

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

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ABSTRACT

The *Initial Single-Shell Tank System Performance Assessment for the Hanford Site* [1] (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. 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). The SST PA element is defined in Appendix I of the *Hanford Federal Facility Agreement and Consent Order (HFFACO)* (Ecology et al. 1989) [2], the document that establishes the overall closure process for the SST and double-shell tank (DST) systems. The approach incorporated in the SST PA integrates substantive features of both hazardous and radioactive waste management regulations into a single analysis. The defense-in-depth approach used in this analysis defined two major engineering barriers (a surface barrier and the grouted tank structure) and one natural barrier (the vadose zone) that will be relied on to control waste release into the accessible environment and attain expected performance metrics. The analysis evaluates specific barrier characteristics and other site features that influence contaminant migration by the various pathways. A “reference” case and a suite of sensitivity/uncertainty cases are considered. The “reference case” evaluates environmental impacts assuming central tendency estimates of site conditions. “Reference” case analysis results show residual tank waste impacts on nearby groundwater, air resources; or inadvertent intruders to be well below most important performance objectives. Conversely, past releases to the soil, from previous tank farm operations, are shown to have groundwater impacts that are significantly above most performance objectives. Sensitivity/uncertainty cases examine single and multiple parameter variability along with plausible alternatives to “reference” cases to judge how well the proposed closure system performs when changes to important assumptions are made to the hydrogeologic and engineered systems. The estimated impacts from these cases are generally consistent with “reference” case results (i.e., performance objectives are exceeded by contaminants from past releases but not tank residuals). This document and its future iterations will play a critical role in the decision making process for the closure of the Hanford Tank Farms. It will support interim decisions related to tank retrievals and interim corrective measures, in addition to supporting the major closure decisions of tanks and tank farms. Hence, it is imperative that the review process of this document is inclusive of the decision makers as well as the Hanford Stakeholders.

