately mobile contaminants were shown to be generally more sensitive to barrier degradation than were mobile contaminants.

The effect of each barrier on peak groundwater impacts from past releases was quite different. Underperformance of the surface barrier at WMA C reduced the WMA C system performance by a factor of 1.39. Similarly, underperformance of the vadose zone reduced the system performance by a factor of 2.98. Again, similar barrier underperformance ratios were estimated for WMA S-SX.

The results of the SST PA support the following:

- Retrieval of tank waste and grouting of the remaining residuals
- Institution of interim measures to reduce the impacts to the groundwater from past tank farm releases
- Examination of the potential for more aggressive corrective measures to mitigate projected early groundwater impacts.

The long-term groundwater impacts from residual tank wastes are shown to be low and are below all performance objectives. Future work on grouted tank waste form residuals and release mechanisms are expected to support even lower estimates of potential impacts. Expected parameter variability and alternative system conceptualizations also support this conclusion.

In many cases, past releases from tank operations simply have too large an impact on groundwater concentrations to make performance objectives achievable under the reference case assumption of no remediation of past releases, as used in this study. Sensitivity analysis of the extent of past release remediation of mobile contaminants required to achieve groundwater performance objectives at an SST WMA fenceline was generally quite high (greater than 90%). Immobilization or removal of contaminated soil of over 90% of mobile technetium-99 from past releases was indicated as necessary to achieve groundwater performance objectives for this contaminant at every WMA, except WMA C.

A number of analysts (Myers 2005; Knepp 2002a, 2002b) have recommended interim measures as an immediate need due to operational period recharge rates on the projected groundwater impacts from large tank releases. These analyses, including the SST PA, primarily examine risk to human health and are not sufficiently comprehensive to support a final decision but instead contribute to the decision making process. Based on principles of risk management alone, the consideration of interim measures is supported at most of the WMAs while the formal RCRA Corrective Action process unfolds. Interim measures can cover a wide range of remedial activities. The SST PA examined barriers to infiltration in detail. Results from the sensitivity analysis generally support the concept that reducing surface infiltration sooner is better than later.

## ES7.0 FUTURE PLANS

DOE will continue to use an iterative approach to updates of the SST PA; updates will be based on significant changes in the approach to closure, conceptual model, or source characteristics used in this SST PA. The SST PA documents the current baseline but, by the nature of any baseline, changes will occur and must be addressed. These changes are driven by insights from laboratory studies, field efforts, numerical analyses, and design modifications.

> The SST PA results will be examined yearly and updated as the closure project changes and new data become available.

The approach taken naturally results in the development of a path for future work that addresses uncertainty where possible and confirms basic assumptions that support the SST PA. The following provides such a path.

- **Improved estimates of past release inventories lost to the vadose zone:** Past releases are clearly indicated as the controlling factor for the estimates of early (less than 300 years after closure) groundwater impacts. Validating estimates of both leak volume and inventory estimates will be continued for past releases that potentially affect the compliance status of a WMA.

- **Site-specific data will be used to simulate WMAs T, TX-TY, U, A-AX, and B-BX-BY:** Future revisions to this SST PA will use site-specific analyses for each WMA, including characterization data from post-retrieval tank waste residuals. Specific sensitivity analyses associated with issues within each WMA will also be identified and analyzed.

- **Development of improved tank residual release models:** The analysis of tank waste residuals demonstrated that their impact was below every groundwater performance objective considered. However, the closeness of the predicted impacts to the very stringent groundwater performance objectives for technetium-99 demonstrated the need for additional work to better ensure future compliance including characterization data from post-retrieval tank waste residuals.

  Given the early nature of predictions regarding the quantity of waste likely to remain in the tank after waste retrieval is complete, analysis of the durability of the grout form will be pursued.

- **Estimation of the level of impacts from surrounding facilities on waste management area impacts:** The current SST PA focuses on impacts from facilities and conditions found within the SST WMAs. Future work will incorporate the impacts from other surrounding cribs, ditches, and other disposal sites, including the double-shell tanks, into the impacts estimated in this analysis.
- **Expansion of the sensitivity analysis:** The sensitivity analysis will be expanded to include additional alternative conceptualizations to further test the robustness of the WMA closure design and assumptions regarding waste remaining in the closed system. Future sensitivity analyses will incorporate data from other SST WMAs.

## ES8.0 REFERENCES

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# READERS GUIDE

The following information is provided to assist the reader in understanding the technical data and format of this document.

## Definitions of Terms

A number of terms are conventionally abbreviated in this document; for example, waste management area is expressed as WMA. Abbreviated terms are spelled out on their first use, and as a convenience for the reader, a list of acronyms and abbreviations with their definitions can be found following the Contents of the main document and in each appendix.

## Reference Citations

Throughout the text of this document, reference citations are presented where information from the referenced document was used. These reference citations are contained within parentheses and provide a brief identification of the referenced document. This brief identification corresponds to the complete reference citation located in the reference list at the end of each chapter and at the end of each appendix.

## Chemical Elements and Radioactive Isotopes

Many chemical elements and radioactive isotopes are referenced in this document. Examples of the chemical elements are cesium, strontium, and uranium; isotopes are expressed after the element name (for example, cesium-137). To save space in tables and illustrations, elements and isotopes may appear in abbreviated form (for example, Cs-137).

## Scientific Notation

Scientific notation is used in this document to express very large or very small numbers. For example, the number one million could be written in scientific notation as 1.0E+06 (or $1.0 \times 10^6$) or in traditional form as 1,000,000. Translating from scientific notation to the traditional number requires moving the decimal point either right or left from the number being multiplied by 10 to some power depending on the sign of the power (i.e., negative power move left or positive power move right).

## Units of Measure

Information derived from historical or referenced sources is presented in the units cited in the reference. Field and laboratory data are presented in the units as measured in the field or as reported by the laboratory. The approximate American customary units are shown in parentheses directly following the use of many of the metric units. For example, a distance presented as 10 meters (m) is followed by 33 feet (ft). This example would be presented in the text as: 10 m (33 ft).

## Electronic Viewing Option

An electronic version of this document is available. The reader is encouraged to utilize the electronic version to view this document, particularly the graphics. Throughout the document, graphics in particular make use of color to convey information. When the document is printed in black and white, the color differences may be lost.

## Well Numbering and Identification

Several well numbering methods exist on the Hanford Site, leading to confusion in identifying those structures on various maps and cross-referencing them in this document. Three numbering methods are used here:

- Tank Farm System – In this method, drywells are numbered to identify the tank farm, associated tank, and the clock position of the well relative to the tank. The tank farm numbers are C = 30, S = 40, and SX =41; each tank is assigned a two-digit number corresponding to its official number (101 = 01, 102 = 02, etc.); and the two-digit clock position numbers are based on north as 12 o'clock (for example, south would be 06).

  *Example: well 30-01-12 is north of tank C-101*

  Many farms have drywells drilled along the peripheries; these wells are noted by the tank farm number, followed by "00", and then the clock position related to the entire farm.

  *Example: drywell 41-00-04 is at the 4:00 position on the periphery of the SX tank farm*

  Use of the tank farm numbering system is common as it permits the reader to readily visualize the spatial position of a given well relative to the tank it monitors.

- Hanford Site Well Numbering – In this method, based on the Hanford Site 200 Area Well Number protocol, each well is assigned a number based on the Hanford Site area in which the well exists (for example, 299 = 200 Area well), followed by a number designating the survey sheet on which it can be found (for T, TX, and TY, these are sheets W10, W11, and W15, respectively), and finally a number based on the sequential order in which the well was drilled.

  *Example: 299-W19-23*

- Washington Department of Ecology Start Card Number – In this method, every well drilled on the Hanford Site has a tracking number assigned by Ecology. Wells drilled solely for the purpose of collecting soils samples, and decommissioned after those samples have been collected, often have only this number. The number is alphanumeric, such as C3104. All characterization boreholes, not extending to groundwater, drilled by the Groundwater Protection Program have only this number assigned.

  *Example: One of the boreholes is designated C3104.*

Every effort has been made to minimize confusion by including the name "well" or "borehole" with the unit identifying number.

## CONTENTS

## APPENDICES

# TERMS

| | |
|---|---|
| amsl | above mean sea level |
| BBI | best basis inventory |
| bgs | below ground surface |
| BTC | breakthrough curve (concentration over time curve) |
| CERCLA | *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* |
| CFR | *Code of Federal Regulations* |
| CLUP | Comprehensive Land-Use Plan |
| CMS | corrective measures study |
| CoC | contaminant of concern |
| DCG | derived concentration guide |
| DCRT | double-contained receiver tank |
| DMT | Decision Management Tool |
| DNFSB | Defense Nuclear Facilities Safety Board |
| DOE | U.S. Department of Energy |
| DQO | data quality objective |
| DST | double-shell tank |
| DWS | drinking water standards |
| Ecology | Washington State Department of Ecology |
| EDE | effective dose equivalent |
| EIS | environmental impact statement |
| EPA | U.S. Environmental Protection Agency |
| ERDF | Environmental Remediation Disposal Facility |
| FFTF | Fast Flux Test Facility |
| FIR | field investigation report |
| HAB | Hanford Advisory Board |
| HFFACO | *Hanford Federal Facility Agreement and Consent Order* |
| HFSUWG | Hanford Future Site Uses Working Group |
| HI | hazard index |
| HLW | high-level waste |
| HMS | Hanford Meteorological Station |
| HTWOS | Hanford Tank Waste Operations Simulator |
| HWMA | “Hazardous Waste Management Act” |
| ILAW | immobilized low-activity waste |
| ILCR | incremental lifetime cancer risk |
| $K_d$ | distribution coefficient |
| $K_{oc}$ | organic carbon partition coefficients |
| LFRG | Low-Level Waste Federal Review Group |
| LLW | low-level waste |
| MCL | maximum contaminant level |
| MMI | Modified Mercalli Intensity |
| MUST | miscellaneous underground storage tank |
| NEPA | *National Environmental Policy Act of 1969* |
| NRC | U.S. Nuclear Regulatory Commission |
| PA | performance assessment |

| | |
|---|---|
| PNNL | Pacific Northwest National Laboratory |
| ppb | parts per billion |
| PUREX | Plutonium Uranium Extraction |
| RCRA | *Resource Conservation and Recovery Act of 1976* |
| REDOX | reduction-oxidation |
| RFI | RCRA field investigation |
| SALDS | State Approved Land Disposal Site |
| SCDR | subsurface conditions description report |
| SIM | Soil Inventory Model |
| SST | single-shell tank |
| SST PA | *Initial Single Shell Tank System Performance Assessment for the Hanford Site* |
| STOMP | Subsurface Transport Over Multiple Phases |
| TEDF | Treated Effluent Disposal Facility |
| TWINS | Tank Waste Information Network System |
| TWRS | Tank Waste Remediation System |
| UPR | unplanned release |
| WAC | *Washington Administrative Code* |
| WIDS | Waste Information Data System |
| WMA | waste management area |

# 1.0 TECHNICAL AND REGULATORY APPROACH

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# 1.0 TECHNICAL AND REGULATORY APPROACH

## 1.1 INTRODUCTION

The U.S. Department of Energy (DOE) has initiated the process of retrieving, treating, and disposing of radioactive mixed wastes from the 149 underground single-shell tanks (SST) located on the Central Plateau in the 200 East and 200 West Areas of the Hanford Site. Figure 1-1 shows the location of the Hanford Site in south-central Washington State and the location of the 200 East and 200 West Areas within the Hanford Site. There are a total of 177 underground tanks; 28 are double-shell tanks (DST) and 149 are SSTs. SSTs are grouped into 12 groups of tanks called tank farms and are further aggregated into 7 waste management areas (WMA) to support compliance with hazardous waste regulations. All of the tanks contain a mixture of radioactive and hazardous wastes (i.e., mixed radioactive waste). SSTs receive their name because only a single steel tank liner is used to contain the waste. DSTs contain waste by using both inner and outer carbon steel liners. The annulus between the inner and outer shells allows for leak detection not available in the SST design.

DOE has committed to removing 99% of the SST system waste volume and transferring it to interim storage and treatment facilities before its ultimate disposal. The radioactive tank waste will be separated into a high-level fraction disposed of offsite at a geologic repository, and a low-activity fraction disposed of onsite as low-level mixed waste to a state-permitted facility. Following retrieval of the SST waste, and in accordance with the *Hanford Federal Facility Agreement and Consent Order* (HFFACO) (Ecology et al. 1989), the SST system with its remaining waste is assumed for the purposes of this document to then be closed as a landfill.[1]

Cleanup and closure of the contaminated SST WMAs is regulated by DOE, the Washington State Department of Ecology (Ecology), and the U.S. Environmental Protection Agency (EPA). Five primary regulatory processes govern cleanup and closure documentation and approval:

- HFFACO (Ecology et al. 1989)
- State of Washington "Hazardous Waste Management" Act (HWMA)
- *Atomic Energy Act of 1954*
- *National Environmental Policy Act of 1969* (NEPA)
- *Radioactive Waste Management* (DOE O 435.1)
- *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA).

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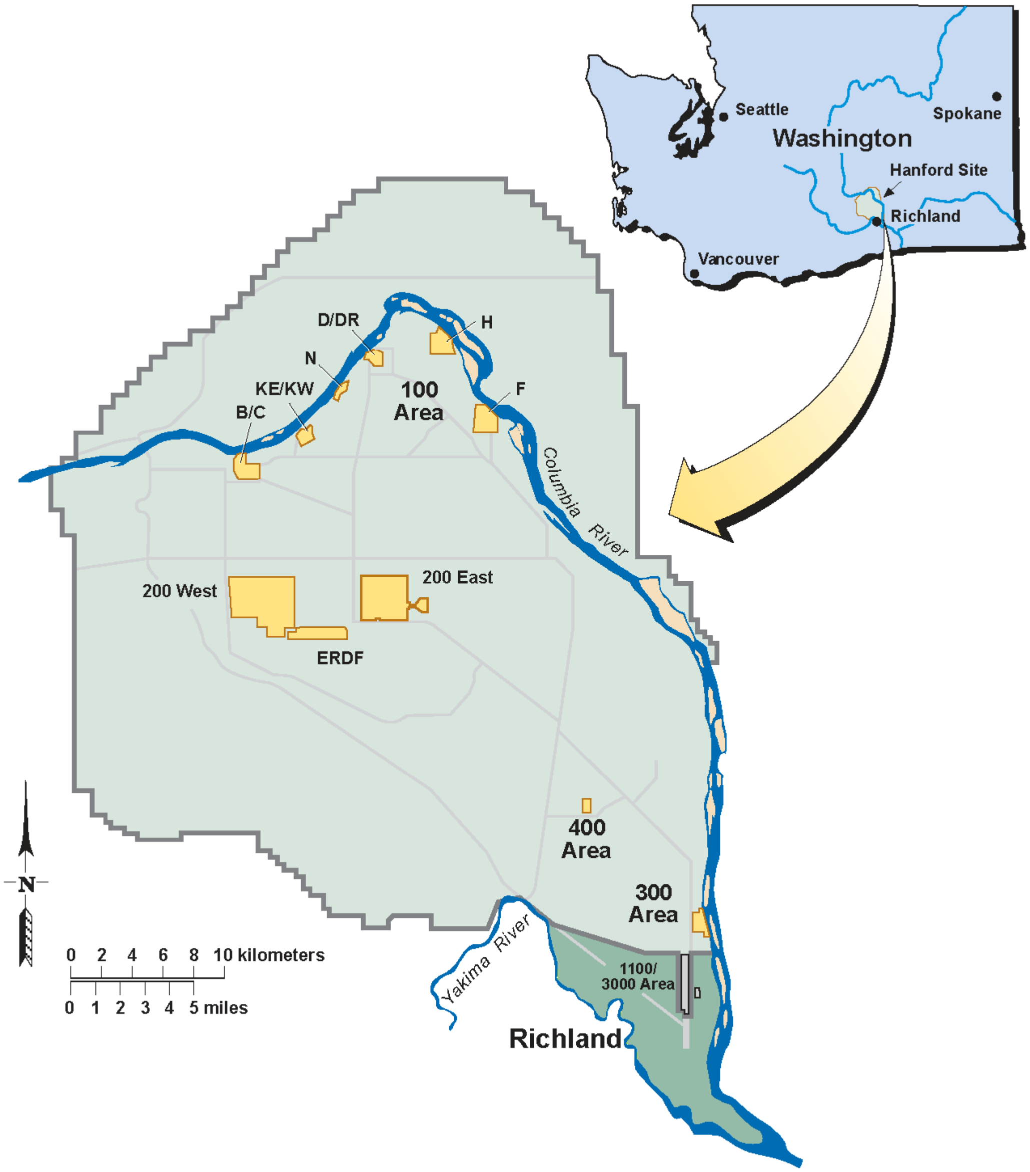
[1] This document assumes the single-shell tank (SST) waste management areas will be landfill closed. As noted, DOE is in the process of preparing an environmental impact statement (EIS) under the *National Environmental Policy Act of 1969* (NEPA). This EIS will evaluate various closure alternatives, including, but not limited to, landfill closure. After completion of the NEPA process, this EIS will form the basis for DOE decision making regarding closure, as memorialized in a record of decision. This SST performance assessment does not represent a DOE decision for landfill closure in advance of completing the NEPA process, but is only intended to evaluate the human health impacts of this alternative.

