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Preliminary Performance Assessment Strategy for Single-Shell Tank Waste Disposal

Prepared for the U.S. Department of Energy
Office of Environmental Restoration and
Waste Management

Westinghouse
Hanford Company Richland, Washington

Hanford Operations and Engineering Contractor for the
U.S. Department of Energy under Contract DE-AC06-87RL10930

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J. C. Sonnichsen, Jr.

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PRELIMINARY PERFORMANCE ASSESSMENT STRATEGY FOR SINGLE-SHELL TANK WASTE DISPOSAL

J. C. Sonnichsen, Jr.

ABSTRACT

The disposal of the waste stored in single-shell tanks at the Hanford Site is recognized as a major environmental concern. A comprehensive program has been initiated to evaluate the various alternatives available for disposal of these wastes. These wastes will be disposed of in a manner consistent with applicable laws and regulations.

Long-term waste isolation is one measure of performance that will be used for purposes of selection. The performance of each disposal alternative will be simulated using numerical models. Contained herein is a discussion of the strategy that has and continues to evolve to establish a general analytical framework to evaluate this performance. This general framework will be used to construct individual models of each waste disposal alternative selected for purposes of evaluation. The strategy includes the following:

- *Use of an existing suite of computer-encoded models*

- *Development of a better understanding of the movement of contaminants through the unsaturated sediments on the Hanford Site*

- *Emphasis on the collection and use of characterization data to quantify, calibrate, and test engineered subsystem and natural subsystem models*

- *An iterative process whereby subsequent analysis builds on previous results and computational experience.*

An implementation plan and a summary of candidate models (computer encoded models) are included.

EXECUTIVE SUMMARY

The disposal of radioactive waste containing both nuclear and chemical constituents stored in single-shell tanks at the Hanford Site represents a major environmental concern. Tank leaks have been recognized as a potential threat to human health and the environment since the 1950's. Beginning in the 1960's, monitoring wells have been installed as needed to trace the migration of unplanned releases (leaked liquid) through the unsaturated sediments that lie between the tanks and the groundwater table.

A comprehensive program to dispose of these wastes in compliance with applicable laws and regulations has been initiated. The U.S. Department of Energy has established a goal to dispose of the radioactive and hazardous waste at the Hanford Site over the next 30 years. This goal includes the disposal of single-shell tank waste. It is recognized that a level of risk is associated with each disposal alternative. This risk results from the existing storage, handling, processing, and disposal of these wastes. To assess this multi-faceted problem, a systems approach will be used to define characterization needs (both waste inventory and geohydrologic) and to evaluate the various disposal alternatives. The goal is to provide sufficient characterization data and to develop selected concepts in sufficient detail to perform a comparative evaluation.

Consistent with this goal, an analytical framework will be developed and applied as appropriate to aid the decision making process. Initially,

generalized models (computer codes and data) will be used for purposes of screening. During this phase, models will be used to evaluate the relative performance of the various waste disposal alternatives. As the list of disposal alternatives is reduced and more characterization information becomes available, the level of analysis will become more specific and detailed.

From a modeling perspective, the goal is to develop an analytical framework that will be sufficiently robust to allow for consideration of various disposal alternatives and/or combinations of alternatives (scenarios). These disposal alternatives will include the following: no action, in situ treatment of SST waste and contaminated soil, retrieval and processing of SST waste and contaminated soil, and various combinations of each (scenarios).

Selection of an appropriate disposal alternative will require consideration of regulatory and technical factors. Performance assessment is the tool that will be used to relate these regulatory and technical factors. As such, the performance assessment activity will maintain a strong interface with other waste disposal activities, which includes engineering analysis and waste characterization, geohydrologic field characterization, laboratory analysis, and regulatory analysis.

The disposal method must prevent significant adverse impact to the biosphere, protect the long-term health and safety of the general public, and maintain worker exposure to as low as reasonably achievable (ALARA). Aspects of performance and risk assessment will be used to evaluate compliance with this requirement. A set of sixteen (16) waste disposal alternatives have been defined and are currently under review as part of the systems engineering evaluation. The number of waste disposal alternatives will be reduced using appropriate scoring criteria. One of these criterion addresses the need to comply with human health, safety, and environmental considerations. The screening of waste disposal alternatives will be documented in a series of engineering studies. As planned, the performance of a reduced list of disposal alternatives will be documented in a supplemental environmental impact statement (S-EIS). This S-EIS will be made available for both public and peer review. Once the comments from these reviews have been dispositioned, a Record of Decision will be issued. This decision will be implemented in accordance with the *Hanford Federal Facility Agreement and Consent Order* (known as the Tri-Party Agreement).[1]

The *Preliminary Performance Assessment Strategy for Single-Shell Tank Waste Disposal*[2] contains a strategy and plan for development and qualification of the numerical models used for conducting performance assessments in support of single-shell tank waste disposal. These models will

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[1]Ecology, EPA, and DOE, 1990, *Hanford Federal Facility Agreement and Consent Order*, 2 vols., Washington State Department of Ecology, U.S. Environmental Protection Agency, and U.S. Department of Energy, Olympia, Washington.

[2]Sonnichsen, J. C., Jr., 1991, *Preliminary Performance Assessment Strategy for Single-Shell Tank Waste Disposal*, WHC-EP-0379, Westinghouse Hanford Company, Richland, Washington.

be used to assess the performance of the various waste disposal alternatives, providing a basis for an assessment of long-term risk. The strategy can be summarized as follows.

- An existing suite of computer-encoded numerical simulation models will be used to assess long-term waste isolation and the health risk that will result from the potential loss of containment.

- Emphasis will be placed on the collection and use of characterization data (waste tank inventory, engineered subsystem, and geohydrologic) to improve and enhance models, demonstrate model veracity, and quantify model parameters.

- Aspects of similitude will be reviewed and applied, as appropriate, to both interpret and scale experimental results on components of both the engineered and natural subsystems.

- Based on the need to support numerical simulations, field data requirements will be specified, and collection of these data (needs) will be addressed during the preparation of characterization work plans.

- An approach is envisioned whereby analyses are performed and reviewed iteratively. Subsequent analyses will build on previous experience.

The report is divided into two parts. Chapter 2.0 describes the strategy and approach that will be used to establish the analytical framework used for the purpose of predicting long-term risk associated with the various disposal alternatives. This discussion amplifies on the elements of the performance assessment strategy summarized in the previous paragraph. The discussion in Chapter 2.0 is organized in terms of the basic steps taken during the course of conducting a performance assessment. These sections include a discussion of performance goals and objectives; the development of conceptual models and use of scenarios; and the selection, status, and application of numerical models. The need to develop a better understanding of the mechanisms that control the release of contaminants from various waste matrices and quantification of the effectiveness of various engineered and natural barriers is stressed throughout these discussions.

Chapter 3.0 describes a plan that will permit development of a credible model for assessing regulatory compliance of the various waste disposal alternatives. A total of 15 tasks are identified and discussed in Chapter 3.0 and a schedule for completing these tasks is proposed.

The existing suite of numerical models from which the single-shell performance assessment model will be configured are summarized in Appendix A. Presented are a brief description; the operational status, testing, and documentation; and the data required to support the use of each model.

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LIST OF TERMS

AEA	Atomic Energy Act
ALARA	as low as reasonably achievable
ANS	American Nuclear Society
DOE	U.S. Department of Energy
Ecology	Washington State Department of Ecology
EDE	effective dose equivalent
EPA	U.S. Environmental Protection Agency
FY	fiscal year
HDW-EIS	Hanford Defense Waste-Environmental Impact Statement
HSPA	Hanford Site Performance Assessment Program
MEPAS	Multimedia Environmental Pollutant Assessment System
PDF	probability density function
PNL	Pacific Northwest Laboratory
RCRA	*Resource Conservation and Recovery Act of 1976*
RFI/CMS	RCRA facility investigation/corrective measure study
ROD	Record of Decision
S-EIS	supplemental environmental impact statement
SST	single-shell tank
Westinghouse Hanford	Westinghouse Hanford Company
WMS	Waste Management System

PRELIMINARY PERFORMANCE ASSESSMENT STRATEGY FOR SINGLE-SHELL TANK WASTE DISPOSAL

1.0 INTRODUCTION

1.1 BACKGROUND

The disposal of radioactive waste containing both nuclear and chemical constituents stored in the single-shell tanks (SST) at the Hanford Site represents a major technological challenge. For years the waste stored in these tanks has been perceived as representing a potential threat to human health and the environment. Recent issues associated with the buildup of hydrogen gas have brought additional attention to the storage of this waste.

Loss of containment resulting from tank leaks and the subsequent transport of contaminants through the vadose zone into the groundwater has long been recognized as a potential pathway that could impact human health and the environment. Beginning in the 1960's, wells were constructed to monitor the migration of contaminants into the soil column. More recently, a number of activities have been performed to lessen the environmental consequences resulting from loss of containment. During the 1960's and 1970's, a major fraction of the cesium and strontium fission products contained in these tanks was removed. Removal of these constituents reduced the heat loading on the tanks and the potential radiological loading to the soil column if containment was breached. More recently, liquid in the form of free-standing supernate or interstitial liquid has been pumped from these tanks. The bulk liquid has been pumped from approximately two-thirds of the SSTs and this form of stabilization continues.

Over the years, studies have been made of technology to remove the salt cake and sludge that will remain in the SSTs after the bulk liquid has been removed. To date, primary attention has been given to those systems that rely on the use of either a mechanical or hydraulic technology. For some concepts, systems have been proposed, conceptual designs have been prepared, and some model- and full-scale testing of components has been performed. However, this work has not been completed and, perhaps more important, retrieval, other than hydraulic sluicing, has not been demonstrated.

In summary, although considerable work has been performed to decrease the threat resulting from breach of containment, a permanent solution to the disposal of SST waste remains to be determined.

1.2 SINGLE-SHELL TANK CLEANUP MISSION

Various alternatives for the disposal of SST waste were considered in the final Hanford Defense Waste-Environmental Impact Statement (HDW-EIS) (DOE 1987). As stated in the HDW-EIS record of decision (ROD), the 'preferred alternative' that was selected for implementation at the Hanford Site included a provision to collect additional information before a decision could be made regarding the disposal of SST waste. The ROD furthermore stipulated that once this additional information was collected, a supplemental environmental impact statement (S-EIS) would be prepared.

Recently, the U.S. Department of Energy (DOE) established a goal to dispose of, over the next 30 years, the radioactive and hazardous waste that exists at the Hanford Site. This commitment is contained in the *Hanford Federal Facility Agreement and Consent Order* (Ecology et al. 1990) (known as the Tri-Party Agreement). A number of milestones that implement the cleanup and disposal of SST waste are contained in the Tri-Party Agreement and include, but are not limited to, the following commitments.

- All tanks will be stabilized by removing all pumpable liquid by September 1995.
- Bench-scale testing of a retrieval model is scheduled for September 1994 with field-scale demonstration of a prototype retrieval system scheduled for October 1997.
- The collection of two cores from each SST is scheduled to be completed by September 1998.
- Preparation of the S-EIS will be completed and a draft will be issued for public review by June 2002.
- Prepare and issue the SST closure/corrective action work plan to support completion of the *Resource Conservation and Recovery Act of 1976* (RCRA) facility investigation/corrective measure study (RFI/CMS) process for all operable units by September 2005.

Although completion of these milestones will provide a definitive measure of progress in terms of stabilization, tank waste characterization, and retrieval, completion of these tasks does not ensure that SST waste can be disposed of in a regulatory-acceptable manner. To accomplish this goal, a comprehensive program has been undertaken to support completion of the disposal work on schedule and, more importantly, to place this disposal work into the desired context (i.e., disposal of SST waste in a safe and regulatory-acceptable manner). A draft closure/corrective action work plan (DOE-RL 1989) has been prepared to outline this program. Specifically, the objective of the work plan is to develop and implement a safe, permanent means for disposing of SST waste in a manner that complies with all applicable regulations. Within this context, safety includes minimizing the threat to human health and the environment during both the operational phase and the long-term waste isolation phase following disposal. Disposal of this waste is an extremely complex problem, possessing considerable uncertainty. As a result, principles of systems analysis and aspects of performance assessment will be used to help manage this problem and aid in the decision-making process.

1.3 SCOPE AND OBJECTIVES

Performance assessment is defined as "... a systematic analysis of the potential risks posed by waste management systems to the public and environment, and a comparison of those risks to established performance objectives" (DOE 1988). It is assumed that all SST waste disposal alternatives will include the need to dispose of the low-level waste component contained within the tanks and surrounding soils at the Hanford Site. In accordance with DOE requirements (DOE 1988), a radiological performance assessment will be conducted to evaluate the risk to human health resulting from this disposal. With regard to disposal, performance objectives will be defined in terms of waste isolation requirements. Although these requirements have not been completely defined for the disposal of SST waste, interim performance objectives are defined in this document. These objectives and the basis for their selection are provided in Chapter 2.0, Section 2.2.

From a performance assessment strategy perspective, it is not possible nor is it important to delineate all of the SST waste disposal alternatives and all the analyses that will be addressed at this time. What is important is to control the work that will be performed, to ensure continuity, and to promote consistency. These attributes will be addressed through "good engineering practice," the guidelines for which are contained in Westinghouse Hanford Company (Westinghouse Hanford) procedures, i.e., standard engineering practice (WHC 1988) and software quality assurance (WHC 1989). With regard to analyses, primary emphasis will be placed on documentation and review of analyses, and the control of analyses and software as deemed appropriate. As this practice evolves, a technical baseline for performance assessment in support of SST waste disposal will emerge, and this baseline will be controlled. At the present time, the technical baseline on performance assessment of SST waste is documented in Appendix R, "Assessment of Long-Term Performance of Waste Disposal Systems," of the HDW-EIS (DOE 1987).

