1928/24

DOE/WIPP 89-011

DRAFT PLAN FOR THE WASTE ISOLATION PILOT PLANT TEST PHASE: PERFORMANCE ASSESSMENT AND OPERATIONS DEMONSTRATION

APRIL 1989

UNITED STATES DEPARTMENT OF ENERGY
WASTE ISOLATION PILOT PLANT
CARLSBAD, NEW MEXICO

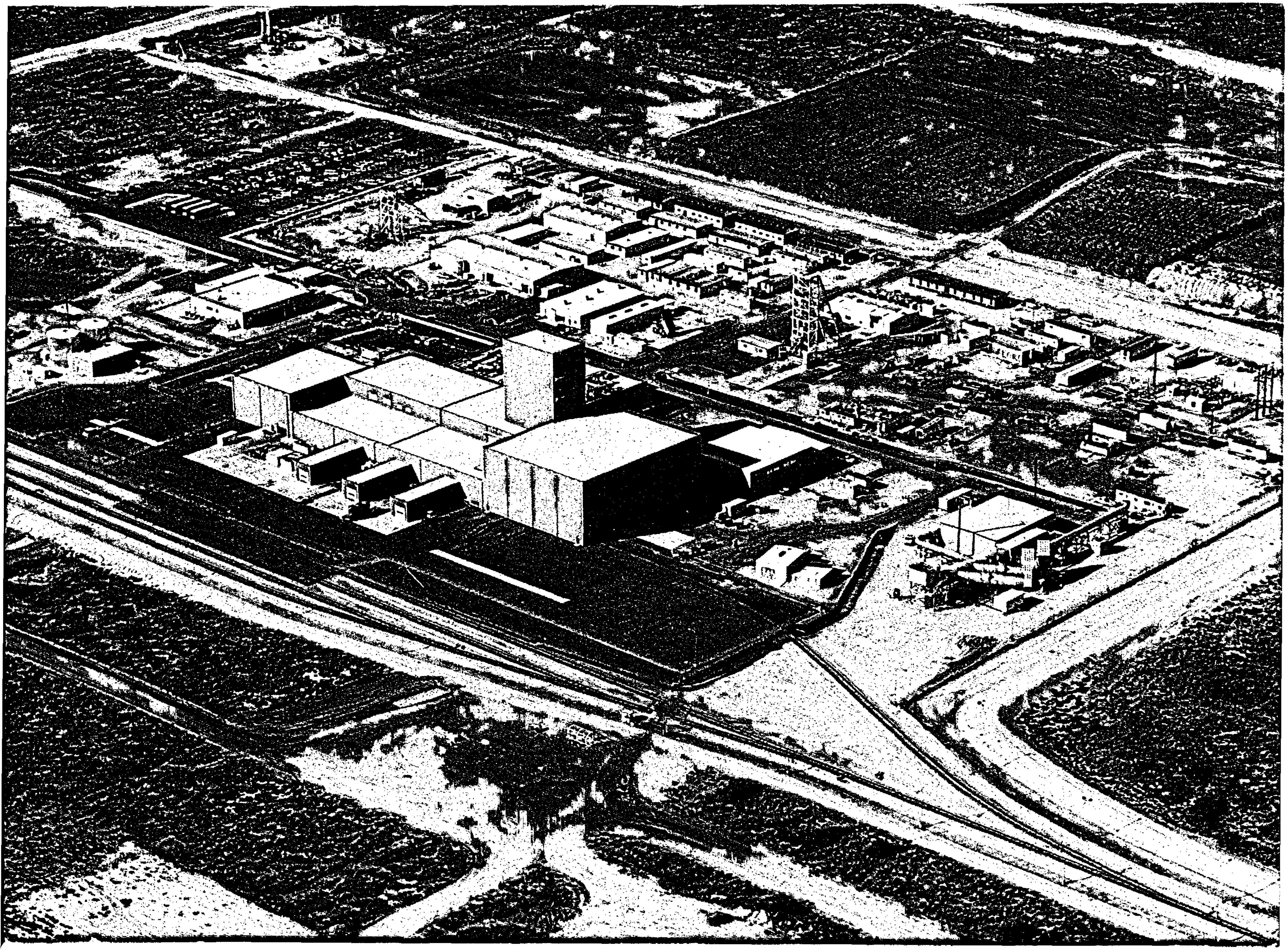
109.5

This report has been reproduced directly
from the best available copy.

Available to DOE and DOE contractors from the
Office of Scientific and Technical Information,
P. O. Box 62,
Oak Ridge, TN 37831;
prices available from
(615) 576-8401, FTS 626-8401.

Available to the public from the
National Technical Information Services,
U. S. Department of Commerce,
5285 Port Royal Rd.,
Springfield, VA 22161

Price: Printed Copy
Microfiche A01



Waste Isolation Pilot Plant — December 1988

Department of Energy
Washington, DC 20585

Notice to Reader

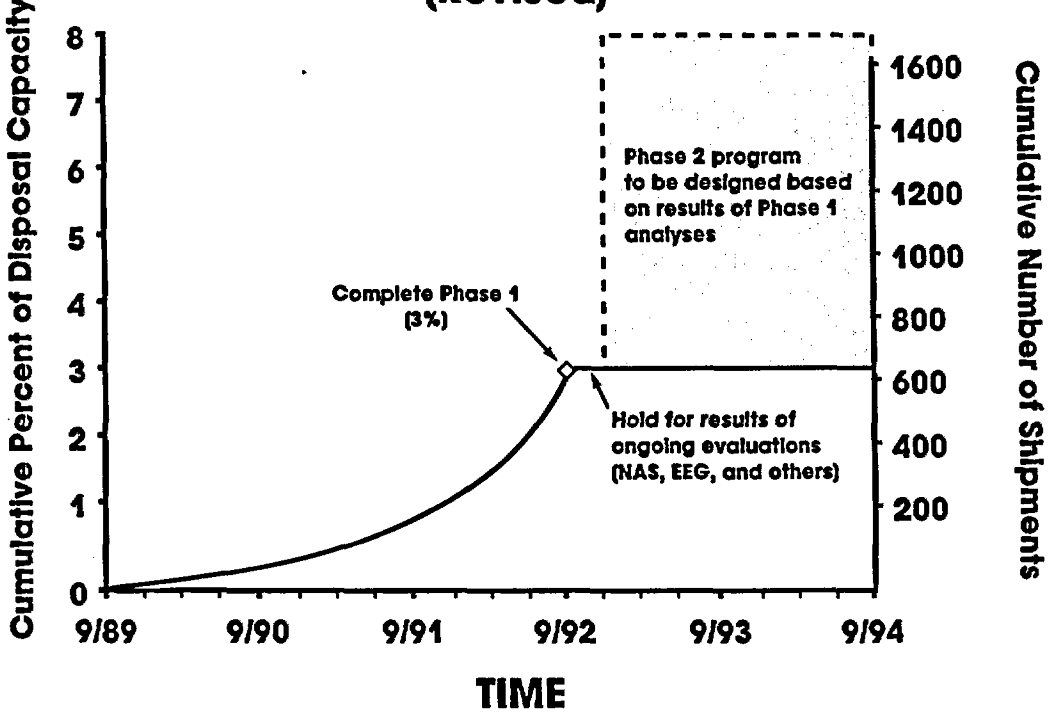
During the Secretarial review of this Test Plan, the adequacy of the proposed approach was reaffirmed. The emplacement of waste in WIPP is necessary to determine that compliance requirements can be met and that the entire TRU waste management system can be operated safely. However, the concern was raised that the amount of waste emplaced should be minimized.

It was determined, therefore, to limit the amount of waste to 3% of WIPP's capacity prior to the holdpoint in 1992. This change will not affect the test activities planned to demonstrate EPA compliance and will still provide credible scientific, geotechnical and operational results. Additional waste beyond the 3% will not be emplaced unless the results of on-going independent evaluations confirm that there is sufficient confidence that the EPA disposal standard can be met.

This plan is being released to obtain review of the specifics of the overall approach. When the review of the current plan is completed, a revised plan will be issued. The revised plan will incorporate comments as appropriate and will reflect the 3% waste limit prior to the 1992 holdpoint. It will also reflect that waste emplacment after the holdpoint would occur only with the Secretary's approval.

This change is described in the figure below:

WASTE EMPLACEMENT SCHEDULE
(Revised)



DOE/WIPP 89-011

DRAFT PLAN FOR THE WASTE ISOLATION PILOT PLANT TEST PHASE:

PERFORMANCE ASSESSMENT

AND OPERATIONS DEMONSTRATION

April 1989

UNITED STATES DEPARTMENT OF ENERGY
WASTE ISOLATION PILOT PLANT
CARLSBAD, NEW MEXICO

The U.S. Department of Energy
acknowledges significant contributions
from the following organizations
during preparation of this Plan.

Sandia National Laboratories
Westinghouse Electric Corporation
IT Corporation

FOREWORD

The mission of the Waste Isolation Pilot Plant (WIPP) Project, established by Public Law 96-164, is to provide a research and development facility to demonstrate the safe disposal of transuranic (TRU) radioactive wastes resulting from United States defense programs. With the Construction Phase of the WIPP facility nearing completion, WIPP is ready to initiate the next phase in its development, the Test Phase. The purpose of the Test Phase is to collect the necessary scientific and operational data to support a determination whether to proceed to the Disposal Phase and thereby designate WIPP a demonstration facility for the disposal of TRU wastes. This decision to proceed to the Disposal Phase is scheduled for consideration by September 1994. Development of the WIPP facility is the responsibility of the United States Department of Energy (DOE), whose Albuquerque Operations Office has designated the WIPP Project Office as Project Manager.

This document describes the two major programs to be conducted during the Test Phase of WIPP: (1) Performance Assessment for determination of compliance with the Environmental Protection Agency Standard, 40 CFR 191, Subpart B, Sections 13 and 15, and (2) Operations Demonstration for evaluation of the safety and effectiveness of the DOE TRU waste management system's ability to emplace design throughput quantities of TRU waste in the WIPP facility. The Plan is a living document, and it will be reassessed and revised periodically based on review comments and the future needs of the Project.

TABLE OF CONTENTS

TABLE OF CONTENTS (Concluded)

LIST OF TABLES

LIST OF FIGURES

EXECUTIVE SUMMARY

The United States Department of Energy (DOE) has the responsibility to manage the disposition of transuranic (TRU) wastes resulting from nuclear weapons production activities of the United States. These wastes are currently stored nationwide at the DOE's waste generating and storage sites. The goal is to eliminate interim waste storage and achieve environmentally acceptable disposal of these TRU wastes. The Waste Isolation Pilot Plant (WIPP) in southeastern New Mexico is being considered as a disposal facility for these TRU wastes.

With the Construction Phase of the WIPP facility nearing completion, WIPP is ready to initiate the next major phase in its development, the Test Phase. This document, *Draft Plan for the Waste Isolation Pilot Plant Test Phase: Performance Assessment and Operations Demonstration* (hereafter referred to as the Plan), describes the two primary programs to be performed during the Test Phase of WIPP: (1) determination of the long-term performance of the WIPP disposal system in accordance with the requirements of the Environmental Protection Agency (EPA) Standard, 40 CFR 191, Subpart B, Sections 13 and 15, and (2) evaluation of the safety and effectiveness of the DOE TRU waste management system's ability to emplace design throughput quantities of TRU waste in the WIPP underground facility.

The Test Phase is scheduled to begin in September 1989 with the first receipt of waste for gas generation tests and operational demonstrations. The Test Phase waste emplacement will be conducted in two parts. The first part involving waste tests and demonstrations in Panel 1 will be completed by September 1992. At that time, a holdpoint will be initiated to assess the ability of the WIPP disposal system to satisfy the EPA Standard, 40 CFR 191, Subpart B, and to assess the TRU waste management system operations. This assessment will determine whether to proceed to the second part of the Test Phase involving Panel 2 waste emplacement. At the conclusion of the Test Phase, the WIPP facility will be evaluated to determine whether it is suitable for disposal of TRU waste. If WIPP is judged to be suitable, the Disposal Phase (an additional 20 years of operation) would then be initiated to demonstrate disposal of current and future TRU waste meeting the requirements of the WIPP Waste Acceptance Criteria.

The purpose of this Plan is to provide a programmatic document to guide the completion of the two major programs of the Test Phase. Specific Project documents have been, or will be, developed to provide the detailed plans necessary to implement this phase.

TRANSURANIC WASTE MANAGEMENT SYSTEM

The DOE TRU waste management system consists of the facilities or sites that generate and/or store TRU waste, a transportation system for shipment of TRU waste, and the WIPP facility to demonstrate deep geologic disposal.

Ten DOE sites generate or store TRU waste and may ship waste to the WIPP facility. The containers used for shipping the TRU waste will be certified by the Nuclear Regulatory Commission. These shipments will be monitored by a satellite-based tracking system. All sites have developed, or will develop, plans and procedures to certify that waste shipped to the WIPP facility meets the requirements of the WIPP Waste Acceptance Criteria. In addition, the sites will meet the requirements of the National Environmental Protection Policy Act and the packaging requirements imposed by the Nuclear Regulatory Commission's Certificate of Compliance for waste shipping containers. Two of the sites will provide the majority of waste to the WIPP facility during the Test Phase. The Idaho National Engineering Laboratory will ship stored contact-handled (CH) and remotely-handled (RH) TRU wastes and the Rocky Flats Plant will ship newly generated CH-TRU waste. Other sites may also ship waste to the WIPP facility during the Test Phase, but in much smaller quantities.

The mission of WIPP as established by Congress in 1979 (Public Law 96-164) is "...for the express purpose of providing a research and development facility to demonstrate the safe disposal of radioactive wastes resulting from the defense activities and programs of the United States exempted from regulation by the Nuclear Regulatory Commission." The Final Environmental Impact Statement on the WIPP Project was completed in 1980, and in January 1981, a Record of Decision (pursuant to regulations of the Council on Environmental Quality for implementation of the National Environmental Policy Act) was issued to proceed with WIPP. The fundamental responsibility of the mission, to demonstrate safe disposal, is being fulfilled in a phased stepwise approach, leading up to the decision whether to designate WIPP a disposal facility. The WIPP Project is in transition from the Construction Phase to the Test Phase. However, prior to initiation of the Test Phase, the following must occur: land withdrawal must be resolved, the Final Safety Analysis Report approved, a Resource Conservation and Recovery Act (RCRA) No-Migration Variance granted, the TRUPACT II Certificate of Compliance obtained, and the Supplement to the Final Environmental Impact Statement completed and Record of Decision issued. Major aspects of WIPP's development have been reviewed by the State of New Mexico's Environmental Evaluation Group and by the National Academy of Sciences WIPP Panel.

The WIPP facility consists of both surface and underground facilities (Figure ES-1). The principal surface structure is the Waste Handling Building. In the Waste Handling Building, both CH-TRU and RH-TRU waste containers will be inspected and then transferred underground for emplacement. The air pressure in all radioactive materials areas of the Waste Handling Building is maintained at a slightly negative pressure relative to outside atmospheric pressure and this air is continuously filtered through high efficiency particulate air filters before it is exhausted from the building. This is a safety measure that will ensure radioactive containment in the event of an accident.

The underground facility is at one mined level about 2,150 ft (655 m) below the surface, located in the middle of the 2,000-ft (600-m) thick bedded salt of the Salado Formation. This 225-million-year-old formation contains halite (salt) with minor amounts of impurities. Four shafts connect the surface to the underground: the Salt Handling Shaft for removing mined salt, the Air Intake and Exhaust Shafts for ventilation, and the Waste Handling Shaft for transporting waste. The design for the underground waste disposal area at the WIPP facility consists of eight panels of seven disposal rooms each. Each room will be 13 ft (4 m) high by 33 ft (10 m) wide by 300 ft (91 m) long. For final disposal, CH-TRU waste drums and boxes will be stacked in the waste disposal rooms and covered with backfill, and RH-TRU canisters will be placed in horizontal boreholes drilled into the walls of the disposal rooms. However, to ensure retrievability during the Test Phase, the CH-TRU waste containers will not normally be

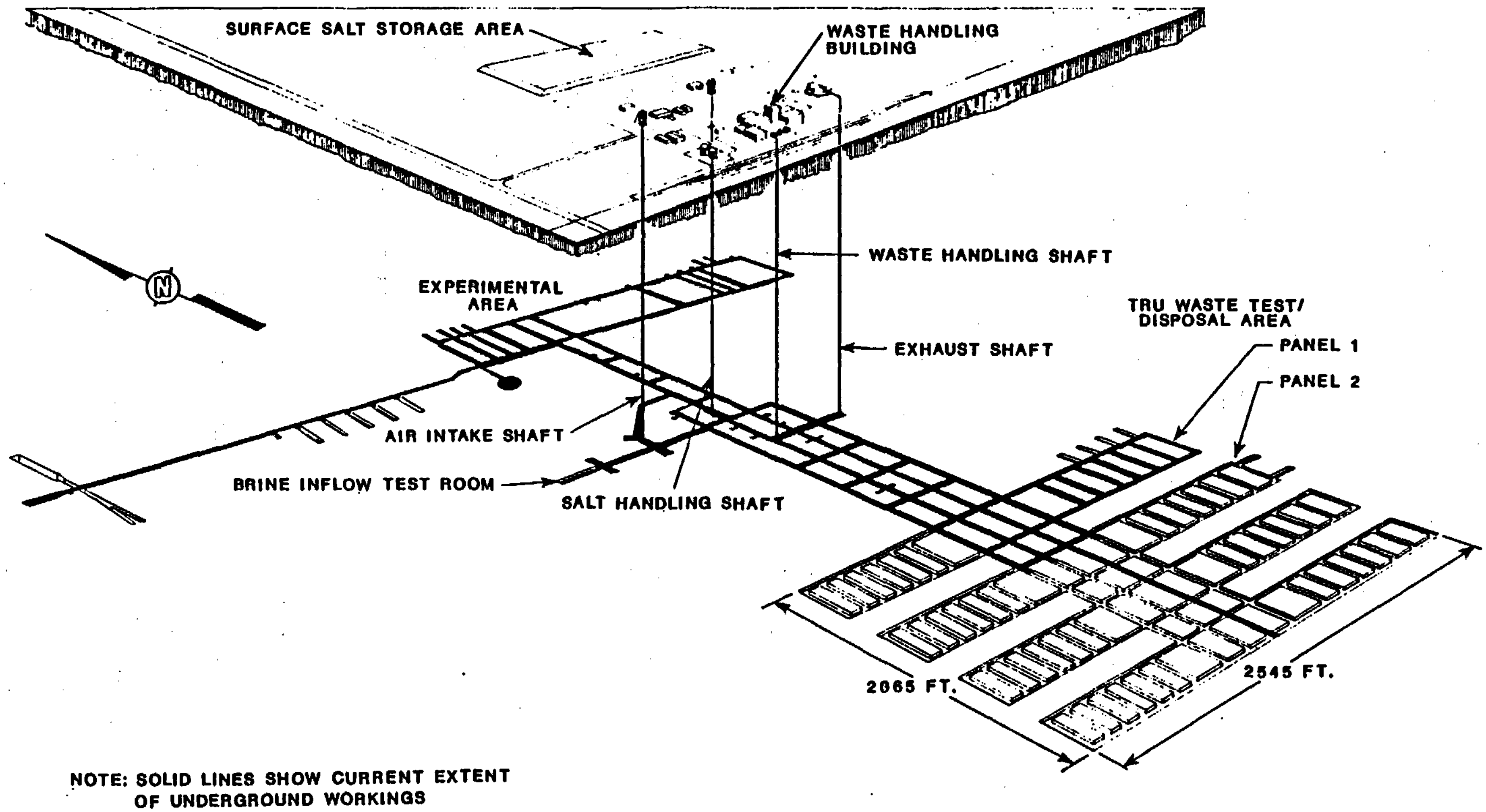


Figure ES-1. The WIPP Facility

covered with backfill, and RH-TRU waste canisters will be retrievably emplaced in steel sleeves in each of the horizontal emplacement holes.

OBJECTIVES OF THE WIPP TEST PHASE

The purpose of the Test Phase is to further the intent of Congress to demonstrate safe disposal of defense wastes and thereby establish a disposal facility for TRU wastes. The activities that will provide the needed information include experiments, analysis, and operations at the WIPP facility as well as evaluation of transportation and waste generating/storage site operations. During the Test Phase, a maximum of eight percent of the WIPP disposal area design capacity, or approximately 500,000 cubic feet of waste, will be used for testing and operational demonstrations. Included within this amount is less than one percent (of the design capacity) for gas generation tests in support of compliance with the EPA Standard, 40 CFR 191, Subpart B. Waste emplaced in the WIPP facility during the Test Phase will be retrievable until a decision is made whether WIPP should become a disposal facility. During the Test Phase, per agreement with the State of New Mexico, WIPP will meet the requirements of the EPA Standard, 40 CFR 191, Subpart A.

The two primary objectives of the Test Phase are to demonstrate:

1. Reasonable assurance of compliance of the WIPP disposal system (the combination of the repository/shaft system and the controlled area) with the long-term disposal standards of the EPA Standard, 40 CFR 191, Subpart B, Sections 13 and 15. Compliance of the disposal system will be determined based on a performance assessment.

2. The ability of the DOE TRU waste management system (the generating/storage sites, the transportation system, and the WIPP facility) to safely and effectively certify, package, transport, and emplace waste at the WIPP facility. Acceptability of the waste management system will be evaluated by operations testing and monitoring, both individually and collectively, of the elements of the TRU waste management system.

These objectives are consistent with the Congressional guidance to demonstrate the safe disposal of TRU waste. Both objectives will be accomplished by conducting activities in parallel with full assurance of safe operations and protection of the environment. Figure ES-2 depicts the process leading to a decision whether WIPP should be designated a TRU waste disposal facility and proceed to the Disposal Phase.

DESCRIPTION OF TEST PHASE ACTIVITIES

The objectives will be accomplished by completion of two important programs - Performance Assessment and an Operations Demonstration. These two programs, which are described below, will provide the necessary information to determine compliance of the disposal system with the EPA Standard and to evaluate the safety and effectiveness of the TRU waste management system operations.

<u>PERFORMANCE ASSESSMENT</u> - The performance objective for the WIPP disposal system is to adequately isolate TRU waste from the accessible environment; the performance requirements are reasonable assurance of compliance with the

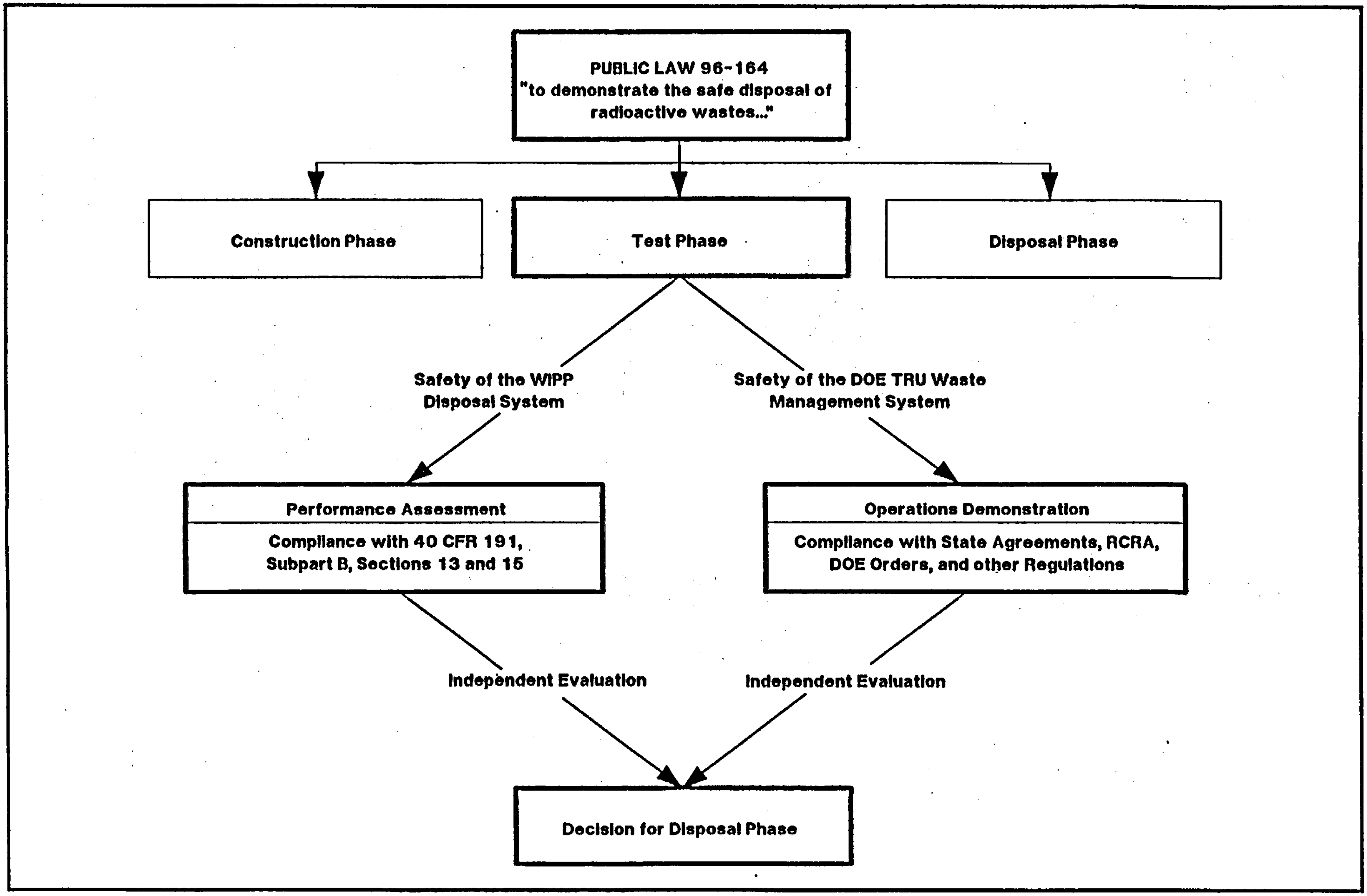


Figure ES-2. Process for Disposal Phase Decision

10,000-year release limits and the 1,000-year dose limits of the EPA Standard, 40 CFR 191, Subpart B, Sections 13 and 15. The 10,000-year performance assessment will predict cumulative releases of radionuclides to the accessible environment resulting from both disturbed and undisturbed performance of the disposal system. The 1,000-year performance assessment will predict annual doses to members of the public in the accessible environment resulting from undisturbed disposal system performance. It will not address the concentration limits established by Subpart B for special sources of ground water because no such sources exist at WIPP. In evaluating compliance with Subpart B, the guidance provided in an appendix to the Standard will be followed. To ensure that all plausible responses are identified, scenarios have been developed by coupling the individual events and processes that occur. To date, over 100 scenarios have been identified. Scenarios are screened by removing those that fall outside the bounds set by the Standard. This process has reduced the number of scenarios of interest to 76; these will continue to be screened during the performance assessment process.

Consequence analysis is used to calculate a performance measure for each of the remaining significant scenarios. The performance measures for the scenarios are normalized, summed, and reported as a "complementary cumulative distribution function" of release probabilities. Uncertainties in the data must be included in calculations of the performance measure for each scenario. To show that WIPP can meet the annual dose limits set for 1,000-year performance, the Standard requires that releases from the undisturbed scenarios be analyzed. If any release to the accessible environment is predicted, transport along biological pathways is modeled and dose estimates are made. Uncertainties in the data are included in the dose calculations.

The performance assessment process is divided into five elements: scenario screening; repository/shaft system behavior and performance modeling; controlled area behavior characteristics and performance modeling; computational system development; and consequence analysis. The combined repository/shaft system and controlled area represent the disposal system being assessed.

Although Subpart B of the Standard was remanded to the EPA by the U.S. Court of Appeals for the First Circuit, this Plan addresses the Standard as first promulgated. The 1987 Second Modification to the Agreement for Consultation and Cooperation between the DOE and the State of New Mexico (1981) commits the WIPP Project to evaluate compliance with the Standard as first promulgated until a revised Standard becomes available. Compliance plans for the WIPP facility will be revised as necessary in response to any changes in the Standard.

The performance assessment process is scheduled to be completed and a Draft 40 CFR 191 Compliance Report issued by September 1992. The draft report will be available for review by the EPA, the State of New Mexico's Environmental Evaluation Group, the National Academy of Science WIPP Panel, and other appropriate organizations. The Final 40 CFR 191 Compliance Report will be issued in September 1993.

Support for the Performance Assessment Process

Accurately simulating behavior of the disposal system requires technical data derived from experiments conducted in the laboratory as well as in the WIPP underground. Such scientific investigations have been conducted since 1975.

These studies have resolved many technical issues and have focused attention on aspects still requiring investigation.

There are four major areas of scientific investigation integral to the assessment of disposal system performance. These areas examine the behavior of the disposal room and drift system, the sealing system, structural and fluid-flow behavior of the Salado Formation, and non-Salado hydrology and radionuclide migration. Investigation of these areas involves both laboratory and large-scale underground tests.

An important parameter of the disposal room and drift system is gas generation. Gaseous products will be generated by microbial and radiolytic decomposition of the TRU waste and corrosion of the waste containers. Gas generation tests with actual TRU waste are required to accurately characterize the behavior of the disposal system under realistic conditions. These tests consist of laboratory tests using radioactive and nonradioactive simulated wastes, bin-scale tests with CH-TRU waste, and room-scale or alcove tests with CH-TRU waste. These tests will provide the data and models needed to evaluate the effects of gas generated by the waste in realistic environments for both the operational (short-term) period and the postoperational (long-term) period. Collection of this information is necessary for application in the performance assessment process to obtain results with a sufficient level of confidence to demonstrate compliance with the EPA Standard. The waste quantities required for these tests represent less than one percent of the WIPP disposal area design capacity.

<u>OPERATIONS DEMONSTRATION</u> - The performance objective of the TRU waste management system is to safely and effectively emplace certified waste at the WIPP facility. Key elements of the Operations Demonstration are waste certification and packaging at the generating/storage sites, the operation of the transportation system, and operation of the WIPP facility. This demonstration is integrated; it includes all elements of the TRU waste management system and requires both CH- and RH-TRU waste operations. Operational data needs include results from the evaluation of the safety, environmental adequacy, and effectiveness of operations that will certify, transport, and emplace waste at the WIPP facility. The goal of the Operations Demonstration is to provide assurance that operations can be conducted within the limits of all applicable regulatory, technical, industrial, and managerial criteria.

The planned sequence of operations is analogous to those used in the nuclear and nonnuclear industries after preoperational testing but before full operations begin. The Operations Demonstration builds upon the results of previously performed facility and operations readiness activities. Although individual parts of the system have been tested to ensure that they function as designed, industrial practice suggests that it is prudent to test the entire system at increasing waste receipt rates culminating in a sustained operations test at design waste throughput rates.

The three elements of the Operations Demonstration are:

<u>Waste Generating/Storage Site Operations</u> - TRU waste is being generated or stored at ten DOE sites nationwide. These sites have been fully operational for a number of years and may ship TRU waste to the WIPP facility on a regular basis if WIPP is designated a TRU waste disposal facility. Waste management, prior to shipment to the WIPP

site, is the responsibility of the individual waste generating/storage sites. However, specific site operations pertaining to waste transportation and certification of waste for WIPP are unique and are included in the Operations Demonstration so that overall safety and effectiveness can be evaluated. The principal sites shipping waste to WIPP during the Test Phase will be the Rocky Flats Plant and the Idaho National Engineering Laboratory.

Transportation System - The transportation system employed for shipment of waste to WIPP is highly visible; it involves interstate movement of TRU waste in newly designed waste shipping containers which will be certified by the Nuclear Regulatory Commission. CH-TRU waste will be shipped in TRUPACT IIs, and RH-TRU waste will be shipped in RH-TRU waste shipping casks. The transportation system includes the use of a satellite tracking system, known as the TRANSportation COMmunications System (TRANSCOM), for monitoring shipments. Access to information from this system will be made available to officials in New Mexico, other corridor states, and to Indian Tribes/Pueblos upon request.

WIPP Facility Operations - The Operations Demonstration will evaluate overall safety and effectiveness of operations at the WIPP facility, compliance with environmental requirements, and compliance with applicable regulations and DOE Orders. Waste management operations at WIPP include waste container receipt, waste unloading, and waste transfer to the underground area. The interaction and integration of surface and underground facilities will be evaluated as the rates of waste receipt are increased to design throughput during the demonstration. Further, this evaluation will include the concurrent handling of both CH- and RH-TRU wastes at rates up to those representing design throughput rates. These waste emplacement operations will be performed concurrently with mining operations. Activities will be documented and analyzed to accumulate a safety, productivity, schedule, and operability data base.

The Operations Demonstration will be conducted in two parts, separated by a two-month "holdpoint" to collectively assess conclusions derived from the Performance Assessment Program and the first part of the Operations Demonstration (Panel 1). To begin the Test Phase, TRU waste for the gas generation tests will be emplaced in test alcoves which are about one-fourth the size of a typical room. Subsequently, CH-TRU waste will be certified, transported, and emplaced in full-sized underground rooms. The first part of the Demonstration, which includes waste for the gas generation tests in Panel 1, will consist of emplacing up to approximately 4.4 percent of the WIPP disposal area design capacity. This CH-TRU waste is scheduled to be emplaced by September 1992 in seven test rooms and three test alcoves in Panel 1. If at the conclusion of the holdpoint it is determined that sufficient confidence is established in the ability to demonstrate compliance with the EPA Standard, and that the TRU waste management system operations are functioning as designed, then the second part of the Operations Demonstration would begin with waste emplacement in Panel 2. Part two will require approximately 3.6 percent of the CH-TRU waste disposal area design capacity and 50 canisters of RH-TRU waste and will occupy six full-sized test rooms and two test alcoves in Panel 2.

Throughout the Operations Demonstration, there are designated checkpoints for analysis and review of safety, environmental, and operational factors, and reporting of monitoring activities. These checkpoints are part of a continuous evaluation of operations and will apply to each element of the waste management system. The purpose of these checkpoints is to provide a basis for WIPP management to determine whether to proceed as planned, or to modify plans based on experience gained.

SUMMARY

DOE must have reasonable expectation, based upon a performance assessment, that WIPP will comply with the EPA Standard, 40 CFR 191, Subpart B, Sections 13 and 15, prior to a determination whether WIPP should become a TRU waste disposal facility. In addition, the DOE is committed to evaluating the safety and effectiveness of the TRU waste management system operations. The intent of the Test Phase is to provide information for the assessment whether WIPP complies with the EPA Standard and whether the overall TRU waste management system can operate in a manner consistent with applicable requirements. In both cases, careful assessment of the data, adoption of modifications if necessary, and adherence to a conservative stepwise approach will be the strategy employed. The Test Phase represents a prudent approach consistent with the start-up of a first-of-a-kind nuclear facility.

A final report of the Test Phase activities and results will be issued in June 1994. This report will summarize the relevant data from the Performance Assessment and Operations Demonstration Programs and will be available for external, independent review by the EPA, the National Academy of Sciences WIPP Panel, the State of New Mexico's Environmental Evaluation Group, and other appropriate organizations. A decision whether WIPP should proceed from the Test Phase to the Disposal Phase is scheduled for consideration by September 1994.

1.0 INTRODUCTION

The United States Department of Energy (DOE) has the responsibility to plan, develop, and implement a long-term defense transuranic (TRU) waste management program. The capabilities must be technically feasible and effective, and economically and institutionally acceptable. TRU waste generated from nuclear weapons production activities is currently stored nationwide at various DOE waste generating/storage sites. The DOE's goal is to end interim storage and achieve permanent disposal of TRU waste. This will not only alleviate short-term storage problems, but also provide environmentally sound, permanent disposal of TRU waste. The primary DOE TRU waste management system components are the TRU waste generating/storage sites, a transportation system, and the Waste Isolation Pilot Plant (WIPP), a first-of-a-kind facility to demonstrate deep geologic disposal. Figure 1-1 shows the location of the TRU waste generating/storage sites and the WIPP site.

In 1979, Congress passed authorizing legislation for WIPP and established its mission in Public Law (PL) 96-164:

> "...the WIPP is authorized as a defense activity of the Department of Energy, administered by the Assistant Secretary of Energy for Defense Programs, for the express purpose of providing a research and development facility to demonstrate the safe disposal of radioactive wastes resulting from the defense activities and programs of the United States exempted from regulation by the Nuclear Regulatory Commission."

The Final Environmental Impact Statement (DOE, 1980) for the WIPP Project was completed in October 1980. Subsequently, a Record of Decision was announced on January 22, 1981, to proceed with WIPP, pursuant to regulations of the Council on Environmental Quality for implementation of the National Environmental Policy Act. A Supplement to the Final Environmental Impact Statement is being prepared to present information acquired since the January 1981 Record of Decision, to provide the public with information about the WIPP facility and its recent modifications, and to further the purposes of the National Environmental Policy Act through continued public involvement.

The fundamental responsibility of the mission, to demonstrate safe disposal, is being fulfilled using a stepwise, phased approach. Figure 1-2 is a flow diagram illustrating the development of the WIPP facility through several decision points leading to a decision whether to designate WIPP a disposal facility. The facility is now in transition from the Construction Phase to the Test Phase. During the Test Phase, the WIPP facility will be utilized to perform TRU waste gas generation tests and operations demonstrations with limited quantities of TRU waste to evaluate the technical and operational aspects of environmentally acceptable disposal of defense TRU waste. During the Test Phase, per agreement with the State of New Mexico, WIPP will meet the requirements of Subpart A of 40 CFR Part 191, the U.S. Environmental Protection Agency's [EPA] *Environmental Radiation Protection Standards for Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes* (the "Standard" [EPA, 1985]). All emplaced waste will be retrievable during the Test Phase (DOE, 1980). Before the Test Phase can be initiated, land withdrawal must be resolved, the Final Safety Analysis Report approved, a Resource Conservation and

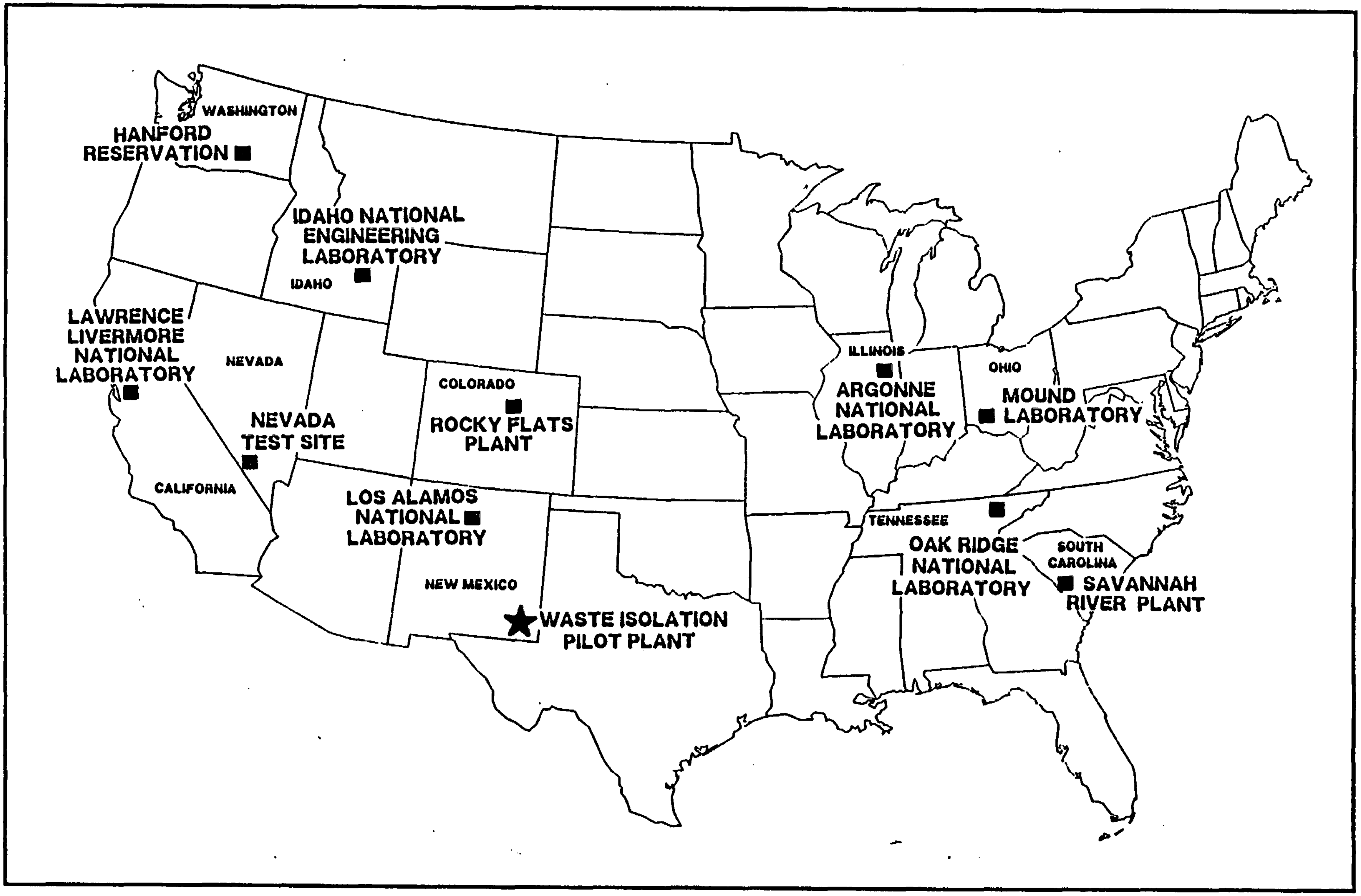


Figure 1-1. Location of the WIPP and Waste Generating/Storage Sites

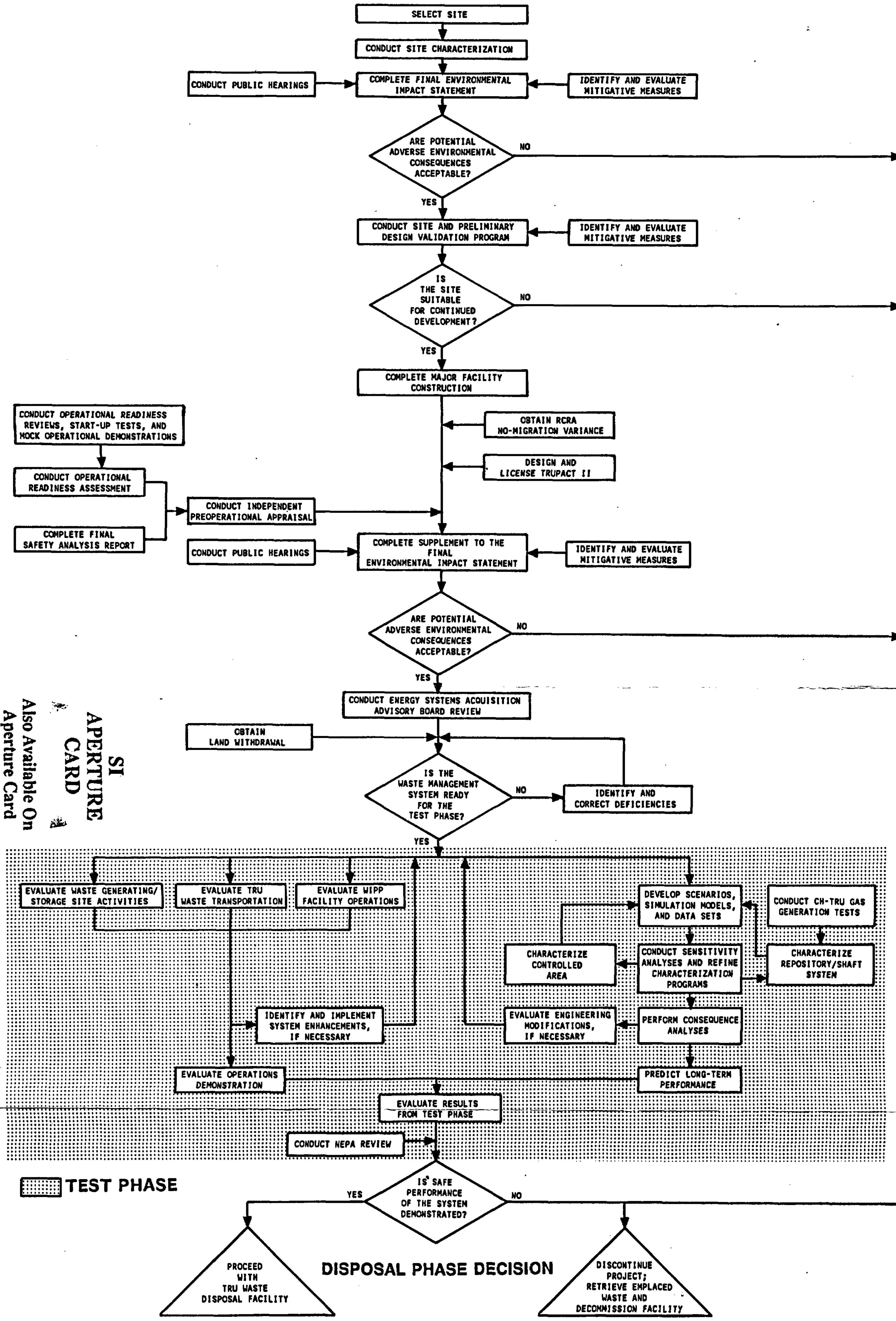


Figure 1-2. Flow Diagram of WIPP Development from Site Selection to the Disposal Phase Decision

Recovery Act (RCRA) No-Migration Variance granted, the TRUPACT II Certificate of Compliance obtained, and the Supplement to the Final Environmental Impact Statement completed and Record of Decision issued.

At the conclusion of the Test Phase, information acquired during this period, in conjunction with data collected earlier, will be evaluated to determine whether the WIPP facility is suitable as a disposal facility for TRU waste. If WIPP is judged to be suitable, the Disposal Phase (an additional 20 years of operation) would then be initiated to demonstrate disposal of current and future TRU waste that meets the WIPP Waste Acceptance Criteria. The WIPP Waste Acceptance Criteria (DOE, 1989a) were developed to certify that only waste with characteristics within certain bounding limits is qualified to be shipped to the WIPP facility. These criteria are being implemented at the TRU waste generating/storage sites. In addition, a transportation system is being prepared for operation that will use shipping containers certified by the Nuclear Regulatory Commission.

WIPP is designed for disposal of certified contact-handled (CH) and remotely-handled (RH) TRU wastes. The TRU waste to be shipped to WIPP is typically comprised of discarded material from defense weapons production and related processes. This material includes glassware, metal pipes, disposable laboratory clothing, cleaning rags, and solidified sludges, all contaminated with TRU elements. Much of the CH-TRU waste is packaged in 55-gallon (208-liter) metal drums; in the future, Standard Waste Boxes will be the primary package for the TRU waste. Some waste is presently stored in large metal boxes whose disposition will be evaluated at a later date. The external dose rate (≤14 mrem/h) from the CH-TRU waste drums and boxes, which constitutes 96 percent of the waste scheduled to be shipped to the WIPP facility, is such that workers may handle the containers without any special shielding precautions. Only 4 percent of the waste drums (RH-TRU) must be remotely handled; these drums are packaged in steel canisters for handling and in specially shielded casks for transportation.

The WIPP facility has been designed for an expected operating life of 25 years (per DOE Order 4700.1). The Test Phase will be initiated in September 1989 with the initial receipt of TRU waste for gas generation tests and operations demonstrations. During the Test Phase, approximately eight percent of the WIPP disposal area design capacity, or approximately 500,000 cubic feet of TRU waste, will be emplaced in Panels 1 and 2 of the WIPP underground facility. Tests which will support 40 CFR 191, Subpart B, Sections 13 and 15 compliance activities will use less than one percent of the WIPP disposal area design capacity. However, the entire amount of waste emplaced during the Test Phase will be utilized in the evaluation of the TRU waste management system operations. Chapter 2 and Appendix A of this document provide the rationale for the CH-TRU waste tests and information on the quantities and types of waste to be used. Chapter 3 discusses the waste quantities associated with the Operations Demonstration.

This document, *Draft Plan for the Waste Isolation Pilot Plant Test Phase: Performance Assessment and Operations Demonstration* (hereafter referred to as the Plan), identifies and describes the key programs to be completed during the Test Phase. These programs are: (1) Performance Assessment for assessing the long-term performance of the WIPP disposal system in accordance with the requirements of the EPA Standard, 40 CFR 191, Subpart B, Sections 13 and 15, and (2) Operations Demonstration for the evaluation of the safety and effectiveness of the TRU waste management system's ability to emplace design throughput quantities of TRU waste in the underground facility. This Plan is a programmatic document which provides an appropriate framework for achievement of the objectives of these programs. Planned activities are clearly delineated and integrated, but not detailed to the level of daily administration. Test plans have been, or will be, prepared to provide further levels of detail as necessary. Other subjects, such as quality assurance and safety, are mentioned but not discussed in detail in this Plan; however, each is thoroughly discussed in appropriate Project documents.

1.1 TRU WASTE MANAGEMENT SYSTEM

For the purposes of this Plan, the DOE TRU waste management system contains three components: the waste generating/storage sites, the transportation system, and the WIPP facility to demonstrate deep geologic disposal. Each is briefly discussed in this section; more detail is provided in Chapters 2 and 3 of this document. In addition, this section contains a brief summary of the WIPP Project development.

1.1.1 Generating/Storage Sites Description

There are ten generating/storage sites (Figure 1-1) within the DOE TRU waste management system. The primary shipping sites for the Test Phase will be the Idaho National Engineering Laboratory, which will ship stored CH- and RH-TRU wastes, and the Rocky Flats Plant, which will provide newly generated CH-TRU waste. Other sites may also ship waste during this period, but in much smaller quantities.

Each site that will ship waste to the WIPP facility must meet the requirements of the National Environmental Policy Act and has developed, or will develop, plans and procedures for certifying the waste in accordance with the WIPP Waste Acceptance Criteria. The sites are authorized to implement certification procedures which, together with records generated by the certification process and periodic audits, provide documented evidence and assurance that only waste meeting the Waste Acceptance Criteria will be shipped to the WIPP facility. Transportation of TRU waste to the WIPP facility in TRUPACT IIs requires that all generating/storage sites meet the requirements of the TRUPACT II Certificate of Compliance, Safety Analysis Report for Packaging, and the TRUPACT II Authorized Method for Payload Control. To control these additional shipping requirements, the shippers are preparing implementation plans, similar to those required for waste certification.

1.1.2 Transportation System Description

The transportation system to be employed for shipment of TRU waste to the WIPP facility from the generating/storage sites is highly visible; it involves interstate movement of TRU waste in newly designed shipping containers. CH-TRU waste drums and boxes will be shipped in TRUPACT II shipping containers, and RH-TRU waste will be shipped in RH-TRU waste shipping casks. These shipping containers will meet Department of Transportation Type B packaging requirements (49 CFR 173) and will be certified by the Nuclear Regulatory Commission for safe transportation of nuclear materials. The Standard Waste Box will be certified to Department of Transportation requirements as a Type A container. A TRUPACT

II shipping container will hold 14 drums (two 7-packs) or two Standard Waste Boxes of waste.

The transportation system will use the satellite tracking TRANSportation COMmunication System (TRANSCOM) to monitor shipments during transit to and from the WIPP site. Access to satellite tracking information will be made available to the officials in New Mexico, other corridor states, and to Indian Tribes/Pueblos requesting such access. Emergency response training is being provided to emergency responders and officials in New Mexico, other corridor states, and Indian Tribes/Pueblos.

1.1.3 WIPP Description

The WIPP site is located in southeastern New Mexico, approximately 26 mi (42 km) southeast of Carlsbad (Figure 1-1). The WIPP facility consists of both surface and underground facilities, including the Waste Handling Building, an Exhaust Filter Building, a Security Building with a visitor center, an Emergency Services Building, a TRUPACT II maintenance facility, various other support buildings, four shafts to the underground area, underground workings at a single level for waste tests and disposal, and underground maintenance shops (Figure 1-3).

The Waste Handling Building is equipped to handle CH- and RH-TRU wastes in separate areas. The CH-TRU waste area includes shipping and receiving, inspection and inventory, preparation, and an overpack and repair room for damaged containers. The RH-TRU waste area includes shipping and receiving, shipping cask preparation and decontamination, cask loading and unloading, and a hot cell above the loading area for waste canister storage, overpacking, decontamination, and transfer. Two independent airlocks at the shaft entrance allow wastes to enter from either the CH- or the RH-TRU waste areas. High efficiency particulate air filtration equipment is utilized in all radioactive materials areas of the Waste Handling Building.

The underground facility is located 2,150 ft (655 m) below the land surface in the bedded salt (halite) of the Salado Formation. The Salado Formation is approximately 2,000 ft (600 m) thick and 225 million years old. The underground facility is at one mined level and designed in a conventional "room-and-pillar" arrangement. It includes three separate mined areas: a test/disposal area for CH- and RH-TRU wastes; an experimental area dedicated to research and development in rock mechanics, seal design, and facility design; and a shaft pillar area that connects the waste test/disposal, shaft, and experimental areas. The typical disposal rooms are 13 ft (4 m) high, 33 ft (10 m) wide, and 300 ft (91 m) in length; each is separated from the next by 100-ft (30-m) wide pillars of rock salt. Ultimately, eight panels of seven rooms each will be mined. The underground areas are excavated using continuous mining machines. The mined salt is then transported via underground haulage vehicles to a surge bin at the Salt Handling Shaft for removal from the mine.