**Figure 1-1. Hanford Site Map and Location in Washington State**



An integrated regulatory closure process has been developed by DOE in conjunction with Ecology and EPA to streamline regulatory approval for Hanford Site closure. The integrated regulatory process uses the existing HFFACO process, action plan, and milestones; completes the HWMA closure process as negotiated by DOE and Ecology; and completes site closure under CERCLA. The process also integrates the applicable requirements of the above regulations consistent with *Radioactive Waste Management Manual* (DOE M 435.1-1) and the *Atomic Energy Act of 1954*. DOE is the responsible agency for the closure of all SST WMAs.

These WMAs will be closed in close coordination with other closure and cleanup activities of the Hanford Site Central Plateau. Washington State has a state program authorized under the *Resource Conservation and Recovery Act of 1976* (RCRA) and executed through the HWMA and its implementing regulations. Ecology is the lead regulatory agency for HWMA and has regulatory authority over RCRA closure of the SST system. The 200 Areas of the Hanford Site, known as the Central Plateau, have been placed on the National Priorities List by EPA. The completion of remediation of the 200 Areas overall will be eventually finalized via CERCLA decisions made by EPA and permitting decisions made by Ecology.

An integrated regulatory closure process has been developed that uses the existing HFFACO process, action plan, and milestones; completes the HWMA closure process as negotiated by DOE and Ecology; and completes site closure under CERCLA.

Implementation of the integrated regulatory closure process is authorized in Appendix I of the HFFACO which establishes expectations for the scope and approval of this *Initial Single-Shell Tank System Performance Assessment for the Hanford Site* (SST PA). Appendix I of the HFFACO establishes regulatory requirements under which waste within the SST WMAs will be retrieved, and the WMAs subsequently closed pursuant to applicable state and federal laws and regulations. Relevant sections from the HFFACO, Appendix I, Section 2.5 (Ecology et al. 1989), are as follows:

> "Ecology, as the lead agency for SST System closure, EPA, and DOE have elected to develop and maintain as part of the SST system closure plan one performance assessment for the purposes of evaluating whether SST system closure conditions are protective of human health for all contaminants of concern, both radiological and nonradiological. DOE intends that this performance assessment (PA) will document by reference relevant performance requirements defined by RCRA, HWMA, *Clean Water Act, Safe Drinking Water Act*, and the *Atomic Energy Act of 1954* (AEA), and any other performance requirements that might be ARARs [applicable or relevant and appropriate requirement] under CERCLA. The PA is of larger scope than a risk assessment required solely for nonradiological contaminants. The PA is expected to provide a single source of information that DOE can use to satisfy potentially duplicative functional and/or documentation requirements. A PA will be developed for each WMA and will incorporate the latest information available. These PAs will be approved by Ecology and DOE pursuant to their respective authorities. For Ecology approval means incorporation by reference, into the Site-Wide Permit through closure plans."

The closure of the SST system as currently projected means that the SST system would be closed as landfill units under the integrated regulatory closure process and is scheduled for completion by year 2032.[2] Figure 1-2 provides an overview of the Appendix I process in the HFFACO.

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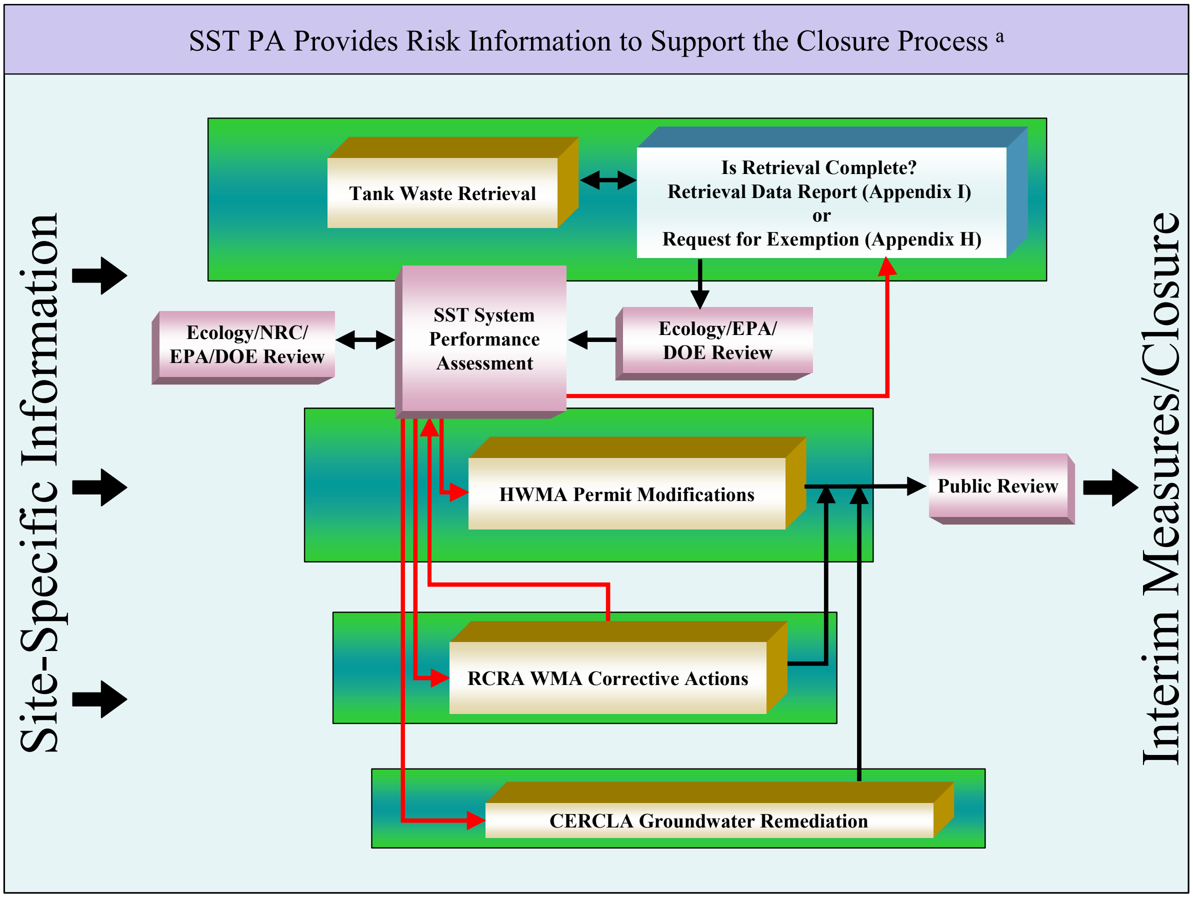
[2] See footnote 1.

**Figure 1-2. Regulatory Purpose of the Single-Shell Tank Performance Assessment through the *Hanford Federal Facility Agreement and Consent Order* Process**



[a] *Ecology et al. (1989)*

This SST PA will serve different purposes depending upon the regulatory process it is supporting. The SST PA will support waste determinations for tank waste residuals remaining after completion of retrieval in accordance with the HFFACO (Ecology et al. 1989). Additionally, Appendix H to the HFFACO requires DOE to interface with the U.S. Nuclear Regulatory Commission (NRC) with respect to allowable waste residuals in tanks and the soil column (i.e., vadose zone). To meet these different purposes, the SST PA includes analysis of past releases within each SST WMA, and will be submitted to the NRC for technical review and comment. The SST PA also supports regulatory waivers through the HFFACO Appendix H process when residual waste volume retrieval goals cannot be achieved. For example, a request for exemption to the HFFACO waste retrieval goal of 360 $ft^3$ for SST C-106 is currently under evaluation with the HFFACO regulatory authorities and the NRC.

The SST PA satisfies a requirement in the HFFACO for DOE to interface with the NRC with respect to allowable waste residuals in tanks and the soil column (i.e., vadose zone), and supports regulatory waivers to the HFFACO tank waste retrieval goals.

With respect to HWMA regulatory processes (both closure and corrective action), closure actions for contaminants associated with the SST system are being evaluated under two separate processes: 1) *Washington Administrative Code* (WAC) 173-303-610 closure requirements for treatment, storage, and disposal units and 2) WAC 173-303-646 corrective action requirements for releases from treatment, storage, and disposal units. WAC 173-303-610 closure requirements assume two closure options are available for tanks systems: 1) removal or decontamination of wastes and waste constituents to levels that allow for unrestricted land use (WAC 173-303-610[2][b]) or 2) landfill closure where such removal and decontamination cannot be achieved. The practicability of achieving removal or decontamination is analyzed in closure plans required under WAC 173-303-610. Selection of the closure option occurs through incorporation of specific closure activities by Ecology as modifications to the Hanford Site-wide permit (Ecology 2001). Corrective action requirements analyze multiple options for the cleanup of releases of waste to the soil column in a corrective measures study (CMS). Selection of corrective actions is achieved through an analysis that identifies those actions that provide the best balance of trade-offs with respect to prescribed balancing and modifying criteria. Similar to closure activities, selected corrective actions are defined by Ecology through incorporation as a modification to the Hanford Site-wide permit.

With respect to the NEPA regulatory process, DOE is in the process of preparing an environmental impact statement (EIS) under NEPA that will address tank closure. This EIS will evaluate various closure alternatives, including, but not limited to, landfill closure. After completion of the NEPA process, this EIS will contribute to the formulation of the basis for DOE decision making regarding closure, as memorialized in a Record of Decision.

This SST PA does not represent a DOE decision or presuppose an Ecology decision for landfill closure in advance of completing the NEPA and Ecology permitting processes, respectively; it is only intended to evaluate the human health and environmental impacts of the landfill alternative described herein. Should the HWMA or NEPA processes determine that the SST system will not close under landfill closure, risks to human health and the environment identified in this document will require re-evaluation to take into consideration the selected actions. As an example, the landfill system described in this document assumes that the direct exposure pathway is unavailable to either human or ecological receptors post-closure as a result of the presumed depth of the barrier. Only impacts to receptors associated with releases to groundwater and to an intruder are analyzed in this document. Evaluation of the direct exposure pathway may be required as part of future closure and corrective action decision-making processes should a barrier system not be selected.

## 1.2 PURPOSE

This SST PA evaluates the extent of protection to human health and the environment provided by the planned closure of the SST system. Both radiological and nonradiological contaminants are included in the analysis, as defined in Appendix I of the HFFACO (Ecology et al. 1989). This document is prepared early in the life cycle of the retrieval and closure project, before much waste retrieval has been performed, to support decision making in regards to completion of SST retrievals, SST system closure plans, and HWMA permit modifications. This SST PA will also support consultation between DOE and the NRC on issues related to disposal of radioactive waste remaining in the SST system.

This SST PA evaluates the extent of protection to human health provided by the planned closure of the SST system as defined in Appendix I of the HFFACO (Ecology et al. 1989).

The purpose of this document is to support risk informed decisions for:

- The HWMA regulatory process (i.e., HWMA treatment, storage, and disposal closure requirements, including HWMA corrective action requirements)
- Integration of HWMA decisions into CERCLA decisions for the rest of the Hanford Site
- Waste determinations for residual waste remaining in the SSTs after retrieval
- Allowable waste residuals in tanks and the soil column
- Justification that the extent of retrieval of waste from an SST is sufficiently protective of human health when retrieval goals cannot be achieved through the Appendix H process, defined in the HFFACO (e.g., SST C-106 is currently under evaluation for exemption from the HFFACO retrieval goal)
- Decisions under the *Atomic Energy Act of 1954* as implemented through DOE O 435.1
- Site-wide planning decisions in coordination with the composite analysis as defined under DOE O 435.1.

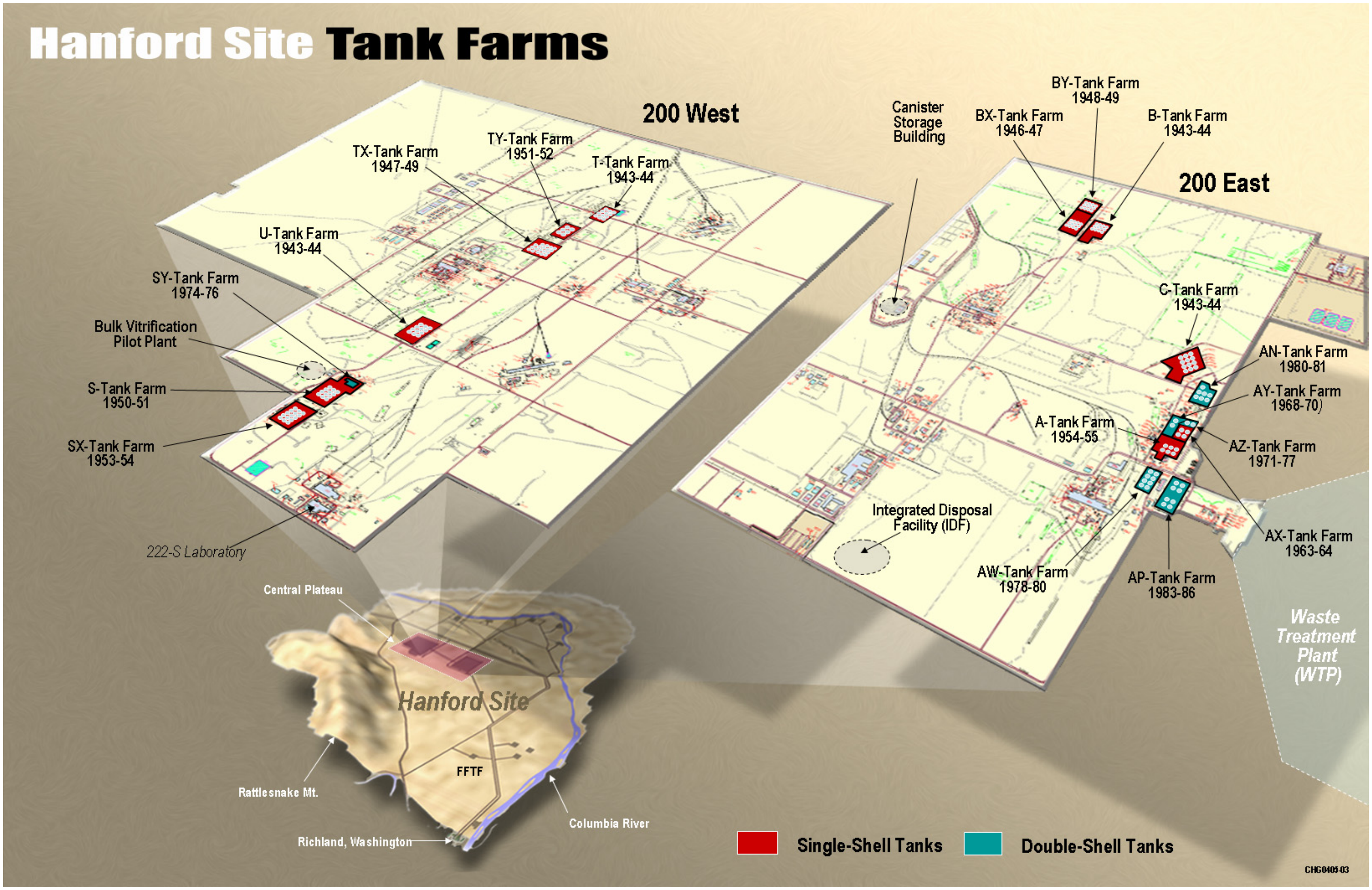
The development of a single document to support risk-informed decisions for all the above processes leading to closure is a direct result of agreements to streamline the closure process that are formalized in Appendix I of the HFFACO (Ecology et al. 1989).