The primary objective of this document is to define an overall strategy and to provide a preliminary high-level plan that can serve as a guide to support development of a performance assessment capability suitable to support regulatory decisions regarding the disposal of SST waste. As such, this document will not address the specific needs, i.e., assumptions and data, used during specific analyses. This documents emphasizes the elements that need to be considered in establishing this performance assessment capability.

1.4 STATUS OF SYSTEMS ANALYSIS AND PERFORMANCE ASSESSMENT

1.4.1 Systems Analysis

Currently, system analysis techniques are used to support two SST waste disposal activities. As part of the engineering studies, aspects of systems analysis will be used to screen the various alternatives available for retrieving, processing, and selecting the final waste form. The procedure that will be used to evaluate the various alternatives available for both the in situ and the various retrieval and process scenarios will take into consideration available technology, facility and support requirements, cost and schedule, safety (including transportation of processed waste), and long-term waste isolation (performance assessment). At the present time, sixteen (16) waste disposal alternatives are under evaluation. A description of the approach has been provided in the Westinghouse Hanford *Single-Shell Tank Systems Engineering Study Work Plan* (Garfield 1990). In another study, aspects of systems analysis are being used to support tank waste characterization. A systems approach is being used to help define the order in which tanks are sampled and to define the specific analytes that will be measured in the laboratory. The approach being used to prioritize the characterization of SST waste has been documented (Droppo et al. 1991).

In both cases, minimization of risk through long-term waste isolation is a function or performance measure that provides a basis for selection. In the case of selecting a waste disposal alternative, the criterion is to prevent significant adverse impact to the biosphere while protecting long-term human health and safety. In the case of prioritizing analytes, the criterion is to identify those waste tank constituents that pose the greatest threat to both the biosphere and long-term human health and safety.

1.4.2 Performance Assessment

Performance assessment focuses on the development and application of the methods that will be used to assess long-term waste isolation, whereas systems analysis views long-term waste isolation and risk reduction as one measure of performance or attribute. Although aspects of performance assessment will be used to support systems analysis, the goal of the performance assessment program is to develop credible methods that allow an evaluation of long-term waste isolation capability of the various disposal concepts. These methods will be used to support the preparation of the S-EIS and other regulatory documents.

The method that will be used to predict long-term waste isolation will rely on the use of numerical simulation models. Emphasis will be placed on the adaptation of existing models supported through the use of extensive field characterization and laboratory studies to calibrate and qualify their use. The focus will be on developing a better understanding of the mechanisms and/or barriers that govern waste isolation. This document contains a strategy (Chapter 2.0) and plan (Chapter 3.0) that outline several areas of information:

- The various physical processes and models that are considered important to assessing long-term waste isolation and quantification of the risk resulting from contamination that may be released

- A description of the performance assessment framework that will be used to assess long-term waste isolation performance

- A discussion of the proposed work scope, consisting of various tasks that will be performed to establish the desired capability (prediction of long-term waste isolation).

1.5 ORGANIZATION OF DOCUMENT

This strategy is presented in the two chapters that follow. Chapter 2.0 describes the strategy and framework that will be used to establish the analytical capability (numerical models) that will be used to simulate long-term waste isolation. These models will be used to predict the fate of contaminants and the risk associated with the transport of these contaminants from the waste disposal system. Chapter 3.0 provides a description of the work that will be performed to implement the strategy discussed in Chapter 2.0. A work plan consisting of 15 tasks is discussed and a proposed schedule for completing this work is presented. This work plan is consistent with the SST Technology Program Plan (Klem et al. 1990).

2.0 STRATEGY

2.1 PURPOSE

The disposal method will prevent significant adverse impact to the biosphere and protect the long-term health and safety of the general public. This chapter provides a general description of a proposed methodology that will be used to assess the long-term performance of various SST waste disposal concepts. The scope of these activities addresses those features of the disposal system that will provide the 'long-term isolation' of these wastes. Emphasis will be placed on evaluating those aspects of the system, both engineered and natural, that limit the migration of contaminants. In principle, a defense in-depth strategy that relies on the use of various barriers that will operate in series to contain the waste is proposed. The proposed work will provide a scientifically based analytical capability for evaluating the long-term waste isolation potential provided by each of the waste disposal alternatives considered.

The goal is to develop a defensible, analytical capability to assess the risk to human health and the environment. Risk assessment requires that the concentration of a risk-producing substance, in this case either hazardous chemicals or radionuclides, be either estimated or measured. It is assumed that the only viable technique available for estimating, that is, predicting future concentrations of risk-producing substances in the soil and groundwater, is through the use of numerical simulation models. The physical reality associated with the scales of time (several thousand years) and space (several kilometers) preclude the use of other predictive techniques such as physical models.

These predicted concentrations form the basis for evaluating performance, which will then be compared to performance goals. Analyses will be performed on an iterative basis, with the results used to help refine functions and requirements supplied through additional engineering and characterization. Eventually, results from these analyses will be used to provide a basis for selecting the disposal system.

The general approach embodied in the strategy is to work from the general to the specific. Typically, the numerical models will trend from simple to detailed. The data and assumptions used to quantify the various model parameters will be defined for each of the analyses. It is assumed that these analyses will become more definitive and detailed with time. However, all analyses will not necessarily become more detailed. The decision regarding the appropriate level of modeling (simple vs. detailed) should be based primarily on the intended use of the results. With regard to data, the goal will be to provide data of a suitable quality to support the level of analyses desired.

Numerical models and analyses (i.e., performance assessment) will be used to calculate the long-term waste isolation potential for each of the disposal alternatives that will be evaluated. Model veracity will be established using information on contaminant migration collected in the field. Information on the characterization of existing plumes will be used to calibrate the models. Aspects of models will be validated using field and laboratory data. As will be discussed, emphasis will be placed on the collection and use of data to support model development, testing, and applications (analyses).

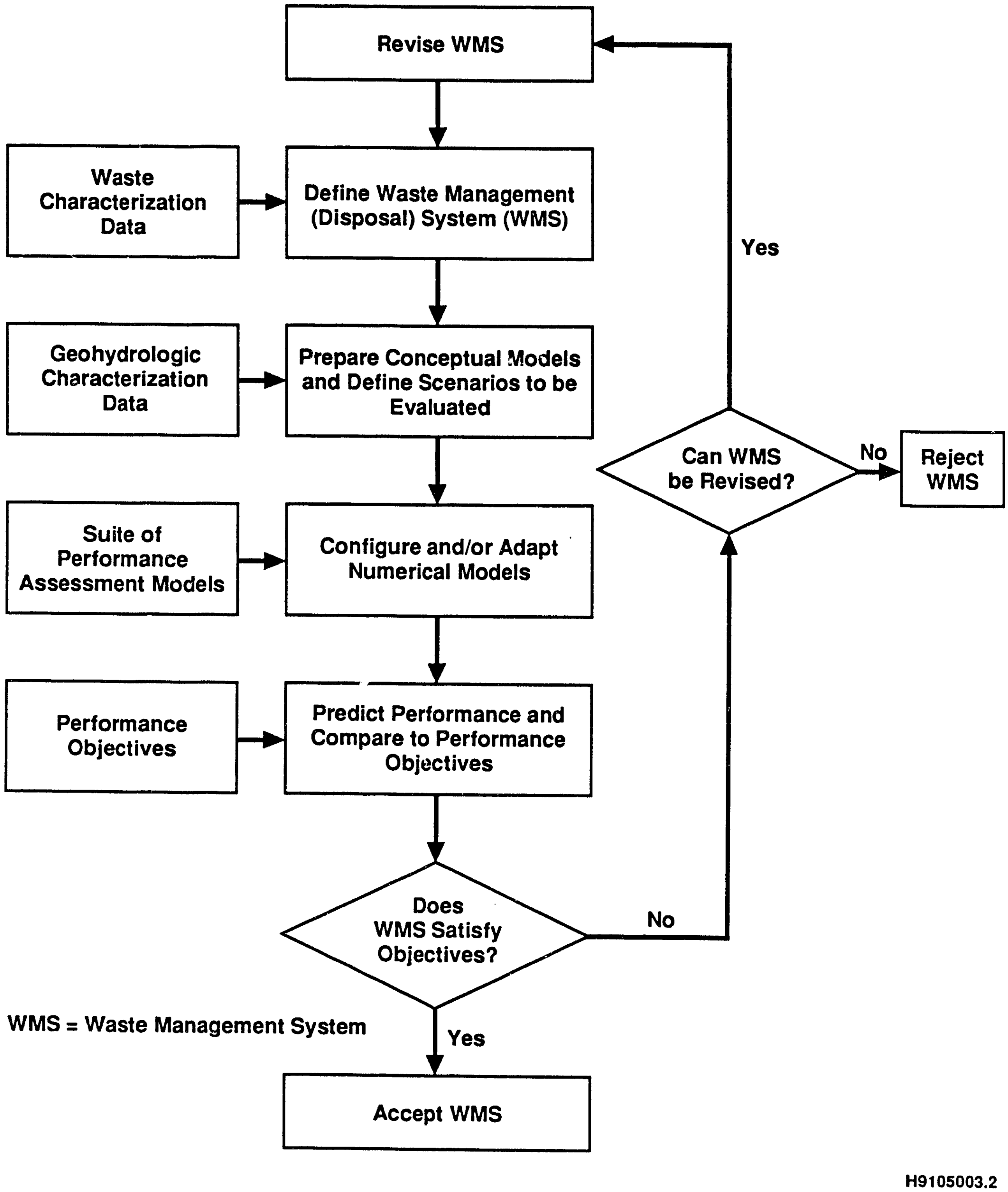
The primary steps and factors in performing a performance assessment are depicted in Figure 1. In the sections that follow, a discussion of the strategy that will be used to complete these steps and to quantify the various factors is presented. Specifically, the discussion is organized around the following topics:

- Applicable regulations and the establishment of performance objectives
- Need to predict performance for purposes of comparing performance with established performance objectives
- Development and use of conceptual models and scenarios
- Selection and application of numerical models
- Use of results.

2.2 REGULATIONS

Closure of the SSTs will be in accordance with all applicable federal and state regulations. Because the wastes in these SSTs contain both radionuclides and hazardous chemicals (mixed waste), a number of regulations will impact the final decision regarding disposal. A summary of these regulations has been prepared by Keller et al. (1989).

Figure 1. Performance Assessment Steps and Flow of Information.



The DOE and Westinghouse Hanford currently manage the SSTs as active hazardous waste storage facilities; therefore, the SSTs are subject to regulation under the RCRA. Within the State of Washington, regulation of hazardous chemicals in these facilities is administered by the Washington State Department of Ecology (Ecology). Therefore, hazardous chemicals contained in these tanks and any contaminated soil resulting from tank leaks will be closed in accordance with RCRA requirements contained in Section 3005(e). Similarly, those features associated with past operation of the tank farms (e.g., the interconnecting pipes, diversion boxes) have been classified as RCRA Past Practice Units and will be closed in accordance with Section 3004(u). The particular requirements contained in this section have not been totally identified.

The SST system been organized into six operable units; these six units include a variety of system components: the SSTs, associated piping, tank wastes, the contaminated soil, interconnecting pipes, diversion boxes, diversion stations, receiving vaults, spills, vault pits, cribs, french drains, and septic tanks. With the exception of the wastes contained inside the SSTs, each of these units will be characterized in accordance with RFI/CMS requirements.

In response to the Model Toxic Control Act (Initiative 97) passed in the 1988 State of Washington general election, Ecology has promulgated cleanup standards for hazardous chemicals (Ecology 1991). These cleanup standards may be applicable to SST waste disposal activities. Included in these regulations are provisions that allow conditional cleanup standards to be established on a case-by-case basis,provided the criteria are protective of human health and the environment and are consistent with applicable federal and state laws. Issues that will be addressed in setting these conditional cleanup standards include the relative background concentration of naturally occurring chemicals, the detection limits, and technological limitations. Additionally, a provision is included to establish conditional cleanup criteria based on an overall assessment of impact to human health and the environment [WAC 173-340-700] (Ecology 1991). The overall assessment will include maintaining worker exposure during cleanup or remediation to as low as reasonably achievable (ALARA). As such, it is assumed that the overall assessment will include both the near-term occupational risk and the long-term environmental and human health risk. An evaluation of this total risk is included as part of the engineering study (Garfield 1990). The goal is to select a waste disposal alternative that minimizes the total risk (the near-term occupational health risk plus the potential long-term health risk associated with disposal).

The radioactive constituents in the tank wastes are subject to regulation under the *Atomic Energy Act of 1954* (AEA), whose requirements are implemented through DOE orders.

The U.S. Environmental Protection Agency (EPA) has the responsibility to promulgate regulations for protecting human health and the environment. Regulations for the disposal of mixed waste have not been issued.

2.2.1 Assignment of Numerical Performance Criteria

Requirements for the disposal of mixed waste in SSTs have not been established, nor have specific quantitative criteria been explicitly defined for the closure of RCRA facilities in the State of Washington. As discussed in the previous section (2.0), promulgation of cleanup standards for hazardous chemicals will help resolve this issue. On the other hand, DOE Order 5820.2A (DOE 1988) provides a basis for establishing performance requirements for radioactive species. All future DOE low-level solid waste disposal facilities must satisfy these requirements.

Because numerical performance standards have not been established, a set of interim numerical performance criteria will be defined. The criteria include a combination of radiological and toxicological health-related requirements that are consistent but more detailed than the requirements contained in DOE Order 5820.2A (DOE 1988).

The general performance criteria are defined as follows:

- The need to protect public health and the environment in accordance with existing standards
- The need to protect the terrestrial environment and the groundwater.

