Proceedings of the 1994 Winter Simulation Conference
ed. J. D. Tew, S. Manivannan, D. A. Sadowski, and A. F. Seila

HANFORD TANK WASTE REMEDIATION SYSTEM OVERVIEW: A DYNAMIC SIMULATION MODEL

K.D. Boomer

Westinghouse Hanford Company
MS H5-49, P.O. Box 1970,
Richland, WA 99352, U.S.A.

R.S. Wittman

Westinghouse Hanford Company
MS B1-59, P.O. Box 1970,
Richland, WA 99352, U.S.A.

M.A. Duffy

Battelle Memorial Institute
505 King Avenue
Columbus, OH 43201-2693, U.S.A.

C.M. Watson

Systems Modeling Corporation
504 Beaver Street,
Sewickley, PA 15143, U.S.A.

ABSTRACT

A dynamic simulation model for the Hanford Tank Waste Remediation System top-level functions has been developed. The model simulates the expected activity occurring between the 177 underground waste storage tanks during the waste remediation campaign period of about 30 years. An animation is also developed that shows the material flow of tank farm waste from storage tank to treated waste form.

1 MOTIVATION

The primary mission of the Hanford Site is waste clean-up and Site remediation. A major aspect of the remediation is long-term protection of the biosphere from hazardous waste stored in 177 underground tanks at Hanford's 200 Area plateau. The hazardous portion primarily consists of longer-lived fission products from reactor fuel processed during various separations campaigns over the past 40 years. Remediation involves retrieving, treating, and immobilizing the waste in a highly stable glass material for safe disposal in an isolated underground location. The activities and functions necessary to accomplish tank waste remediation in a timely/cost-contained manner are being developed to support the Tank Waste Remediation System (TWRS 1993) Program at Hanford.

Given the complexity of, and interaction between, Site activities, the relative importance of system function assumptions can be hidden. A dynamic simulation model offers a computational framework for which sensitivity studies on the assumptions become tractable. Information on potential throughput bottle-necks and required storage capacities can also bottle-necks and required storage capacities can also be computed.

Additionally, the TWRS effort has brought together a diverse group of specialists from broadly varying fields – each with their own focus and specialized language. The animation features of simulation models can provide direct visual insight on tank waste clean-up activities and associated time scales. Such animated presentations can convey information at varying levels to a broad audience – ideally they can contribute to the public awareness and involvement aspect of the Hanford Site mission.

Even as the TWRS functions become defined there remain competing technical alternatives to accomplish the goal. Studies have been made (ANC 1975) of a wide spectrum of waste processing technologies subject to scheduling and financial constraints. A recent study by Boomer *et al.* (1993) indicates that the most efficient and fiscally sound way to approach the problem is to concentrate resources on the treatment and disposal technology. This allows a reduced dependency on extensive pretreatment technologies which could involve extensive development costs and a prolonged clean-up schedule. The results of the technical options studies along with the recent Tri-Party agreement (TPA, Washington 1994) negotiations offer a technical base-line which more narrowly brackets the processes to be employed.

Therefore, the need and opportunity to simulate the expected top-level functions for tank farm waste remediation exists now more than ever before. This work represents a first step to formally simulate and animate the dynamics of TWRS tank farm operations.

2 SIMULATION-ANIMATION PRELIMINARIES

The model was developed using the SIMAN (1994) discrete event simulation language to drive an animation within the ARENA software development window. The SIMAN language is coded in two separate files – the *experiment* file and the *model* file. The experiment file contains the variable and logic-element declarations with their default (if any) values. The model file contains the logic structures directing the flow of abstract "entities", which control the occurrence of physical events having associated time durations.

Most applications of SIMAN are found in the manufacturing field where discrete operations are performed on discrete parts or pieces moving through a complex assembly system. Such a system is accurately represented by discrete changes in the processing state. Within TWRS, both discrete and continuous processes occur. For example, the continuous flow of material between tanks is formalized as a number of discrete transfer events. If conditions permit, a transfer event occurs and the associated delay time is logged. (Notice that it is the occurrence of events that control the passage of time rather than time controlling the flow of events.) Each delay time (as well as the total number of delays) depends on the transfer rate and the amount of material specified in the transfer event. A continuous process is approximated as the amount of material specified in each transfer event becomes small enough. Of course this "small enough" amount varies with the characteristic time scale of the process.