## 1.3 BACKGROUND

The SST system is large and varied and comprises underground waste storage tanks, pipelines, waste transfer lines, water lines, diversion boxes, and other facilities and equipment. Vadose zone contamination from past releases or spills is present to varying degrees in all of the SST farms. For compliance with dangerous waste requirements, the SST farms have been further grouped into seven SST WMAs. These SST WMAs are A-AX, B-BX-BY, C, S-SX, T, TX-TY, and U. Figure 1-3 shows the location of the SST farms and other associated facilities.

As of September 2004, the SSTs contained approximately 30 million gal of mixed radioactive wastes (Hanlon 2004). Waste retrieval activities are under way and will continue for a number of years. The current plan, as stated in HFFACO Milestone M-45-00, is "… retrieval of as much waste as is technically possible, with tank residues not to exceed 360 $ft^3$ in each of the 100-Series tanks, 30 $ft^3$ in each of the 200-Series tanks, or the limit of waste retrieval technology capability, whichever is less" (Ecology et al. 1989). Retrieved tank wastes will be transferred to treatment facilities. At the time of SST system closure, it is anticipated that there will be contamination remaining in the tanks, ancillary equipment, and soils within each SST tank farm.

**Figure 1-3. Facilities in the 200 East and 200 West Areas**



## 1.4 SCOPE

The scope of this SST PA includes all the information and analyses necessary to develop credible estimates of impacts to human health related to planned closure and post-closure conditions for the SST system. Estimated impacts include those to groundwater quality, to atmospheric releases of gaseous contaminants, and to an inadvertent intruder pathway.

Estimated impacts include those to groundwater quality, to atmospheric releases of gaseous contaminants, and to an inadvertent intruder pathway.

Though the scope of this SST PA is broad, some elements were not included:

- Impacts associated with the closure of DSTs and associated facilities (e.g., cross-site transfer lines)
- Impacts from transfer lines outside the immediate SST system
- Impacts from cribs, trenches, and other intentional discharge facilities located inside or in close proximity to a SST WMA boundary
- Short-term operational impacts (e.g., cost, safety, direct exposures, technical feasibility).

The first two of the elements above will be addressed in future revisions of the SST PA (Section 1.11). The third element above will be addressed in the future under the integrated regulatory closure process. The remaining element is addressed in site-specific operational documents developed to support retrieval of SST wastes and closure of the SSTs.

## 1.5 PERFORMANCE OBJECTIVES

In addition to the HFFACO (Ecology et al. 1989), the principal regulatory requirements for closure of the SST WMAs are the HWMA and its implementing requirements in the "Dangerous Waste Regulations" (WAC 173-303), and the DOE closure requirements in DOE O 435.1 under the *Atomic Energy Act of 1954*. These regulatory requirements have closure performance standards to ensure that after closure has occurred, any releases will not adversely impact human health above acceptable limits. These performance standards are presented in this document as performance objectives. Chapter 6.0 presents a comparison of the results of the analysis to the performance objectives.

Closure performance standards are defined in regulations to ensure that after closure has occurred, any releases will not adversely impact human health above acceptable limits. These performance standards are presented in this document as performance objectives.

The performance objectives for tank farm closure PAs are documented in *Performance Objectives for Tank Farm Closure Performance Assessments* (Mann et al. 2005). Because this SST PA is to meet both federal and Washington State requirements, some explanation of terms used is necessary. In DOE O 435.1 and its supporting documents on radioactive waste management, DOE uses the terms "performance objectives," "times of compliance," and "points of compliance" because these terms become part of the disposal authorization statement, that is the DOE formal permitting authorization. Ecology, however, requires that terms containing "compliance" be restricted to the WMA point of compliance (Hedges 2002). Therefore, in this SST PA, instead of using "time of compliance" or "point of compliance," the terms "times of comparison" for "times of compliance" and "points of comparison" for "point of compliance" will be used. Exceptions to this practice are only made when directly quoting from another document.

The initial step in identifying performance objectives is to note the requirements that could be applied to the proposed action. If that action is the disposal of radioactive mixed waste on the Hanford Site, a variety of requirements should be considered:

- DOE requirements
- NRC requirements
- EPA requirements
- State of Washington requirements
- Public participation requirements.

The SST PA evaluates the following contaminant migration pathways and exposure scenarios (Section 1.9):

- Potential future site users including the general public and post-closure site workers
- Inadvertent intruders
- Groundwater
- Air resources.

In addition, there are restrictions on the waste itself if the waste is land disposed. However, land disposal restrictions are not evaluated in this document. Land disposal restrictions were addressed in *Single-Shell Tank System Closure Plan* (Lee 2004) and will be evaluated in updates to the closure plan at a future date.

The performance objectives identified here are for the long-term assessment of the public health from the closure of SSTs. Thus, for example, worker and public safety during the actual closure operation are not considered. Although reviewed by others performing Hanford Site assessments, it must be emphasized that these performance objectives deal only with the tank closure activities and not with the performance objectives of other Hanford Site actions. The performance objectives for a set of contaminants (e.g., beta-photon emitters) are summarized in Table 1-1. The use of appropriate performance objectives for their appropriate regulatory purpose is provided in Mann et al. (2005). The objectives for specific contaminants for groundwater are displayed in Table 1-2. The values for these objectives were chosen to be the most stringent maximum contaminant levels (MCL) of the applicable or relevant and appropriate requirements for its regulatory purpose (i.e., all-pathways dose under CERCLA and all pathways dose under DOE and NRC requirements). For organic chemicals, performance objectives are provided only for those organics most often found in tank waste. The performance objectives for specific contaminants are provided in Mann et al. (2005). Many of the objectives specify concentrations [e.g., (mg-contaminant)/(kg of soil) or (pCi-contaminant)/(liter of groundwater)] that are derived from defined exposure scenarios. Other objectives (e.g., all-pathways dose, incidental cancer risk) require that the exposure scenario (e.g., industrial, residential) be specified in order to calculate values for comparison.

## Table 1-1. General Performance Objectives for Tank Closure

| ***Protection of General Public and Workers*** [a, b, c, d] | |
|---|---|
| All-pathways dose from an SST WMA (CERCLA) | 15 mrem in a year [k] |
| All-pathways dose from an SST WMA (DOE and NRC) | 25 mrem in a year [e] |
| All-pathways dose including other Hanford Site sources | 100 mrem in a year [e] |
| Chemical carcinogens (incremental lifetime cancer risk) | $1 \times 10^{-5}$ (f) |
| Radiological carcinogen (incremental lifetime cancer risk) | $1 \times 10^{-4}$ to $1 \times 10^{-5}$ (l) |
| Non-cancer-causing chemicals (hazard index) | 1 [f] |
| ***Protection of an Inadvertent Intruder*** [a, e, g] | |
| Acute exposure (driller) | 500 mrem |
| Continuous exposure (post-intrusion) | 100 mrem in a year |
| ***Protection of Groundwater Resources*** [b, c, d, h, i] | |
| Alpha emitters | |
| Radium-226 plus radium-228 | 5 pCi/L |
| All others (excluding uranium) | 15 pCi/L |
| Beta and photon emitters | 4 mrem in a year |
| ***Protection of Air Resource*** [a, b, e, j] | |
| Radon (flux through surface) | 20 pCi $m^{-2}$ $s^{-1}$ |
| All other radionuclides | 10 mrem in a year |

[a] Doses are calculated as effective dose equivalents. Values given are in addition to any existing amounts or background.

[b] Evaluated for 1,000 years, but calculated to the time of peak or 10,000 years, whichever is longer.

[c] Groundwater use is assumed to be potable and suitable for use.

[d] Evaluated at the point of maximal exposure, but no closer than the fenceline of the SST WMA in which the tank farm belongs.

[e] *Radioactive Waste Management* (DOE O 435.1).

[f] Washington State “Model Toxics Control Act – Cleanup” (WAC 173-340), as applicable.

[g] Evaluated for 500 years, but calculated from 100 to 1,000 years.

[h] All concentrations are in water taken from a well.

[i] “National Primary Drinking Water Regulations” (40 CFR 141), as applicable.

[j] Main driver is “National Emission Standards for Hazardous Air Pollutants” (40 CFR 61 and 40 CFR 61 subparts H and Q).

[k] Main driver is EPA Memorandum OSWER 9200.4-18 (EPA 1997a).

[l] “National Oil and Hazardous Substances Pollution Contingency Plan” (40 CFR 300).

**Table 1-2. Performance Objectives of Specific Contaminants for Groundwater Protection [a]**

| ***Radionuclides*** | | | |
|---|---|---|---|
| Tritium | 20,000 pCi/L | Strontium-90 | 8 pCi/L |
| Radium-226 | 3 pCi/L | Radium-226 and radium-228 | 5 pCi/L |
| Uranium | 30 µg/L | Beta and photon emitters | 4 mrem/yr |
| Gross alpha (excluding radon and uranium) | 15 pCi/L | Cobalt-60 | 100 pCi/L [b] |
| Carbon-14 | 2,000 pCi/L [b] | Technetium-99 | 900 pCi/L [b] |
| ***Inorganic Chemicals*** | | | |
| Antimony | 0.006 mg/L | Arsenic | 0.05 mg/L |
| Barium | 2.0 mg/L | Beryllium | 0.004 mg/L |
| Cadmium | 0.005 mg/L | Chloride | 250.0 mg/L |
| Chromium (total) | 0.1 mg/L | Cyanide | 0.2 mg/L |
| Fluoride | 4.0 mg/L | Iron | 0.3 mg/L |
| Manganese | 0.05 mg/L | Mercury | 0.002 mg/L |
| Nickel | 0.1 mg/L | Nitrate (as $NO_3$) [c] | 45.0 mg/L |
| Nitrite (as $NO_2$) [c] | 3.3 mg/L | Selenium | 0.05 mg/L |
| Silver | 0.1 mg/L | Sulfate (as $SO_4$) | 250.0 mg/L |
| Thallium | 0.002 mg/L | Zinc | 5.0 mg/L |
| ***Organic Chemicals*** | | | |
| Benzene | 0.005 mg/L | bis(2-ethylhexyl)phthalate | 0.006 mg/L |
| Carbon tetrachloride | 0.005 mg/L | Chloroform | 0.08 mg/L |
| 1,4-Dichlorobenzene | 0.075 mg/L | 1,1-Dichlorethene | 0.007 mg/L |
| Dichloromethane | 0.005 mg/L | Ethyl benzene | 0.7 mg/L |
| Toluene | 1.0 mg/L | 1,1,1-Trichloroethane | 0.2 mg/L |
| 1,1,2-Trichloroethane | 0.005 mg/L | Xylenes (total) | 10.0 mg/L |
| Styrene | 0.1 mg/L | | |

[a] Values are from DOE O 5400.5, 40 CFR 141, 40 CFR 143, 40 CFR 264.94, WAC 173-200, WAC 173-303, and WAC 246-290.

[b] Based on 4 mrem/yr if this is the only contaminant (EPA 1976).

[c] Nitrate as nitrogen is equal to 10 mg/L. Nitrite as nitrogen is equal to 1 mg/L.

## 1.6 DEFENSE IN DEPTH PHILOSOPHY APPLIED TO TANK FARM CLOSURE

Planned closure actions for the SSTs and the PA of these actions are consistent with a defense in depth philosophy initially developed by the NRC to demonstrate a nuclear facility could be operated safely. Key elements of the defense in depth philosophy are the use of multiple barriers (both natural and engineered) to isolate waste in the disposal site and institutional controls to prevent or limit human access to the waste. This philosophy has been applied to high-level radioactive waste disposal in a deep geologic repository at Yucca Mountain, Nevada, with primary emphasis on individuals who might use contaminated groundwater.[3] DOE has also endorsed the defense in depth philosophy (Chapter 1, Section 2.F [9] of DOE M 435.1-1) as a necessary means of addressing "potential uncertainties or vulnerabilities" in system performance. The defense in depth philosophy provides direction to the design of SST system closure, insight into the extent and type of characterization needed for the disposal system and the geologic environment, and the approach for conducting the performance analysis of the proposed SST closure system.

> Key elements of the defense in depth philosophy are the use of multiple barriers (both natural and engineered) to isolate waste in the disposal site and institutional controls to prevent or limit human access to the waste.

Although there are distinct differences between closure actions in the Hanford Site SST system versus disposal actions at Yucca Mountain, these principles are relevant to SST system closure. The need for defense in depth is generated largely by the irreducible variability that is associated with radioactive mixed waste disposal in a geologic setting. To improve confidence in closure actions, a means of offsetting such uncertainties is desirable. The two primary factors that generate uncertainty about system performance are: 1) long-term performance (a minimum of 1,000 years) to protect against the long-term hazards from radioactive materials and 2) the natural heterogeneities of a geologic environment. The basic strategy is to implement multiple isolating functions in a multi-component system that control waste migration to human access points such that both independent and redundant functions are operational. With this approach, even if one or more parts of the performing system fail or function at a less effective level than projected, overall system performance will be satisfactory.

The SST PA analysis evaluates both the barrier performance relative to assigned functions and the degree of performance uncertainty for each barrier in the context of the complete barrier system and geologic environment. A key aspect of the evaluation is identifying failure modes for each barrier and considering the impact of single barrier failure or underperformance on the total system performance. Quality assurance, performance confirmation activities, and model verification activities are actions undertaken to ensure a credible representation for the performance of individual barriers as well as total system performance.

Multiple waste-isolating functions are provided by multiple barriers that isolate waste. The NRC requires the use of both natural and engineered barriers for the geologic repository (10 *Code of Federal Regulations* [CFR] 63.102 (h)) where a barrier is defined as "any material, structure, or feature that…prevents or substantially reduces the rate of movement of water or radionuclides…to the accessible environment, or prevents the release or substantially reduces the release rate of radionuclides from the waste" (10 CFR 63.2). Natural barriers are those features of the geologic system that contribute substantially to waste isolation (10 CFR 63.102(h)) regardless of other barriers. Their performance as barriers is expected to be consistent over the long term because the natural system in an adequate disposal site is essentially stable during the performance time period. However, due to the heterogeneities in the natural system properties

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[3] See NRC policy issue paper, *Staff Plan for Clarifying How Defense-In-Depth Applies to the Regulation of a Possible Geologic Repository at Yucca Mountain, Nevada* [NRC 1999] and "Disposal of High-Level Radioactive Wastes in a Geologic Repository at Yucca Mountain, Nevada" [10 CFR 63].

and processes favorable to waste isolation, there is an inherent uncertainty around estimated performance.

Engineered barriers are the structures or materials of the disposal facility that isolate waste. Compared to natural barriers, engineered barriers provide short-term performance that can be determined with greater certainty than long-term natural system performance. However, long-term performance changes resulting from expected degradation processes are not as well understood because few examples of engineered structure performance beyond a few hundred years are available. Thus, long-term engineered barrier performance uncertainty is generated.

The use of combined natural and engineered barriers provides additional benefits. Engineered barriers can be designed to augment the performance of the natural system by improving the effectiveness of a particular function or by providing a different function that isolates waste. For example, an engineered barrier (e.g., a grouted waste form) can be designed to minimize the release rate of contaminants by providing a more favorable local geochemical environment, and/or a less permeable isolating medium than can be provided by the natural soil-water system. These qualities provide some level of redundant performance and protection against single failure mechanisms that could eliminate adequate performance. Altogether, the combined multi-component system allows the strengths of one or more barriers to compensate for the weakness of other barriers.

To achieve the proposed SST closure condition (Section 1.6), three primary activities will be completed that contribute to defense in depth:

- At least 99% of the waste by volume present in the SSTs at the signing of HFFACO Milestone M-45-00 (36 million gal) will be retrieved and transferred to waste treatment facilities.
- Tank space created by waste retrieval will be filled with grout to isolate the residual waste from infiltrating water.
- A 15-ft thick surface cover will be placed over the SST WMAs.

The resulting engineered barriers are a grouted residual waste overlain by the grouted tank structure and a surface cover (i.e., barrier). These two engineered barriers work in conjunction with one natural barrier, the vadose zone, to isolate and impede waste. Strictly speaking, the unconfined aquifer is not a barrier in the true sense of the definition because it does not retard water or radionuclide movement as defined in 10 CFR 63.2, and because it is part of the accessible environment. However, the unconfined aquifer is an important geologic feature that provides a significant contaminant dilution benefit through the mixing of uncontaminated groundwater with contaminants prior to human access. Therefore, the unconfined aquifer is a component of the SST PA analysis along with the two engineered barriers and vadose zone.