To satisfy these general criteria, the following specific criteria have been defined.

- Disposal systems will be designed to ensure that the external exposure to the waste and concentrations of radioactive material released into the surface water, groundwater, soil, plants, and animals will not exceed an effective dose equivalent (EDE) of 25 millirems per year to any member of the general public (DOE 1988).*
- Disposal systems will be designed to ensure that the waste and concentration of radioactive material released into the groundwater does not exceed an EDE of 4 millirems per year to the general public resulting from the ingestion of groundwater. This dose will be based on a rate of ingestion equivalent to 2 liters per day (DOE 1988).*
- Disposal systems will be designed to ensure that an intruder (person within 100 meters of a disposal site during the period of institutional control) exposure will be limited to 100 millirems per year for continuous exposure, or 500 millirems per year for a

*These criteria will need to be apportioned if the total dose resulting from all disposal actions on the Hanford Site exceeds the EDE requirements specified.

single exposure. Institutional control is assumed to be 100 years from the time of disposal (DOE 1988).

- The concentration of hazardous chemicals released from the disposal system into the environment under nominal design conditions will not exceed the draft cleanup standards proposed by Ecology. These standards are assumed to be consistent with existing health-based standards, i.e., prescribed drinking water standards.

- Releases to the atmosphere will meet the requirements contained in 40 CFR 61 (EPA 1989).

2.2.2 Evaluation Criteria

A wide spectrum of possible disposal configurations, ranging from 'clean closure' to 'leave in place,' will be examined. For the purposes of establishing evaluation criteria, it will be assumed that the ingestion of groundwater is the primary pathway of interest. The groundrules or evaluation criteria that will be imposed to assess this pathway are defined as follows and are consistent with existing Hanford Site radiological performance assessment requirements (DOE 1990).

- For the groundwater pathway, the location of the groundwater well is assumed to be 100 meters downgradient from the edge of the disposal system.

- For the purpose of calculating radiological dose and the intake of chemicals, physiological data such as the rates of ingestion and body weights will be consistent with the data used in the GENII (Napier 1988) radiological dose code and the guidance contained in the proposed cleanup standards.

- The duration over which the performance will be evaluated will be 1,000 years. A longer time period will be analyzed to ensure that no major degradation in the performance of the disposal system is experienced.

For purposes of evaluation, comparison of predicted concentrations with the numerical performance criteria defined in Section 2.1 will be performed for nominal conditions. The need for analyses of off-normal conditions will also be included in the final performance assessments. However, a discussion on the scope and nature of these analyses is considered premature at this time.

2.3 CONCEPTUAL MODELS AND SCENARIOS

All waste disposal systems to be considered for disposal of SST waste consist of two subsystems: engineered and natural. The engineered subsystem includes the waste matrix and the various barriers that will be constructed to limit the migration of contaminants away from the disposal site. The natural subsystem is the environment into which the engineered subsystem is placed. Disposal of SST waste in the 200 Area on the Hanford Site includes both modeling of contaminant transport in the partially saturated zone (vadose) above the water table, as well as modeling of contaminant transport in the unconfined aquifer. This strategy does not address the interaction of groundwater contamination resulting from SST waste disposal activities and other waste disposal activities such as plume mixing. The combined effects and modeling of the underlying groundwater system will be the subject of independent (200 Area) groundwater operable unit or aggregate area study(s). Interface with the SST waste disposal studies is recognized and will be required as the work plans for the groundwater operable units are prepared.

An engineering study (Garfield 1990) has been initiated to evaluate the various waste disposal system alternatives. As part of the evaluation process, the long-term waste isolation potential offered by each of these alternatives will be examined. This study represents the first of several iterations that are anticipated. It is assumed that long-term waste isolation potential will be evaluated several times during the process of selecting alternatives and in support of design.

When considering waste disposal in a semi-arid environment such as the Hanford Site, the natural subsystem features of primary interest include the water balance at the air and soil interface, the soil water movement and transport of hazardous constituents in the partially saturated zone above the water table (vadose zone), and the groundwater movement and transport of hazardous constituents in the saturated zone or unconfined aquifer.

2.3.1 Conceptual Models

As shown in Figure 1, the first step in the performance assessment process is to define the waste management system and the conditions under which this system will be analyzed. A model is defined as a representation of the real world. Natural systems, particularly geohydrologic systems, tend to be very complex, containing numerous uncertainties. However, there is a need to define the natural subsystem based on current understanding and to use this information in support of planning and in support of management decisions. Definition is accomplished by assimilating the existing state of knowledge and database, supported by necessary additional assumptions. Because of these interpretations and assumptions, the resulting consequence is a product that is not unique nor exact and is best defined as a concept, or 'Conceptual Model.'

The first step in the modeling process is to define a conceptual model of the waste source, engineered barriers, surrounding geohydrologic system, and pathways for reception (i.e., ingestion). This conceptual model usually consists of a narrative description with supporting schematic diagrams that assimilate the set of assumptions and existing database into a cohesive definition of the problem to be analyzed. Formulation of the conceptual model will be consistent with the goals and objectives of each analysis. The conceptual model could, and usually does, change with time as the goals and objectives change and/or the database and general understanding of the subsystems (engineered and/or natural) change.

2.3.2 Scenarios

A scenario can be considered a statement of conditions for which an analysis will be performed. The conditions may be stable or constant, may include transient phenomena, and may result from disruptive natural or artificially (human) induced events. Typically, a scenario assumes a conceptual model and relates this model to human health or environmental factors through the specification of an environmental pathway and receptor characteristics. To assess risk, a probability of occurrence is specified. For likely or nominal events, this probability can be assigned a value of unity.

A natural consequence of preparing the conceptual models is a heightened awareness of the various assumptions and uncertainties that surround the formulation of the conceptual model. Data uncertainties typically result from natural variation and the difficulties associated with geohydrologic characterization. These uncertainties can be addressed deterministically through the use of sensitivity analyses or stochastically through the use of probabilistic analyses. The extent to which these uncertainties will be explicitly addressed has not been defined. Therefore, from a strategy perspective, for the near term, it will be assumed that an evaluation of the expected or nominal condition is sufficient.

Those effects associated with accident or disruptive situations represent a different kind of uncertainty. Typically, these uncertainties are evaluated by formulating either a different conceptual model or by assuming that the various elements described in the conceptual model do not function or are configured differently. For example, a design feature might not satisfy the function for which it was intended to perform and, therefore, no credit will be taken for its use. Other types of hypothetical or 'what if's,' such as accident or disruptive situations, can be addressed in a similar manner. The scenarios that will be prepared and addressed will take these variabilities into consideration. These kinds of variation can also be addressed through the use of sensitivity analysis. Accidental or disruptive situations will not be explicitly addressed until the list of alternatives has been reduced. As discussed previously, selection of disposal alternatives will be facilitated by the systems engineering studies.

Waste disposal design alternatives to be considered include the separation, processing, and offsite disposal of some SST waste. For example, the disposal of vitrified waste in a geologic repository will be addressed. Health risk associated with retrieving, processing, and transporting the waste will be quantified; however, the long-term health risk associated with geologic disposal will not be calculated. (In the HDW-EIS [DOE 1987] the risk associated with geologic disposal was assumed to be zero.)

2.3.3 Characterization

A characterization program has been initiated to determine the chemical, physical, and radiological properties of the waste contained in the tanks. A program is also required to characterize the extent of contaminated soil, and ancillary units, the geohydrologic characteristics of the soils in the partially saturated zone, and the confined aquifer beneath the 200 Areas. To allow for future development and enhancement of conceptual models as well as scenario definition to support future performance assessment, this characterization work should include (but not be limited to) the following activities.

- Prepare and upgrade conceptual models that support the systems engineering activity and reflect the engineering design.
- Collect information necessary to prepare a defensible vadose zone flow and transport model.
- Develop a better understanding and quantification of the mechanisms that control the mobility of the constituents contained in SST waste.

2.4 SELECTION AND APPLICATION OF NUMERICAL MODELS

After the conceptual models have been prepared, they are transformed into mathematical and numerical models. The selection of the appropriate numerical model is a function of the study needs and usually varies with time. For example, during the evaluation of engineering alternatives, rather crude 'order of magnitude' estimates may be sufficient at one stage of the selection process; whereas at a different stage, modeling using detailed sophisticated techniques may be required. In all cases, the question that needs to be addressed is, "What level of modeling is most appropriate to complete the task at hand?".

2.4.1 Model Selection

Model selection is based primarily on use. Models are used to address different types of problems. For example, the model that will be used to support planning and to screen various choices may differ from the model(s) that will be used to evaluate regulatory compliance. Although in both cases an iterative process probably will be followed, the criteria for acceptance could be different. Engineering judgment will be used to support planning and to screen alternatives; however, regulatory approval may be required before these models can be used to support regulatory decisions regarding compliance. For example, if analyses (performance assessment/risk assessment) are used to establish conditional cleanup criteria as discussed in Section 2.0, "Regulations," then the models that are used to provide the basis for these criteria could be considered 'new scientific information' as discussed in the proposed cleanup standards [WAC 173-340-702(6)] (Ecology 1991) and, therefore, are subject to review and approval.

From an analysis perspective, long-term waste isolation is primarily a function of analyzing how the two major subsystems perform. This analysis includes:

- An assessment of release or rate at which contaminants leave the waste matrix and are transported through the various barriers that constitute the engineered subsystem
- An assessment of migration or subsequent transport of these constituents in the natural system once they are no longer contained in the engineered subsystem.

The analyses required to support these two aspects of modeling are different, and the resulting steps also will be different.

2.4.1.1 Engineered Subsystem. The engineered subsystem will rely on the use of engineering techniques to plan, screen, select and design the appropriate disposal system. The various aspects of the engineered subsystem can be studied and tested in controlled environments. Conceptually, the ultimate design will evolve slowly and provide a comprehensive understanding on how the engineered subsystem will work. In general, the approach will be to work from the general, using simple models, to the specific, requiring the use of more detailed models. Laboratory and bench-scale testing are considered essential elements in the refinement of these models. From a waste isolation performance perspective, two aspects of major concern exist: (1) the effect of radiogenic heating and chemistry on the long-term integrity of the waste matrix, and (2) the effect of elevated temperature and matrix chemistry on the transport characteristics of the constituents contained in the matrix. Both of these concerns will receive considerable attention during the next few years.

As will be discussed in Section 2.4.3.1, the waste package release models described in Appendix P of the HDW-EIS (DOE 1987) will be used to simulate the release of contaminants from the various waste matrices. Aspects of similitude and the collection of additional laboratory data will be used to refine these models.

2.4.1.2 Natural Subsystem. The models required to support decisions regarding the potential migration of contaminants in the natural subsystem will place primary emphasis on interpretations of field-scale characterization activities, laboratory analysis, and calibration. It is assumed that calibrated groundwater flow and transport models (simulation models) will be required to assess the threat to human health and the environment resulting from direct or indirect interactions with contaminated soil. A discussion of the numerical models that will be used to simulate groundwater flow and contaminant migration in support of SST waste disposal is provided in Section 2.4.3.2. No specific plans for validation of these models have been incorporated into the strategy at this time. It is proposed that a position paper be prepared during the 1994-1995 timeframe to address this need if desired.

A calculated health risk is a function of those constituents that escape containment and that are intercepted by potential receptors. Decisions regarding the need to remove, treat, or leave the contaminated soil will be based on the use of simulation models to assess this risk. As discussed previously, it is assumed that these models will be used to evaluate compliance with cleanup standards or will be used to establish conditional cleanup levels for SST waste if consideration of 'net environmental protection' or total risk warrants the need to develop conditional cleanup levels.

2.4.2 Status of Hanford Site Defense Waste Performance Assessment Modeling

Implementation of DOE Order 5820.2A (DOE 1988) requires that a performance assessment be completed to assess the long-term waste isolation impacts associated with the disposal of low-level solid waste at all future waste burial facilities. In support of constructing new solid waste disposal trenches in the 200 Areas, a performance assessment was completed. This assessment quantified the need for a surface barrier and for preliminary information to establish waste form-acceptance criteria for the wastes to be placed in the trenches (Khaleel and LeGore 1990).

An analysis has been completed on the long-term performance of phosphate/sulfate-grouted waste at the Hanford Site (Stewart et al. 1987). An assessment of the performance of DST-grouted waste is nearing completion. These performance assessments employ the use of measured data on the leachability of the grout matrix, measured data on the rate of diffusion through various engineered barriers, and the application of sophisticated groundwater flow and transport models to simulate the long-term transport and fate of contaminants.

The HDW-EIS (DOE 1987) provides a baseline for future performance and risk assessments and establishes a database to be used in support of conducting waste form-specific analyses. This database will be updated appropriately as new data becomes available. The HDW-EIS also provided an assessment of the threat to human health resulting from the existing Hanford Site defense waste. Conceptual models were prepared and, based on these models, a set of relatively simple numerical models were defined and used to evaluate the release from the engineered structure as well as the flow and transport of contaminants in the environmental system. Based on these analyses, the following general recommendations were prepared.

- Characterize the waste in the SSTs.
- Develop a better understanding of, and prepare a model of, soil water movement and contaminant transport in the vadose zone.
- Quantify the water balance over the Hanford Site.
- Develop the Hanford Site-engineered surface barrier.

Since the preparation of the HDW-EIS (DOE 1987), a program to secure this information has been implemented. This ongoing work represents the cornerstone for the strategy and tasks discussed in this document. As such, the focus of this strategy is the adaptation of ongoing work to the potential disposal of SST waste.

2.4.3 Application of Numerical Models

The engineered and natural subsystem models that will be used to support an evaluation of the available alternatives for disposing of SST waste will build on past experience.