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 shows the location of the

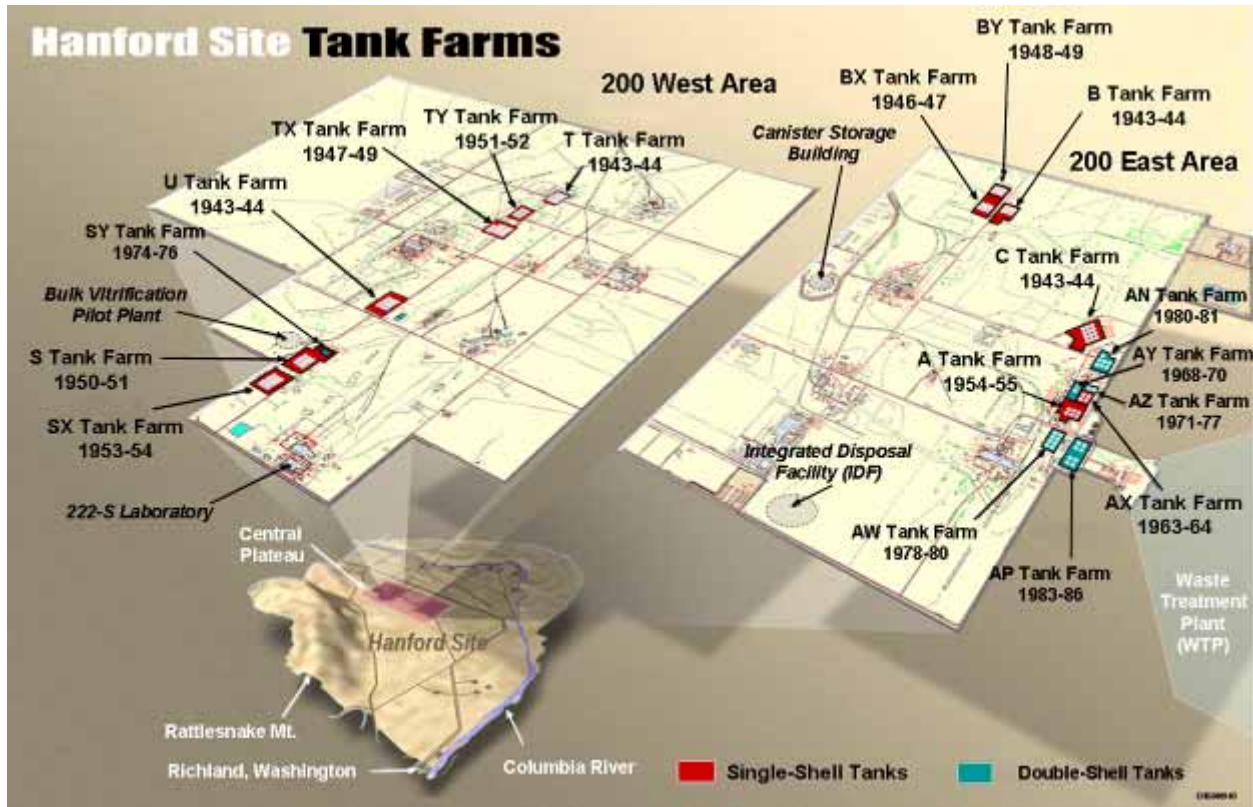


Fig. 1. Tank Farm facilities in the 200 East and 200 West Areas at the Hanford Site.

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 DSTs and 149 are SSTs. SSTs are grouped into 12 groups of tanks called tank farms and are further aggregated into seven waste management areas (WMA) to support compliance with hazardous waste regulations. These SST WMAs are A-AX, B-BX-BY, C, S-SX, T, TX-TY, and U. 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.

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. As of September 2004, the SSTs contained approximately 30 million gallons of mixed radioactive wastes (Naiknimbalkar, 2004 [3]). 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 f³ in each of the 100-Series tanks, 30 f³ in each of the 200-Series tanks, or the limit of waste retrieval technology capability, whichever is less." 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.

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, to be disposed offsite at a geologic repository, and a low-activity fraction, to be disposed onsite as low-level mixed waste to a state-permitted facility. Following retrieval of the SST waste and in accordance with HFFACO, the SST system with its remaining waste is assumed for the purposes of the SST PA document to be closed as a landfill.

Regulatory Approach

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
- State of Washington “Hazardous Waste Management” Act (HWMA [4])
- *Atomic Energy Act of 1954* [5]
- *National Environmental Policy Act of 1969* (NEPA [6])
- Radioactive Waste Management (DOE O 435.1 [7])
- Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA [8]).

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 [9]) 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 [10]) 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.

Implementation of the integrated regulatory closure process is authorized in Appendix I of the HFFACO, which establishes expectations for the scope and approval of the *Initial Single-Shell Tank System Performance Assessment for the Hanford Site*. 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, 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 and the environment 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 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 the closure plans.”

The closure of the SST system as currently projected means that the SST WMAs would be closed as landfill units under the integrated regulatory closure process, to be completed by the year 2032. The 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). Additionally, Appendix H to the HFFACO [2] 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). The SST PA also supports regulatory waivers through the HFFACO [2] 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 ft³ for SST C-106 is currently under evaluation with the HFFACO regulatory authorities and the NRC.

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 [11] 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 [12]). 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.

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. The 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.

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 the PA 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.

Purpose

The initial SST PA evaluates human-health impacts from tank residuals and deep vadose contamination assumed left in the tank farms following closure using presently available information and presents the first results of an iterative analysis. The SST PA 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.

Furthermore, while waiting for the completion of the Tank Closure and Waste Management Environmental Impact Statement and its implementing Record of Decision, DOE will be using the PA to support the following:

- Development of approach, assumptions, and methodology for evaluating long-term human health impacts related to the closure of the tank farm system
- Regulatory requirements for pre- and post-retrieval documentation
- Interim activities such as temporary barriers to prevent infiltrating water
- Additional characterization activities
- Risk-informed decisions related to:
 - 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
 - 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
- Venue to promote an open, transparent process of the SST-PA approach, assumption methods (how to do a PA).

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.

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.