Groundwater monitoring of the closed SST system will be performed at appropriate locations to provide assurance that the combined measures taken to protect the public are adequate, or to provide a basis for further actions. Institutional controls are expected to initially be active (e.g., guards, fences, groundwater monitoring), and eventually transition to passive (e.g., monoliths warning trespassers, deed restrictions).

In the various SST WMAs, unintentional past releases have contaminated the vadose zone sediment within the SST WMAs, and are currently subject to contact with recharge water. Similarly, unintentional releases during waste retrieval are possible. Past releases and unintentional releases are being addressed as part of the RCRA Corrective Action and closure processes that lead to eventual closure of the Hanford Site under CERCLA. Both regulatory-based cleanup processes will address the remediation of these past releases. In support of this future work, this SST PA provides an analysis of the ability of the proposed engineered and natural barriers of the closure system to mitigate the potential impacts from these contaminated zones. These analytical results will be used to support necessary remediation decisions for current and future vadose zone contamination.

Barriers and their functions are defined for two major contaminant migration pathways in the following sections. These are the groundwater pathway resulting in contamination of the unconfined aquifer within the SST WMAs, and the intruder pathway caused by human excavation of waste. The other significant aspect of the defense in depth philosophy, institutional controls, is an important part of inadvertent intruder protection and is discussed in Section 1.6.2.

### 1.6.1 Defense in Depth Strategy for the Groundwater Pathway

For the groundwater pathway, all three barriers (i.e., surface cover, grouted tank structure, and vadose zone) contribute to the isolation of grouted waste residuals (Figure 1-4). Contaminant migration through the groundwater pathway occurs when water contacts waste, dissolves contaminants, and carries waste through the vadose zone and the unconfined aquifer. Water contact with waste is limited by minimizing recharge into the subsurface with an efficient evapotranspiration surface cover. Evapotranspiration is an effective process for impeding infiltration in the Hanford Site semiarid climate where annual precipitation is low (i.e., 6.5 in./yr average) and indigent natural vegetation species survive partly because they store water efficiently. Water contact with waste is further limited by the low permeability grouted tank structure designed to isolate grouted residual waste and divert water to the more permeable backfill surrounding the tank structure.

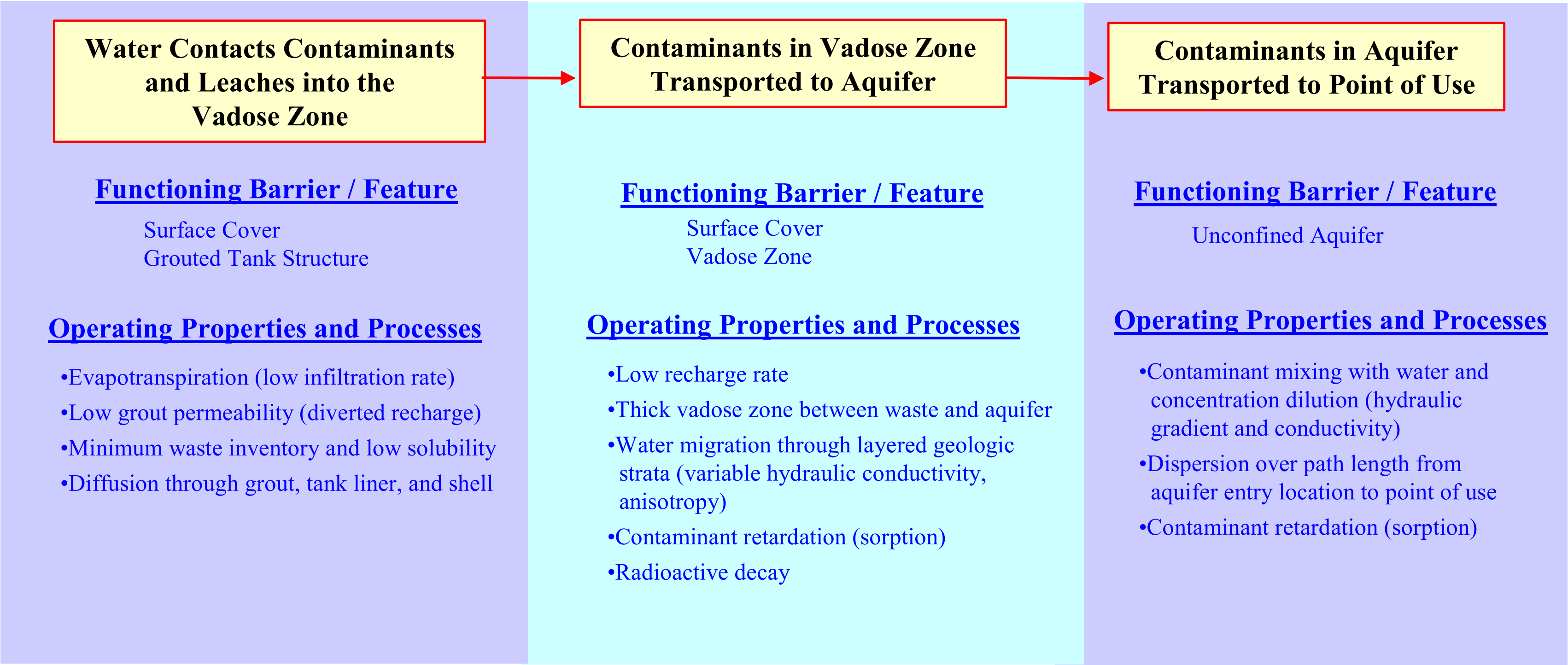
Contaminant release and transport from the tank residuals is minimized by the engineered and natural barriers. The available inventory in tank residuals is reduced by the retrieval process. For tank retrieval based on water sluicing techniques, the residual contaminants are expected to be highly insoluble. The grouting of the tank residuals minimizes any advective component of release. Instead, diffusion is anticipated to be the major mechanism for contaminant release from the grouted tank structure into the vadose zone.

Once contaminants enter the vadose zone, the low infiltration rate controlled by the surface cover, the thickness of the vadose zone between tank bottom and the unconfined aquifer (i.e., greater than 155 ft), and the chemical and physical reactivity between contaminants and the soil-water system (e.g., sorption and anisotropy) prevent all but the least reactive contaminants from reaching the unconfined aquifer for thousands of years, thereby allowing radioactive decay to reduce inventory. For the small number of mobile contaminants that do reach the unconfined aquifer, mixing with groundwater and dispersion during transport to a potential receptor reduces peak concentration levels. As the radioactive contaminants migrate to the groundwater, radioactive decay aids in reducing the amount of contaminant inventory reaching a potential receptor.

To assess the defense in depth philosophy, the SST PA methodology is designed to evaluate the performance of both the total multiple barrier system and the individual barriers against performance objectives. This is accomplished by first identifying the functions that each barrier performs and, then, the associated parameters that describe the function quantitatively (i.e., numeric model parameter). Generally, parameters are barrier properties (e.g., vadose zone thickness) or mathematical descriptions of physical or chemical processes (e.g., distribution coefficients [$K_d$]) that control contaminant migration). The key functions and associated parameters are shown in Table 1-3. Using the key parameter values as inputs, a numerical model calculates water and contaminant migration through the geologic system. The entire groundwater migration pathway is modeled beginning with meteoric water infiltration through the surface cover and ending with contaminated water migration past the point of comparison in the unconfined aquifer.

**Figure 1-4. Groundwater Pathway Contaminant Migration Process and Associated Multiple Barriers, Features, and Processes**

The upper blocks (linked by arrows) show a three-step groundwater migration pathway to the accessible environment for contaminants initially present in tank residual waste. The various natural and engineered barriers and important features and processes that control migration are shown for each step. The multiplicity of barriers reduces reliance on any given barrier while also helping to compensate for the uncertainties implicit in any long-term predictions.



**Water Contacts Contaminants and Leaches into the Vadose Zone**

**Functioning Barrier / Feature**

Surface Cover
Grouted Tank Structure

**Operating Properties and Processes**

- Evapotranspiration (low infiltration rate)
- Low grout permeability (diverted recharge)
- Minimum waste inventory and low solubility
- Diffusion through grout, tank liner, and shell

**Contaminants in Vadose Zone Transported to Aquifer**

**Functioning Barrier / Feature**

Surface Cover
Vadose Zone

**Operating Properties and Processes**

- Low recharge rate
- Thick vadose zone between waste and aquifer
- Water migration through layered geologic strata (variable hydraulic conductivity, anisotropy)
- Contaminant retardation (sorption)
- Radioactive decay

**Contaminants in Aquifer Transported to Point of Use**

**Functioning Barrier / Feature**

Unconfined Aquifer

**Operating Properties and Processes**

- Contaminant mixing with water and concentration dilution (hydraulic gradient and conductivity)
- Dispersion over path length from aquifer entry location to point of use
- Contaminant retardation (sorption)

### Table 1-3. Barriers, Features, Functions, Feature Effects, and Key Parameters Affecting Contaminant Migration along the Groundwater Pathway and Peak Groundwater Concentrations at Points of Use

| Barrier/Feature | Functions/Feature Effects | Key Parameters [a] |
|---|---|---|
| Surface cover | Minimize recharge to the subsurface. | Average annual recharge rate |
| Grouted tank structure (Grout fill, liner, shell, sluiced waste) | Divert recharge water away from waste by lower permeability than surrounding backfill.<br>Isolate waste and limit contaminant release to diffusion levels.<br>At least 99% of the inventory removed by waste retrieval leaving behind mostly insoluble contaminants. | Grout permeability<br>Diffusion coefficient<br>Contaminant-specific inventory<br>Contaminant-specific solubility |
| Vadose zone | Provide extended contaminant travel time to unconfined aquifer.<br>Retard contaminant migration by chemical reaction with soil-water system. | Thickness between waste and unconfined aquifer<br>Hydraulic properties of major geologic strata (hydraulic conductivity, anisotropy, dispersion)<br>Initial moisture content<br>Distribution coefficients ($K_d$) |
| Unconfined aquifer | Dilute contaminant concentrations entering from vadose zone by mixing.<br>Disperse contaminants in three dimensions along flow path.<br>Retard migration by chemical reaction with soil water system. | Hydraulic gradient<br>Hydraulic conductivity<br>Dispersion coefficient<br>Distribution coefficients ($K_d$) |

[a] Different key parameters can be used to represent barrier functions. The surface cover is likely a multiple barrier system whose layers and processes could be modeled explicitly (e.g., evapotranspiration processes) or episodic recharge. In this analysis, a simple approach was taken, using an assumed annual recharge rate as a boundary condition to represent a more complex infiltration process.

In this SST PA, both reference case and sensitivity/uncertainty analyses were completed (see Sections 3.4.7 and 3.5 for detailed discussion). For the reference case, a set of conditions, human actions, and environmental processes that were considered the best estimate of future conditions and events were assumed. The numerical model used to estimate the long-term performance of the closed SST system under reference case conditions simplified representation of the physical system and processes controlling flow and contaminant transport. A reference case set of "central tendency" parameter values (i.e., those values considered most representative of actual conditions) was selected that represented the best current understanding of final closure and environmental conditions. From this parameter set, reference case outcomes (primarily contaminant concentration levels in the unconfined aquifer over time and space) were calculated at a point of comparison (e.g., SST WMA fenceline).

A reference case set of "central tendency" parameter values (i.e., those values considered most representative of actual conditions) was selected that represented the current understanding of final closure and environmental conditions.

The selection of process models, simplification of the physical system, and parameters used in the models generate variability around the projected outcome. Two types of sensitivity analyses were performed to address this issue. First, assuming reference case conditions, the significant parameters (e.g., recharge rate, diffusion coefficient/length, $K_d$) were varied over the range of possible site-specific values, and the associated changes in outcomes were calculated. The key outcomes were maximum groundwater contaminant concentrations calculated during the modeling time frame for each case. These concentrations were labeled "peak values." Parameters were varied one at a time to determine which parameters provided the greatest differences in the peak values.

Significant parameters (e.g., recharge rate, diffusion coefficient/length, $K_d$) were varied over the range of possible site-specific values, and the associated changes in outcomes were calculated. Alternate conceptual models of contaminant propagation in which processes and events that differ from the reference case were evaluated.

Several insights were derived about the performance of the total SST system (SST WMA closure structures and its associated hydrogeologic environment) including:

- A ranking of parameter influence on potential groundwater contamination level variability was determined by comparing the parameter-specific ranges of estimated peak values around the reference case peak values. A larger range indicated greater parameter influence.
- Because parameters represented specific barrier functions, the effects of parameter variability on peak value changes indicated the sensitivity of total system performance to degradation or failure of single barrier performance.
- Peak value variability estimated from assumed parameter value variability provided a qualitative estimate of performance uncertainty. With this approach, uncertainty was assessed as a limited range of plausible peak values. The likelihood of a particular outcome was not determined other than to assume a general tendency for the outcome to be near the peak value projected by the reference case.

The second type of sensitivity analysis considers alternate conceptual models of contaminant propagation in which processes and events that differ from those assumed in the reference case and that have an impact on single-barrier or total system performance are evaluated. These analyses are sometimes referred to as "what if" analyses. The "what if" analyses estimate the flexibility and robustness of single-barrier and total system performances for a greater range of conditions than the "single parameter variable" analyses.

### 1.6.2 Defense in Depth Strategy for the Inadvertent Intruder Pathway

Implementation of the defense in depth philosophy to protect the inadvertent intruder who unknowingly exhumes waste and is exposed to contaminants has not been addressed directly by either NRC or DOE in previous guidance documents. Considering the relevance of defense in depth concepts to the inadvertent intrusion pathway for this analysis, it can be concluded that closure actions for the SST system do provide defense in depth for the inadvertent intruder, but the applicability of the defense in depth philosophy is mostly limited to affecting human actions.

The inadvertent intrusion event consists of two major parts; the first being a deterrence interval (the time period between site closure and the intrusion event) and the second being the intrusion and exposure event. For the deterrence interval, defense in depth philosophy is implemented by the application of both institutional controls and engineered barriers. The natural system has no impact on the inadvertent intrusion scenario. The primary purpose of the defense in depth approach is to delay intrusion long enough to reduce the inventory of moderate half-life radionuclides, primarily cesium-137 and strontium-90, to less harmful levels. This time period is usually 10 half-lives or approximately 300 years. This reduces the initial inventories to 0.1% of the original quantities for these radionuclides.

Because deterrence is primarily a matter of human actions taken to prevent other human actions, institutional controls are the first and most important defense. Active institutional controls (direct human oversight) are instituted first. Controls may include public records developed to identify waste locations, human guards to inspect the facilities routinely and turn away unauthorized individuals, and fences erected and maintained to deny access to waste sites. Later, when resources are assumed unavailable to support active institutional control, passive institutional controls deter the intruder (e.g., markers). If institutional controls fail and the waste site is disturbed, engineered barriers provide additional deterrence. The engineered barriers are the surface cover and the grout-filled tank structure. Surface covers containing markers and icons to warn intruders of buried waste, and the high strength grout tank fill deter drillers from penetrating waste. These various activities comprise the defense in depth philosophy whereby several distinct methods are employed to prevent intrusion.

If intruder deterrence fails, intrusion and exposure occurs. Because the tank residual waste is buried a minimum of 55 ft below ground surface (bgs) (this includes the distance from the surface cover to the base of the tank), the only reasonable access mode is drilling. The act of drilling is the single failure mechanism that eliminates all institutional controls and the functionality of all engineered barriers (i.e., common mode failure).

The SST PA methodology is not well equipped to evaluate the effectiveness of defense in depth actions that promote deterrence. Unlike the groundwater pathway, where physical and chemical processes imposed by barriers do occur that affect contaminant behavior and future exposure levels, deterrence is largely dependent on human actions that may or may not occur in response to preventative measures taken. The effectiveness of a particular institutional control or the performance of the composite set of various institutional controls is a subjective decision. Similarly, the operating engineered barrier functions are essentially warnings to dissuade an intruder from drilling into the waste. The success of these functions is also a subjective and arbitrary decision and no probability of occurrence is assigned.