A discussion of the models that will be used to assess off-normal disruptive conditions is not addressed in this strategy. At this time, it is assumed that the models that will be developed will be sufficiently robust to accommodate an appropriate evaluation of off-normal conditions simply by adjusting various model parameters. As such, the effects on performance resulting from off-normal conditions will be addressed through applications of sensitivity and uncertainty analyses.

2.4.3.1 Simulation of Engineered Subsystem. Long-term waste isolation analyses will be performed in support of the systems engineering task. The near-term strategy will apply the waste package release models described in Appendix P of the HDW-EIS (DOE 1987) to estimating the performance of the engineered subsystem. As the list of alternatives is reduced and specific information on the performance of the different engineered subsystems becomes available, the models used to predict performance will become more detailed. The capability to model engineered subsystem performance in more detail will include the following.

- The capability to simulate the performance of the Hanford Site engineered surface barrier--the UNSAT-H model (Fayer et al. 1986) has been developed to simulate the air-soil-water balance and will be calibrated using data from the Hanford Site lysimeters.

- The collection of data and conceptualization of models that will be used to simulate the performance of the waste matrix--in situ treatment of the wastes will include vitrification and grouting. Characterization data will be collected for the resulting waste package, and these data will be used to prepare appropriate simulation models. Emphasis will be placed on evaluating the thermal and chemical effects on the integrity of the waste matrix and mobility of contaminants. Aspects of similitude will be applied to evaluate the effects of scaling.

- Collection of data and conceptualization of models to simulate the placement of any additional engineered barriers that may be placed around the waste matrix, and the in situ treatment of SST waste.

2.4.3.2 Simulation of Natural Subsystem. To support near-term system engineering needs, the natural subsystem will be simulated in a manner similar to the analysis performed for the HDW-EIS (DOE 1987). It is assumed that this level of analysis is suitable to support the screening of disposal alternatives. However, the long-term assessment of health risk, the need to assess the performance of soil treatment options, and the assessment of regulatory compliance will require the development of a more detailed capability to simulate the migration of contaminants (contaminant concentration) in both the vadose zone and the unconfined aquifer. Therefore, future activities will include the following:

- The flow and transport modeling of contaminants in the vadose zone using two- and three-dimensional unsaturated flow and transport models

  The capability to model in two and three spatial dimensions is required because of the various soil layering, thermal loading, unsaturated geohydrologic and geochemical characteristics that exist at the Hanford Site. The VAM2DH (Huyakorn et al. 1988) and PORFLO-3 (Sagar and Runchal 1990) variably saturated flow and transport models are available and will be applied. These codes will need to be calibrated using characterization data collected in the field. Consideration of thermal effects may force the use of PORFLO-3 rather than VAM2DH because PORFLO-3 explicitly includes the conservation of thermal energy.

- An assessment of contaminant migration in the unconfined aquifer

  Emphasis will be placed on the use of the integrated unsaturated and saturated flow and transport models (VAM2DH, PORFLO-3) in the future. The VTT (Reisenauer 1979), and CFEST (Gupta et al. 1982) models have been calibrated for use at the Hanford Site and will be used in support of performance assessments. These models will be used to define boundary and initial conditions for flow in the unconfined aquifer and will also be used for modeling flow and transport in the unconfined saturated zone as the horizontal and vertical scale increases.

- Characterization of mechanisms that govern the release and transport of SST waste constituents

  Laboratory studies will be performed to quantify release and transport properties.

- Application of MINTEQ (Felmy et al. 1984) and EQ3/EQ6 (Wolery 1979) geochemical equilibrium simulation models to quantify the effects of varying chemistry on transport

  Data collected in the field and in the laboratory will be used to support these analyses. It is assumed that the existing flow and transport models will not be modified to provide more detail on geochemistry, but that this aspect will be addressed externally; if a temporal and spatial variation of transport properties is considered appropriate, this information will be input to the flow and transport models.

2.4.3.3 Assessment of Radiological and Chemical Dose. The flow and transport models will be used to estimate the concentration of contaminants in the various media of interest. Once these concentrations have been calculated, the following standard methods will be used to assess their impact on human health:

- To quantify the risk to human health resulting from carcinogenic and noncarcinogenic chemicals, the EPA protocol outlined in The Superfund Public Health Manual (EPA 1989) will be applied.

- To assess dose, the Hanford Radiological Dose Assessment Model GENII (Napier et al. 1988) will be applied.

These methods will be used to assess the impacts associated with both nominal and off-normal conditions, if required.

A summary of the numerical simulation models proposed for use in support of SST waste disposal performance assessment is provided in Appendix A. The operational status, code documentation, testing, and data needs for each model are also provided in Appendix A. In addition to these models, models depicting the engineered subsystem will be developed from the suite of waste package release models discussed in Appendix P of the HDW-EIS (DOE 1987).

2.5 USE OF RESULTS

Performance assessment results will be used to support several activities, including but not limited to the following.

- Assist in the selection of and eventual design of the waste disposal system(s). In particular, these analyses will provide a basis for both the selection and the refinement of functions and requirements supporting the various phases of design (conceptual, preliminary and final).

- Support characterization activities through the use of screening and sensitivity analysis. Screening analyses have been performed to determine those radionuclides and hazardous chemicals of greatest concern (Morgan 1988). The Pacific Northwest Laboratory (PNL) continues to study this area.

- Assist in the interpretation of geohydrological characterization data; monitor data collected in situ, and provide a basis for defining what information should be collected.

- Provide a basis for the preparation of the RFI/CMS work plans by establishing the need for site characterization data, and by providing numerical guidelines for corrective actions, if necessary.

- Assess waste disposal system performance against cleanup standards and provide a basis for proposing conditional cleanup criteria, if appropriate.

- Provide a basis for the screening and selection of disposal alternatives that will be included in the system engineering evaluations.

- Provide assessments of long-term waste isolation to support the preparation of regulatory documents including the S-EIS.

The systems engineering task will be used to select the engineered disposal configuration that best satisfies the criteria for disposing of SST wastes. A selection criterion will include the need to minimize the 'total risk,' to human health and the environment. Total risk includes an assessment of the risk to human health during the operational and closure phase of the disposal as well as the long-term waste isolation. Assessment will be accomplished through an iterative series of analyses. Initially these analyses will provide assessment on the relative isolation potential associated with each disposal alternative through the use of relatively simple models. As the list of alternatives is reduced and the engineered subsystems become better defined, the level of analyses will be upgraded to be commensurate with the state of design. The environmental (natural) subsystem model will be upgraded also as additional geohydrologic characterization information becomes available. The models will be tested in accordance with regulatory requirements as the need to assess regulatory compliance becomes an issue. It is assumed that the need to assess compliance will become an issue once the conceptual design phase for the candidate disposal system(s) has been initiated.

The environment is the principal protective barrier against long-life radionuclides and persistent chemicals. Therefore the need to calculate the concentration of contaminants as a function of time and location within the system's natural subsystem is required. When considering the natural subsystem, two aspects must be addressed:

- Formulating and upgrading the conceptual model

- Quantifying the physical parameters used to define the conceptual model and to quantify the numerical model.

Most of the information required to support these two aspects of performance assessment will be secured through implementation of the RFI/CMS process. As such, performance assessment data needs must be addressed during the preparation of work plans to secure geohydrologic characterization information.

Performance assessment results will be used during the preparation of regulatory documents. An assessment of the long-term waste isolation potential associated with each of the proposed disposal alternatives will be discussed in the S-EIS. Similarly, the final design and predicted performance will provide a basis for permitting the waste disposal system and will be incorporated into the closure plan.

2.6 SUMMARY OF STRATEGY

As discussed in the Introduction (Chapter 1.0), the primary objective of the performance assessment strategy is to develop a credible numerical simulation model that can be used to assess the long-term isolation potential of various SST waste disposal alternatives. The goal is to establish this capability in time to support the preparation of the S-EIS. In the interim, preliminary performance assessments will be performed using available models and data to support decisions. Assessments will be performed iteratively with each subsequent analysis building on results from the preceding analysis.

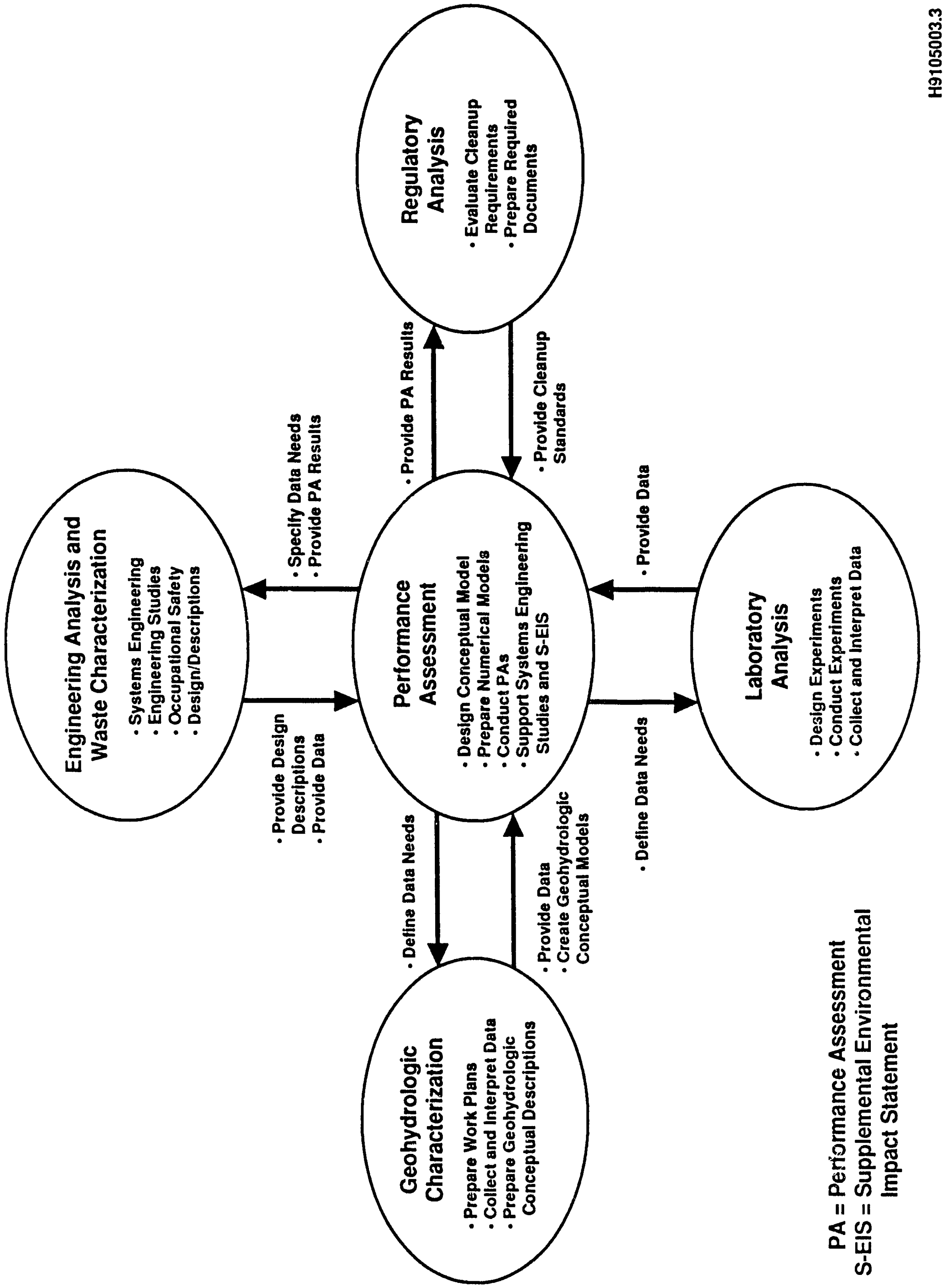
Performance assessments are being conducted to screen and assist in the selection of the alternatives that will be considered for disposal of SST waste. Performance assessments are also being used to assist in the development of the waste characterization strategy. In particular, performance assessments will be used to prioritize the contaminants of greatest concern and to prioritize the order in which the SSTs will be sampled. Results from the performance assessments are compared to performance objectives. The assignment of performance objectives will be based on waste disposal regulations and numerical standards.

Results from performance assessments will be combined with occupational safety analyses results to quantify the total risk associated with each disposal alternative. The selection of an appropriate waste disposal system will be based on an assessment of total risk. Results from the performance assessments may be used as a basis for establishing conditional cleanup criteria as a means of minimizing the total risk. The extent to which this can be accommodated will be determined by the parties responsible for the various disposal decisions.

A performance assessment model suitable for demonstrating regulatory compliance will be developed from the existing suite of models. Primary emphasis will be on establishing an empirical database of field characterization and laboratory analysis; the database will be used to improve current models. A description of these models and information required to support their use is provided in Appendix A. Of equal importance is the development and acceptance of the conceptual models that will be defined and used to represent the engineered and natural subsystems. These conceptual models provide the basis for selection and quantification of the numerical models.

The performance assessment activity will maintain a strong interface with four other SST waste disposal activities: engineering analysis and waste characterization, geohydrologic characterization, laboratory analysis, and regulatory analysis. Figure 2 depicts the interface and interaction of these activities as presently envisioned (and discussed in Chapter 2.0).

Figure 2. Performance Assessment Interfacing.