For final disposal, CH-TRU waste drums and boxes will be stacked in the waste disposal rooms and covered with backfill. RH-TRU waste canisters will be emplaced in horizontal boreholes drilled into the walls of the rooms. However, to ensure retrievability during the Test Phase, the CH-TRU waste containers will not normally be covered with backfill, and RH-TRU waste canisters will be retrievably emplaced in steel sleeves placed in the emplacement holes. After

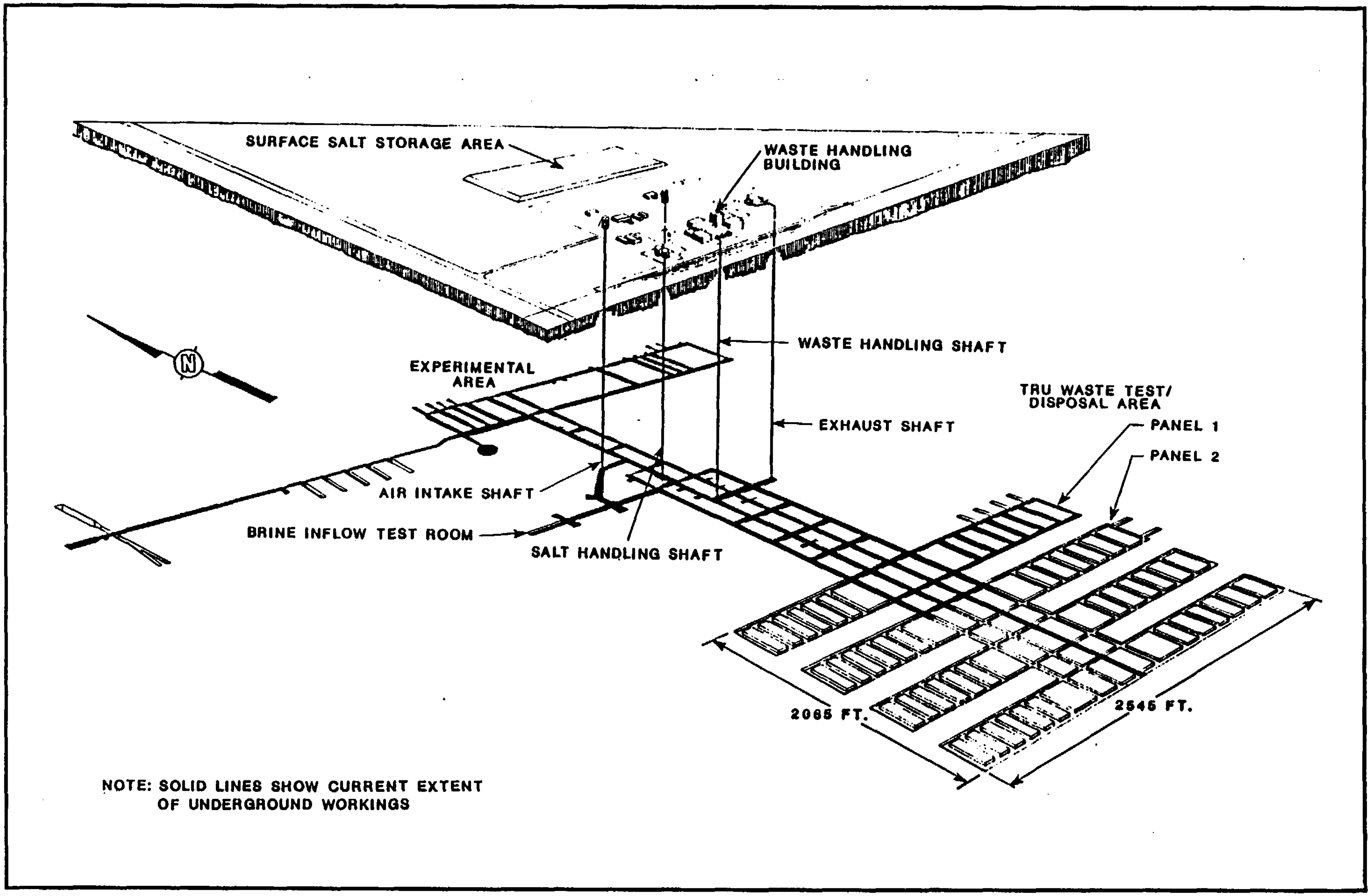


Figure 1-3. The WIPP Facility

the Test Phase, RH-TRU waste canisters may no longer require sleeves. The capacity of the WIPP disposal facility is 6,200,000 cubic feet of CH-TRU waste and 250,000 cubic feet of RH-TRU waste.

1.1.4 WIPP Project Development

Since PL 96-164 was enacted establishing the mission of the WIPP Project, program activities have focused on completion of major segments or phases of the Project, thereby allowing significant progress to be made toward demonstrating the safety of WIPP. Each major phase has provided an opportunity to study and evaluate the most recent information, individually and collectively, prior to proceeding with the next phase. Strong influences on the development of the WIPP Project have been the adherence to DOE Order 4700.1 (and its predecessor) regarding "Major System Acquisition" for DOE construction projects, the Consultation and Cooperation Agreement with the State of New Mexico, applicable EPA regulations, and interaction with the National Academy of Sciences WIPP Panel. The following summary of progress for the WIPP Project illustrates the extent of information collected to date and clarifies the readiness of the Project to enter the Test Phase.

The major phases of the WIPP Project and their relationship to the Key Decisions required in DOE Order 4700.1 are illustrated in Figure 1-4. Key Decision 1 in October 1979 was based upon preliminary site characterization and conceptual design and marked the beginning of the Preliminary Design (Title I). Key Decision 2 in September 1981, to initiate Detail Design (Title II), was made after evaluation of the preliminary design and the 1981 Record of Decision to proceed with the WIPP Project. Key Decision 3 occurred in July 1983 and was based on the successful conclusion of the Site and Preliminary Design Validation Program. This decision initiated the Construction Phase. Key Decision 4, the last decision in terms of DOE Order 4700.1, will be the decision whether to proceed from construction to operations, or in this case, the Test Phase. The transition from construction to operations would be made after the capability to meet technical performance goals approved in the Project baseline and operational readiness have been demonstrated. In addition, before Key Decision 4 can be made, the Final Safety Analysis Report must be completed, a Resource Conservation and Recovery Act No-Migration Variance granted, the TRUPACT II Certificate of Compliance obtained, the Preoperational Appraisal approved, and the Supplement to the Final Environmental Impact Statement completed and Record of Decision issued. The decision is the responsibility of the Energy Systems Acquisition Advisory Board and is expected to be made in August 1989.

Numerous activities were completed to provide the basis for the Key Decisions described above. Investigation of the geographic area proposed for WIPP, the Los Medanos region of southeastern New Mexico, began in 1972 with a careful review of the extensive geologic data base developed by potash and hydrocarbon industry exploration activities in the area. The results of this review were favorable, and detailed characterization of the present site was initiated in 1976 with drilling of a stratigraphic borehole, ERDA-9, at the center of the site. Between 1975 and 1988, over 95 boreholes were drilled and over 35,000 ft of core were retrieved specifically for geologic evaluation of the site. More than 40 of these WIPP boreholes have been used to acquire hydrologic data needed to establish models of local and regional hydrology. In addition, a variety of geophysical exploration techniques, including electrical resistivity, seismic

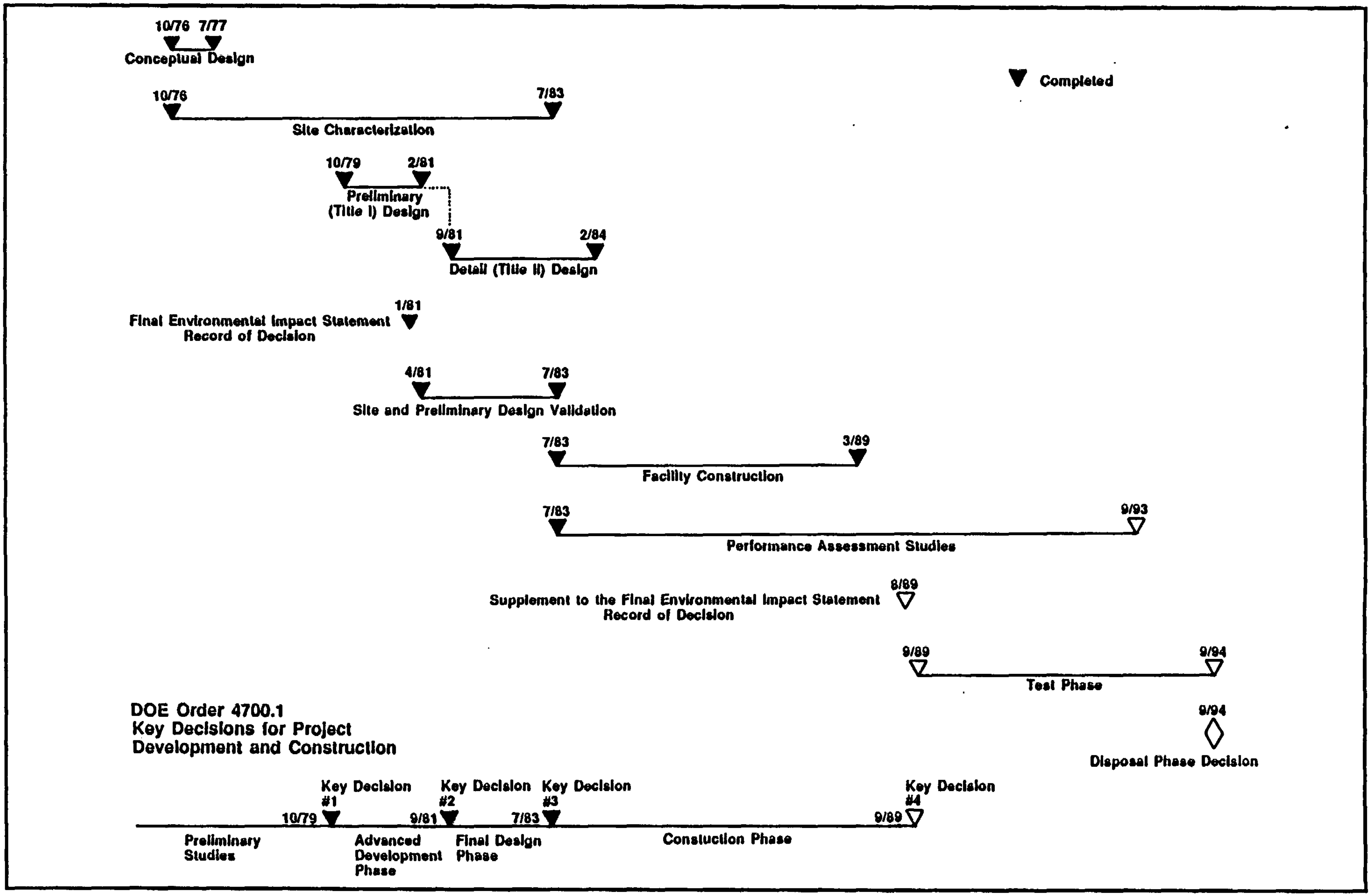


Figure 1-4. WIPP Project Summary Schedule

reflection, gravity, and magnetic surveys, have contributed to understanding the site geology (Lappin, 1988).

A comprehensive WIPP research and development program began in 1975 with investigations of salt creep properties and constitutive laws, gas generation from the degradation of TRU waste, corrosion behavior of TRU waste containers, and backfill behavior. From 1981 through 1983, field tests were conducted on waste package materials, large-scale salt deformation, and brine transport in a potash mine near the WIPP site. Investigations in the WIPP underground began in 1982 with the instrumentation of the Salt Handling Shaft and selected underground drifts. An extensive underground (in situ) test program for thermal/structural interactions, plugging and sealing, brine inflow, and waste package performance began in 1983 and is still in progress (Tyler et al., 1988).

In October 1980, the Final Environmental Impact Statement was issued for public comment. These comments were considered and responses made prior to announcing a Record of Decision on January 22, 1981, to proceed with WIPP. Following issuance of the Record of Decision, development and construction of the WIPP facility was initiated. Construction was accomplished in two distinct phases: (1) the Site and Preliminary Design Validation (SPDV) Program, and (2) Facility Construction.

The SPDV Program (1981 - 1983) was developed and implemented consistent with the Record of Decision to permit direct observation of geologic conditions at the proposed underground facility horizon and to allow determination of the geomechanical response of the salt beds after excavation of underground workings. Two shafts were drilled, and a four-room test panel was excavated at the selected disposal depth. Extensive data from geologic investigations showed the geology of the disposal horizon to be consistent with predictions based on previous investigations and as described in the Final Environmental Impact Statement (DOE, 1980). SPDV Program results (DOE, 1983) were made available for review by the State of New Mexico and the public. The results were also presented to the National Academy of Sciences WIPP Panel, which concluded that a repository meeting the geologic criteria for site selection could be constructed at the WIPP site (NAS, 1983). Based upon the SPDV data and in consideration of comments from all program reviewers, it was concluded that a sound basis had been established to proceed with Facility Construction.

In concert with the technical activities conducted during the SPDV phase, WIPP was engaged in a comprehensive institutional program. Most significant among the institutional efforts were those which culminated in formal agreements with the State of New Mexico. Several State oversight groups were formed during the late 1970s. The Environmental Evaluation Group was established to provide independent technical review of safety and environmental aspects of the WIPP Project. An Interim Legislative Radioactive Materials Committee, now known as the Radioactive and Hazardous Materials Committee, consisting of New Mexico legislators was formed to provide the State with legislative oversight. The Executive Branch convened a Radioactive Waste Consultation Task Force, comprised of cabinet-level members, to provide input and advice to the Governor. The Environmental Evaluation Group has provided continuous independent technical oversight of environmental, health, and safety aspects of the WIPP Project by reviewing geologic, hydrologic, environmental/ecological, and engineering studies and reports concerning the Project. The Environmental Evaluation Group has also conducted independent studies and prepared formal reports of their evaluations.

In addition to the open communication with these State organizations, the DOE entered into both a Stipulated Agreement and a Consultation and Cooperation Agreement with the State of New Mexico in 1981. The Stipulated Agreement identified geotechnical work to be performed to resolve certain State concerns. The Consultation and Cooperation Agreement defined the process and procedures for consultation and cooperation between the DOE and the State of New Mexico. The geotechnical studies included as part of the original Stipulated Agreement were completed during the SPDV phase. In December 1982, the DOE and the State of New Mexico entered into a Supplemental Stipulated Agreement which included additional geotechnical studies, environmental monitoring, transportation monitoring, emergency response activities, road upgrading, and State liability issues. The Consultation and Cooperation Agreement has been modified several times since its inception. Discussions have also been conducted with representatives from corridor states and Indian reservations through which TRU waste shipments to WIPP are planned. These discussions included such subjects as routing, emergency response, and notification of shipments.

The WIPP Construction Phase (1983 - 1989) encompassed all major surface facilities, two additional shafts leading to the underground, excavation and outfitting of the underground experimental areas, and excavation of Panel 1 and associated drifts. During the Construction Phase, a formal construction acceptance program was implemented, which required walk-throughs to compare design drawings and specifications to actual construction, system and subsystem testing and certifications to demonstrate that systems were constructed as designed, and as-built drawings. A subsequent start-up program evaluated all the identified critical operating systems, including the Waste Handling and Exhaust Filter Buildings, the shaft and hoisting systems, the CH-TRU waste handling system and equipment, all monitoring systems, controls and instrumentation, utilities (electrical, water, and fire protection), and the underground ventilation system. This process of systematic testing and audits of the construction systems and facilities, which is nearly complete, provides assurance that the intent of the designs has been implemented.

Following the completion of appropriate elements of the start-up program, a series of operational demonstrations was performed focusing on the full CH- and RH-TRU waste handling operations to be used for waste emplacement, as well as the demonstration of retrievability of both waste types. These demonstrations included mock CH- and RH-TRU waste retrieval demonstrations and CH- and RH-TRU waste preoperational checkouts. To further ensure that WIPP will operate safely, two oversight programs have been implemented. An Operational Readiness Review is providing a comprehensive check on safety, administrative, and operational aspects of the WIPP systems. A comprehensive Preoperational Appraisal, independent of WIPP management, is providing a thorough review of the WIPP environmental, safety, and health programs with an in-depth inspection of the site facilities, and a review and analysis of operations and supporting documentation. Chapter 3 provides more detailed explanations of these programs.

1.2 OBJECTIVES OF THE TEST PHASE

The purpose of the Test Phase is to continue activities in support of the intent of Congress to demonstrate safe disposal of defense waste. To accomplish this, the WIPP Project will demonstrate compliance with the appropriate requirements of the EPA Standard, 40 CFR 191, which regulates TRU waste management and disposal, as well as with other applicable regulations and DOE Orders (Figure 1-5). Although Subpart B of the Standard was remanded to the EPA by the U.S. Court of Appeals for the First Circuit, this Plan addresses the Standard as first promulgated. The 1987 Second Modification to the Agreement for Consultation and Cooperation between the DOE and the State of New Mexico (1981) commits the WIPP Project to evaluate compliance with the Standard as first promulgated until a revised Standard becomes available. Compliance plans for the WIPP facility will be revised as necessary in response to any changes to the Standard.

The two primary objectives of the Test Phase are to demonstrate:

- Reasonable assurance of compliance of the WIPP disposal system (the combination of the repository/shaft system and the controlled area) with the long-term disposal standards of 40 CFR 191, Subpart B, Sections 13 and 15. Compliance of the disposal system will be determined based on a performance assessment.

- The ability of the DOE TRU waste management system (the generating/storage sites, the transportation system, and the WIPP facility) to safely and effectively certify, package, transport, and emplace waste at the WIPP facility. Acceptability of the waste management system will be evaluated by operations testing and monitoring, both individually and collectively, of the elements of the TRU waste management system.

The two major programs required to successfully complete the Test Phase are discussed below in more detail.

1.2.1 Performance Assessment

This program will evaluate whether the WIPP disposal system can reasonably be expected to isolate TRU waste from the accessible environment after decommissioning in accordance with the requirements set forth in 40 CFR 191, Subpart B, Sections 13 and 15. The formal process for making this determination is called performance assessment.

The performance objective of the WIPP disposal system is to adequately isolate the waste from the accessible environment; the performance requirements are compliance with the 10,000-year release limits and the 1,000-year dose limits in Subpart B, Sections 13 and 15. In evaluating compliance with Subpart B, the WIPP Project will follow the guidance provided in an appendix to the EPA Standard. The Standard requires different predictions of disposal system performance for 1,000-year and 10,000-year periods. The Standard specifies that a performance assessment be used to predict the cumulative releases of radionuclides to the accessible environment for the 10,000-year period; cumulative releases must be within the limits established in Appendix A of the Standard. Parts of the WIPP 10,000-year performance assessment methodology can be used to assess compliance with the 1,000-year performance requirements. The 1,000-year performance assessment will predict annual doses to members of the public in the accessible environment resulting from undisturbed disposal system performance. It will not address the concentration limits established by Subpart B for special sources of ground water because no such sources exist at WIPP.

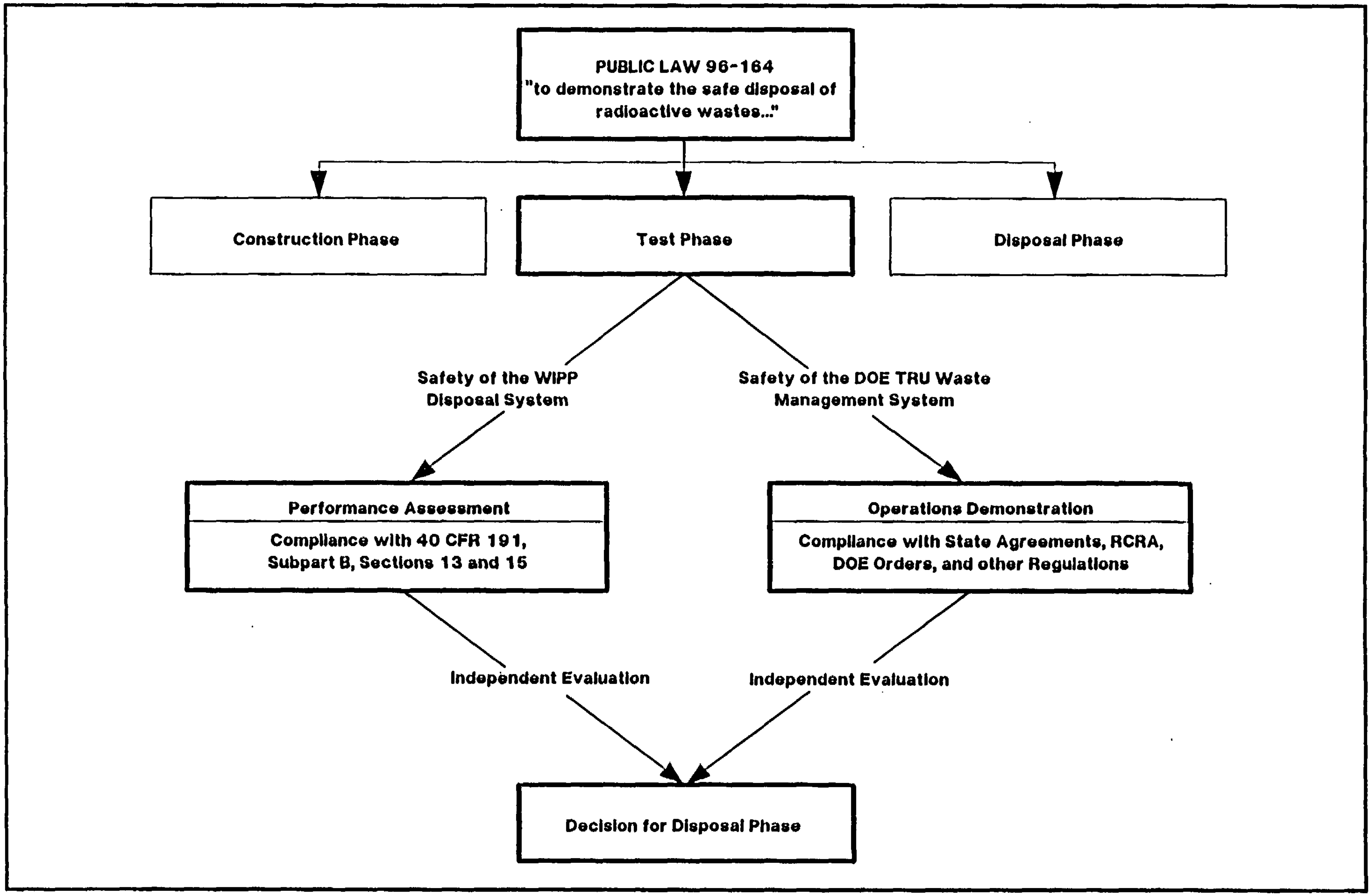


Figure 1-5. Process for Disposal Phase Decision

The EPA Standard, 40 CFR 191, is procedural; it identifies the approach to be taken and provides explicit guidance for implementation. To show that WIPP can meet cumulative release limits set for the 10,000-year requirements, the performance of the disposal system must be predicted, taking into account all plausible responses to all significant events and processes that might affect the disposal system. To ensure that all plausible responses are identified, scenarios are developed by coupling the individual events and processes that could occur. Scenarios are screened by removing those that fall outside the bounds set by the regulation. Consequence analysis is used to calculate a performance measure for each of the remaining significant scenarios. The performance measures for all remaining scenarios are normalized, summed, and reported as a complementary cumulative distribution function of release probabilities. Uncertainties in the data must be included in calculations of the performance measure for each scenario. To provide a reasonable expectation that the WIPP facility can meet annual dose limits set for 1,000-year performance, the Standard requires that releases from the undisturbed scenario be analyzed. If any release to the accessible environment is predicted, transport along biological pathways is modeled and dose estimates are made. Uncertainties in the data are included in the dose calculations.

The performance assessment will provide quantitative measures of the long-term performance of the WIPP disposal system. EPA recognized that sole reliance on numerical predictions of releases and doses to determine compliance may not be appropriate and acknowledged that such predictions may need to be supplemented with qualitative judgments. The final decision will be based on a reasonable expectation of compliance with Subpart B, Sections 13 and 15, and will include quantitative measures of performance and qualitative judgments.

In the performance assessment process, model segments will be developed to simulate the response of the disposal system to each process or event within each scenario. The development of model segments begins with laboratory and field research to identify and begin to assess the individual processes, such as creep closure, brine inflow, gas generation, and migration of radionuclides through panel seals, shaft seals, and overlying water-bearing rock units. While the models are being developed, field and laboratory studies continue acquiring data necessary for use in the model segments. Sensitivity analyses will be performed on individual parameters to provide guidance on the relative importance of these parameters during model development and data acquisition.

Sensitivity analyses performed on a preliminary room model segment have identified the importance of two components, the TRU waste gas generation rates and the Salado Formation gas permeabilities. Early studies of gas generation from the CH-TRU waste suggested that the gas would be generated from microbial, radiolytic, and corrosion reactions. Calculations of the rate of gas diffusion out of the rooms, using Salado Formation permeability values available at that time, indicated that the gas generation at the maximum rate would not create a gas pressure high enough to adversely affect the disposal facility.

More recent Salado Formation permeability values indicate that the earlier values were at least three orders of magnitude higher than actual in situ permeabilities. Calculations using the new permeability values suggest that for gas generation rates greater than about 0.1 mole/drum/year, the disposal facility could become pressurized with gas to near lithostatic pressures within several hundred years of closure.

Several tests have been designed to provide realistic data on TRU waste gas generation and to evaluate the effectiveness of gas getters in the backfill. These tests include laboratory tests with simulated waste; bin-seal tests, which use approximately six drums of waste per bin to produce conditions representative of long-term effects; and underground (in situ) room-scale tests designed to develop gas generation and consumption data that are representative of the heterogeneous mixture of CH-TRU waste. Additional information on these underground tests can be obtained in Chapter 2, Activities S.1.3.2 (p. 2-107) and S.1.3.3 (p. 2-111), and Appendix A.

An additional component of the performance assessment methodology is the development of local and regional hydrologic and contaminant transport model segments that describe the movement of water and dissolved waste along potential pathways from the underground facility to the environment. A regional hydrologic and contaminant transport model of the water-bearing units of the Rustler Formation has been developed and tested, and a description of the code is currently in preparation. Other key components of the disposal system behavior include the performance of seals emplaced in drifts to isolate waste panels and in shafts to isolate the disposal area from the environment.

Model segments that predict the behavior of the waste disposal rooms, panel seals, access drifts, shaft seals, and the migration of radionuclides through the controlled area will be integrated into an overall performance model. This performance model will then be used to predict the consequences of credible scenarios to evaluate compliance with the Standard.

1.2.2 Operations Demonstration

This program will evaluate whether the TRU waste management system will provide safe and effective handling, waste certification, transportation, and disposal of the TRU waste at emplacement rates up to those required for full-scale operation of the WIPP facility. It is important to determine whether disposal of the identified amounts of CH- and RH-TRU wastes within the design life of the WIPP facility can be attained.

The performance objective of the DOE TRU waste management system is to safely dispose of certified TRU waste at the WIPP facility. Operating data needs include demonstration of the safety, environmental adequacy, and effectiveness of operations that will certify, transport, and emplace TRU waste at the WIPP facility. This demonstration is integrated; it includes all elements of the DOE TRU waste management system (the generating/storage sites, the transportation system, and WIPP), and requires both CH- and RH-TRU wastes, including CH-TRU waste for the in situ gas generation tests in support of the Performance Assessment Program. The goal of this Operations Demonstration is to provide assurance that operations can be conducted within the limits of all applicable regulatory, technical, industrial, and managerial criteria.

The Operations Demonstration builds upon previous confirmation of facility and operational readiness and proceeds to the next step, operations with radioactive waste. It reflects an integrated, stepwise progression of facility readiness, training, nonradioactive operational demonstrations, and demonstrations with radioactive wastes progressing from initial receipt rates to higher quantities representative of required WIPP throughput rates. The Operations Demonstration will be initiated with the first shipment of waste, which is planned to support the gas generation tests.

Throughout the Operations Demonstration, there are designated checkpoints for review and analysis of safety, environmental, and operational (procedural or administrative) factors, and reporting of monitoring activities. These checkpoints are part of a continuous evaluation of operations and will apply to each element of the waste management system. The purpose of these checkpoints is to provide a basis for WIPP management to determine whether to proceed as planned, or to modify plans based on experience gained.

1.3 APPROACH

1.3.1 Test Phase Program Structure

A hierarchical structure was established to guide the acquisition of information during the Test Phase. The hierarchy consists of four levels of detail: programs, elements, subelements, and information needs. The elements grouped under each program pertain to regulatory and programmatic concerns, as well as to technical concerns. The programs and elements hierarchy is shown in Figure 1-6. For each program and associated elements, the information needs and the activities planned to satisfy those needs are discussed in Chapters 2 and 3.

The Performance Assessment Program is divided into elements and subelements based on the computational sequence required to simulate performance of the disposal system for the consequence analysis. An example is the performance of a waste disposal room within the performance of the repository/shaft system. The hierarchy portrays the logic of the performance assessment and the related supporting activities to characterize the disposal system.

The Operations Demonstration Program concerns the operational aspects of the DOE TRU waste management system. This program is derived from Congressional guidance to demonstrate the safe disposal of TRU wastes. The demonstration of TRU waste disposal will include meeting the requirements of 40 CFR 191, Subpart A, per agreement with the State of New Mexico, as well as other applicable federal regulations, DOE Orders, and other requirements for each of the three main components of the DOE TRU waste management system.

1.3.2 TRU Waste Requirements for the Test Phase

An important component of the Test Phase is the need to emplace actual TRU waste underground in the WIPP facility. The waste will be used to conduct underground (in situ) gas generation tests, which are necessary to establish an acceptable level of confidence in the performance assessment process, and to evaluate the operational safety and effectiveness of the TRU waste management system. Approximately eight percent (500,000 cubic feet) of the WIPP facility disposal area design capacity will be emplaced during the Test Phase (Table 1-1). Included within this amount is less than one percent (of the design capacity) for gas generation testing.

The waste emplacement operations will be accomplished in two parts. The first part involves emplacing 4.4 percent of the disposal area design capacity in Panel 1. At the conclusion of the first part, a holdpoint will be initiated to

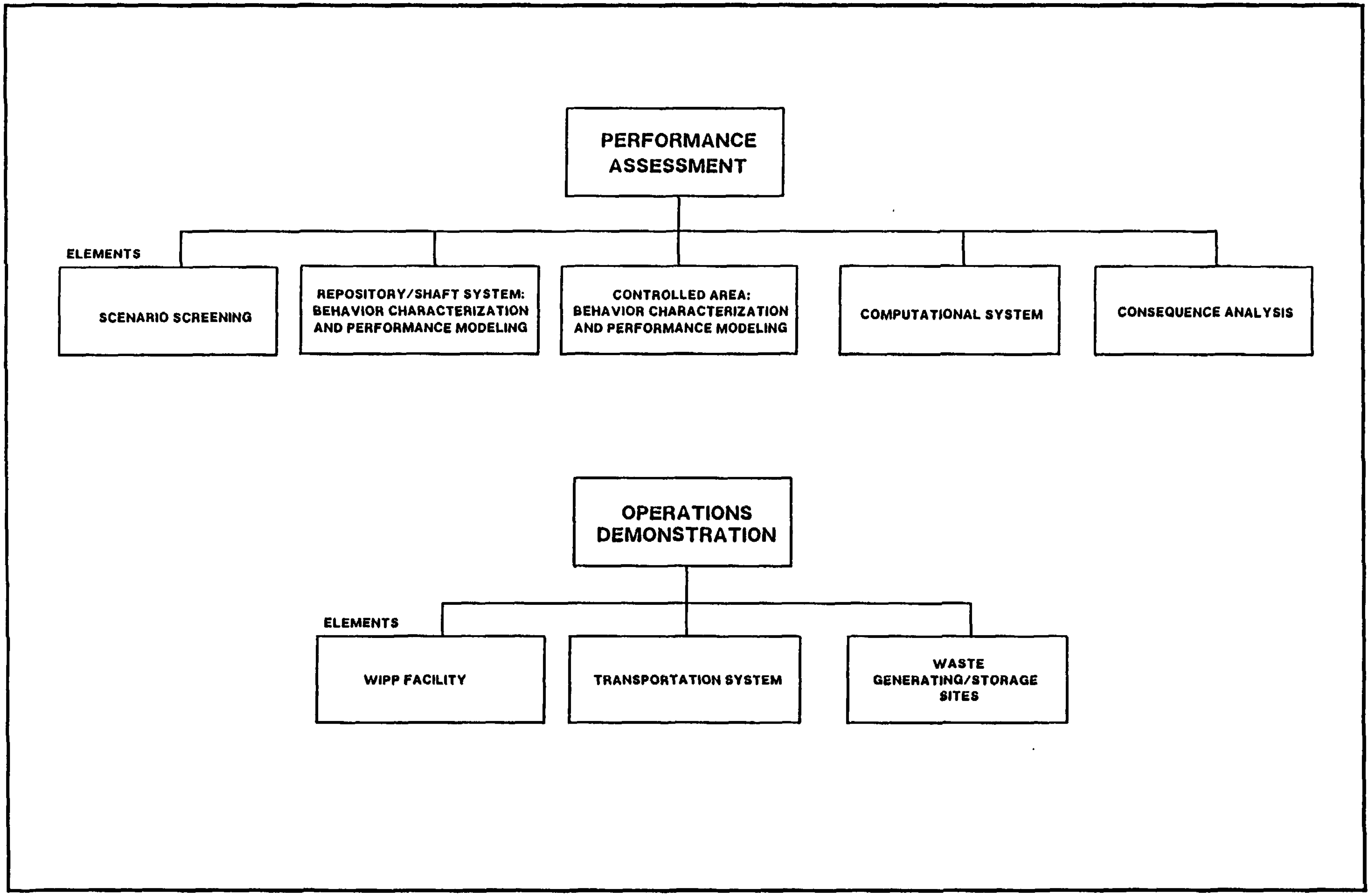


Figure 1-6. Program Structure

TABLE 1-1. TEST PHASE: WASTE TYPE AND QUANTITY

CH-TRU Waste	Type	Panel 1 (1) Drums (2)	Panel 1 (1) Cubic Feet	Panel 1 (1) Percent (3)	Panel 2 (1) Drums (2)	Panel 2 (1) Cubic Feet	Panel 2 (1) Percent (3)
Gas Testing	As-Received	1,100	8,100	0.1			
	Compacted	1,600	11,800	0.2	1,600	11,800	0.2
	Prepared	1,100	8,100	0.1	1,100	8,100	0.1
	Bins	600	4,400	0.1			
CH-TRU Waste Emplacement	As-Received	33,000	242,600	3.9	27,500	202,100	3.3
Subtotals		37,400	275,000	4.4	30,200	222,000	3.6
Totals	CH-TRU Waste RH-TRU Waste	67,600 Drums 50 Canisters		497,000 Cubic Feet 1,600 Cubic Feet			8.0 percent 0.6 percent (4)

NOTES:
(1)Quantities are approximate.
(2)These quantities are expressed in equivalent number of drums; however, some waste will be packaged in Standard Waste Boxes.
(3)Based on WIPP design capacity of 6,200,000 cubic feet of CH-TRU waste disposal area.
(4)Based on WIPP design capacity of 250,000 cubic feet of RH-TRU waste disposal area.

assess the ability of the WIPP disposal system to satisfy the EPA Standard for long-term performance and to assess the TRU waste management system operations. This assessment will determine whether to proceed to the second part of the Test Phase operations in Panel 2.

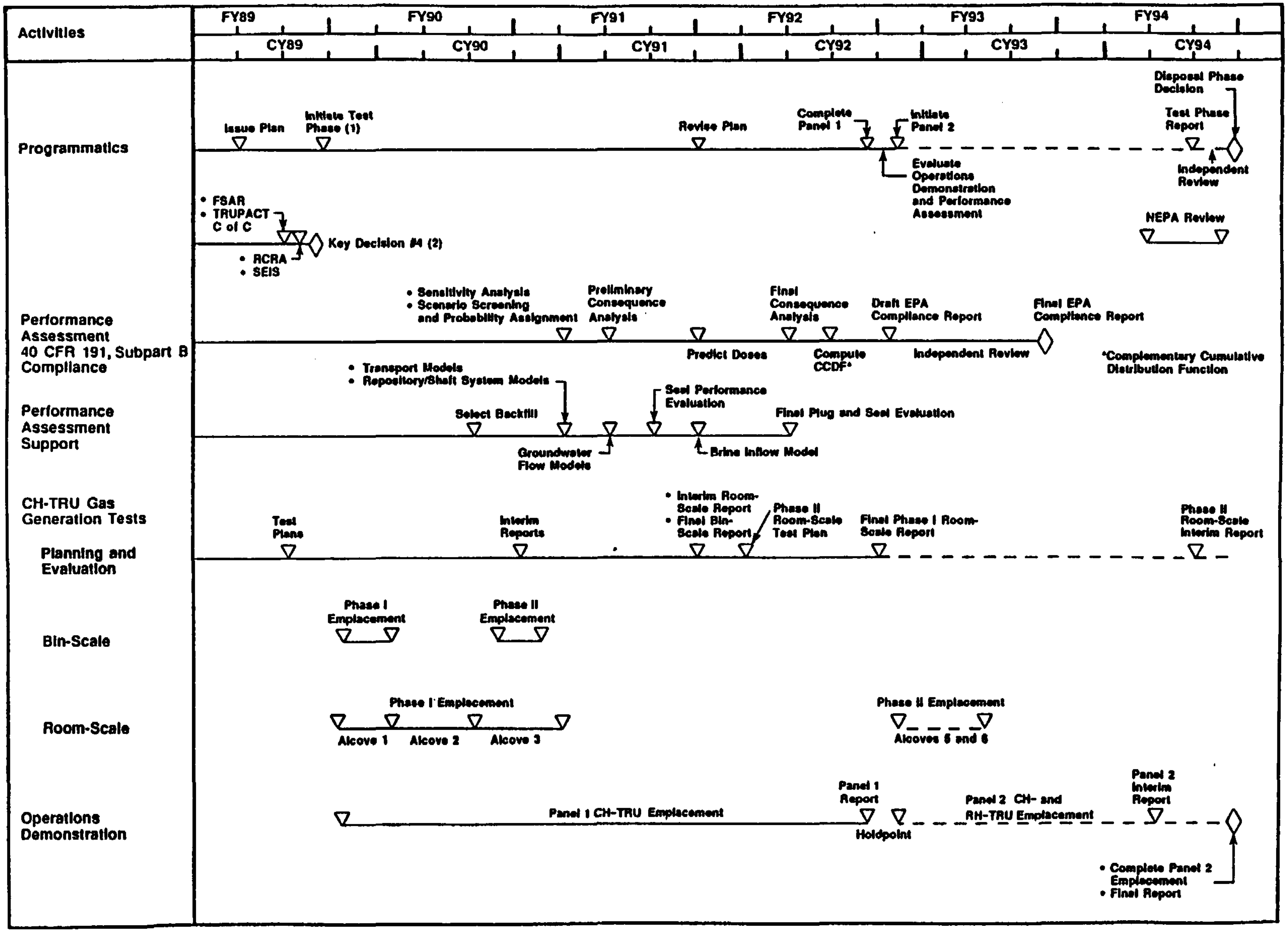
The Performance Assessment Program requires simulation of the WIPP disposal system and an evaluation of the consequences of credible release scenarios. An adequate understanding of the disposal room behavior is an important element of these consequence predictions. As part of the characterization of the room, gas generation and consumption from the microbial and radiolytic decomposition of the TRU waste and corrosion of the waste containers, as well as the influx of naturally occurring gas from the host rock, must be evaluated. This evaluation will include two basic types of tests conducted in the WIPP underground bin-scale and room-scale tests. Data from monitoring approximately 100 specially designed bins, each containing the equivalent of six drums of CH-TRU waste plus various other constituents, will be used to verify laboratory data concerning gas generation during the postoperational phase of the facility. In the room-scale tests, which represent both initial operational conditions and postoperational conditions, approximately 6,500 drums of CH-TRU waste will be emplaced in specially mined alcoves in the WIPP facility. Chapter 2, Performance Assessment, and Appendix A, Tests with CH-TRU and Simulated Wastes, provide further descriptions of the TRU waste requirements for the EPA compliance effort.

The Operations Demonstration will be accomplished by demonstrating the ability to safely and effectively operate the DOE TRU waste management system with actual TRU waste. This demonstration is a prudent next step in the phased approach of the WIPP facility to answer questions concerning the overall system operations. The long standing experience of nuclear and nonnuclear industry suggests that this type of pilot-scale operations demonstration is a prudent precursor to full-scale operations.

As previously described, waste emplacement operations for the Operations Demonstration will be accomplished in two parts. During the first part, TRU waste for the gas generation tests will be emplaced. Subsequently, CH-TRU waste for the Operations Demonstration will be certified, transported, and emplaced at increasing rates. Approximately 37,400 drums (4.4 percent of WIPP capacity) of waste will be emplaced in seven waste test rooms and three test alcoves in Panel 1 during the first part of the Operations Demonstration. During the second part of the Operations Demonstration, approximately 30,200 drums (3.6 percent of WIPP capacity) of CH-TRU waste will be emplaced in five test rooms and two test alcoves, and approximately 50 RH-TRU waste canisters will be emplaced in another room in Panel 2 during the second part. These Operations Demonstration requirements are described further in Chapter 3.

1.3.3 Schedule

The Test Phase is expected to be initiated in September 1989 with the first waste receipt and will extend for up to five years (Figure 1-7). Many of the performance assessment activities have been ongoing for several years and will extend into the Test Phase. The Draft 40 CFR 191 Compliance Report will be issued by September 1992 and made available for review and comment by the EPA, the State of New Mexico's Environmental Evaluation Group, the National Academy



NOTES:
(1) Land withdrawal is required to initiate the Test Phase.
(2) Key Decision #4 pertains to the transition from construction to operations as described in DOE Order 4700.1.

Figure 1-7. Summary Schedule for the Test Phase of Sciences WIPP Panel, and other appropriate organizations. The Final 40 CFR 191 Compliance Report will be issued in September 1993.

The Operations Demonstration will consist of emplacing CH- and RH-TRU wastes in Panels 1 and 2 during the Test Phase. An integral part of waste emplacement operations will be checkpoints to evaluate the status of the Operations Demonstration as the panels are filled. A major holdpoint will be instituted in September 1992, at the conclusion of Panel 1 waste emplacement. The holdpoint will allow an assessment of the TRU waste management operations to date and an assessment of the ability of the disposal system to satisfy the EPA Standard. Should the judgment at that time be that waste management operations are proceeding safely, without significant incident, and that sufficient confidence can be established in the ability to demonstrate compliance with the Standard, the holdpoint will be discontinued and waste emplacement operations resumed to install Panel 2 alcove tests and perform concurrent emplacement of CH- and RH-TRU waste types. This holdpoint is expected to last up to two months.

A summary report of the Test Phase is planned for June 1994. This report will summarize the results from the two major programs (40 CFR 191 compliance and the Operations Demonstration) and will be made available for independent review by appropriate organizations. A decision whether to proceed with the Disposal Phase of the WIPP facility is scheduled for consideration by September 1994.

1.4 ORGANIZATION OF THE PLAN

The remainder of this Plan discusses details of each program:

- Chapter 2 - Performance Assessment: This chapter presents the methodology and specific activities designed to provide a confident assessment of the disposal system performance.

- Chapter 3 - Operations Demonstration: This chapter presents an overview of the operational demonstration for each segment of the DOE TRU waste management system and activities designed to show the acceptability of the integrated waste handling system.

Implementation of this Plan will provide information required for, and appropriate to, the decision whether WIPP should be designated a disposal facility for TRU waste and proceed to the Disposal Phase. As in earlier phases, the intent is to ensure the satisfactory completion of WIPP's mission: to demonstrate the safe disposal of defense-generated TRU waste.

2.0 PERFORMANCE ASSESSMENT

This chapter establishes the information needs and activities that will be performed to determine compliance with the EPA Standard, 40 CFR 191, Subpart B, Sections 13 and 15. Section 13, the Containment Requirements, and Section 15, the Individual Protection Requirements, require predictions of releases of radionuclides for 10,000 years and doses for 1,000 years, respectively. The term "performance assessment" is used herein to refer to the prediction of long-term performance for both requirements. In this Plan, the elements and activities related to evaluation of compliance with the Standard focus on long-term performance for these two requirements. A more detailed presentation of the background and descriptions of the performance assessment and supporting activities that will be performed during the Test Phase can be found in a report by Bertram-Howery and Hunter (1989b) entitled *Plan for Disposal System Characterization and Long-Term Performance Evaluation of the Waste Isolation Pilot Plant.* Additional information on the performance assessment methodology is available in *Plans for Evaluation of the Waste Isolation Pilot Plant's Compliance with EPA Standards for Radioactive Waste Management and Disposal* (Bertram-Howery and Hunter, 1989a).

This chapter is organized as follows. Section 2.1 briefly describes the EPA Standard, 40 CFR 191, Subpart B. A brief summary of the performance evaluation presented in the WIPP Final Environmental Impact Statement (DOE, 1980) is presented in Section 2.2. Section 2.3 discusses the factors that affect the long-term performance of the disposal rooms. An overview of the technical approach for the determination of compliance with Subpart B of the Standard is provided in Section 2.4, and more detailed descriptions of the work elements and information needs are presented in Section 2.5. Section 2.6 provides summaries of the activities to be performed to complete the performance assessment, and Section 2.7 contains a description of the scheduling of activities.

2.1 BRIEF DESCRIPTION OF 40 CFR 191, SUBPART B

The EPA Standard, 40 CFR 191, is divided into two subparts. The application of both Subpart A and Subpart B of the Standard to WIPP is described in the report, *Waste Isolation Pilot Plant Compliance Strategy for 40 CFR Part 191* (DOE, 1989e), which discusses the application of various terms and definitions contained in the Standard to WIPP.

Subpart A applies to a disposal facility prior to decommissioning and limits annual radiation doses to members of the public from waste management and storage operations. Subpart B applies after decommissioning and limits cumulative releases of radioactive materials to the accessible environment for 10,000 years. Subpart B also limits both annual radiation doses to members of the public in the accessible environment and radioactive contamination of certain sources of ground water for 1,000 years after disposal. Table A in Appendix A to the Standard specifies how to determine the 10,000-year release limits, and Appendix B provides nonmandatory guidance for implementation of Subpart B. The four sections of Subpart B, the associated definitions, and two appendices establish a framework of procedures to be applied in complying with the Standard. Terms from the Standard important to the discussions in this Plan are briefly discussed below.

As defined in the Standard, "disposal" will occur after the waste is permanently emplaced underground and the repository and shafts are sealed. "Accessible environment" is defined in the Standard as: (1) the atmosphere, (2) land surfaces, (3) surface waters, (4) oceans, and (5) all of the lithosphere beyond the controlled area.

The concept of "sites" is integral to Subparts A and B limits on releases of waste from the repository or disposal facility, both during operation and after closure. "Site" is used differently in the two subparts. Passive institutional control of the controlled area (Figure 2-1), which is important to determining compliance with Subpart B of the Standard, depends on the definition of "site." "Site" has also been used generically for many years by the waste management community (e.g., in the phrases "site characterization" or "site-specific"); few generic uses of the word correspond to either of the EPA's usages. However, "site" is used both in the sense of the Standard and generically in this Plan.

The term "disposal site" as used in Subpart B and Appendix B to the Standard differs from "site" as defined for Subpart A. For the purposes of the WIPP strategy for compliance with Subpart B, the disposal site, which must be marked for protection of future generations, is the same as the controlled area. The controlled area for Subpart B includes the surface and subsurface of the secured area and additional surrounding areas, the extent of which will be determined during the performance assessment (DOE, 1989e). The Standard limits the controlled area to the region within 3 mi (5 km) of the waste panel boundaries, it will not be less than the area withdrawn.

Sections 13 and 15 of 40 CFR 191, Subpart B, the Containment Requirements and Individual Protection Requirements, necessitate predictions of releases of radionuclides for 10,000 years and doses for 1,000 years.

Section 14 of 40 CFR 191, Subpart B, contains the Assurance Requirements, which complement the Containment Requirements. No testing is required to satisfy Section 14; therefore, it is not addressed in this Plan. The Assurance Requirements implementation plan contains additional information (Westinghouse, 1987a).

Section 16 of 40 CFR 191, Subpart B, protects "special sources of ground water" from contamination at concentrations greater than certain limits. This is the only requirement in the Standard that limits radionuclide concentrations. No ground water within 3 mi (5 km) of the maximum allowable extent of the controlled area satisfies the definition of a "special source of ground water." Therefore, the WIPP Project will comply with this requirement by documenting that no "special source of ground water" exists. No additional data acquisition or analysis is necessary for compliance with this requirement.

Appendix A to the Standard establishes the release limits for all the regulated radionuclides. Table 1 in that appendix gives the limit for cumulative releases to the accessible environment for 10,000 years after disposal for each radionuclide per unit of waste. Note 1(e) to Table 1 defines the unit of waste as an amount of TRU wastes containing one million curies of alpha-emitting transuranic radionuclides with half-lives greater than 20 years. Note 2(b) describes how to develop release limits for a TRU waste disposal system: the release limits are the quantities in Table 1 multiplied by the units of waste. Note 6 describes the manner in which the release limits are to be used to determine compliance

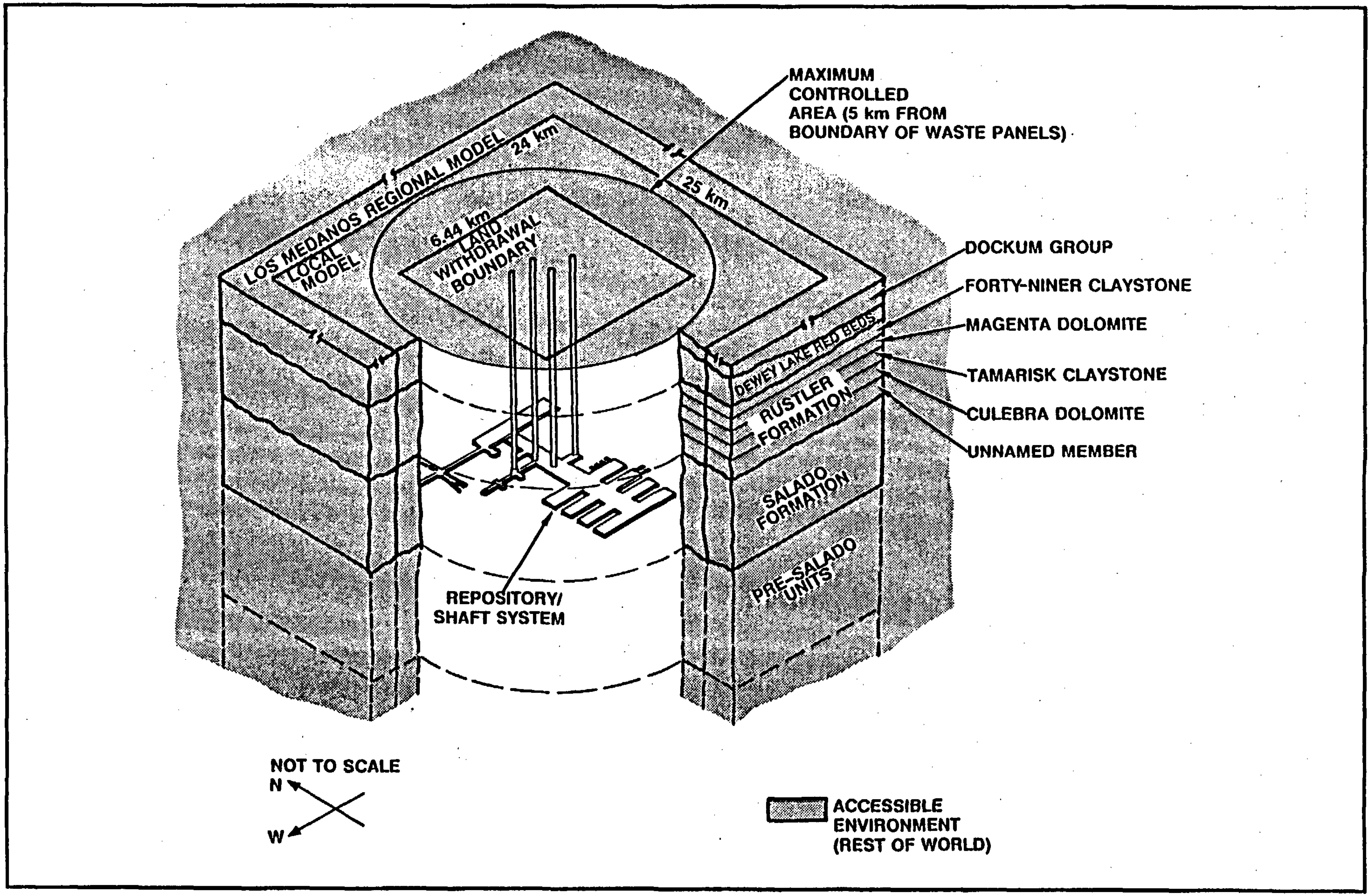


Figure 2-1. Cutaway View of the Controlled Area and the Repository/Shaft System

with Section 13: for each radionuclide released, the ratio of the cumulative release to the total release limit for that radionuclide must be determined; the ratios for all radionuclides released are then summed for comparison to the requirements of Section 13: thus the quantity of a radionuclide that may be safely released depends on the quantities of all other nuclides projected to be released, but cannot exceed its own release limit. The summed normalized release cannot exceed 1 for probabilities greater than 0.1 and cannot exceed 10 for probabilities greater than 0.001. Releases that occur with probabilities less than 0.001 are not regulated.

Appendix B to the Standard is EPA's guidance to the implementing agency (in this case, the DOE). In the preamble to the Standard (EPA, 1985, p. 38069), the EPA states that it intends the guidance to be followed: "...Appendix B...describes certain analytical approaches and assumptions through which the [EPA] intends the various long-term numerical standards of Subpart B to be applied. This guidance is particularly important because there are no precedents for the implementation of such long-term environmental standards, which will require consideration of extensive analytical projections of disposal system performance." The EPA based Appendix B on some of the analytical assumptions it used to develop the technical basis for the numerical disposal standards. Thus, the EPA "believes it is important that the assumptions used by the [DOE] are compatible with those used by the EPA in developing this rule. Otherwise, implementation of the disposal standards may have effects quite different than those anticipated by EPA" (EPA, 1985, p. 38074).

The primary objective of Subpart B is to ensure that the disposal system will isolate the waste from the accessible environment by limiting long-term releases and the associated risks to populations. This objective is reflected in the Containment Requirements. Evaluation of compliance is based on a performance assessment, which has specific meaning within the Standard:

> "Performance Assessment" means an analysis that: (1) identifies the processes and events that might affect the disposal system; (2) examines the effects of these processes and events on the performance of the disposal system; and (3) estimates the cumulative releases of radionuclides, considering the associated uncertainties, caused by all significant processes and events. These estimates shall be incorporated into an overall probability distribution of cumulative release to the extent practicable (40 CFR 191, Section 12[q]).

Subpart B limits risks to individuals in ways compatible with the primary objective (EPA, 1985, p. 38070). The methodology developed for performance assessment can be used to predict releases so that doses can be predicted as specified by the Individual Protection Requirements. This dose assessment must provide a reasonable expectation that the annual dose equivalent from the disposal system to any member of the public in the accessible environment will not exceed 25 millirems to the whole body or 75 millirems to any critical organ. The Standard requires that modeled individuals be assumed to consume 2 liters (2.1 quarts) of drinking water per day from a "significant source of ground water" outside the controlled area. These requirements apply to undisturbed performance of the disposal system, considering all potential release and dose pathways, for 1,000 years after disposal:

> "Undisturbed performance" means predicted behavior of a disposal system, including consideration of the uncertainties in predicted behavior, if the disposal system is not disrupted by human intrusion or the occurrence of unlikely natural events (40 CFR Part 191.12[p]).