The SST PA analysis indirectly evaluated the effects of the defense in depth actions taken to deter intrusion in the post-intrusion analysis. Table 1-4 identifies important barriers, features, and associated parameters. The post-intrusion analysis was completed by selecting scenarios that involved different kinds of exposure based on time spent near waste and the use of materials contaminated by waste (e.g., rural pasture). A significant parameter in these analyses was the waste inventory that was exhumed, which, in turn, was determined by the volume of waste exhumed and the contaminant concentrations in that waste. Defense in depth actions minimized the waste volume that was exhumed. A maximum amount of waste was removed during retrieval, and the depth to waste created by the surface cover and grouted tank structure limited all reasonable options for waste exhumation to borehole drilling where the cuttings (including waste) were brought to the surface. The extended deterrence interval reduced contaminant concentrations of radionuclides, primarily cesium-137 and strontium-90, whose half-lives are appreciably shorter (i.e., half-life of 30 years or less) than the deterrence interval (i.e., 500 years after closure). In the SST PA analysis, a reference case engineered barrier configuration was assumed that assigned unique values to these parameters.

**Table 1-4. Barriers, Features, Functions, Feature Effects, and Key Parameters Affecting Contaminant Exposure from Inadvertent Intrusion**

| Barrier/Feature | Functions/Feature Effects | Key Parameter [a] |
|---|---|---|
| Surface cover | Provide deterrence to inadvertent intruder by construction and embedded markers and icons.<br>Provide distance between surface and waste that limits credible waste exhumation methods to drilling. | Time to breach post-closure<br>Thickness |
| Grouted tank structure (grout fill, liner, shell, sluiced waste) | Provide contrasting hard-to-drill material to deter penetration of borehole to waste.<br>Provide distance between surface and waste (55 ft) that limits credible waste exhumation methods to drilling.<br>At least 99% of waste volume removed by waste retrieval, leaving behind mostly insoluble contaminants. | Time to breach post-closure<br>Thickness<br>Contaminant-specific inventory and concentrations at intrusion<br>Contaminant-specific solubility |

[a] The only parameters used in the inadvertent intruder models are the time to breach and inventory.

### 1.6.3 Air Pathway Considerations

The final contaminant migration pathway considered in the SST PA analysis was the air pathway. In this pathway, volatile radionuclide constituents in the wastes contaminated vapors that migrated upward through the grouted tank structure and the surface cover. The need for defense in depth measures was greatly reduced by the lack of contaminants that could be reasonably expected to volatilize in significant quantities (typically, carbon-14, tritium, and radon), the low concentrations of these constituents in tank residue, and the unlikely human activity scenarios needed to cause significant exposure. Thus, the SST PA analysis considered bounding conditions rather than "central tendency" reference case analyses and associated sensitivity analyses.

## 1.7 PLANNED SINGLE-SHELL TANK SYSTEM CLOSURE ACTIONS AND END STATE

This section includes discussion of the closure action processes to achieve a landfill closure end state. Closure of the individual SSTs and SST WMAs occurs in three major steps: 1) SST waste retrieval, 2) tank filling for stabilization, and 3) surface barrier placement. Each of these steps will be described in the respective component closure activity plan. A general description of these steps follows.

> Closure of the individual SSTs and SST WMAs occurs in three major steps: 1) SST waste retrieval, 2) tank filling for stabilization, and 3) surface barrier placement.

For near-surface disposal to occur (i.e., landfill closure), DOE must retrieve as much waste as technically possible (Ecology et al. 1989). DOE should meet the performance objectives for the disposal of Class C low-level waste (LLW) provided in 10 CFR 61, subpart C. In addition, because the tank waste residual is mixed waste, it has to meet Washington State dangerous waste requirements for closure (WAC 173-303). In the HFFACO Appendix I (Ecology et al. 1989) entitled, “SST System Waste Retrieval and Closure Process,” closure permits will be incorporated into the Hanford Site-wide permit (Ecology 2001).

At the time SST system closure is completed (i.e., year 2032), approximately 0.5 million gal of waste (i.e., 1% by volume) containing approximately 2 million curies (Ci) of radioactivity will remain in the 149 SSTs. In this, strontium-90 and cesium-137 represent approximately 99% of that radioactivity. Both contaminants (strontium-90 and cesium-137) are relatively immobile in the environment and decay rapidly (i.e., short half-lives of approximately 30 years). During or shortly after the waste retrieval process, DOE, in conjunction with EPA and Ecology, would establish levels of soil remediation necessary, if needed, to ensure protection of groundwater resources and the general public.

The next closure action process after Ecology and DOE Headquarters approval would be to fill the tanks with grout to stabilize and immobilize the residual waste (Figure 1-5) to prevent further long-term degradation of the SSTs, and to discourage intruder access as required for a near-surface disposal facility. Remediation and stabilization, if needed, of waste in ancillary equipment and other contaminant sources with the SST system would also occur.

The final closure process activity would be placement of an engineered surface cover (about 15 ft in thickness). This surface cover will provide a barrier to infiltration and intrusion in compliance with federal and state regulations. Figure 1-6 shows a configuration of the planned SST system closure end state and how it will be designed to impede contaminant migration.

The closure process includes the preparatory actions to characterize components within the SST system for the purposes of closure, the tank fill proposed to prepare the SSTs for closure, and the surface cover design proposed for the SST system and closure of each SST WMA. In preparation for these actions and as required by Condition II.D.1 of the Hanford Site-wide permit (Ecology 2001), all waste in the SST WMA vadose zone and ancillary equipment components will be analyzed in accordance with a written waste analysis plan or sampling and analysis plan. Sampling and analysis plans will be developed to support sampling activities for closure, and a data quality objectives (DQO) process will be used to ensure agreement between Ecology and DOE on the appropriate sampling and analysis requirements for closure purposes.

The characterization process has begun for 3 SSTs (i.e., tanks C-106, C-202, C-203) and will continue for the remaining 146 tanks. Characterization will also be conducted for soil, SST systems, and ancillary equipment at the SST WMA level, and details (e.g., crosswalk to DQO and/or sampling and analysis plan) will be included in the appropriate SST WMA closure action plan, component closure activity plan, and/or corrective action documentation and incorporated into the closure permit as outlined in Appendix I of the HFFACO (Ecology et al. 1989). Groundwater characterization will occur as part of the remedial investigation and feasibility study process under CERCLA.

**Figure 1-5. Stabilized Waste Tank**

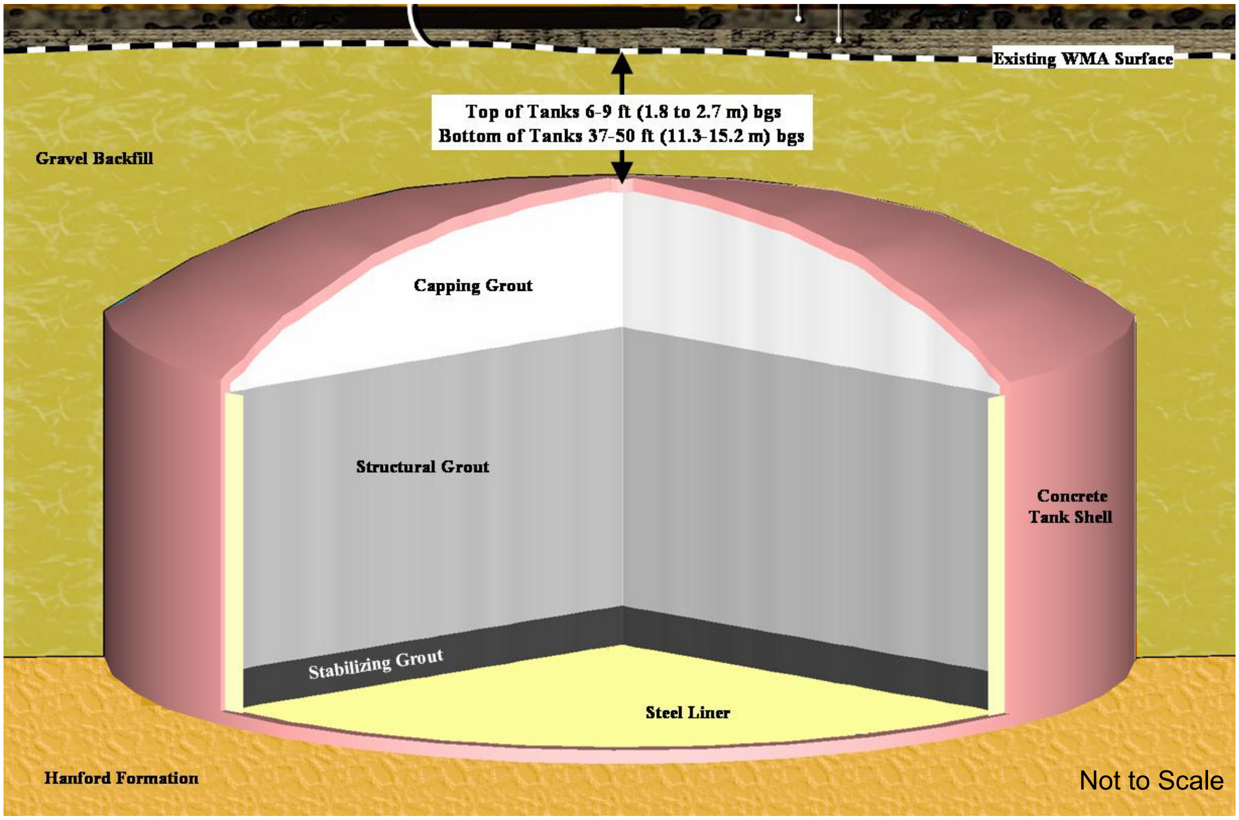
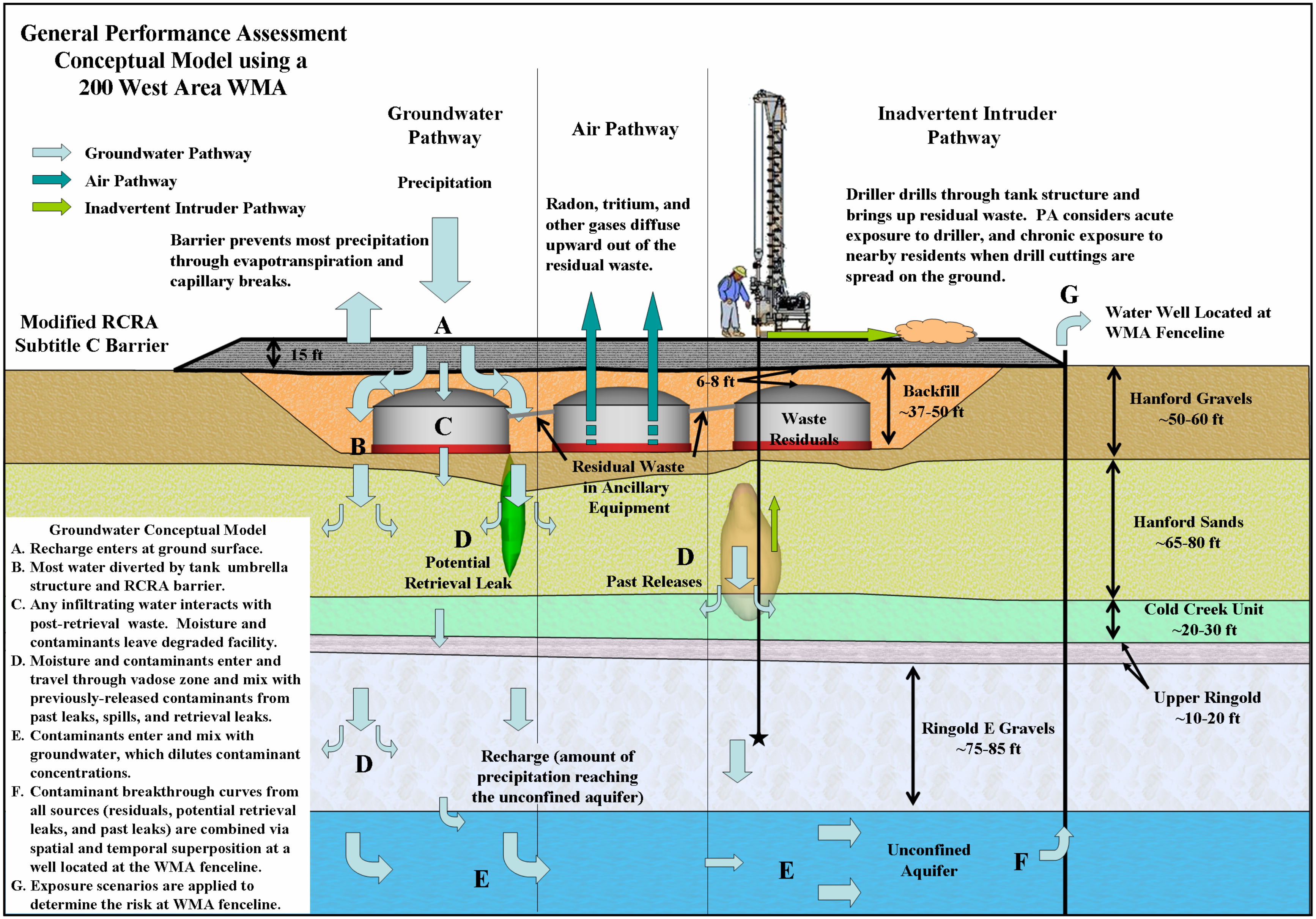


Figure 1-6. General Performance Assessment Conceptual Model



Barrier prevents most precipitation through evapotranspiration and capillary breaks.

Radon, tritium, and other gases diffuse upward out of the residual waste.

Driller drills through tank structure and brings up residual waste. PA considers acute exposure to driller, and chronic exposure to nearby residents when drill cuttings are spread on the ground.

Groundwater Conceptual Model

A. Recharge enters at ground surface.
B. Most water diverted by tank umbrella structure and RCRA barrier.
C. Any infiltrating water interacts with post-retrieval waste. Moisture and contaminants leave degraded facility.
D. Moisture and contaminants enter and travel through vadose zone and mix with previously-released contaminants from past leaks, spills, and retrieval leaks.
E. Contaminants enter and mix with groundwater, which dilutes contaminant concentrations.
F. Contaminant breakthrough curves from all sources (residuals, potential retrieval leaks, and past leaks) are combined via spatial and temporal superposition at a well located at the WMA fenceline.
G. Exposure scenarios are applied to determine the risk at WMA fenceline.

*The geology shown in the figure is specific to the 200 West Area.*

### 1.7.1 Waste Retrieval

HFFACO Milestone M-45-00 states: "Closure will follow retrieval of as much tank waste as technically possible, with waste residuals not to exceed 360 $ft^3$ in each of the 100-Series tanks, 30 $ft^3$ in each of the 200-Series tanks, or the limit of waste retrieval technology capability, whichever is less" (Ecology et al. 1989). DOE will retrieve as much waste as technically possible, with a remaining waste residual of no more than 360 $ft^3$ for the 100-Series tanks and 30 $ft^3$ for the 200-Series tanks (i.e., 99% retrieval by volume). Following waste retrieval activities, DOE will use in-tank survey methods to determine whether retrieval volume criteria have been met. Also as part of this milestone, a data report will be submitted to Ecology for approval to demonstrate completion of waste retrieval in accordance with HFFACO Milestone M-45-00. For tanks that are not subject to milestones (e.g., small miscellaneous underground storage tanks [MUST]), an Ecology-approved data report will also be submitted to demonstrate completion of retrieval.

The residual waste will be characterized to support disposal decisions and risk assessments. DOE will follow a DQO process for conducting the tank waste residual characterization activities. As part of the DQO process, characterization requirements will be documented in tank-specific component closure action DQOs. A sampling and analysis plan has been developed for tank C-106 (Banning 2004), and general sampling and analysis plans will be developed for the 100-Series tanks and the 200-Series tanks.

If the waste residual in individual tanks meets the waste retrieval criteria and the risk metrics related to the waste residual are accepted, DOE will modify the closure activity plan and the Hanford Site-wide permit, if necessary, and then proceed with implementing the approved component closure activity plan. If waste residual exceeds the waste retrieval criteria, DOE will either attempt additional retrieval or request an exception to the retrieval criteria. This request will be prepared pursuant to the procedure in Appendix H, Attachment 2, of the HFFACO (Ecology et al. 1989).