3.0 PLAN

Consistent with the performance assessment strategy discussed in Chapter 2.0, the primary objective of the plan is to identify those tasks that will be required to develop a credible performance assessment model. This model will evolve over the next few years; the key to its successful development will be the periodic application (performance assessments) during the interim to continually focus and scope the work performed. This iterative 'bootstrap' process will use existing models and data to calculate results that will be reviewed and critiqued, providing a basis for future work. For example, the performance assessment in support of the HDW-EIS (DOE 1987) provided a basis for developing the unsaturated groundwater flow and transport models and identified the need to further characterize the wastes in the SSTs. Currently existing models and data are being used to evaluate the performance of the various waste disposal alternatives as part of the systems engineering, as well as to prioritize the contaminants in the SSTs, based on their contribution to risk (analyte prioritization). These analyses are envisioned as the first of many such analyses to be performed in support of SST waste disposal. Each of these analyses will provide insight into the need for subsequent work.

The plan is to develop the performance assessment model from an existing suite of computer-encoded numerical simulation models, a summary of which is provided in Appendix A. As will be discussed in this plan, primary emphasis is on the collection and use of data to qualify and calibrate the numerical models. During the interim (between now and the time a credible model becomes available for assessing regulatory compliance), preliminary performance assessments will be performed to aid in the decision-making process. The results from these assessment analyses will be used not only to support interim decisions concerning waste characterization, screening of waste system alternatives, and geohydrologic characterization, but also to be used for periodic reviews of the model development process. Review is considered an important aspect of model qualification.

In general, data and a request to perform a specific analysis will be provided to the performance assessment activity. An analysis will be performed and the results will be provided to the requestor. As shown in Figure 2, this process will be iterative. Following this process, performance assessment activities are envisioned to aid the following activities.

- From a design perspective, evaluate the performance of the engineered subsystems and provide results and recommendations for subsequent refinements of functions and requirements.

- From both a design and in situ stabilization perspective, results from performance assessment analyses will be used to establish performance requirements.

- From a regulatory perspective, evaluate system performance against the various cleanup standards and provide a basis for advancing conditional cleanup criteria if the risk to human health and the environment warrants such an adjustment.

- From a characterization perspective, define and prioritize data needs to the extent possible and provide a basis for interpretation of data collected in both the laboratory and in the field. These data will be provided through characterization and supported through the specification of data needs defined and discussed in work plans.

Specifically, performance assessments will be prepared to examine the following conditions:

- Evaluation of the no-action alternative

- In situ treatment of SST waste and contaminated soil

- Retrieval and processing of SST waste and contaminated soil

- Appropriate combinations of the preceding three cases.

These proposed analyses are consistent with the scenarios evaluated in the HDW-EIS (DOE 1987) and the range of waste disposal alternatives currently under review as part of the systems engineering evaluation.

The plan includes 15 tasks necessary to complete the performance assessment work scope. Primary emphasis is on the use of existing models, as well as the collection of field and laboratory data for both corroborating and calibrating their use. The tasks have been organized into four performance assessment activities: performance assessment work in support of evaluating the performance of the engineering subsystem; development and qualification of the models that will be used to represent the geohydrologic subsystem; applications as relate to an assessment of risk in support of three activities (systems engineering, closure/corrective action, S-EIS); and a discussion of ancillary tasks. These activities are summarized in the following sections.

Section 3.1 provides a discussion of the tasks planned in support of modeling the engineered subsystem. This work will be performed in support of the systems engineering analyses (Garfield 1990). Waste disposal systems will be defined through the systems engineering process and the performance of these systems will be evaluated. The alternatives that will be examined are consistent with the disposal scenarios analyzed in the HDW-EIS (DOE 1987).

Section 3.2 discusses preparation of a defensible model of the geohydrologic subsystem. Emphasis will be placed on improving understanding of groundwater flow and contaminant transport in the unsaturated soils. Vadose zone models will be configured and tested.

Section 3.3 outlines the need to conduct performance assessments in support of three SST waste disposal activities. These activities include an evaluation of the various waste disposal alternatives, analysis in support of preparing the updating the closure/corrective action work plan, and analysis in support of the S-EIS. As will be discussed, the plan described herein assumes that work on the S-EIS will be initiated in fiscal year (FY) 1997. If the schedule for completing the S-EIS is accelerated, then the plan described herein will be modified, as appropriate.

Section 3.4 describes those ancillary activities that will be performed to support the tasks described in Sections 3.1 through 3.3. These activities include software quality assurance, sensitivity analysis, and uncertainty analysis.

In addition to the work discussed in Sections 3.1 through 3.4, a subject of primary interest to performance assessment is the acquisition and use of characterization data. The scope outlined in this plan does not include specific planning for collection of geohydrologic characterization information for each of the 6 operable units nor for the characterization of the wastes contained in the 149 SSTs. Appendix A lists the information required to support the use of the various models.

An important link between performance assessment and characterization is through the formulation and refinement of conceptual descriptions (i.e., models) of the engineered and natural subsystems. Therefore, the objective of the performance assessment activity is to specify data and/or information needs as a requirement to each of the design and characterization functions. These needs will be supplied by the functions. This interaction is depicted in Figure 2.

3.1 MODELING THE ENGINEERED SUBSYSTEM

3.1.1 Task 1: Preparation of Engineered Subsystem Models

3.1.1.1 Discussion. A number of alternatives will be considered, ranging from in situ disposal of SST waste to the retrieval and processing of all wastes. A family of models will be prepared and used to evaluate the various alternatives. These models will be capable of simulating the performance of the waste matrix (e.g., existing salt cake, grout, glass, ceramic), the various packaging or vaults considered for emplacement, and additional barriers (e.g., lateral, surface), that will be incorporated into the various conceptual designs. All work on this task will be directed by, and in support of, the systems engineering study. Consistent with the needs of these studies, various concepts will be defined and conceptual models (narratives) will be prepared. Once the conceptual models have been prepared, a suitable numerical model for each concept will be prepared (configured). It is anticipated that the suite of waste package release models defined in Appendix P of the HDW-EIS (DOE 1987) will satisfy most modeling needs.

3.1.1.2 Work Plan. This work was initiated in FY 1990 and will continue at a level of support appropriate to satisfy the needs of the systems engineering work (Garfield 1990). As envisioned, this work will provide the basis for defining the waste disposal systems and waste package models that will be used in the S-EIS. Definition of the models and analysis in support of the S-EIS analysis is assumed to start 3 years before the planned completion date of the S-EIS. Performance assessment analysis in support of the S-EIS is assumed to be initiated no later than mid-FY 1998.

From an interface perspective, results from these analyses will be used to update the risk assessment baseline and to provide guidance for the analytical work performed in the laboratory. Results from sensitivity analyses, waste characterization, and laboratory analyses will be used to refine the design of the engineered subsystem.

3.1.2 Task 2: Collection of Data in Support of Preparing Engineered Subsystem Models

3.1.2.1 Discussion. It is assumed that radionuclides and hazardous chemicals either will be leached from, or will diffuse through, the waste matrix. With a functioning engineered surface barrier, transport through the remaining engineered barriers is assumed to follow the process of diffusion. Laboratory data will be collected to quantify the diffusion coefficients. The diffusion coefficients are a function of both the waste matrix and the inventory of contaminants to be disposed of.

The work proposed in this task will parallel the laboratory work performed in support of grout performance assessment analyses. Using existing laboratory procedures detailed in American Nuclear Society test procedures (ANS 1986), effective diffusion coefficients were established for approximately 40 key radionuclides and hazardous chemicals in grout. It is proposed that after a preliminary list of matrices has been defined, a similar approach be used to measure the effective diffusion coefficients resulting from the potential disposal of hazardous materials in these waste matrices.

3.1.2.2 Work Plan. It is anticipated that a multiyear (minimum 5-year) program will be required to measure the effective diffusion coefficients and to assess waste form integrity. The plan will address resistance to leaching, evaluation of effective diffusion coefficient, and bench-scale testing of matrix integrity. The effect of temperature on these factors will be evaluated. Optical techniques will be used to examine the character of pore geometry. To support the timetable discussed in Task 1, this work must be initiated during FY 1992.

The primary interface includes a continuous dialogue with the engineered subsystem modeling activity. In addition, results from the sensitivity analyses on the dissipation of thermal energy from various waste compositions and configurations, as well as the studies on similitude scaling, will provide guidance for the work to be performed in the laboratory.

3.1.3 Task 3: Scaling Considerations

3.1.3.1 Discussion. In support of the grout performance assessment, the effective diffusion coefficients were estimated based on the use of an accepted semi-infinite solid diffusion-leach model. Using this model, the time averaged and instantaneous diffusion coefficient was measured, using small-scale cylindrical samples. The measured diffusion coefficients were then scaled geometrically to estimate the rate of release from the grout monolith. No bench-scale testing on the adequacy of this extrapolation technique was performed.

It is proposed that a study be performed to assess the adequacy of this approach to scale effective diffusion coefficients. In particular, the laws of similitude will be reviewed and applied to the problem to better understand, and thereby better estimate, the effective diffusion coefficient that should be used to calculate the release of contaminants from the prototype grout matrix and other waste matrices that might be considered. A number of bench-scale tests should be performed to validate the method that will be used to scale the laboratory results.

3.1.3.2 Work Plan. A minimum 3-year program will be needed to collect the necessary information on similitude required to support Tasks 2 and 3. A study will be performed to establish a basis for supporting the laboratory work discussed in Task 2. This study will be followed by a follow-on (phase 2) effort that will be performed before initiating work on the S-EIS. The focus will be on scaling the results measured in the laboratory, with emphasis on testing larger-scale models. A FY 1995 start date is suggested for phase 2.

Results from the studies on similitude will be used to focus the analytical work performed in the laboratory and to scale the prototype engineered structures based on laboratory findings.

3.2 MODELING THE NATURAL SUBSYSTEM

3.2.1 Task 4: Tank Farm Water Balance Study

3.2.1.1 Discussion. The drainage of water through the soil column provides the primary transport mechanism for contaminant migration. During FY 1989, a preliminary assessment was completed of the net percolation and drainage of water through the unsaturated soils in the vicinity of the 241-T Tank Farm (Rockhold et al. 1990). Based on this preliminary assessment, it was estimated that approximately 75% of the incident precipitation drained through the soil column. This rate of drainage is considerably higher than the rate of infiltration previously assumed in the tank farms. Additional analysis is required to verify this rate.

The UNSAT-H model will be used to quantify the tank farm water balance. The work performed in support of this task will interface with the model development work and Hanford Site lysimeter studies funded through the

Hanford Site Performance Assessment Program (HSPA). In particular, the general calibration of the UNSAT-H water balance model will be addressed through the HSPA. Site-specific calibration as it relates to the specific tank farms will be addressed in this task. A quantification of the air-soil-water balance using UNSAT-H is required to define a 'flux' boundary condition for the vadose zone groundwater flow and transport models.

3.2.1.2 Work Plan. It is assumed that the base program required to support the characterization and quantification of infiltration across the Hanford Site will continue as part of the HSPA effort. The results of this work will be applied on a case-by-case basis to the various tank farms as needed. The detailed work plans that will be prepared in support of SST closure and/or corrective actions are considered the primary vehicle for collecting the site-specific data required to calibrate the UNSAT-H model used in support of tank farm cleanup. At a minimum, a 1- to 2-year effort will be required to prepare information in support of the S-EIS. Collecting tank farm water balance information is assumed to be initiated in FY 1992 to support the need for scoping the Hanford Site-engineered surface barrier.

An interface is required with the analytical work performed within the HSPA project in support of developing the Hanford Site-engineered barrier. During the preparation of the tank farm past practice operable unit work plans, the data requirements associated with using the Hanford Site water balance model (UNSAT-H) will be defined. Site-specific data will be collected as a result of implementing the work plans, with this data being used to quantify the water balance in the various tank farms. It is assumed that tank farm specific-water balance analyses will be initiated in FY 1994.

3.2.2 Task 5: Calibration of Vadose Zone Plume Model

3.2.2.1 Discussion. The modeling of contaminant migration in the vadose zone is critical for the purpose of assessing the long-term health risk posed by past tank leaks. During FY 1989, calibration was initiated of the PORFLO-3 unsaturated flow and solute transport model using existing field data from the 241-T-106 tank leak (Smoot and Sagar 1989). Although some success was achieved, many questions remain unanswered. During FY 1990, activities that will result in an additional characterization boring were initiated in the 241-T Tank Farm to help resolve these questions. It is assumed that additional emphasis will be placed on qualification of the vadose zone flow and transport models through calibration activities using contaminant transport data collected in situ. In addition to data on tank leaks, information from liquid waste sites (e.g., cribs, trenches) provide a potential basis for model calibration.

The scope of this task is limited to the activities associated with model calibration. The work required to map the extent of existing soil contamination is considered outside the scope of this task and will be provided through the geohydrologic characterization function.

The current coupled-groundwater flow and transport models address the interaction of chemicals and radionuclides with the soil, using simple parametric models. These models may be too simple to adequately simulate the behavior of existing soil contamination resulting from past tank leaks. As a result, a provision is included to use specialized geochemistry models such as EQ3/EQ6 and MINTEQ. In particular, these specialized models will evaluate the need for assigning temporal- and spatial-varying transport parameters. Constant parameters are routinely used in performance assessments to simulate the geochemistry interaction of contaminants with the soil (e.g., the distribution coefficient, retardation coefficient).

3.2.2.2 Work Plan. The work in this task consists of two parts:

- The application of flow and transport models
- The definition and collection of appropriate field data to calibrate the models.

Characterization and calibration of the 241-T-106 contaminant plume was initiated during FY 1989; this work will continue. In addition, it is proposed that characterization of at least one other major contaminant plume be performed to corroborate the 241-T-106 analyses. Tentatively, the plume resulting from leakage of the 241-BX-102 tank will be evaluated. A third characterization is also being considered. It is proposed that this characterization work (initiated in FY 1989) continue through FY 1992 and that some form of plume characterization be performed continuously until work on the S-EIS has been initiated.