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 are being considered. For the groundwater pathway, all the barriers impede water movement in the subsurface and two of the barriers, the grouted tank structure and the vadose zone, retard contaminant 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 also considers plausible barrier failure modes or underperformance and evaluates 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.

Contaminant Exposure Scenarios and Exposure Pathways

The initial 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 selected that define levels of interactions by humans with air, water, and soil contaminated by waste. Human interactions with the waste generally occur 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 direct exposure to radiation (typically gamma radiation from relatively short-lived isotopes such as Cs-137). 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.

Model Methodology

A conceptual model for each contaminant migration pathway was developed for each WMA, incorporating all available and relevant site-specific data. For the groundwater pathway, much of these data have been collected under the RCRA Corrective Action process conducted by the DOE Office of River Protection. Figure 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) can indicate a need for an improved understanding of the system and/or a design change.

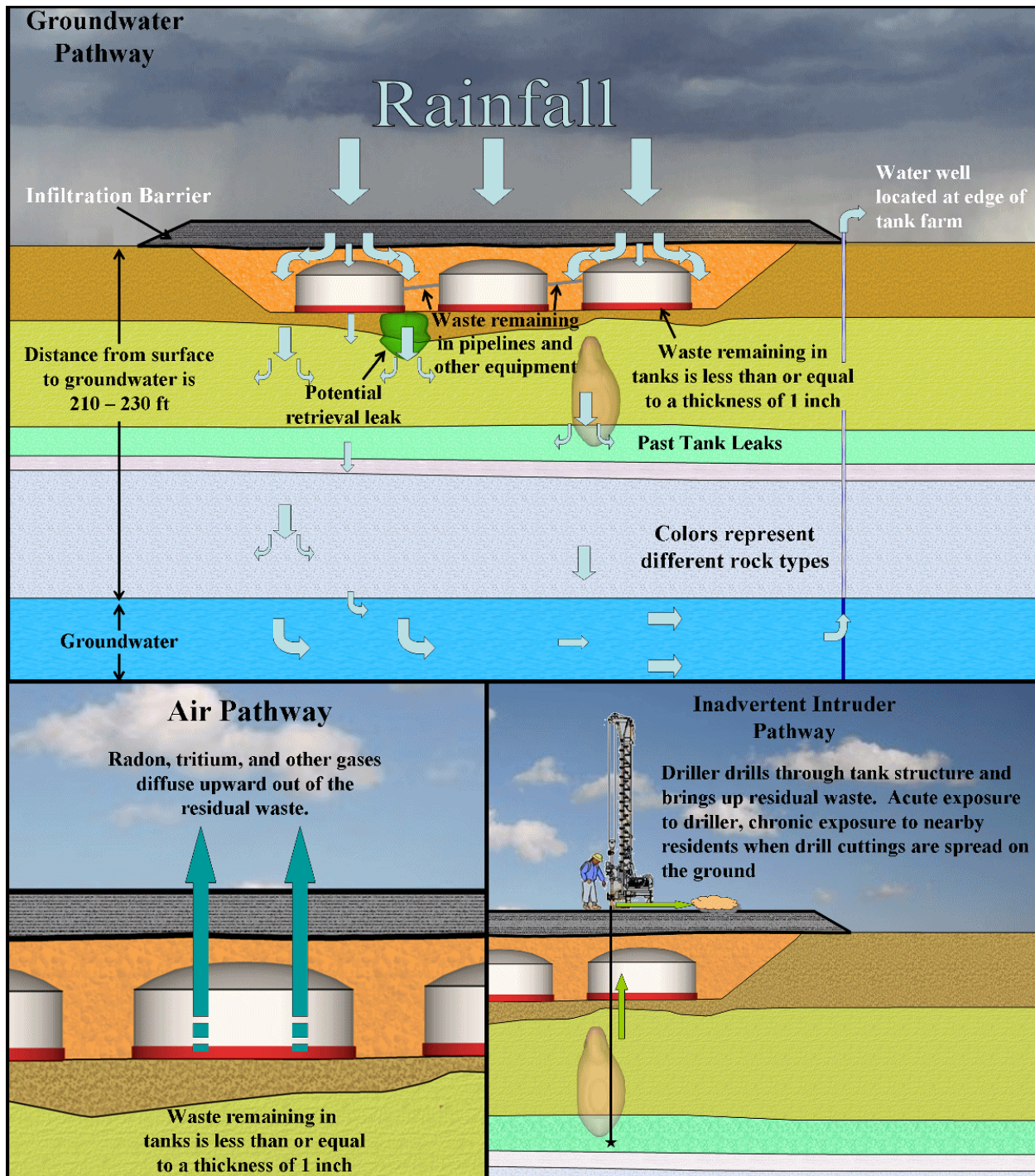


Fig. 2. Conceptual model of general performance for each pathway analyzed.

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).

For the inadvertent intruder, impacts include both acute and chronic dose. Reference case exposure scenarios are well driller (acute dose) and rural farmer with a dairy cow (chronic dose). Alternate exposure scenarios considered for purposes of a sensitivity analysis are chronic dose for a suburban resident with a garden and for a commercial farmer. The analytical results indicate that only the sensitivity case of the suburban resident with a garden exceeds the performance objective for three WMAs. Doses are generally more than a factor of 10 below applicable performance objectives at 500 years from closure.

Table I. 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	WAC173-340 Hazard Index Method B 1.0
WMA	Tank Residuals						
S-SX	◇	◇	◇	◇	◇	◇	◇
T	◇	◇	◇	◇	◇	◇	◇
TX-TY	◇	◇	◇	◇	◇	◇	◇
U	◇	◇	◇	◇	◇	◇	◇
C	◇	◇	◇	◇	◇	◇	◇
B-BX-BY	◇	◇	◇	◇	◇	◇	◇
A-AX	◇	◇	◇	◇	◇	◇	◇
WMA	Past Releases						
S-SX	●	●	◇	●	◇	●	●
T	●	●	◇	●	◇	●	◇
TX-TY	●	●	◇	●	◇	◇	◇
U	●	●	◇	●	◇	◇	◇
C	◇	◇	◇	◇	◇	◇	◇
B-BX-BY	●	●	◇	●	◇	◇	◇
A-AX	●	●	◇	●	◇	◇	◇

Below Performance Objective:

- ◇ Greater than a factor of 10
- ◇ Less than a factor of 10

Above Performance Objective:

- Greater 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

Sensitivity Analysis

The sensitivity analysis provides information that addresses the following issues:

- How well can the performance of the closure system be estimated?