Unlikely natural events are those that have not occurred rapidly enough in the past to affect the Salado Formation at the repository horizon within the controlled area so as to have caused the release of radionuclides, had they been present. Only the presence of ground water has affected the Salado Formation in the vicinity of WIPP at the repository horizon for the past several million years. Therefore, the WIPP Project will simulate only ground-water flow and the effects of the repository as the undisturbed performance (DOE, 1988a).

The EPA defines a "significant source of ground water" as:

> (1) An aquifer that: (i) Is saturated with water having less than 10,000 milligrams per liter of total dissolved solids; (ii) is within 2,500 feet of the land surface; (iii) has a transmissivity greater than 200 gallons per day per square foot; and (iv) is capable of continuously yielding at least 10,000 gallons per day to a pumped or flowing well for a period of a least a year; or (2) an aquifer that provides the primary source of water for a community water system as of November 18, 1985 (40 CFR Part 191, Section 12[n]).

No water-bearing unit in the vicinity of WIPP meets the EPA's first definition of a "significant source of ground water" throughout its extent because the level of dissolved solids is high and the transmissivity is low in most places (Mercer, 1983; LaVenue et al., 1988; Siegel et al., 1988); however, the WIPP Project will assume that any portion of a water-bearing unit that meets the first definition is a "significant source of ground water." Communication between nonqualifying and qualifying portions will be evaluated. No water-bearing unit near the WIPP facility meets the EPA's second definition of "significant source of ground water."

The Project does not expect releases to occur outside the controlled area within 1,000 years; therefore, dose calculations for the undisturbed performance may be unnecessary outside the controlled area. Recent calculations for site characterization suggest that, under modern head gradients, ground-water travel time from the center of the site (essentially the tops of the shafts) to the land withdrawal boundary is significantly longer than 1,000 years (Reeves et al., 1987; LaVenue et al., 1988). If the performance assessment predictions of travel times from the repository, up the shafts into the Culebra Dolomite Member, and to the boundary of the controlled area corroborate this, no radionuclides could be transported to a significant source of ground water outside the controlled area within the time of regulatory interest. The nearest aquifer that is certainly a significant source of ground water is the Pecos Valley alluvial fill at Malaga Bend, 16 mi (26 km) away. The Project does not plan to predict transport of radionuclides so far outside the controlled area. The current understanding of ground-water flow strongly indicates that such a prediction will not be required.

The EPA acknowledged that implementation of the Containment Requirements might require modification of those standards in the future. This implementation "will require collection of a great deal of data during site characterization, resolution of the inevitable uncertainties in such information, and adaptation of this information into probabilistic risk assessments. Although EPA is currently confident that this will be successfully accomplished, such projections over thousands of years to determine compliance with an environmental regulation are unprecedented. If - after substantial experience with these analyses is acquired - disposal systems that clearly provide good isolation cannot reasonably be shown to comply with the containment requirements, the EPA would consider whether modifications to Subpart B were appropriate" (EPA, 1985, p. 38074).

EPA recognized that Subpart B must be implemented in the design phase because active surveillance cannot be relied upon over the very long time frames of interest. EPA also recognized that the Standard "must accommodate large uncertainties, including uncertainties in our current knowledge about disposal system behavior and the inherent uncertainties regarding the distant future" (EPA, 1985, p. 38070).

Both the Containment Requirements and the Individual Protection Requirements require a "reasonable expectation" that their various quantitative tests can be met. EPA intends this test of judgment to "acknowledge the unique considerations likely to be encountered upon implementation of these disposal standards" (EPA, 1985, p. 38071). The Standard "clearly indicates that comprehensive performance assessments, including estimates of the probabilities of various potential releases whenever meaningful estimates are practicable, are needed to determine compliance with the containment requirements" (EPA, 1985, p. 38076). These requirements "emphasize that unequivocal proof of compliance is neither expected nor required because of the substantial uncertainties inherent in such long-term projections. Instead, the appropriate test is a reasonable expectation of compliance based upon practically obtainable information and analysis" (EPA, 1985, p. 38076). The EPA believes that the Standard requires "very stringent isolation while allowing the [DOE] adequate flexibility to handle specific uncertainties that may be encountered" (EPA, 1985, p. 38076).

The EPA's assumptions regarding performance assessments and uncertainties are incorporated in Appendix B to the Standard, which the EPA intends the implementing agencies to follow. EPA intended these assumptions to "discourage overly restrictive or inappropriate implementation" of the requirements (EPA, 1985, p. 38077). The guidance in Appendix B to the Standard indicates that "compliance should be based upon the projections that the [DOE] believes are more realistic....Furthermore,...the quantitative calculations needed may have to be supplemented by reasonable qualitative judgments in order to appropriately determine compliance with the disposal standards" (EPA, 1985, p. 38076). In particular, Appendix B states:

> The (EPA) believes that the (DOE) must determine compliance with §§191.13, 191.15, and 191.16 of Subpart B by evaluating long-term predictions of disposal system performance. Determining compliance with §191.13 will also involve predicting the likelihood of events and processes that may disturb the disposal system. In making these various predictions, it will be appropriate for the (DOE) to make use of rather complex computational models, analytical theories, and prevalent expert judgment relevant to the numerical predictions. Substantial uncertainties are likely to be encountered in

making these predictions. In fact, sole reliance on these numerical predictions to determine compliance may not be appropriate; the (DOE) may choose to supplement such predictions with qualitative judgments as well.

In Section 13(b), the Containment Requirements state that:

> Performance assessments need not provide complete assurance that the requirements of 191.13(a) will be met. Because of the long time period involved and the nature of the events and processes of interest, there will inevitably be substantial uncertainties in projecting disposal system performance. Proof of the future performance of a disposal system is not available in the ordinary sense of the word when compared to situations that deal with much shorter time frames. Instead, what is required is a reasonable expectation, on the basis of the record before the (DOE), that compliance with 191.13(a) will be achieved.

The EPA recognized that there are too many uncertainties in projecting the behavior of natural and engineered components for 10,000 years and too many opportunities for errors in calculations or judgments for the numerical requirements to be sufficient for determining disposal system acceptability. Qualitative requirements were included in the Standard to ensure that "cautious steps are taken to reduce the problems caused by these uncertainties" (EPA, 1985, p. 38079). These qualitative Assurance Requirements are an essential complement to the quantitative Containment Requirements. Each qualitative requirement was chosen to compensate for some aspect of the inherent uncertainty in projecting the future performance of a disposal system. The Assurance Requirements state that compliance with their provisions will "provide the confidence needed for long-term compliance with the requirements of 191.13." A WIPP Project document (Westinghouse, 1987a) has been prepared to guide future program implementation of the Assurance Requirements.

The determination of compliance with Subpart B depends on the calculated complementary cumulative distribution function and the calculated doses; however, it also depends on the strength of the assurance strategies that will be implemented and on the qualitative judgment of the DOE and its analysts. The preceding discussion clearly demonstrates the EPA's recognition of the difficulties involved in predicting the future and in quantifying the outcomes of future events. It also shows that the EPA expects the DOE to understand the uncertainties in the disposal system's behavior only to the extent practical.

One type of uncertainty that cannot be completely resolved is the validity of available models for predicting disposal system behavior 10,000 years into the future. Although models will be validated to the extent possible, expert judgment must be relied upon where validation is not possible. In the case of competing conceptual models, if a single conceptual model cannot be demonstrated to be the most consistent with available data, the most conservative conceptual model that is consistent with the data will be used.

2.2 PERFORMANCE EVALUATION IN THE FINAL ENVIRONMENTAL IMPACT STATEMENT

The adequacy of the WIPP disposal system to isolate wastes was considered in the WIPP Final Environmental Impact Statement (DOE, 1980). That evaluation of performance was deterministic and predated the Standard, which now requires a probabilistic assessment. A brief summary of the evaluation is provided here. Although the methodology used for evaluation in the Final Environmental Impact Statement would not satisfy the procedural requirements of the current Standard, the results do provide an indication that WIPP geologic environment will safely isolate wastes.

Both ground-water flow and radionuclide transport from WIPP to Malaga Bend on the Pecos River were evaluated in the WIPP Final Environmental Impact Statement. Calculations were performed for release into the Pecos River at Malaga Bend and for a location 3 mi (4.8 km) downgradient from the center of the repository. One-dimensional models were used for flow and transport outside the site; vertical and lateral dispersion were not considered. Calculations included the following assumptions:

- Wastes were not considered safe after any period of time (consequences were evaluated as a function of time after each release out to several million years).
- Fluid breach of the repository was assumed to occur after 1,000 years and human intrusion was assumed to occur 100 and 1,000 years after closure.
- Radionuclides were assumed to be dissolved at the same rate as salt.
- The gradient between the Rustler and the Bell Canyon Formations was assumed to be upward.
- The Salado Formation was assumed to be anhydrous.
- The Culebra and Magenta Dolomite Members were treated as one completely confined unit with a uniform porosity.
- Flow and transport behavior in all units was assumed to be that of a porous medium.
- Geologic and hydrologic steady states were assumed.

The calculations included two worst-case analyses that represented "physically plausible" (DOE, 1980, V.1, p. 9-124) extremes for fluid disruption of the repository and for human intrusion into the repository. One worst-case scenario assumed that all the water flowing in the Rustler Formation above the repository was diverted through the repository and back to the Rustler Formation. The other worst-case scenario assumed that material from a waste container was carried directly to the surface. The probability of occurrence of scenarios was not estimated. Uncertainty analyses were not performed, although the calculations were considered reasonably conservative. Cumulative releases were not calculated; instead, peak releases and their times of occurrence were predicted. The maximum peak release predicted in the Final Environmental Impact Statement to occur at Malaga Bend was 2×10^{-4} curies per year 1,200,000 years after decomissioning. The maximum peak release at 3 mi (4.8 km) was 3.3×10^{-4} curies per year at 400,000 years. Fifty-year dose commitments (integrated dose from a one-year intake) were estimated for all scenarios and found to be significantly less than natural background at the WIPP site.

In contrast, the Standard promulgated in 1985 requires that the WIPP disposal system's impact on the accessible environment (as defined by the EPA) be calculated quite differently. Cumulative radionuclide releases to the accessible environment (at the boundary and on the surface of the controlled area) over the 10,000 years following repository closure must be predicted. The annual dose to man, resulting from any releases to the accessible environment must also be predicted for 1,000 years after closure, considering only the undisturbed performance of the disposal system and including drinking from a significant source of ground water outside the controlled area, if radionuclide contamination of such ground water occurs within 1,000 years. Both sets of predictions must consider the uncertainties associated with the disposal system's performance. The release predictions are presented as a single complementary cumulative distribution function, which incorporates the probabilities and the parameter uncertainties of all the scenarios.

New information acquired since issuance of the Final Environmental Impact Statement in 1980 are being evaluated in a Supplement to the Final Environmental Impact Statement. The Record of Decision based on the Supplement to the Final Environmental Impact Statement will be made prior to receipt of waste.

2.3 FACTORS AFFECTING THE LONG-TERM PERFORMANCE OF THE DISPOSAL SYSTEM

An accurate assessment of the long-term performance of the disposal system requires an understanding of disposal room behavior during and after the consolidation process; an understanding of the effectiveness of the panel and shaft seals; and an understanding of the effectiveness of the local geology and hydrology to prevent or retard the transport of radionuclides to the environment.

The objective of this section is to summarize the present understanding of the long-term performance of the disposal system and draw upon the extensive amount of work completed to date for WIPP. The discussion briefly considers: (1) creep closure of the WIPP underground workings, including the disturbed rock zone; (2) brine seepage both into and out of the excavations; (3) gas generation, consumption, and transport as a result of radiolytic, biological, or corrosion reactions involving emplaced waste and waste containers; (4) sealing of the shafts and panels; and (5) hydrologic and geologic characteristics of the overlying and underlying strata.

This discussion specifically excludes consideration of radionuclide solubilities in Salado and Castile brines and any engineering modifications to the existing design of the WIPP underground workings, waste, or backfill.

2.3.1 Room Closure Rates

The observed closure behavior of openings at the facility horizon is more rapid and more complex than expected prior to underground experience. In fact, both the total macroscopic wall-to-wall and ceiling-to-floor closure to date and present closure rates (after five years) are approximately three times those originally expected. Ignoring possible complications, the more rapid closure results in time estimates of 60 to 200 years for closure to a near final state.

Certain structural effects or processes resulting from excavation of the rooms were not fully anticipated prior to underground experience. The observed excavation effects result in the formation of a disturbed rock zone at the facility horizon (Borns and Stormont, 1988). At present, the significantly disturbed zone extends approximately 7 ft (2 m) from the underground workings. However, it has not been possible to include the disturbance due to excavation in numerical modeling to date, nor is there consensus concerning its long-term importance.

The disturbed rock zone has the following characteristics:

1. Volumetric dilation as a result of grain boundary opening, as evidenced by detailed geophysical surveys.

2. Macroscopic fracturing as a result of opening preexisting fractures and generating new structures, extending from at least the base of Marker Bed 139 (about 5 ft (1.5 m) below the floor of the disposal horizon) to anhydrite "b" (about 7 ft (2 m) above the top of the disposal horizon).

3. Increases in apparent permeabilities (as interpreted from gas injection tests) by as much as several orders of magnitude, from a few nanodarcies (or less) in the far field to the darcy range in the very near field.

4. An apparent decrease in rock mass shear modulus (decreased mechanical strength), as a result of grain boundary dilation or macroscopic fracturing.

5. Growth of zones of partial hydrologic saturation and/or two-phase flow, as a result of some combination of volumetric dilation at a rate faster than brine inflow, rock mass dehydration by ventilation, and two-phase (gas driven) flow in response to near-field depressurization of gas charged brines.

Two conceptual levels of complexity in the mechanical closure behavior of the Salado Formation are at least partially consistent with available data. The existing model, amenable to numerical modeling, is based on the interpretation that coherent creep of the Salado Formation will dominate the system, independent of any disturbed rock zone that might develop. With this model, more rapid macroscopic closure is strictly beneficial. The model assumes: (1) that any disturbed rock zone is very small in volume and importance relative to the volume of deforming portions of the Salado Formation, and (2) that any disturbed rock zone developed during closure will be eliminated by the back pressures exerted by the waste and backfill emplaced in rooms and drifts. Mechanical back pressures are not expected to be generated until the waste and backfill are compacted to approximately 95 percent of their final state density. Thus, removal of a disturbed rock zone by back pressure, especially if the disturbed rock zone has expanded to include anhydrite, will not occur until very late in the closure process.

The second level of conceptual complexity, based on underground observation of the disturbed rock zone, also assumes that coherent creep of the Salado Formation outside the disturbed rock zone is the major structural process involved in repository closure. However, observation suggests that the disturbed rock zone may:

1. Serve as a "sink" for some or all of the brine that seeps into the rooms and shafts by storing brine in macroscopic fractures and perhaps the volumetrically dilated zone, thus resulting in a more complex, time- and geometry-dependent brine behavior than expected in the absence of a disturbed rock zone.

2. Enlarge the effective room dimensions during closure (not by increasing the total room volume, but by moving the surface at or near atmospheric pressure to the outer boundary of the disturbed rock zone), increasing both the time required for closure to final state and the volumes available for brine inflow beyond those estimated on the basis of wall closure calculations assuming coherent creep.

3. Affect the final degree of closure by extending to intersect the relatively brittle Marker Bed 139 or other more permeable units outside of the Salado Formation and allowing gas and/or brine entry into these units.

4. Complicate the design and/or postemplacement behavior of seals in panel entries, access drifts, and shafts.

Strong structural members, such as pipes and rods, within waste drums emplaced in WIPP may locally prevent complete compaction of waste and backfill under lithostatic load, even in the absence of brine seepage, gas generation, and disturbed rock zone effects. Although such members may result in local zones of increased porosity, it is not clear that these zones will interconnect; i.e., it is not clear that they will themselves result in any effective increase in room-scale permeability.

Two additional facts complicate prediction of the long-term closure behavior of the repository. First, the WIPP waste varies greatly in porosity, mechanical properties, and inorganic and organic chemistry, making it difficult to define the time-dependent geochemical and mechanical state of the waste as a source term for calculations. Second, the present design of the WIPP, even including backfill and getters, calls for the initial postemplacement porosity to be relatively high, approximately 50 percent. As a result, a large reduction of volume within the rooms must occur before final state is reached. Engineered modifications to mitigate the potential impact of many of the uncertainties discussed in this section would decrease the initial free volume within the rooms, and hence the time required for final closure. Systems analysis of potential modifications are being considered.

In summary, the uncertainty about the mechanical behavior of the Salado Formation during closure of the WIPP repository does not extend to fundamentally different conceptual models. Far-field coherent creep of the Salado Formation is considered to be the dominant process involved. The present uncertainty concerns only the time-dependent extent and possible role of the disturbed rock zone observed to develop in the underground facility.

2.3.2 Brine Flow or Seepage Within the Salado Formation

There are two major reasons for the difference between brine volumes within WIPP expected prior to underground experience and those observed underground. Prior to underground experience, the possibility of leakage from the Rustler Formation downward into the rooms through the shafts was not considered. Secondly, it was assumed that the Salado Formation contained no free water on grain boundaries.

Leakage from the Rustler Formation (largely the Culebra Dolomite Member) into each of the WIPP shafts does not exceed approximately 6×10^{-2} liters per second, even when the shaft is unlined and no effort is made to control drainage. This amount is minimal compared to that observed in many mines, but it does require control. Accordingly, the WIPP shafts have been lined and grouted through the Rustler Formation, successfully eliminating inflow. This conventional treatment will be adequate to control leakage from the Rustler Formation during the operational lifetime of WIPP, approximately 25 years. After this operational period, shaft seals will be emplaced to eliminate any further leakage.

The occurrence and behavior of brine within the Salado Formation is of greatest interest, however. The presence of brine in the Salado Formation adjacent to the underground workings is indicated primarily by the small "weeps" that commonly develop on the walls shortly after excavation. Small amounts of brine also drain from some of the instrumentation and observation holes in the walls or roofs of the underground or collect in holes emplaced in the floor. The weeps, which are indicated by small salt crusts formed by evaporation of the moisture, are stratigraphically controlled, being more abundant in argillaceous than in clean halite. Rarely does the brine flow rate to the mine face or wall exceed the evaporation rate due to mine ventilation. In fact, growth of the weeps generally ceases less than a year after construction of a given face (Deal and Case, 1987).

In the simplest interpretation, consistent with assumptions prior to underground experience, the transient brine weeps could be interpreted as the direct result of stress-driven flow, with no contribution of flow from the far field, i.e., from beyond the zone that is hydrologically or structurally affected by the presence of the underground workings. Alternatively, it may be assumed that the disturbed rock zone is dilational, that the zone serves as a "sink" for brine flow, and that the outer boundary of the disturbed rock zone represents the "effective room surface" for purposes of fluid flow, i.e., the surface at which fluid pressures are reduced to near atmospheric. In this interpretation, the fact that weep growth on wall surfaces ceases may indicate only that the effective room surface has moved into the rock mass in response to the formation of a disturbed rock zone and may not indicate that the flow rate into the disturbed zone is transient on the same one year time scale as weep growth.

The time scale of the transient brine seepage behavior should decrease with decreasing geometric scale of measurement. Consistent with this interpretation, a measured near steady-state brine inflow of 5×10^{-8} to 1×10^{-7} liters per second into sealed and unheated test holes (Nowak and McTigue, 1987) has been used as one basis to calculate a permeability supporting long-term Darcy flow in the far field. To date, the best direct measurements of far-field hydraulic conductivity within the Salado Formation are in the range of 10^{-14} to 10^{-16} meters/second (Peterson et al., 1987; Saulnier and Avis, 1988; Tyler et al., 1988). The conductivities calculated from brine inflow to test boreholes are also within this range (Nowak et al., 1988). However, stratigraphic effects have not yet been measured reliably, nor have the relative effects of borehole closure and fluid flow on either estimated permeability or extrapolated far-field fluid pressures been unambiguously determined. However, the general effect of borehole closure during pulse withdrawal testing of a discrete interval is to increase the measured fluid pressure (and hence both apparent fluid-flow rate and apparent permeability) above values calculated including the effects of closure.

Presently there are several uncertainties about the hydraulic characteristics of the Salado Formation. These include: (1) the state of hydraulic saturation in the far field; (2) the driving forces for fluid flow, i.e., whether flow results from mechanical deformation, induced head gradients, or gas driven, two-phase behavior; and (3) the relevant flow paths, i.e., whether porous medium flow (including stratigraphic effects) or fracture flow is more important. These uncertainties affect the time scale of fluid flow and the rock mass volumes involved in flow for both short and long time scales.

As a result of these uncertainties, there are at present two general types of conceptual models for brine movement within the Salado Formation. One conceptual model, based on far-field Darcy flow (e.g., Bredehoeft, 1988; Nowak et al., 1988), assumes that: (1) the Salado Formation is hydraulically saturated in the far-field, although near-field effects may include formation of a local zone of two-phase behavior or partial saturation, and (2) fluid flow from the far-field is the controlling or limiting process in the long term and can be modeled adequately using the Darcy equation, after accounting for stratigraphic effects and variability. In a Darcy formalism, fluid flow is directly proportional to the pressure gradient even when these gradients are very low. Even using such an approach, transient effects may extend over hundreds of years or more on the repository scale.

Other concepts for fluid movement within the Salado Formation are based on the interpretation that the concept of Darcy permeability within a sequence of layered evaporites such as the Salado Formation is valid only in those regions that have been significantly disturbed. In one such interpretation, the far-field permeability of the pristine halite is assumed to be essentially zero under any pressure gradient, i.e., undisturbed halite is assumed to have no interconnected porosity. By this interpretation, brine will flow into or out of the WIPP repository only in response to formation of a disturbed rock zone within which mechanical deformation is sufficient to generate interconnected porosity.

A less extreme but similar conceptual model assumes that there is some interconnected porosity within the Salado Formation even under undisturbed conditions. This model assumes that grain boundary fluids are so strongly bound that fluid flow only occurs under strong gradients, such as those generated near an underground excavation. With this model, fluid flow would take place in the near field even in the absence of mechanical disturbance. However, there would be no far-field fluid flow, due to the absence of sufficient gradients in this region.

The long-term or steady-state fluid inflow to the repository would decrease to zero by either non-Darcy conceptual model, possibly prior to complete saturation of the rooms and panels. Thus, either of the latter conceptual model may indicate that it is not necessary to assume that the repository will become hydraulically saturated in the long term, even in the absence of human intrusion.

Currently, it is not certain either that the different conceptual models of fluid flow within the Salado Formation have significantly different impacts to the long-term performance of the WIPP repository or that adequate measurements can be made in the field to distinguish between the models. All three conceptual models are consistent with the measurement of significant permeabilities within the disturbed rock zone and with observed transient flow behavior at relatively early times. In fact, preliminary calculations indicate that the volumes of brine collected to date may all come from within the present disturbed rock zone, even if modeled assuming Darcy flow. In general, interpretations assuming Darcy flow in the far field appear to be conservative, in that they do not result in an extrapolated zero flow rate at long times and do indicate maximum amounts of brine inflow.

From the view point of long-term performance of the WIPP facility, the fundamental questions are whether: (1) brine inflow into the disposal rooms will be sufficient to saturate backfill, waste, and the disturbed rock zone, either before or after compaction to the final mechanical state; and (2) the far-field permeability will be sufficient to dissipate brine and/or gas pressures at and near the final state, at some fluid pressure below lithostatic load.

2.3.3 Gas Generation in Waste Disposal Rooms

Microbial and radiolytic decomposition of the waste and corrosion of the drums could potentially lead to the generation of large volumes of gas. Pressurization of the disposal rooms may result if the rate of gas production exceeds the rate by which gas can migrate out of the disposal area. This pressurization could become a driving force for the release of radionuclides from the repository in the event of human intrusion.

Activities S.1.1.4, S.1.3.2, and S.1.3.3 and Appendix A of this Plan focus on the questions and studies directly related to gas generation and consumption within the repository. In summary, present knowledge concerning gas behavior within the repository suggests that:

1. The total amount of gas generated within the repository may be significantly greater than expected in 1980, as a result of microbial action and drum corrosion reactions.

2. The addition of gas getters to the backfill should be considered for reducing the buildup of CO_2 and possibly H_2.

3. As a result of very low permeabilities and apparent far-field hydraulic saturation of the Salado Formation, gas transport rates from the disposal rooms into the undisturbed Salado Formation may be minimal at long times. This transport will be limited by solubility and diffusion, rather than by mass flow, thus giving rise to high gas pressures if gas generation rates are significant.

The combined impact of these changes is that gas generation, consumption, and transportation within the repository are extremely significant and are being reconsidered. At present, the limited data and combined uncertainties in net gas behavior result in broad uncertainty in the expected gas pressure history of the repository. If gas pressures are allowed to exceed lithostatic pressure, these effects may:

1. Result in gas driven tensile fracturing of the Salado Formation in the near-field or far-field domains by generating pressures exceeding the least principle stress (near field) or lithostatic load (far field).

2. Stop structural closure at some porosity and permeability greater than that expected to occur in the absence of gas effects, by maintaining long-term gas pressures approximating the lithostatic load.

3. Result in a gas charged, one-phase fluid or a two-phase fluid system providing a driving force during human intrusion involving a single borehole.

4. Stop brine inflow.

If rigid structural members in the waste and the presence of a disturbed rock zone prohibit compaction to a final state of near-zero porosity, it may be possible to maintain a two-phase fluid system within the waste filled rooms and disturbed rock zone at fluid pressures below lithostatic. The maintenance of a one-phase, gas charged brine capable of providing a driving force in the event of human intrusion requires only that pressures greater than that of a column of brine extending to the surface be developed and maintained within the waste disposal facility.

Results of testing will be used to determine the need for and extent of additional measures to mitigate any potential adverse impacts associated with gas generation from the waste.

2.3.4 Shaft and Panel Seals

The goal for both shaft and panel sealing systems is to minimize migration of radionuclides from the waste disposal horizon into the surrounding environment. Many of the specifications for panel seals are directly applicable to shaft seals. The major difference between the two sealing systems is the host rock/seal interaction. All panel seals are contained within the Salado Formation while various units and a wider range of lithologies must be sealed in the shaft. These different lithologies affect the interaction of the seal and the host rock. As with the panel seals, the primary long-term sealing strategy for WIPP shafts is based on the reconsolidation of crushed salt to be emplaced in the Salado Formation at the lower section of the shafts (Stormont, 1988a; Tyler et al., 1988).

The evaluation of sealing materials and seal designs has been derived from laboratory and in situ testing, as well as from numerical modeling and analysis. The laboratory work has focused on sealing materials: crushed salt blocks and quarried salt, cementitious materials, and clays (primarily bentonite). For salt, laboratory and in situ studies have been directed toward understanding reconsolidation of crushed salt and the resulting fluid-flow properties. For bentonite, the density, swelling, and fluid-flow properties have been investigated. Laboratory and in situ test data indicate that bentonite-based seals will effectively restrict fluid flow over the short term. The long-term stability and integrity of salt and bentonite, as well as cement and cement/bentonite mixtures, have been the primary focus of laboratory investigations (Tyler et al., 1988).

The long-term behavior of the sealing system's structure, fluid flow, and in situ interactions was modeled by numerical codes. These codes were based on preliminary laboratory data and were used to predict results of in situ tests. As in situ data became available, the codes were refined to more accurately reflect the physical processes and behavior.

In situ experiments have tested various sealing materials and designs under actual conditions. These experiments include permeability measurements of the various host or representative lithologies, tests of sealing systems representative of shaft seals, and evaluations of backfill and borehole plugs. These sealing tests have provided high quality thermal, structural, and fluid-flow data for candidate sealing materials in various configurations.

A comprehensive evaluation of shaft sealing materials, seal geometries, and locations within certain stratigraphic units has been completed (Stormont, 1988a). The factors evaluated include Rustler Formation hydrology, adjacent disturbed rock zone permeabilities, brine inflow in the Salado Formation, and shaft closure in the Salado. The reference design for seals in the Rustler is a concrete/bentonite composite. The reference design for Salado seals incorporates both multicomponent and reconsolidated, crushed salt seals. The primary material for sealing WIPP shafts is reconsolidated salt excavated from the waste disposal area. Although the WIPP reference shaft sealing system requires work to reduce uncertainty and corroborate the findings of the preliminary evaluations, no fundamental reason has been found to revise the design concepts (Tyler et al., 1988).

2.3.5 Hydrology and Radionuclide Transport Outside the Disturbed Rock Zone

Geologic and hydrologic site characterization activities at the WIPP facility have updated or refined the overall conceptual model of the geologic, hydrologic, and structural behavior of the WIPP site, with the objective of providing data adequate for use in performance assessment. A summary of the current conceptual model for geologic, hydrologic, and structural behavior of the WIPP site can be found in a report by Lappin (1988).

Two types of transient responses are occurring at and near the WIPP site: the continuing natural response of geologic and hydrologic systems to the end of the last pluvial period (period of decreased temperatures and increased precipitation approximately 12,000 to 16,000 years ago) in southeast New Mexico, and the continuing geologic responses to hydrologic, geochemical, and structural transients induced by WIPP site characterization and facility construction activities.

The Bell Canyon Formation (Figure 2-2) (largely shales, siltstones, and sandstones) contains the first relatively continuous, water-bearing zone beneath the WIPP facility. In some parts of the northern Delaware Basin, the unit contains permeable channel sandstones that are targets for hydrocarbon exploration. Recent studies suggest, however, that the upper Bell Canyon Formation at the WIPP site does not contain any major channel sandstone. These studies indicate that the final direction of fluid flow following interconnection of the Bell Canyon, Salado, and Rustler Formations would be downward into the Bell Canyon Formation, contrary to earlier assumptions. These observations indicate that the Bell Canyon Formation will not provide a source of fluids for contamination

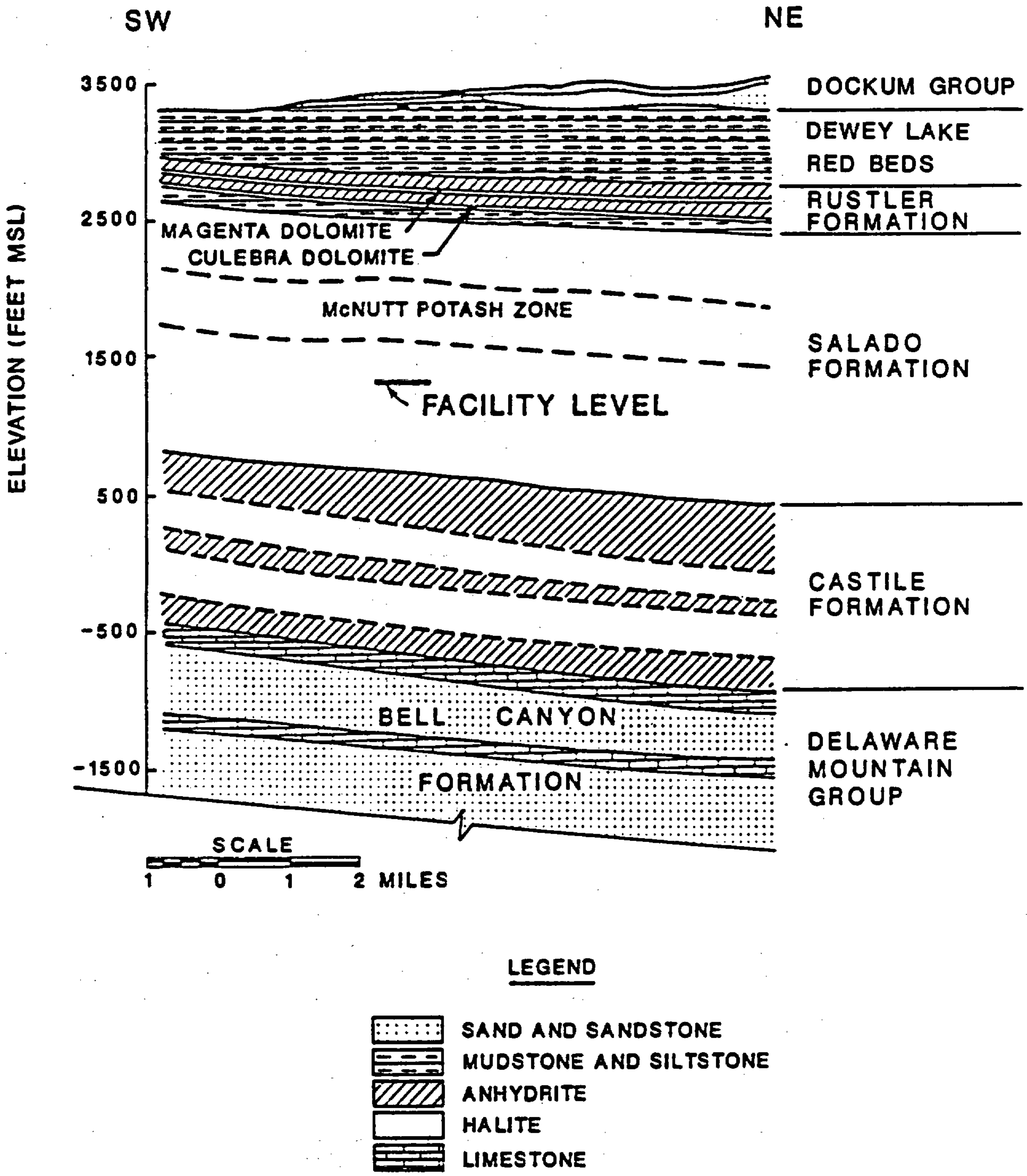


Figure 2-2. Stratigraphic Cross Section at WIPP

of the overlying Rustler Formation water-bearing units should a breach of the repository occur.

The Castile and Salado Formations, sequentially overlying the Bell Canyon Formation, are predominantly layered anhydrites and halites. Studies indicate that the Castile and Salado Formations are low permeability units that deform on a large scale in response to gravity. Formation permeabilities in the Castile and Salado Formations remote from the WIPP excavations are generally less than 0.1 microdarcy. The low permeability of these two formations provides effective confining boundaries to fluid flow from the repository to water-bearing zones, both stratigraphically above and below the facility horizon.

Pressurized brines have been encountered in Castile Formation anhydrite in the WIPP-12, ERDA-6, and Belco boreholes (Popielak et al., 1983), north and south of the center of the WIPP site (Figure 2-3). Geophysical studies indicate that Castile Formation brines are probably present beneath a portion of the WIPP waste emplacement panels (Earth Technology, 1988), consistent with earlier assumptions. However, these brines are approximately 660 ft (200 m) or more below the WIPP facility horizon and are not of concern to long-term performance except in case of a human-intrusion breach of the facility.

The Rustler Formation is a layered unit of anhydrites, siltstones, and halites containing two variably fractured carbonate units, the Culebra and Magenta Dolomite Members. The Culebra Dolomite is the first continuous water-bearing unit above the WIPP facility and is at least an order of magnitude more permeable than other members of the Rustler Formation, including the Magenta Dolomite. As a result, the Culebra Dolomite dominates fluid flow within the Rustler Formation at the WIPP site and is the most significant pathway to the accessible environment from the WIPP facility except for direct breach to the surface. Culebra Dolomite transmissivity varies by approximately six orders of magnitude in the region containing the WIPP site ranging from 2.15×10^{-9} meters^2/second to 1.34×10^{-3} meters^2/second (Lappin, 1988). Culebra Dolomite transmissivity in the central portion of the site, including all four WIPP shafts, is low; higher Culebra Dolomite transmissivities are found in areas to the southwest, southeast, and northwest.

In the WIPP site area, modern flow in the Culebra Dolomite Member is confined and largely north to south. However, fluid flow and geochemistry within the Culebra Dolomite and shallower units are in continuing transient response to the marked decrease or cessation of localized recharge at approximately the end of the last pluvial period. Both bulk chemistry and isotopic relations of Culebra Dolomite fluids are inconsistent with modern flow directions if steady-state, confined flow is assumed. It is assumed that recharge to the Rustler in the past occurred within Nash Draw, with resultant flow generally to the east and southeast. Flow is interpreted to have reoriented to its present general southerly direction in response to the end of recharge. This interpretation of the change in flow directions within the Rustler is based largely on uranium-disequilibrium studies (Lambert and Carter, 1987). Because of the relative head potentials within the Rustler Formation at and near the WIPP site, there appears to be a small amount of vertical fluid flow between its members, even though the permeabilities of Rustler Formation members other than the Culebra Dolomite are quite low. Where measured successfully, the modern head potentials within the Rustler Formation prevent fluid flow from the surface downward into the Rustler

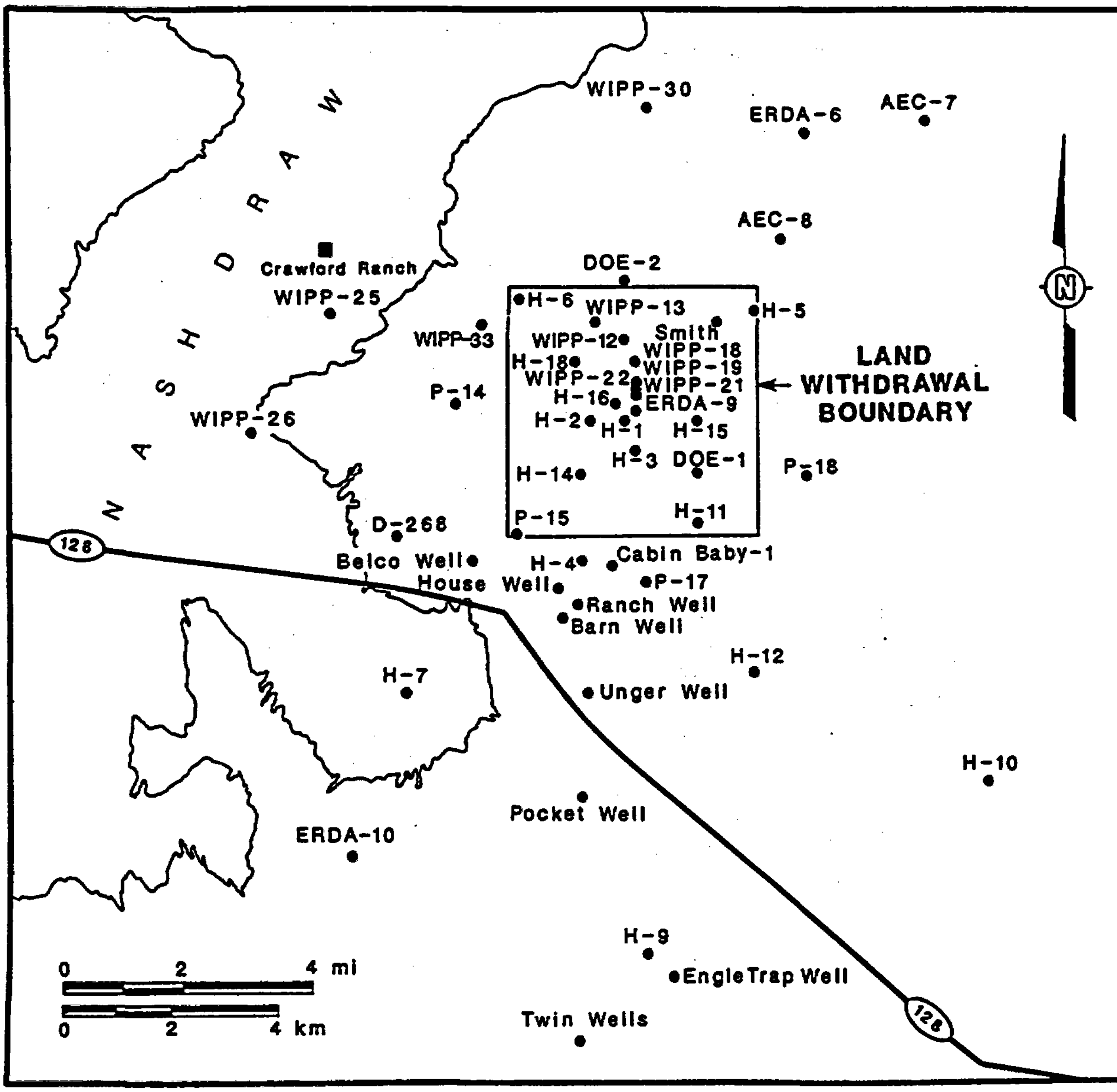


Figure 2-3. Hydrologic Test Wells Near WIPP

carbonates. These results suggest that recharge from the surface to the Rustler Formation is not occurring at the WIPP site. Deuterium-oxygen analyses available from the Rustler Formation consistently indicate an isotopic character distinct from that of modern meteoric precipitation in the area (Lambert and Harvey, 1987). The results of stable isotope, radiocarbon, and uranium disequilibrium studies are also consistent with the interpretation of no measurable modern recharge to the Culebra Dolomite from the surface at or near the WIPP site.

Within and near Nash Draw, evaporite karst processes operate within the Rustler Formation, as evidenced by the continuing development of small caves and sinkholes in near-surface anhydrites and gypsums of the Forty-niner and Tamarisk Members. There is no evidence of karstic hydrology in the Rustler Formation at the WIPP site. However, fracturing of some portions of the Culebra Dolomite is sufficient at the site to strongly affect both hydraulic and transport behavior over distances of approximately 100 ft (30 m). Detailed transport calculations and ground-water flow modeling indicate that fracturing effects are not significant in regional-scale transport within the Culebra Dolomite, as long as the modern head distribution is not significantly disturbed.

The Dewey Lake Red Beds overlying the Rustler Formation consist largely of siltstones and claystones, with subordinate sandstones. In tested locations, the Dewey Lake Red Beds are too low in permeability for successful hydrologic testing. At the WIPP site the Dewey Lake Red Beds are unsaturated but less than 1/2 mi (1 km) south of the WIPP site boundary, sandstones within the Dewey Lake Red Beds produce potable water. Isotopic relations suggest that surficial waters have contributed to the formation of secondary gypsum veins within the Dewey Lake Red Beds, but that the Dewey Lake Red Beds and Rustler Formation hydrologic systems are not currently well connected. Limited strontium isotope studies of the Rustler Formation and Dewey Lake Red Beds appear to indicate limited vertical fluid flow from the Rustler upward into the Dewey Lake Red Beds and a major involvement of surficial materials in crystallization of secondary veins within the Dewey Lake Red Beds (Lambert, 1988). Similar studies, again based on a limited data base, indicate that secondary gypsum veins within the Rustler could not have crystallized in equilibrium with modern meteoric recharge in the area.

2.4 OVERVIEW OF TECHNICAL APPROACH FOR COMPLIANCE WITH 40 CFR 191, SUBPART B

2.4.1 Performance Assessment

The performance assessment methodology presented here is a complex process comprising seven major components: (1) data collection and model development, (2) scenario development and screening, (3) preliminary consequence analysis, (4) sensitivity and uncertainty analysis, (5) final consequence analysis and comparison with Standard, (6) analysis of undisturbed performance, and (7) documentation. The interrelationships between these components are shown in Figure 2-4 and are briefly described below; a more complete description can be found in Bertram-Howery and Hunter, 1989b.

Data Collection and Model Development: Consequence modeling requires the development of conceptual models, which are geologic and hydrologic descriptions of the region surrounding the WIPP and descriptions of the repository, derived from

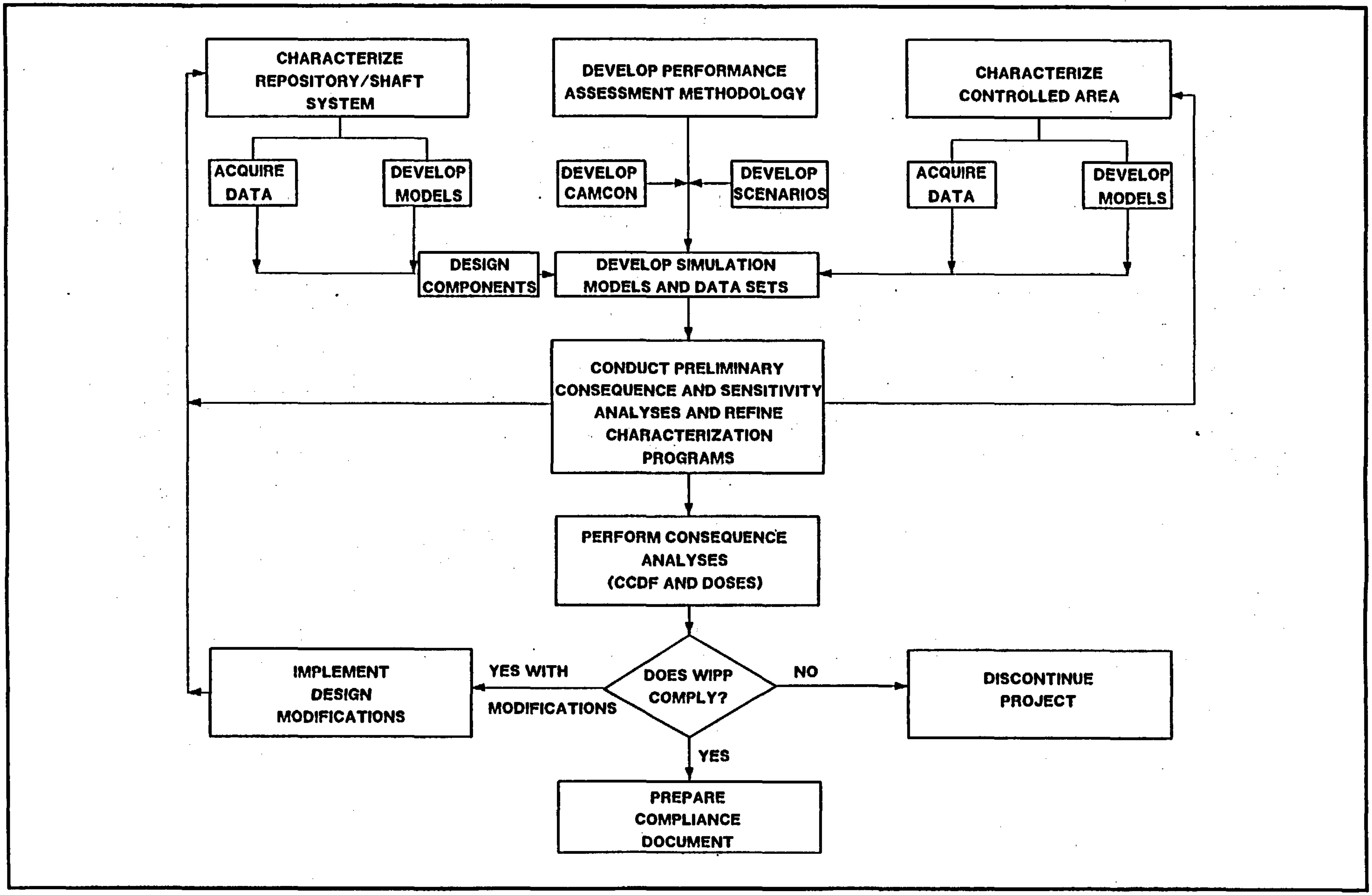


Figure 2-4. Flow Chart of the Performace Assessment Process

disposal system characterization data. The activities that provide this information are described in Section 2.6.2, beginning on p. 2-84. Because WIPP site characterization and repository design have been underway since 1975, the observational data base is large. These programs have also developed several numerical models that will be incorporated into the performance assessment computational methodology. Characterization of the disposal system and the surrounding area and development of models will continue during the Test Phase, both to support the performance assessment and to complete the disposal facility conceptual design. The existing data base will be expanded to support a larger, regional conceptual model domain for performance assessment. This expansion includes gathering and synthesizing additional geologic and hydrologic data for the selected domain and for outlying regions that may influence this domain. The data base will also be expanded to include more specific data on the backfill performance and salt creep closure. It also will include the conceptual design of the seals and data on gas generation. The disposal system characterization activities provide most of this component of the performance assessment methodology. Inability to fulfill data requirements does not preclude the necessity for the data. If no data or sparse data are available for a given parameter, performance assessment will use the best available estimates of the parameter's range and distribution and perform appropriate sensitivity analyses to determine the effect of the parameter uncertainty on the results for each affected scenario. The uncertainty in the parameter may be larger than would be the case if the necessary information were well characterized.

Scenario Development and Screening: Scenarios can be omitted, or screened out, from the performance assessment if the probability of occurrence is less than 1 in 10,000 years. Preliminary estimates of consequences can also be used to screen out scenarios, if their omission is not expected to change the remaining probability distribution of cumulative releases significantly. Establishing the probability of occurrence of scenarios is therefore necessary to show compliance with the Standard. The events retained for further WIPP scenario development in the present scenario report include the effects of a pressurized brine occurrence beneath the WIPP, climatic change, dissolution of waste or rock immediately adjacent to the repository, drilling into the repository, groundwater flow, the effects of mining for resources, seal performance, subsidence of overlying rock into the repository, waste/rock interaction, and waste effects. The 110 scenarios arising from these events and processes provide enough detail to guide consequence modeling and continued data collection within the WIPP Project. The scenario development report screened scenarios on the basis of probability and retained 76 scenarios for further analysis. These scenarios will be further screened on the basis of simple consequence modeling, which will determine whether events and processes are significant enough to be retained for final consequence analysis. It is anticipated about ten will be retained for full evaluation. In each case, performance assessment models will be adapted to simulate the scenario and bounds on consequences will be calculated.

The final scenario report (Hunter, 1988) will describe the development and screening of the scenarios and their probability assignments. Supplements to the scenario development report will contain the results of scenario screening and will incorporate or respond to any comments from outside organizations and individuals. If it is necessary to develop or expand scenarios because of new data, these new scenarios will be reported in the supplements.

<u>Preliminary Consequence Analyses</u>: The preliminary consequence analysis will assemble and test the entire suite of codes, models, and techniques necessary to prepare a complementary cumulative distribution function (CCDF) that indicates the probability of exceeding various levels of cumulative release and for comparison with the Standard. If the performance assessment methodology is found to be deficient during the preliminary analyses, these deficiencies will be corrected before the final consequence analysis is performed. Scenarios that survive the screening will be analyzed. Regional and local hydrologic models will be used to examine ground-water flow under the various scenarios. Codes appropriate for simulating the transport of radionuclides through geologic formations will be selected. Models provided by various disposal system characterization activities will be assembled and adapted into the model of the repository/shaft system, which will comprise linked codes for models of the rooms, panel seals, drifts from the panel seals to the shafts, and shafts and seals.

Effects of uncertainty in scenario probabilities will be examined and potential problems identified during the preliminary consequence analysis. A determination of the need for dose calculations can also be made at this stage. The complementary cumulative distribution functions calculated during this preliminary work will be incomplete. Some data will not be available yet, and the Project will still be carrying out important sensitivity analyses to design scenario-dependent computational strategies. The preliminary complementary cumulative distribution functions will be used for scoping purposes and internal evaluation only.

The WIPP methodology will be implemented using a modular system of computer codes referred to as the "compliance assessment system." The complex disposal system at the WIPP requires that the series of computer codes in the compliance assessment system be controlled by an executive software package, CAMCON (Compliance Assessment Methodology CONtroller; Rechard, 1989). CAMCON minimizes analyst intervention and automatically handles quality assurance during the calculational process. The primary data base comprises the analyzed, strictly quality-assured data for performance assessment purposes. The primary data base must be interfaced with CAMCON by objectively or subjectively extending it to regular grid information. These new data files will be placed into the secondary data base where they may be directly accessed by the various model components of CAMCON. The preliminary consequence analysis will set up the entire calculation sequence, using CAMCON and the appropriate data bases, for each significant scenario.

<u>Sensitivity and Uncertainty Analysis</u>: Sensitivity analyses will be performed for each scenario that appears to be of regulatory interest as part of the preliminary consequence analysis. Figure 2-4 shows sensitivity analysis as an iterative step preceding consequence analysis. The main function of sensitivity analysis is to determine the relative importance of the parameters that provide input to the consequence analysis. This information provides guidance to the Performance Assessment Program in the following ways:

<u>Identifying the critical input parameters</u>. Determine the critical input parameters at both the system and subsystem levels. Sensitivity analyses of the model segments and the input parameters help identify those model segments and input parameters which are important in modifying the response of the model segment (input parameter) or the total scenario (model

segment). These input parameters or model segments are then analyzed in greater detail to see how they are changing. For those components which are changing in a nonlinear manner, more precise values will be needed for both the parameter range and the distribution.

<u>Determine the relative importance of data collection activities</u>. As the relative importance and required accuracy of input parameters are determined, sensitivity analysis provides the opportunity to upgrade or downgrade the priorities of data collection activities. This prioritization will provide direction to the Project with more efficient use of finite resources and expertise.

<u>Provide guidance to the development of design enhancements</u>. If it is determined that a critical parameter needs to be known to an accuracy that is beyond the capabilities of the current technology, design modifications may be employed to lessen the importance of that parameter on the long-term performance. For example, if it is determined that brine inflow rates cannot be established with sufficient confidence to be within an acceptable range, compaction of the waste and the use of a grout backfill could greatly reduce the time required for the rooms to close and thus reduce the quantity of brine expected to flow into the room.

Sensitivity analysis for a given scenario begins with a description of a conceptual model of the disposal system. The best available computational models and required input data for each affected subsystem are then assembled to simulate the response of the disposal system to the scenario. Response, or performance, is usually measured in terms of either potential doses to individuals over a 1,000-year interval, or as 10,000-year cumulative releases of individual radionuclides. Key input parameters are then varied over some reasonable range of values to determine the effect of varying these parameters on the consequence of the scenario. Poorly defined parameters that are shown through sensitivity analysis to have a strong effect on performance are highlighted as key parameters. Activities that provide accurate and defensible values for these key parameters will be given a high priority. Activities that provide values for parameters that are shown to be less critical to performance will be downgraded to a lower priority.

A preliminary sensitivity study identified the human-intrusion scenarios as critical. Four energy sources were identified that could move waste from the repository horizon to the accessible environment: drilling equipment and fluids, gravitational effects, gas generation and entrainment within the rooms or panels, and the pressurized brine occurrence below the repository. None of these sources can move sufficient waste to violate the Standard if the rooms are compacted to a porosity or permeability comparable to the undisturbed salt. That study identified needs for better understanding of room closure, brine inflow from the Salado Formation, the compaction of the wastes and backfill, gas generation, transport out of the facility, and the effectiveness of gas getters.

The study also showed that an understanding of the waste inventory (both radioactive and chemical) was needed for the source term. The radioactive inventory has since been relatively well defined, but an adequate understanding of the nonradioactive waste inventory has not been acquired. A second preliminary sensitivity analysis is being performed for the Supplement to the

Final Environmental Impact Statement. It may also affect modeling and data acquisition requirements.