Perhaps as many as four or five new characterization borings will be required to support model calibration. The need to complete these characterizations will be based on the results from the ongoing characterization discussed in the previous paragraph.

Plume modeling and calibration will be supported through the use of the data collected from the borings. In addition, laboratory analyses will be required to quantify the flow and transport properties of the soils and contaminants of interest. The calibration work will be initiated when additional data from the boring becomes available. It is assumed that these analyses will be initiated during FY 1992 and will be performed somewhat continuously throughout model development.

Use of the geochemical models will be defined as needed. It is assumed that modeling and calibration of the plumes will require the specification of a temporal and spacial variation of the geochemical transport properties. The analytical laboratory support required to address these enhancements are addressed in Task 2.

NOTE: Additional characterization will be required to define the extent of existing contamination in the Hanford Site soils; this aspect of characterization is not included in the scope of work.

3.2.3 Task 6: Calibration of Vadose Zone Flow Model for Uncontaminated Soils

3.2.3.1 Discussion. Because the transport of contaminants in partially saturated and saturated soils results primarily from the movement of water through pore openings, it is important to develop an adequate understanding of this process. In addition to the use of contaminated soil data to calibrate groundwater flow and transport plume model(s), described in Task 5, there is a need to calibrate and validate the use of these same models with uncontaminated soil data. In particular, there is a need to characterize the variability of the soil properties in the horizontal and vertical planes, thus providing reasonable confidence in using these models to simulate the natural movement of water in the unsaturated soils. The conditions, assumptions, and acceptance criteria have not been identified.

Characterization of the soils in the vadose zone are required for at least two reasons: (1) to support the development of defensible conceptual models, and (2) to establish the relationship between soil physical properties and their hydraulic and geochemical properties. However, formulation of a comprehensive program to satisfy these objectives goes beyond the collection of that information required to support use of the numerical groundwater flow and transport simulation models in SST waste disposal. Geohydrologic modeling is far from an exact science, and this task cannot address all the inherent uncertainty associated with this science. Therefore, the goal for this task is twofold: (1) to define a program of study that will allow the delineation of appropriate acceptance criteria for use in support of the study, and (2) to conceptualize and collect data that will provide for an adequate representation of the heterogeneous features of the Hanford Site soils in the vicinity of the various SSTs.

3.2.3.2 Work Plan. A strong interface must be established between the geohydrologic characterization program and performance assessment. Based on existing geohydrologic information, conceptual models for each of the tank farms will be prepared and will identify existing data gaps and uncertainties. Through the use of sensitivity analysis, the relative importance of the gaps and uncertainties will be evaluated in relationship to a better understanding of groundwater flow. This evaluation will provide a basis for deciding what additional information is required to characterize the geohydrology within the tank farms. In effect, this exercise (i.e., evaluation of sensitivity) will help establish the acceptance criteria and will define additional information required to characterize a site (i.e., how much data is enough).

Field sampling and laboratory analysis will follow. Conceptual models will be redefined and compared to previous models. A single iteration is proposed at this time.

Generic Hanford Site geohydrologic characterization data and specific operable unit geohydrologic data will be used to develop the conceptual models for each of the tank farms. Numerical models will be configured, and results will be used to update the baseline risk assessment. Once completed, the resulting vadose zone flow and transport model(s) will be used to support the preparation of the S-EIS.

It is assumed that this characterization program will take up to 7 years to complete. Therefore, it is recommended that a program be initiated in FY 1992 to characterize the vadose zone soils.

3.2.4 Task 7: Unconfined Aquifer Flow and Transport Modeling

3.2.4.1 Discussion. The 149 SSTs have been aggregated into 6 operable units. These operable units are defined as 'source term' operable units that interface with one or more groundwater operable units underlying the 200 Areas. The contaminants entering the vadose zone might be transported to the unconfined aquifer. It is assumed that an evaluation of contaminant migration, the risk posed by contamination in the unconfined aquifer, and an assessment of the needs associated with the cleanup of this contamination will be addressed in the 200 Area groundwater operable unit work plan(s).

Numerical models will be used to model contaminant migration and to assess risk. The PORFLO-3 and VAM2DH flow and transport models can be used to simulate concentration distribution in the saturated-unsaturated media. However, it is proposed that the VTT or CFEST models be used to support larger-scale flow and transport modeling in the saturated (unconfined) aquifer.

3.2.4.2 Work Plan. A model of the unconfined aquifer will be prepared for each groundwater operable unit. It is assumed that this model will interface with the Hanford Site geohydrologic performance assessment model. The Hanford Site model will be used to establish the boundary conditions for the operable unit models. The vadose zone flow and transport models prepared in support of the source term operable units will simulate the concentration of contamination entering the unconfined aquifer. Therefore, the source operable unit models will interface with the groundwater operable unit models.

It is assumed that the characterization and modeling needs associated with groundwater flow and transport of contaminants in the unconfined aquifer will be addressed during the preparation of the 200 Area groundwater operable unit work plan(s). Preparation and implementation of the work plan(s) will be initiated during FY 1992. At the present time, work on this task is limited to an interface activity. It is recognized that to complete the exposure step of the risk assessment, a model of the groundwater flow path is required. Initially, a simple one-dimensional model will be used to simulate this pathway. As more detailed groundwater flow and transport models are developed through the implementation of the 200 Area operable unit work plan(s), the use of these models will be substituted for assessing risk. It is anticipated that these models will become available during the FY 1994 timeframe.

All work required to quantify the various source terms and assess the risk resulting from contamination of the groundwater operable units will be addressed in the groundwater operable unit work plan(s).

3.2.5 Task 8: Simulation of Empty Tanks and Contaminated Soil

3.2.5.1 Discussion. As discussed in the closure/corrective action work plan (DOE-RL 1989), an option under consideration involves closing the SSTs, after the waste has been removed, as underground tanks. In this scenario, the waste would be removed from the tanks and the empty tanks and contaminated soil would be left in place. The acceptability of using this method of closure depends on the risk associated with the remaining hazard.

A model will be configured to address the risk associated with leaving stabilized empty tanks and contaminated soil. This task will build on the results from Tasks 2 and 5. Basically, the vadose zone flow and transport models will be used to evaluate the transport potential associated with the small amount of hazardous waste remaining in the tanks as well as the time-dependent risk associated with the levels of contamination in the soil and groundwater. For this scenario, the tanks will be backfilled and stabilized, reducing the mobility of the small residual waste left in the tank.

The model will be used to establish the functions and requirements associated with stabilizing the tanks. The benefit (risk reduction) associated with various means of stabilization will be addressed through simulation.

3.2.5.2 Work Plan. This task will be initiated in FY 1995. An engineering study will be performed during FY 1995 to quantify the rate at which the tanks will decompose. Characterization data on the extent and nature of contaminated soil will be compiled during FY 1995 and FY 1996. Once this information has been compiled, a preliminary risk assessment will be performed to assess the potential risk associated with the in situ disposal of the waste. Completion of the analyses will establish a basis for establishing the functions and requirements associated with this disposal alternative. It is assumed that the specification of these functions and requirements will be completed before work on the S-EIS is initiated.

3.2.6 Task 9: Model Calibration and Validation

3.2.6.1 Discussion. A position paper will be prepared to present the methods and data that will be used to qualify the performance assessment and risk assessment model. In particular, primary attention will focus on the method that will be used to qualify the geohydrologic groundwater flow and transport models and the engineered subsystem models. This task will integrate the work outlined in Tasks 1 through 8. The position paper will be peer reviewed and made available for public comment.

3.2.6.2 Work Plan. Model benchmark testing, calibration, and validation will be initiated in FY 1992 and will continue through FY 1997. The position paper will be prepared during FY 1994. The paper will be peer reviewed and released to the general public for review and comment during FY 1995. Final testing and documentation of test results will be initiated during FY 1996 and is estimated to last 3 years. All testing and documentation of test results will be completed before completing the S-EIS, which will include a summary of the test results.

3.3 APPLICATIONS OF PERFORMANCE ASSESSMENT

3.3.1 Task 10: Performance Assessment in Support of Systems Engineering

3.3.1.1 Discussion. The long-term risk associated with the various disposal alternatives will be addressed in an iterative manner. This task will be coordinated through the systems engineering study (Garfield 1990). The systems engineering task is designed to systematically examine the engineering and environmental aspects associated with the various cleanup alternatives available. As stated previously, disposal of SST waste is a very complex process involving many possible configurations. A multiattribute scoring system will be used to compare the various alternatives. One attribute included in these assessments will be the reduction of risk resulting from the use of each alternative.

The models discussed in Sections 3.1 and 3.2 will be configured to predict the long-term fate of both the hazardous material stored in the SSTs, and the hazardous material existing in the contaminated soil. Results from these analyses will establish a 'baseline' to compare the relative risks associated with the various waste disposal alternatives. This baseline will be updated periodically as the results from characterization and technology improve our understanding of the work that must be performed. At the present time, the existing baseline on the risk posed by the wastes in the SSTs is reflected in the results documented in the HDW-EIS (DOE 1987). The information will be updated periodically and will reflect the status of the systems engineering work. Preparation of conceptual models and definition of scenarios (discussed in Chapter 2.0, Sections 2.3.1 and 2.3.2) are a natural consequence of performing these analyses. Emphasis will be placed on defining the conditions (conceptual models, scenarios) for which the results apply.

3.3.1.2 Work Plan. Work on this task was initiated during FY 1990. Work will continue at a level of effort consistent with the needs of the systems engineering study. Major updates to the risk assessment baseline will occur every other year (FY 1992, FY 1994, and FY 1996). The FY 1992 update will emphasize the use of enhanced engineering subsystem models. During FY 1994, the update will incorporate the use of enhanced plume modeling, and the FY 1996 update will include the use of enhanced geohydrologic groundwater flow and transport models. Funding for this baseline updating will be provided through the systems engineering study.

3.3.2 Task 11: Support of Closure/Corrective Action Planning

3.3.2.1 Discussion. Closure of the SSTs will be in accordance with WAC 173-303-610 (Ecology 1990). It is proposed that performance assessments be used to support formulation of the strategy for closing these facilities.

In particular, performance assessment will be used to support the ROD by providing a means whereby the following can be accomplished.

- The risks and benefits associated with the various disposal alternatives can be compared.
- The established cleanup standards can be reviewed and can provide a technical basis for establishing alternative cleanup criteria if limitations in technology and human health and environmental considerations warrant their use.

Furthermore, from a RCRA perspective, once the appropriate remedial cleanup has been completed, the performance assessment simulation models could be used to perform the following.

- Interpret the data to be collected during the approximate 30-year monitoring period.
- Establish a basis for setting the controls to be used to trigger corrective actions.

It is proposed therefore that the methodology that will be developed and used to support the decision regarding the disposal of SST waste will also be used to (1) establish a basis for corrective actions if required, and (2) provide a basis for verifying the performance of the waste disposal systems after construction.

3.3.2.2 Work Plan. Work on this task was initiated in FY 1989 and a discussion of planned performance assessment work is provided in Chapter 6 of the closure and corrective action work plan (DOE-RL 1989). Chapter 6, "Performance Assessment," will be revised to reflect the work scope contained in this strategy and planning document, as appropriate. Subsequently, the closure and corrective action work plan will be periodically updated.

3.3.3 Task 12: Performance Assessment in Support of the Supplemental Environmental Impact Statement

3.3.3.1 Discussion. An evaluation of the risk associated with the various disposal options will be included in the S-EIS. The models to assess these risks will reflect a state-of-the-art understanding of groundwater flow and contaminant transport at the Hanford Site.

3.3.3.2 Work Plan. Preparation of the S-EIS is scheduled to be initiated in FY 1998.

3.4 ANCILLARY TASKS

3.4.1 Task 13: Software Quality Assurance

3.4.1.1 Discussion. Westinghouse Hanford software quality assurance requirements are defined in *Standard Engineering Practices* (WHC 1988). Because results from the application of these models will be used to support regulatory decisions regarding human health and safety, an impact level 2 is assigned to aspects of software quality assurance associated with the development, testing, control, and application of these computer-encoded models. As such, all software must be properly documented and tested before use, and all documented applications must be reviewed and approved in accordance with "Engineering Document Approval and Release Requirements" (WHC 1988).

A discussion of the suite of models that will be used to support SST waste disposal performance assessments is included in Appendix A. The primary documentation requirements for these models have been satisfied. However, testing of these models to support the specific applications discussed in this plan has not been initiated. To be consistent with Westinghouse Hanford requirements, verification records will be established for these models. The requirements for testing will be defined in the position paper discussed in Task 9.

Radiological doses will be calculated using GENII. The software documentation requirements associated with the use of GENII have generally been satisfied.

3.4.1.2 Work Plan. Documentation of computer-encoded models and the establishment of configuration controls consistent with Westinghouse Hanford requirements is ongoing. Verification records will be established for each of the primary computer-encoded models used in support of SST performance assessment work. The verification records will be compiled from the testing requirements and finalized through the preparation of the calibration and validation position paper discussed in Task 9. Preparation of these records has been initiated. During the next 3 years, emphasis will be placed on the qualification of the PORFLO-3, VAM2DH, and the UNSAT-H computer-encoded models.

3.4.2 Task 14: Sensitivity Analysis

3.4.2.1 Discussion. Sensitivity analyses will be performed as needed to evaluate the variability of a result, to a change in assignment of a model input parameter. This change could result from the uncertainty associated with the quantification of model input parameters or variations resulting from different assumptions. During the first few years, sensitivity analysis will be used to assess the importance of radiogenic heating; results could impact the laboratory analysis work discussed in Task 2 and the engineering subsystem modeling work discussed in Task 1. Sensitivity analyses will also be used to address the needs associated with characterization.