As such, tank-specific considerations such as riser availability, waste condition, or in-tank interferences might offer advantages to one retrieval technology over other technologies, and lead to the selection of that technology to retrieve a particular tank. Based on tank-specific considerations, the following representative waste retrieval technologies were selected for the SSTs:

- Modified sluicing is selected for 100-Series SSTs that are not classified as assumed leakers. This technology is representative of other fluid based retrieval technologies (e.g., past-practice sluicing). Deployments are limited to those tanks that are not classified as assumed leakers because of concerns over the potential for leakage to occur during waste retrieval. There are 67 tanks currently classified as assumed leakers. It is recognized that a number of tanks classified as assumed leakers may be candidates for deployment of modified sluicing after further evaluation of historical leak data. Based on current design information, modified sluicing is expected to be capable of retrieving 99% by volume of the tank waste.

- The mobile retrieval system is selected for 100-Series SSTs that are classified as assumed leakers. This technology provides for waste retrieval using lower liquid volumes, thereby reducing the potential volume of a retrieval leak should one occur.
- Vacuum-based retrieval is selected for retrieving waste from the 200-Series tanks and may be selected for MUSTs. This technology is flexible in that it can be operated as a dry-vacuum retrieval method, or liquid can be introduced near the vacuum head depending on the type of waste to be retrieved. This technology is well suited for deployment in small tanks and would minimize the potential for leakage in a number of the 200-Series tanks that are classified as assumed leakers.

### 1.7.2 Tank Stabilization and Isolation Options

Upon completion of SST waste retrieval, physical and administrative isolation of the SST will occur. Each SST will be stabilized in accordance with component closure activity plans approved by Ecology. SST stabilization may consist of adding fill into the waste-retrieved tanks and may differ from SST to SST, depending primarily on the volume and characteristics of the residual waste remaining after waste retrieval and also depending on the integrity of the SST.

Physical isolation refers to filling and/or capping of pipelines, drains, ducting, or other openings into the SST structure as needed, and will occur progressively as individual SSTs near final stabilization. Administrative isolation controls tank access through procedural actions. Both physical and administrative isolation measures are intended to prevent infiltration of water or inadvertent reintroduction of waste and/or grout into a partially stabilized or stabilized tank.

Numerous tank fill materials have been evaluated in the past in other documents, including EISs. These have included in situ vitrification, gravel fill, and grout or cementitious material. Based on anticipated cost, as well as implementability and technical uncertainties, grout was chosen for the fill material. This is consistent with the closure contingency in Lee (2004) if clean closure cannot be achieved.

Tank stabilization will be accomplished by adding grout or other structural material in layers into each tank. The addition of grout or cementitious material will occur over three separate phases (Figure 1-5). The Phase I fill will consist of a free-flowing grout and will cover the waste residuals and debris on the tank bottom, and will additionally provide structural support for subsequent fills. The Phase II fill will provide structural stability and fill the majority of the tank volume. The Phase III fill will be a high-compressive-strength grout placed in the remaining void space between the Phase II grout and the tank dome and will fill tank risers to the maximum dome height. The function of the Phase III grout is to discourage intruder access. The entire fill system, consisting of Phases I, II, and III, provides structural support to the tank dome to prevent subsidence and degradation of the surface cover placed at the time of WMA closure (Lee 2004). Under the RCRA Corrective Action process, WMA soils will be remediated on an as-needed basis.

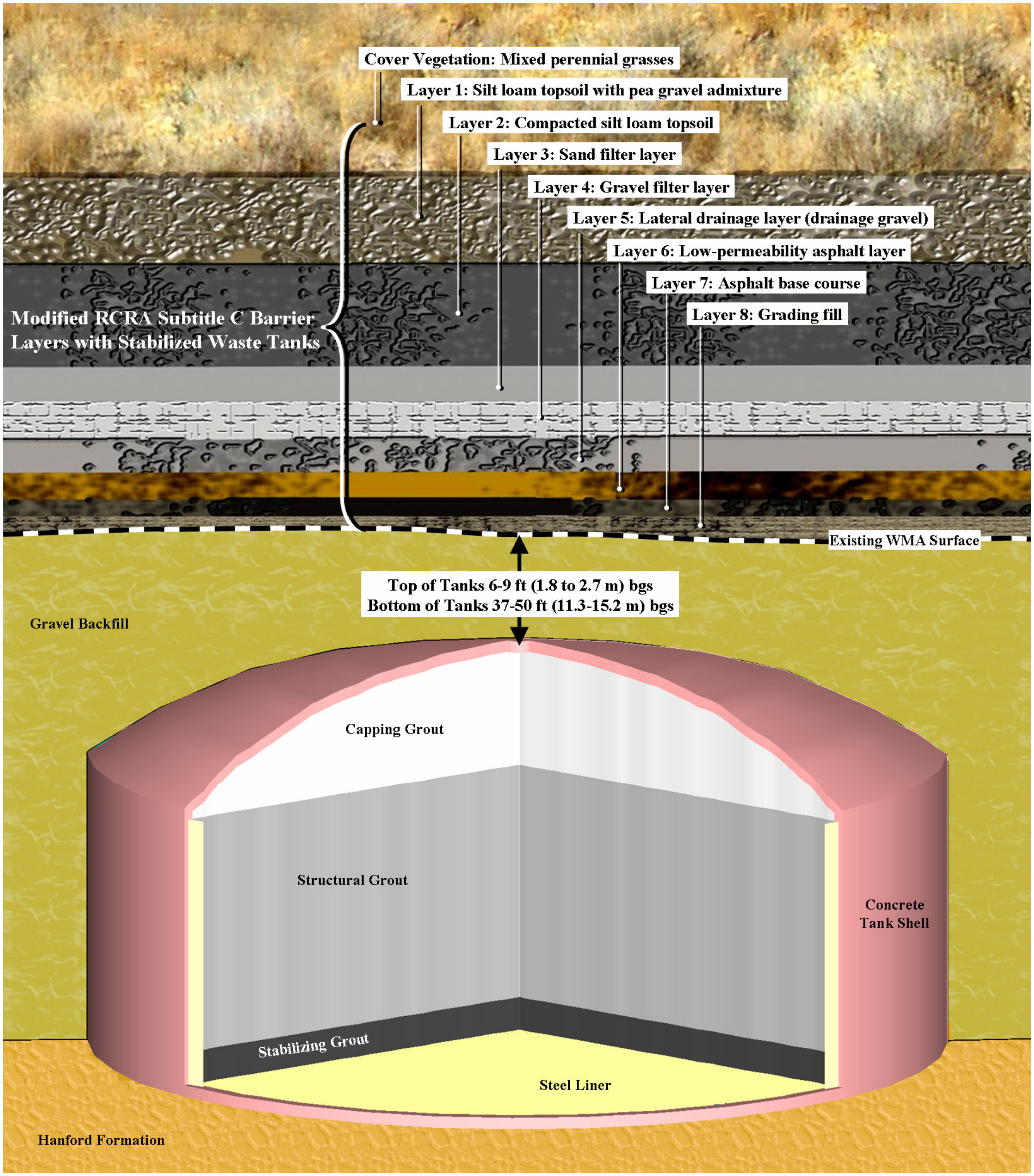
### 1.7.3 Surface Cover Placement

As SST farms are retrieved, stabilized, and isolated for closure, 15-ft-thick surface covers will be constructed to restrict precipitation from contacting stabilized waste and transporting contaminants to the groundwater. The surface covers will be designed to deter inadvertent access or intrusion to the underlying wastes by flora and fauna. The design will also include features that both emulate geologic phenomena known to last for extended periods of time and provide hydraulic isolation from infiltrating precipitation.

The closure surface cover for SST WMAs is assumed to be a Modified RCRA Subtitle C Barrier as conceptually described in *Focused Feasibility Study of Engineered Barriers for Waste Management Units in the 200 Areas* (DOE-RL 1996) and currently designed for the Integrated Disposal Facility in the 200 East Area (Fayer and Szecsody 2004). This surface cover is the baseline design for sites containing dangerous waste, Category 3 low-level waste, and/or Category 3 mixed low-level waste, and Category 1 mixed low-level waste (DOE-RL 1996). This surface cover is designed to provide long-term containment and hydrologic protection for a 500-year period of performance and is composed of up to eight layers of durable material (Figure 1-7). A summary description of each of the layers in this surface cover is given in DOE-RL (1996) including thickness, layer description, specifications, and functions. This design incorporates RCRA minimum technology guidance with modifications for extended performance of up to 500 years. Major changes to account for Hanford Site-specific conditions include elimination of the clay layer, which is projected to desiccate and crack over time in the Hanford semiarid environment, and elimination of the geomembrane component due to uncertainty regarding its long-term durability.

At the current stage in the SST WMA closure process, site-specific surface cover designs are not available. Specifically, an infiltration rate could not be assigned to a specific SST WMA cover design. To address this issue, an infiltration rate for the assumed surface cover was selected that has been shown to be easily attainable (Fayer and Szecsody 2004) based on current design concepts, as described above, and availability of materials. Assumptions on the performance of the SST WMA closure surface cover also incorporated performance expectations from the detailed designs associated with the Integrated Disposal Facility that is currently under construction. Section 3.4.2 presents a detailed discussion of this component of the SST WMA closure system.

**Figure 1-7. Modified RCRA Subtitle C Barrier Profile [a] with Stabilized Waste Tank (not to scale)**



[a] *DOE-RL (1996)*

## 1.8 CONTAMINANT MIGRATION PATHWAY MODELING APPROACH

A conceptual model of each contaminant migration pathway will be developed for each SST WMA that incorporates all the site-specific data available. For the groundwater pathway, much of these data have been collected under the HWMA corrective action activities conducted by the DOE Office of River Protection under the oversight of Ecology. Figure 1-6 presents a schematic of a typical conceptualization for a generalized SST WMA. The conceptualization is then simplified (retaining the important features that include the dominant processes controlling transport of contamination) to allow construction of a numerical model and begin the process of qualitatively investigating the performance of the specified SST closure system.

In keeping with the defense in depth philosophy, a reference case for each contaminant migration pathway was defined. The reference case represents the set of parameters and engineering assumptions that provides a “central tendency” estimate of the input parameter values for the SST closure system. This reference case is complemented by a concurrent examination of the expected range in parameter values for barrier or feature of the SST closure system. To estimate the robustness of the SST closure system features, alternative conceptualizations are also analyzed using the reference case design to establish the level of performance degradation that might occur. This degradation might represent an underestimate in the performance of a feature (e.g., surface cover) or an error in the geologic conceptualization of the system. Poor system performance noted through either the sensitivity analysis or the alternative conceptualization “what if” analysis indicates a need for an improved understanding of the system or a design change.

Three migration pathways (i.e., groundwater, air, and inadvertent intrusion) are modeled differently in this analysis, and focus on different aspects of the closure system depending on the contaminant migration pathway characteristics. However, certain features and assumptions are common to the modeling of each pathway and SST WMA. These are described as follows and refer primarily to the reference case:

- Retrieval of tank waste is assumed sufficient to meet the waste retrieval goals of the HFFACO (Ecology et al. 1989) (i.e., at most, 360 $ft^3$ of waste remaining in 100-Series tanks and 30 $ft^3$ of waste remaining in 200-Series tanks).
- Institutional controls of the site are assumed for the reference case for 300 years (industrial land use) for protection of groundwater (Section 6.2.1).
- Simulation of contaminants including 25 chemicals, 46 radionuclides, and supplemental analytes is analyzed.
- A surface cover is assumed to perform up to its design specifications for 500 years (NRC 2000).
- SSTs will be filled with grout after the completion of waste retrieval (Section 1.7.2).

Three contaminant migration pathways (i.e., groundwater, air, and inadvertent intrusion) are addressed in this analysis.

Modeling of the groundwater pathway assumes that:

- Site-specific contaminant flow and transport analyses conducted for WMA C in the 200 East Area and WMA S-SX in the 200 West Area are sufficient to estimate the groundwater concentration for other SST WMAs at their points of comparison. Due to similarities in the geology, WMA C performance was extrapolated to other SST WMAs in the 200 East Area; similarly, WMA S-SX performance was extrapolated to the SST WMAs in the 200 West Area (Section 3.2.2.4.8).
- The period of simulation was selected at 10,000 years due to the long periods for impacts to be observed in the environment for mobile contaminants and from NRC guidance (NRC 2000).
- Deterministic analyses coupled with sensitivity analyses address uncertainty issues (Section 3.2 and Section 3.5).

Deterministic analyses coupled with sensitivity analyses address uncertainty issues.

Modeling of the air migration pathway uses a bounding analysis due to the very low impacts from radioactive gases expected.

The inadvertent intruder pathway is described as a set of assumptions that form the initial conditions for modeling of subsequent exposure scenarios. These include:

- Active and passive institutional controls (consistent with other Hanford Site PAs) that deter intrusion into the waste form for 500 years
- Intrusion occurs through drilling through the past releases and/or waste residuals; a portion of the waste is brought to the surface in drill cuttings.

Modeling of the reference case inadvertent intruder scenario assumes:

- A one-time acute dose to the driller occurs from exposure to exhumed waste over 5 days
- A chronic dose to the inadvertent intruder occurs from the use of the exhumed waste spread over an area for a rural lifestyle over a period of 50 years.

A complete discussion of the methodology used in this SST PA is presented in Chapter 3.0.

## 1.9 SCENARIOS

This section discusses the assumed exposure scenarios[4] that are used to investigate the potential future impacts to public health of the closed SST WMAs. For the reference case, scenarios were developed on the basis of land use assumptions that define an assumed future use of the remediated site. Scenarios are typically defined for industrial and residential uses of land (DOE-RL 1995a; Ecology 2001; EPA 1989); however, many other exposure scenarios exist. Within each scenario, the receptor interacts with contaminants through pathways such as dermal

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[4] A scenario is a collection of human activities that defines a lifestyle or an action that can be used to assess the level of interaction of the individual with their environment.

exposure, inhalation, ingestion, and in some cases, adsorption through the skin. For each exposure scenario pathway, inputs are developed that define the impact of the contaminant through its exposure pathways. Typical inputs define breathing rates, exposure duration, diet, and other inputs. *Exposure Scenarios and Unit Factors for the Hanford Tank Waste Performance Assessment* (Rittmann 2004) provides a complete description of the exposure scenarios and toxicological information.

For the reference case, scenarios were developed on the basis of land use assumptions that define an assumed future use of the remediated site.

### 1.9.1 Future Land Use

The selection of assumed exposure scenarios begins with the selection of land use. In 1992, the Hanford Future Site Uses Working Group (HFSUWG) was charged with determining potential future uses of the various parts of the Hanford Site. This group consisted of local, state, and federal officials, representatives of affected Tribal Nations, agricultural and labor organizations, as well as members of environmental and other special interest groups. The efforts of the HFSUWG form the basis of the Hanford Site comprehensive land-use EIS (DOE 1999b).

The following four general land uses (DOE 1999b) can be envisioned for the Central Plateau over the time of interest to this SST PA:

- Industrial or commercial
- Dry-land farming
- Irrigated farming
- Natural.

**Industrial or Commercial:** The present land use classification is heavy industrial. An industrial use generally means properties that are or have been characterized by, or are committed to, traditional industrial uses. Waste management or waste processing would represent an industrial classification.

**Dry-Land Farming:** An example of dry-land farming can be observed in the nearby Horse Heaven Hills. Like the Central Plateau, the Horse Heaven Hills, south of the Hanford Site, are near the Columbia River, but are at a significantly higher elevation. Although the irrigation activity is increasing at certain locations, comparatively little irrigation occurs in the Horse Heaven Hills because of the relatively high energy (hence economic) cost of bringing water to the surface. Dry-land farming continues to be the main land use for the Horse Heaven Hills.

**Irrigated Farming:** East of the Central Plateau and across the Columbia River, irrigated farming is common. The water, however, does not come from the nearby stretches of the Columbia River, but from the Columbia Basin Project, which uses water stored behind Grand Coulee Dam, over 322 km (200 mi) upstream of the Hanford Site. The water is gravity-fed to the farms. The regional geography makes such a water delivery system unlikely for the Central Plateau.

**Natural:** West of the Central Plateau is the Fitzner/Eberhardt Arid Lands Ecology Reserve, a nature preserve area. This area now is part of the Hanford Reach National Monument (65 FR 37253) and, for the most part, is preserved in its original (i.e., pre-pioneer settlement) state. Exposure scenarios associated with a "natural" land use typically have intermittent or periodic uses in common, such as, hunting, recreational, or park ranger activities.