While the treatment of continuous processes in certain cases can be tedious, the general logic control features of SIMAN make it a powerful tool for modeling the process logic aspects of TWRS. This event-based formalism forces model development to precisely define events and their elemental logical links.

3 MODEL ORGANIZATION

The goal of the modeling effort is to track tank waste volume from storage tank to final treated waste form. Tracking involves numerically simulating the intermediate processes, which change and transfer waste. Therefore, the primary dynamic variables are the waste volumes contained in the 177 underground storage tanks. The primary processes which are modeled and thereby control the dynamics are the following:

1) Concentration of dilute liquid waste in the double-shell tanks (DST) to provide space for storage and processing,
2) Retrieval of the waste from remaining DSTs and from single-shell tanks (SST),
3) Separation of liquid and solid portions of retrieved waste,
4) Pretreat liquid portion to remove higher activity aqueous components,
5) Vitrification of the solids and separated aqueous components, and
6) Concentration and vitrification of the pretreated liquid portion in low-level waste LLW glass facility.

The interrelationships of the various processing activities are shown schematically in Figure 1. The simulation model estimates flow rates, capacities, and interdependencies associated with the boxes in Figure 1 to estimate the time dependence of waste moving through the system.

The model is organized such that storage capacities are fixed and preassigned rather than floating. Therefore, the delays caused by throughput bottle-necks are computed by the model and can be displayed in the animation. There is no strong advantage to this organization for performing sensitivity studies; but, it is necessary to drive an animated representation of the simulation.

General tank farm information used by the model is contained in three text files, which are read during program execution. Initially, all waste volumes are set by two of these data files to the current DST and SST waste inventory reported by Hanlon (1994).

For the SSTs, the third data file contains a retrieval schedule which directs the removal of waste from the tanks to designated transfer annexes (Fig?). The schedule is based on a modification of the retrieval sequence outlined by Williams (1993) to reflect the recent TPA goals. Retrieval is one of the first activities to occur and continues well into the simulation when other activities are concurrently being performed. Even though a relatively fast retrieval rate is conceivable, transfers are constrained by the available volume in designated target tanks and by other processing activities involving those tanks.

Because the model accounts for this type of intertank dependency, the retrieval schedule is best understood as tentative – the actual retrieval date is tentative, yet the retrieval sequence is preserved. As already mentioned continued retrieval of the SST wastes is postponed until a certain number of DSTs become available for storage and for performing the in-tank wash. Additionally, dependence on the operation of new (to-be-built) facilities coming on-line will also affect the actual time of retrieval during the simulation. Presently, the simulation assumes the existence of transfer annexes, cross-site transfer line, 6 new 100 kgal and 6 new 1 Mgal DSTs. The assumptions are consistent with the TPA milestones, because the simulation starts in the year 1998. The time at which particular resources and facilities become available can be easily varied in a sensitivity study.

partial transfer from a single tank to multiple tanks. In addition, the dependency itself is dynamic because processing is allowed to begin before all DST wastes are retrieved.

The output volume from sludge wash is contained in 8 DSTs. Feed for high-level waste (HLW) vitrification is taken from tanks 101-102AZ, and two of the new DSTs. Feed for pretreatment of the liquid waste is taken from 105-106AP and two of the new DSTs. Although pretreatment will remove a major