- How important are the “barriers” to the performance of the system?

- What is the value of additional information to reduce estimated uncertainty?

These issues arise largely because of inherent variability within the tank closure system. Heterogeneities in the natural system, long-term degradation of engineered barrier performance, and future human actions can affect future environmental contamination. Such variability generates uncertainty about real-time contaminant migration characteristics and limits the ability of the modeler to adequately portray system features and processes that affect future environmental contamination levels (e.g., predictive uncertainty). Because tank closure system variability cannot be completely resolved (also referred to as irreducible variability), a range of future environmental impacts are estimated that account for effects of this variability and provide a qualitative measure of uncertainty. To complete these estimates, a suite of sensitivity cases has been formulated in which variability was quantified as ranges of modeling input parameter values that envelope reference case values. The resulting set of changes in estimated environmental (e.g., groundwater) contamination levels in combination with reference case results provided ranges of plausible future contamination levels caused by tank closure system variability effects.

Of the three major pathways (i.e., groundwater, air, and intruder), the most complicated analysis involves the groundwater pathway. Contaminant migration through the subsurface is influenced by all major components of the closure system. Therefore, the greatest amount of potentially significant parameter variability is associated with this pathway. The methodology for the groundwater pathway uses a deterministic approach to calculate a plausible range of future groundwater contamination levels at the WMA fenceline that is generated by site-specific closure system variability and encompasses the reference case result. This approach is deterministic because potential groundwater contamination levels are determined for discrete parameter values that define ranges in parameter (e.g., minimum, reference case, and maximum values). Collectively, the suite of analytical results defines a finite range of plausible future groundwater contamination levels. Although there is a qualitative expectation that the actual groundwater contamination levels should tend toward the reference case estimate (e.g., the purpose of the reference case assumptions is to provide the best estimate of actual closure system conditions), the analyses do not assign a likelihood of occurrence to a particular outcome. These results contrast with those provided by a probabilistic/stochastic approach, in which a continuum of parameter values are often considered and their likelihood of occurrence is assumed. These assumptions are then propagated through the analysis to a set of realizations where the likelihood of a particular outcome occurring can be calculated.