#### 1.9.1.1 Reference Case Land Use Scenarios

Recently, Advice #132 provided by the Hanford Advisory Board (HAB) (Martin 2002) addressed exposure scenarios in the 200 Areas (Central Plateau) and provided direction for a range of potential human health risks, including the reasonable maximum risk expected over time. The corresponding response to the HAB advice from Ecology, DOE, and EPA (Klein et al. 2002) provided additional direction recognizing that the most likely use of the land in the Central Plateau will remain industrial and that the existing use of groundwater will be restricted up to approximately 300 years. This "Risk Framework Description" (Klein et al. 2002) provides the basis used for the land use assumptions shown in Table 1-5 and defined here as the reference case. The current cleanup activities are projected to finish by 2032 and will be followed by 300 years of active institutional controls, with no drilling for water use or other uses allowed in the Central Plateau. Passive institutional controls will continue for the next 200 years, totaling 500 years of institutional controls that will limit access to the closed SST WMAs. Land use is assumed to remain industrial but the restrictions on the use of groundwater are projected to end 300 years after closure in keeping with the response to the HAB advice (Klein et al. 2002). This advice is consistent with the Hanford Site comprehensive land-use EIS (DOE 1999b) and the HFSUWG (HFSUWG 1992a).

> Land use is assumed to remain industrial but the restrictions on the use of groundwater are projected to end 300 years after closure in keeping with the response to the HAB advice (Klein et al. 2002).

The reference case analysis of Table 1-5 presents the assumed future land use exposure scenarios. The listed exposure scenarios address a combination of CERCLA decisions being implemented on the Central Plateau, DOE O 435.1 requirements, and NRC guidance as presented in *A Performance Assessment Methodology for Low-Level Radioactive Waste Disposal Facilities: Recommendations of NRC's Performance Assessment Working Group* (NRC 2000). Time frames shown for the end of active and passive controls recognize the NRC philosophy of "testing the robustness of the facility against a reasonable range of possibilities" and are not intended as a prediction of the future. The 10,000-year time frame selected for the analysis recognizes the need to capture the expected peak dose from mobile long-lived radionuclides associated with tank waste residues remaining after closure. EPA guidance for CERCLA cleanups and DOE O 435.1 recommend the analysis conclude after 1,000 years. The EPA guidance and DOE O 435.1 are considered addressed by use of the longer time frame of 10,000 years selected here. Table 1-5 provides different time frame assumptions for groundwater use under the industrial land use scenario (groundwater pathway) and intrusion into the contaminated waste beneath each SST WMA (intruder pathway). These time frame differences are driven by different regulatory assumptions and past practices in earlier Hanford Site PAs. This SST PA will use these time frames for the reference case and provide estimated impacts for other time frames for each pathway.

**Table 1-5. Future Land Use Scenarios and Time Frame Assumptions for Reference Case Analysis**

| Time Frame | Scenario | Comment |
|---|---|---|
| 2000 to 2032 | DOE cleanup/closure activities | Current conditions |
| 2032 to 2332 | Industrial land use, no groundwater use | Active institutional controls for 300 years after closure |
| 2332 to 12032 | Industrial land use, groundwater use | Drilling may occur as close as the SST WMA fenceline, but no waste exhumation occurs until year 2532 |
| 2532 | Inadvertent intruder (driller), rural pasture | Passive institutional controls are assumed to end in year 2532 and intrusion into the waste site occurs, bringing waste to the surface |

As part of the reference case, intrusion into the waste residual is also evaluated. The impacts to both an intruder and to a subsequent inadvertent intruder onto the remnants of the original intrusion are evaluated. The reference case assumes a drilling scenario is needed to reach and exhume the waste, and a rural pasture scenario is a reasonable scenario to estimate baseline inadvertent intruder impacts. The intruder scenario addresses requirements under DOE O 435.1.

#### 1.9.1.2 Sensitivity Analysis Land Use Scenarios

Table 1-6 addresses alternative future land uses that are considered possible, but not as likely as the reference case analysis. These are addressed as part of the sensitivity analysis. Of particular interest in Table 1-6 are the plausible exposure scenarios. These are proposed to provide an upper range on human health risk to the public resulting from tank waste residuals and past releases remaining after closure of the SST WMAs. These scenarios assume that a residential or a residential agricultural scenario occurs immediately after the loss of institutional control and, further, that the residence is at the edge of the closed SST WMA.

Table 1-6 also lists two additional inadvertent intrusion scenarios into the closed waste site: the suburban gardener and the commercial farmer. These scenarios assume that, at the end of passive institutional controls, an individual drills into the waste site thus providing exposure to the waste residuals. The scenarios noted as “post-intrusion” are addressed as sensitivity analyses on the assumed post-intrusion scenario of rural pasture.

**Table 1-6. Alternative Land Use Scenarios for Sensitivity Analyses**

| Scenario | Location |
|---|---|
| ***Future Plausible Exposure Scenarios*** | |
| Residential | Edge of the waste management area after 300 years |
| All-pathway farmer | Edge of the waste management area after 300 years |
| ***DOE Order 435.1 Inadvertent Intruder Exposure Scenarios*** | |
| Post Intrusion:<br>Suburban gardener<br>Commercial farmer | Onsite ground maximum at 500 years from closure [a] |

[a] Ground maximum is defined as within the closed waste management area.

### 1.9.2 Exposure Scenario Descriptions

Descriptions of all the exposure scenarios and the supporting toxicological information can be found in Rittmann (2004). Typically, exposure scenarios are inherently conservative. Tables 1-7 and 1-8 present a summary of exposure pathways for each land use scenario considered. Table 1-7 summarizes the exposure pathways for a typical PA as required by DOE O 435.1. For the intruder and all-pathways farmer scenarios presented in Table 1-7, impacts are quantified only in terms of radiological doses. The all-pathways farmer scenario assumes that some of the waste materials have migrated into the groundwater. Table 1-8 summarizes exposure scenarios that are consistent with EPA and the HFFACO (Ecology et al. 1989). These exposure scenarios also assume that some of the waste materials have migrated into the groundwater. For the exposure scenarios presented in Table 1-8, only the incremental lifetime cancer risk (ILCR) and hazard index (HI) are of interest. All scenarios are consistent with the EPA risk assessment guidance (EPA 1989), WAC 173-340, and the HFFACO, as appropriate. Sections 1.9.2.1 through 1.9.2.8 provide details of each exposure scenario used in the SST PA. No direct exposure pathway exists under a 15-ft thick surface barrier.

#### 1.9.2.1 Industrial Worker

The industrial worker exposure scenario is one of the reference case land use scenarios. This receptor is exposed to radiological contaminants from groundwater and soil. Exposures to chemical contaminants are not evaluated under this exposure scenario. The primary exposure pathways for the industrial worker scenario include direct contact with groundwater (ingestion and dermal contact) and inhalation of vapors from showering; direct contact with soil (external radiation, incidental ingestion, and dermal contact); and inhalation of vapors, fugitive dust, and tritium vapors. The industrial worker cancer risk calculations assume a body mass of 70 kg, an exposure duration of 20 years (250 day/year) working period, and a 250 L/year (1 L/day for 250 days) consumption of water while at work with an averaging time of 70 years. Table 1-1 provides the performance objective for this scenario as $1 \times 10^{-5}$ ILCR.

#### 1.9.2.2 Model Toxics Control Act Method C (Industrial)

This industrial exposure scenario is one of the sensitivity analysis land use scenarios. Under this Washington State regulatory scenario, a receptor is exposed to carcinogenic and non-carcinogenic chemical contaminants through the groundwater pathway. Exposure to radiological contaminants is not examined. The exposure pathway is ingestion. This scenario is described in WAC 173-340(720)(5) and is referred to as the Method C scenario. It is applicable for setting groundwater cleanup levels for an assumed industrial land use scenario. For non-carcinogens, the receptor is assumed to represent a 70-kg adult, consuming 2 L/day for an exposure duration of 6 years. For carcinogens, the receptor is assumed to represent a 70-kg adult, consuming 2 L/day over an exposure duration of 30 years, with an averaging time of 75 years. Performance objectives for the carcinogenic chemical exposure is an ILCR of $1 \times 10^{-5}$ and for non-carcinogenic chemicals is a hazard index (HI) value of 1 (Table 1-1).

# Table 1-7. Exposure Pathway Summary for DOE Order 435.1 Performance Assessment Exposure Scenarios [a]

| Media | Exposure Pathways | Waste Intruders [b] | | | | All Pathways Farmer |
|---|---|---|---|---|---|---|
| | | Driller | Suburban Gardener | Rural Pasture | Commercial Farmer | Groundwater |
| Water | Ingestion | | | | | ● |
| | Vapor inhalation | | | | | ● |
| | Shower, dermal | | | | | ● |
| | Swimming, dermal | | | | | |
| | Sweat lodge, inhalation | | | | | |
| Soil | Ingestion | ● | ● | ● | ● | ● |
| | Inhalation | ● | ● | ● | ● | ● |
| | Dermal contact | | | | | ● |
| | External radiation dose | ● | ● | ● | ● | ● |
| | Tritium vapor inhalation | | ● | ● | ● | ● |
| Food chain | Garden produce | | ● | | | ● |
| | Grains | | | | | |
| | Beef and milk | | | Milk only | | ● |
| | Poultry and eggs | | | | | ● |
| | Fish | | | | | |
| | Wild game | | | | | |

[a] Modified from Rittmann (2004).

[b] The water media pathway is assumed to contribute nothing to the intruder scenario doses, per DOE O 435.1.

● indicates exposure pathway included in analysis

**Table 1-8. Exposure Pathway Summary for EPA and Model Toxics Control Act [a] Performance Assessment Exposure Scenarios [b, c]**

| Media | Exposure Pathways | Industrial Groundwater | Residential Groundwater | WAC 173-340 Residential and Industrial Groundwater |
|---|---|---|---|---|
| Water | Ingestion | ● | ● | ● |
| | Vapor inhalation | ● | ● | |
| | Shower, dermal | ● | ● | |
| | Swimming, dermal | | | |
| | Sweat lodge, inhalation | | | |
| Soil | Ingestion | ● | ● | |
| | Inhalation | ● | ● | |
| | Dermal contact | ● | ● | |
| | External radiation dose | ● | ● | |
| | Tritium vapor inhalation | ● | ● | |
| Food chain | Garden produce | | ● | |
| | Grains | | | |
| | Beef and milk | | | |
| | Poultry and eggs | | | |
| | Fish | | | |
| | Wild game | | | |

[a] WAC 173-303-610

[b] The annual effective dose equivalent (in mrem) is not calculated for the exposure scenarios shown in this table. The risk quantifiers for these scenarios are incremental lifetime cancer risk from exposure to both radionuclides and chemicals, and hazard index for chemicals.

[c] Modified from Rittmann (2004).

● indicates exposure pathway included in analysis

### 1.9.2.3 Residential

The residential exposure scenario is one of the sensitivity analysis land use scenarios. This receptor is exposed to radiological contaminants from well water, soil, and through the food chain. Exposure to chemical contaminants is not evaluated for this exposure scenario. The exposure pathways for the residential scenario include direct contact with water (ingestion and dermal contact) and inhalation of vapors from showering; direct contact with soil contaminated by groundwater (external radiation, incidental ingestion, and dermal contact); inhalation of vapors (including tritium) and fugitive dust; and food chain exposure from ingestion of garden produce.

The lifetime increase in the risk of developing some type of cancer from radionuclides for a resident is the exposure duration of 30 years. The first 6 years are at the intake rate for a child for exposure pathways, while the last 24 years are at the intake rate for an adult. Drinking water consumption is 730 L/year (2 L/day). Table 1-1 indicates the performance objective for this scenario is $1 \times 10^{-5}$ ILCR.

#### 1.9.2.4 Model Toxics Control Act Method B (Residential)

The residential exposure scenario is one of the reference case land use scenarios. Under this Washington State regulatory scenario, the receptor is exposed to carcinogenic and non-carcinogenic chemical contaminants through the groundwater pathway. Exposure to radiological contaminants is not examined. The exposure pathway is ingestion. This scenario is developed under WAC 173-340(720)(4) and is referred to as the Method B scenario. It is applicable for setting cleanup levels for an assumed residential land use scenario. For non-carcinogens, the receptor is assumed to represent a child (16 kg), consuming 1 L/day for a duration of 6 years. For carcinogens, the receptor is assumed to represent a 70-kg adult, consuming 2 L/day over an exposure duration of 30 years, with an averaging time of 75 years. Performance objective for the carcinogenic chemical exposure is an ILCR of $1 \times 10^{-5}$ and for non-carcinogenic chemicals is an HI value of 1 (Table 1-1).

#### 1.9.2.5 All-Pathways Farmer

The all-pathways farmer scenario is one of the sensitivity analysis land use scenarios. This receptor is exposed to radiological contaminants from well water, soil, and the food chain. The primary exposure pathways for the all-pathways farmer include direct contact with water (ingestion and dermal contact) and inhalation of vapors from showering and other household activities; direct contact with soil (external radiation, incidental ingestion, and dermal contact); inhalation of vapors (including tritium) and fugitive dust; and food chain exposure from ingestion of garden produce, beef, milk, poultry, and eggs.

This scenario represents a reasonable maximum expected exposure. A subsistence farm located downgradient from the disposal site uses groundwater for domestic needs (drinking, cooking, showering), for irrigation (garden and pasture), and for watering livestock. The receptor obtains one-fourth of his fruit and vegetable intake each year from his garden, and half of his meat, milk, poultry, and egg intake from his livestock. In addition, he inhales resuspended garden soil and ingests small amounts of it each day. His external dose comes from soil contaminated through groundwater application near his dwelling. The radiation dose to this receptor is the 50-year committed effective dose equivalent (EDE) from 1 year of exposure. Table 1-1 provides the performance objective for this scenario as 15 mrem/yr.

#### 1.9.2.6 Inadvertent Intruder

In this exposure scenario, the restrictions and warnings are lost or not effective for the closed WMA site and someone drills a well (the only credible intrusion scenario) that passes through the buried waste to obtain groundwater. Radiation hazard is the only hazard considered for this receptor consistent with DOE O 435.1. The exposure occurs during a drilling operation that lasts 40 hours spread over 5 days. The performance objective for this acute exposure scenario is 500 mrem (Table 1-1).

**1.9.2.6.1 Driller Intruder Scenario.** This receptor is exposed to radiological contaminants in exhumed waste while drilling a well through a closed tank and/or contaminated soil assumed to remain in the WMA after closure. The primary exposure pathways include direct external radiation, incidental ingestion, dermal contact, and inhalation of vapors and fugitive dust. This is considered an acute exposure because the driller is in contact with the waste for a relatively short period of time (i.e., 5 days). The driller intruder scenario is a reference case land use scenario.

**1.9.2.6.2 Post-Intrusion Resident Scenarios.** This receptor is primarily exposed to radiological contaminants from exhumed waste. For these exposure scenarios, the drill cuttings are distributed onto land that will be used for food consumption or gardening. These are known as chronic exposure scenarios because the post-intruder resident is exposed over a number of years. The performance objective for these scenarios is 100 mrem/yr (Table 1-1). Given the present land use around the Hanford Site, there are three post-intrusion resident scenarios:

- **Post-Intrusion Suburban Garden:** This scenario assumes that a receptor lives near the drill cuttings and spreads the cuttings in his garden. The receptor obtains one-fourth of his fruit and vegetable (but not grain) supply each year from his garden. In addition, he inhales resuspended garden soil and ingests small amounts of it each day. His external dose comes from spending time in or near the garden. The radiation dose to this receptor is the 50-year committed EDE from the first year of exposure after the well is drilled. This post-intrusion scenario is a sensitivity analysis land use scenario.
- **Post-Intrusion Rural Pasture:** This scenario assumes that a receptor lives near the drill cuttings and spreads cuttings in his pasture and hay field. The receptor obtains half of his annual intake of milk from the cow. He inhales resuspended soil and ingests small amounts of it each day. His external dose comes from spending time in or near the pasture and hay field. The radiation dose to this receptor is the 50-year committed EDE from the first year of exposure after the well is drilled. This scenario is included as part of the reference case land use scenarios.
- **Post-Intrusion Commercial Farm:** This scenario assumes that a receptor lives near the drill cuttings and spreads the cuttings in his field used for growing a food crop for market. The individual inhales resuspended soil and ingests small amounts of it each day. His external dose comes from spending time in or near the field. The radiation dose to this receptor is the 50-year committed EDE from the first year of exposure after the well is drilled. This scenario is one of the sensitivity analysis land use scenarios.