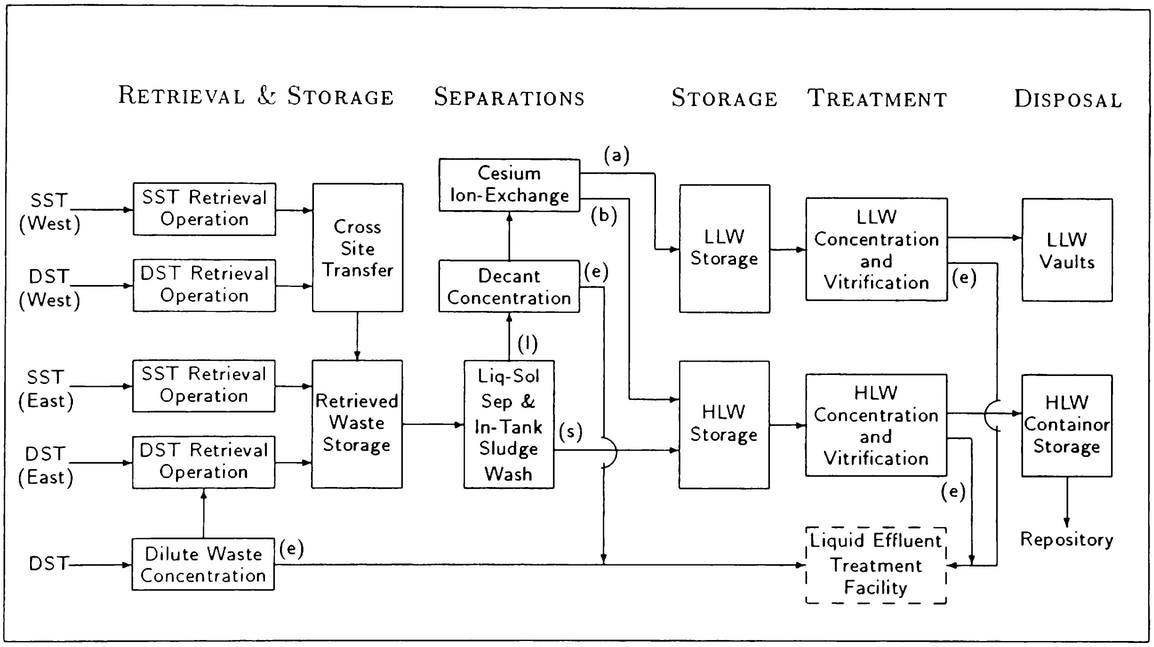

Figure 1: Top-level Processing Activities

On the 200 East side, waste received from the B and C Farm annexes is stored directly in the 5 AN farm DSTs and in the 2 AY farm DSTs, with the latter serving as feed for the in-tank wash. On the 200 West side, waste received from T, U, and S Farm annexes is stored in the 3 SY Farm DSTs, the 2 new 1 Mgal capacity DSTs, and in 4 of the 100 kgal WSSF tanks. When one or more of the 1 Mgal DSTs are full, a cross-site transfer to AN Farm is attempted. Cross-site transfer is allowed, if DST waste retrieval has been completed and if space in AN or AY Farm is available. As waste slurry is transferred from the transfer annexes to the DST system, in-tank washing of dispersed solids begins becomes the rate limiting process in the simulation.

The most complex intertank dependence in the model occurs within the in-tank sludge wash process. This process allows the possibility of requests for transfers from multiple tanks to a single tank and/or

part of the activity from the liquid waste, only a small amount of material is removed – numerically the volume change is insignificant. Nearly the entire volume entering pretreatment will exit the pretreatment process as feed for low-level waste (LLW) vitrification.

Because most of the existing storage and processing tanks are located in 200 East Area, pretreatment and vitrification operations are also located in 200 East. Many other considerations will be examined before siting of facilities is finalized.