Uncertainty analysis determines the uncertainty in the performance-measure calculation resulting from uncertainty in scenarios, models, and input data. The WIPP Project will address scenario uncertainty through external peer review. Uncertainty in the models will be addressed through verification, validation, calibration programs, and quality assurance. Uncertainty in the input data will be incorporated by Monte Carlo sampling. The Standard requires that the performance assessment results be incorporated into an overall probability distribution of cumulative release to the extent practicable. Appendix B of the Standard suggests that the results be assembled into a single complementary cumulative distribution function that indicates the probability of exceeding various levels of cumulative release. This single curve will incorporate all parameter uncertainty. If this single distribution function meets the release limits, then a disposal system can be considered to be in compliance with the Containment Requirements. Uncertainty analysis is an integral part of consequence analysis.

<u>Final Consequence Analysis and Comparison with Standard</u>: Final consequence analysis will be performed for each scenario determined to be significant during the scenario-screening process. It will be performed using the performance assessment methodology described for the preliminary consequence analysis, modified as necessary to correct any deficiencies found during that earlier analysis. The results of the final analysis will be assembled and presented in the form of a complementary cumulative distribution function, which will be compared with the Standard. This activity comprises several tasks: finalizing all data and models, simulating all scenarios through CAMCON, analyzing each scenario's results, producing the final complementary cumulative distribution function, and comparing the complementary cumulative distribution function with the Standard.

<u>Analysis of Undisturbed Performance</u>: If any release of radionuclides from the undisturbed scenario during the first 1,000 years is projected by the final consequence analysis, annual doses will be calculated and compared with 40 CFR 191, Section 15, Individual Protection Requirements. Releases to the accessible environment are not expected during that time, so dose calculations should not be necessary; however, the WIPP Project will be prepared to perform such calculations. The Project intends to use the compliance assessment system in demonstrating compliance with the Individual Protection Requirements. A scenario describing the undisturbed performance of the repository will be simulated using reasonable projections of the expected behavior of the repository. Release calculations for the undisturbed scenario will use CAMCON models to determine the need for dose calculations. Pathways and dosimetry models and corresponding data bases will be included in CAMCON.

<u>Documentation</u>: DOE is responsible for determining whether WIPP complies with Subpart B of the Standard. That determination will be based on an unprecedented document describing the compliance evaluation process and compares the disposal system performance with the Standard. Careful planning will assure that the document can be prepared and accepted on time, will adequately support the determination of compliance, and will withstand external challenges. A report to be issued in 1989, *Forecast of the Comparison to 40 CFR 191, Subpart B,*

and Methodology Demonstration, will be a preview of the 1992 compliance report, having the same format, table of contents, and, where available, text. Where not yet available, the 1989 text will be an annotated outline of the final text. The 1992 document will include descriptions and results of the final consequence analysis and the complementary cumulative distribution function for the Containment Requirements (Section 13) and dose estimates for the Individual Protection Requirements (Section 15). It will also address the Assurance Requirements (Section 14) and the Ground Water Protection Requirements (Section 16).

2.4.1.1 Methodology

In 1986, the Project reviewed the performance assessment activities, the regulatory requirements, and the methodology developed at Sandia National Laboratories for the Subseabed Disposal Project and for the Nuclear Regulatory Commission (NRC) and EPA regulatory development programs. The outcome of the review was a decision for the performance assessment to use proven conceptual methodology rather than develop a new methodology. The Standard suggests that if another methodology is used, different from the NRC/EPA conceptual methodology, comparisons of the new methods with those used to develop the NRC/EPA methodology would have to be made. The NRC/EPA methodology, documented by Hunter et al. (1986), was selected.

Using this methodology, the first step was to develop and begin screening the scenarios that will guide the performance evaluation. The master list of scenarios has been constructed, using all existing data and understanding, and is currently in review (Hunter, 1989). The next step was to develop tools allowing the conceptual performance assessment methodology to be used in an actual performance assessment. The main, undeveloped computational tool was an executive code that would control, track, and store for future reference all parts of each calculation for each scenario. Earlier work by the Subseabed Disposal Project and NRC/EPA groups identified human error in translation between different subcodes within a given scenario as a major failure mode. An executive code, CAMCON, has been developed to remove most, if not all, of the possible human errors. That code is currently being tested and the document describing it is in review (Rechard, 1989).

An important component of the methodology is the development of accepted regional and local hydrologic and material-transport models that describe the movement of water and dissolved waste through the site. The upper aquifer, regional, fluid- and material-transport model has been developed and tested, and a description of the code is currently in preparation (Brinster, 1989).

A report to be issued in 1989, *Forecast of the Comparison to 40 CFR 191, Subpart B, and Methodology Demonstration*, showing the complete performance assessment process using two preliminary scenarios, one natural and one human intrusion (Hunter, 1988), and the best models and codes available at that time will demonstrate that the process is operational and accepted. A complete set of calculations can be done as soon as certain models and data are developed (e.g., shaft seals).

2.4.2 Technical Support

The technical approach for the WIPP disposal system characterization has been and continues to be a systematic process that will obtain sufficient technical information for establishing a design basis for waste isolation and for performance assessment of the disposal system. Five major processes have been identified that will ultimately provide a level of confidence that the data base is adequate:

- Laboratory Testing and Model Development including theoretical analysis and the determination of physical and chemical properties of materials.

- Site Characterization including geology, hydrology, geochemistry, and geophysics.

- In Situ Testing including the acquisition of data from full-scale tests underground, in some cases using actual waste.

- Data Reduction and Analysis including the feedback process of comparing in situ and field data with predictions.

- Evaluation and Validation including the adjustment and refinements of theoretical models and techniques to predict long-term behavior that would be expected in the host rock.

Laboratory testing and model development for waste isolation has been a continuing efforts of the WIPP Project since 1975. These efforts include extensive model development, theoretical analysis, and laboratory testing. Depending on the technical issue being addressed, model development can be associated with a laboratory, material property testing program, or with a theoretical study of mechanisms, physical and chemical processes, or fundamental static or dynamic laws. Laboratory testing and theoretical studies are performed in an appropriate sequence or in parallel to evaluate the adequacy of the model to represent the phenomenon in question. Laboratory testing and theoretical analyses are usually conducted as complementing efforts so that when complete, a predictive model can be used to represent material behavior or response of a physical/chemical process.

Site characterization activities have been underway since 1975. The overall conceptual model of the geologic, hydrologic, and structural behavior of the site has been developed and refined. The site characterization work is nearly complete.

In situ testing with and without radioactive wastes is necessary to validate design concepts and models to be used for performance assessment. Although models and theoretical developments can be evaluated in part by laboratory or bench-scale experiments, in situ testing has been considered a vital part of the WIPP for:

- Providing the basis for establishing a level of confidence in models by validation with actual data from in situ tests.

- Establishing designs and systems concepts including appropriate performance criteria.

- Demonstrating the developed technology for scientific and public scrutiny and acceptance.

In situ testing for waste isolation is limited for practical reasons because it cannot in all situations accurately simulate effects over large areas (repository size) nor can it directly address long-term effects. Configurations for the in situ tests at WIPP are therefore linked with theoretical techniques so that test results can then be used to evaluate the capability to predict response through the testing period and 10,000 years into the future.

In situ tests at WIPP have been configured to measure a wide range of parameters that are used in models and data developed from laboratory studies. These models and the information obtained from numerous studies are also used in calculations that determine the scope, configuration, and measurement location of the individual in situ tests. Calculations, normally completed prior to initiating a test, establish reference predictions of the proposed test and develop a format against which a direct comparison can be made with in situ measurements. This comparison between model prediction and in situ measurement then forms the basis for data analysis and evaluation studies.

The data reduction and analysis process is significant; it must ensure that large volumes of in situ test data and field data are managed in an efficient and effective manner while ensuring adequate quality control. The data reduction portion of the process provides for a systematic procedure developed appropriately for: (1) screening the raw data, (2) reviewing it for missing information, (3) making appropriate corrections and adjustments for time shifts or calibrations based on the judgment of the principal investigators, (4) evaluating and analyzing the corrected data for consistency based on comparisons with similar measurements or expected physical or chemical responses, and (5) presenting the information in data reports for subsequent analyses.

The evaluation and validation process includes a thorough examination of analyzed, in situ data and its comparison with early laboratory and theoretical studies. Detailed correlations will be performed between the data obtained from the full-scale tests and the results from the calculations made using models and computer codes. Many of the material property, chemical, and radioactive interactions, fluid flow, and other constitutive models will be evaluated against in situ behavior of material components and systems. These models will subsequently be modified and refined if scientific rationale and physical/chemical justification are found. Adjustments to computer codes and analytical techniques will also be made so that the predictive procedures will more closely represent actual behavior.

2.5 DESCRIPTION OF THE PERFORMANCE ASSESSMENT PROGRAM

The program for determination of compliance with 40 CFR 191, Subpart B, is organized into five basic elements: (1) scenario screening, (2) repository/shaft system behavior, (3) controlled area behavior, (4) computational system development, and (5) consequence analysis. These elements are further divided into subelements. Each subelement, in turn, develops information needs. These information needs define the activities that will be performed to resolve the issue. There are two basic sets of activities described in Section 2.6: (1) performance assessment, and (2) supporting (disposal system charactization) activities. The performance assessment activities focus on the development of models that will be used to predict the consequences of credible processes and events that could potentially lead to releases of radionuclides from the disposal system. Disposal system characterization activities focus on obtaining the information necessary to provide input data to the performance assessment models.

The performance of the WIPP disposal system must be predicted to determine whether the disposal system can satisfy both the Containment Requirements and the Individual Protection Requirements of 40 CFR 191. The behavior of the system will be simulated under various conditions to predict long-term performance. These conditions include the predicted behavior of the undisturbed system, significant natural events and processes that may change the predicted behavior, and human intrusion. Only the undisturbed behavior will be simulated for the 1,000-year performance requirement for individual protection. The disposal system's behavior under all the above conditions may be simulated and the results combined into one function for the 10,000-year performance requirement for containment. Uncertainties in all simulations must be considered in the predictions.

The procedural approach to predict performance is based on the guidance provided by the EPA with the Standard. Although this is not the only possible approach, it is based on techniques used by the EPA to evaluate the feasibility of the Standard itself. The conditions to be simulated will be determined by scenario development and screening, a process that identifies the significant scenarios whereby radionuclides could be released to the accessible environment and assigns probabilities to those scenarios. Each scenario will then be used to define a disposal system conceptual model that will allow assessment of the system's performance under the conditions required by that scenario. The conceptual model will be described by the appropriate data sets and the scenario simulated by a set of computational models that are linked and, if necessary, coupled. Consequence analysis will then be used to predict the quantities of radionuclides that may be released for the scenario, considering the uncertainties in the behavior of the components of the disposal system and of the system as a whole.

Parameter uncertainty will be handled by treating the parameters as random variables with a distribution of values. For one scenario simulation, the value for each parameter will be selected using a Monte Carlo sampling procedure. This process requires numerous simulations for each scenario to provide a reliable distribution of releases.

For the 10,000-year performance, the EPA has indicated that the predicted releases from all simulations for all scenarios analyzed will be combined with the scenario probabilities and presented in one complementary cumulative distribution function. This single function will be compared with the release limits set by the Standard. For the 1,000-year performance, the annual release distribution for each release location is used to calculate an annual dose distribution. The EPA has indicated that the mean or the median of each dose distribution will be used for comparison with the dose limits.

These analyses will require that the behavior of the entire system be adequately simulated to determine compliance, and that certain components of the system also be simulated separately. For example, the undisturbed performance will require simulation of the entire system, while certain human-intrusion scenarios will require simulation of intrusion into a room and subsequent transport in the Culebra Dolomite Member of the Rustler Formation. Some scenarios, such as intrusion into a pressurized brine occurrence, may require specialized models. The assessment elements address the scenario analysis, the assembly of appropriate subsystem and system computational models to describe conceptual models for each scenario, the complexity of the computational system, and the calculation of releases and doses. Assembly of the models requires characterization of the total disposal system, including the behavior of the repository and shaft system and the potential for hydrologic transport of radionuclides beyond the repository and shaft system.

The Performance Assessment Program will be considered complete when:

- The complete set of significant scenarios with probabilities of occurrence has been defined and the corresponding set of disposal system conceptual models described.

- Each conceptual model can be adequately simulated by a system of optimized computational models using appropriate, well-defined data sets.

- The data sets have undergone quality assurance and the computational models and systems of models have been verified and validated to the extent possible.

- The computational system is operational and record keeping is adequate to support repetition or modification of each simulation.

- The final analyses and comparisons to the release limits and dose limits in the Standard are complete and a peer review process has affirmed that the analyses are adequate.

2.5.1 Structure of the Performance Assessment Program

This section provides a description of the work elements and subelements that support completion of the Performance Assessment Program. The work is divided into five elements and corresponding subelements and information needs (Table 2-1). Each subelement provides a list and description of the information needs required to address that subelement. Each information need identified has been given a four-digit reference number. The first two digits refer to the element it supports, the third digit refers to the subelement, and the fourth digit refers to the specific information need established under the subelement. In addition, each information need description provides a reference (with page number) to the relevant activities that support the information need.

TABLE 2-1. WORK ELEMENTS, SUBELEMENTS, AND INFORMATION NEEDS FOR PERFORMANCE ASSESSMENT

Element 1.1
Scenario Screening

Subelement 1.1.1 Climatic Change
- 1.1.1.1 Modern Hydrology
- 1.1.1.2 Paleoclimatology/Hydrology
- 1.1.1.3 Recharge

Subelement 1.1.2 Nuclear Criticality
- 1.1.2.1 Radionuclide Inventory
- 1.1.2.2 Radionuclide Distributions and Concentrations
- 1.1.2.3 Reconcentration

Subelement 1.1.3 Human Intrusion
- 1.1.3.1 Flow Direction in Bell Canyon Formation Boreholes
- 1.1.3.2 Room Effects
- 1.1.3.3 Bell Canyon Formation Flow
- 1.1.3.4 Culebra Dolomite Hydrology
- 1.1.3.5 Two-Borehole Effects
- 1.1.3.6 Subsidence Zone
- 1.1.3.7 Flow Variations

Subelement 1.1.4 Seal Performance
- 1.1.4.1 Seal Performance
- 1.1.4.2 Failure Modes

Subelement 1.1.5 Probability Assignment
- 1.1.5.1 Scenarios
- 1.1.5.2 Expert Opinion
- 1.1.5.3 Probabilities

Element 1.2
Repository/Shaft System: Behavior Characterization and Performance Modeling

Subelement 1.2.1 Waste Disposal Room Behavior and Modeling
- 1.2.1.1 Source Term
- 1.2.1.2 Backfill
- 1.2.1.3 Container Response
- 1.2.1.4 Closure
- 1.2.1.5 Brine Inflow and Room Resaturation
- 1.2.1.6 Gas
- 1.2.1.7 Disturbed Rock Zone
- 1.2.1.8 Systems Interactions
- 1.2.1.9 Disposal Room Design

Subelement 1.2.2 Panel Seal Behavior and Modeling
- 1.2.2.1 Disturbed Rock Zone and Fluid Flow Characteristics
- 1.2.2.2 Sealing System
- 1.2.2.3 Closure
- 1.2.2.4 Sealing Criteria, Concepts, and Designs

Subelement 1.2.3 Access Drift Behavior and Modeling
- 1.2.3.1 Backfill
- 1.2.3.2 Disturbed Rock Zone
- 1.2.3.3 Closure

Subelement 1.2.4 Shaft Seal Behavior and Modeling
- 1.2.4.1 Backfill
- 1.2.4.2 Sealing System
- 1.2.4.3 Disturbed Rock Zone and Fluid Flow Characteristics
- 1.2.4.4 Closure
- 1.2.4.5 Sealing Criteria, Concepts, and Designs

Subelement 1.2.5 Transport Modeling
- 1.2.5.1 Subdomains
- 1.2.5.2 Transport Mechanisms
- 1.2.5.3 Transients
- 1.2.5.4 Transport Codes
- 1.2.5.5 Optimization

Element 1.3
Controlled Area: Behavior Characterization and Performance Modeling

Subelement 1.3.1 Los Medanos Regional Flow Modeling
- 1.3.1.1 Culebra-Magenta
- 1.3.1.2 Dewey Lake Red Beds
- 1.3.1.3 Culebra
- 1.3.1.4 Fluid Density
- 1.3.1.5 Regional Boundary Conditions
- 1.3.1.6 Recharge
- 1.3.1.7 Extent of Dissolution

Subelement 1.3.2 Controlled Area Flow Modeling
- 1.3.2.1 Salado Formation
- 1.3.2.2 Culebra Dolomite Member
- 1.3.2.3 Rustler/Salado Formation
- 1.3.2.4 Rustler Formation
- 1.3.2.5 Dewey Lake Red Beds
- 1.3.2.6 Rustler/Dewey Lake Red Beds
- 1.3.2.7 Castile Formation Brines
- 1.3.2.8 Pressurized Brine Hydrofracturing and Transport
- 1.3.2.9 Bell Canyon Flow and Geochemistry
- 1.3.2.10 Optimization
- 1.3.2.11 Composite Domain

Subelement 1.3.3 Hydrologic Transport Modeling
- 1.3.3.1 Subdomains
- 1.3.3.2 Transport Mechanisms
- 1.3.3.3 Transients
- 1.3.3.4 Transport Codes
- 1.3.3.5 Optimization

Subelement 1.3.4 Borehole Plug Behavior and Modeling
- 1.3.4.1 Borehole Plugging Material Behavior
- 1.3.4.2 Borehole Plug Interactions
- 1.3.4.3 Borehole Plugging Criteria, Concepts, and Designs

Element 1.4
Computational System

Subelement 1.4.1 Development of the Compliance Assessment System
- 1.4.1.1 Computer Codes
- 1.4.1.2 Variable Mesh
- 1.4.1.3 Vertical Resolution
- 1.4.1.4 Diagnostics
- 1.4.1.5 Sampling
- 1.4.1.6 Translators

Subelement 1.4.2 Compliance Assessment Data Bases
- 1.4.2.1 Primary Data Assembly
- 1.4.2.2 Primary Data Interpretation

Element 1.5
Consequence Analysis

Subelement 1.5.1 Containment Requirements
- 1.5.1.1 Scenarios and Probabilities
- 1.5.1.2 Conceptual Models
- 1.5.1.3 Computational Models
- 1.5.1.4 Release Simulations
- 1.5.1.5 Complementary Cumulative Distribution Function

Subelement 1.5.2 Individual Protection Requirements
- 1.5.2.1 Scenario
- 1.5.2.2 Conceptual Model
- 1.5.2.3 Computational Model
- 1.5.2.4 Release Simulations
- 1.5.2.5 Pathway Simulations
- 1.5.2.6 Doses

ELEMENT 1.1 Scenario Screening

The WIPP Project is in the process of publishing a report (Hunter, 1989) that will describe scenario development, identify all processes and events examined for inclusion in the WIPP consequence analysis, and justify dismissal of those scenarios, processes, or events that have been screened out and require no further consideration. The scenarios retained for the final consequence analysis will define the disposal system conceptual models, which must be simulated for the 10,000-year performance. Currently, 76 scenarios must be screened. However, it is expected that approximately 10 significant scenarios will be thoroughly analyzed; the remainder are not expected to contribute significantly to the complementary cumulative distribution function.

A number of scenarios, events, and processes require further consequence analyses to determine whether they are of regulatory interest. These analyses are part of scenario screening, and may be relatively simple or complex. Screening begins with analyses of the particular events, processes, or scenarios listed below. The subelements are not necessarily scenarios to be retained for the final consequence analysis; no scenarios are included that definitely have been retained. After examining Hunter's (1989) results, these subelements were chosen for early examination because: (1) they are likely to be dismissed as a result of the screening analyses; (2) they are ready for screening analysis; and (3) results of these analyses can be used to guide data collection, further screening efforts, and both preliminary and final consequence analyses. These analyses will be documented in the first supplement to Hunter (1989). Other analyses may be subsequently defined; those would be documented in later supplements.

Performance Assessment Activities PA.1 and PA.2 address the information needs for Element 1.1.

Subelement 1.1.1 Climatic Change

This subelement requires screening of climatic change processes (that should be included in the final consequence analysis) to determine whether any reasonable change can cause variations in flow in any of the stratigraphic units of the controlled area within 10,000 years.

The information needs for this subelement may include:

1.1.1.1 Modern Hydrology: three-dimensional models of the hydrologic characteristics of the region and the controlled area.

1.1.1.2 Paleoclimatology/Hydrology: predictions of future climatic changes and their effects on the hydrology, based on the relationship between past climate and past hydrology.

1.1.1.3 Recharge: incorporating potential recharge rates and changes in the hydrologic model.

Subelement 1.1.2 Nuclear Criticality

This subelement requires screening of radionuclide concentrations to determine whether any likely conditions could lead to nuclear criticality in the disposal system after the shafts are sealed, and whether the response of the disposal system would significantly affect the results of the consequence analysis by increasing thermal loading or changing the radionuclide inventory.

The information needs for this subelement include:

1.1.2.1 Radionuclide Inventory: inventory of radionuclides to be disposed of at the WIPP facility.

1.1.2.2 Radionuclide Distributions and Concentrations: a description of the distributions and concentrations of those radionuclides of concern throughout the waste panels over the regulatory time period.

1.1.2.3 Reconcentration: incorporating the potential for reconcentration of radionuclides outside the waste panels into the criticality calculations.

Subelement 1.1.3 Human Intrusion

Human-intrusion events that must be screened include boreholes into the Bell Canyon Formation, the effects of two boreholes through one panel, and solution mining.

This subelement requires: (1) determining whether the Bell Canyon Formation borehole scenario is significant; (2) determining whether penetration of the same waste panel by two boreholes is likely to alter the flow pattern in the Culebra Dolomite Member within the controlled area; and (3) determining whether solution mining is probable, and if so, whether it is likely to affect releases.

The following information needs for this subelement will be obtained from field studies or from the literature:

1.1.3.1 Flow Direction in Bell Canyon Formation Boreholes: the expected direction of flow in a borehole between the Culebra Dolomite Member and the Bell Canyon Formation.

1.1.3.2 Room Effects: the effect of the flow direction in Bell Canyon Formation Boreholes on an intersected disposal room.

1.1.3.3 Bell Canyon Formation Flow: the rate of flow to the accessible environment in the Bell Canyon Formation if flow is confirmed to be downward from the Culebra Dolomite Member.

1.1.3.4 Culebra Dolomite Hydrology: a model of ground-water flow in the Culebra Dolomite.

1.1.3.5 Two-Borehole Effects: incorporating flow down a borehole, through a waste panel, up a second borehole, and back into a water-bearing unit.

1.1.3.6 Subsidence Zone: hydrologic properties of the subsided zone above an abandoned, collapsed potash mine in the site vicinity.

1.1.3.7 Flow Variations: changes in adjacent flow patterns caused by any of the above scenarios.

Subelement 1.1.4 Seal Performance

This subelement requires identification of the major effects of nonstandard seal performance to determine which effects cannot be screened out.

The information needs for this subelement include:

1.1.4.1 Seal Performance: data on seal component performance.

1.1.4.2 Failure Modes: potential modes of seal failure.

Subelement 1.1.5 Probability Assignment

This subelement requires assignment of a probability of occurrence to each scenario that cannot otherwise be screened out.

The WIPP scenario development (Hunter, 1989) identified 76 scenarios for consideration in the performance assessment. Some scenarios were retained because they are sufficiently probable to be of regulatory interest. The remainder were retained because there is insufficient data to assign or calculate probabilities of occurrence and they could not be dismissed on the basis of physical reasonableness, regulatory guidelines, or earlier estimates of consequences. Scenario screening will be used to identify which scenarios in the latter group may be eliminated on the basis of consequence. Probabilities must be assigned to those that survive the screening.

Information needs for this subelement include:

1.1.5.1 Scenarios: identifying scenarios that require probability assignments.

1.1.5.2 Expert Opinion: obtaining expert opinion on the probabilities of events and processes that make up each scenario.

1.1.5.3 Probabilities: calculating or assigning a probability for each scenario.

ELEMENT 1.2 Repository/Shaft System: Behavior Characterization and Performance Modeling

The repository/shaft system is one part of the two-part disposal system. Performance of the repository/shaft system must be adequately simulated over 1,000- and 10,000-year periods to determine whether radionuclides can migrate to the surrounding formations or to the surface above the shafts. If such movement is predicted, then transport through the other part of the disposal system, the controlled area, must be adequately simulated (Element 1.3). For scenarios that change the expected performance without human intrusion, performance of the entire repository/shaft system may be simulated using the appropriate conceptual models of the disposal system. For most human-intrusion scenarios, the performance of only parts of the repository/shaft system may be simulated.

The behavior of the integrated repository and shaft system, including the response of the waste disposal rooms (Subelement 1.2.1), panel seals (Subelement 1.2.2), drift backfill materials (Subelement 1.2.3), shaft seal systems (Subelement 1.2.4), and transport (Subelement 1.2.5) must be sufficiently understood to support a reasonable expectation of compliance with the Standard. Characterization requires theoretical analyses and model studies, laboratory testing, and in situ investigations.

The most likely natural mechanisms for transporting radionuclides out of the repository and into the surrounding rock are ground water movement and diffusion through ground water. Disposal systems can be designed to prevent or delay radionuclide migration into the accessible environment. Backfill barriers, specifically mixtures of bentonite clay and crushed salt, are being designed to provide a material that will eventually have permeabilities low enough to significantly limit movement of fluids. The backfill's sorptive properties and low permeability may slow the migration of most radionuclides if dissolution of the waste occurs.

Gases generated from the bacteriological and radiological decomposition of the TRU waste and corrosion of the drums could become a driving force for radionuclide movement, if intermediate or final consolidation states of the waste disposal rooms include appreciable gas filled porosity. However, additives could consume or act as getters for most gases generated within the waste room and eliminate gas as a driving force for radionuclide migration.

The characteristics of the source term and predictions of how these characteristics change over time are also considerations for waste disposal. Knowledge of the initial waste characteristics and their subsequent alterations through radioactive decay and possible organic complexing is required to design adequate waste confinement systems. The effects of backfill materials and additives and of brine inflow must also be known. Estimates of the radionuclide and nonradionuclide inventories of the waste, including physical and chemical states, are necessary for evaluating the capability of a disposal room to confine radionuclides. These estimates are necessary for predicting the movement of radionuclides out of the repository toward the accessible environment.

Waste form confinement within a waste disposal room isolates radioactive material from the accessible environment. Isolation is achieved if the host rock (including any sealed manmade penetration within it and any disturbed rock adjacent to the panels and seals) forms a barrier to radionuclide transport. Waste isolation focuses on the integrity and continuity of rock salt, its potential for encapsulating the waste through creep closure of waste disposal rooms, its ability to deform without severe fracturing and fracture propagation, its ability to self-heal fractures from natural or manmade disturbances, and its inherent resistance to fluid flow (low permeability).

Penetrations made in characterizing the WIPP site and constructing the facility could provide pathways for radionuclide release. As a result, seals in underground openings and in shafts and plugs in boreholes are required for waste isolation. These barriers must perform effectively soon after emplacement as well as throughout the 10,000-year period of regulatory interest.

Performance of the repository and shaft system can be simulated for the final consequence analysis when:

- The repository/shaft system's behavior has been defined and modeled, and testing has shown that the system is adequately understood.

- The understanding of the repository/shaft system's effect on long-term containment has been determined by models and analyses to be adequate for input to performance assessment.

- Computational models for performance assessment scenario simulations can be developed from and supported by more detailed mechanistic or phenomenological models and interpretations of the repository and shaft system.

- A peer review process has affirmed that the characterization has been completed to an acceptable confidence level.

Subelement 1.2.1 Waste Disposal Room Behavior and Modeling

Waste disposal room behavior must be characterized. The behavior is affected by bacteriological and radiological decomposition of the emplaced TRU waste and by creep closure of the surrounding salt formation encapsulating the waste and backfill materials. The effects of generated gas, fluid inflow and outflow through the disturbed rock zone, and the interactions of room deformation, backfill consolidation, waste container deformation and fluid absorption in the solid waste/backfill matrix must also be understood. This subelement will define the total system interaction that would, in any way, impact waste confinement, encapsulation, and radionuclide movement out of the room.

Performance assessment requires simulating the behavior of the waste disposal rooms in a panel while the rooms are in a transient state and after a final steady state has been attained. It also requires simulating disturbance of the rooms in either state. Simulating room behavior will determine the quantities of radionuclides and brine that can be moved out of the rooms and through the panels and shafts, the surrounding rock in the disturbed rock zone, or through penetrating boreholes under various scenarios. Because waste will also be emplaced in the drifts that connect the panels, performance of these drifts south of the northernmost panel seals will be simulated using appropriate models.

Information needs for this subelement include:

1.2.1.1 Source Term: (a) defining the room source term (considering the waste inventory, its radioactive composition, organic and inorganic chemical constituents, decomposition processes, and radioelement speciation in solution), that considers the effects of the disposal room environment from waste emplacement to final equilibration; and (b) developing a mathematical model that considers variability in the source term resulting from variability in brine inflow, brine chemistry, gas volume and chemistry, and room consolidation in various scenarios. Modeling capability will include those disturbed conditions under which large quantities of water or brine are introduced or injected (e.g., pressurized brine occurrence scenario) and the room contents are disrupted by drilling (including mechanical removal of wastes in drill cuttings and drilling mud, erosion and entrainment of room contents by water or brine, and leaching). The source term is defined as the quantities of the important radionuclides in the WIPP inventory that will be mobilized for possible transport to the accessible environment, and the scenario-dependent rates at which these radionuclides will be mobilized.

Relevant Activities:

Lab:	S.1.1.4 (p. 2-93), S.1.1.5 (p. 2-96)
Modeling:	S.1.2.6 (p. 2-103)
In Situ:	S.1.3.2 (p. 2-106), S.1.3.3 (p. 2-110)
PA:	PA.5 (p. 2-72), PA.7 (p. 2-75), PA.9 (p. 2-80)

1.2.1.2 Backfill: (a) understanding the behavior of the crushed salt and bentonite-clay backfill mixture(s) surrounding the TRU waste drums during reconsolidation and the backfill's capacity for consuming brine, gas, and radionuclides if additives are mixed into the backfill; and (b) incorporating mechanical, hydrologic, and geochemical properties of backfill and the effects of backfill on the source term, gas generation, reconsolidation, resaturation, and retardation in appropriate mathematical models and data sets.

Relevant Activities:

Lab:	S.1.1.1 (p. 2-90), S.1.1.2 (p. 2-91), S.4.1.2 (p. 2-167), S.4.1.3 (p. 2-168)
Modeling:	S.1.2.1 (p. 2-98), S.1.2.3 (p. 2-100)
In Situ:	S.1.3.1 (p. 2-105), S.3.3.12 (p. 2-159)
PA:	PA.5 (p. 2-72), PA.7 (p. 2-75), PA.9 (p. 2-80)

1.2.1.3 Container Response: (a) determining the reduction in void volume that would take place in each container when disposal room closure reconsolidates the backfill, ruptures the container, collapses the container and compacts its contents into a solid matrix; (b) defining the intermediate and final states of the container, backfill, and fluid system; and (c) incorporating the effects of reconsolidation, resaturation, and gas generation in appropriate mathematical models and data sets on waste containers.

Relevant Activities:

- Lab: S.1.1.3 (p. 2-92), S.3.1.1 (p. 2-134), S.3.1.2 (p. 2-135), S.3.1.4 (p. 2-138)
- Modeling: S.1.2.2 (p. 2-99), S.3.2.1 (p. 2-140), S.3.2.2 (p. 2-141)
- In Situ: S.1.3.1 (p. 2-105), S.3.3.12 (p. 2-159)
- PA: PA.5 (p. 2-72), PA.7 (p. 2-75), PA.9 (p. 2-80)

1.2.1.4 Closure: (a) determining the rate at which the disposal room closes, based on the mechanisms deforming the surrounding salt (deformation results when salt is subjected to overburden stresses and room- and panel-geometry effects; this behavior is affected by clay seams and anhydrite layers and could result in fractures and near-field dilation followed by partial healing due to redistribution of compressive stresses); and (b) developing mathematical models of room closure that account for time dependent room and panel geometry, creep, structural support of the backfill, drum collapse, gas generation, and the mechanical behavior of the disturbed rock zone around the facility.

Relevant Activities:

- Lab: S.3.1.1 (p. 2-134), S.3.1.2 (p. 2-135), S.3.1.3 (p. 2-137), S.3.1.4 (p. 2-138)
- Modeling: S.3.2.1 (p. 2-140), S.3.2.2 (p. 2-141), S.3.2.3 (p. 2-142), S.3.2.6 (p. 2-147)
- In Situ: S.3.3.12 (p. 2-159)
- PA: PA.5 (p. 2-72), PA.7 (p. 2-75), PA.9 (p. 2-80)

1.2.1.5 Brine Inflow and Room Resaturation: (a) determining the rates of brine inflow from the formation into the disposal room, as influenced by the pattern and density of rock fractures or otherwise continuous flow paths and by stress differentials around the excavated disposal room opening; and (b) developing mathematical models of room resaturation that account for variability in brine inflow, unsaturated flow, gas generation effects, effects of the disturbed rock zone, and the time-dependent response of both waste and backfill to fluid flow.

Relevant Activities:

- Lab: S.3.1.5 (p. 2-139)
- Modeling: S.3.2.4 (p. 2-144), S.3.2.6 (p. 2-147)
- In Situ: S.3.3.4 (p. 2-151), S.3.3.6 (p. 2-153), S.3.3.7 (p. 2-154), S.3.3.8 (p. 2-155), S.3.3.9 (p. 2-156), S.3.3.13 (p. 2-160)
- PA: PA.5 (p. 2-72), PA.7 (p. 2-75), PA.9 (p. 2-80)

1.2.1.6 Gas: developing a mathematical model that includes rates of production and removal, potential pressure buildup, and effects on room closure and brine inflow of gas resulting from in situ waste and container decomposition.

Relevant Activities:

- Lab: S.1.1.2 (p. 2-91), S.1.1.4 (p. 2-93), S.1.1.5 (p. 2-96)

Modeling: S.1.2.6 (p. 2-103)
In Situ: S.1.3.2 (p. 2-106), S.1.3.3 (p. 2-110)
PA: PA.5 (p. 2-72), PA.7 (p. 2-75), PA.9 (p. 2-80)

1.2.1.7 Disturbed Rock Zone: (a) defining and characterizing the disturbed rock zone that excavation produces in the host rock surrounding the disposal room; (b) investigating the time-dependent behavior of the disturbed rock zone and its effect on permeability and fluid flow into and out of the disposal room and on radionuclide transport capacity.

Relevant Activities:
Lab: S.3.1.3 (p. 2-137), S.3.1.5 (p. 2-139)
Modeling: S.3.2.1 (p. 2-140), S.3.2.2 (p. 2-141), S.3.2.5 (p. 2-145), S.3.2.6 (p. 2-147)
In Situ: S.3.3.9 (p. 2-156), S.3.3.12 (p. 2-159)
PA: PA.5 (p. 2-72), PA.7 (p. 2-75), PA.9 (p. 2-80)

1.2.1.8 Systems Interactions: (a) understanding the synergistic behavior of the above components as they affect the total performance of the waste panel, including effects of room closure, backfill, wastes, brine, and gas; (b) incorporating these effects in appropriate mathematical models.

Relevant Activities:
Lab: S.1.1.3 (p. 2-92)
Modeling: S.1.2.2 (p. 2-99), S.1.2.4 (p. 2-101)
In Situ: S.1.3.1 (p. 2-105)
PA: PA.5 (p. 2-72), PA.7 (p. 2-75), PA.9 (p. 2-80)

1.2.1.9 Disposal Room Design: modifying or refining the design based on information acquired during the WIPP Test Phase, if necessary. Systems analysis of engineered modifications to waste forms and emplacement approaches will be performed in parallel with the current testing program; these analyses will consider the long-term isolation characteristics of materials placed in the room.

Relevant Activities:
Lab: S.1.1.1 (p. 2-90), S.3.1.1 (p. 2-134), S.3.1.2 (p. 2-135), S.3.1.3 (p. 2-137), S.3.1.4 (p. 2-138), S.3.1.5 (p. 2-139)
Modeling: S.1.2.2 (p. 2-99), S.1.2.4 (p. 2-101), S.1.2.5 (p. 2-102), S.3.2.1 (p. 2-140), S.3.2.2 (p. 2-141), S.3.2.3 (p. 2-142)
In Situ: S.1.3.2 (p. 2-106)
PA: PA.5 (p. 2-72), PA.7 (p. 2-75), PA.9 (p. 2-80)

Summary of Disposal Room Data Base

Investigations concerning disposal room behavior provided the following extensive data base and understanding of phenomena that can be applied to an assessment of waste confinement and isolation:

- Waste container buoyancy, temperature increase at water-bearing strata and ground surface, deformation at water-bearing strata and ground surface, and surface subsidence all have been found insignificant for conditions at WIPP.

- Sophisticated constitutive models have been formulated from laboratory tests of rock specimens, accounting for all major observed mechanical behaviors and thermal conductivity observed in the laboratory.

- Numerical codes have been developed that can solve large-scale, two-dimensional problems with multiple layers of nonlinear materials. Three-dimensional codes having significant potential are being developed.

- Benchmarking and parallel calculation exercises have provided confidence in the precision of the codes available for structural calculations.

- Reference constitutive laws and material parameters have been established so that calculations may proceed for the waste room/ panel configuration.

- A series of large-scale, in situ tests has been fielded and is providing high quality data on structural interactions, fluid flow, and waste container performance. Analyses of the in situ results are proceeding.

- Recent calculations, which used the Tresca flow rule and a simplified constitutive model, provided exceptional agreement with in situ data (within 2 percent for vertical closures and 18 percent for horizontal closures).

- Performance of CH- and RH-TRU waste containers in the WIPP environment has been examined through accelerated test data and found to be predictable.

- Structural response of CH-TRU waste containers has been determined for early time loadings.

- Preliminary gas generation data from laboratory tests of radioactive CH-TRU wastes have been documented.

- The reconsolidation and sorptive properties of crushed salt/clay-backfill mixtures are generally understood. Additives to enhance waste confinement in the disposal room are being investigated.

- Early laboratory, modeling, and in situ investigations of brine flow in the host rock and into disposal rooms have been completed and evaluated.

- Data on the disturbed rock zone surrounding an excavated opening underground have been acquired and the disturbed rock zone's influence on waste confinement is being evaluated.

- A properly tailored backfill mixture has the potential to absorb at least as much brine as the maximum calculated inflow.

Subelement 1.2.2 Panel Seal Behavior and Modeling

The panel sealing system's capability to function for the required period as an internal repository barrier for radionuclide migration to the access drifts must be understood. This includes external effects that influence the sealing system behavior and the behavior's performance under changing physical, chemical, and environmental conditions. Seal behavior will be resolved when a sealing system has been developed, evaluated, and tested in an actual environment, and found to perform as predicted.

Performance assessment requires simulating transport through or around the panel seals during the transient state and after a steady reconsolidation state has been attained; it also requires simulating panel seal disturbance in either state. The computational model will include flow through the seals, between the host rock and the seal, and through the surrounding disturbed rock zone. Simulating panel seal behavior will determine the quantities of radionuclides and brine that can be moved through or around the panel seals in various scenarios.

Information needs for this subelement include:

1.2.2.1 Disturbed Rock Zone and Fluid-Flow Characteristics: (a) determining the permeability and fluid-flow properties of the surrounding rock units so that the rate of brine influx to disposal rooms and potential gas buildup and dissipation out of disposal rooms to the panel seals can be understood; (b) examining other fluid flow influences such as excavation effects, existing natural anomalies, and pore pressure phenomena that may affect sealing system performance; and (c) developing a mathematical model of transport through the disturbed rock zone, accounting for changes in the behavior of the disturbed rock zone around the panel seals, and for resaturation and retardation.

Relevant Activities:

Lab:	S.1.1.1 (p. 2-90), S.2.1.2 (p. 2-118), S.3.1.5 (p. 2-139)
Modeling:	S.1.2.1 (p. 2-98), S.2.2.1 (p. 2-120), S.3.2.4 (p. 2-144), S.3.2.5 (p. 2-145), S.3.2.6 (p. 2-147)
In Situ:	S.3.3.4 (p. 2-151), S.3.3.5 (p. 2-152), S.3.3.9 (p. 2-156)
PA:	PA.5 (p. 2-72), PA.7 (p. 2-75), PA.9 (p. 2-80)

1.2.2.2 Sealing System: (a) understanding the behavior of seal materials under in situ conditions over the long term; (b) evaluating structural and chemical stability, flow restriction capability, and emplacement requirements; (c) understanding the synergistic effects and performance of the entire panel sealing system and the host rock, particularly the capability of the seal to restrict fluid-flow and radionuclide transport from the panel; (d) understanding the integrated, long-term interactions between seal system components, the host rock and the expected waste matrix (including fluids, backfill, and the source term materials); and (e) developing a mathematical model of transport through and around the seals, accounting for retardation and for possible disintegration and/or fracture of the seals.

Relevant Activities:

Lab:	S.2.1.1 (p. 2-117), S.2.1.2 (p. 2-118), S.2.1.3 (p. 2-119)
Modeling:	S.2.2.1 (p. 2-120), S.2.2.2 (p. 2-121)
In Situ:	S.2.3.1 (p. 2-122), S.2.3.2 (p. 2-125)
PA:	PA.5 (p. 2-72), PA.7 (p. 2-75), PA.9 (p. 2-80)

1.2.2.3 Closure: (a) understanding the time-dependent behavior of the interface between the seal and host rock units and the effects that rock creep closure has on the structural integrity of the sealing system, including healing of the disturbed rock zone surrounding the panel entry; (b) evaluating the mechanisms required for restricting fluid flow and resisting displacement at the interface and the reactivity of the seal with the rock units, considering the influence of the disturbed rock zone; and (c) developing a mathematical model of panel closure, accounting for panel drift and seal geometry, creep, and structural interaction of the seals from emplacement to final structural equilibration.

Relevant Activities:

Lab:	S.2.1.3 (p. 2-119), S.3.1.1 (p. 2-134), S.3.1.2 (p. 2-135), S.3.1.3 (p. 2-137), S.3.1.4 (p. 2-138)
Modeling:	S.3.2.1 (p. 2-140), S.3.2.2 (p. 2-141), S.3.2.3 (p. 2-142), S.3.2.6 (p. 2-147)
In Situ:	S.2.3.1 (p. 2-122), S.2.3.2 (p. 2-125)
PA:	PA.5 (p. 2-72), PA.7 (p. 2-75), PA.9 (p. 2-80)

1.2.2.4 Sealing Criteria, Concepts, and Designs: (a) defining a panel sealing system that will be effective as a barrier under the EPA Standard; (b) establishing quantitative parameters for the sealing system for use in performance assessment; (c) establishing engineering criteria and concepts for more detailed panel seal designs.

Relevant Activities:

Lab:	S.2.1.1 (p. 2-117), S.2.1.2 (p. 2-118), S.2.1.3 (p. 2-119)
Modeling:	S.2.2.2 (p. 2-121), S.3.2.6 (p. 2-147)
In Situ:	S.2.3.1 (p. 2-122), S.2.3.2 (p. 2-125), S.3.3.4 (p. 2-151), S.3.3.5 (p. 2-152)
PA:	PA.5 (p. 2-72), PA.7 (p. 2-75), PA.9 (p. 2-80)

Summary of Panel Seal Data Base

The long-term strategy for sealing panels includes use of reconsolidated, crushed salt at the panel entryways. This reconsolidated salt will eventually form a seal that approaches the density, permeability, strength, and other mechanical properties of the intact salt.

The present data base for panel seal behavior is summarized below (Stormont, 1988a; Tyler et al., 1988):

- A reference panel sealing concept appears adequate to ensure long-term waste isolation.
- The principal, long-term sealing strategy involves reconsolidation of crushed salt. Studies regarding crushed salt behavior have resulted in a numerically implemented, constitutive equation for salt reconsolidation, and emplacement techniques have been verified by in situ tests.
- Laboratory and in situ data indicate that bentonite-based seals will be viable in the short term.
- Reference cementitious mixtures have been developed and emplaced in situ. A structural model for the cementitious seal/rock system based on the in situ data will be further evaluated.
- Characterization of the disturbed rock zone, principally by gas flow tests, has guided panel seal concepts.
- A series of intermediate-scale, in situ sealing tests has yielded high quality thermal, structural, and fluid-flow data for candidate sealing materials in various configurations. Data and preliminary analysis reports have been completed and others will be prepared.
- Initial analyses of sealing systems, incorporating structural and fluid-flow response of the sealing material and the host rock, suggest the current seal system design should be successful.
- The current brine inflow model, based on Darcy-like flow, satisfactorily agrees with all available brine inflow data for unheated and heated WIPP boreholes and with independent in situ measurements of near-field gas and brine flow in the WIPP host rock. Scaled-up predictions and certain mechanistic assumptions in the model concerning brine pore pressure and flow paths will be tested with data from ongoing and planned WIPP in situ tests.

Subelement 1.2.3 <u>Access Drift Behavior and Modeling</u>

The performance of backfill materials in the access drifts must be understood (i.e., the potential for fluid flow and resulting radionuclide transport between the waste disposal panel and shaft seals). The reconsolidation behavior of the backfill under overburden stresses due to creep closure and under environmental effects, particularly brine inflow, will be investigated.

Performance assessment requires simulating transport through or around the access drifts between the panel seals adjacent to the disposal area and the seals at the bases of the four shafts during the transient state and after reconsolidation has reached a steady state. The computational model will include flow through the drift backfill, between the host rock and the backfill, and through the surrounding disturbed rock zone. Because these access drifts must remain open for the entire operational phase of WIPP, the history of the disturbed rock zone and its response to remedial actions to maintain the access drifts is likely to be complex. Simulating drift behavior will determine the quantities of radionuclides and brine that can be moved through or around the drift in various scenarios.

Information needs for this subelement include:

1.2.3.1 Backfill: (a) defining the extent of crushed salt reconsolidation of (and possible additives) as a function of the rate of drift closure; (b) understanding brine inflow to the excavations; and (c) evaluating fluid-flow characteristics of reconsolidated backfill; and incorporating backfill properties and the effects of reconsolidation, resaturation, and retardation in appropriate mathematical models and data sets.

Relevant Activities:

Lab:	S.1.1.1 (p. 2-90), S.2.1.2 (p. 2-118)
Modeling:	S.1.2.1 (p. 2-98), S.1.2.3 (p. 2-100), S.2.2.1 (p. 2-120)
In Situ:	S.1.3.1 (p. 2-105)
PA:	PA.5 (p. 2-72), PA.7 (p. 2-75), PA.9 (p. 2-80)

1.2.3.2 Disturbed Rock Zone: developing a mathematical model of flow and transport through the disturbed rock zone, accounting for both resaturation and retardation.

Relevant Activities:

Lab:	S.3.1.3 (p. 2-137), S.3.1.5 (p. 2-139)
Modeling:	S.3.2.1 (p. 2-140), S.3.2.2 (p. 2-141), S.3.2.5 (p. 2-145), S.3.2.6 (p. 2-147)
In Situ:	S.3.3.9 (p. 2-156), S.3.3.12 (p. 2-159)
PA:	PA.5 (p. 2-72), PA.7 (p. 2-75), PA.9 (p. 2-80)

1.2.3.3 Closure: (a) determining the rate at which the drift closes and the surrounding rock deforms during salt creep subjected to overburden stress and excavation geometry effects (drift response in some locations could result in superficial fracturing followed by healing due to redistribution of compressive stresses); and (b) developing a mathematical model of drift closure that accounts for geometry of the drifts, creep, and structural interaction of the backfill.

Relevant Activities:

Lab:	S.3.1.1 (p. 2-134), S.3.1.2 (p. 2-135), S.3.1.3 (p. 2-137), S.3.1.4 (p. 2-138)
Modeling:	S.3.2.1 (p. 2-140), S.3.2.2 (p. 2-141), S.3.2.3 (p. 2-142)
In Situ:	None
PA:	PA.5 (p. 2-72), PA.7 (p. 2-75), PA.9 (p. 2-80)

Summary of Access Drift Data Base

Extensive investigations of materials appropriate for backfilling excavations following waste emplacement have been completed (Tyler et al., 1988a). These studies concerned sealing (Stormont, 1988a) and disposal room backfill and structures (Nowak, 1980; Nowak, 1981; Pfeifle, 1987; Tyler et al., 1988). The results are directly applicable to backfill material emplacement in drifts during repository sealing. In summary, the investigations for behavior of emplaced backfill and for the structural response of the drift configurations have provided the following data base:

- Reference constitutive models and computer codes including multi-layer and nonlinear material properties have been developed to solve two-dimensional, structural problems.

- In situ tests have provided high quality data on structural interaction and fluid flow that are applicable to preliminary analyses of interactions between the drift and the backfill and of the response of backfill materials.

- Reconsolidation and sorptive properties of candidate backfill materials, particularly crushed salt and clay mixtures, are generally understood. Effectiveness of backfill additives in retarding radionuclide transport is being investigated.

Subelement 1.2.4 Shaft Seal Behavior and Modeling

The shaft sealing system must function as a barrier to migration of radionuclides up to the water-bearing strata in the Rustler Formation and to the flow of fluids down to the facility horizon for the required period. External influences on sealing system behavior include changing structural conditions (stress and creep) and chemical environments in the different geologic units of WIPP stratigraphy within which shaft seals will be placed. Characterization requires development, evaluation, and testing of shaft seal systems that perform their intended purpose and are sufficiently understood to permit long-term performance predictions.

Performance assessment requires simulating transport through or around the shafts and seals from the repository horizon to the scenario-dependent discharge horizon. This requires the ability to simulate the entire length of the shafts to the surface after a steady reconsolidation state has been attained and perhaps during the transient state, as well as under various conditions of possible seal failure. The computational model must include leakage down the shaft from overlying water-bearing units and transport up the shaft as required by various scenarios. Flow must be simulated through the shaft seals and backfill, through the surrounding disturbed rock zone, and between the host rock and the shaft components. Shaft behavior simulating will determine the quantities of unsaturated brines from overlying water-bearing units that might enter the repository through the shafts and to determine the quantities of radionuclides and brine that can be moved through or around the shafts in various scenarios.

Information needs for this subelement include:

1.2.4.1 Backfill: (a) incorporating shaft backfill properties and the effects of reconsolidation, resaturation, and retardation, and the effects on the backfill of dissolution/precipitation from downward leakage of overlying units in appropriate mathematical models and data sets.

Relevant Activities:

Lab:	S.1.1.1 (p. 2-90), S.2.1.2 (p. 2-118)
Modeling:	S.1.2.1 (p. 2-98), S.1.2.3 (p. 2-100), S.2.2.1 (p. 2-120)
In Situ:	None
PA:	PA.5 (p. 2-72), PA.7 (p. 2-75), PA.9 (p. 2-80)

1.2.4.2 Sealing System: (a) understanding the long-term behavior of sealing materials subjected to in situ configuration and geometry effects; (b) understanding brine inflow to the excavations; (c) evaluating structural and chemical stability of seal materials emplaced in the stratigraphic units, flow restriction capability, and emplacement techniques; (d) evaluating the impact of the coupled interactions of brine inflow, closure, and crushed-salt reconsolidation process; (e) evaluating the ability of the entire shaft-seal system and the host rock to restrict fluid flow to the repository from the overlying water-bearing strata and from the repository up the shaft to the overlying strata and surface, considering the long-term physical and chemical stability of each sealing system component emplaced in the various stratigraphic units in the shaft; and (f) developing a mathematical model of flow and transport through and around the seals, accounting for retardation and for possible disintegration and/or fracture of the seals, with accompanying dissolution/precipitation from downward leakage.

Relevant Activities:

Lab:	S.2.1.1 (p. 2-117), S.2.1.2 (p. 2-118), S.2.1.3 (p. 2-119)
Modeling:	S.2.2.1 (p. 2-120), S.2.2.2 (p. 2-121)
In Situ:	S.2.3.1 (p. 2-122), S.2.3.2 (p. 2-125)
PA:	PA.5 (p. 2-72), PA.7 (p. 2-75), PA.9 (p. 2-80)

1.2.4.3 Disturbed Rock Zone and Fluid-Flow Characteristics: (a) determining the permeability, hydrologic behavior, and brine inflow properties of WIPP shaft stratigraphic units so that seal system effectiveness and host rock influence at various levels can be understood, considering effects of the disturbed rock zone on fluid-flow properties of the host rock over time; and (b) developing a mathematical model of flow and transport through the disturbed rock zone accounting for resaturation, retardation, and changes in brine chemistry.

Relevant Activities:

Lab:	S.1.1.1 (p. 2-90), S.2.1.2 (p. 2-118), S.3.1.5 (p. 2-139)

Modeling: S.1.2.1 (p. 2-98), S.2.2.1 (p. 2-120), S.3.2.4 (p. 2-144), S.3.2.5 (p. 2-145), S.3.2.6 (p. 2-147)
In Situ: S.3.3.6 (p. 2-153), S.3.3.7 (p. 2-154), S.3.3.8 (p. 2-155), S.3.3.10 (p. 2-157), S.3.3.11 (p. 2-158), S.4.3.2 (p. 2-177)
PA: PA.5 (p. 2-72), PA.7 (p. 2-75), PA.9 (p. 2-80)

1.2.4.4 Closure: (a) understanding the interfaces between shaft seals and host rock and the effects that shaft closure rates and mechanisms have on the reconsolidation of compacted crushed salt used in seals and on other seal materials, considering the mechanisms required for ensuring fluid-flow restriction and displacement resistance at the interface, the reactivity of the seal components with the host rock, and the influence of the disturbed rock zone; and (b) developing a mathematical model of shaft closure that accounts for geometry, creep, and structural interaction of the seals with the surrounding rock.

Relevant Activities:
Lab: S.3.1.1 (p. 2-134), S.3.1.2 (p. 2-135), S.3.1.3 (p. 2-137), S.3.1.4 (p. 2-138)
Modeling: S.2.2.2 (p. 2-121), S.3.2.1 (p. 2-140), S.3.2.2 (p. 2-141), S.3.2.3 (p. 2-142), S.3.2.6 (p. 2-147)
In Situ: S.2.3.1 (p. 2-122), S.3.3.1 (p. 2-148), S.3.3.2 (p. 2-149)
PA: PA.5 (p. 2-72), PA.7 (p. 2-75), PA.9 (p. 2-80)

1.2.4.5 Sealing Criteria, Concepts, and Designs: (a) determining shaft sealing requirements for an effective engineered barrier under the EPA Standard by establishing quantitative sealing system parameters at specific depths in the shaft so that performance assessment studies, criteria, concepts, and engineering designs for shaft seals can be completed.