3.4.2.2 Work Plan. During FY 1992, primary emphasis will be placed on performing those analyses considered appropriate for defining the importance of geohydrologic characterization. Beginning in FY 1991 and continuing through 1996, emphasis will be placed on performing those sensitivity analyses that will be used to define soil geohydrologic characterization needs discussed in Task 6. Sensitivity analyses in support of waste package design were initiated in FY 1991, and analyses on those factors affecting the design of the Hanford Site surface barrier will be initiated in FY 1992.

3.4.3 Task 15: Uncertainty Analysis

3.4.3.1 Discussion. It may be desirable to present results in the form of a probability density function (PDF). Probabilistic versions of the PORFLO-3 family of computer codes are available and could be used to perform these analyses.

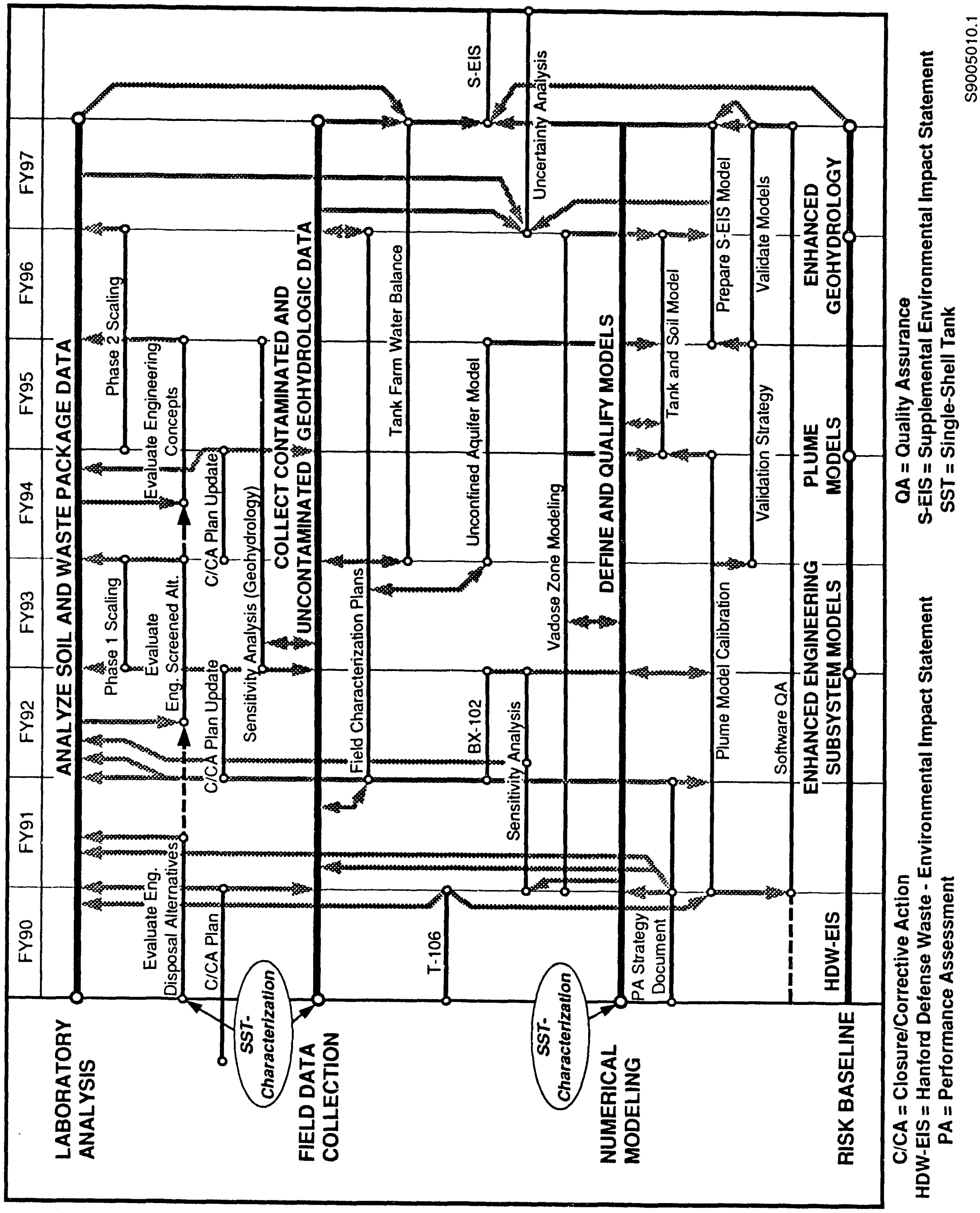
3.4.3.2 Work Plan. The need to perform uncertainty analysis has not been determined. It is assumed that some form of uncertainty analysis will be required and the results will be reported in the S-EIS, similar to the analyses included in Appendix R, "Assessment of Long-Term Performance of Waste Disposal Systems," of the HDW-EIS (DOE 1987).

3.5 INTEGRATED SCHEDULE

An integrated schedule of the tasks described in Sections 3.2 through 3.4 is provided in Figure 3. Figure 3 is not intended to present a level of detail commensurate with the narrative description contained in Sections 3.2 through 3.4, but rather to provide an understanding of the information flow between the various tasks, the timing for conducting the work scope discussed in each task, and the interface of performance assessment work with other work performed in support of SST cleanup. Currently, the primary interface of performance assessment work is with ongoing work in support of HSPA and SST characterization. In the future, a primary interface will be established between performance assessment and the work that will be performed in support of geohydrologic characterization. These data needs will be defined and work plans will be prepared to collect the data. In Section 5.4.5 of the SST Closure/Corrective Action Work Plan (DOE 1989), the need for additional geohydrologic characterization data is discussed; similarly, in Section 10.3.2, the need for characterization of the contaminant plumes is discussed.

The systematic updating of the 'Baseline Risk Assessment' is considered an important element of performance assessment by essentially setting the standard and goals for subsequent performance assessment work. During FY 1992, it is assumed that the baseline risk assessment will be updated to incorporate the preliminary work performed in support of the engineering study. At the completion of this update, the baseline will contain information from the health risk assessment performed in support of the HDW-EIS augmented with the results of the preliminary assessment on the

Figure 3. Integrated Schedule.



relative risks associated with disposing of the SST waste, using the 12 to 15 disposal concepts that will be evaluated. The second major updating of the risk baseline is assumed to take place in FY 1993. At that time, it is assumed that results from more detailed geohydrologic analysis and refined engineered subsystem modeling will be incorporated. A third major update is assumed to take place in FY 1995; at that time, the long-term waste isolation risk associated with the disposal of SST waste (using one of several concepts) should be relatively well-defined. Finally, the last update to the risk baseline is scheduled to take place in FY 1997. At the completion of these four analyses, the cases for inclusion in the S-EIS will have been defined. The final step will be to prepare and submit the S-EIS to the regulators and general public for review and comment.

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APPENDIX A

MODEL SUMMARIES

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APPENDIX A

MODEL SUMMARIES

As discussed in Chapter 2.0, "Strategy," a suite of existing models will be used to construct the performance assessment model for assessing the performance of SST waste disposal alternatives against regulatory requirements. These models provide the capability to simulate the following mechanisms:

- The release of potential contaminants from the various waste package configurations
- The transport of these contaminants through the partially saturated sediments
- The mixing of contaminants with the water in the unconfined aquifer, and subsequent transport of contaminated water to a potential receptor
- The calculation of concentration as a function of time and space.

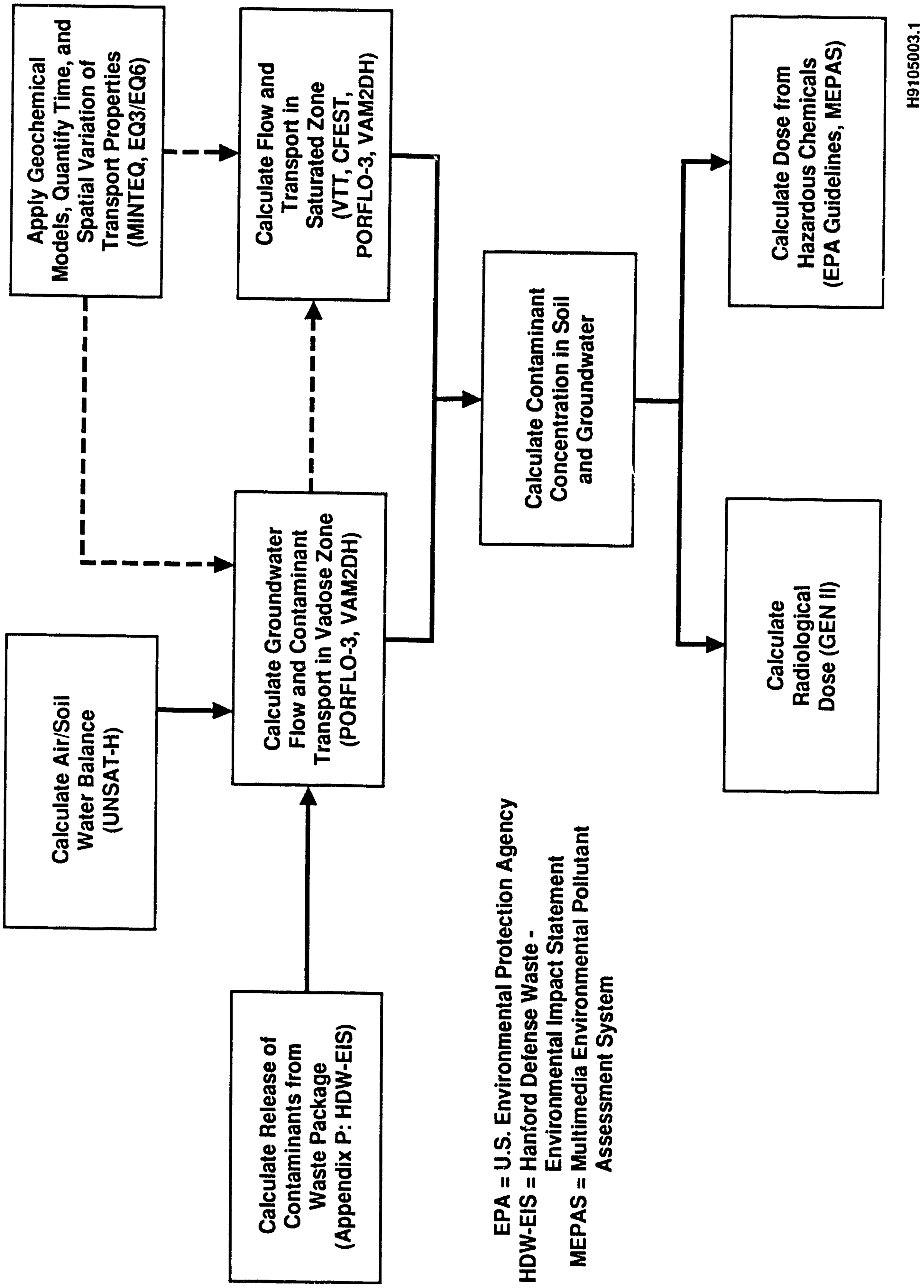
The calculated concentration will be used as the basis for predicting health risk and the impact on the environment resulting from potential releases. To accomplish this objective, an existing suite of models will be configured as shown in Figure A-1.

As shown, the existing waste package models described in Appendix P of the *Final Environmental Impact Statement - Disposal of Hanford Defense High-Level, Transuranic, and Tank Wastes* (HDW-EIS) (U.S. Department of Energy, DOE/EIS-0113, 1987) will be used to estimate release from various waste package configurations. The primary release mechanisms include leaching of contaminants through direct contact with a moving solvent and diffusion in both a liquid and solid phase. Extensive laboratory analyses will be required to quantify these release mechanisms for the various contaminants of interest. Aspects of similitude will be used to scale release parameters and to quantify waste form integrity.

The movement of groundwater in both the partially saturated and saturated soils is considered the primary means of transport. The UNSAT-H model will be used to estimate the rate at which water enters the soil column at the air-soil interface. This model will be used to quantify the rate of infiltration for all cases, both with and without the Hanford Site engineered surface barrier.

The migration of contaminants through the partially saturated soil column (vadose zone) will be simulated using the PORFLO-3 and/or VAM2DH unsaturated groundwater flow and transport models. The rate at which water flows through the soil is a function of hydraulic conductivity. For most soils, the hydraulic conductivity varies as a function of moisture content and this

Figure A-1. Single-Shell Tank Performance Assessment Model.



characteristic must be measured. Typically, a moisture retention curve is constructed and the hydraulic conductivity is predicted analytically usingvarious formulations. In addition to water movement, the rate at which specific contaminants move through the soils, is a function of their chemical interaction or adsorption with the soil. In most performance assessments, the adsorption is assumed to vary with each contaminant; but for each contaminant, it is assumed to be constant throughout the spacial domain. This could be a misleading or erroneous assumption and, consequently, a provision has been included to use state-of-the-art models to assess the geochemical interaction. The MINTEQ and EQ3/EQ6 geochemical equilibrium models will be used to investigate this assumption. Again, laboratory analysis and field-scale measurements on the rate of contaminant migration are required to quantify the transport parameters.

The transport of contaminants in saturated sediments, that is, unconfined aquifer, could be simulated using the VTT and/or CFEST groundwater flow and transport model. Selection of these models, rather than using PORFLO-3 and/or VAM2DH, will depend primarily on scale. For larger areas, it may be more cost effective to use the VTT or CFEST models.