4 SIMULATION MODEL ASSUMPTIONS

Retrieval (SST)

The retrieval of each of 149 single shell tanks is considered. While a wide range of wastes are contained in the tanks, an average composition is assumed. Hydraulic retrieval (or sluicing) is assumed in each case. In the simulation, this is represented by assigning 5

Transfer Annexes (normally with two 50 kgal tanks) to the 12 single shell tank farms. The U Farm annex is an exception. In this case a proposed waste sampling and storage facility (WSSF) functions as transfer annex to both U Farm and to SY (DST) Farm. WSSF tanks that are not used for transfers are assumed to be available to store retrieved waste prior to cross-site transfer. Table 1 shows the grouping of SST farms with the five annexes. A given annex services only one SST at a time from it's assigned farms. As the first 50 kgal annex tank is filled, a dilution Factor of ≈ 3.5 (based on 5 M Na) is applied. This waste is then transferred to the second 50 kgal tank where it awaits transfer to retrieved waste storage. It is assumed that 48 hours is needed to accumulate 50 kgal of diluted waste. For 200 West Area, waste is stored prior to cross site transfer primarily in two new 1 Mgal DSTs and in previously retrieved SY Farm tanks. When 1 Mgal or more of retrieved waste is stored, a cross-site transfer to AN Farm is sought. Transfer to 200 East is made at 200 gpm when one or more targeted AN Farm DSTs become available. For 200 East Area, waste is transferred from the annex directly to AN Farm or to AY Farm. Once retrieved, the two 1 Mgal AY Farm tanks are used to hold feed for liquid-solid separation and sludge washing.

The TPA prescribes that retrieval activities begin in 1998 with SST retrieval completed by 2018. The actual retrieval order will be defined by blending studies and safety considerations.

Table 1. Assignment of Retrieval Annexes

Annex Number	Tank Farms	Annex Parameters
1	A,AX,C	2 tanks × 50 kgal
2	B,BX,BY	2 tanks × 50 kgal
3	T,TX,TY	2 tanks × 50 kgal
4	U,*SY*	6 tanks × 100 kgal
5	S,SX	2 tanks × 50 kgal

Retrieval (DST)
Dilute waste is concentrated to provide space for storage and processing. It is assumed that it takes about 30 days to concentrate 1 Mgal of dilute waste by a factor of ≈ 3.5. Double shell tanks 101-108AP, 101-102AW, 101-102AY, 101-102AZ, 101-102AN and 105-106AN waste is concentrated then sent to tanks 101-102AN and 105-106AN. This occurs as soon as possible (no TPA date is specified) in the simulation to free-up space in AP Farm for settle/decant and storage activities.