The approach described herein was selected for the following reasons:

- Closure system performance is being compared with respect to numerous deterministic criteria (e.g., groundwater protection criteria and various human health effects). Comparison of deterministic criteria with deterministic analytical results provides a transparent indication of acceptable or unacceptable performance.
- The available database describes the major features and processes affecting contaminant transport in some detail (e.g., precipitation and infiltration rates, subsurface hydrogeologic characteristics, contaminant-specific geochemical behavior) and is amenable to the quantification of minimum and maximum values of critical parameters. The database, for the most part, is not considered adequate to assign probability distribution functions to various parameters.
- Manipulation of single and multiple changes in parameter values coupled with associated changes in future groundwater contamination levels provides insight into the relative importance of various features and processes affecting contaminant transport. These results also provide estimates of plausible variability in future groundwater contamination levels (e.g., uncertainty

around the reference case outcome) and illustrate the estimated range of plausible outcomes due to irreducible system variability.

- This approach identifies additional important data needs. Importance is defined as data that are currently unavailable and are needed to better quantify a parameter value range that may generate relative large changes in projected groundwater contamination levels.

A flow chart of the sensitivity case methodology for the groundwater pathway is provided in Figure 3. In this methodology, sensitivity cases were derived to evaluate the effects of system variability, groundwater contamination analyses were completed for each case, and comparisons of sensitivity case results (estimated groundwater contamination levels at the WMA fenceline) to reference case results were made.

Initially, sensitivity cases were derived from the reference case modeling assumptions which defined the following:

- Site-specific closure system features and processes affecting contaminant migration
- Parameters that describe these features and processes
- Site-specific reference parameter values.