From a performance assessment perspective, the output of primary interest from the unsaturated or saturated groundwater flow and transport models is the calculated concentration for each of the contaminants as a function of time and space. Depending upon the scenario analyzed (e.g., point of compliance), the calculated concentration will be provided at the point of interest and these concentrations will be used to calculate the risk to human health and the environment. The radiological risk to human health will be evaluated using the Hanford Site radiological dose assessment model GENII. The risk to human health resulting from hazardous chemicals will be assessed using the U.S. Environmental Protection Agency guidelines. The RAPS/MEPAS model is presently being evaluated as a means of expediting these calculations. The methods that will be used to quantify environmental risk have not been defined.

A summary of each model identified in Figure A-1 is provided in this Appendix A and includes a brief description of each model, operational status, testing and documentation, as well as a discussion of data required to support the model use.

UNSAT-H

DESCRIPTION

UNSAT-H simulates the dynamic process of infiltration, drainage, evaporation, soil heat flow, surface-energy balance, and water uptake by plants. The model employs the use of one-dimensional unsaturated flow, diffusion of water vapor, and heat conduction. The model was developed by the Pacific Northwest Laboratory (PNL) to specifically quantify the air-soil-water balance in arid environments.

OPERATIONAL STATUS

Two versions of UNSAT-H are operational. Version 1.0 has been operational for several years. This version does not include heat flow. Solutions are obtained using finite-difference and Newton-Raphson integration techniques. Version 2.0 was recently developed and has been in operation since the spring of 1990. Both models are under configuration management at PNL.

TESTING AND DOCUMENTATION

The documentation (theory and user manual) are available for both models. Both models have been benchmark tested at PNL. An independent benchmark testing of UNSAT-H is ongoing at Idaho National Engineering Laboratory. Results from use of UNSAT-H have been published extensively in the open literature.

Fayer, M. J., G. W. Gee, and T. L. Jones, 1986, *UNSAT-H Version 1.0: Unsaturated Flow Code Documentation and Application for the Hanford Site*, PNL-5899, Pacific Northwest Laboratory, Richland, Washington.

Fayer, M. J., and T. L. Jones, 1990, *UNSAT-H Version 2.0: Unsaturated Soil Water and Heat Flow Model*, PNL-6779, Pacific Northwest Laboratory, Richland, Washington.

DATA NEEDS

Soil Properties: moisture content vs. suction head, hydraulic conductivity vs. moisture content, thermal conductivity, volumetric heat capacity.

Meteorological Data: solar radiation, air temperature, wind speed, atmospheric vapor pressure, precipitation.

Plant Data: root length, leaf area, root density, fraction of vegetated surface area.

VAM2DH

DESCRIPTION

VAM2DH simulates water flow and solute transport in a variably saturated porous media. Flow and transport can be simulated concurrently or sequentially. The model simulates two-dimensional fluid flow and single-specie transport including decay. The model is used to simulate fluid flow and mass transport in two dimensions under partially or fully saturated conditions. The geologic media can be heterogeneous and anisotropic. Nonlinear geometries can be taken into consideration using the finite element construction. Version 5.0 was developed under the auspices of the U.S. Nuclear Regulatory Commission for use in assessments of low-level waste disposal.

OPERATIONAL STATUS

VAM2DH is a proprietary code. The Westinghouse Hanford Company has a license agreement with the developer, HydroGeoLogic, Inc., to use Version 1.0. Aspects of software quality assurance are being pursued at the Hanford Site for Version 1.0. Although Version 5.0 is available, the current agreement does not extend to use of this code.

TESTING AND DOCUMENTATION

The documentation (theory and users manual) are available for both versions of the code. Both models have been tested under various conditions. An independent third-party testing of the code is not available because of proprietary constraints. Results from application of VAM2DH have been published in the open literature.

Huyakorn, P. S., J. E. Buckley, J. B. Kool, and H. O. White, Jr., 1988, *VAM2DH: A Variably Saturated Flow and Transport Analysis Model in 2-Dimensions - Documentation and User's Manual*, Version 1.0, HydroGeologic, Inc., Herndon, Virginia.

DATA NEEDS

Soil Properties: moisture content vs. suction head, hydraulic conductivity vs. moisture content for each soil of interest, specific storage, effective porosity, saturated hydraulic conductivity components (Kxx, Kyy, Kxy).

Transport Properties: molecular diffusion coefficients (Dxx, Dyy), longitudinal and transverse dispersivity, decay coefficient, and effective retardation.

PORFLO-3

DESCRIPTION

PORFLO-3 simulates the flow and solute transport in a variable saturated porous media in three dimensions. The model calculates fluid flow, heat transfer, and mass transfer. The geologic media may be heterogeneous and anisotropic and contain linear and planar features. The model can be used to simulate conditions under partially and or fully saturated conditions with multiple sources (fluid, heat, and mass). Numerical solutions are obtained using finite-difference and nodal point integration techniques.

OPERATIONAL STATUS

PORFLO-3 is operational and has been used to support several environmental cleanup analyses performed recently at the Hanford Site. Version 1.0 is under configuration management at the PNL. The model was developed by Analytic and Computational Research, Inc., who maintains intellectual property rights concerning its use. The model is available to support U.S. Department of Energy (DOE) work at the Hanford Site.

TESTING AND DOCUMENTATION

The documentation (theory and users manual) is available. The model has been verified and benchmarked. Independent third-party testing has been performed at Idaho National Engineering Laboratory. Results from applications of PORFLO-3 have been published in the open literature.

Sagar, B., and A. K. Runchal, 1990, *PORFLO-3: A Mathematical Model for Fluid Flow, Heat, and Mass Transport in Variably Saturated Geologic Media, Theory and Numerical Methods*, Version 1.0, WHC-EP-0042, Westinghouse Hanford Company, Richland, Washington.

DATA NEEDS

Soil Properties: specific storage, density, total porosity, effective porosity, hydraulic conductivity vs. moisture content for all directions of interest, moisture content vs. suction head for all soils of interest.

Transport Properties: molecular diffusion coefficient for each species of interest in water, partition coefficient or retardation coefficient, longitudinal and transverse dispersivity.

Thermal Properties: specific heat for all media, thermal conductivity.

WASTE PACKAGE RELEASE MODELS

DESCRIPTION

The waste package release models that will be used initially are described in Appendix P of the HDW-EIS. These models are represented as analytical expressions, and include the following:

- Adsorption-Controlled Release
- Solubility-Controlled Release
- Dissolution-Controlled Release
- Diffusion-Controlled Release.

The Diffusion-Controlled Release model will be modified to account for diffusion-controlled release within the waste matrix. The current model only accounts for diffusion control resulting from transport through the soil.

OPERATIONAL STATUS

The models were independently reviewed before issuing the HDW-EIS. The models have not been computer encoded.

TESTING AND DOCUMENTATION

See "Description" and "Operational Status" (HDW-EIS).

DATA NEEDS

The contaminants and inventory of contaminants in the waste package must be specified. Information on leach rate and/or permeability of waste package is required to support use of the Adsorption-Controlled model. Information on the diffusional transport of species through soil is required. An effective diffusion coefficient (liquid and/or solid) for each species and each waste package of interest must be specified.

CFEST

DESCRIPTION

CFEST is a coupled fluid flow, thermal, and solute transport (one specie) three-dimensional model that can be used to simulate groundwater flow and contaminant transport in a porous saturated media. It treats single-phase Darcy flow in one, two, or three dimensions. Aquifer properties (porosity, permeability, and thickness) may be space-dependent. Fluid and porous media properties are assumed to be constant with time. The model is an extension of the finite-element three-dimensional groundwater code (FE3DGW) that has been used for many years.

OPERATIONAL STATUS

The model is under configuration control at the PNL. The model represents a Hanford Site standard and has been calibrated to Hanford Site conditions. The model has been used extensively at the Hanford Site and throughout this country.

TESTING AND DOCUMENTATION

The documentation (theory and users manual) is available. The model is under configuration control at the PNL.

Gupta, S. K., C. R. Cole, C. T. Kincaid, P. R. Meyer, and C. A. Newbill, 1982, *A Multi-Dimensional Finite Element Code for the Analysis of Coupled Fluid, Energy, and Solute Transport (CFEST)*, PNL-4260, Pacific Northwest Laboratory, Richland, Washington.

DATA NEEDS

Soil Properties: permeability, porosity, specific storage, and dispersivities.

Transport Properties: molecular diffusion coefficient in water, retardation coefficient.

Thermal Properties: thermal conductivity, heat capacity.

VTT

DESCRIPTION

VTT is a two-dimensional saturated groundwater flow model that was developed at the Hanford Site in support of past operations. Results from VTT are used to provide estimates of contaminant migration assuming one-dimensional transport along a calculated pathline using the TRANSS algorithm. For situations requiring an assessment of contaminant migration in the aquifers beneath the Hanford Site, use of the VTT/TRANSS model has usually been replaced with CFEST.

OPERATIONAL STATUS

For years, VTT/TRANSS was accepted and, from a groundwater flow perspective, still remains the Hanford Site standard. The model is under configuration control at PNL. The model has been calibrated against the piezometric head data that have been collected across the Hanford Site.

TESTING AND DOCUMENTATION

The VTT model has been documented. Aspects of the numerical model have been verified extensively over the years. As stated, the model has been calibrated to conditions at the Hanford Site.

Reisenauer, A. E., 1979, *Variable Thickness Transient Groundwater Flow Model*, Vol. 1-3, PNL-3160, Pacific Northwest Laboratory, Richland, Washington.

DATA NEEDS

Soil Properties: permeability (transmissivity), porosity.

Transport Properties: longitudinal dispersivity, effective retardation.

GENII

DESCRIPTION

The Hanford Environmental Dosimetry System (GENII) is composed of seven linked computer codes and their associated libraries. The system is used to calculate both external and internal exposure resulting from inhalation and ingestion of radionuclides. For performance assessment applications, source terms for GENII will be calculated externally using separate models as depicted in Figure A-1.

OPERATIONAL STATUS

GENII was developed to integrate and standardize the assessment of radiological doses resulting from operations and disposal of nuclear waste at the Hanford Site. The model is under configuration management at PNL. The model is used by all Hanford Site contractors.

TESTING AND DOCUMENTATION

The model has been extensively documented and is used routinely in support of the Hanford Site programs.

Napier, B. A., R. A. Peloquin, and J. V. Ramsdell, D. L. Strenge, 1988, *Hanford Environmental Dosimetry Upgrade Project: GENII - The Hanford Environmental Radiation Dosimetry Software System*, PNL-6584 Vol. 1-3, Pacific Northwest Laboratory, Richland, Washington.

DATA NEEDS

The concentration of radioactive contaminants in the various transport media are calculated external to GENII. GENII is used to calculate the various exposures (doses) for various scenarios that will be specified. Generally speaking, the information required to run GENII will not be derived directly through characterization activities.

GEOCHEMICAL MODELS
(EQ3/EQ6, MINTEQ)

DESCRIPTION

The specific need for and use of these geochemical models has not been identified at this time. However, their use is considered an option and may be required depending on how the field characterization and laboratory analysis proceeds. As envisioned, EQ3/EQ6 will be used to predict the equilibrium distribution of aqueous species and mineral phases given a system or solution of constituents. MINTEQ will be used to model the surface chemistry or sorptive reactions given the equilibrium conditions calculated by EQ3/EQ6.

OPERATIONAL STATUS

Both computer codes are operational at Westinghouse Hanford Company. However, neither code is currently under configuration management. Both codes are widely used throughout the industry.

TESTING AND DOCUMENTATION

Both codes are extensively documented and have undergone considerable testing. Models contained in each of these codes are in various stages of validation.

Wolery, T. J., 1979, *Calculation of Chemical Equilibrium Between Aqueous Solutions and Minerals: The EQ3/6 Software Package*, UCRL-52658, Lawrence Livermore National Laboratory, Livermore, California.

Felmy, A. R., D. C. Girvin, and E. A. Jenne, 1984, *MINTEQ - A Computer Program for Calculating Aqueous Equilibria*, EPA 600/3-84-032, U.S. Environmental Protection Agency, Washington, D.C.

DATA NEEDS

Characterization will provide a definition of the system to be studied, i.e., groundwater chemistry, contaminants of interest, soil chemistry. The specific data required to operate the geochemical models will be derived from literature, for example, thermodynamic information, equilibrium constants, stoichiometric information, information on reactants (surface area), composition of groundwater, Eh, and pH.

MEPAS

DESCRIPTION	The Multimedia Environmental Pollutant Assessment System (MEPAS) is a computer code that was developed to quantify the relative impacts to humans resulting from the release of various contaminants into the environment. The computer code can be used to assess the impacts associated with the release of both hazardous chemicals and radioactive materials. The various models contained within MEPAS are used to predict contaminant concentrations in the environment, and these estimated concentrations are used to estimate potential health effects for major exposure pathways.
OPERATIONAL STATUS	MEPAS is operational and has been used by the DOE and the EPA as a tool for both screening and prioritization of proposed cleanup actions.
TESTING AND DOCUMENTATION	The computer code has been extensively documented and tested. The code is being used to define the priority analytes and provide a basis for defining sampling needs, i.e., waste tank characterization. Droppo, J. G., R. D. Brockhaus, J. W. Buck, B. L. Hoopes, D. L. Strenge, M. B. Walter, and G. Whelan, 1989, "Multimedia Environmental Pollutant Assessment System (MEPAS) Application Guidance, PNL-7216, Vol. 1-2, Pacific Northwest Laboratory, Richland, Washington.
DATA NEEDS	Data needs include physical and chemical properties of organic and inorganic compounds, transfer coefficients and bioconcentration factors, half-life data for radioactive and non-radioactive constituents, noncarcinogenic and carcinogenic health factors, and radiation dosimetry factors.

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