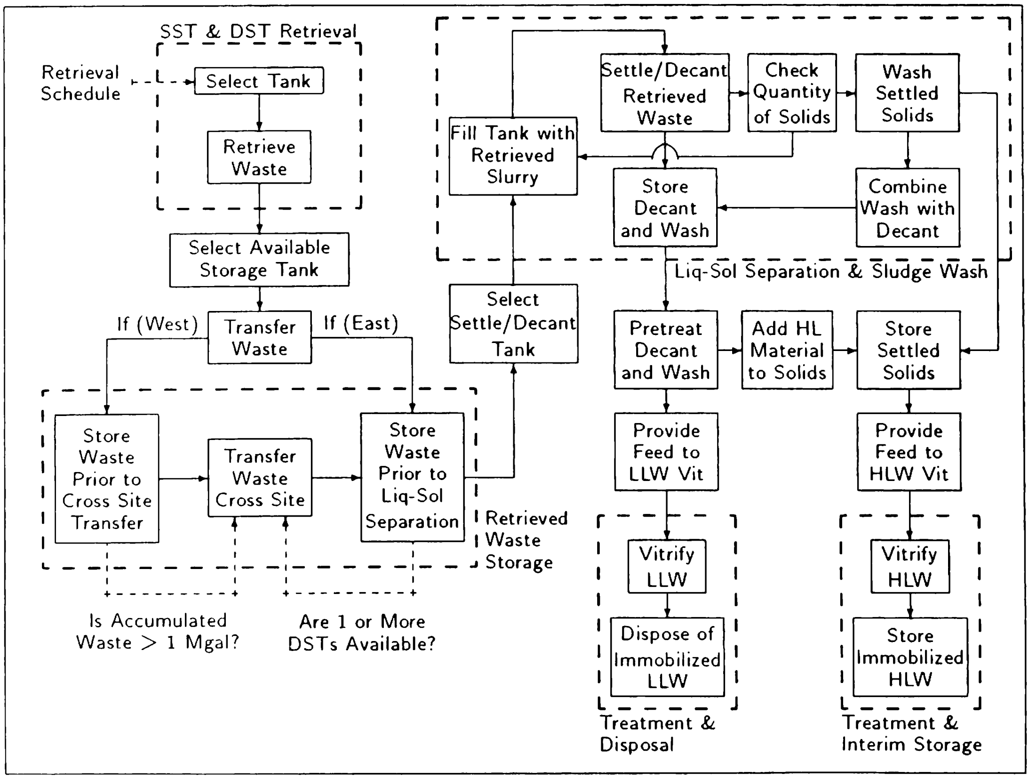

Figure 2: Waste Flow Overview

Initially, only one pair of settle/decant tanks function (107-108AP). The remaining DSTs are retrieved with a 1:1 dilution ratio. A total of four pairs of (first and second stage) settle/decant tanks operate with the full retrieval of AW Farm.

Liquid-Solid Separation/Sludge Washing
To reduce the fraction of waste going to HLW vitrification, multitank settle/decant of retrieved waste slurry and sludge washing of dispersed solids is assumed. The simulation model assumes that *all* liquid-solid separation is performed within a settle/decant multitank system. Furthermore, it is assumed that all accumulated solids are leached through sludge washing.

tioned 107AP becomes available early in the simulation; transfers to the other first stage settle/decant tanks will follow based on their retrieval and on availability of retrieved waste feed. It is assumed a three month settling period will yield about 40-50 kgal (on average) of settled solids in each of the four first stage settle/decant tanks. Including tank transfers and washes, each first stage settle/decant tank will perform a settle/decant operation about three times a year. It is assumed that the transfer of 1 Mgal can take about 10 days. After the 3 month settling period, the supernatant is decanted to one of four second stage settle/decant clarification tanks for a