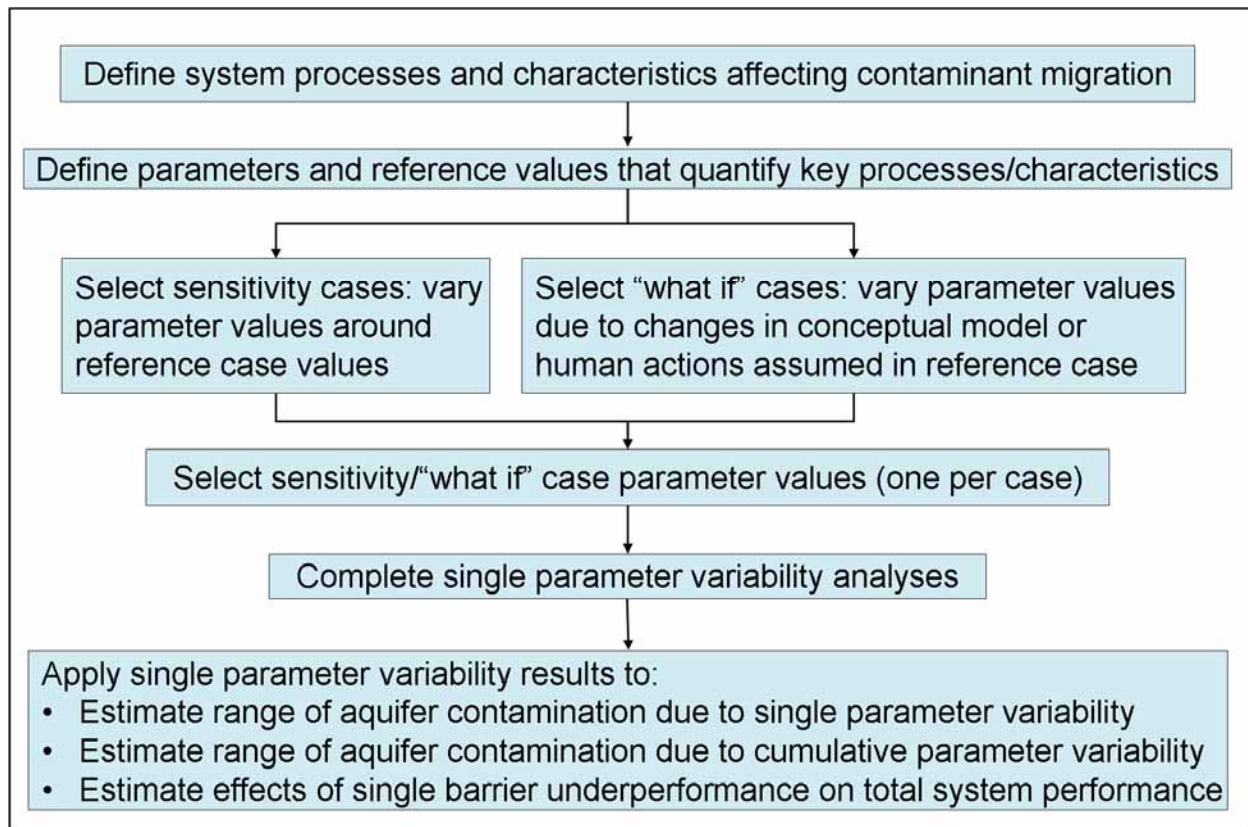


Fig. 3. Methodology used in the sensitivity/‘what-if’ analysis.

Critical features and processes included site-specific natural system characteristics such as low infiltration rates, a thick vadose zone, the current distribution of contaminants within the vadose zone, and engineered components including the surface barrier, and the grouted tank structure. Significant processes included unsaturated flow in the vadose zone, contaminant-specific geochemical reactivity with the subsurface sediments, and mixing of contaminated vadose zone water with clean unconfined aquifer

water. Parameters describing these features and processes fell into three broad categories: recharge rates, waste characteristics (e.g., inventory and release mechanisms), and geohydrologic properties of the vadose zone and unconfined aquifer.

To proceed with the sensitivity analysis, two types of cases were distinguished, sensitivity cases and “what if” cases. The sensitivity cases assumed all primary reference case assumptions were unchanged and simply varied parameter values with respect to reference case values. In the “what if” cases, alteration of postulated reference case assumptions affecting contaminant migration was assumed (e.g., different physical or chemical processes or human actions that altered system conditions). To represent these different assumptions, different parameter estimates were considered. In these analyses, only contaminant migration to the WMA fenceline and only migration from waste sources in WMAs C and S-SX were considered. Also, sensitivity analysis results were only generated for constituents that reached the unconfined aquifer at non-negligible levels in reference case analyses.

Each sensitivity and “what if” case usually assumed a change in one parameter value and, in some cases, the substitution or addition of a parameter relative to the reference case. By grouping cases that considered value changes to the same parameter for specific contaminants present in specific waste sources, a value range for a given parameter was generally defined by at least three values, a reference case value, a minimum value, and a maximum value. For example, the reference case operational period recharge rate was 100 mm/yr and two sensitivity cases were generated that assumed operational period recharge rates of 40 and 140 mm/yr to define the minimum and maximum values, respectively. Then, by completing a contaminant migration analysis that estimated the groundwater impacts for each sensitivity/“what if” case and associated parameter value change within each parameter group, a range of groundwater contamination levels was generated in response to parameter value change.