Relevant Activities:
Lab: None
Modeling: S.2.2.2 (p. 2-121)
In Situ: S.2.3.2 (p. 2-125), S.3.3.1 (p. 2-148), S.3.3.2 (p. 2-149), S.3.3.3 (p. 2-150), S.3.3.10 (p. 2-157)
PA: PA.5 (p. 2-72), PA.7 (p. 2-75), PA.9 (p. 2-80)

Summary of Shaft Seal Data Base

The data base for evaluating sealing materials and seal designs has been derived from laboratory and in situ testing, as well as from numerical modeling and analysis. The laboratory work has focused on sealing materials: crushed salt blocks and quarried salt, cementitious materials, and clays (primarily bentonite). For salt, laboratory and in situ studies have been directed toward understanding reconsolidation of crushed salt and the resulting fluid-flow properties. For bentonite, the density, swelling, and fluid-flow properties have been investigated. The long-term stability and integrity of salt and bentonite, as well as cement and cement/bentonite mixtures, have been the primary focus of laboratory investigations (Tyler et al., 1988).

In summary, the present data base (Tyler et al., 1988; Stormont, 1988a) for behavior of shaft seals suggests the following:

- Reference concepts for shaft seals appear adequate to ensure long-term waste isolation, subject to further evaluation.

- The principal long-term sealing strategy depends on reconsolidation of crushed salt at the lower level of the shaft. Studies of crushed salt behavior have resulted in a numerically implemented constitutive equation for salt reconsolidation. Emplacement techniques have been proven by in situ tests.

- Laboratory and in situ test data indicate that bentonite-based seals will effectively restrict fluid flow over the short term.

- Reference cementitious mixtures have been tested in situ. A structural model for the cementitious seal/rock system based on in situ data will be further evaluated.

- Characterization of the disturbed rock zone principally by brine and gas flow tests, has guided shaft sealing concepts.

- A series of intermediate-scale, in situ sealing tests has provided high quality thermal, structural, and fluid-flow data for candidate sealing materials in various configurations. Data and preliminary-analysis reports have been completed.

- Initial analyses of sealing systems, incorporating structural and fluid flow response of the sealing material and host rock, have been completed. Calculations of creep closure have been used to evaluate the reconsolidation of crushed salt.

Subelement 1.2.5 <u>Transport Modeling</u>

Appropriate computational models will be selected, adapted, and optimized for coupling with the hydrologic-flow computational models to model long-term transport of radionuclides through or around the repository/shaft system.

This subelement is addressed by performance assessment activity PA.5. Information needs for this subelement include:

1.2.5.1 <u>Subdomains</u>: identifying important subdomains for transport modeling (e.g., including Marker Bed 139 as a transport path).

1.2.5.2 <u>Transport Mechanisms</u>: identifying important transport mechanisms for the various scenarios.

1.2.5.3 <u>Transients</u>: determining whether transport models capable of simulating transient hydraulic conditions, including specialized modeling components such as a brine-pocket model, are needed based on the results of scenario screening.

1.2.5.4 <u>Transport Codes</u>: selecting computational codes for transport in the repository/shaft system.

1.2.5.5 Optimization: optimizing coupling between hydrologic and transport domains and optimizing transport computational efficiency.

ELEMENT 1.3 Controlled Area: Behavior Characterization and Performance Modeling

The controlled area is the second part of the two-part disposal system. Modeling ground-water flow in the accessible environment and through the controlled area will establish boundary conditions for modeling transport out of the controlled area. Modeling ground-water flow in the controlled area will establish boundary conditions for the repository/shaft system. After the repository/shaft system model determines the source term, modeling of transport in the controlled area will determine the release to the accessible environment.

For undisturbed performance (expected conditions), the performance of the controlled area must be simulated to determine whether migration of radionuclides to the accessible environment can occur, if the repository/shaft system model predicts migration into the controlled area. For scenarios which change the predicted behavior without human intrusion, the controlled area will be simulated again using the appropriate conceptual models of the disposal system. For some human-intrusion scenarios, the performance of some hydrologic units of the controlled area will be simulated.

Subelement 1.3.1 Los Medanos Regional Flow Modeling

The boundary conditions and flow and transport properties within geologic units of interest must be defined well enough in the accessible environment to reliably model conditions and radionuclide releases at the outer boundary of the controlled area over a 10,000-year time frame under undisturbed conditions and to model changes in flow and transport for disturbed conditions. The existing conceptual models and data bases characterizing the hydrologic flow must be extended to a three-dimensional computational model that will adequately simulate undisturbed and disturbed, long-term flow over a sufficiently large area to minimize boundary condition effects throughout the stratigraphic column on flow in the controlled area.

The recent completion and comparison of isotopic, geochemical, and hydrologic studies (see Siegel et al., 1988) indicate that the hydrologic and geochemical setting of the Rustler Formation and shallower units at the WIPP site has changed significantly over approximately 10,000 years, the time frame of regulatory interest. Both flow direction within the Rustler Formation and the state of saturation within the Dewey Lake Red Beds appear to have changed during this time in response to the cessation of surficial recharge at and near the WIPP site at least 10,000 years ago. However, the extent of these changes and the extent of changes that might be associated with human intrusion in the accessible environment is not yet defined.

Figure 2-1 shows the relationship of the regional Los Medanos model domain to the local domain; the controlled area lies within the local domain. The model domain for the Los Medanos model will include about eight stratigraphic layers. The lateral boundaries will be determined by sensitivity studies. The layers in the present model are, from the surface downward, the Dockum Group, the Dewey Lake Red Beds, five members of the Rustler Formation (Forty-niner, Magenta, Tamarisk, Culebra, and unnamed), and the Salado Formation This model domain extends laterally to natural boundaries, or far enough out to avoid boundary-condition effects on the simulation of flow in the controlled area. The Los

Medanos three-dimensional model will be completed and used to develop initial computational fields and to establish computational meshes for analyses of the scenarios retained for the consequence analysis.

Information needs for this subelement include:

1.3.1.1 Culebra-Magenta: incorporating the Culebra-Magenta hydrologic connection into the Los Medanos model.

Relevant Activities:

Lab:	None
Modeling:	None
In Situ:	None
PA:	PA.3 (p. 2-68), PA.4 (p. 2-70), PA.5 (p. 2-72), PA.7 (p. 2-75), PA.9 (p. 2-80)

1.3.1.2 Dewey Lake Red Beds: incorporating Dewey Lake Red Bed hydrologic parameters into the Los Medanos Model.

Relevant Activities:

Lab:	None
Modeling:	None
In Situ:	None
PA:	PA.3 (p. 2-68), PA.4 (p. 2-70), PA.5 (p. 2-72), PA.7 (p. 2-75), PA.9 (p. 2-80)

1.3.1.3 Culebra: incorporating fracture flow within the Culebra Dolomite into the Los Medanos Model, if transport calculations show that this phenomenon is important.

Relevant Activities:

Lab:	None
Modeling:	None
In Situ:	None
PA:	PA.3 (p. 2-68), PA.4 (p. 2-70), PA.5 (p. 2-72), PA.7 (p. 2-75), PA.9 (p. 2-80)

1.3.1.4 Fluid Density: incorporating updated fluid density data in the area south of the controlled area into the Los Medanos Model.

Relevant Activities:

Lab:	None
Modeling:	None
In Situ:	None
PA:	PA.3 (p. 2-68), PA.4 (p. 2-70), PA.5 (p. 2-72), PA.7 (p. 2-75), PA.9 (p. 2-80), PA.11 (p. 2-83)

1.3.1.5 Regional Boundary Conditions: incorporating additional hydrologic data for the Clayton Basin, eastern boundary of the Los Medanos model, and southwest boundary of the model at Balmorrhea-Loving Trough into the Los Medanos model, if initial 10,000-year simulation shows that boundary conditions affect the results.

Relevant Activities:

Lab:	None
Modeling:	None
In Situ:	None
PA:	PA.3 (p. 2-68), PA.4 (p. 2-70), PA.5 (p. 2-72), PA.7 (p. 2-75), PA.9 (p. 2-80)

1.3.1.6 Recharge: (a) estimating temperature and precipitation in southeastern New Mexico over approximately the last 10,000 years (paleoclimate); estimating the effects of variations in temperature and precipitation on surficial recharge at and near the WIPP site and on the hydrologic settings and behavior of the Rustler Formation and Dewey Lake Red Beds over the last 10,000 years; (b) determining whether reasonably estimated changes in climate and hydrologic setting can have significant impact on ground-water travel times and transport behavior; and (c) incorporating potential recharge rates and changes in the Los Medanos model.

Relevant Activities:

Lab:	S.4.1.4 (p. 2-169)
Modeling:	S.4.2.1 (p. 2-171), S.4.2.3 (p. 2-174)
In Situ:	S.4.3.9 (p. 2-184), S.4.3.10 (p. 2-185), S.4.3.11 (p. 2-186)
PA:	PA.3 (p. 2-68), PA.4 (p. 2-70), PA.5 (p. 2-72), PA.7 (p. 2-75), PA.9 (p. 2-80)

1.3.1.7 Extent of Dissolution: (a) estimating the possible extent of evaporite dissolution within the Rustler Formation over the next 10,000 years, and the possible effects of this dissolution on flow directions and rates within the Rustler; and (b) incorporating potential changes in the Los Medanos model.

Relevant Activities:

Lab:	None
Modeling:	S.4.2.3 (p. 2-174)
In Situ:	S.4.3.9 (p. 2-184), S.4.3.10 (p. 2-185), S.4.3.11 (p. 2-186)
PA:	PA.3 (p. 2-68), PA.4 (p. 2-70), PA.5 (p. 2-72), PA.7 (p. 2-75), PA.9 (p. 2-80)

Summary of Boundary Condition Data Base

Investigations applicable to establishing boundary conditions have provided the following data base.

- Recent isotopic and geochemical studies are inconsistent with the assumption of steady-state boundary conditions and the hydrology and geochemistry of the Rustler Formation appear to be still in transient response to a cessation of recharge occurring 12,000 to 16,000 years ago.

- Limited uranium-disequilibrium studies indicate that ground-water flow directions within the two Rustler dolomite water-bearing units have changed since the end of the last recharge episode.

- The isotopic character of the Rustler Formation is distinct from that of modern meteoric precipitation in the area.

- The limited radiocarbon data base supports the interpretation of no modern vertical recharge to the Culebra.

- Analyses from the Dewey Lake Red Beds indicate that some of the water in this unit may be "modern."

- In general, the stable isotope data base for the Rustler Formation is probably adequate, while that from the Dewey Lake Red Beds and shallower units is inadequate.

- Two tests show that the Dewey Lake Red Beds are too impermeable to determine either the state of saturation or permeability.

- There appears to be limited vertical fluid flow from the Rustler upward into the Dewey Lake Red Beds.

- A major involvement of surficial materials is indicated in crystallization of secondary gypsum veins within the Dewey Lake Red Beds. Secondary gypsum veins within the Rustler could not have crystallized in equilibrium with modern meteoric recharge in the area.

Subelement 1.3.2 <u>Controlled Area Flow Modeling</u>

The Salado Formation contains the underground workings of the WIPP facility, except for the four WIPP shafts, which penetrate overlying formations and the Salado Formation. Many of the subelements concerning the repository/shaft system, outlined in Element 1.2, include both the disturbed rock zone around the WIPP facility and the interaction of emplaced waste, backfill, and seals with the disturbed rock zone. However, the mechanical and hydrological behavior of the repository/shaft system is strongly influenced by the behavior of the geologic systems outside the disturbed rock zone.

The initial performance assessment site characterization results for non-Salado units will be used to assemble the Los Medanos three-dimensional model and the composite model of the controlled area to determine flow conditions for undisturbed performance. This approach assumes that the modern hydrologic settings and properties in the surrounding geology are not disturbed, except from the emplacement of shafts through the Rustler and overlying units. However, the undisturbed scenario requires evaluation of flow up and down the WIPP shafts and of transport up the shafts and through the Rustler Formation and Dewey Lake Red Beds to the accessible environment.

One human-intrusion scenario for the WIPP facility involves an incompletely plugged borehole interconnecting the Rustler/Dewey Lake Red Beds, the WIPP facility, and a brine occurrence within the Castile Formation. Brine occurrences are brines pressurized to near-lithostatic pressure and localized within fractured portions of the uppermost Castile Formation anhydrites. The high pressures associated with these brine occurrences have the potential to hydrofracture competent, unfractured rocks when in communication with the above geologic units, or to expand and extend preexisting fractures. Conventional practice in drilling, following penetration of a pressurized Castile brine occurrence, would include plugging, casing, and/or grouting, but the long-term effectiveness of these procedures remains to be demonstrated. Therefore, an understanding of the important flow and transport mechanisms within the Rustler and Dewey Lake Red Beds between an incompletely plugged hole and the accessible environment must be evaluated.

A second human-intrusion scenario involves borehole interconnection of the Bell Canyon Formation (underlying the Castile Formation), the WIPP facility, and the Rustler Formation; in this scenario, Castile brines are not included. In the WIPP Final Environmental Impact Statement (1980) it was assumed that the result of such interconnection would be flow and transport upward into the Rustler Formation. More recent studies (Beauheim et al., 1983; Beauheim, 1986) indicate that fluid flow and transport resulting from interconnection of the Bell Canyon would be downward into the Bell Canyon.

The model domain for controlled area modeling will be 15 mi by 15.5 mi (24 km by 25 km). It will extend laterally beyond the boundary of the controlled area so that flow across the boundary into the accessible environment can be simulated without artificial boundary condition effects. The vertical domain may include the same layers as the Los Medanos model.

Information needs for this subelement include:

1.3.2.1 <u>Salado Formation</u>: (a) determining and documenting permeabilities, long-term fluid pressures, brine contents, and degree of hydraulic saturation in Salado Formation halites, anhydrites, and clays in the far field; (b) determining whether the Salado Formation behaves as a continuous hydrologic system in the far field on the time scales of regulatory interest; (c) determining far-field deformation rates and mechanisms within the Salado Formation, and the mechanical interaction in the far field between the Salado and overlying units; and (d) developing a mathematical model of Salado Formation zone of influence around the repository and shafts.

Relevant Activities:

Lab:	None
Modeling:	S.3.2.2 (p. 2-141), S.3.2.3 (p. 2-142), S.3.2.4 (p. 2-144), S.3.2.5 (p. 2-145), S.3.2.6 (p. 2-147)
In Situ:	S.3.3.6 (p. 2-153), S.3.3.7 (p. 2-154), S.3.3.8 (p. 2-155), S.3.3.9 (p. 2-156), S.3.3.10 (p. 2-157), S.3.3.11 (p. 2-158), S.3.3.12 (p. 2-159), S.3.3.13 (p. 2-160)
PA:	PA.3 (p. 2-68), PA.5 (p. 2-72), PA.7 (p. 2-75), PA.9 (p. 2-80)

1.3.2.2 <u>Culebra Dolomite Member</u>: (a) determining the final, regional distribution of heads, transmissivities, and storativities in the Culebra Dolomite Member, including evaluation of the uncertainties in both measurement and distribution of these variables; (b) determining the distribution of fracturing within the controlled area and determination of the effects of fracturing on groundwater flow under undisturbed conditions; (c) determining flow directions and rates under undisturbed conditions within the controlled area, including both flow under "preshaft" conditions and an estimate of how long it will take flow conditions at the WIPP site to recover from the effects of shaft sinking and hydraulic testing; (d) determining fluid geochemistry and behavior of radionuclides in Culebra fluids and in mixtures of Culebra and repository fluids, including organic complexing agents; (e) determining the effects of fracturing, matrix diffusion, and sorption/precipitation on radionuclide transport in the Culebra under undisturbed conditions; and (f) refining the Culebra model.

Relevant Activities:

Lab:	S.4.1.1 (p. 2-166), S.4.1.2 (p. 2-167), S.4.1.3 (p. 2-168), S.4.1.4 (p. 2-169), S.4.1.5 (p. 2-170)
Modeling:	S.4.2.1 (p. 2-171), S.4.2.2 (p. 2-172), S.4.2.3 (p. 2-174), S.4.2.4 (p. 2-175)
In Situ:	S.4.3.1 (p. 2-176), S.4.3.2 (p. 2-177), S.4.3.3 (p. 2-178), S.4.3.4 (p. 2-179), S.4.3.5 (p. 2-180), S.4.3.8 (p. 2-183), S.4.3.9 (p. 2-184), S.4.3.10 (p. 2-185), S.4.3.11 (p. 2-186)
PA:	PA.3 (p. 2-68), PA.4 (p. 2-70), PA.5 (p. 2-72), PA.7 (p. 2-75), PA.9 (p. 2-80)

1.3.2.3 <u>Rustler/Salado Formation</u>: (a) determining the time scales required for significant hydrologic interaction between the Salado Formation and overlying (and underlying) formations; and (b) extending Rustler Formation computational meshes to simulate the Salado/Rustler connection for screening scenarios.

Relevant Activities:

Lab:	None
Modeling:	S.3.2.5 (p. 2-145), S.4.2.1 (p. 2-171), S.4.2.3 (p. 2-174)
In Situ:	S.3.3.9 (p. 2-156), S.3.3.10 (p. 2-157), S.4.3.5 (p. 2-180), S.4.3.6 (p. 2-181), S.4.3.7 (p. 2-182)
PA:	PA.3 (p. 2-68), PA.4 (p. 2-70), PA.5 (p. 2-72), PA.7 (p. 2-75), PA.9 (p. 2-80)

1.3.2.4 <u>Rustler Formation</u>: (a) estimating the regional distribution of relative permeabilities and head potentials among the several members within the Rustler Formation and between the Rustler Formation and saturated portions of the Dewey Lake Red Beds; and (b) selecting codes and developing computational meshes for scenarios requiring Rustler Formation hydrology.

Relevant Activities:

Lab:	None
Modeling:	S.4.2.1 (p. 2-171), S.4.2.3 (p. 2-174)
In Situ:	S.3.3.10 (p. 2-157), S.4.3.2 (p. 2-177), S.4.3.3 (p. 2-178), S.4.3.5 (p. 2-180)
PA:	PA.3 (p. 2-68), PA.4 (p. 2-70), PA.5 (p. 2-72), PA.7 (p. 2-75), PA.9 (p. 2-80)

1.3.2.5 Dewey Lake Red Beds: (a) determining the regional distribution of hydraulic saturation within the Dewey Lake Red Beds; and (b) extending Rustler Formation computational meshes for scenarios including Dewey Lake Red Bed hydrology.

Relevant Activities:

Lab:	None
Modeling:	S.4.2.3 (p. 2-174)
In Situ:	S.4.3.7 (p. 2-182), S.4.3.8 (p. 2-183)
PA:	PA.3 (p. 2-68), PA.4 (p. 2-70), PA.5 (p. 2-72), PA.7 (p. 2-75), PA.9 (p. 2-80)

1.3.2.6 Rustler/Dewey Lake Red Beds: determining the bounding directions and magnitudes of modern vertical fluid flow within the Rustler Formation and between the Rustler Formation and Dewey Lake Red Beds.

Relevant Activities:

Lab:	None
Modeling:	S.3.2.5 (p. 2-145), S.4.2.1 (p. 2-171), S.4.2.3 (p. 2-174)
In Situ:	S.3.3.10 (p. 2-157), S.4.3.2 (p. 2-177), S.4.3.3 (p. 2-178), S.4.3.5 (p. 2-180), S.4.3.7 (p. 2-182)
PA:	PA.3 (p. 2-68), PA.4 (p. 2-70), PA.5 (p. 2-72), PA.7 (p. 2-75), PA.9 (p. 2-80)

1.3.2.7 Castile Formation Brines: (a) estimating the distribution and time dependent fluid pressures and flow rates of Castile Formation pressurized brine occurrences at and near the WIPP site; and (b) estimating the timing and efficiency of borehole plugging.

Relevant Activities:

Lab:	None
Modeling:	S.4.2.2 (p. 2-172), S.4.2.4 (p. 2-175)
In Situ:	None
PA:	PA.3 (p. 2-68), PA.4 (p. 2-70), PA.5 (p. 2-72), PA.7 (p. 2-75), PA.9 (p. 2-80)

1.3.2.8 Pressurized Brine Hydrofracturing and Transport: (a) evaluating the hydrologic behavior (including response of preexisting fractures) and the effects on radionuclide transport of changes in fracture properties within the Culebra Dolomite Member and the Dewey Lake Red Beds in response to injection of Castile Formation brine, over the geometric area extending from the point of brine injection to that where fluid-pressure heads and flow rates approximate those under undisturbed conditions, perhaps extending into the accessible environment; (b) evaluating the possibility of hydrofracturing within the Salado Formation as a consequence of Castile brine injection; and (c) incorporating the effects of brine injection in models for the Castile scenarios.

Relevant Activities:
- Lab: None
- Modeling: S.4.2.2 (p. 2-172), S.4.2.3 (p. 2-174), S.4.2.4 (p. 2-175)
- In Situ: S.4.3.7 (p. 2-182), S.4.3.8 (p. 2-183)
- PA: PA.3 (p. 2-68), PA.4 (p. 2-70), PA.5 (p. 2-72), PA.7 (p. 2-75), PA.9 (p. 2-80)

1.3.2.9 Bell Canyon Flow and Geochemistry: (a) evaluating possible flow directions and rates between the Rustler and Bell Canyon Formations and within the Bell Canyon; (b) evaluating the available Bell Canyon Formation geochemical, hydrologic, and nuclide-transport data bases and augmenting the data bases as required; and (c) extending Rustler Formation computational meshes to simulate the Rustler/Bell Canyon connection for screening scenarios.

Relevant Activities:
- Lab: None
- Modeling: S.4.2.3 (p. 2-174)
- In Situ: S.4.3.6 (p. 2-181)
- PA: PA.3 (p. 2-68), PA.4 (p. 2-70), PA.5 (p. 2-72), PA.7 (p. 2-75), PA.9 (p. 2-80)

1.3.2.10 Optimization: performing vertical and lateral resolution studies to optimize meshes for computational efficiency.

Relevant Activities:
- Lab: None
- Modeling: None
- In Situ: None
- PA: PA.3 (p. 2-68), PA.4 (p. 2-70), PA.5 (p. 2-72), PA.7 (p. 2-75), PA.9 (p. 2-80)

1.3.2.11 Composite Domain: linking the Los Medanos and local three-dimensional computational models on a composite domain for computational efficiency.

Relevant Activities:
- Lab: None
- Modeling: None
- In Situ: None
- PA: PA.3 (p. 2-68), PA.4 (p. 2-70), PA.5 (p. 2-72), PA.7 (p. 2-75), PA.9 (p. 2-80)

Summary of Controlled Area Data Base

The current understanding of the controlled area is summarized as follows:

- Current values for the far-field permeability of the Salado Formation are in the range of 10^{-9} darcy, and it is not known if the Salado Formation behaves as a continuous hydrologic system in the far field.

- Recent modeling studies of Rustler/Culebra hydrology indicate a general southerly flow direction under modern undisturbed conditions.

- Culebra fluids are highly variable in composition and concentration of dissolved solids, ranging from essentially pure water to brines half saturated with halite.

- The hydrologic and geochemical setting of the Rustler Formation at and near the WIPP facility is not at steady state and is responding to the cessation of recharge occurring 12,000 to 16,000 years ago.

- The Culebra transmissivity and head data bases will be adequate for performance assessment and the Culebra storativity data bases should be adequate for performance assessment modeling.

- Transmissivity of claystones/siltstones in the Forty-niner, Tamarisk, and the Unnamed Lower Members of the Rustler Formation are in the range of 2.4×10^{-10} to 7.6×10^{-8} meters^2/second. The anhydrites of the Rustler are too low to measure successfully in the field.

- Vertical fluid flow between the Magenta and the overlying Forty-niner Member of the Rustler Formation is upward. In areas where the Dewey Lake Red Beds are unsaturated or too tight to measure, no potential exists for downward flow from the surface to Rustler carbonates.

- There appears to be potential for limited upward flow into the Culebra Dolomite Member from the Unnamed Lower Member, the Rustler/Salado contact zone, and at least a portion of the Salado Formation.

- Although important on the hydropad scale, the effects of fracturing are not significant to regional ground-water flow and performance assessment modeling for undisturbed conditions. Matrix diffusion plays a strong role in contaminant transport within the Culebra under these same conditions.

- The Dewey Lake Red Beds in the vicinity of the WIPP site appear to be hydrologically unsaturated. A limited number of private wells south of the WIPP site appear to produce water from "perched" zones within the unit.

- The Castile Formation contains highly pressurized brines both north and south of the WIPP site. Geophysical studies indicate that similar brines may be present beneath a portion of the WIPP waste-emplacement panels.

- At WIPP-12, fluid pressures at the surface, resulting from pressurized Castile brines, were approximately 200 psi, sufficient to drive saturated brine to the surface and has the potential to alter head gradients and flow directions/rates within the Culebra, at least temporarily, under a breach scenario.

- Fluid flow following an interconnection of the Bell Canyon and Rustler Formations would be downward, into the Bell Canyon.

Subelement 1.3.3 Hydrologic Transport Modeling

Appropriate computational models will be selected, adapted, and optimized for coupling with the hydrologic-flow computational models to simulate transport of radionuclides through the controlled area to the accessible environment.

Subelement 1.3.3 is addressed by performance assessment activities PA.3, PA.4, PA.5, PA.7, and PA.9. Information needs for this subelement include:

1.3.3.1 Subdomains: identifying important subdomains for transport modeling.

1.3.3.2 Transport Mechanisms: identifying important transport mechanisms in the various hydrologic units identified in 1.3.4.1 for various scenarios.

1.3.3.3 Transients: determining whether transport models capable of simulating transient hydraulic conditions, including specialized modeling components such as a model for pressurized brine, are needed based on the results of scenario screening.

1.3.3.4 Transport Codes: selecting computational codes for transport in the controlled area.

1.3.3.5 Optimization: optimizing coupling between hydrologic and transport domains and optimizing transport computational efficiency.

Subelement 1.3.4 Borehole Plug Behavior And Modeling

This subelement concerns the behavior and long-term performance of plugs that would be emplaced in drilled boreholes within the controlled area during facility closure. It also concerns the potential for communication between boreholes and the repository and the flow rate of fluids that could transport radionuclides from the controlled area into the accessible environment, especially flow to the surface resulting from human intrusion into a Castile Formation pressurized brine occurrence.

Information needs for this subelement include:

1.3.4.1 Borehole Plugging Material Behavior: determining how effective cement- or mineral-based grouts will be in restricting fluid flow and maintaining the grout's stability and properties in the various host rocks over the required time period. Host rocks considered must include the Castile Formation anhydrites and both carbonate and noncarbonate units within the Rustler Formation.

Relevant Activities:
Lab: S.2.1.1 (p. 2-117), S.2.1.3 (p. 2-119)
Modeling: S.2.2.2 (p. 2-121)

In Situ: S.2.3.1 (p. 2-122), S.2.3.3 (2-126)
PA: PA.3 (p. 2-68), PA.5 (p. 2-72), PA.7 (p. 2-75), PA.9 (p. 2-80)

1.3.4.2 Borehole Plug Interactions: understanding the interaction between the plugging material and the host rock, including both salt and nonsalt units. The materials interactions will be examined to determine whether the borehole casing can be left in place while the plug is being installed.

Relevant Activities:
Lab: None
Modeling: S.2.2.2 (p. 2-121)
In Situ: S.2.3.1 (p. 2-122), S.2.3.3 (p. 2-126), S.3.3.1 (p. 2-148), S.3.3.2 (p. 2-149), S.3.3.3 (p. 2-150), S.3.3.10 (p. 2-157)
PA: PA.3 (p. 2-68), PA.4 (p. 2-70), PA.5 (p. 2-72), PA.7 (p. 2-75), PA.9 (p. 2-80)

1.3.4.3 Borehole Plugging Criteria, Concepts, and Designs: determining the requirements for borehole plugs, emplacement techniques, and plug performance as engineered barriers under the EPA Standard. Quantitative parameters for the plugging system at specific units in the stratigraphy will be established so that performance assessment can be completed and criteria, concepts, and engineering designs for borehole plugs can be developed.

Relevant Activities:
Lab: None
Modeling: S.2.2.2 (p. 2-121), S.3.2.5 (p. 2-145)
In Situ: S.2.3.1 (p. 2-122), S.2.3.3 (p. 2-126)
PA: None

Summary of Borehole Plug Data Base

Some of the characteristics of shaft and panel sealing materials are applicable to borehole plugging requirements. Previous assessments of borehole plugging requirements indicated that existing, open boreholes in the vicinity of the WIPP facility pose a negligible threat to the public (INTERA, 1981; Christensen et al., 1981; Stormont, 1984). Existing boreholes do not penetrate the WIPP facility; salt between the boreholes and the repository must be dissolved or hydrofractured by high fluid pressures before connection to the repository can occur. As a result, long-term performance of plugs is not required in the Salado Formation and a cementitious mixture can therefore be used as the principal plugging material in the short-term. The Bell Canyon testing program provides a data base for evaluating the performance of borehole plugging materials and the techniques for emplacement (Christensen and Peterson, 1981). Summary evaluations of borehole plugging materials, strategy, and concepts are contained in more recent documents (Stormont, 1988a; Tyler et al., 1988). However, additional studies are needed to develop adequate plugs for boreholes drilled in the Rustler Formation. These plugs must restrict fluid flow and radionuclide transport from the Culebra Dolomite Member to the surface in the event of human intrusion into a pressurized brine occurrence.

ELEMENT 1.4 Computational System

Consequence analysis of the complex WIPP disposal system, including evaluation of uncertainties for all significant scenarios, will entail up to a 1,000 simulations, assuming 100 Monte Carlo simulations per scenario for 10 scenarios. Each simulation should be reproducible and available for examination. Distributions will be developed for each scenario, and for the 10,000-year performance, the distributions must be combined probabilistically. The many different, complex computational models will be linked and/or coupled and executed for each simulation. The system must be automated to complete the performance assessment in a reasonable time period. The analyst should be able to set up new calculations quickly. The data flow through the system should be reliable and not specific to the particular computational models, because different scenarios may require different models. A significant procedural element in performance assessment of geologic repositories is reducing the computational problem to manageable dimensions.

The data base is an integral part of the compliance assessment system. The data selected for the performance assessment must be of high quality. The primary data should be reduced, analyzed, and carefully quality controlled, and should involve minimal subjective interpretation. The primary data base must contain all data necessary for the compliance assessment. The secondary data base must be constructed from the primary data base by evaluating and interpreting the data to arrive at a conceptual model of the disposal system for each scenario to be simulated. Interpretation can require objective or subjective interpolation of data. Objective techniques are easily reproduced by others. However, subjective interpretation requiring extrapolation of data requires professional judgment and must be well-documented to allow reproduction by others. Selection and interpretation of the primary data for conceptual models are the starting points for simulation of significant scenarios for the consequence analysis. Activity PA.11 addresses the information needs for Element 1.4 (Computational System).

Subelement 1.4.1 Development of the Compliance Assessment System

The set of computational models assembled for the subsystems of the disposal system will be linked, coupled where necessary, and integrated into CAMCON, a modular system that automatically controls the simulation. CAMCON has been developed and initial tests are complete.

Information needs for this subelement include:

1.4.1.1 Computer Codes: (a) evaluating available flow and transport codes for performance, user friendliness, running speed, quality assurance, and capabilities; and (b) calibrating or benchmarking codes selected.

1.4.1.2 Variable Mesh: (a) adding variable mesh capability to the system; (b) developing three-dimensional interpolators for domain decomposition for hydrology and/or transport codes, and if necessary, (c) rezoning transport computational subdomains.

1.4.1.3 Vertical Resolution: determining necessary vertical stratigraphic resolution between layers in the three-dimensional hydrologic-flow models.

1.4.1.4 Diagnostics: developing appropriate diagnostics for the system.

1.4.1.5 Sampling: adding a sampling module to the system.

1.4.1.6 Translators: adding input and output translators for each code, to keep the data base independent of the codes.

Subelement 1.4.2 Compliance Assessment Data Bases

The primary data provided by the characterization programs will be interpreted to develop a secondary data base that adequately describes an appropriate conceptual model of the disposal system for long-term simulation of each significant scenario.

Information needs for this subelement include:

1.4.2.1 Primary Data Assembly: assembling all the pertinent data from the disposal system characterization activities into the primary data base.

1.4.2.2 Primary Data Interpretation: objectively or subjectively interpreting the primary data to develop a secondary data base containing appropriate data sets to describe the various parameters required to simulate each of the scenarios.

ELEMENT 1.5 Consequence Analysis

Assessment of compliance with Subpart B of the Standard requires comprehensive consequence analyses. These analyses must provide quantitative predictions of the doses that could occur during the first 1,000 years and of the releases that could occur over the first 10,000 years. The numerical predictions will be based on complex computational models, analytical theories, and prevalent expert judgment. Elements 1.1 through 1.4 address the incorporation of judgment, theory, and models into the performance assessment. Element 1.5 represents the culmination of all the disposal system characterization efforts and the assessment methodology development. When the disposal system has been adequately characterized and modeled, conceptual models have been developed for the scenarios, uncertainties have been resolved to the extent possible, and the compliance assessment system is in place, two tasks will remain. These are a consequence analyses to predict the releases of radionuclides to the accessible environment resulting from both disturbed and undisturbed performance and the doses that might occur from undisturbed performance.

Subelement 1.5.1 Containment Requirements

In Appendix B to the Standard, EPA describes the manner in which the quantitative comparison to the Containment Requirements should be made. "The (EPA) assumes that, whenever practicable, the (DOE) will assemble all of the results of the performance assessments to determine compliance with §191.13 into a complementary cumulative distribution function that indicates the probability of exceeding various levels of cumulative release. When the uncertainties in parameters are considered in a performance assessment, the effects of the uncertainties considered can be incorporated into a single such distribution function for each disposal system considered. The (EPA) assumes that a disposal system can be considered to be in compliance with §191.13 if this single distribution function meets the requirements of §191.13(a)." Activities PA.8 and PA.10 address the information needs for Subelement 1.5.1.

Information needs for this subelement include:

1.5.1.1 Scenarios and Probabilities: all scenarios of regulatory interest and their probabilities of occurrence for disturbed performance (as defined in Subpart B) of the disposal system for the first 10,000 years after disposal.

1.5.1.2 Conceptual Models: a conceptual model of the disposal system for each scenario.

1.5.1.3 Computational Models: a set of computational models for each scenario that will simulate behavior of the disposal system in response to that scenario.

1.5.1.4 Release Simulations: simulating behavior of the disposal system and developing a distribution of releases to the accessible environment for each scenario based on the parameter uncertainty in its conceptual model.

1.5.1.5 Complementary Cumulative Distribution Function: combining the releases and the associated scenario probabilities into a single complementary cumulative distribution function.

Subelement 1.5.2 Individual Protection Requirements

In Appendix B to the Standard, EPA describes the manner in which the quantitative comparison to the Individual Protection Requirements should be made. "When the uncertainties in undisturbed performance of a disposal system are considered, the (DOE) need not require that a very large percentage of the range of estimated radiation exposures ... fall below limits established in §191.15.... The EPA assumes that compliance can be determined based upon 'best estimate predictions' (e.g., the mean or the median of the appropriate distribution, whichever is higher)." Activities PA.8 and PA.10 address the information needs for Subelement 1.5.2; Activity PA.6 also addresses information needs 1.5.2.5 and 1.5.2.6.

Information needs for this subelement include:

1.5.2.1 Scenario: the undisturbed behavior (as defined in Subpart B) of the disposal system for the first 1,000 years after disposal.

1.5.2.2 Conceptual Model: a conceptual model of the disposal system for undisturbed behavior.

1.5.2.3 Computational Model: a set of computational models that will simulate undisturbed behavior of the disposal system.

1.5.2.4 Release Simulations: simulating behavior of the disposal system and developing a distribution of releases to the accessible environment based on the parameter uncertainty in the conceptual model.

1.5.2.5 Pathway Simulations: simulating transport of released radionuclides through soil, water, air, and biota to man.

1.5.2.6 Doses: making the best-estimate dose prediction for each release distribution.

2.6 ACTIVITY DESCRIPTIONS

This section provides brief descriptions of the specific activities that will be performed to obtain the information needed to support the five work elements described in Section 2.5.1 beginning on p. 2-30. Each activity description contains: (1) a discussion of the focus of the activity, (2) the methodology that will be employed, and (3) a list of the information need or element addressed by the activity. For each information need or element listed, a reference number is given to allow cross-referencing with Section 2.5.1.

Activities directly related to the long-term performance assessment of the disposal system are described in Section 2.6.1. These activities are identified by the letters "PA" followed by a single digit that sequentially numbers the 11 activities.

The supporting activities that provide conceptual models, input data, and model validation for the performance assessment are described in Section 2.6.2. The laboratory, modeling, and in situ activities are further divided into disposal room and drift system activities (Section 2.6.2.1), sealing system activities (Section 2.6.2.2), Salado Formation structural and fluid-flow activities (Section 2.6.2.3), and non-Salado hydrology and nuclide migration activities (Section 2.6.2.4). The supporting activities for these four technical areas are each identified by the letter "S" followed by a three-digit reference number. The first digit corresponds to the specific activity area (i.e., S.2._._ refers to a supporting activity in the sealing system category); the second digit is a 1 if the supporting activity is a laboratory study, a 2 if the supporting activity is a modeling activity, and a 3 if it is to be performed in situ. The third digit is the sequential number of supporting activities. For example, S.2.1.3 is the third laboratory activity of the sealing system area.

More detailed activity descriptions can be found in Bertram-Howery and Hunter (1989b) and in individual test plans, which have been or are being prepared as appropriate.

2.6.1 Performance Assessment Activities

The 11 performance assessment activities described in this section are related to the development of scenarios and the performance of an assessment of compliance with 40 CFR 191, Subpart B. The supporting activities that provide conceptual models, input data, and model validation for the performance assessment activities are described in Section 2.6.2.

Activity PA.1
SCENARIOS: Screening

1. Focus

The scenarios retained to date (Hunter, 1989) are too numerous for direct modeling and inclusion in the complementary cumulative distribution function as suggested by the EPA; preliminary modeling will be used to screen out some of the scenarios before preliminary and final consequence modeling can take place (Activities PA.8 and PA.10). Screening on the basis of probability, physical reasonableness, regulatory guidelines, and earlier estimates of consequences is complete and documented (Hunter, 1989).

There are currently 76 retained scenarios; typical performance assessments for hypothetical repositories have analyzed about five scenarios. The 76 scenarios were retained either because their probabilities were definitely high enough to make them of regulatory interest or because no data are available to suggest that the probabilities are minimal. The retained scenarios will be screened on the basis of simple consequence modeling. It is likely that all scenarios retained after simple consequence modeling will be included in the complementary cumulative distribution function.

2. Methodology

Preliminary modeling for the screening will initially seek answers to the following questions:

- Climatic Change - Can any reasonable climatic change cause important flow variations within 10,000 years?

- Nuclear Criticality - Can any likely waste/backfill/host-rock configurations give rise to nuclear criticality after the shafts have been sealed?

- Human Intrusion - Do boreholes connecting the Culebra, repository, and Bell Canyon result in travel times to the accessible environment less than 10,000 years? Does the existence of two boreholes in the same panel change the flow pattern? Is solution mining outside the controlled area likely to affect releases?

- Seal Performance - What are the major effects of nonstandard seal performance?

In each case, existing models will be adapted to the scenario being examined, and bounds on consequences will be calculated. Results of screening these scenarios will help determine whether other scenarios from the retained set will be examined and possibly screened. The scenario set retained for consequence analysis will be updated annually. Finally, the significant set of scenarios for final consequence analysis will be chosen.

3. Element Addressed

Scenario Screening (1.1)

Activity PA.2
SCENARIOS: Probability Assignment

1. Focus

Consequences for each significant scenario are combined with scenario probabilities to produce a single complementary cumulative distribution function for release to the accessible environment. Calculated or assigned probabilities for most events and processes currently retained for further analysis are completed (Hunter, 1989). However, based on further research, it may become necessary to reevaluate a few of these assigned probabilities or to estimate probabilities for as-yet unexamined events and processes.

Probabilities of occurrence of selected scenarios that survive screening on the basis of simple consequence analysis, either for further screening or for direct use in preparing a complementary cumulative distribution function, must be estimated.

2. Methodology

The procedure for estimating probabilities of occurrence for events and processes is part of scenario development and screening. During scenario development, events and processes were screened on the basis of physical reasonableness, probability, and regulatory guidance. Consequence modeling will be used to further screen the remaining scenarios. Some scenarios for which sufficient data on probability do not exist may survive screening by consequence modeling. If so, probabilities of occurrence for these scenarios probably will have to be estimated using expert opinion.

A number of procedures for estimating probabilities of occurrence are available (Hunter and Mann, 1989). Hunter (1989) has analyzed numerous events and processes of interest at WIPP and the available data to determine the applicability of each of the probabilistic techniques. More than one probability technique was applicable to some of the events and processes, but in other cases, probabilities must be assigned using expert opinion. If scenarios to which probabilities were assigned, and not calculated, survive screening on the basis of consequence, it may be appropriate to select a panel of experts to determine or estimate their probabilities of occurrence.

3. Element Addressed

Scenario Screening (1.1)

Activity PA.3
HYDROLOGIC MODELING: REGIONAL (LOS MEDANOS MODEL)

1. Focus

Modeling of regional and local ground-water flow is the basis of radionuclide-transport calculations (Activity PA.5). A number of activities provide direct and indirect support to regional and local hydrologic modeling for performance assessment.

Site characterization defines the local conceptual model and the present flow fields, synthesizes observational data into flow and material-property fields that help explain and reproduce the data, and establishes confidence in our understanding of the geology, hydrology, and geochemistry of the WIPP site. This conceptual model and present flow fields will be used as initial conditions from which simulations of the system are run far into the future (10,000 years) to perform the consequence and uncertainty analyses required by 40 CFR 191.

Past ground-water flow modeling has been concerned primarily with the Culebra Dolomite Member of the Rustler Formation in the immediate vicinity of the controlled area. An important measure of our understanding of the site is how well we can reproduce observations (e.g., pumping drawdowns) with model calculations. These calibrated model fields represent only an initial field in the 10,000-year simulation that must be carried out to assess compliance with 40 CFR 191. Over 10,000 years, processes that affect flow and transport within the accessible environment could occur at some distance vertically and laterally from the present characterized domain; therefore, the spatial extent of the modeling/observational survey domain will be enlarged to reduce uncertainty in the result.

The model domain has been enlarged laterally from 14.9 mi x 15.5 mi (24 x 25 km) to 21.1 x 24.8 mi (34 x 40 km) and vertically to eight layers as a first step. However, data are sparse within the larger model (called the Los Medanos model) domain in some key areas; both modeling and field surveys are needed to reduce uncertainties. Within the original domain, the vertical extent of the models and field data will be expanded beyond the Culebra Dolomite Member. A three-dimensional model of the Rustler and younger formations is necessary, because scenarios include potential hydrologic transport to (and leakage from) the Magenta Member. Some scenarios also include the Dewey Lake Red Beds. These vertical model extensions require additional field data and modeling to reduce uncertainties in calculated releases.

The Los Medanos model is a "first-step," three-dimensional, conceptual model. The present numerical code used for simulations is SWIFT II. Domain size is 21.1 x 24.8 mi (34 x 40 km) with eight vertical layers. The Culebra Dolomite Member of the Rustler Formation represents one computational layer of the model. Mesh optimization, vertical resolution studies, and coupling with transport models on appropriate subdomains will be performed before final consequence analysis.

2. Methodology

Reducing uncertainty in lateral boundary conditions is important. Data along the computational domain boundaries are sparse in key areas. To improve simulations of ground-water flow, primarily by reducing boundary uncertainties, the following studies are useful:

- Determine areal extent of Culebra-Magenta hydraulic connection.

- Determine hydrologic parameters of the Dewey Lake Red Beds.

- If transport calculations show that these parameters are important, estimate fracture frequency and orientation (vertical versus horizontal) within the Culebra Dolomite Member.

- Expand the fluid-density data base to fill in areas in field maps where data are sparse.

- If initial 10,000-year modeling shows that boundary conditions are significantly affecting the results, fill out data coverage for remaining boundary conditions (Clayton Basin, eastern boundary, and southwest boundary at Balmorrhea-Loving Trough).

- Study paleoclimate.

As additional data become available, the Los Medanos model will be used to calibrate an updated numerical model and to provide fields for sensitivity analyses, benchmark simulations for code comparisons, and mesh studies. Ultimately, the Los Medanos model will simulate ground-water flow for consequence analyses.

3. Element Addressed

Controlled Area: Behavior Characterization
and Performance Modeling (1.3)

Activity PA.4
HYDROLOGIC MODELING: LOCAL

1. Focus

Modeling of regional and local ground-water flow is the basis for radionuclide-transport calculations. A number of activities provide direct and indirect support to hydrologic modeling for performance assessment. A ground-water flow model of the local hydrology for use in the preliminary and final consequence analysis must be established.

Site characterization has focused primarily on the Culebra Dolomite Member within and near the controlled area. This member is now well characterized; the SWIFT II code has been calibrated (in two dimensions) on the conceptual model and data. The calibrated fields provide a benchmark against which other models and/or meshes will be tested. As previously noted, scenarios also include the Magenta Dolomite Member and Dewey Lake Red Beds.

2. Methodology

The local model will be extended in three dimensions, and the three-dimensional local model will extend through the Rustler Formation for most scenarios. Therefore, studies examining the potential for vertical fluid flow within the Rustler Formation would be useful.

The extension of the local model to three dimensions has several subtasks. One is to choose appropriate codes and develop meshes for those scenarios requiring only Rustler hydrology. A second subtask is to extend Rustler codes and meshes for those scenarios that include Dewey Lake Red Beds hydrology. A third subtask, probably needed only in the scenario-screening stage, is to extend Rustler meshes to address the Salado-Rustler connection. This last subtask also includes: (1) applying existing models to the site characterization conceptual model and incoming data from Subtasks 1 and 2, (2) studying vertical and lateral resolution to optimize meshes for computational efficiency, and (3) designing scenario-dependent calculations.

Some scenarios require additional data on the local scale. These scenarios examine the Salado and Bell Canyon Formations and pressurized brine occurrences in the Castile Formation. For the Salado and Bell Canyon Formations, hydrologic properties and radionuclide retardations are needed. These data will be used primarily in scenario screening, but Salado data are also needed for the repository/shaft systems model which will be used in some final scenario-dependent release calculations. These near-field data will need to be less uncertain than the others.

Because geophysical evidence indicates the possible presence of pressurized brine occurrences beneath the repository horizon (Earth Technology, 1988), and because it is difficult to rule out the existence of such features with absolute certainty, pressurized brine occurrences are important in several human-intrusion scenarios. Data on pressurized brine occurrences include volume, pressure, chemistry, and geometry. If the brine chemistry of these pockets is much different from brines expected to resaturate the rooms, the source term will have to be modified to include them after a borehole breach. However, it should be possible to define a standard brine for possible reservoirs based on existing data from other locations. Pressure will also be estimated from data on other pressurized brine occurrences. Sizes and volumes will be estimated from geophysical surveys.

3. Element Addressed

Controlled Area: Behavior Characterization and Performance Modeling (1.3)

Activity PA.5
TRANSPORT MODELING

1. Focus

The release and dose calculations required to assess compliance with 40 CFR 191 cannot be completed without transport models. A number of activities provide direct and indirect support to transport modeling for performance assessment.

Three types of studies relating to the transport of radionuclides through geologic formations are needed. The first identifies important transport mechanisms in the various scenarios being considered and thus guides the selection of models and codes used for the consequence analysis. This study would ensure that the models and codes selected correctly simulate the relevant physical and chemical processes. The second type of study actually selects codes. This study assesses the capabilities, benchmarking, verification, and validation of various codes. Codes selected in this manner would have the most appropriate capabilities and also would provide confidence that they meet the WIPP quality assurance standards. The third type of study optimizes the implementation of the selected codes. The study would facilitate and streamline the actual computations during consequence analysis.

2. Methodology

This effort will consist of three tasks:

a. Identify the types of models and codes needed.

   - Perform sensitivity analysis of radionuclide transport in transient ground-water flow fields to determine whether transport models with transient capability are needed.
   - Determine which transport mechanisms (porous versus fracture, equivalent porous versus dual porosity) are important in the Culebra Dolomite Member for each of the various scenarios.
   - Identify important subdomains for transport modeling.

b. Select codes.

   - Assess capabilities of potential codes and compare with code requirements for performance assessment.
   - Assess codes' benchmarking, verification, and validation.
   - Select final codes for use in WIPP performance assessment and modify, if necessary.

c. Optimize transport computations for consequence analysis.

   - Optimize coupling between hydrologic (Activities PA.3 and PA.4) and transport domains.
   - Optimize computational efficiency for selected transport codes.

Data needs are retardation of radionuclides, porosities, fracture geometry, dispersion coefficients, and water chemistry in all geological units through which transport might be expected, e.g., Rustler Formation, especially the Culebra Dolomite Member; Dewey Lake Red Beds; and Salado Formation. In the geologic formations and their members, spatial variability in material properties and brines are also needed.

3. Elements Addressed

Repository/Shaft System: Behavior Characterization
and Performance Modeling (1.2)
Controlled Area: Behavior Characterization
and Performance Modeling (1.3)

Activity PA.6
PATHWAYS/DOSIMETRY

1. Focus

Compliance with 40 CFR 191 on individual protection requires predictions of doses during the time period from repository closure to 1,000 years for undisturbed performance of the repository. Although releases to the accessible environment in 1,000 years are not expected, dose calculations may be necessary because: (1) 40 CFR 191 has been remanded and its future is uncertain, and (2) releases to the accessible environment from undisturbed performance, while not expected, have not been ruled out.

The objective is to include pathways and dosimetry models in CAMCON (CAMCON is an automated system to manage the many simulations to be performed for the preliminary and final consequence analyses) and prepare corresponding data bases if dose calculations are needed for assessing compliance with individual protection regulations or for responding to possible results of the 40 CFR 191 remand.

2. Methodology

Two types of models are needed: biological pathways models and human dosimetry models. Biological pathways models are numerous and well documented. Two such models have been selected and will be adapted to WIPP scenarios and included in CAMCON. Historical data for these models are also plentiful. These data are the result of extensive biological and environmental surveys of the WIPP site and vicinity. The data will be collected in summary form for the appropriate pathways and computerized.

Human dosimetry models are also numerous and well documented. Appropriate dosimetry models have been selected for use in CAMCON. Their underlying data bases will be updated depending on radionuclide inventories.

3. Element Addressed

Consequence Analysis (1.5)

Activity PA.7
REPOSITORY/SHAFT SYSTEM MODELING

1. Focus

The behavior of the repository/shaft system must be understood sufficiently to simulate migration of radionuclides out of the repository to support Activities PA.6, PA.8, and PA.10. A large number of activities provide direct and indirect support to the modeling of the repository/shaft system using simple or complex models.

2. Methodology

An efficient, fast computational model or system of models for the simulation of repository/shaft behavior is needed. The repository/shaft system model will comprise a system of linked computational models:

a. Models of the rooms (closure, resaturation, waste containers, room chemistry, backfill, and retardation).

b. Models of the panel drifts and seals (flow and transport through seals, annular flow around seals, flow through surrounding disturbed rock zone, disintegration and/or fracturing, adjacent backfills, resaturation, closure, chemistry, and retardation).

c. Models of the drifts from panel seals to shafts (backfill, disturbed zone, resaturation, closure, brine chemistry, and retardation).

d. Models of the shafts and seals (flow and transport through and around the disturbed rock zones and seals, brine chemistry, retardation, and seal disintegration or fracture).

CAMCON will be the package for controlling this system's model during analyses performed to characterize sources in overlying formations for some scenarios.

The room model provides the source term for transport calculations. The room model will include the coupled effects of the waste containers and contents, backfill (including any chemical additives), gas generation, room closure, resaturation, retardation, and repository chemistry. Some of these components have been extensively modeled, but no attempt has been made to couple models into a complete package. To the extent possible, this coupling will be performed and tested. For performance assessment purposes, the room model will be studied and possibly simplified. The data needs, as presently conceived, are included in Table 2-2.

The model of panel drifts and seals will simulate flow and transport through and around the panels and seals, flow through the surrounding disturbed zone (accounting for resaturation), retardation in these materials (accounting for near-field brine chemistry), and possible degradation of the seals. For the adjacent backfill materials, the model should include the mixture with any chemical additives, material properties, effects on reconsolidation, resaturation, and retardation, and dissolution and precipitation. The data needs, as presently conceived, are included in Table 2-2.

TABLE 2-2. MODELS FOR REPOSITORY/SHAFT SYSTEMS SIMULATION AND ASSOCIATED DATA NEEDS

Data	Models: Room	Models: Panel Drifts/ Seals	Models: Drifts from Panel Seals to Shafts	Models: Shaft/Seals
Source:				
Repository chemistry	X			
Inventory	X			
Concentrations of radionuclides in brine	X			
Volume of brine transferred	X			
Migration rate	X			
Backfill:				
Mixture	X	X	X	X
Porosity	X	X	X	X
Permeability	X	X	X	X
Waste Containers and Contents:				
Response to closure and brine inflow	X			
Room Closure Rate	X			
Gas Generation:				
Rate	X			
Pressure	X			
Resaturation (brine inflow rate)	X	X	X	X
Disturbed Rock Zone:				
Porosity vs. distance		X	X	X
Brine/gas permeabilities vs. distance	X	X	X	X
Transport:				
Retardation due to backfill materials	X	X	X	X
Retardation due to seal materials		X		X
Retardation due to host rock	X			X
Geometry	X	X	X	X
Final Consolidation State	X	X	X	X
Seals:				
Porosity		X		X
Permeability		X		X
Reliability (failure modes)		X		X

The model of the drifts from the northernmost panel seals to shafts will simulate flow and transport from the panel seals adjacent to the storage area to the shaft facility-level seals, accounting for creep closure, geometry, backfill, repository chemistry, retardation, and the disturbed rock zone. Presently conceived data needs are similar to Table 2-2.

The model of the shaft and seals will simulate flow and transport through the shafts and their seals from the repository horizon to the scenario-dependent discharge horizon, e.g., the Culebra Dolomite Member of the Rustler Formation. The model will include flow through and around seals and backfill, flow through the disturbed rock zone, brine chemistry, retardation due to backfill, seal, and matrix materials, effects of seal disintegration and fracture, and dissolution and precipitation. Simulations will include flow down the shaft from leakage of overlying aquifers and flow with transport up the shaft required by various room pressurization scenarios. The presently conceived data needs are similar to Table 2-2.

The Salado component of the repository/shaft system model is an encompassing hydrologic model covering the larger zone of influence that drains during the resaturation period. This Salado component will be connected to the three-dimensional local model, so that potential Rustler-Salado vertical leakage will be included for scenario screening. A simplified version of the repository/shaft model will be embedded within the Salado component for scenario screening. Hydraulic properties and chemical interaction of radionuclides with rock matrix will be needed.

This system of models will interface with the larger CAMCON performance assessment system that includes geologic, hydrologic, and transport models. Many of the processes listed above are studied with various individual models. Some models are detailed, complex, finite element models for understanding processes and data, while other models are simplified for performing parameter variation studies that are useful for facility design. Therefore, some models may be more complex than needed for performance assessment and may be simplified, while others need to be enhanced to be adequate for the performance assessment application. These models will be adapted to performance assessment and included in a systems model of the repository and shafts.