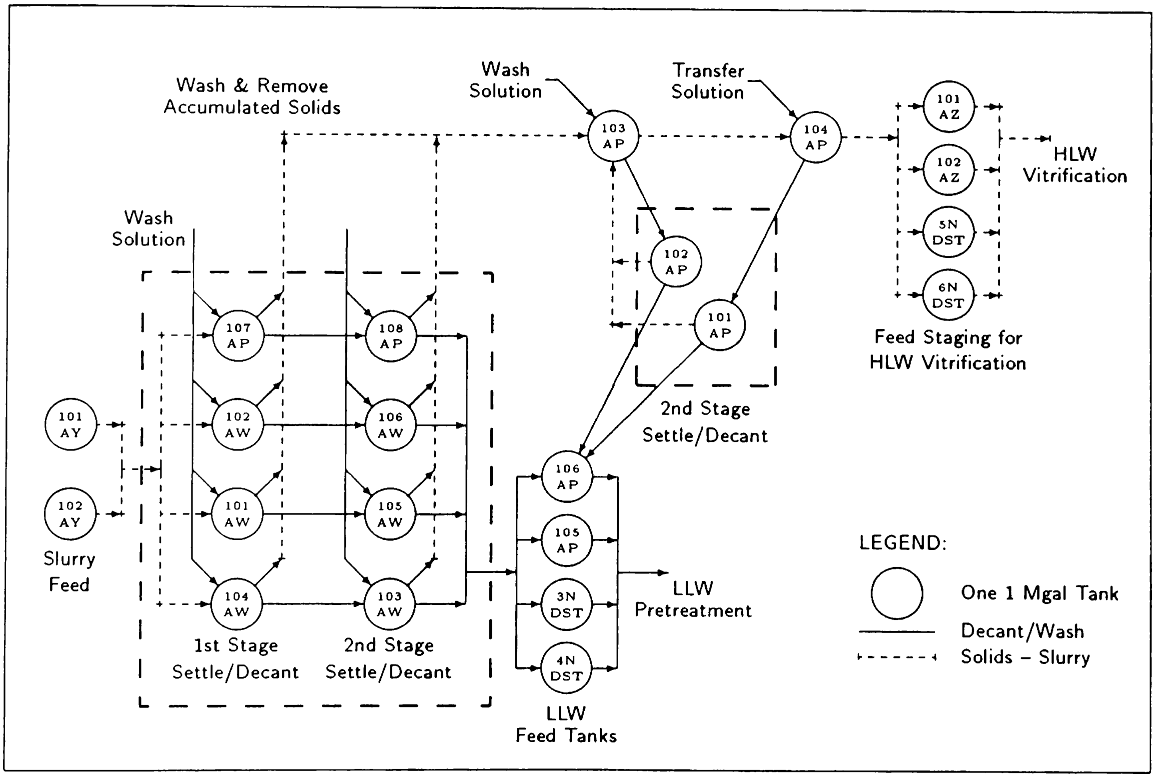

Figure 3: In-Tank Sludge Wash Operation (Boldt, Johnson & Kupfer, 1993)

The first wash effectively occurs during retrieval as insoluble solids are mobilized and dispersed through the retrieved waste slurry. Retrieved waste is stored in AN and AY tank farms, where AY Farm supplies feed to settle/decant tanks. Figure 3 summarizes the in-tank sludge wash operation and shows the assignment of specific tanks used in the model. The settle/decant process begins after retrieved waste slurry is transferred from an AY Farm DST to one of four first stage settle/decant tanks (in the model 107AP, 101-102AW and 104AW are designated). As men-

second 3 month settling period. Meanwhile, the supernatant from the first stage settle/decant tanks is replaced with more retrieved waste slurry (from AY Farm) for the next three month settling period.

After a first stage settle/decant tank accumulates about 160 kgal of settled solids (about once a year), 480 kgal of wash solution is added to the tank to remobilize the solids for a second wash. After a brief period of washing, the slurry is transferred to the first (of the two 103-104AP) washed solids settle/decant tank(s). Another 3 month period is allowed for settling of the 160 kgal of solids. As before, the supernatant is decanted – this time to an additional (fifth) second stage settle/decant clarification tank (101AP) for a 3 month settling period.

A third wash is performed on the 160 kgal of settled solids with the addition of another 480 kgal of wash solution. The washed solids are transferred to the second washed solids settle/decant tank (104AP). Again a 3 month period is allowed for settling of the 160 kgal of solids. The supernatant from this tank is decanted to the last (sixth) second stage settle/decant clarification tank (102AP) for a 3 month settling period. After each of their 3 month settling periods, the clarified supernatants from each corresponding second stage settle/decant clarification tanks are decanted to a four tank system to provide feed to LLW pretreatment. Tanks 105-106AP and two new DSTs are used for this purpose. The solids accumulation rate in each of the six second stage settle/decant tanks (103,105-106AW, 101-102,108AP) will be small. Small sources result from both routine (remnant) solids carry-over dispersed in the decant and from unplanned operator control deviations during decant transfer. They are not represented in the model.

Additionally, the solids in the second (of two) washed solids settle/decant tank(s) are mobilized and transferred to a four tank system for HLW feed staging. The model assumes that the two AZ Farm tanks and two new 1 Mgal DSTs perform this function.

It is assumed that about 80 wt% of the sludge is solubilized as a result of all the wash steps.

LLW Storage

As mentioned, 105-106AP and two new DSTs are assigned to store decanted liquid and to provide feed to LLW pretreatment.

HLW Storage

Tanks 101-102AZ and two new DSTs are used to store washed solids (25% in H_2O) and to provide feed to HLW vitrification. Additionally, the animation depicts the addition of separated cesium from LLW pretreatment to these tanks. While the activity addition to the tanks is significant, the volume addition is proportionally small and is not tracked in the simulation.

Pretreatment/Cs Removal

Decant from sludge wash is concentrated and separated at Rate of 60 gpm. The low-activity portion is transferred to LLW Vitrification. Its assumed that the high-activity portion is combined with the washed solids for HLW Vitrification.