Changes in groundwater contamination levels at the WMA fenceline in response to parameter value changes were calculated and, for ease of comparison, expressed as ratios of the peak groundwater contamination levels from the sensitivity case to peak levels estimated in the reference case. These ratios, referred to as peak ratios, indicated the sensitivity of contaminant migration to variability of a particular parameter because each ratio was associated with specific single parameter value changes (e.g., single parameter variability). Estimated increases or decreases in groundwater contamination levels were indicated by peak ratio values greater or less than unity, respectively. Relatively larger or smaller ratios for given parameter ranges indicated greater sensitivity of groundwater contaminant levels to variability of the feature or process represented by the parameter. These ratios also indicated uncertainty around the reference case estimate with respect to variability of a particular parameter. That is, the plausible range of estimated groundwater contamination levels was constrained by the plausible range of site-specific parameter values determined from site-specific data. Figure 4 provides the results of this analysis for the sensitivity of groundwater contamination levels of Tc-99 initially present in past leak inventories to variations in recharge for past leak inventories. The barrier recharge rate after the year 2032 has no impact on the Tc-99 concentration at the fenceline because the major fraction of the initial inventory reaches the groundwater before the barrier has been placed over the WMA.

The results of the single parameter variability analyses were then used for two additional applications, a cumulative variability analysis and a barrier underperformance analysis. The cumulative variability analysis estimated the effects of multiple and simultaneous parameter value changes on groundwater contamination levels for given contaminant/waste type combinations. Because the effects of variability in all significant parameters were considered to occur simultaneously, a cumulative uncertainty in peak groundwater contamination levels with respect to the reference case estimates are provided.

The barrier underperformance analysis estimated the effects of single or multiple barrier underperformances (i.e., the surface barrier, the grouted tank structure, and/or the vadose zone) on total system performance with respect to reference case assumptions. 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.

Based on the sensitivity analysis, the 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) [13] and corroborates the estimate of variability provided here.