3. Elements Addressed

Repository/Shaft System: Behavior Characterization
and Performance Modeling (1.2)
Controlled Area: Behavior Characterization
and Performance Modeling (1.3)

Activity PA.8
PRELIMINARY CONSEQUENCE ANALYSIS

1. Focus

Preliminary consequence modeling will allow the WIPP Project to assess the availability of data, techniques, and codes necessary to produce the release and dose calculations required to demonstrate compliance with 40 CFR 191 (Activities PA.6 and PA.10).

Preliminary consequence analysis is the process of setting up the calculation sequence, using CAMCON for each significant scenario. Preliminary release calculations are combined with probabilities to produce complementary cumulative distribution functions that scope the extent of the problem in the compliance-assessment step.

2. Methodology

All scenarios retained after screening (Activity PA.1) will be examined by the preliminary consequence analysis. However, the process of setting up the calculation sequence for each scenario is complex and time consuming, so scenarios may be grouped by commonality of modeling approach. For example, scenarios that can be analyzed by the same mesh would appear in the same group.

The preliminary groupings are the undisturbed scenario, the climate-hydrology-repository-shaft scenario group, and the human-intrusion scenario group. Grouped in this way, the preliminary consequence analysis can proceed in the sequence, undisturbed, climate-hydrology-repository-shaft and human-intrusion. Thus, more difficult modeling tasks are deferred. Some early calculations may be repeated when the last models are completed. However, recalculations will be time-consuming.

Conceptual models must be defined for each group. In developing these models, several items must be addressed:

- Sampling techniques will be compared to assure credibility and determine whether Latin hypercube sampling is the optimum sampling technique for these scenarios.

- Because each scenario is a sequence of events and processes, the order and time of occurrence of the event may be important to the calculated releases.

- Care must be taken to choose parameters that are sensitive, with ranges and distributions sufficiently known that the results will be realistic. These decisions will be based on sensitivity analyses.

- It is possible that analysis of some scenarios will require specialized modeling components. For example, the examination of human intrusion may require a model of pressurized brine occurrences.

After scenarios are grouped, codes selected, meshes defined, calibrated initial fields developed, and the input parameter space to be sampled identified, the preliminary consequence analysis calculations can be made. Preliminary complementary cumulative distribution functions will be produced so that potential problems can be identified during this stage of the work. The complementary cumulative distribution functions calculated during this preliminary work will be incomplete, because each will represent only one or a few scenarios. Some data will not yet be available but important sensitivity analyses for designing scenario-dependent computational strategies will continue. Therefore, the complementary cumulative distribution functions will be used only for scoping purposes. A determination of the need for dose calculations will also be made; regardless of the determination for the current performance assessment, biological pathways and human dosimetry models are being included in CAMCON, in the event that the 40 CFR 191 remand results in a more stringent standard.

This activity will identify any deficiencies in the WIPP performance assessment methodology and correct or supplement the methodology as necessary before final consequence analysis begins.

3. Element Addressed

   Consequence Analysis (1.5)

Activity PA.9
SENSITIVITY ANALYSIS

1. Focus

Sensitivity analyses will be performed on various components of scenarios during the preliminary consequence analysis (Activity PA.8) to determine where additional data are needed and where computer code efficiency can be improved.

2. Methodology

As the calculations for the performance assessment continue, sensitivity analyses will provide feedback on data collection, models and code development, and validation. There are three primary areas of sensitivity analysis:

a. Comparison of Sensitivity Analysis Methods for Computer Codes: Sensitivity analyses of computer codes can be performed using a response-surface methodology based on input determined from fractional factorial design, Latin hypercube sampling with and without regression analysis, differential analysis, adjoint and Green's function techniques, and the Fourier amplitude sensitivity test. The choice of approach will be based on the ease of implementation, flexibility, estimation of the cumulative distribution function of the output, and adaptability. For such a complex system of computer codes to be used in the WIPP performance assessment, a variety of techniques will probably have to be used. Care will be used to assure that the complexity of the sensitivity-analysis technique is appropriate where implemented.

b. Sensitivity Analysis of Geohydrologic System and Transport: The geohydrologic transport component of the performance assessment system can be separated from the repository/shaft part of the system. The geohydrologic component has defined the initial fields so that, given a source, the combined geohydrologic transport component can calculate the performance measure.

   Sensitivity analysis of this component will:

   - Assess computational, physical, and chemical parameter sensitivities,
   - Assess effects on the flow field and transport of brine density variations, pumping, injection, recharge, material and hydrologic data gaps, and boundary conditions, and
   - Identify important processes and data for the analysis of the various scenarios.

c. Sensitivity Analysis - Repository/Shaft System: The repository/shaft component of the performance assessment system can be run as a separate systems analysis for performance assessment. The repository/shaft systems model will use CAMCON as a separate application. Its components will probably be room, panel and drifts, and shafts and seals models (Activity PA.7). Some calculations will require embedding parts of this system within a Salado or Salado-Rustler component.

Sensitivity analysis of this component will:

- Assess computational, physical, and chemical parameter sensitivities,
- Identify important parameters for the analysis of the various scenarios, and
- When appropriate, simplify complex models used by the facility design group for use by performance assessment.

The latter item is an important step in the repository/shaft model case because mechanical, resaturation, source, and transport models are complex and finely meshed compared to performance assessment needs. CAMCON will accept these codes, but simplification, primarily in meshing, would lower running times. However, important processes within the whole system must be identified and retained and cannot be sacrificed just for the sake of simplification. This task is a methodical procedure for adapting individual complex models to performance assessment needs by assembling a repository/shaft systems model through CAMCON. The model will be interfaced with the geohydrologic transport model through the larger CAMCON performance assessment application.

3. Elements Addressed

Repository/Shaft System: Behavior Characterization
and Performance Modeling (1.2)
Controlled Area: Behavior Characterization
and Performance Modeling (1.3)

Activity PA.10
FINAL CONSEQUENCE ANALYSIS

1. Focus

For assessing compliance of WIPP with the Containment Requirements of 40 CFR 191, Subpart B, consequence analysis must be performed for each scenario that is determined to be significant during scenario screening. The results of the release analyses must be assembled and represented in the form of a single complementary cumulative distribution function, which will then be compared with the Standard.

2. Methodology

Final consequence analysis will examine the same scenarios and use the same codes and techniques used in the preliminary consequence analysis, with two exceptions. Any scenarios that have been shown to contribute negligibly to the complementary cumulative distribution function may be omitted from the final consequence analysis. Any codes or techniques that have shown deficiencies during the preliminary analysis will be corrected before the final anlaysis. In addition, the final consequence analysis will have access to additional and improved data than will the preliminary consequence analysis.

This activity comprises several tasks:

a. Finalizing all data and models so they can be used in the final consequence analysis.

b. Processing all scenarios through CAMCON and analyzing the results.

c. Combining scenario consequences with probabilities to produce the final complementary cumulative distribution function, and then comparing the complementary cumulative distribution function with Section 191.13, Containment Requirements, of the Standard. In addition, if there is any release of radionuclides resulting from undisturbed repository performance during the first 1,000 years, doses will be calculated and compared with Section 191.15, Individual Protection Requirements, of the Standard.

3. Element Addressed

Consequence Analysis (1.5)

Activity PA.11
DEVELOP PRIMARY DATA BASE

1. Focus

Performance assessment calculations (Activities PA.6, PA.8, and PA.10) require a dedicated primary data base which must be interfaced with CAMCON. Data will continue to be collected by the experimental and design activities described in this plan and must be integrated into the data base.

2. Methodology

The primary data base comprises those observed data selected to be used in the performance assessment. These data are analyzed and reduced. Data reduction, assembly, and interpretation is a complex task.

Primary data will be objectively or subjectively extended to regular grid information and placed into the secondary data base, where they can be directly accessed by the various model components of CAMCON. The primary data base is the foundation of a credible consequence analysis. These observed, experimental, and design data are supported by other WIPP programs through reports, scientific publications, and quality assurance. Therefore, performance assessment use of these data is critically important and must follow prescribed quality assurance procedures. To accomplish this task, a data base management system will be prepared.

3. Element Addressed

Computational System (1.4)

2.6.2 Supporting Activities

This section describes supporting activities either underway or proposed for implementation during the Test Phase and continuing until compliance with the EPA Standard is satisfactorily demonstrated. Scientific investigations of technical issues related to safe isolation of nuclear wastes in bedded salt have been conducted as part of the WIPP Project since 1975 (Matalucci et al., 1982). These studies have resolved many technical issues and have focused attention on aspects still requiring investigation. The promulgation of the EPA Standard, 40 CFR 191, has also helped to delineate areas of study that require more extensive data to assure adequate confidence in WIPP's isolation performance.

There are four major technical areas to address Elements 1.2 and 1.3:

The disposal room and drift system activities will address the interaction of TRU waste and backfill in a waste room. The combined interactions of the source term, waste containers, emplaced backfill and admixtures, brine inflow, and gas generation are studied through laboratory testing, modeling, and in situ testing. The behavior and performance of possible backfills to be emplaced in access drifts as part of facility decommissioning are also investigated.

The CH-TRU waste gas generation tests are an important part of the in situ test program at WIPP. These tests will confirm laboratory data sets and validate model predictions of gas generation as a function of water content, waste heterogeneity, gas and water getters, backfills, etc., in the room; and transport out of the room. Planned and existing laboratory tests will bracket the times and conditions of interest for each important gas (H_2, CO_2, N_2) for 10,000 years. Bin-scale tests containing approximately six drums per bin of the appropriate CH-TRU waste, backfill materials, getters, and moisture are planned to provide a real waste, synergistic test that complements the laboratory tests for those repository conditions found to be important. Finally, the room-scale tests will validate the gas generation models that will be developed from laboratory- and bin-scale tests. These models will be the basis of performance assessment models. The results will show whether predictions bracket the measured responses and thus determine, at least partially, if the models and data sets are adequate to predict long-term behavior of the gases in the repository.

The sealing system activities involve seal design, system behavior, and overall performance evaluation. Seals will be developed for use in drifts to isolate waste panels, in access shafts to isolate the repository from the accessible environment, and in exploratory boreholes. Laboratory and in situ tests will evaluate behavior of potential seal materials such as crushed salt, salt/clay mixtures, and concretes.

Studies of structural and fluid-flow behavior of the Salado Formation improve the capability to model fluid flow, hydrologic transport, waste room and drift response, and shaft closure. Healing of fractures in the disturbed zone outside excavations and around seals in shafts and access drifts is evaluated. Effects of brine on salt creep are examined. Laboratory and in situ tests provide data for improving models of excavation closure, fracture behavior, permeability, and fluid-flow characteristics of the Salado Formation, and brine inflow to excavated rooms. A wide range of studies addresses the behavior of penetrations through the Salado Formation, openings at the repository level, and fluid flow to and through these disturbances in the host rock.

The non-Salado hydrology and radionuclide migration activities will address transport of waste to the Rustler Formation and in the Rustler Formation under present and future conditions. Laboratory studies of sorption and retardation in the Rustler Formation are included, as well as in situ geophysical and hydrological tests from the surface.

Activities within the four major areas will be conducted during the Test Phase according to the overall assignment of priority based on data needs for seal-system design and performance assessment. Except if radical departures from existing information are found, the data base that exists in mid-1991 will be used in the extensive calculations required for consequence analysis.

Most in situ supporting activities described in this chapter are conducted in the northern part of the WIPP underground and in the Air Intake Shaft. CH-TRU gas generation tests to be conducted in the southern part of the underground facility will provide full-scale confirmation of the previous laboratory and simulated-waste tests.

The discussions of the four activity areas which follows each contain: (1) an activity flow diagram, (2) an activity matrix table, and (3) descriptive narratives. The activity matrix lists the activities and their applications to specific phenomena and parameters that will be examined. Each descriptive narrative describes the focus of the activity, the methodology to be used to perform the activity, and the information needs it supplies. The activities of each program area are further separated into: (1) laboratory studies, (2) modeling studies, and (3) in situ tests.

2.6.2.1 Disposal Room and Drift System Activities

The disposal room and drift system activities (Table 2-3) focus on: (1) the final state of waste entombment and how rapidly it will be achieved (in collaboration with the seal system activities described in this chapter), and (2) design of the backfill for the drift system to further assure isolation of the waste. The activities in this section represent final integration of various individual and often independent components of the disposal system. Integration is accomplished by systems analyses that determine how the components respond in concert (Tyler et al., 1988), leading to comprehensive models (Activity S.1.2.4) for evaluating the long-term performance of the repository system.

Information from a number of activities will be used to select backfill and to model entombment of the disposal room contents. Most obvious are the rate of room closure (Activity S.1.2.4), the compaction properties of the room contents (Activities S.1.1.1 to S.1.1.3, S.2.1.2, and S.2.1.3), and the rate of brine seepage into the room (Activities S.3.2.4, S.3.3.5, S.3.3.6, S.3.3.8 and S.3.3.9). Results from these activities will be combined to predict: (1) bounds on void volumes in the rooms and drifts during the final stages of compaction, (2) the rate at which the voids will become saturated, and (3) the final permeability of the resaturated rooms, drifts, and surrounding disturbed zone (Activity S.3.2.6). Similar considerations in modeling seal performance can be found in Stormont and Arguello (1988).

TABLE 2-3. APPLICATIONS OF THE DISPOSAL ROOM AND DRIFT SYSTEM INVESTIGATIONS

Program-Area Activity	Phenomena/Parameters Being Addressed			
	Disposal Room and Drift System	Sealing System	Structural and Fluid Flow Behavior, Salado	Hydrology and Nuclide Migration, Non-Salado
S.1.1 Laboratory Studies:				
S.1.1.1 Backfill-Mix Creep and Permeability Behavior	Room Closure, Brine Distribution	Seal Permeability*		
S.1.1.2 Backfill-Mix Selection Tests	Getter Effectiveness, Backfill Performance			
S.1.1.3 Drum and Box Mechanical Response	Container Collapse, Room Closure, Waste/Backfill/Brine/ Room Interactions			
S.1.1.4 Repository Chemistry	Source Term Chemistry, Gas Generation, Backfill Performance			
S.1.1.5 Radionuclide Chemistry	Source Term Chemistry, Radionuclide Solubility			
S.1.2 Modeling Studies:				
S.1.2.1 Backfill-Mix Model	Backfill Performance	Seal Permeability*		
S.1.2.2 Drum and Box Collapse Models	Room Closure, Container Collapse			
S.1.2.3 Backfill-Mix Selection Analysis	Room Closure, Drift Seal Performance			
S.1.2.4 Disposal Room Performance Model	Room Closure			

*Denotes a secondary application

TABLE 2-3. APPLICATIONS OF THE DISPOSAL ROOM AND DRIFT SYSTEM INVESTIGATIONS (Concluded)

Program-Area Activity		Phenomena/Parameters Being Addressed: Disposal Room and Drift System	Sealing System	Structural and Fluid Flow Behavior, Salado	Hydrology and Nuclide Migration, Non-Salado
S.1.2.5	Engineered Modifications	Systems Stability			
S.1.2.6	Additional Development of EQ3/6	Radionuclide Solubility			Radionuclide Solubility, Radionuclide Transport*
S.1.3 In Situ Tests:					
S.1.3.1	Simulated TRU Testing	Waste/Room Interactions, Backfill Performance			
S.1.3.2	Room-Scale Gas Generation Tests	Waste/Room Interactions, Gas Generation, Backfill Performance			
S.1.3.3	Bin-Scale Gas Generation Tests	Gas Generation, Backfill Performance, Getter Effectiveness			

*Denotes a secondary application

Predictions of change in the state of waste entombment with time also depend on source-term predictions (the amount and mobility of the radioactive species and gases produced by waste decomposition). Source term activities quantify the chemical behavior of the disposal rooms (Activity S.1.1.4), predict radionuclide solubilities in concentrated brines (Activity S.1.1.5), and model radionuclide solubilities (Activity S.1.2.6). This information must be available to assess the mobility of the radionuclides.

The room behavior model will represent an understanding of a number of complex interactions. Data will be collected for the behavior of each component in the room and some data will be collected on the interactions of room closure, room backfill, drum collapse, gas generation, and brine inflow. Although all interactions and data sets may not be defined, sufficient data will be collected to allow expert judgment to define the models and data used in the performance assessment.

A flow diagram (Figure 2-5) illustrates how the activities in this program and information from other program areas are combined. First, laboratory tests and models of backfill consolidation are needed to select a backfill for the disposal rooms and the drift system. After a backfill is prescribed (Activity S.1.2.3), its mechanical response to closure is combined with the waste container collapse data (Activity S.1.1.3) and model (Activity S.1.2.2) to develop the disposal room performance model (Activity S.1.2.4). Best estimates of source characteristics, room closure, brine inflow, and gas formation are needed at various stages of model development. Experiments with CH-TRU waste and simulated wastes (Activities S.1.3.1, S.1.3.2, and S.1.3.3) will provide as complete in situ data as possible for partial validation of repository-system models.

Although a great deal of data have been collected on room closure and the mechanical response of the Salado Formation, expert judgment may be required to define the models and data used in the performance assessment. In March 1991, available data, and estimates where data are unavailable, will be used by Activity PA.8 to perform the preliminary consequence analysis.

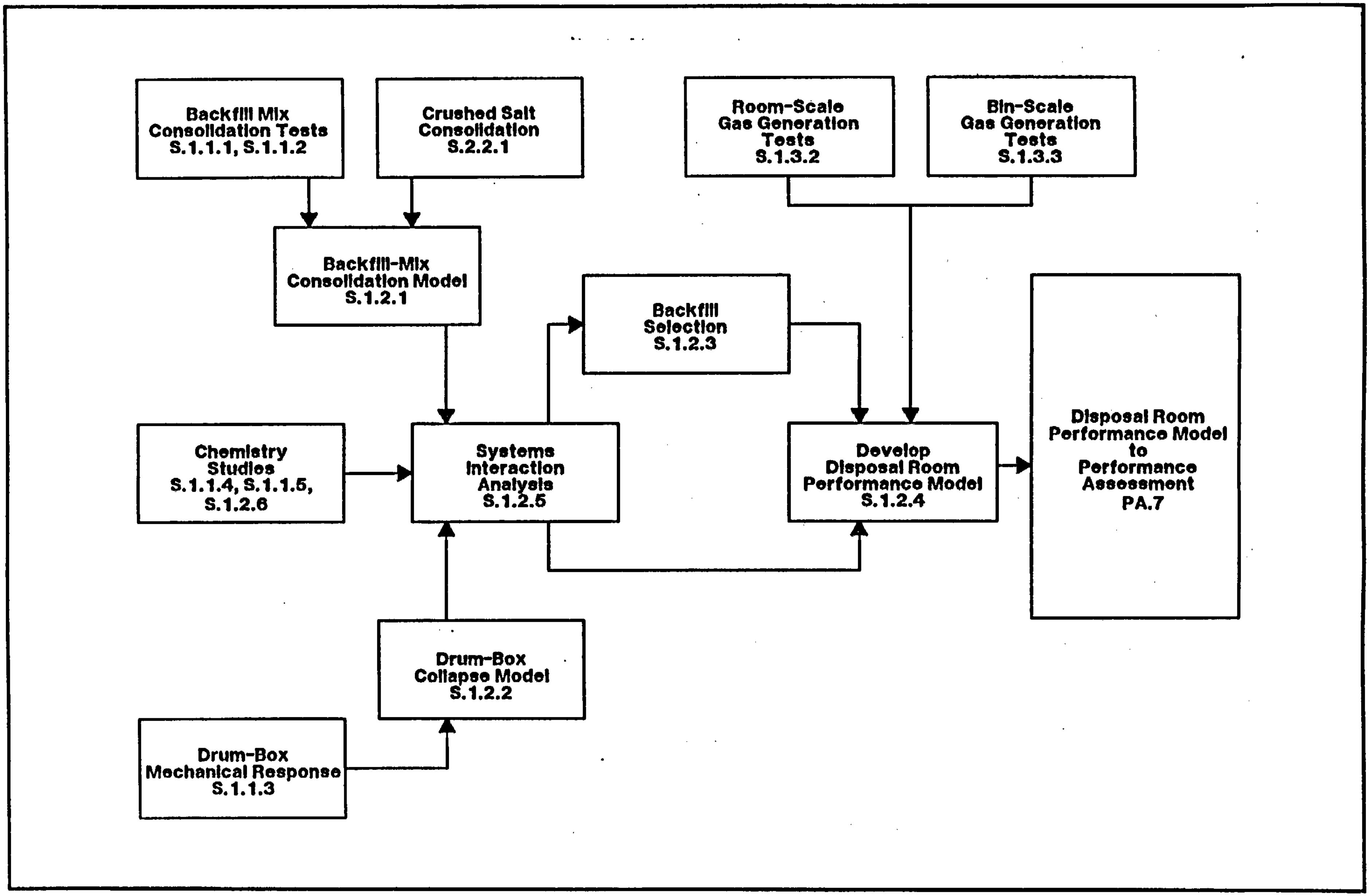


Figure 2-5. Relationship of Disposal Room and Drift System Activities

Activity S.1.1.1
BACKFILL-MIX CREEP AND PERMEABILITY BEHAVIOR

1. Focus

Additives to the crushed salt backfill, such as bentonite (Stormont, 1988a), are being considered because of their ability to absorb brine that may leak toward the seals (Nowak, 1988). However, sorption of brine is accompanied by swelling which may exert pressures on the surrounding rock, thereby retarding room closure (Pusch, 1980). Knowledge of the permeability also allows an assessment of the potential migration of soluble radionuclides. Additives other than bentonite should be tested to control gases produced during waste decomposition. Data on additives and their effects on seal permeability and room closure must be determined so that a suitable model can be developed, and backfills and seal mixes (Activity S.1.2.3) can be selected.

2. Methodology

Laboratory tests on creep rates of a salt-bentonite backfill mixture are under way, to be followed by permeability and swelling tests. Determinations of how much brine can be absorbed by the bentonite or other additives will be performed at various moisture levels. The effects of gas getters on the backfill consolidation will be determined.

3. Information Needs Addressed

Backfill (1.2.1.2)
Disposal Room Design (1.2.1.9)
Disturbed Rock Zone and Fluid-Flow Characteristics (1.2.2.1)
Backfill (1.2.3.1)
Backfill (1.2.4.1)
Disturbed Rock Zone and Fluid-Flow Characterization (1.2.4.3)

Activity S.1.1.2
BACKFILL-MIX SELECTION TESTS

1. Focus

Most backfill tests in the laboratory are on uniform mixes with various additives (Activity S.1.1.1). However, an assessment should be made whether emplacement of different backfill mixes at various locations within the disposal rooms could better control brine inflow, soluble compounds, or gases. For example, backfill-rich bentonite could be placed next to the walls, thereby acting as a barrier to brine inflow. This activity will provide data for model development (Activity S.1.2.1) and backfill-mix selection analysis (Activity S.1.2.3).

2. Methodology

Various configurations of backfill will be investigated analytically and results will be correlated with laboratory tests before a backfill design is proposed. Brine or gases will be introduced from one boundary into various configurations of tailored backfill and the effectiveness of gas getters and brine sorption will be measured. Results will be evaluated and a backfill design proposed.

3. Information Needs Addressed

Backfill (1.2.1.2)
Gas (1.2.1.6)

Activity S.1.1.3
DRUM AND BOX MECHANICAL RESPONSE

1. Focus

Laboratory studies of the extent of drum and box collapse as a function of applied load are necessary to predict: (1) when backstress from the collapse process will begin to retard room closure, and (2) the final state of collapse of the containers.

Predictions of the void and brine content of disposal rooms in their terminal consolidated state, as well as estimates of the time required for achieving this state, depend upon the final state of collapse of the containers. The contents of these containers are highly variable, ranging from low-density, easily compressible, combustible materials to dense, metal objects. Void space within containers can be as much as 75 percent of the container volume (Clements and Kudera, 1985). The state of collapse of the CH drums and boxes will be determined by stresses developed during room closure (Huerta et al., 1983; VandeKraats, 1987). Pressures will not exceed the lithostatic pressure (2,200 psi), which may be insufficient to produce a final state of consolidation near theoretical solid density.

2. Methodology

In experiments on drum and box collapse, load/volume measurements will be made during crushing of individual drums containing simulated CH waste to augment results already reported. First, the stiffening of the container during collapse as lithostatic stress levels are approached will be examined. The next experiments will crush scale models of assemblages of drums and boxes to determine how mechanical interactions between adjacent containers alter their collapse. Finally, crushed containers will be surrounded by wet backfill to determine rates of brine entry into the waste.

3. Information Needs Addressed

Container Response (1.2.1.3)
Systems Interaction (1.2.1.8)

Activity S.1.1.4
LABORATORY STUDIES OF REPOSITORY CHEMISTRY

1. Focus

Laboratory studies provide a unique opportunity to develop a mechanistic understanding of repository chemistry because they can: (1) quantify the effects of significant processes under conditions that isolate each process from the complex effects of other processes, yet are nevertheless realistic; (2) determine the effects of variations in repository conditions on these processes.

Several processes could affect the repository gas and water budget. The air trapped in WIPP disposal rooms at the time they are filled and sealed will comprise mainly nitrogen and oxygen. The Salado Formation will release brine and will initially release gas, mostly nitrogen, possibly with some methane. Eventually, the Salado may serve as a sink for all gases, except perhaps nitrogen. Microbial activity, either aerobic and anaerobic, halophilic or nonhalophilic, will oxidize cellulosic materials and perhaps other materials in the waste such as plastics and rubbers. Microbial degradation of the waste may produce carbon dioxide in potentially significant amounts, as well as potentially significant quantities of other gases under certain conditions. These other gases could include hydrogen sulfide, methane, and nitrogen. Microbial activity could also affect the water budget of the repository, but the net effect is presently unclear. Corrosion, either oxic or anoxic, of drums, metal boxes, and metallic constituents of the waste will consume significant quantities of water and (in the case of anoxic corrosion) produce significant quantities of hydrogen. Microbial consumption of hydrogen during sulfate reduction might remove one of these gases, and the reaction of hydrogen sulfide with metal containers, metallic constituents of the waste, and their corrosion products to form pyrite will probably remove others. The formation of pyrite, however, will release the hydrogen consumed during sulfate reduction and perhaps produce additional hydrogen, as well as release any water consumed during oxic or anoxic corrosion. Radiolysis of brine, cellulosics, plastics, and rubbers will consume water and produce carbon dioxide, carbon monoxide, hydrogen, and oxygen. Radiolysis could also increase the gas production potential by transforming plastics and rubbers into more biodegradable materials. Brush and Anderson (1988a, 1988b, 1988c) have described these reactions in detail.

Brush and Anderson (1988a, 1988c) proposed several backfill additives to remove or prevent the production of gas. Calcium carbonate, calcium oxide, potassium hydroxide, and sodium hydroxide might remove carbon dioxide. Calcium oxide, along with bentonite, might also remove water. The addition of manganese dioxide, an electron acceptor, may prevent microbial sulfate reduction, the concomitant production of hydrogen sulfide, the reaction of hydrogen sulfide with drums, metal boxes, metallic constituents of the waste, and their corrosion products to form pyrite, and the concomitant production of hydrogen. Copper sulfate, an oxidant, might corrode metal containers and metallic constituents of the waste without producing hydrogen. It is presently unclear whether these proposed backfill additives will be effective, affect other aspects of repository chemistry deleteriously, or inhibit the closure of WIPP disposal rooms by increasing the strength of the materials in the rooms.

Reactions between any brine present in WIPP disposal rooms and backfill additives, drums, boxes, and nonradioactive constituents of the waste could change the Eh and pH of the brine significantly. Microbial activity and corrosion of drums, metal boxes, and metallic constituents of the waste will decrease the Eh. Microbial activity, for example, could decrease the Eh to values characteristic of denitrification or nitrate reduction, the reduction of manganese (IV) oxides and hydroxides, the reduction of iron (III) oxides or hydroxides, or even sulfate reduction. Microbial production of carbon dioxide could decrease the pH of the brine to acidic values. Reactions between brine and the cements used to grout some of the drum contents, as well as in seals, could increase the pH to basic values. Reactions between brine and three of the backfill additives proposed for the removal of carbon dioxide (calcium oxide, potassium hydroxide, and sodium hydroxide) could increase the pH to very basic values.

Because the possible ranges of Eh and pH for any brine after the reactions described above are so wide, the speciation, solubilities, and sorptive behavior of the important radionuclides in TRU waste could vary significantly. Unfortunately, there are no thermodynamic data for the actinide elements in solution with ionic strengths of likely WIPP brines. Laboratory studies of radionuclide chemistry will therefore be necessary over a wide range of conditions.

The objectives of the repository chemistry laboratory studies can be summarized as follows:

1. Quantify the effects of microbial degradation of the nonradioactive constituents of TRU waste on the gas and water budget of WIPP disposal rooms, the Eh and pH of any brine present, and the chemical behavior of radionuclides.

2. Determine the effects of radiolysis on the bioavailability of plastics and rubbers.

3. Quantify the production of hydrogen by anoxic corrosion of drums, metal boxes, and metallic constituents of the waste under various conditions.

4. Quantify the chemical effects of proposed backfill additives to remove gas or prevent its production.

2. Methodology

Brush (1989) describes the laboratory studies of repository chemistry discussed below in much greater detail.

The methodology of each category of laboratory studies appears separately below.

<u>Laboratory Studies of Microbial Degradation of Nonradioactive Simulated Waste</u>:

1. Determine whether potentially significant microbial processes occur under expected repository conditions.

2. Quantify the effects of those potentially significant processes that actually occur on the gas and water budgets of the repository under realistic, not overtest, conditions.

3. Determine whether the microorganisms responsible for significant processes are likely to survive for periods sufficient to affect the long-term performance of the WIPP.

4. Quantify the effects of any potentially significant microbial processes that actually occur under expected repository conditions on the chemical behavior of the important radionuclides in TRU waste under realistic, not overtest, conditions.

Laboratory Studies of Radiolysis:

1. Quantify the effect of waste compaction on the radiolytic gas production rate.

2. Determine whether radiolysis increases the bioavailability of plastics and rubbers.

Laboratory Studies of Anoxic Corrosion:

1. Measure anoxic corrosion rates for relevant iron and steel alloys in likely WIPP brines at 30°C, if possible.

2. Determine whether anoxic corrosion of iron and steel alloys occurs using water vapor and, if so, measure its rate.

3. Determine whether anoxic corrosion of iron and steel alloys occurs using water absorbed by bentonite and, if so, measure its rate.

4. Determine whether anoxic corrosion of other metals in the WIPP inventory occurs and, if so, measure rates for these metals.

Laboratory Studies of Proposed Backfill Additives:

1. Determine whether proposed backfill additives remove gas or prevent its production effectively.

2. Quantify the effects of proposed backfill additives on repository chemistry.

3. Information Needs Addressed

Source Term (1.2.1.1)
Gas (1.2.1.6)

Activity S.1.1.5
RADIONUCLIDE CHEMISTRY

1. Focus

Predictions of the chemical behavior of radionuclides in WIPP brines are necessary to determine the source term (i.e., the quantities of the important radionuclides in the WIPP inventory that will be mobilized for possible transport to the accessible environment) and the scenario-dependent rates at which these radionuclides will be mobilized. Because the vast majority of the plausible release scenarios involve advective or diffusive transport of radionuclides dissolved or suspended in aqueous fluids, the source term comprises: (1) the product of the concentrations of radionuclides in brines that could enter WIPP disposal rooms after they are filled and sealed and the volumes of these brines; and (2) the rates at which these concentrations are attained and these volumes accumulate. (The rates at which radionuclide-bearing brines will migrate from the repository will be determined by transport studies described elsewhere.)

It would be extremely difficult to predict the rates at which radionuclides dissolve or become suspended in WIPP brines. These rates depend critically on the chemical and physical nature of the solid phases with which each radionuclide is associated. Because TRU waste is complex and difficult to characterize, it would probably be impossible to specify the nature of these phases accurately enough for meaningful kinetic studies.

Furthermore, the solubilities of radionuclides in WIPP brines could well be so low that the rates at which solubility equilibria are attained would not affect repository performance even if they could be predicted. It will therefore be assumed that the expected concentrations of radionuclides in brines are attained instantaneously.

These studies of radionuclide chemistry will determine how processes such as the dissolution and precipitation of radionuclide-bearing solids and the sorption of radionuclides by solids such as bentonite or drum-corrosion products distribute radionuclides between brines and solids in the repository, including colloidal-size particles. Transport studies will then determine the mobility of radionuclide-bearing brines and solids.

Radionuclide speciation affects the solubilities of radionuclide-bearing solids and the sorption of radionuclides by other solids such as bentonite and iron oxides. These processes in turn determine the concentrations of radionuclides in any available aqueous solutions. The most important radionuclides in TRU waste are isotopes of the actinide elements, especially plutonium (Pu) and americium (Am). These elements can occur in two, three, or even four oxidation states under natural conditions, and the speciation, solubility, and sorption of an element can differ significantly from one oxidation state to another. These variations are difficult to study experimentally because it is hard to control the Eh of natural systems, especially at the low values that could be established by microbial activity in WIPP disposal rooms. Actinide chemistry is also sensitive to pH, which is difficult to measure in concentrated brines. Both the Eh and pH of the repository could vary significantly with time. Furthermore, these parameters could vary significantly over distances of several centimeters at any given time because of the heterogeneity of TRU waste. It will thus be necessary to carry out experimental and/or modeling studies of actinide chemistry under a wide range of conditions.

2. Methodology

Efforts are currently under way to identify and, if possible, quantify the organic and inorganic ligands in TRU waste.

Laboratory measurements of thermodynamic data will be made for the important radionuclides in the WIPP inventory. These data comprise stability constants for organic and inorganic actinide complexes and solubility products for actinide-bearing solids in concentrated brines. Laboratory and, if necessary, in situ tests will be implemented under a wide range of conditions to simulate possible variations in Eh, pH, and the concentrations of ligands expected for WIPP disposal rooms.

Laboratory and, perhaps, underground tests are necessary to quantify the effects of microbial activity on the concentrations of organic ligands and the oxidation state of multivalent actinide elements.

In addition, modeling studies of the long-term chemical behavior of radionuclides will be performed.

3. Information Needs Addressed

Source Term (1.2.1.1)
Gas (1.2.1.6)

Activity S.1.2.1
BACKFILL-MIX MODEL

1. Focus

This effort will: (1) convert the present constitutive model for crushed salt into a model describing the consolidation of mixtures of salt and inert materials; and (2) develop a means for including either swelling or pore pressure in backfill consolidation and sealing predictions.

This activity will be initiated when the nature of the additives (gas getters and sorbents) is better defined.

2. Methodology

A model predicting how nonsalt substances alter the rate of backfill consolidation will be developed so that the effect on room closure and the final consolidated state of the room can be estimated. A description of how swelling in bentonite varies with moisture content is also needed for the analysis of seal performance.

Bentonite or some other water sorber may be added to crushed salt backfill within the disposal rooms at locations where the amount of brine inflow is of concern (Activities S.1.1.1, S.1.1.2). Other additives may be introduced to scavenge decomposition gases. Salt/bentonite mixtures could also be important seal components. Introduction of nonswelling, insoluble substances into the voids during consolidation is expected to have little effect upon predictions with the present constitutive model for moistened, crushed WIPP salt (Sjaardema and Krieg, 1987). However, brine sorption by bentonite causes swelling, which has the effect of increased back pressure or pore pressure within the voids, opposing consolidation.

3. Information Needs Addressed

Backfill (1.2.1.2)
Disturbed Rock Zone and Fluid-Flow Characteristics (1.2.2.1)
Backfill (1.2.3.1)
Backfill (1.2.4.1)
Disturbed Rock Zone and Fluid-Flow Characteristics (1.2.4.3)

Activity S.1.2.2
DRUM AND BOX COLLAPSE MODELS

1. Focus

An improved mathematical model of CH-TRU waste container collapse is needed to predict the final void and brine content of the disposal rooms.

Because pressures for compaction will not exceed lithostatic pressure (2,200 psi), they may not be sufficient to collapse the containers to near-theoretical solid density. The collapse model will estimate: (1) when backstress from the container collapse process will begin to retard room closure, and (2) whether significant residual void volume remains within the containers to enhance brine mobility and the spread of radionuclides.

2. Methodology

Drum and box collapse modeling will involve two tasks. First, data from laboratory tests on individual drums and boxes (Activity S.1.1.3) will be used to construct as realistic a mathematical description of their final stages of collapse as possible. The variability of the container contents and their location within the disposal room (e.g., whether adjacent to the walls, or within the uppermost layer of containers next to the air gap) will be considered. Second, the model will be generalized to estimate how the entire assemblage of drums within a room might respond collectively.

3. Information Needs Addressed

Container Response (1.2.1.3)
Systems Interactions (1.2.1.8)
Disposal Room Design (1.2.1.9)

Activity S.1.2.3
BACKFILL-MIX SELECTION ANALYSIS

1. Focus

Backfill-mix selection and configuration analysis will determine the optimum backfill for the disposal rooms. The selection of backfill will be based on comparisons of coupled analyses that consider room closure. This represents the groundwork for a room performance model (Activity S.1.2.4). It differs from room performance analysis, however, because results from highly detailed, but normally independently functioning, models will be applied to candidate backfill configurations to arrive at a best design. For room performance assessment, one model, fully coupling all important variables in detail commensurate with importance, will be needed.

2. Methodology

Candidate backfills in engineered configurations will be analyzed to determine how brine inflow, waste container collapse, and other factors control the final state of consolidation of the room contents. These best estimate states of consolidation will be examined so that an optimal configuration for waste isolation can be identified.

A series of calculations will model as closely as possible the introduction of brine or gases from one boundary into various configurations of tailored backfill to determine the uniformity of brine (wicking action) and free gases throughout the configuration.

3. Information Needs Addressed

Backfill (1.2.1.2)
Backfill (1.2.3.1)
Backfill (1.2.4.1)

Activity S.1.2.4
DISPOSAL ROOM PERFORMANCE MODEL

1. Focus

A model that fully couples all the important variables of disposal room closure, in detail commensurate with importance, is needed to define the mechanical and physical state of the disposal room at the beginning of the various scenarios for the release of transuranic waste.

Several aspects of room closure must be specified at any given time: (1) how much room closure has occurred, (2) the state of consolidation of the backfill (Activity S.1.1.1), (3) how rigid the backfill is, (4) the permeability of various portions of the room, (5) the extent of dispersal of radioactive species from their containers (Activity S.1.1.5), (6) how much water and gas are present (Activities S.3.2.4 and S.1.1.4), and (7) their distribution throughout the room.

2. Methodology

Five steps are necessary in constructing a disposal room performance model: (1) identify critical components, such as the type of waste being stored, rate of room closure, and amount of inflowing brine that will determine the state of the room at any given time, (2) develop a means of mathematically describing these features that reproduce the essential features of the room without requiring excessive computation time, (3) develop and demonstrate a method of analysis, (4) incorporate into the model those features that reflect the backfill selection, as well as the final best estimates of room closure and brine inflow, and (5) complete and document a final version of the model.

3. Information Needs Addressed

Systems Interactions (1.2.1.8)
Disposal Room Design (1.2.1.9)

Activity S.1.2.5
ENGINEERED MODIFICATIONS

1. Focus

As a contingency, engineered modifications to the proposed method of storing waste in the WIPP facility are being examined. These modifications could enhance safe containment of the waste by accelerating elimination of voids, controlling gas generation, controlling brine inflow, and restricting dispersion of radionuclides.

As an example of the type of study that this activity encompasses, CH-TRU waste containment could be accelerated by immediately eliminating most of the void volume within the disposal room. To achieve this condition, the CH-TRU waste might be precompacted to a highly dense state prior to emplacement and then encased in grout to form a dense, impenetrable mass. The remaining volume of the disposal room would be filled with backfill. (Various backfill engineering fixes are described in Activity S.1.1.2.) With compacted waste and nearly solid backfill, the disposal room would be filled with an almost incompressible material at the time of panel seal emplacement, causing rapid room closure.

The proposed emplacement mode for RH-TRU waste is to emplace a single cask in each borehole. An alternative scheme for isolation would be to place a number of RH-TRU canisters in a long horizontal borehole.

2. Methodology

Engineered modifications are under consideration. Systems analyses of the more feasible of these concepts will be implemented to establish the trade-off between the benefits to be accrued and the complexity of the system.

Certain activities are already addressing such possibilities as accelerated closure and backfill modifications for sorption and getters. CH-TRU waste studies using grout and bitumen as additives are planned. Other modifications will be pursued when the situations that require engineering modifications become better defined.

3. Information Needs Addressed

Disposal Room Design (1.2.1.9)

Activity S.1.2.6
ADDITIONAL DEVELOPMENT OF EQ3/6

1. Focus

EQ3/6 is a set of computer codes and supporting data bases that calculate the speciation of solutes and the solubilities of mineral and other solids in aqueous solutions (EQ3NR), and predict the chemical reactions between these solutions and solids, gases, or other solutions (EQ6). This software package, which has been under development for several years at Lawrence Livermore National Laboratory for use by the commercial nuclear waste repository projects, can now model the chemical behavior of several key radionuclides in solutions with ionic strengths less than or equal to 1 M. Recently, Lawrence Livermore National Laboratory added the Pitzer activity coefficient model to EQ3/6. The Pitzer model uses empirical ion interaction parameters to calculate activity coefficients for solutes. EQ3/6 then calculates solubilities and simulates chemical reactions. With the Pitzer option and currently available ion interaction parameters, EQ3/6 can now model the chemical behavior of various WIPP brines and evaporite minerals.

EQ3/6 cannot, however, model reactions between these brines and silicates (minerals or other solids that contain silicon, Si, and often aluminum, Al) because there are no ion interaction parameters yet for Al and Si. Thus EQ3/6 cannot predict reactions between WIPP brines and any bentonite in the backfill, or between brines and the cements used to grout some of the drums, and in seals. The University of California at San Diego is now developing ion interaction parameters for Al and Si.

Because ion interaction parameters are also unavailable for the important radionuclides in TRU waste, spent fuel, or high-level waste, EQ3/6 cannot model the behavior of radionuclides in brines. It would be difficult, if not impossible, to obtain ion interaction parameters for the actinide elements from previously obtained experimental data, because few of these data were obtained at ionic strengths greater than or equal to 1 M. Furthermore, the Pitzer approach might not work at all for the actinides, because this model explicitly recognizes very few complex aqueous species, and the actinide elements form complexes readily.

Without an alternative activity-coefficient model, it will be impossible to predict the behavior of radionuclides in WIPP disposal rooms under conditions different from those investigated experimentally. It would prove extremely costly and time-consuming to measure radionuclide solubilities under all of the conditions that could occur in the repository.

2. Methodology

A model capable of predicting activity coefficients of radionuclides in brines will be developed and incorporated in the EQ3/6 software package developed by Lawrence Livermore National Laboratory. This effort would comprise: (1) compilation of an internally consistent data set (ion sizes and hydration numbers) which, when used in the model, gives activity coefficients that agree with the experimental values for solution of simple composition; (2) evaluation of these equations and data in solutions of complex composition; (3) incorporation of the equations and data base into the EQ3/6 software package; (4) verification of the computational capability of the code; and (5) documentation of the code.

3. Information Needs Addressed

Source Term (1.2.1.1)
Gas (1.2.1.6)

Activity S.1.3.1
SIMULATED TRU TESTING (ROOMS T AND J)

1. Focus

In situ testing under both near reference and severe overtest conditions is in progress to examine drum deformation and backfill interactions. Other objectives are to measure backfill material behavior (emplacement, moisture, sorption, consolidation, and backfill applicability) and to provide data for the disposal room performance model (Activity S.1.2.4). These tests involve "near-reference" CH-TRU waste tests in Room T in a heated environment at 40°C (104°F) to accelerate results. Similar tests are also being conducted in Room J, in the presence of a large excess of brine, to accelerate aging and to simulate a "worst-case" repository environment.

2. Methodology

Tests in Room T involve the response of 240 CH-TRU waste drums backfilled with either crushed salt or a tailored backfill consisting of 70 weight percent crushed salt and 30 weight percent bentonite. These drums are instrumented with remotely read pressure gages to measure the effect of closure on drum deformation. The tests have been in operation since March 1987 and will continue for a total of two to three years. Tests in Room J are similar, and have been in operation since June 1986.

3. Information Needs Addressed

Backfill (1.2.1.2)
Container Response (1.2.1.3)
Systems Interaction (1.2.1.8)
Backfill (1.2.3.1)

Activity S.1.3.2
ROOM-SCALE GAS GENERATION TESTS

1. Focus

Data on the large-scale production, depletion, and composition of gases resulting from the in situ degradation of TRU wastes are needed to support performance assessment analyses and predictive modeling of long-term repository behavior (Activity S.1.2.4). Repository relevant and representative data are needed on TRU waste degradation rates, and must be representative of time periods ranging from the operational phase emplacement to the longer term, postoperational phase. Data must be obtained in a controlled research mode, not simply as a monitoring function, to allow interpretations of multiple degradation mechanisms and impacts to be assessed.

Due to potential uncertainties introduced by extrapolating laboratory, small, or even bin-scale results to the full-scale repository configuration, it becomes necessary to validate gas generation models and the predicted impacts and consequences of gas generation by conducting room-scale tests with actual CH-TRU waste in the WIPP facility. In addition to eliminating scaling factor effects, these room-scale tests are the only tests planned which can incorporate the impacts of actual repository environment on the degradation behavior of the wastes. These repository impacts include gases released from the rock (such as nitrogen and methane) intermixing with waste degradation gases, possibly influencing long-term bacterial degradation rates or modes for cellulosics or other types of wastes; brine intrusion; long-term waste compaction; and total encapsulation of waste drums by backfill and getter materials. The conduct of this room-scale test underground can help immensely to uncover any unexpected phenomena or problems (which can then be technically resolved) and to eliminate most "what if" type questions and concerns. There is no credible alternative to conducting these room-scale tests in situ at the WIPP facility, and conducting them in such a manner and time-scale as to fully support the performance assessment data needs.

The full spectrum of data needed to address performance assessment concerns can be obtained and satisfactorily resolved when data from the room-scale tests are combined with the parallel laboratory- (Activity S.1.1.5) and bin-scale tests (Activity S.1.3.3). The room-scale, in situ data will be acquired from some of the first CH-TRU waste to be emplaced in the WIPP, under actual (as-received) and modified conditions.

Other major advantages exist for these room-scale tests: besides helping to provide the necessary repository and waste gas production data in a useful time period, these in situ tests can be conducted less expensively, in a more radiologically controlled safe manner, and will be more relevant to the WIPP repository than alternative laboratory experiments or similar tests conducted in a surface facility - which must by nature introduce many test artifacts and simulations.

This room-scale test program has four objectives:

1. Determine baseline gas generation, composition, and depletion for as-received, TRU waste in a representative, operational phase repository room environment.

2. Determine gas generation, composition, and depletion for specially prepared mixtures of actual TRU waste (with and without compaction), backfill materials, gas getters, and intruding brine under representative, postoperational phase disposal room conditions.

3. Confirm on a room scale, the gas generation results and interpretations of the laboratory and bin-scale tests of TRU waste degradation and gas production.

4. Decrease the uncertainty in the performance assessment calculations for those scenarios involving gas generation and depletion with actual in situ gas measurements; help verify assumptions used in modeling.

2. Methodology

The CH-TRU waste to be tested in situ will be both as-received and specially prepared at the generator site, then shipped to the WIPP site. The waste must (room-by-room) include a representative mixture of waste types, waste loadings, and variations thereof. Waste types include high organic/newly generated (both standard and compacted from Rocky Flats Plant); low organic/newly generated (both standard and compacted from Rocky Flats Plant); processed, inorganic sludges; and high organic/old (stored) wastes.

The room-scale tests will involve six sealed, atmospheric controlled test rooms or alcoves. Five of the alcoves will contain test wastes; the sixth will remain empty to serve as a gas baseline alcove. This testing arrangement allows the emplacement of lesser quantities of waste per room, so that more types of test conditions can be accommodated. A test alcove is tentatively defined as about one-third of the length of a full-sized waste room, with about 1,100 drums of test waste per alcove. Each test alcove is planned to be 13 ft (4 m) high by 25 ft (7.6 m) wide by 100 ft (30.5 m) long, essentially standard size but shortened, with a smaller 13 ft (4 m) high by 12 ft (3.7 m) wide access entry drift, to facilitate easier sealing. The first four test alcoves will be available for waste loading and subsequent gas testing by September 1989 to adequately meet performance assessment schedular needs; the remaining two test alcoves will be available for testing at a later date.

The room-scale tests will be conducted in two phases. Phase I will include emplacing CH-TRU test waste in three alcoves and establishing a gas baseline room in a fourth alcove in Panel 1. Phase II involves emplacing test waste in two alcoves in Panel 2.

The first sealed test alcove in Panel 1, Alcove 4, is to be an empty gas reference baseline room, to provide gas composition data, (i.e., trapped atmosphere and gases released from the rock) necessary for comparison to the waste filled test rooms. Alcove 1 will contain as-received (with no special preparation) CH-TRU waste. This alcove will provide room-scale data on gas generation under actual, in situ conditions (oxic, dry, no salt or backfill materials in contact with the wastes) representative of the short-term, operational phase of the facility. Alcove 1 also provides the initial data for repository time t=0, necessary for the other tests and the performance assessment calculations. These first two test rooms are considered a "proof of concept" that such measurements can be successfully conducted in the underground facility.

Gas measurement testing in the follow-on part of the Phase I tests (Alcoves 2 and 3 in Panel 1) and from the Phase II tests (Alcoves 5 and 6 in Panel 2) will provide the major confirmation and validation data for performance assessment and predictive calculations, with comparisons to the preceding, smaller scale laboratory and bin-scale tests. These test alcoves are to be conducted under conditions representative of the longer term, postoperational phase of the repository: the waste in these drums will be specifically prepared and/or packaged; there will be layers of TRU waste, container metals, and backfill and getter materials within the drums; small amounts of brine will be injected into the drums (at the WIPP) to be representative of potential, long-term brine inflow; and the sealed, test room atmosphere will be initially purged with nitrogen, representative of the expected long-term, sealed repository.

Alcove 2 in Panel 1 will contain a representative mixture of specially prepared and packaged, noncompacted waste. Panel 1, Alcove 3, will contain similar waste that has been compacted. Most high organic ("soft") and low organic ("hard," primarily metals and glasses), newly generated waste is scheduled to be compacted at the Rocky Flats Plant starting in June 1990. This waste will constitute a major fraction of TRU wastes to be shipped to the WIPP facility in the future. The advantage of testing the in situ degradation behavior of compacted waste is that such waste is very similar to regular (noncompacted) waste that has been crushed/compacted in situ by the expected long-term closure of repository rooms; impacts on gas generation caused by compaction can thus be realistically evaluated during the course of these tests and factored into the performance assessment calculations. As a result of compaction, the compacted waste alcoves will be loaded with fewer drums, about 350 drums per alcove (1,600 drum-equivalents per alcove), beginning about June 1990. In this manner, these tests can be brought on-line and generate needed data for the performance assessment program in the appropriate time frame.

Phase II Alcoves 5 and 6 (in Panel 2) will contain prepared waste (similar to Alcove 2) and compacted waste (similar to Alcove 3) but will have backfill and gas getter material surrounding and encapsulating the drums. Backfilling of the alcoves will be performed after a successful mock waste retrieval demonstration. This will provide an in situ area for testing the effectiveness of backfill getters, as well as for providing an operational demonstration of the backfilling concept.

All waste containers used in these tests are vented (through small high efficiency particulate air filters), thereby ensuring exchange of gases between drums and the disposal room environment (gases released from the rock). In addition, the bags of wastes (within the drums) in the prepared and compacted waste alcoves will be broken to allow for the in-drum mixing of waste, backfill materials, and brine. This is to be representative of the postoperational phase of the repository.

Periodic gas samples from each of the test alcoves will be analyzed by gas chromatography-mass spectrometry. Interpretations of this data will be input in to the performance assessment modeling program as soon as available, and also used to guide and modify further testing. Details on the waste mix compositions, types and quantities of waste drums and backfills, getters, degradation product contaminants, extent of brine moistening, atmosphere control (aerobic/anaerobic, pressures), instrumentation and control hardware, and emplacement schedules are being prepared. These details will be available in a draft *Test Plan for WIPP Room-Scale CH-TRU Tests*, in mid-FY89.

3. Information Needs Addressed

   Source Term (1.2.1.1)
   Gas (1.2.1.6)
   Disposal Room Design (1.2.1.9)

Activity S.1.3.3
BIN-SCALE GAS GENERATION TESTS

1. Focus

The gases generated by disposed TRU waste and their rates of generation as a function of time may significantly affect the assessment of radioactivity releases from the repository by human intrusion. For the confident evaluation of the effect of the gases on potential release scenarios, relevant data that define the appropriate waste degradation reactions and the amount and rates of gases generated are required. Several kinds of data on the potential in situ behavior of CH-TRU waste are needed: gas speciation, generation, and depletion rates as a function of time and several other waste condition parameters; source term definition of leached or mobilized chemical and radiochemical species; systems interactions and synergisms, etc. The impacts of radiolytic, bacterial, and chemical corrosion degradation mechanisms can be adequately analyzed and evaluated in these planned bin-scale tests using actual, radioactive TRU waste. The added degree of test control and the multiple test conditions to be used in these bin-scale tests allow the interpretation of obtained data to be simpler and more straightforward. Attainment of test data must not be simply a monitoring activity, it must be necessary for both analytical and predictive performance assessment modeling calculations and for validation of smaller scale laboratory data on simulated wastes. The full spectrum of required data can be obtained when these bin-scale tests are combined with the in situ room-scale tests (Activity S.1.3.2) and supporting laboratory tests (which use simulated wastes, Activity S.1.1.4).

The technical objectives of these bin-scale tests are to:

a. Quantify gas composition, generation, and depletion rates from actual TRU waste as a function of time, waste type, and other conditions, with a high degree of control.

b. Provide a larger scale, repository relevant confirmation of the laboratory-scale test results.

c. Evaluate source term data from measured actual TRU waste brine leachate radiochemistry, as a function of several environmental variables.

d. Evaluate the synergistic impacts of bacterial action, potential saturation, waste compaction, degradation product contamination, etc., on the gas generation capacity and radiochemical environment of TRU waste.

e. Evaluate (gas and/or radionuclide) getter effectiveness in a bin-scale, controlled series of tests.

f. Provide necessary gas generation/depletion data and source term information for performance assessment analyses and predictive modeling.