#### 1.9.2.7 Offsite Exposure Scenarios

Only scenarios directly associated with the SST WMAs are analyzed as part of this report. Offsite exposures will be estimated as part of the *Composite Analysis for Low-Level Waste Disposal in the 200 Area Plateau of the Hanford Site* (Kincaid et al. 1998). Updates to Kincaid et al. (1998) will address waste sites adjacent to the SST WMAs where liquid disposal from SSTs were intentionally released to the vadose zone.

## 1.10 RELATED DOCUMENTS

Sections 1.10.1, 1.10.2, and 1.10.3 contain a discussion of the most relevant Hanford Site tank closure documents, environmental assessments, and regulatory agreements, respectively. Documents used to provide guidance for preparation of this SST PA are described in Section 1.10.4. Section 1.10.5 contains a description of documents used to define the scope of the SST PA.

### 1.10.1 Other Relevant Tank Closure Documents

A number of documents dealing with PAs for closing tank farms have been issued. In addition to the documents written by the CH2M HILL Hanford Group, Inc. Tank Closure Project (Section 1.10.5), documents have been written to satisfy the requirements of DOE and Ecology.

Prior to this document, PAs covering separate tank farms include:

- *Single-Shell Tank System Closure Plan* (Lee 2004)
- *Preliminary Performance Assessment for Waste Management Area C at the Hanford Site, Washington* (Mann and Connelly 2003).

Lee (2004) contains the risk assessment for WMA C.

### 1.10.2 Other Relevant Hanford Site Long-Term Environmental Assessments

This SST PA builds on the many environmental assessments that have been performed at the Hanford Site. They pertain to the Hanford Site tank farms while fulfilling the requirements of DOE O 435.1 or requirements of Washington State.

#### 1.10.2.1 Previous Work Related to Hanford Site Tank Farms

A number of reports have been published on risk assessments for the Hanford Site tank farms. They can be grouped into two classes: 1) tank closure EISs and 2) documents supporting the RCRA Corrective Action process.

**1.10.2.1.1 Environmental Impact Assessments.** Two major EISs on tank farms and their waste have been prepared. A third EIS is in preparation.

The Hanford defense waste EIS, *Final Environmental Impact Statement: Disposal of Hanford Defense High-Level Transuranic and Tank Wastes* (DOE 1987) addressed all defense waste. For the tank waste alternatives, the EIS separated the high-level waste for shipment to a geologic repository and the low-activity waste for grouting in grout vaults. *Tank Waste Remediation System, Hanford Site, Richland, Washington, Final Environmental Impact Statement* (TWRS EIS) (DOE and Ecology 1996) analyzed various options to manage the Hanford Site tank waste. The record of decision, issued shortly thereafter (62 FR 8693), defined the current strategy of tank waste retrieval, separation, and immobilization described in Section 1.2.2.2 of the TWRS EIS (DOE and Ecology 1996). The TWRS EIS did not evaluate closure of the SSTs at the Hanford Site.

Currently, DOE is preparing a new, expanded, comprehensive EIS that will combine the scope of the 2004 solid waste EIS (DOE 2004) and the ongoing tank closure EIS for retrieval, treatment, and disposal of tank waste and closure of SSTs at the Hanford Site along with all of the waste types addressed in the Hanford solid waste EIS. Issuance of this expanded tank closure and waste management EIS is planned for fiscal year 2008.

**1.10.2.1.2 RCRA Corrective Action Process.** Because wastes from the SSTs and associated facilities had leaked and impacted groundwater during SST farm operations, Ecology placed DOE under RCRA Corrective Action. To comply with this action, DOE is to gather all data that would be useful in estimating past releases and their contaminant nature and extent to allow Ecology and EPA to evaluate the potential human health and environmental impacts, and to identify appropriate interim corrective measures. Among the many documents created for this activity, two sets are important for this SST PA:

- Subsurface conditions description reports (SCDR)
- Field investigation reports (FIR).

The SCDRs compile the historical data is useful in estimating past releases and their potential impacts and the areas where additional data are needed. The following SCDRs have been issued for the SST WMAs:

- *Subsurface Conditions Description for the S-SX Waste Management Area* (Johnson et al. 1999)
- *Subsurface Conditions Description of the B-BX-BY Waste Management Area* (Wood et al. 2000)
- *Subsurface Conditions Description of the T and TX-TY Waste Management Areas* (Wood et al. 2001)
- *Subsurface Conditions Description of the C and A-AX Waste Management Area* (Wood et al. 2003)
- *Subsurface Conditions Description of the U Waste Management Area* (Wood and Jones 2003).

The FIRs document the results of field and laboratory characterization activities within the WMAs and the associated experiments that aided in the understanding of the transport of contaminants from the SST WMA to the groundwater. FIRs have been published for four WMAs:

- *Field Investigation Report for Waste Management Area S-SX* (Knepp 2002a)
- *Field Investigation Report for Waste Management Area B-BX-BY* (Knepp 2002b)
- *Field Investigation Report for Waste Management Areas T and TX-TY* (Myers 2005).

FIRs for the remaining SST WMAs (i.e., A-AX, C, and U) are scheduled over the next few years to fulfill HFFACO Milestone M-45-55 (Ecology et al. 1989).

#### 1.10.2.2 Other Hanford Site Project-Specific Performance Assessments

This SST PA also builds on previous PAs prepared for the Hanford Site, in particular, *Hanford Immobilized Low-Activity Waste Performance Assessment: 2001 Version* (Mann et al. 2001), known as the immobilized low-activity waste (ILAW) PA.

The ILAW PA addresses the disposal of packaged vitrified waste produced by the Hanford Waste Treatment and Immobilization Plant at a location 1.6 km (1 mi) southwest of WMA C. The ILAW PA formed a preliminary basis for the disposal authorization of Waste Treatment Plant ILAW in an undesignated disposal site. Changes in treatment plans and identification of detailed disposal plans have prompted revision of the ILAW PA; that revision is planned in accordance with DOE M 435.1-1 to support ILAW and bulk vitrified waste disposal, as well as secondary treatment waste disposal for high-level waste treatment processes. The Hanford Site presently has a disposal authorization statement that also covers disposal of wastes at the Solid Waste Burial Grounds and the Environmental Remediation Disposal Facility (ERDF).

The following PAs were developed under *Radioactive Waste Management*, (DOE O 5820.2A), a predecessor to DOE O 435.1:

- *Performance Assessment of Grouted Double-Shell Tank Waste Disposal at Hanford* (Kincaid et al. 1995) addresses the disposal of low-level liquid waste from the DSTs. The waste was to be combined with cement, fly ash, and clay to form a grout that would cure and solidify in large subsurface vaults located to the east of the 200 East Area.
- *Environmental Restoration Disposal Facility Performance Assessment* (Wood et al. 1995b) was written to support disposal of waste generated by the cleanup of the Hanford Site, but was not immediately issued. Instead, *Remedial Investigation and Feasibility Study Report for the Environmental Restoration Facility* (DOE-RL 1994) was prepared. A crosswalk between DOE-RL 1994 and the requirements of DOE O 435.1 has been approved (DOE 2001). The ERDF is regulated under CERCLA. Most of the waste to be disposed of at ERDF is expected to be contaminated soil.
- *Performance Assessment for the Disposal of Low-Level Waste in the 200 West Area Burial Grounds* (Wood et al. 1995a) addresses the disposal of solid waste from operations at the Hanford Site and other DOE sites. These wastes are placed into trenches in the western part of the 200 West Area, then covered with a surface cover.
- *Performance Assessment for the Disposal of Low-Level Waste in the 200 East Area Waste Burial Grounds* (Wood et al. 1996) addresses waste that is similar to that addressed in the 200 West Area PA (Wood et al. 1995a). However, the disposal trenches for this waste are in the northern part of the 200 East Area. Annual summaries also have been submitted to the Low-Level Waste Federal Review Group (LFRG); the latest in 2003 (Wood 2003).

#### 1.10.2.3 General Hanford Site Environmental Assessments

A series of general environmental assessments also has been prepared for Hanford Site activities. These assessments look at the Hanford Site as a whole or address environmental impacts in a more general manner.

*Composite Analysis for Low-Level Waste Disposal in the 200 Area Plateau of the Hanford Site* (Kincaid et al. 1998) was prepared in response to Recommendation 94-2 of the Defense Nuclear Facilities Safety Board (DNFSB) to the Secretary of Energy (DNFSB 1994). The recommendation noted the need for a risk assessment that investigates the environmental impacts of all radioactive waste disposal actions or leaks at DOE sites. The LFRG conditionally approved the composite analysis in "Disposal Authorization Statement for the Hanford Site Low-Level Waste Disposal Facilities" (DOE 1999a), and provided further documentation in *Low-Level Waste Disposal Facility Federal Review Group Manual* (DOE 1999c). The schedule for updating the composite analysis is presented in *Maintenance Plan for the Composite Analysis of the Hanford Site, Southeast Washington* (DOE-RL 2003a). The authors of the composite analysis documentation are working with the authors of the PAs discussed above to maximize consistency in data and methods.

*Draft Hanford Remedial Action Environmental Impact Statement and Comprehensive Land-Use Plan* (DOE 1996) analyzed the potential impacts associated with establishing future land use objectives for the Hanford Site. These impacts will come primarily from remediation activities. The document also proposes a land use plan for near-future activities. TWRS activities were not extensively considered. Based on comments received, the draft EIS was rewritten and issued as a land-use plan EIS (DOE 1999b) with an associated record of decision (64 FR 61615).

*Final Hanford Site Solid (Radioactive and Hazardous) Waste Program Environmental Impact Statement, Richland, Washington* (DOE 2004) has recently been issued. This EIS addresses the disposal of non-CERCLA LLW at the Hanford Site. Such waste includes LLW generated at the Hanford Site, melters from the Waste Treatment and Immobilization Plant, ILAW, and LLW imported from other DOE sites. The record of decision (69 FR 39449) selected the ILAW disposal site as the location of a new disposal facility named the Integrated Disposal Facility. Pending finalization of the tank closure and waste management EIS, *Final Hanford Site Solid (Radioactive and Hazardous) Waste Program Environmental Impact Statement, Richland, Washington* (DOE 2004) will remain in effect to support ongoing waste management activities at the Hanford Site.

### 1.10.3 Regulatory Agreements and Documents

The HFFACO (Ecology et al. 1989) is an agreement between DOE, EPA, and Ecology concerning the cleanup of the Hanford Site. The HFFACO contains legally enforceable milestones, many of which cover SST system closure (the M-45 series). The milestones related to SST system closure are listed in Table 1-9. Other milestones can be found in the HFFACO.

**Table 1-9. Key *Hanford Federal Facility Agreement and Consent Order* Milestones Related to Single-Shell Tank System Closure [a]**

| HFFACO Milestone | Title | Completion Date |
|---|---|---|
| M-45-06-T03 | Initiate Closure Actions on WMA Basis. Closure shall follow Completion of the Retrieval Actions Under Proposed Milestone M-45-05. | 3/31/2012 |
| M-45-06-T04 | Complete Closure Actions On One WMA. | 3/31/2014 |
| M-45-00 | Complete Closure of All Single-Shell Tank Farms. | 9/30/2024 |
| M-045-06 | Complete Closure of All Single-Shell Tank Farms in Accordance with Approved Closure/Post Closure Plan(s) | 9/30/2024 |

[a] This SST PA uses year 2032 as an assumed date of closure.

*Hanford Site Ground Water Protection Management Plan* (DOE-RL 1995b) has been superseded by *Hanford's Groundwater Management Plan: Accelerated Cleanup and Protection* (DOE-RL 2003b). DOE-RL (2003b) presents plans for remediation of high-risk waste sites, reducing the amount of the contaminated area at the Hanford Site, reducing recharge near waste sites, remediating existing groundwater plumes, and monitoring groundwater conditions. However, the current version of the management plan does not address long-term protection of the groundwater resource.

### 1.10.4 Guidance Documents

The main document guiding the development of this SST PA is Appendix I of the HFFACO (Ecology et al. 1989). The following additional documents were also used as guidance in preparing this SST PA:

- *A Performance Assessment Methodology for Low-Level Radioactive Waste Disposal Facilities: Recommendations of NRC's Performance Assessment Working Group*, NUREG-1573 (NRC 2000)
- *Low-Level Waste Disposal Facility Federal Review Group Manual* (DOE 1999c).

Performance assessments from other DOE sites and the comments on those studies also have been reviewed to understand different approaches and methods used elsewhere.

### 1.10.5 Definition Documents

A series of documents has been created to define the scope and major parts of this SST PA:

- *Performance Objectives for Tank Farm Closure Performance Assessments* (Mann et al. 2005)
- *Maintenance Plan for Hanford Tank Farm Closure Performance Assessments* (Mann and Newell 2006).

Mann et al. (2005) define the performance objectives to be used in the PAs, as well as the media to be protected (groundwater, air) after closure. The performance objectives are provided for the protection of inadvertent intruders, assessment of engineered barrier performance, and validation of potential waste acceptance limits.

Mann and Newell (2006) describe the plans to create and maintain the SST PA. This SST PA effort is a many-year effort yielding better analyses and documents as additional information becomes available.

## 1.11 EVOLUTION OF THIS PERFORMANCE ASSESSMENT

Performance assessments are done iteratively to take into account new information from research, characterization, and monitoring. As DOE moves toward final closure of the entire SST system, the following activities are planned to ensure that DOE remains on a technically valid path toward closing tank farms in a manner that protects human health. The near-term plans include the following:

- **Update of this performance assessment to reflect new findings:** This is the first of a series of PAs of the SST system. The SST PA will be updated to incorporate significant changes in the approach to closure, conceptual model, or source characteristics (Mann and Newell 2006).
- **Expansion to include the DST system:** The tank farm system comprises the SST system, the DST system, and many facilities (e.g., pipelines and vaults) outside the SST and DST farm fences. An expanded PA is planned for issue in 2008. The expanded PA will address the entire SST and DST systems including ancillary equipment that is part of the DST system.
- **Incorporate future closure plans:** Finally, there will be simulations based on new plans of the retrieval/closure projects of the Tank Farm Contractor. As the closure of the tank systems are more fully planned, additional details can and will be inserted into the computer models to describe how proposed changes affect the long-term human health of closure activities. These long-term human health impacts will be documented in SST WMA-specific PAs as required by Appendix I of the HFFACO (Ecology et al. 1989).

## 1.12 STRUCTURE OF THIS PERFORMANCE ASSESSMENT

This SST PA is divided into seven chapters and seven appendices. The appendices provide additional detailed information about topics presented in the individual chapters. The contents of each chapter and appendix are as follows:

- Chapter 1.0 provides a summary of the purpose, background, scope, approach, and structure of the SST PA.
- Chapter 2.0 describes Hanford Site characteristics and environment, including details of the geography, geology, and the groundwater hydrology and geochemistry. In addition, past and present activities at the Hanford Site and land uses are described. Waste characteristics and the SST WMAs are also described in detail.
- Chapter 3.0 covers the methods used to assess system performance, including the radionuclide transport pathways and exposure scenarios. It also discusses the assumptions used in modeling system performance.
- Chapter 4.0 presents and integrates results from the transport and exposure models used to estimate the potential consequences of long-term contaminant release from the closed tank farms.
- Chapter 5.0 presents the results from the inadvertent intruder analyses.
- Chapter 6.0 interprets disposal facility performance with respect to the scenarios and the performance objectives defined in Chapter 1.0.

- Chapter 7.0 discusses the major themes of the results presented in Chapters 4.0, 5.0, and 6.0; identifies data and analyses gaps in the SST PA; and discusses further work associated with the SST PA activity.
- Appendix A contains a crosswalk to the LLW disposal facility federal review group criteria and where those criteria are associated in this SST PA.
- Appendix B contains information on process chemistry history and facility history.
- Appendix C contains detailed information on inventory inputs to the SST PA modeling.
- Appendix D contains detailed information on groundwater pathway modeling results.
- Appendix E contains detailed intruder and air pathway analyses information.
- Appendix F contains a description of the quality assurance program applied to production of the SST PA.
- Appendix G provides brief resumes of contributors to this document.

## 1.13 REFERENCES

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40 CFR 61, "National Emission Standards for Hazardous Air Pollutants," *Code of Federal Regulations*, as amended.

40 CFR 141, "National Primary Drinking Water Regulations," *Code of Federal Regulations*, as amended.

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