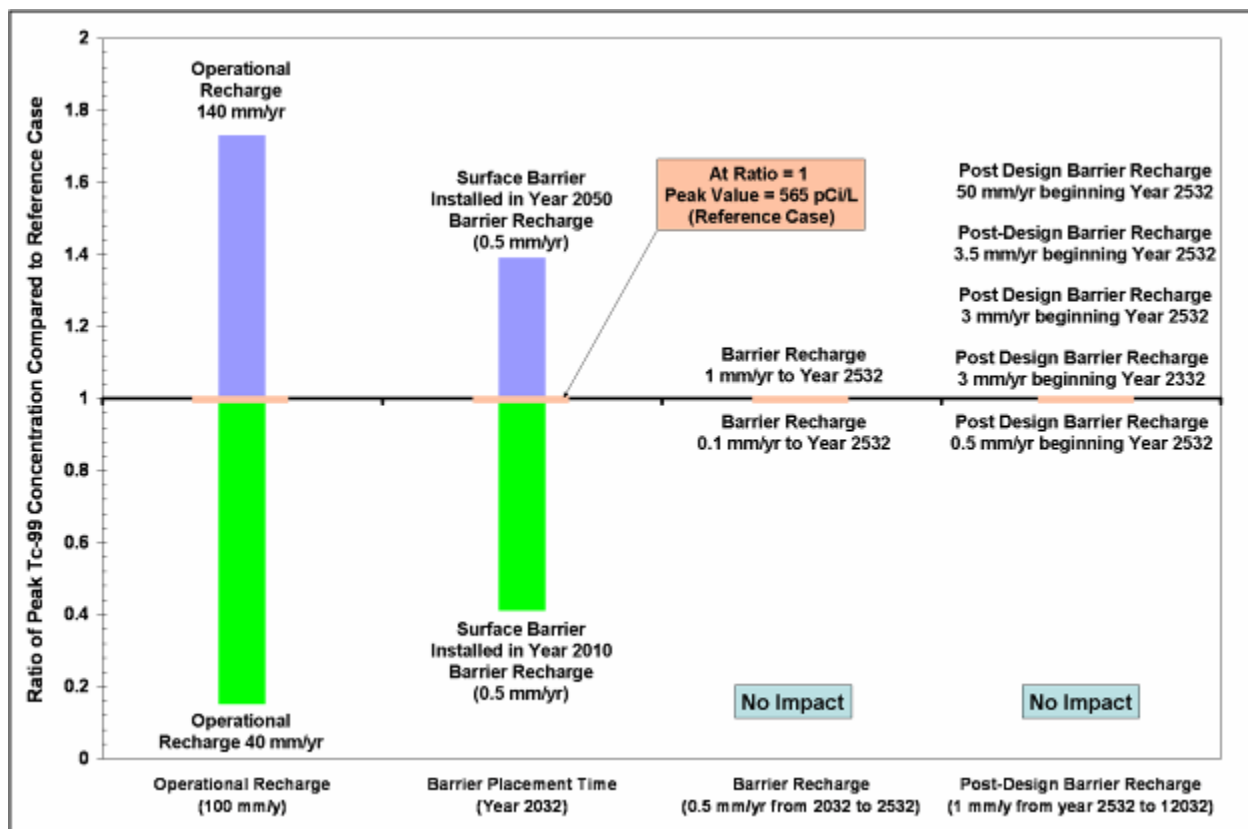


Fig. 4. Sensitivity of peak Tc-99 to variations in recharge assumptions (WMA C) from past leak inventory.

CONCLUSIONS

The results of the SST PA support the following: (1) retrieval of tank waste and grouting of the remaining residuals; (2) institution of interim measures to reduce the impacts to the groundwater from past tank farm releases (3) 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 Tc-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 [14]; Knepp 2002a [15], 2002b [16]) 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 [10] 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.

DOE will continue to use an iterative approach to update the SST PA; updates will be based on significant changes in the approach to closure, conceptual model, or source characteristics used in the latest 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 as DOE moves toward closure of the waste management areas.

REFERENCES

1. DOE-ORP, *Initial Single-Shell Tank System Performance Assessment for the Hanford Site*, DOE/ORP-2005-01 Rev. 0, U.S. Department of Energy, Office of River Protection, Richland, Washington (2006).
2. Ecology, EPA, and DOE, *Hanford Federal Facility Agreement and Consent Order*, as amended, Washington State Department of Ecology, Olympia, Washington, U.S. Environmental Protection Agency, and U.S. Department of Energy, Washington D.C. (1989).
3. A. N. Naiknimbalkar, *Waste Tank Summary Report for Month Ending June 30, 2006*, HNF-EP-0182, Rev. 219, CH2M HILL Hanford Group, Inc., Richland, Washington (2006).
4. "Hazardous Waste Management Act," RCW 70.105, *Revised Code of Washington*, as amended.
5. *Atomic Energy Act of 1954*, 42 USC 2011 et seq.
6. *National Environmental Policy Act of 1969*, 42 USC 4321 et seq.
7. DOE O 435.1., *Radioactive Waste Management*, U.S. Department of Energy, Washington, D.C (2001).

8. *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*, 42 USC 9601 et seq.
9. DOE M 435.1-1., *Radioactive Waste Management Manual*, U.S. Department of Energy, Washington, D.C (2001).
10. *Resource Conservation and Recovery Act of 1976*, 42 USC 6901 et seq.
11. WAC 173-303, "Dangerous Waste Regulations," *Washington Administrative Code*, as amended.
12. Ecology, *Dangerous Waste Portion of the Resource Conservation and Recovery Act Permit for the Treatment, Storage, and Disposal of Dangerous Waste*, Permit No. WA7890008967, Rev. 7, Washington State Department of Ecology, Olympia, Washington (2001).
13. DOE-RL *Retrieval Performance Evaluation Methodology for the AX Tank Farm*, DOE/RL-98-72, U.S. Department of Energy, Richland Operations Office, Richland, Washington (1999).
14. D.A. Myers, *Field Investigation Report for Waste Management Areas T and TX-TY*, RPP-23752, Rev. 0-A, CH2M HILL Hanford Group, Inc., Richland, Washington (2005).
15. A.J. Knepp, *Field Investigation Report for Waste Management Area S-SX*, RPP-7884, Rev. 0, CH2M Hill Hanford Group, Inc., Richland, Washington (2002a).
16. A.J. Knepp, *Field Investigation Report for Waste Management Area B-BX-BY*, RPP-10098, Rev. 0, CH2M Hill Hanford Group, Inc., Richland, Washington (2002b).