2. Methodology

These bin-scale tests are being designed to provide gas production and radiochemical source term data from actual, CH-TRU waste as a function of (the degradation and interaction behavior of): several representative types or classifications of waste; aerobic and anaerobic atomosphere conditions, representative of the operational phase and longer term, postoperational phase, respectively, of the repository; impacts of several types and quantities of brine inflow; impacts of waste interactions with salt, container metals, backfill, and gas getter materials - particularly on gas production and consumption; and waste gas production results which include synergisms between the various degradation modes. The following test conditions must also be incorporated: conduct of the test must be controlled so that personnel safety is maintained; the scope and scale of the test must be adequately large to collect the quantities and types of data needed; the facility must not be contaminated during the course of the tests; facility operations and procedures must be realistically utilized.

The WIPP bin-scale tests involve testing of specially packaged and prepared TRU wastes contained in specially designed and transportable sealed bins. The test "bin" will fit within a Standard Waste Box for both transportation to the WIPP site and eventual posttest disposal. A test bin can contain about six drum volume-equivalents of CH-TRU waste. Each bin will be specially prepared and filled at the waste generator site(s) and shipped to the WIPP facility for in situ testing. Each bin will also function as a nominally independent, isolated, and controlled test system, although all the test bins will be isolated within one underground test room (Room 1, Panel 1).

All test bins will have a closely controlled and sealed environment (internal atmosphere), with gas sampling ports, pressure gage and control systems, and internal temperature monitors. Some bins will also have ports for brine injection, liquid (brine leachate) sampling, and possibly solids sampling. Waste types will consist of: high organic/newly generated waste, both standard and compacted at the Rocky Flats Plant; low organic/newly generated wastes, both standard and compacted at the Rocky Flats Plant; processed, inorganic sludges; and, high organic/old (stored) wastes. Other representative wastes types (i.e., high activity, etc.) may be defined and tested in the future. Various (in-the-bin) moisture conditions ranging from dry to moist to brine saturated will be tested. Backfill materials including none, rock salt/bentonite clay, and salt/bentonite/gas getter mixes would be interlayered with the waste in the test bins.

This bin-scale tests will take place in two phases. The first phase can be initiated at the WIPP facility in September 1989 and will incorporate the simpler system tests, mostly applicable to the operational phase time period. Approximately 32 bins of different waste compositions, including replicates, will be included in Phase I; there will also be 4 empty test bins used for gas baseline reference purposes. Phase II will use another 68 waste-filled bins with varying moisture conditions, and will include compacted high organic and low organic, newly generated wastes. Phase II will be oriented to expected postoperational phase repository conditions. In total, 100 waste-filled test bins plus a contingency of 8 waste-filled bins (included in Phase II) are planned for the entire test program.

Initiation of Phase II is dependent on supporting laboratory data (particularly as to the composition of gas getter or other backfill material components) and the availability of compacted wastes. Phase II tests would not be anticipated to start sooner than about eight months after initiation of Phase I.

All test bins will have gas sampling ports, gas flushing ports (to control the initial bin atmosphere), pressure gage and control systems, and internal temperature monitoring instrumentation. Many of these bins will also be equipped with brine injection hardware (with liquids injected at the WIPP), liquid sampling ports, and possibly materials sampling ports. Periodic gas samples from each test bin will be analyzed by gas chromatography-mass spectrometry. Periodic liquid leachate samples from multiple bins will also be radiochemically analyzed for source-term (solution chemistry) data and evaluations.

Further details on the waste-mix compositions, exact types and quantities of wastes, backfill and getter materials, degradation product contaminants, bacterial inoculants, extent of brine moistening, atomosphere control (aerobic/anaerobic, pressures), hardware, and emplacement schedules are being prepared. These details will be available in a draft *Test Plan for WIPP Bin-Scale CH-TRU Waste Tests*, in FY89.

3. Information Needs Addressed

Source Term (1.2.1.1)
Gas (1.2.1.6)

2.6.2.2 Sealing System Activities

The sealing system characterization activities contain several laboratory, analytical, and in situ studies for the development of seal designs for WIPP shafts, panel drifts, and boreholes (Stormont, 1985; Stormont, 1988a; Tyler et al., 1988). These studies also develop techniques and models for assessing sealing system behavior and evaluating seal performance and provide data and analysis techniques for performance assessment of sealing systems.

The activity matrix, Table 2-4, for the sealing system identifies the applications. Laboratory studies provide data that are used in establishing material behavior and stability for seals and in evaluating the fluid-flow characteristics of the seal components. Modeling studies develop techniques for understanding and predicting interactions of seal components and the entire system in a host rock and for evaluating fluid-flow rates and paths through or around the sealing system. In situ testing provides data to evaluate performance of materials, establish interaction effects, and provide an understanding of the behavior of intact and disturbed rock surrounding the seals. Some of the tests can be conducted at smaller scales to reduce costs and increase the number of variables tested. The data are used to validate models to the extent possible and assess design concepts and ultimately to complete the performance assessment for the WIPP facility.

The sealing activities will evaluate: (1) seal materials performance in small-scale seal tests, (2) seal systems performance in full sized seal tests, and (3) candidate seal materials and their performance in various rock environments. Figure 2-6 indicates the use of the data and information acquired from tests or theoretical studies. These data will be used in designing sealing systems and alternatives and to validate performance models of salt consolidation as a seal component. The product of this effort will be the recommended panel and shaft seal concepts and designs for the WIPP facility at decommissioning and input to the final performance assessment studies of transport through the sealing system.

The WIPP sealing system has undergone an extensive evaluation (Stormont, 1988a; Tyler, et al., 1988). Data have been collected on seal system performance, formation permeabilities, and brine inflow. Data from these studies and the additional data that are being collected will provide a basis for addressing uncertainty about the WIPP seal system. The extensive models and data will require use of expert judgment to define the models and data used in the performance assessment.

The activities to support the sealing system will continue to collect data through March 1992. In March 1991, available data and estimates where data are unavailable will be used by Activity PA.8 to perform the preliminary consequence analysis. Data collected between March 1991 and March 1992 will be used to confirm the data and assumptions used in 1991 and will be incorporated into the final consequence analysis (PA.10).

TABLE 2-4. APPLICATIONS OF THE SEALING SYSTEM INVESTIGATIONS

Program-Area Activity	Phenomena/Parameters Being Addressed: Disposal Room and Drift System	Sealing System	Structural and Fluid Flow Behavior, Salado	Hydrology and Nuclide Migration, Non-Salado
S.2.1 Laboratory Studies:				
S.2.1.1 Geochemical Stability		Seal Material Properties		
S.2.1.2 Crushed Salt Consolidation	Waste/Backfill/Brine/ Room Interactions*	Seal Permeability		
S.2.1.3 Cementitious Materials Development	Seal Material Properties*	Seal Material Properties*		
S.2.2 Modeling Studies:				
S.2.2.1 Crushed Salt Consolidation Modeling	Waste/Backfill/Brine/ Room Interactions*	Seal Permeability		
S.2.2.2 Seal System Design Integration		Seal Performance		
S.2.3 In Situ Tests:				
S.2.3.1 Small-Scale Seal Performance Tests				
Vertical Concrete Seal		Concrete Seal Performance		
Horizontal Concrete Seal		Concrete Seal Performance		

*Denotes a secondary application

TABLE 2-4. APPLICATIONS OF THE SEALING SYSTEM INVESTIGATIONS (Concluded)

Program-Area Activity	Phenomena/Parameters Being Addressed: Disposal Room and Drift System	Sealing System	Structural and Fluid Flow Behavior, Salado	Hydrology and Nuclide Migration, Non-Salado
Horizontally Emplaced Block-Type Seal		Salt and Salt/Bentonite Seal Performance		
Vertically Emplaced Block-Type Seal		Salt and Salt/Bentonite Seal Performance		
Composite Shaft Seal Simulation		Composite Seal Performance		
Anhydrite Seal Test		Anhydrite Seal Performance		
S.2.3.2 Large-Scale Seal Test		Seal Performance		
S.2.3.3 Borehole Plugging		Seal Material Properties		Borehole Plug Performance*

*Denotes a secondary application

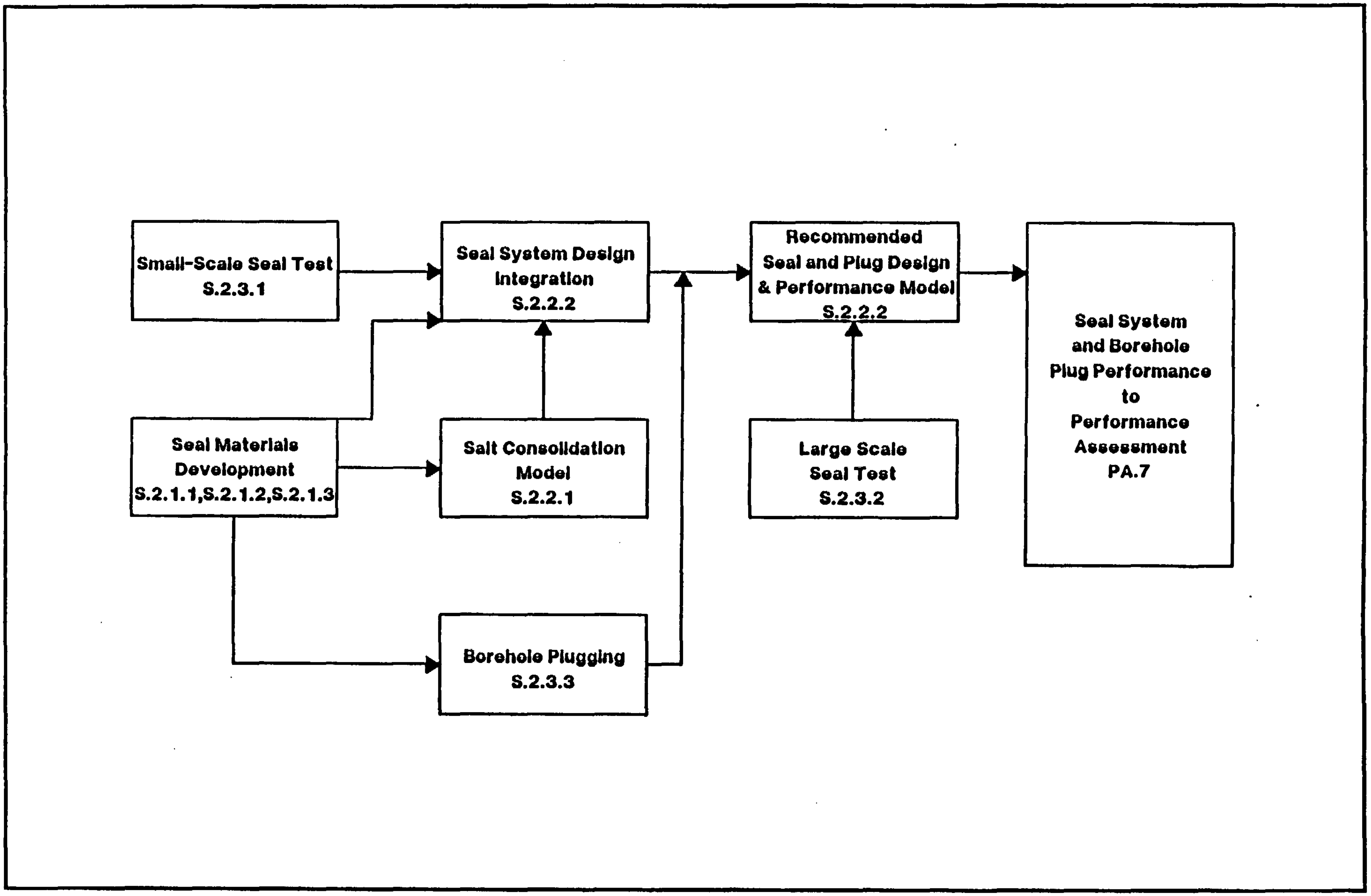


Figure 2-6. Relationship of Sealing System Activities

Activity S.2.1.1
GEOCHEMICAL STABILITY

1. Focus

Laboratory studies of chemical reactions that could degrade seal material performance and the development of chemical models (Tyler et al., 1988) are necessary to provide reasonable assurance of adequate useful life for cementitious materials such as concrete and other component materials. Although reconsolidated salt has been chosen as the primary seal material, other proposed seal materials must function long enough to prevent brine and water inflow from inhibiting reconsolidation of the salt. Reactions of bentonite with WIPP brines and ground waters and chemical interactions that might occur between bentonite and cementitious materials must be identified to prevent seal degradation.

2. Methodology

Laboratory work will include studies of chemical reactions and dissolution of cementitious materials in brines and ground waters. The aqueous phases are to have the compositions expected in the Salado Formation and overlying formations. Chemical reactions at the interface between concrete and anhydrite will also be studied. Emphasis will be on reactants other than dissolved halite; previous work indicates that halite does not significantly degrade cementitious materials. Chemical models will then be developed to describe dissolution and rates of chemical reactions that may degrade seals. Seal materials will be chosen to maximize stability and meet required performance criteria.

3. Information Needs Addressed

Sealing System (1.2.2.2)
Sealing Criteria, Concepts, and Designs (1.2.2.4)
Sealing System (1.2.4.2)
Borehole Plugging-Material Behavior (1.3.4.1)

Activity S.2.1.2
CRUSHED SALT CONSOLIDATION

1. Focus

Because reconsolidated crushed salt is a key material in current seal designs (Activity S.2.2.2), accurate constitutive models, permeability relationships, and mechanistic understanding of crushed salt consolidation are essential. Consolidation is due to host rock creep. Shaft seal analyses have shown that crushed salt emplaced as a seal material will reconsolidate sufficiently to seal the shaft within 100 years (Nowak and Stormont, 1987). The constitutive relationships and permeabilities (10 nanodarcies at 95 percent consolidation) should be verified with further tests and expanded to include brine-saturated crushed salt.

2. Methodology

Laboratory studies have confirmed the rapid reconsolidation of moistened crushed WIPP salt under hydrostatic pressure. Consolidation rates of crushed salt under deviatoric (shear) loading will be determined next. Measurements will then be made on samples completely saturated with brine, to determine how fluid filled pores inhibit compaction. Finally, the extent that reconsolidation is accelerated by moisture will be measured in tests on samples which contain controlled quantities of added brine. The relationship between reconsolidation density and permeability will be determined in all test series. The results from this testing program will provide the information needed to couple consolidation modeling with brine inflow. Micromechanical models for consolidation of crushed salt (effect of particle size, etc.) will also be developed to support the constitutive models.

3. Information Needs Addressed

Disturbed Rock Zone and Fluid-Flow Characteristics (1.2.2.1)
Sealing System (1.2.2.2)
Sealing Criteria, Concepts, and Designs (1.2.2.4)
Backfill (1.2.3.1)
Sealing System (1.2.4.2)
Disturbed Rock Zone and Fluid-Flow Characteristics (1.2.4.3)

Activity S.2.1.3
CEMENTITIOUS MATERIALS DEVELOPMENT

1. Focus

The properties and performance of cementitious materials are extremely variable depending on their mixture, the application method, and the intended use. Previous development has identified candidate saltwater concrete, saltwater grout, and freshwater grout (Gulich and Wakeley, 1988) for uses in shafts, drifts, and boreholes. Because of peripheral gypsum formation, typical concretes may not be stable in anhydrite, which is found in key shaft seal locations. Development must now focus on anhydrite bonding concretes, pressure grouts, and grouting techniques. Continued testing and characterization of previously developed WIPP specific cementitious materials should continue.

2. Methodology

A series of tests will be developed to investigate workability, heat evolution, strength, stiffness, and permeability of possible anhydrite-bonding concrete mixtures. Once a mixture is identified as a candidate, field tests will be conducted (Activity S.2.3.1). Existing pressure grout formulations will be similarly screened, laboratory tested, and field tested. Standard laboratory tests will supplement these field tests as well as field tests supporting previously identified candidate mixtures.

3. Information Needs Addressed

Sealing System (1.2.2.2)
Closure (1.2.2.3)
Sealing Criteria, Concepts, and Designs (1.2.2.4)
Sealing System (1.2.4.2)
Borehole Plugging Material Behavior (1.3.4.1)

Activity S.2.2.1
CRUSHED SALT CONSOLIDATION MODELING

1. Focus

Reconsolidated, crushed WIPP salt is the key seal material in current seal-system concepts (Activity S.2.2.2). Numerical model calculations will be used to predict the density and permeability of emplaced crushed salt as a function of time after emplacement.

In response to reconsolidation by creep closure, crushed salt can reach permeabilities comparable to that of intact host rock salt within 100 years (Nowak and Stormont, 1987). Tailored seal shapes may be needed to facilitate rapid and uniform reconsolidation of emplaced, crushed salt seal material. Numerical calculations of consolidation are needed to guide the design of seal shapes. New information on the deviatoric behavior of WIPP crushed salt is a key input to this effort. Therefore, updated calculations are needed as deviatoric behavior is quantified by laboratory tests.

Numerical calculations should be repeated as constitutive relationships for crushed salt are updated from the laboratory test results and the development of a mechanistic model. These calculations will provide the most accurate estimates of seal system permeability and offer the best guidance for seal system design and seal excavation shapes.

2. Methodology

The numerical, crushed salt consolidation model will be updated to include the latest data from laboratory tests. New information on deviatoric behavior will be incorporated. The consolidation behavior of brine-saturated crushed salt may also be included. Consolidation calculations will be repeated for cases that are likely to be changed significantly by an updated model. The time required to reach a low permeability is important for evaluating seal performance.

Calculations will be made of crushed salt consolidation in proposed seal excavation shapes to guide the choice of seal shapes for rapid consolidation to high density and low effective permeability.

3. Information Needs Addressed

Disturbed Rock Zone and Fluid-Flow Characteristics (1.2.2.1)
Sealing System (1.2.2.2)
Backfill (1.2.3.1)
Backfill (1.2.4.1)
Sealing System (1.2.4.2)
Disturbed Rock Zone and Fluid-Flow Characteristics (1.2.4.3)

Activity S.2.2.2
SEAL SYSTEM DESIGN INTEGRATION

1. Focus

A large number of diverse activities, including modeling and numerical analyses of complex seal systems, must be integrated to complete conceptual seal designs for the WIPP facility.

The structural and flow responses of the seals and the surrounding host rock must be modeled and analyzed to evaluate seal system performance. Coupled processes of brine inflow, consolidation, creep closure, disturbed zone formation, and stress concentration will be included. These analyses will require that outputs from many testing and model development activities (Activities S.2.1.2, S.2.1.3, S.2.2.1, S.2.3.1, S.2.3.2, S.2.3.3) be available for the numerical analyses.

2. Methodology

Models and codes to calculate and analyze the structural and flow performance of seal components will be developed and will include the response of the surrounding host rock, including disturbed zone formation. Numerical analyses of structural and flow processes to evaluate seals and to guide the design of tests or experiments will include coupled processes, such as brine inflow during crushed salt consolidation.

A conceptual design for WIPP plugging and sealing systems will be prepared by an architect/engineering contractor after evaluating seal designs by analyzing the structural- and fluid-flow processes that occur. The design will be sufficiently detailed to provide a basis for preparing a WIPP construction design.

3. Information Needs Addressed

Sealing System (1.2.2.2)
Sealing Criteria, Concepts, and Designs (1.2.2.4)
Sealing System (1.2.4.2)
Closure (1.2.4.4)
Sealing Criteria, Concepts, and Designs (1.2.4.5)
Borehole Plugging Material Behavior (1.3.4.1)
Borehole Plug Interaction (1.3.4.2)
Borehole Plugging Criteria, Concepts, and Designs (1.3.4.3)

Activity S.2.3.1
SMALL-SCALE SEAL PERFORMANCE TESTS

1. Focus

Measurement of thermal/structural/fluid flow performance of the shafts, drifts, and panels sealing system will provide data for seal design (Activity S.2.2.2) and long-term performance. Stresses and strains induced in the seal and rock will result from hydration of concrete, if used, and from the interactions of salt creep and the seal material. The stresses and strains are important in assessing the stability of the sealing system and in evaluating the structural/fluid-flow relationships. Sealing system permeability measurements are needed to provide data on flow rates through the system, identify dominant flow paths, and determine the difference between gas and brine seal system permeability.

To provide the data, tests are required on: (a) vertical concrete seals, (b) vertically emplaced salt and bentonite block seals (Stormont, 1988b), (c) a composite shaft seal (Stormont, 1988b), (d) a horizontal concrete seal (Stormont and Howard, 1986), (e) a horizontal seal of salt blocks (Stormont, 1988b), and (f) a seal compatible with anhydrite layers (Stormont, 1984).

2. Methodology

Testing has been initiated to support many of the data needs. Boreholes ranging in size up to 38 in. (96 cm) in diameter, both horizontally and vertically, have been instrumented and are collecting data with simulated plugs installed. Gas and brine fluid-flow measurements will determine in situ fluid flow performance of a simulated seal. Rooms will need to be excavated to initiate composite shaft seal tests and to support anhydrite seal tests.

Horizontal concrete seals tests were initiated in 1986. Structural data will continue to be collected and compared to the predicted model response. The concrete/salt rock model, which incorporates elastic as well as inelastic behavior of both concrete and salt, will be used to develop the design and stability of facility level panel and drift seals (Labreche and Van Sambeek, 1988). Fluid-flow/permeability measurements for gas and brine will be continued and will include gas with tracers and brine as the working fluids.

Horizontally-emplaced block seal tests were initiated in the spring of 1986. Structural data will continue to be collected and will be compared with the response predicted using the laboratory-developed, salt consolidation constitutive model. This model will be used for the design of panel and drift seals.

There are four instrumented seals: two salt-block seals and two salt/bentonite block seals. The remaining four uninstrumented seals (two salt and two salt/bentonite) are for permeability or fluid-flow testing. Instrumentation in the four seals will measure deformations and pressures. The present understanding of the consolidation process implies that crushed salt provides little resistance to closure until it is very dense; measurements of deformation of the seal and the pressure buildup at the seal/rock interface should verify or refute this laboratory determination. The magnitudes of the pressures and deformations will aid in assessing the stability of the block-type seals and, when coupled with the fluid-flow measurements, in evaluating the structural/fluid flow interaction. For example, laboratory measurements suggest that the potential for flow should dramatically decrease when the porosity of crushed salt decreases to a range of 5 to 10 percent.

Fluid-flow testing is ongoing. Nitrogen gas is being used as the working fluid for some of the fluid-flow or permeability tests, because gas measurements are faster, easier, and less costly. Gas tests will be less destructive to the sealing systems than brine, particularly to salt-block seals before they have consolidated to relatively low porosities. Brine is being used to test salt/bentonite seals soon after emplacement to assess brine uptake, the physical stability of the salt/bentonite system, swelling pressures, "steady-state" permeability, and erodibility.

Vertical concrete seals testing was initiated in 1985. Structural/thermal data will continue to be collected and compared to the predicted model response (Stormont, 1987). The concrete/salt rock model, which incorporates elastic and inelastic behavior of concrete and salt, will be used to develop the design and stability of concrete shaft seals, which is a key component in the present seal design concept for the Salado Formation (Stormont, 1988a; Van Sambeek and Stormont, 1987).

Emplacement of vertically emplaced salt-block seal tests was initiated in November 1987. One uninstrumented seal has been emplaced, one empty borehole has been instrumented with closure gages, and two instrumented seals have been installed. Four more seals will be installed and structural data will continue to be collected and compared with the response predicted using the laboratory developed, salt-consolidation constitutive model. This model is for the design of shaft seals. There will eventually be eight boreholes, of which seven will contain seals. Currently, one borehole contains closure instrumentation only, one emplaced seal is uninstrumented, and the other six emplacements will be instrumented. Three seals are 100 percent salt blocks, four seals are all bentonite. Half of the seals are instrumented to measure deformations and pressures. The remaining half are intended for permeability or fluid-flow testing. The current salt consolidation model implies that crushed salt provides little resistance to closure until it becomes very dense (i.e., seal material properties approach that of the surrounding rock mass). The measurements of seal deformation and pressure buildup at the seal/rock interface and within the seal itself should assess and improve the current salt consolidation modeling. Quantitative measurements of pressure and deformation will aid: (1) in assessing the stability of the salt block and bentonite/salt block seals and (2) in evaluating the structural/reconsolidation/fluid flow interaction when coupled with the fluid-flow measurements. For example, laboratory measurements suggest that the potential for flow should dramatically decrease when the porosity of crushed salt decreases to a range of 5 to 10 percent.

Fluid-flow testing will be conducted similarly to the horizontally emplaced block-type seal. Brine will be used to test the seals one to two years after seal emplacement to assess reconsolidation, stability of the sealing system, brine uptake, swelling pressures, erodibility, and the like.

Six composite seals will be emplaced in six 48-ft (15-m) deep, 3.3-ft (1-m) diameter boreholes at the WIPP facility. The seals will consist of approximately 3.3-ft (1-m) thick layers of expansive salt saturated concrete and salt or sand mixed with bentonite clay on either side of a central core of quarried salt blocks. Three of the sealing systems will be instrumented with thermocouples, pressure cells, and displacement gages. The other three seals will be used solely for fluid-flow testing. Short duration tracer gas testing and long duration brine testing is planned. The emplacements may include shapes other than simple cylindrical shapes for the individual seal components.

Six seals will be emplaced in six 3.3-ft (1-m) diameter boreholes that pass through the 3.3-ft (1-m) thick Marker Bed 139 anhydrite layer. One test will monitor the mechanical performance of an anhydrite-bonding concrete (ABC) by means of thermocouples, pressure cells, and strain and displacement gages. The remaining five seals are for fluid-flow testing: (1) ABC plug, (2) ABC plug with adjacent rock grouting, (3) bentonite-based seal confined by ABC, (4) bentonite-based seal confined by crushed salt blocks, and (5) bentonite-based seal confined by ABC with adjacent rock grouting. Short duration, tracer gas testing will be followed by long-term, brine flow testing.

3. Information Needs Addressed

Sealing System (1.2.2.2)
Closure (1.2.2.3)
Sealing Criteria, Concepts, and Designs (1.2.2.4)
Sealing System (1.2.4.2)
Closure (1.2.4.4)
Borehole Plugging Material Behavior (1.3.4.1)
Borehole Plug Interaction (1.3.4.2)
Borehole Plugging Criteria, Concepts, and Designs (1.3.4.3)

Activity S.2.3.2
LARGE-SCALE SEAL TEST

1. Focus

The expected performance of shaft and waste panel seals will be based primarily upon laboratory and field data, small-scale in situ tests, and modeling. Small-scale tests do not fully simulate the development of the disturbed zone around an excavation. Therefore, a large-scale test is needed to evaluate sealing concepts for the shaft and panel seals (Activity S.2.2.2). Previous seal evaluations indicate that the seal/rock interface and rock adjacent to the seals are the most likely hydrologic flow paths. Additionally, the excavation, seal emplacement, and rock creep may result in stresses or deformations that will affect both seal and rock performance. Mechanical and fluid-flow performance data on both the reference (salt) seals and the alternative (concrete) seals are required.

Current conceptual designs call for seals to be composed of quarried salt, salt/bentonite mixtures, and pressed salt blocks (Stormont, 1988a). This design should provide a seal comparable to the intact formation in less than 100 years. This design provides for removal of heavily fractured rock at strategic locations to minimize the potential for seal bypass. The multiple component design also provides some redundancy. An alternative design includes concrete, which could be used in the panel seal design for several reasons: (1) for confinement of salt- or bentonite-based seal components, (2) to reverse formation disturbance by causing stress build-up, (3) as a short-term flow barrier, or (4) as an additional redundant component.

2. Methodology

Tests will be designed to examine both salt and concrete seals for both shafts and panels. The test will be designed in a drift mined to approximately 10 by 10 by 50 ft (3 by 3 by 15 m). Both salt-block and concrete plugs will be installed and open intervals pressurized to determine the effective seal permeabilities as a function of time as salt creep acts upon the system. Therefore, with both tests, a proven optional design can be used if the primary design does not perform as expected.

3. Information Needs Addressed

Sealing System (1.2.2.2)
Closure (1.2.2.3)
Sealing Criteria, Concepts, and Designs (1.2.2.4)
Sealing System (1.2.4.2)
Sealing Criteria, Concepts, and Designs (1.2.4.5)

Activity S.2.3.3
BOREHOLE PLUGGING

1. Focus

The principle fluid-bearing zones above the repository are the Culebra and Magenta Members of the Rustler Formation. To prevent dissolution, these fluid-bearing zones must be sealed off from the disposal horizon and from the halides of the Salado and Castile Formations. Plugging boreholes will also enhance confidence that the radiologic consequences have been bounded by further slowing or preventing flow into the boreholes. Sealing concepts should address both the Salado and Castile Formations and the formations above and below them. Grouts and cementitious materials, appropriate to the geology and geochemistry of each formation, should be evaluated to their ability to restrict fluid flow and maintain structural stability. Borehole plugging supports Activity S.2.2.2.

2. Methodology

An evaluation of the borehole-plug-material interaction and the interactions of different plug compositions with each other will be conducted. The borehole plug criteria, concepts, and designs will be performed in parallel to the extent possible. Finally, an evaluation report on borehole plugging performance will be prepared.

3. Information Needs Addressed

Borehole Plugging Material Behavior (1.3.4.1)
Borehole Plug Interaction (1.3.4.2)
Borehole Plugging Criteria, Concepts, and Designs (1.3.4.3)

2.6.2.3 Salado Formation Structural and Fluid-Flow Activities

This section describes activities related to the structural- and fluid-flow behavior of the Salado Formation (Table 2-5). The activities support, first, the development of the general structural-response predictive technology, including validation of models against in situ data, and second, the evaluation of fluid-flow characteristics (Figures 2-7 and 2-8) of the Salado Formation in the shaft and in the salt surrounding the disposal room.

The predictive technology for understanding the structural behavior consists of three important elements: (1) constitutive model development (Activity S.3.2.1), (2) the numerical or code framework (Activity S.3.2.2), and (3) material properties (Activity S.3.1.1-S.3.1.5). Laboratory material property studies reduce the uncertainty in the properties data base, and hence in performance assessment calculations, for investigating the effect of moisture on the creep rate as it applies to closure. This also relates to an understanding of the role of healing under pressure of salt around seal systems. In addition, a possible source of the discrepancy noted earlier (Morgan et al., 1985; Munson et al., 1986) between measured and predicted in situ response may be the stress generalization (Munson and Fossum, 1986). As a result, an intensive laboratory effort to define the proper stress generalization is being undertaken. Analysis will guide the successful development of the prediction technology by determining the underlying physics and material response of salt as observed in laboratory and in situ. The predictive technology will ultimately be validated to the extent possible by comparing numerical predictions with the results of extensive, large-scale, in situ tests. Gathering suitable, in situ data for validation is a major task (Activity S.3.3.1). Proper Quality Assurance-certified, authenticated data are the result of strictly controlled data reduction to produce an archived data base, which is made available to the scientific and engineering community through data reports (e.g., the Room H report, Munson et al., 1987).

The ability to predict the closure of and brine inflow to rooms and shafts is a fundamental requirement of the WIPP Project and forms the basis for several other programs. The closure and fluid inflow rates and conditions are the principal input to specifying the physical and mechanical condition of the room contents, as required by the system studies of drum condition and backfill recompaction. The closure rates, and hence the rate of stress buildup of on the seals, determines how the seal retains its integrity with time and how salt surrounding the seal returns to the impermeable condition required. As a result, nearly all design and performance calculations specifying the state of the seal systems and the formation or specifying the damage and rehealing of salt around the seal systems are based on the structural-response predictive technology. Ultimately, structural and fluid inflow calculations for the disposal rooms will be called upon to predict long-term closure and reconsolidation times.

Some activities will evaluate the fluid-flow characteristics and behavior of: (1) brine and gas inflow and permeability in the far-field domain, (2) brine and gas flow within the near-field or disturbed rock zone, and (3) geophysical properties of the rock formations in the shaft and underground, with emphasis on the disturbed rock zone. The flow diagram (Figure 2-9) indicates the manner in

TABLE 2-5. APPLICATIONS OF THE STRUCTURAL AND FLUID-FLOW BEHAVIOR OF THE SALADO INVESTIGATIONS

Program-Area Activity	Phenomena/Parameters Being Addressed: Disposal Room and Drift System	Sealing System	Structural and Fluid Flow Behavior, Salado	Hydrology and Nuclide Migration, Non-Salado
S.3.1 Laboratory Studies:				
S.3.1.1 Stress Generalization; Verification of the Creep Flow Surface	Waste/Backfill/Brine Room Interactions*	Seal/Rock Interaction	Room Closure	
S.3.1.2 Transient Strain Limit Determination	Waste/Backfill/Brine/ Room Interactions*	Seal/Rock Interaction	Room Closure	
S.3.1.3 Pressure Effect on Fracture Rehealing	Waste/Backfill/Brine/ Room Interactions*	Seal/Rock Interaction	Room Closure, Fracture Healing	
S.3.1.4 Moisture Effect on Creep Rate	Waste/Backfill/Brine/ Room Interactions*	Seal/Rock Interaction	Room Closure	
S.3.1.5 Stress, Strain/ Brine Transport	Salt Permeability*		Salt Permeability	
S.3.2 Modeling Studies:				
S.3.2.1 Constitutive Model Development	Waste/Backfill/Brine/ Room Interactions*	Seal/Rock Interaction	Room Closure	
S.3.2.2 Numerical Code Development	Waste/Backfill/Brine/ Room Interactions*	Seal/Rock Interaction	Room Closure	

*Denotes a secondary application

TABLE 2-5. APPLICATIONS OF THE STRUCTURAL AND FLUID-FLOW BEHAVIOR OF THE SALADO INVESTIGATIONS (Continued)

Program-Area Activity	Phenomena/Parameters Being Addressed			
	Disposal Room and Drift System	Sealing System	Structural and Fluid Flow Behavior, Salado	Hydrology and Nuclide Migration, Non-Salado
S.3.2.3 Code Verification Procedures	Waste/Backfill/Brine/ Room Interactions*	Seal/Rock Interaction*	Room Closure	
S.3.2.4 Brine Inflow To Excavations	Brine Inflow*		Brine Inflow	
S.3.2.5 3-D Mechanistic Hydrological Transport Model of Facility	Brine Inflow*		Brine Inflow	Ground-Water Flow, Radionuclide Transport*
S.3.2.6 Integrated Mechanical Model, Disturbed Rock Zone (DRZ) and Excavation Effects	Brine Inflow*	Seal Permeability, Seal Performance*	DRZ Properties, DRZ Behavior	
S.3.3 In Situ Tests:				
S.3.3.1 Air Intake Shaft Performance		Shaft Closure, Seal/Rock Interaction*	Shaft Closure	
S.3.3.2 Intermediate-Scale Borehole Test (Room C1)	Room Closure*	Seal/Rock Interaction*	Room Closure	
S.3.3.3 Panel Structural Response Test	Panel Response*		Panel Response	
S.3.3.4 Gas Flow/Permeability	Salt Permeability	Seal Performance, DRZ Properties*	Salt Permeability, DRZ Properties*	
S.3.3.5 Near-Field Flow Characterization	Salt Permeability*	Seal Performance, DRZ Properties*	Salt Permeability, DRZ Properties	

*Denotes a secondary application

TABLE 2-5. APPLICATIONS OF THE STRUCTURAL AND FLUID-FLOW BEHAVIOR OF THE SALADO INVESTIGATIONS (Concluded)

Program-Area Activity		Phenomena/Parameters Being Addressed: Disposal Room and Drift System	Sealing System	Structural and Fluid Flow Behavior, Salado	Hydrology and Nuclide Migration, Non-Salado
S.3.3.6	Brine Inflow Scale and Stratum Effects	Brine Inflow	Brine Inflow*	Brine Inflow	
S.3.3.7	Pore Pressure for Brine Inflow			Brine Inflow	
S.3.3.8	Brine Inflow to Excavated Rooms	Brine Inflow	Brine Inflow*	Brine Inflow	
S.3.3.9	Brine Permeability Testing at the Disposal Horizon	Brine Inflow, Salt Permeability	DRZ Properties, Salt Permeability*	Salt Permeability, Brine Inflow	
S.3.3.10	Air Intake Shaft Brine Permeability Testing		DRZ Properties, Salt Permeability, Seal Performance, Fracture Healing*	DRZ Properties, Salt Permeability	DRZ Properties, Lower Rustler Hydrologic Properties, Ground-Water Flow, Radionuclide Transport*
S.3.3.11	Shaft Geophysics		Seal Permeability, Salt Permeability, DRZ Properties, Seal Performance*	DRZ Properties, Fracture Healing	
S.3.3.12	Underground Geophysics	DRZ Properties, Salt Permeability*	Seal Permeability, Salt Permeability, DRZ Properties, Seal Performance*	DRZ Properties, Fracture Healing	
S.3.3.13	Brine Sampling and Evaluation Program	Brine Inflow, Brine Distribution*		Brine Inflow, Brine Distribution	

*Denotes a secondary application

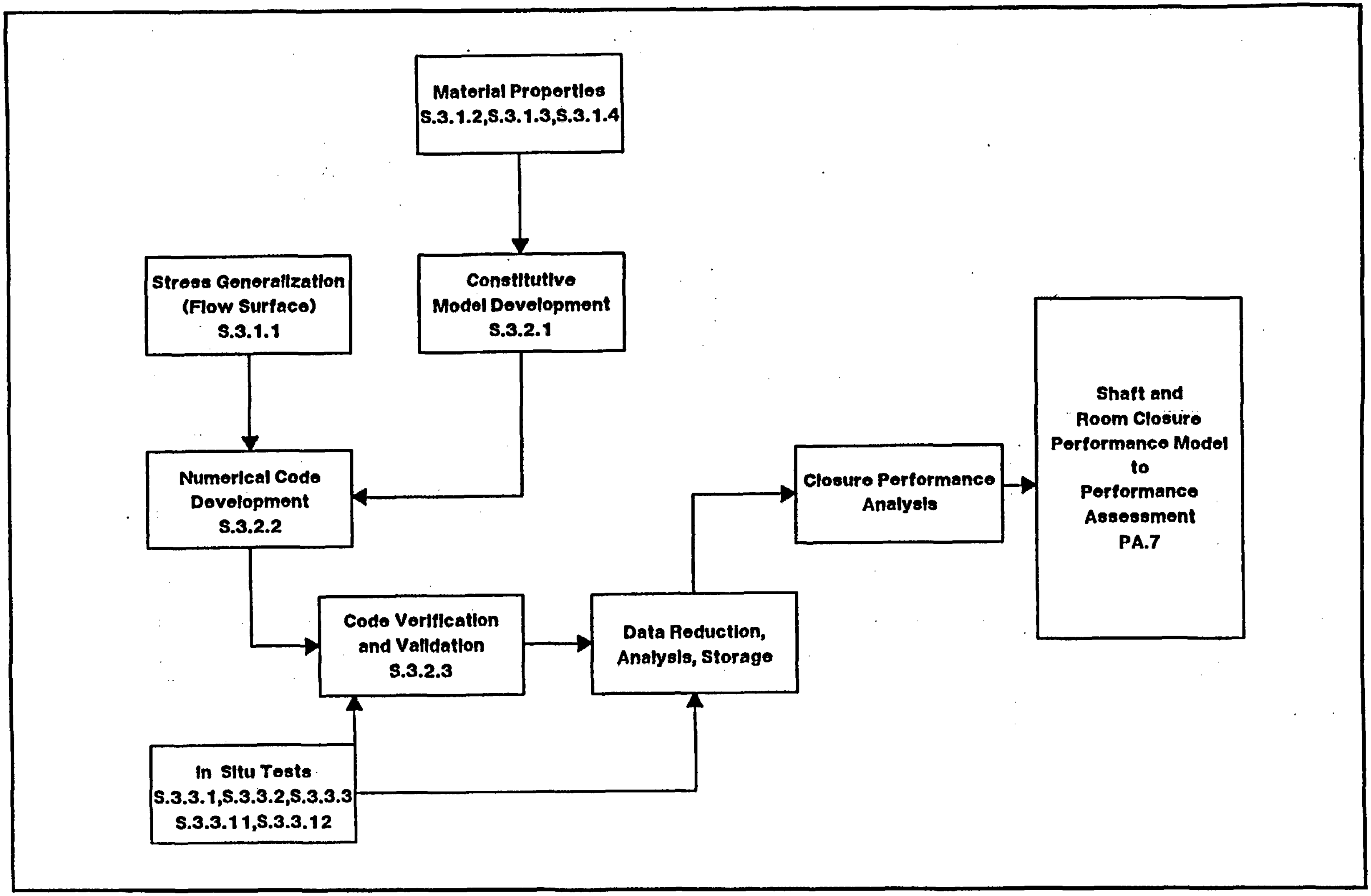


Figure 2-7. Relationship of Salado Formation Structural Behavior Activities

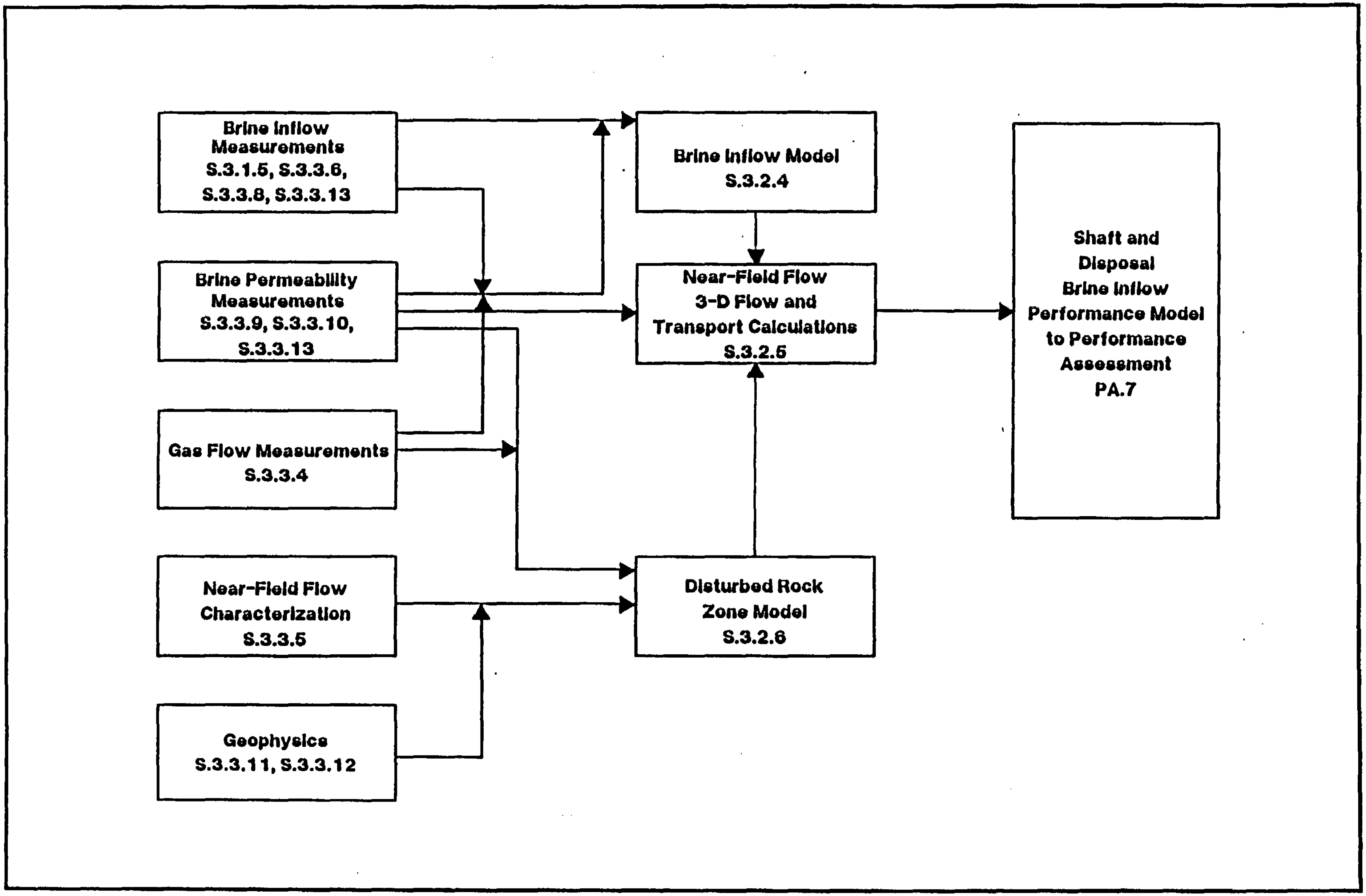


Figure 2-8. Relationship of Salado Formation Fluid-Flow Behavior Activities

which the fluid-flow activities support the developments of models that will be used in the WIPP performance assessment.

The activities investigating the structural- and fluid-flow behavior of the Salado Formation will collect data through March 1992. In March 1991, available data and estimates where data are unavailable will be used by Activity PA.8 to perform a preliminary consequence analysis. Data collected between March 1991 and March 1992 will be used to confirm the data and assumptions used in 1991 and to perform a final consequence analysis (PA.10).

Activity S.3.1.1
STRESS GENERALIZATION, VERIFICATION OF THE CREEP FLOW SURFACE

1. Focus

Most compliance arguments strongly depend upon the time at which the waste is encapsulated. As a result, uncertainties in the numerical calculations of the time for room or shaft closure must be reduced. These tests focus on identifying which of two probable stress generalizations (von Mises or Tresca) should be used in calculating creep rate and, therefore, room closure. Significant differences in creep rate exist depending on which stress generalization more accurately reflects the conditions at WIPP.

2. Methodology

The three-dimensional creep flow surface for pure salt will be determined by: (1) testing large thin-walled cylinders of salt under pure shear, and (2) testing of thick-walled cylinders under controlled, known stress gradients. The proper form of the stress generalization can then be developed and incorporated into numerical solution techniques. Finally, verification of the form of the stress generalization for the range of WIPP salt and evaluation of the influence of the intermediate principal stress on salt creep will be completed.

3. Information Needs Addressed

Container Response (1.2.1.3)	Closure (1.2.2.3)
Closure (1.2.1.4)	Closure (1.2.3.3)
Disposal Room Design (1.2.1.9)	Closure (1.2.4.4)

Activity S.3.1.2
TRANSIENT STRAIN LIMIT DETERMINATION

1. Focus

Transient-strain parameters of the constitutive models (Activity S.3.2.1) are important in resolving the discrepancy between calculated and measured room closure (Munson and Dawson, 1982).

This parameter appears to control the magnitude of the calculated strain, somewhat independently of the strain rate. While, theoretically, the evaluation of the transient strain limit (a measure of the total transient strain) should be apparent from the conventional creep data, it has actually proven difficult to quantify. The difficulty arises from the nature of the conventional creep test and from the prestrain condition of the salt being tested. Standard creep tests measure the strain at constant stress as a function of time; as a result, strain that occurs within the sample during loading before the value of constant stress has been reached is "zeroed out." Therefore, this loading strain never appears in the material parameters or calculations within the constitutive model that is determined from the laboratory creep data, and thus, any calculation of actual room deformation excludes an important component of transient strain (Munson and Fossum, 1986). Loading strain will be included in the material parameter data base and incorporated into the constitutive models. Additional testing will be performed on the ERDA-9 deep borehole salt, which forms the principal data base for the constitutive modeling, to evaluate the loading strains and transient creep behavior of this material.

Laboratory measurements of creep strains also exclude strains accumulated in the specimen before it reaches the laboratory for testing. Although testing of natural salt is similar to metals testing, it differs in that the initial condition of the salt is not well controlled and rarely defined. This problem becomes significant for salt, because natural salt specimens may have a strain history that differs according to how and when they were cored from the parent salt body. This history may change the appearance and magnitude of the transient strain measured in laboratory creep tests. These small prestrains are especially important in predicting underground room closure, because the strains are comparable to those experienced in the salt surrounding the rooms. This prestrain influences the transient strains observed in the two major WIPP creep data bases, the ERDA-9 deep borehole data base, and the WIPP-D facility horizon data base. As a result, observed transient creep strains in these two data bases differ because the histories differ. Specifically, the WIPP-D facility specimens are thought to contain more prestrain than the ERDA-9 borehole specimens. It is essential to quantify the effects of these prestrain histories on transient creep and then to correct the data bases back to the undisturbed state of the in situ salt.

2. Methodology

This activity consists of three major tasks:

a. Creep testing of core from the ERDA-9 deep borehole to establish loading strains and any other testing strains not in the current data base.

This testing program contains only three ERDA-9 borehole specimens from the same material layer as the WIPP-D specimens. Thus, the transient strain data can be compared directly (with the exception of differences in prestrain history) between identical material. The specimens used for the previous or existing ERDA-9 creep tests all came from a horizon well above the facility horizon.

b. Continued determination of the free dislocation density for ERDA-9 and WIPP-D salt to establish quantitative comparisons. A more detailed study will be made of WIPP-D salt to obtain the dislocation density as a function of distance from the room opening for comparison with the known displacement values measured in salt surrounding the room. This study will quantify the dislocation density with the measured displacements.

c. An annealing study of WIPP-D specimens to intentionally reduce the free-dislocation density will be continued, first to determine the annealing conditions needed to achieve the desired densities, and second to generate the WIPP-D data base by creep-testing annealed specimens at conditions comparable to those used in previous tests of unannealed specimens.

Minor routine testing will be used to decrease uncertainty in the creep parameters, as necessary.

3. Information Needs Addressed

Container Response (1.2.1.3)	Closure (1.2.2.3)
Closure (1.2.1.4)	Closure (1.2.3.3)
Disposal Room Design (2.1.1.9)	Closure (1.2.4.4)

Activity S.3.1.3
PRESSURE EFFECT ON FRACTURE REHEALING

1. Focus

The integrity of seals emplaced in the repository includes the salt around the seal, because of increased permeability of the host rock caused by the excavation. Laboratory study of the amount of fracturing developed by strain under confining conditions and the fracture behavior dependence on time and pressure will quantify fracture rehealing. This activity also supports constitutive model development (Activity S.3.2.1). Laboratory evidence from nonspecific tests suggests that existing fractures will heal under the pressure state as it developed in the salt around the seal (Sutherland and Cave, 1978; Costin and Wawersik, 1980). However, confirming this will require experiments specifically designed to quantify the healing process.

2. Methodology

An ultrasonic technique for identifying fracturing in salt laboratory specimens will be calibrated for the WIPP salt. Then the ability to quantify the generation of fracture as a function of creep or strain will be possible. The time-dependent relationships between pressure and the decrease of fractures will be established to obtain healing kinetics.

3. Information Needs Addressed

Closure (1.2.1.4)
Disturbed Rock Zone (1.2.1.7)
Disposal Room Design (1.2.1.9)
Closure (1.2.2.3)
Disturbed Rock Zone (1.2.3.2)
Closure (1.2.3.3)
Closure (1.2.4.4)

Activity S.3.1.4
MOISTURE EFFECT ON CREEP RATE

1. Focus

The potential influence of brine within the repository or in the salt surrounding the repository as it affects room closure has been studied (Hunche, 1984; Borns, 1987). There are two schools of thought on the effect of the brine moisture: (1) moisture increases the creep rate of salt, or (2) moisture has no effect on the creep rate. No specific mechanism or model consistent with both extremes has been constructed. Most interpretations suggest that the phenomenon is related to changes in the bulk creep property of the salt even though, theoretically, it seems unlikely. If it is hypothesized that the location or influence of moisture accelerates the growth of fractures that result from dilatant deformation it appears most of the previous unreconcilable results could be explained. This experiment would test the hypothesis.

2. Methodology

Experimental equipment and test procedures for moisture testing and specimen preparation must be developed. Then, the extent of fractures as a function of creep strain and confining pressures will be determined. Also a determination of the response of the creep rate to moisture conditions will be made. To complete the process, the reversibility of the effect of moisture on salt creep will be assessed.

3. Information Needs Addressed

Container Response (1.2.1.3)	Closure (1.2.2.3)
Closure (1.2.1.4)	Closure (1.2.3.3)
Disposal Room Design (1.2.1.9)	Closure (1.2.4.4)

Activity S.3.1.5
STRESS, STRAIN/BRINE TRANSPORT

1. Focus

Host rock permeability is critical for predicting brine inflow to the rooms and shafts using the existing brine transport model. The current model (McTigue and Nowak, 1987) treats the host rock as a poroelastic medium customarily used for clay-bearing soils that exhibit a plastic behavior. However, plastic effects could cause changes in the salt permeability that are not accounted for in this model. Using quarried salt blocks for room or shaft seals may reduce the time required for the seal to reach a state of permeability nearly the same as the intact host rock. The mechanical behavior during creep closure could also be better quantified.

The strain associated with creep closure could also initiate brine inflow mechanisms other than the Darcy flow mechanisms used in the model, and this possibility should be considered. Such mechanisms are likely to be significant only during early times after excavation and then to decrease in importance. However, strain induced brine flow changes should be included in the model to quantify their potential for long-term contribution to inflow.

2. Methodology

The first step is to derive the relationships between strain resulting from creep closure of the excavations and the effective permeability of the host rock. A mechanistic understanding of damage, dilatation, or other restructuring that occurs with the creep during excavation closure could then be developed. Strain induced changes in the host rock must be related to brine inflow models. Finally, computer models of quarried salt blocks must be derived to facilitate predictions of seal component behavior and interaction with the host rock.

3. Information Needs Addressed

Brine Inflow and Room Resaturation (1.2.1.5)
Disturbed Rock Zone (1.2.1.7)
Disposal Room Design (1.2.1.9)
Disturbed Rock Zone and Fluid-Flow Characteristics (1.2.2.1)
Disturbed Rock Zone (1.2.3.2)
Disturbed Rock Zone and Fluid-Flow Characteristics (1.2.4.3)

Activity S.3.2.1
CONSTITUTIVE MODEL DEVELOPMENT

1. Focus

Two distinct efforts are involved in the creep constitutive modeling: (1) reassessment or reevaluation of parameters and incorporation of secondary effect functions and (2) development of a fracture model. A consistent set of parameters will be developed for each of the relevant constitutive models of salt creep. Those secondary functions (now required) will be added to the constitutive models to replace constants currently in the models. The fracture model development effort will center on a fracture mechanism map related to the actual observation of fracture modes in the repository horizon.

2. Methodology

All relevant laboratory data from the ERDA-9 borehole and WIPP-D (Room D) data bases will be assembled. The data bases will be evaluated in a consistent manner for the specific constitutive creep models relevant for use in performance assessment activities. The necessary secondary functions will be formulated and the data base parameters evaluated to construct a fracture mechanism map. The appropriate fracture models from the mechanism map and the observed underground fracture modes will be formulated. The fracture parameters for the models will be evaluated for existing laboratory and underground data.

3. Information Needs Addressed

Container Response (1.2.1.3)
Closure (1.2.1.4)
Disturbed Rock Zone (1.2.1.7)
Disposal Room Design (1.2.1.9)
Closure (1.2.2.3)
Disturbed Rock Zone (1.2.3.2)
Closure (1.2.3.3)
Closure (1.2.4.4)

Activity S.3.2.2
NUMERICAL CODE DEVELOPMENT

1. Focus

This activity consists of five major development efforts. Three of the efforts are two-dimensional code development for: (1) incorporating alternative stress generalizations into the codes, (2) incorporating the effects of a layered media into the codes, and (3) modifying codes to permit progressive fracturing and to incorporate fracture models. The remaining two efforts involve three-dimensional code development and will (4) improve the material models and stratigraphy descriptions permitted in the codes and (5) improve the input generation and output graphics of the codes.