LLW Vitrification

Presently, it is assumed that no bottle-neck occurs here or that the rate of LLW vitrification and of associated activities is sufficient to match pretreatment processing rates. Waste concentration based on Na content of decant (4-5 M Na) with treated volume based on 25% oxide loading and 74% glass in surrounding matrix. For animation purposes the disposal unit is assumed to be a 5400 m^3 vault.

HLW Vitrification

The HLW Vitrification plant is on line 12/2009. The average throughput is set at 1,240 MT/year. It is also assumed that a 45% waste loading in glass is achieved.

General

The baseline case assumes that overall material throughput is consistent with the integrated flowsheet (Orme, 1994) predictions for enhanced in-tank sludge wash with 40-45 wt% waste loading in HLW glass and 25 wt% waste loading in LLW glass. Currently, the baseline model assumes that no existing DSTs are removed from service during the simulation. The potential for DST (and other facility) downtimes will be added to future versions of the model. The model presently considers the existing tank waste; no additional process generated waste enters the system during the simulation. Condensate from evaporation is not tracked in the model. Work is in progress to include treatment and tracking of condensate water, because the timing of the simulation is sensitive to overall water economy adjustments controlled by recycle efficiency (Zimmerman, 1994).

5 RESULTS

So far the major result is an operational model that yields a plausible simulation/animation of the baseline strategy. A limited sensitivity study is in progress. Further results will include a discussion of dependencies between various waste transfer and processing events. Time dependent information on stored waste volume and on retrieval and treatment progress will be provided. Overall rate limiting activities will be identified. Utilization of modeled resources such as cross-site transfer will be reported.

REFERENCES

ANC, 1975. *High-Level Waste Management Technology Development Program*, Applied Nucleonics Corporation for Atlantic Richfield Hanford Company, Richland, Washington.

Boomer, K.D., S.K. Baker, A.L. Boldt, J.D. Galbraith, J.S. Garfield, C.E. Golberg, B.A. Higley, L.J. Johnson, M.J. Kupfer, R.M. Marusich, R.J. Parazin, A.N. Praga, G.W. Reddick, E.J. Slaathaug, L.M. Swanson, T.L. Waldo and C.E. Worcester. 1993. *Tank Waste Technical Options Report*, WHC-EP-0616, Rev. 0.

Boldt, A.L, and L.J. Johnson. 1994. Private communication.

Hanlon, B.M., 1994. *Tank Farm Surveillance and Waste Status Summary Report for July 1993*, WHC-EP-0182-64, November 1993.

Kupfer, M.J., J.D. Galbraith, C.E. Golberg and A.F. Manuel. 1993. *Increased Capacity HWVP - TWRS Integrated Evaluation*, WHC Memo from Waste Management Engineering, 22170-93-033.

Orme, R.M., 1994. *et al.*, *TWRS Process Flowsheet*, WHC-SD-WM-TI-613.

SIMAN V and ARENA v1.1, 1994. Discrete event simulation software developed and maintained by Systems Modeling Corporation.

TWRS Systems Engineering. 1993., *Tank Waste Remediation System Functions and Requirements*, DOE/RL-92-60 Rev. 1 (Draft).

Washington State Department of Ecology, United States Environmental Protection Agency and United States Department of Energy. 1994. *Hanford Federal Agreement and Consent Order.*

Williams, L.S., 1993. *Near-Term DST/SST Retrieval Sequence (TPA Compliance Case)*, WHC-SD-WM-ER-193, Rev. 0.

Zimmerman, B.D., and Tang Chiao. 1994. Results communicated in simulation model presentation.

AUTHOR BIOGRAPHIES

KAYLE D. BOOMER is a Principal Engineer with Westinghouse Hanford Company.

RICHARD S. WITTMAN is a Senior Scientist with Westinghouse Hanford Company.

MICHAEL A. DUFFY is a Fellow Engineer with Battelle Memorial Institute.

CHRISTINE M. WATSON is a Senior Consultant with Systems Modeling Corporation.