2. Methodology

The Tresca stress generalization criterion will be developed and installed in a large strain/deformation code. The proper formulation for the clay seam and bedded material representation will be investigated. A "true" fracture physics for progressive fracture development during the calculation including stress redistribution will be developed. The codes will incorporate the appropriate fracture models for the observed modes of underground fractures. Methods and equipment for input and output for the three-dimensional code solutions will be improved also.

3. Information Needs Addressed

Container Response (1.2.1.3)
Closure (1.2.1.4)
Disturbed Rock Zone (1.2.1.7)
Disposal Room Design (1.2.1.9)
Closure (1.2.2.3)
Disturbed Rock Zone (1.2.3.2)
Closure (1.2.3.3)
Closure (1.2.4.4)
Salado Formation (1.3.2.1)

Activity S.3.2.3
CODE VERIFICATION AND VALIDATION

1. Focus

There must be a continuous effort to assure that numerical codes are, in fact, producing physically correct calculations independent of the structural model involved or the details of the constitutive equations. Code confirmation, verification, and validation will continue as each new generation of code becomes available (Activity S.3.2.2) and as significant advances are made in constitutive modeling. Among the new two-dimensional codes that must be advanced through this system are the large strain/deformation codes with more sophisticated constitutive models and alternative stress generalizations.

The benchmarking process for two-dimensional codes is relatively well defined. The increasing use of new three-dimensional codes means that a method for code verification is a critical element in the development of a three-dimensional calculational capability, however. Many thermal/structural interaction problems related to WIPP configurations are three-dimensional, and a two-dimensional analysis will not produce acceptable results. These problems must be analyzed with codes capable of handling exact three-dimensional configurations. JAC-3D is a recently developed code using the conjugate gradient iterative technique for the quasistatic analysis of three-dimensional, nonlinear solids. Although this code has been evaluated, and in some sense benchmarked, throughout its development, it has not been benchmarked specifically to the WIPP class of nonlinear problems, a step that must be accomplished to establish the necessary degree of confidence for WIPP calculations. The final stage in developing code prediction techniques is the formal validation process of showing acceptable prediction of in situ results for a range of conditions, configurations, and uncertainties in input parameters. The initial validation must establish code readiness in time for performance-assessment calculations for EPA compliance, and the formal process must be completed and documented prior to the acceptance of the WIPP facility as a repository. All relevant two- and three-dimensional codes used for these calculations must be validated, if possible, and made available for use by the Project.

2. Methodology

Typically codes are evaluated against simple analytic solutions, which leaves the bigger and more significant problem of verification as a major activity. Verification is not straightforward, because of the nonlinearity of the problems being solved. As a consequence, no analytic solutions are available against which the codes can be verified. The approach taken is to "benchmark" several codes against the same well-defined boundary value problems; comparable code solutions indicate that the codes are solving the physics correctly, even though the benchmark exercise does not guarantee that the calculations produce the correct answer (Matalucci et al., 1981; Morgan et al., 1981; Munson and Morgan, 1986). Since the correct answer cannot be assured by verification exercises alone, the codes require validation against actual in situ data, whenever possible, to assure correctness of the solutions.

The two major tasks within this activity are verification by benchmarking and validation by comparing calculations to in situ results. Continued verification of new two-dimensional codes through established benchmarking methods will produce acceptable codes for performance assessment and operational safety questions. Because so few three-dimensional codes are available, a somewhat new approach will be developed for verifying three-dimensional codes. To this end, JAC-3D will be benchmarked initially by using it three-dimensionally to compute solutions to simple two-dimensional boundary value or creep problems that have been previously analyzed with two-dimensional codes. Any discrepancies will be resolved. The next step in benchmarking will consist of three-dimensionally solving a more realistic, two-dimensional configuration, such as the configurations of the Benchmark II and Parallel Calculation exercises. When all discrepancies of these nonlinear problems have been resolved, the final step will be to benchmark the JAC-3D code to another three-dimensional code in a direct code-to-code comparison for a complex, but controlled, problem.

Validation will be the culmination of the analysis of the in situ data. It will summarize the current status of the codes, uncertainties, and accuracy of the prediction of the in situ results. The task will establish the formal documentation of the validation process against the in situ data for the most appropriate two- and three-dimensional codes.

3. Information Needs Addressed

Closure (1.2.1.4)
Disposal Room Design (1.2.1.9)
Closure (1.2.2.3)
Closure (1.2.3.3)
Closure (1.2.4.4)
Salado Formation (1.3.2.1)

Activity S.3.2.4
BRINE INFLOW TO EXCAVATIONS

1. Focus

Any scale-up of brine inflow test data to large excavations and extrapolation of those data to long times for performance assessment requires a model (Activity S.3.2.5). A brine-inflow model, based on mechanistic understanding, will be developed from the results of in situ brine-inflow, pore-pressure, flow-characterization, and permeability studies (Nowak and McTigue, 1987) (Activities S.3.3.6, S.3.3.8, S.3.3.13). The brine-inflow rate from the host rock is a key input to models for the consolidation of emplaced crushed salt in seal structures and for waste room response to creep closure.

2. Methodology

Numerical techniques will be developed to expand the existing brine-inflow model to include spatially and temporarily variable permeability. Permeability will be allowed to vary as a function of stress and/or strain in the host rock. Heterogeneities in the host rock, strain induced changes in host rock flow characteristics, and multiple brine flow mechanisms will be assessed as potential contributors to the total flow.

Mechanistic submodels (based on both in situ and laboratory test data designed to test and elucidate brine-inflow mechanisms) will be developed to provide the fundamental relationships in the numerical model. Simplified geometries may be used to maximize the efficiency of this effort, and emphasis will be given to modeling and matching the experimental results.

Numerical models will be modified to include new mechanisms that may contribute significantly to brine inflow. The mechanistic, experimental, and numerical modeling efforts must be closely coupled for that reason.

3. Information Needs Addressed

Brine Inflow and Room Resaturation (1.2.1.5)
Disturbed Rock Zone and Fluid-Flow Characteristics (1.2.2.1)
Disturbed Rock Zone and Fluid-Flow Characteristics (1.2.4.3)
Salado Formation (1.3.2.1)

Activity S.3.2.5
THREE-DIMENSIONAL MECHANISTIC HYDROLOGICAL TRANSPORT MODEL OF FACILITY

1. Focus

A detailed, three-dimensional model describing mechanisms of flow and radionuclide transport will provide a framework for assimilating field and laboratory data into a characterization of hydrologic conditions at and near the WIPP facility.

2. Methodology

A documented data base from past and ongoing field testing programs will be developed. The data base will continue to evolve from ongoing near- and far-field permeability testing in the facility and shafts (e.g., Activities S.3.3.4, S.3.3.5, S.3.3.6, S.3.3.9, S.3.3.10).

The model will analyze flow and transport mechanisms near the WIPP facility and will provide a predictive capability for simulating flow and transport under a variety of physical conditions.

The analysis will primarily use the SWIFT II code and will include the underground facility, shafts, and surrounding rock mass (including both the disturbed zone and intact rock) from the Bell Canyon Formation to the surface. Modeling will emphasize: (1) flow and transport mechanisms at and near the shafts and facility horizon under both undisturbed and disturbed (high-pressure-breach) conditions; (2) the impact of stratigraphic heterogeneities and excavation-related stresses on flow and transport; and (3) the hydrologic relationships between the Salado Formation and adjacent units. The upper portion of this model (Rustler Formation to land surface) will provide a three-dimensional interface for climate related modeling in Activity S.4.2.1. The approach taken in determining the controlling transport mechanisms will be an outgrowth of that taken by Reeves et al. (1987) in considering the Culebra Dolomite Member under undisturbed conditions and transport within the Culebra under brine-reservoir-breach conditions (Activity S.4.2.2). This method evaluates parameter sensitivity and importance based on the development of dimensionless type curves for solute breakthrough under single-porosity and dual-porosity (fracture) conditions.

SWIFT II will be used for numerical modeling studies because of: (1) its capabilities in handling both flow and transport in dual-porosity and variable fluid density environments, (2) its ongoing use in Culebra flow and transport studies (Activities S.4.2.1, S.4.2.2), and (3) its complete public documentation and Quality Assurance status (e.g., Reeves et al., 1986a; 1986b). SWIFT II will be modified for coupling with an appropriate mechanical deformation code, if preliminary analyses show this capability to be important for simulating flow in the immediate vicinity of the excavations.

3. Information Needs Addressed

Disturbed Rock Zone (1.2.1.7)
Disturbed Rock Zone and Fluid-Flow Characteristics (1.2.2.1)
Disturbed Rock Zone (1.2.3.2)
Disturbed Rock Zone and Fluid-Flow Characteristics (1.2.4.3)
Salado Formation (1.3.2.1)
Rustler/Salado Formation (1.3.2.3)
Rustler/Dewey Lake Red Beds (1.3.2.6)
Boreholes Plugging Criteria, Concepts, and Designs (1.3.4.3)

Activity S.3.2.6
INTEGRATED MECHANICAL MODEL, DISTURBED ROCK ZONE, AND EXCAVATION EFFECTS

1. Focus

The design and emplacement of drift, panel, and shaft seals require a description of the disturbed rock zone, which forms in response to excavation. Evolution of the disturbed rock zone through time and in response to emplacement of and closure around the seals will be predicted.

The primary objective of this activity is to compile and update the geologic or conceptual model of the disturbed rock zone. To the extent possible, however, the applicability of available numerical modeling techniques to the mechanical behavior of the disturbed rock zone will also be evaluated, in conjunction with Activity S.3.2.5.

2. Methodology

This task will integrate visual observations during mining with geophysical data around the underground openings at the WIPP facility (Activities S.3.3.11 and S.3.3.12) into a conceptual mechanical model of the disturbed rock zone. This model will be an outgrowth of the preliminary conceptual model (Borns and Stormont, 1988) and will incorporate the results of ongoing studies, such as the seismic tomography studies (Skokan et al., 1988). Some predictive capability for modeling fracture development will be acquired. This and other activities, such as Activities S.3.3.1 - S.3.3.13, will provide a data base that ensures consistency of the three-dimensional mechanistic flow and transport model (Activity S.3.2.5).

3. Information Needs Addressed

Closure (1.2.1.4)
Brine Inflow and Room Resaturation (1.2.1.5)
Disturbed Rock Zone (1.2.1.7)
Disturbed Rock Zone and Fluid-Flow Characteristics (1.2.2.1)
Closure (1.2.2.3)
Sealing Criteria, Concepts, and Designs (1.2.2.4)
Disturbed Rock Zone (1.2.3.2)
Disturbed Rock Zone and Fluid-Flow Characteristics (1.2.4.3)
Closure (1.2.4.4)
Salado Formation (1.3.2.1)

Activity S.3.3.1
AIR INTAKE SHAFT PERFORMANCE

1. Focus

Detailed shaft closure data will form the basis for validating shaft-closure models to determine the time for reconsolidation of shaft fill material and stress configurations around seals (Activity S.3.2.3). The microfracture/permeability correlation will be used for evaluations of effective seal conditions. The structural investigation of the shaft will determine its closure rates as a function of depth. Additional tests will correlate the ultrasonic signal attenuation with strain and microfracturing-induced permeability increases in the shaft wall.

2. Methodology

The complete closure history of the shaft wall can be determined from early time data onward as a function of time and location within the shaft. Instrumentation consisting of extensometers, thermocouples, and closure measurement points will be installed at five elevations in the shaft. Several sets of paired holes were drilled on opposite walls of the shaft immediately after that section of the shaft was bored to provide early-time data on shaft closure. The time dependent changes within the host rock as a function of distance into the salt will be determined by ultrasonic signals. The changes in ultrasonic velocities in the shaft wall may then be correlated with strain displacement and permeability. Finally, the effects of seasonal temperature variations on the salt will be measured and analyzed in conjunction with the structural behavior of the shaft.

3. Information Needs Addressed

Closure (1.2.4.4)
Sealing Criteria, Concepts, and
  Designs (1.2.4.5)
Borehole-Plug Interaction (1.3.4.2)

Activity S.3.3.2
INTERMEDIATE SCALE BOREHOLE TEST (ROOM C1)

1. Focus

   The test will resolve whether a scale effect can be observed in salt to better resolve the difference between laboratory and field data used in predicting room closure rates. Although salt lacks the joint sets that account for scale effects in hard rock, it does contain interbeds that could account for a scale effect.

2. Methodology

   A test will be initiated to drill and instrument a pilot hole and other boreholes through the pillar in Room C1. The pilot hole will be overcored with a 36-in. (91-cm) diameter hole while monitoring the three-dimensional array of extensometers and closure gages surrounding it. Data from the instrumentation will be acquired for two to three years to evaluate the scale effect and then correlated with data from other structural tests and calculations.

3. Information Needs Addressed

   Closure (1.2.4.4)
   Sealing Criteria, Concepts, and
     Designs (1.2.4.5)
   Borehole-Plug Interaction (1.3.4.2)

Activity S.3.3.3
PANEL STRUCTURAL-RESPONSE TESTS

1. Focus

The closure rates of the disposal rooms and the overall structural response of a seven room panel has been based on data from the Site and Preliminary Design Validation rooms and access drifts (Bechtel, 1986a, 1986b). Other information about creep response has resulted from in situ tests supporting other experiments (Tyler et al., 1988). Data from a full-scale seven room panel would provide increased confidence and reduced uncertainty in the long-term structural behavior of a panel.

2. Methodology

A full-sized seven-room panel was excavated (Panel 1) and geomechanical gages immediately installed in the pillars and roof to measure creep rates and convergence over time. Remotely read instruments are connected to a data acquisition system. Both remotely and manually-read instruments will contribute to a five-year data base. The data will be evaluated and analyzed, then correlated with other data to reduce uncertainties in the structural response of the panel.

3. Information Needs Addressed

Closure (1.2.4.4)
Sealing Criteria, Concepts, and
  Designs (1.2.4.5)
Borehole Plug Interaction (1.3.4.2)

Activity S.3.3.4
GAS FLOW/PERMEABILITY

1. Focus

Gas flow measurements help to define the extent of the disturbed rock zone surrounding a mined opening (Activity S.3.2.6). The measurements indicate relative permeability of the host rock to gas as a function of distance from the opening. The data are important to seal design and evaluation because flow through the total seal system depends in part on the rock in which the seals are placed. The gas flow tests may also provide information for evaluating the buildup and dissipation of natural and waste-generated gas.

2. Methodology

Portions of boreholes will be isolated using a packer system. Nitrogen will be injected in the test interval, then either a flow rate at constant pressure or pressure decay will be measured. The data will be used to estimate gas dissipation rates, determine gas permeability variations, and better understand the creation and nature of the disturbed rock zones. These data will be input to models of permeability strain and permeability stress coupling.

3. Information Needs Addressed

Brine Inflow and Room Resaturation (1.2.1.5)
Disturbed Rock Zone and Fluid-Flow Characterisitics (1.2.2.1)
Sealing Criteria, Concepts, and Designs (1.2.2.4)

Activity S.3.3.5
NEAR-FIELD FLOW CHARACTERIZATION

1. Focus

Near-field flow characterization is part of the effort to better understand the ability of the host rock to transmit fluids (Activity S.3.2.6). This is important to brine inflow estimates, seal design, gas dissipation and overall facility performance. Fundamental assumptions used when calculating permeability from single hole tests will be assessed based on characterization of near-field flow. Interpretations of previous single hole injected flow and inflow measurements have not considered instantaneous, near-field, excavation-induced changes. These changes may dominate flow characteristics of the rock surrounding the drift.

2. Methodology

A test will be initiated in which dye is injected into boreholes that will then be overcored. The dye in the fractures will delineate flow paths in the near field. Another test will be an array containing pressurized gas and brine, which will be monitored during the drilling of an adjacent large diameter hole. The brine-hole response will provide data to be directly related to the poroelastic model used to predict brine inflow. The gas-hole response will be compared with the brine response and previous gas-flow measurements. These data will assist in estimating the amount and significance of deformation concurrent with excavation.

3. Information Needs Addressed

Disturbed Rock Zone and Fluid-Flow
  Characteristics (1.2.2.1)
Sealing Criteria, Concepts, and
  Designs (1.2.2.4)

Activity S.3.3.6
BRINE INFLOW SCALE AND STRATUM EFFECTS

1. Focus

It is necessary to measure the effect of excavation scale on brine inflow as a further test of the current brine inflow model (Nowak and McTigue, 1987). The scale effect is predicted by the current model. A scale effect is a consequence of the predominant brine transport mechanism, and a model is necessary to quantify that effect (Activities S.3.2.4 and S.3.2.5). A complete model of brine inflow will include the potential for brine-inflow heterogeneity among strata. Brine inflow to horizontal boreholes in the host rock as well as vertical boreholes above and below the facility horizon can be measured by collecting and weighing the brine. Brine inflow rates as a function of borehole size for comparison with predicted scale effects must be measured. Also, the difference in brine inflow rates among identifiably different strata in the disposal horizon must be measured to assess the magnitude of the effect of host rock heterogeneity.

2. Methodology

Existing and new boreholes will be monitored to measure and compare brine inflow rates and trends. The boreholes range in diameter from 4 to 36 in. (10 to 91 cm) and penetrate various strata. The measured versus predicted scale effects on brine inflow will be compared to assess the consistency of the model with in situ conditions.

3. Information Needs Addressed

Brine Inflow and Room Resaturation (1.2.1.5)
Disturbed Rock Zone and Fluid-Flow Characteristics (1.2.4.3)
Salado Formation (1.3.2.1)

Activity S.3.3.7
PORE PRESSURE FOR BRINE INFLOW

1. Focus

Pore pressure (including the test-interval pressure rise) will be measured at the ends of 4-in. (10-cm) diameter test boreholes using tools designed and manufactured specifically for that purpose. The tools measure borehole closure and pressure simultaneously in the test interval. The end of the borehole will be sealed with a double packer to create the test interval. The volume between the packers serves as a guard zone to detect leakage past the primary packer. The pressure rise will be measured with a transducer.

Test intervals will be approximately 3 ft to 65 ft (1 m to 20 m) from WIPP excavation walls. Tests will be located in the WIPP test area to the north and in the disposal area to the south. Test boreholes are planned to include measurements in, above, and below the disposal horizon. Anhydrite beds (e.g., Marker Bed 139) and clay beds (or seams) will be included among the test intervals.

This effort will concentrate on obtaining an integrated set of data for the brine-inflow excavated room (Activity S.3.3.8). Pore-pressure data will be obtained from vertical and horizontal boreholes (above, below, and to one side) at several distances from the brine room. The first set of data will be obtained while the circular-cross-section brine room is bored and passes by the pore-pressure test locations.

2. Methodology

The near-field (disturbed) and the far-field (undisturbed) distribution of pore pressures will be measured. The degree of interconnected flow will be inferred from this pore-pressure data. Brine inflow models will be tested for consistency with the pore pressure data, and pore pressure boundary conditions will be established for model calculations.

3. Information Needs Addressed

Brine Inflow and Room Resaturation (1.2.1.5)
Disturbed Rock Zone and Fluid-Flow Characteristics (1.2.4.3)
Salado Formation (1.3.2.1)

Activity S.3.3.8
BRINE INFLOW TO EXCAVATED ROOMS

1. Focus

It is important to test the scale-up capability of the brine-inflow model from small (4- to 36-in. [10- to 91-cm] diameter) boreholes to excavations having diameters of several feet and intercepting most of the proposed waste disposal horizon (Nowak and McTigue, 1987). Experimental excavations with a characteristic size of several feet are needed to test scale-up with the model and to sample a representative portion of host rock salt.

Data from this brine flow test will be used to test the current brine inflow model with regard to scale-up from boreholes to room size excavations. The results may be useful in differentiating among potential mechanisms and corresponding models for brine flow. Data obtained will characterize the excavation induced disturbed zone without including the complexities of Marker Bed 139, an anhydrite interbed several feet below the proposed waste disposal horizon. Possible effects of Marker Bed 139 on brine inflow and on the disturbed zone may be measured separately in a second phase of testing.

A room with a circular cross section is expected to maximize the fraction of incoming brine that can be collected in instrumented containers and measured directly without the need to infer brine volumes. In this way, the circular cross section addresses the possibility that inaccuracies in brine inflow measurements to test rooms could result from the accumulation of brine in fractures surrounding the room, particularly in the underlying Marker Bed 139 and overlying seams. This curved cross section may also minimize the disturbed zone on the surrounding host rock, further minimizing occurrences of undetected incoming brine. Characterization of the disturbed zone will be performed using methods such as electrical conductivity and acoustic measurements.

2. Methodology

As a circular brine-inflow room is bored, instrumentation will measure the pore-pressure response of the host rock. After the room is excavated and sealed, remotely read instrumentation will collect data on humidity, closure, pore pressure vs. distance from the wall, and other variables. Liquid brine inflow will be collected from troughs and shallow sumps to be weighed, measured, and analyzed. Salt samples will also be analyzed for brine content. Finally, posttest studies will be conducted including analyses of core samples and measurements in exploratory boreholes. The data will then be interpreted in terms of brine transport mechanisms.

3. Information Needs Addressed

Brine Inflow and Room Resaturation (1.2.1.5)
Disturbed Rock Zone and Fluid-Flow Characteristics (1.2.4.3)
Salado Formation (1.3.2.1)

Activity S.3.3.9
BRINE PERMEABILITY TESTING OF THE DISPOSAL HORIZON

1. Focus

This testing will reduce the uncertainty in permeability values for the far-field domain of the Salado Formation and will support seal and backfill designs. The rate of brine seepage into the facility, although influenced by near-field transient effects, will likely be largely controlled by the far-field permeability unless the permeability is effectively zero. The degree and rate of backfill consolidation will be influenced by brine inflow. Activities S.3.2.4, S.3.2.6, S.3.3.4, S.3.3.5, S.3.3.6, S.3.3.8, S.3.3.9, S.3.3.10, S.3.3.11, S.3.3.12, and S.3.3.13 combine into an overall approach to the hydrologic behavior and characterization of the disposal horizon. The testing in this activity delineates the extent of the hydrologically disturbed zone by comparing results with those obtained in near-field activities. Data on the permeability of different zones in the Salado Formation when undisturbed by the presence of the excavation will be obtained.

2. Methodology

Ten to fifteen locations will be identified to drill an array of five holes, including vertical (up and down), subhorizontal, and inclined holes. Permeability tests will be conducted at various intervals from 10 to 50 ft (3 to 15.2 m) from the facility in the halites, polyhalites, anhydrites, and clay interbeds. The data will resolve the above mentioned uncertainties and will be used in the mechanistic modeling (Activity S.3.2.5).

3. Information Needs Addressed

Brine Inflow and Room Resaturation (1.2.1.5)
Disturbed Rock Zone (1.2.1.7)
Disturbed Rock Zone and Fluid-Flow Characteristics (1.2.2.1)
Disturbed Rock Zone (1.2.3.2)
Salado Formation (1.3.2.1)
Rustler/Salado Formation (1.3.2.3)

Activity S.3.3.10
AIR INTAKE SHAFT BRINE PERMEABILITY TESTING

1. Focus

Pressure changes measured in the Rustler Formation behind the shaft liner are either due to changes in leakage rates into the shaft or to hydrologic testing being conducted around the site (Activity S.4.3.2, Beauheim, 1987a; Haug et al., 1987). These pressure changes could affect the successful sealing of the shaft if fluid bypasses the seals in a zone of higher permeability. The Rustler and Salado Formations around the shaft must be characterized with respect to their ability to provide fluids to the shafts. Long-term pressure data are also required that can be used to evaluate changes in the hydrologic regime around the shaft. Data and interpretations appropriate for use in shaft seal design (Activity S.2.2.2) and three-dimensional mechanistic modeling (Activity S.3.2.5) are required.

2. Methodology

Three subhorizontal holes will be drilled and tested at each of eleven levels in the Air Intake Shaft. The levels include six water-bearing horizons above the Salado Formation and five horizons in the Salado. The holes will extend about 50 ft (15.2 m) outward and permeability testing of at least three intervals will be conducted. At least one borehole in each horizon will be completed for long-term pressure and borehole closure monitoring. One to two years after completion of the testing selected holes will be retested to assess if any changes in the disturbed zone have occurred.

3. Information Needs Addressed

Disturbed Rock Zone and Fluid-Flow Characteristics (1.2.4.3)
Sealing Criteria, Concepts, and Design (1.2.4.5)
Salado Formation (1.3.2.1)
Rustler/Salado Formation (1.3.2.3)
Rustler Formation (1.3.2.4)
Rustler/Dewey Lake Red Beds (1.3.2.6)
Borehole Plug Interactions (1.3.4.2)

Activity S.3.3.11
SHAFT GEOPHYSICS

1. Focus

   Variations in seismic velocity and electrical resistivity can be used to monitor the development of fractures and changes in porosity and permeability around a shaft. Geophysical methods can investigate the first 3 to 6 ft (1 to 2 m) of the wall rock to delineate the disturbed rock zone and stratigraphic variations in water content and porosity. This will provide data on the nature of the rock at the proposed seal locations. These methods could monitor changes in resistivity and seismic velocity around large-scale seal tests to provide a performance measure for seal design.

2. Methodology

   The design for the electromagnetic and refraction studies must be completed; then refraction stations will be installed in the Air Intake Shaft. An electromagnetic survey could be conducted in the Salado Formation. Periodic resurveys in the shaft would then be conducted with both refraction and electromagnetic methods.

3. Information Needs Addressed

   Disturbed Rock Zone and Fluid-Flow
     Characteristics (1.2.4.3)
   Salado Formation (1.3.2.1)

Activity S.3.3.12
UNDERGROUND GEOPHYSICS

1. Focus

The geophysical techniques previously described (Activity S.3.3.11) can also be used to investigate back-filled rooms, the facility host rock, and proposed seal locations. Electrical and seismic methods can be used to remotely measure changes in density, void volume, and moisture. Variations in permeabilities relative to depth and position in the facility will provide indications where additional detailed testing might be conducted.

2. Methodology

Experimental high-resolution refraction surveys will be conducted as well as initiating an experimental remotely-monitored electromagnetic system. These systems can be refined if needed and provide support tools for other performance assessment activities.

3. Information Needs Addressed

Backfill (1.2.1.2)
Container Response (1.2.1.3)
Closure (1.2.1.4)
Disturbed Rock Zone (1.2.1.7)
Disturbed Rock Zone (1.2.3.2)
Salado Formation (1.3.2.1)

Activity S.3.3.13
BRINE SAMPLING AND EVALUATION PROGRAM

1. Focus

The Brine Sampling and Evaluation Program characterizes the extent and composition of visually identified brine inflow. This will assist in evaluating brine sources, areal extent and volume of existing and potential brine, relationships between brine and gas occurrences, and the long-term behavior of known occurrences. This activity supports the modeling of brine inflow to the facility (Activities S.3.2.4 and S.3.2.5).

2. Methodology

Photographic documentation of brine weeps as well as observation and measurements of brine accumulations in drill holes has been ongoing for over five years and will be continued. The existing data document the variation in moisture content that occurs stratigraphically, laterally, and with time since the areas were mined. Salt efflorescences will be dried and weighed to determine the quantity of brine that evaporated to form the deposits. Visual and geophysical logging of boreholes will assist in delineating specific zones of higher moisture content. Brine samples will be collected periodically and the chemical composition analyzed.

3. Information Needs Addressed

Brine Inflow and Room
  Resaturation (1.2.1.5)
Salado Formation (1.3.2.1)

2.6.2.4 Non-Salado Formation Hydrology and Nuclide Migration Activities

This section describes the activities involving non-Salado hydrology and nuclide migration (Table 2-6). Figure 2-9 illustrates the manner in which this technical area provides input necessary for performance assessment. Transport of radionuclides to the accessible environment is the ultimate concern of WIPP performance assessment. The Rustler Formation contains the first laterally continuous water-bearing zone above the WIPP facility, the Culebra Dolomite Member. For this reason, evaluation of the Rustler Formation, and especially the Culebra Dolomite Member, has been a major focus of WIPP site characterization (Lappin, 1988). The final stages of testing, interpretation, and numerical modeling of the physical hydrology, radionuclide transport, and geochemical behavior of the Rustler Formation form the major focus of this area. Some data will be collected from the interval between the WIPP facility horizon and the Rustler Formation.

One group of activities in this section will collect data and report for the final numerical model describing the present day hydrology of the Culebra Dolomite at and near the WIPP site. This model will directly support regional-scale performance assessment calculations. The major activities include a multipad interference test at the H-11 hydropad and monitoring of the Rustler Formation response to installation of the WIPP Air Intake Shaft; both activities are ongoing.

A second group of activities will determine the relevant radionuclide-transport mechanisms that must be considered by performance assessment in modeling transport between the WIPP facility horizon and the accessible environment through the Rustler Formation. Regional scale calculations have already been completed for transport through the Culebra Dolomite Member under undisturbed conditions (Reeves et al., 1987). Major Rustler Formation field and modeling activities remaining to be completed include the conservative-tracer test at the H-11 hydropad, final reporting of all conservative-tracer testing completed to date, and completion of regional scale Culebra transport calculations under disturbed conditions, analogous to calculations contained in Reeves et al. (1987). Laboratory activities will provide updated data and an understanding of the reliability of radionuclide retention mechanisms within the Rustler Formation.

The third group of activities directly supports the required consideration of a 10,000-year time frame in regional scale radionuclide transport. Major focuses include geochemical and geophysical studies, in addition to limited hydrologic studies of units above and below the Rustler Formation. The studies are largely an outgrowth of completed studies indicating the transient nature of WIPP hydrology (e.g., Lambert, 1987; Lambert and Harvey, 1987). Because the studies address how the hydrologic and geochemical settings of the Rustler Formation have changed over about the past 10,000 years, the results can be used to indicate defensible boundary conditions for modeling studies addressing hydrology and nuclide migration over the next 10,000 years.

The activities investigating non-Salado hydrology and nuclide migration will likely continue to collect data through March 1992. In March 1991, available data, and estimates where data are unavailable, will be used by Activity PA.8 to perform the preliminary consequence analysis. Data collected between March 1991 and March 1992 will be used to confirm the data and assumptions used in 1991 and to provide input to the March 1992 final consequence analysis (PA.10).

TABLE 2-6. APPLICATIONS OF THE NON-SALADO HYDROLOGY AND NUCLIDE MIGRATION INVESTIGATIONS

Program-Area Activity	Phenomena/Parameters Being Addressed: Disposal Room and Drift System	Sealing System	Structural and Fluid Flow Behavior, Salado	Hydrology and Nuclide Migration, Non-Salado
S.4.1 Laboratory Studies:				
S.4.1.1 Batch Kd Measurements	Backfill Performance, Radionuclide Retardation*			Radionuclide Retardation
S.4.1.2 Mechanistic Studies of Sorption	Backfill Performance, Getter Effectiveness			Radionuclide Retardation
S.4.1.3 Solute Column Transport	Radionuclide Transport*			Radionuclide Retardation
S.4.1.4 Rustler Radiocarbon				Ground-Water Flow, Rustler Hydrologic Properties
S.4.1.5 Mineralogical and Hydrochemical Studies in Support of Sorption Experiments				Radionuclide Retardation, Rustler Chemical Properties
4.2 Modeling Studies:				
S.4.2.1 Final 2-D Culebra Modeling				Ground-Water Flow, Radionuclide Transport, Hydrologic Properties
S.4.2.2 Solute Transport - Brine Reservoir Breach into the Culebra				Ground-Water Flow, Radionuclide Transport, Hydrologic Properties

*Denotes a secondary application

TABLE 2-6. APPLICATIONS OF THE NON-SALADO HYDROLOGY AND NUCLIDE MIGRATION INVESTIGATIONS (Continued)

Program-Area Activity	Phenomena/Parameters Being Addressed			
	Disposal Room and Drift System	Sealing System	Structural and Fluid Flow Behavior, Salado	Hydrology and Nuclide Migration, Non-Salado
S.4.2.3 Far-Field Hydrologic Flow and Boundary Conditions				Ground-Water Flow, Radionuclide Transport, Culebra Hydrologic Properties
S.4.2.4 Far-Field Culebra Transport Mechanisms Under Disturbed and Undisturbed Conditions				Ground-Water Flow, Radionuclide Transport, Culebra Hydrologic Properties
S.4.3 In Situ Tests:				
S.4.3.1 H-11 Multipad/Tracer Test				Ground-Water Flow, Radionuclide Transport, Culebra Hydrologic Properties
S.4.3.2 Rustler Response to Air Intake Shaft		Seal Performance*		Ground-Water Flow, Hydrologic Properties
S.4.3.3 Single-Hole Hydraulic Tests of the Rustler Formation				Ground-Water Flow, Hydrologic Properties
S.4.3.4 Single-Pad Interference Tests of the Culebra Dolomite				Ground-Water Flow, Hydrologic Properties

*Denotes a secondary application

TABLE 2-6. APPLICATIONS OF THE NON-SALADO HYDROLOGY AND NUCLIDE MIGRATION INVESTIGATIONS (Concluded)

Program-Area Activity	Phenomena/Parameters Being Addressed			
	Disposal Room and Drift System	Sealing System	Structural and Fluid Flow Behavior, Salado	Hydrology and Nuclide Migration, Non-Salado
S.4.3.5 Conceptual Hydrogeologic Model of the Rustler Formation				Hydrologic Properties, Rock Properties
S.4.3.6 Bell Canyon Hydrologic Information				Hydrologic Properties
S.4.3.7 Dewey Lake Red Beds Hydrology				Hydrologic Properties
S.4.3.8 Surface Geophysics		Seal Performance*		Rustler Rock Properties
S.4.3.9 Regional Geochemical Studies: Solute Chemistry and Mineralogy				Rustler Rock Properties
S.4.3.10 Regional Geochemical Studies: Dissolution				Rustler Rock Properties
S.4.3.11 Regional Geochemical Studies: Paleoclimate				Climate Properties

*Denotes a secondary application

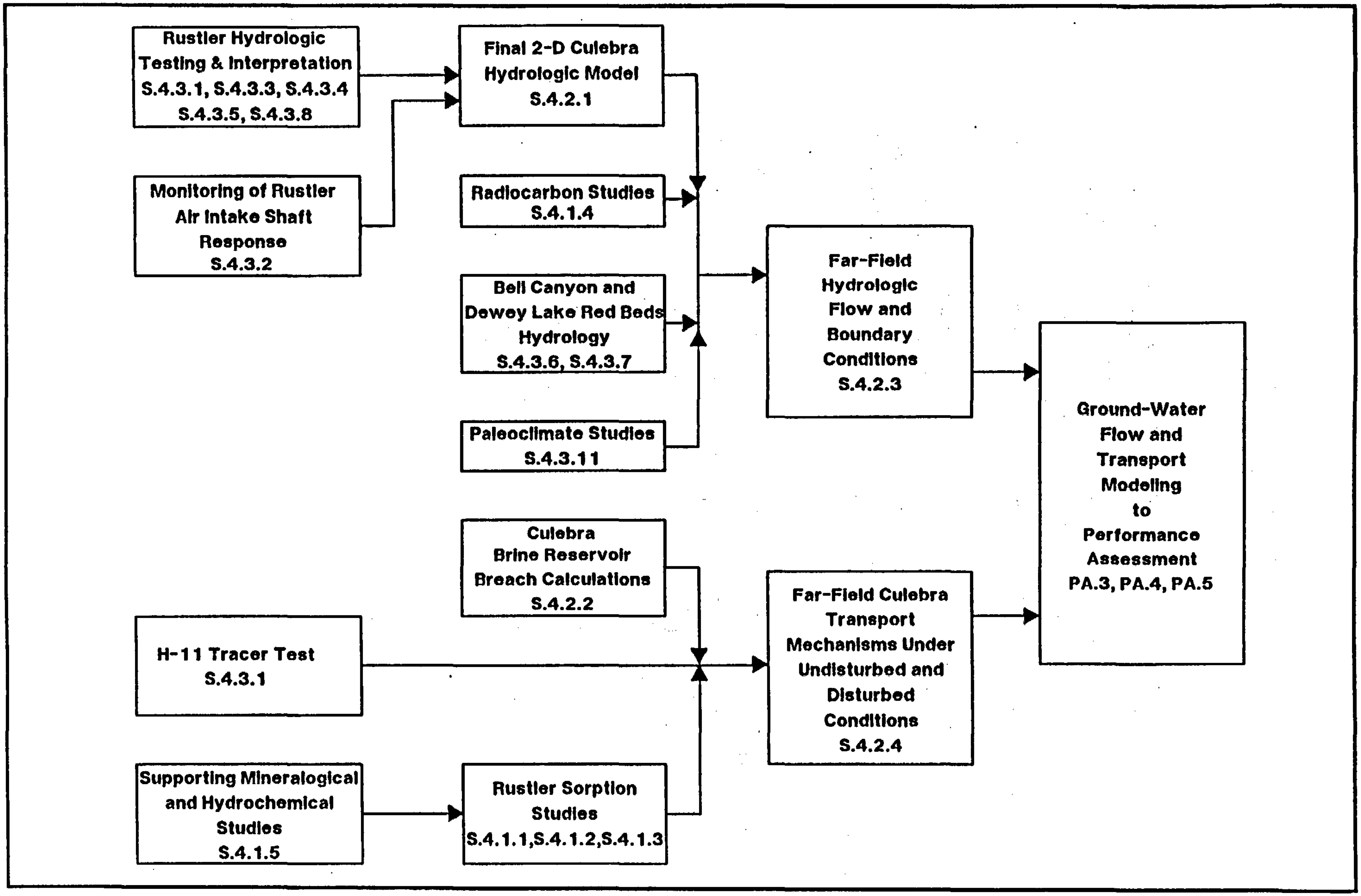


Figure 2-9. Relationship of Non-Salado Hydrology and Nuclide Migration Activities

Activity S.4.1.1
BATCH K_d MEASUREMENTS

1. Focus

Broad-based semiempirical data on radionuclide retention within the Rustler Formation are needed for radionuclide release scenarios. Batch K_d measurements will obtain K_d data for use in performance assessment calculations for most radionuclide release scenarios, with emphasis on the Culebra Dolomite. In addition, the batch experiments will provide information describing chemical interactions among radionuclides, minerals, and waters (both inorganic and organic solutes) potentially present at the WIPP site.

Data are insufficient to determine whether K_ds obtained in during previous batch studies were due to sorption or other chemical processes occurring during the experiment. New experiments must be carefully designed to ensure that potentially important speciation effects are not overlooked. Batch sorption data will be obtained for plutonium, americium, and uranium under a range of experimental conditions with natural materials.

2. Methodology

The available literature describing sorption of radionuclides on rocks from the WIPP site and generic clays, sulfates, and carbonates in saline waters or in the presence of organic ligands (complexing agents) will be reviewed. The batch K_d experiments will be designed to avoid the problems identified by the literature review. An experimental factorial matrix will be designed to examine effects of mineral composition, brine composition, and radionuclides concentration.

Radionuclide sorption will also be qualitatively studied by contacting rock slabs with radionuclide-doped solutions and examining the locations of fission tracks or fogging of photographic film laid on top of the sample. The purpose will be to identify sites of radionuclide uptake on whole rock samples for a large number of combinations of radionuclides, organics, major solutes, and well-characterized rocks.

3. Information Needs Addressed

Culebra Dolomite Member (1.3.2.2)

Activity S.4.1.2
MECHANISTIC STUDIES OF SORPTION

1. Focus

Extrapolation of K_d measurements (Activity S.4.1.1) and the conduit and interpretation of fracture flow or column experiments (Activity S.4.1.3) must be done on a defensible basis. K_d values are now valid only for the specific conditions of the experiment. Therefore, it is necessary to obtain a defensible theoretical understanding of the mechanisms of radionuclide/rock interactions for several simple systems relevant to WIPP. The information will be used to design batch K_d experiments and column studies to ensure that potentially important speciation or complexion effects are not overlooked.

2. Methodology

Techniques to measure the site-binding capacity of carbonates, sulfates, and clays in WIPP waters as a function of pH, redox ionic strength, and other solution chemistry variables must be developed. Stability constants for potentially important complexes in WIPP ground waters must be obtained, and sites of uptake radionuclides must be identified for clays, sulfates, and carbonates. Studies of rates of sorption, coprecipitation, and matrix diffusion important to radionuclide retardation must be implemented. These studies will all increase confidence in the ability to make long-term predictions of radionuclide transport at the WIPP facility (Activity S.4.2.4).

3. Information Needs Addressed

Backfill (1.2.1.2)
Culebra Dolomite Member (1.3.2.2)

Activity S.4.1.3
SOLUTE COLUMN TRANSPORT

1. Focus

Batch K_d experiment data and column transport data will provide radionuclide sorption values for use in predictions of radionuclide transport through water-bearing units at the WIPP facility (Activity S.4.2.4).

Available K_d and column data are inadequate for the needs of performance assessment. There are few data from column experiments on WIPP materials; the available data are not for radionuclides of interest, and the solutions used in the experiments contained no organic complexants. Additional column-experiment data will support performance assessment; new experiments must be carefully designed to ensure that potentially important speciation effects within the fluid are not overlooked. The column experiments will form the final experimental evaluation of the transport behavior within the Culebra Dolomite.

2. Methodology

Wafer and column transport experiments for a small number of radionuclide/organic/rock/water combinations will be guided by information obtained from Activities S.4.1.1 and S.4.1.2. The studies will differ from previous column studies in that more relevant experimental material will be used. In addition, greater care will be taken to: (1) account for the fate of all of the radionuclides introduced in the experiments (mass balance), (2) characterize the solids involved in sorption, (3) avoid supersaturation or complexation by agents not expected in waters at WIPP, and (4) design and bound flow conditions to ensure that matrix diffusion can be accounted for in the final data interpretation. The theoretical calculations of radionuclide transport in the columns will be applicable to chemical systems typical of the WIPP site and facility.

Development of a coupled chemical reaction/transport code to model the results of column experiments is required. Such a code is currently under development at Oak Ridge National Laboratory with partial support from Sandia National Laboratories. The code will be adapted for this project and will be used to calculate theoretical elution curves for the columns using basic thermodynamic and kinetic data.

3. Information Needs Addressed

Backfill (1.2.1.2)
Culebra Dolomite Member (1.3.2.2)

Activity S.4.1.4
RUSTLER RADIOCARBON

1. Focus

Data resulting from this activity may better establish the magnitudes of uncertainties in radiocarbon activity measurements arising from: (1) natural variability of less heavily organic contaminated sampling localities with time, (2) transient variability of moderately to heavily organic contaminated sampling localities as a function of degree of purging, and (3) variability among different modes of sample preservation and sample storage times.

The primary use of radiocarbon analysis of Rustler ground waters (Lambert, 1987) has been in the attempt to determine ground-water residence times at the WIPP site. The results to date (Lambert and Harvey, 1987; Lambert and Carter, 1987) are consistent with the interpretation that the overall hydrologic setting of the WIPP site is transient (Activity S.4.2.3).

2. Methodology

Water samples will be collected and analyzed from six wells chosen to represent a spectrum of degrees of organic contamination based on experience from WIPP water sampling programs. Samples collected will address questions on organic contamination, precision of sampling, preservation methods, and sample shelf life. Eighteen archived radiocarbon samples will be analyzed for comparison. Finally the integrity of samples stored for over three years before being analyzed will be verified.

3. Information Needs Addressed

Recharge (1.3.1.6)
Culebra Dolomite Member (1.3.2.2)

Activity S.4.1.5
MINERALOGICAL AND HYDROCHEMICAL STUDIES IN SUPPORT OF SORPTION EXPERIMENTS

1. Focus

Results of short-term laboratory studies of radionuclide transport (Activities S.4.1.1 - S.4.1.3) are difficult to extrapolate to the long times considered by the EPA Standard. Natural analogs of nuclide behavior in complex solute systems are believed to provide valuable insights into the long-term behavior of radionuclides under natural conditions.

Laboratory studies of radionuclide sorption and transport (Activities S.4.1.1 - S.4.1.3) can be applied to predictions of performance of the WIPP facility only if the data have been collected under the physiochemical conditions relevant to the natural system. Important characteristics of the ground water and minerals that would react with radionuclides released from the facility are uncertain. Important solution parameters include the saturation state of the waters with respect to the dominant carbonate phases, dolomite and calcite; pH; pCO_2; and redox equilibria. Previous studies of Rustler Formation mineralogy have focused on detailed aspects of clays in a few well-documented intact cores. Sampling bias inherent in such a focus is twofold: (1) horizons most likely to contain extractable clay minerals in sufficient quantity are favored and (2) principal water-bearing zones, commonly a fraction of the whole thickness of the Culebra Dolomite Member, are likely to be reduced to rubble by partial dissolution and hence were poorly represented in core recovery. Additional rock samples containing surfaces previously in contact with ground waters will be obtained. Water and rock properties profoundly influence speciation and sorption of radionuclides and must be better characterized for proper design of sorption and transport experiments.

2. Methodology

The component tasks in this effort are: (1) collecting shaft samples or core fragments likely exposed to natural occurrences of fluid for use in sorption experiments, (2) mineralogical determinations on the core, including petrographic examination, analyses of organic carbon, X-ray diffraction, and electron optics studies, (3) measuring total CO_2 content and improving estimates of the pH and carbonate mineral/water equilibria of Culebra waters, (4) evaluating the nature of redox disequilibria of the Culebra, and (5) formulating a natural analog model to understand the behavior of naturally occurring uranium in the Rustler Formation to complement theoretical and experimental studies of uranium sorption and speciation at the WIPP site.

3. Information Needs Addressed

Culebra Dolomite Member (1.3.2.2)

Activity S.4.2.1
FINAL TWO-DIMENSIONAL CULEBRA MODELING

1. Focus

A numerical ground-water model that demonstrates quantitative understanding of the present day Culebra flow regime and investigates the sensitivity of model results to data uncertainties is necessary to understanding radionuclide transport in the Culebra Dolomite Member. This model must also demonstrate a quantitative understanding of possible long-term changes in the flow system associated with climatic change or with other transient changes in boundary conditions (Activity S.4.2.3).

This model will be used as the mechanistic hydrologic model for the Culebra Dolomite Member at and near the WIPP site (Activities PA.3 and PA.4) and will be the basis for regional scale transport calculations.

The Culebra Dolomite is the most transmissive, laterally continuous hydrogeologic unit above the WIPP facility. It is considered to be the major potential off-site pathway for radionuclide transport in the subsurface, should a breach of the facility occur. Past modeling studies have focused on developing a calibrated model of the flow regime for approximately steady-state head conditions and for simulating two multipad-scale interference tests.

2. Methodology

Continuing work extends model calibration to include the transient hydraulic stresses caused by Air Intake Shaft construction and the H-11 multipad/tracer test (Activity S.4.3.1) and other new data from other single well and single-pad hydrologic tests. Model calibration will use an adjoint-sensitivity approach that provides feedback on the sensitivity of simulated heads at observation wells as a function of variations in the transmissivity distribution. This feedback will significantly enhance the calibration process.

Uncertainties in the final calibrated model of the present day flow regime, including travel time uncertainty between the WIPP site center and southern boundary, will be quantitatively estimated.

After the model has been calibrated and the present-day flow regime can be simulated satisfactorily, the model will be extended to simulate possible long-term changes in the Culebra flow system associated with climatic change. These simulations will be implemented by coupling the Culebra model with the regional-scale Culebra model and with the upper portion of the three-dimensional model being constructed as part of Activity S.3.2.5. This coupling will allow the examination of the hydrologic impact including travel time of various climate-related scenarios over 10,000 years.

3. Information Needs Addressed

Recharge (1.3.1.6)
Culebra Dolomite Member (1.3.2.2)
Rustler/Salado Formations (1.3.2.3)
Rustler Formation (1.3.2.4)
Rustler/Dewey Lake Red Beds (1.3.2.6)

Activity S.4.2.2
SOLUTE TRANSPORT-BRINE RESERVOIR BREACH INTO THE CULEBRA

1. Focus

One group of WIPP scenarios includes breach of the facility by drilling into an underlying pressurized brine occurrence in the Castile Formation. This activity supports calculations needed to evaluate flow and transport in the Culebra Dolomite Member following such a breach and calculations of releases resulting from these breach scenarios.

Breaches of the WIPP facility that involve injection of contaminated fluids into the Culebra Dolomite Member and their subsequent transport to the accessible environment can be bounded by two pressure conditions at the injection point: low-pressure injection that does not disturb the natural hydraulic gradients within the Culebra Dolomite Member, and high-pressure injection that substantially alters the hydraulic gradients. An example of a high-pressure injection would be a connection between the Culebra and a Castile pressurized brine occurrence. Reeves et al. (1987) evaluated the relative importance of the parameters governing solute transport through double-porosity portions of the Culebra under a low-pressure injection scenario. They showed that under the gradients naturally occurring within the Culebra, diffusion of solutes from the fractures to the rock matrix may lead to an overall regional-scale transport behavior similar to that of a simple porous medium. Whether this same conclusion applies in the case of a high-pressure injection scenario is unknown and must be resolved. This activity will provide information on transport mechanisms and approaches for far-field modeling of disturbed conditions.

2. Methodology

The areal, steady-state ground-water flow field of the Culebra Dolomite Member derived from modeling will be used as the initial condition for simulating ground-water flow and solute transport for a high-pressure injection scenario. An internal boundary condition in the model will dynamically link a well connecting a Castile pressurized brine occurrence to the Culebra Dolomite at a point above the disposal panels. Transient simulations will be used to define the resulting time-dependent changes in the flow field. Based on hydraulic testing of existing pressurized brine occurrences, a range of parameter values governing brine-reservoir behavior will be used.

To examine solute transport under high hydraulic gradients, a number of flow paths from the breach point to the accessible environment will be selected for further study. Dual-porosity transport will be examined under a variety of conditions. Free-water diffusivity, matrix tortuosity, matrix-block length, matrix porosity, fracture porosity, fracture dispersivity, fracture flux, and sorption will be varied systematically over their ranges of uncertainty to establish their relative importance in affecting solute travel times. Comparisons will be made to solute transport through a simple porous medium under the same hydraulic conditions. If the results of the numerical modeling indicate that transport through the Culebra Dolomite Member in the event of a brine-reservior breach is of concern, then it will be necessary to compile and assess available data on the composition of Castile brines.

3. Information Needs Addressed

Culebra Dolomite Member (1.3.2.2)
Castile Formation Brines (1.3.2.7)
Pressurized Brine Hydrofracturing
and Transport (1.3.2.8)

Activity S.4.2.3
FAR-FIELD HYDROLOGIC FLOW AND BOUNDARY CONDITIONS

1. Focus

Site characterization activities which have emphasized the Rustler Formation and shallower units indicate that the geohydrologic setting of the WIPP site is transient on the 10,000-year time scale of regulatory interest. For performance assessment calculations, the extent of time-dependent variations in hydrologic flow and boundary conditions for all water-bearing units of interest over 10,000 years must be estimated. The units of interest extend from the surface downward through the Bell Canyon Formation.

2. Methodology

This activity will compile and examine recommendations on time-dependent boundary conditions and flow behaviors for individual stratigraphic units and develop an internally consistent description of the overall time-dependent hydrologic behavior of the WIPP region. The modeling of the hydrology of the Rustler Formation will be completed. The Bell Canyon, Salado, and Dewey Lake Red Beds hydrologic information will be correlated with paleoclimate information and its estimated effects within the Rustler Formation.

3. Information Needs Addressed

Recharge (1.3.1.6)
Extent of Dissolution (1.3.1.7)
Culebra Dolomite Member (1.3.2.2)
Rustler/Salado Formation (1.3.2.3)
Rustler Formation (1.3.2.4)
Dewey Lake Red Beds (1.3.2.5)
Rustler/Dewey Lake Red Beds (1.3.2.6)
Pressurized Brine Hydrofracturing and Transport (1.3.2.8)
Bell Canyon (1.3.2.9)

Activity S.4.2.4
FAR-FIELD CULEBRA TRANSPORT MECHANISMS UNDER DISTURBED AND UNDISTURBED CONDITIONS

1. Focus

Testing with conservative tracers at the borehole hydropads has demonstrated the important role of fractures in controlling the transport of conservative "contaminants" on at least the 164 to 492 ft (50 to 100 m) scale in fractured portions of the Culebra Dolomite Member. To reduce uncertainty in transport modeling, it is necessary to determine whether such fracturing also plays a significant role in transport to the accessible environment through fractured portions of the Culebra Dolomite, under both undisturbed and brine-reservior-breached conditions.

2. Methodology

This activity examines the importance of various mechanisms for radionuclide transport through the Culebra Dolomite from a point above the WIPP waste-emplacement panels to the accessible environment. Final interpretations of conservative-tracer tests at the three hydropads will be completed. These interpretations will estimate effective block sizes and effective fracture porosities within fractured portions of the Culebra Dolomite. Completed calculations investigating the role of fractures under undisturbed conditions (Reeves et al., 1987) use a preliminary transmissivity distribution within the Culebra Dolomite (Haug et al., 1987) and preliminary estimates of fracture spacings and porosities (Kelley and Pickens, 1986). The conclusions of Reeves et al. (1987), namely that fracturing effects need not be included in numerical modeling of transport to the accessible environment within the Culebra Dolomite under undisturbed conditions, will be examined in light of the final estimated transmissivity distribution (Activity S.4.2.1) and effective block sizes and fracture porosities.

Ongoing calculations are examining the potential effects of fracturing on transport within the Culebra Dolomite following a brine-reservoir breach of the WIPP facility (Activity S.4.2.2). Conclusions based on these calculations, which use the Culebra Dolomite transmissivity distribution estimated by LaVenue et al. (1988), will be examined in light of the final estimated Culebra Dolomite transmissivity distribution, fracture spacings, and fracture porosities provided by Activity S.4.2.1. The result will be a final estimate of the importance of various transport mechanisms within fractured portions of the Culebra Dolomite under both undisturbed and brine-reservoir-breached conditions, with emphasis on determining whether transport through fractures plays any significant role on the regional scale.

3. Information Needs Addressed

Culebra Dolomite Member (1.3.2.2)
Castile Formation Brines (1.3.2.7)
Pressurized Brine Hydrofracturing and Transport (1.3.2.8)

Activity S.4.3.1
H-11 MULTIPAD/TRACER TEST

1. Focus

Large-scale testing at the H-11 hydropad, similar to multipad pump and tracer tests performed elsewhere at WIPP (Beauheim, 1987a; Beauheim, 1987c), will better define the extent and properties of the relatively higher permeability zone within the Culebra Dolomite in the southeastern part of the WIPP site. Numerical modeling of ground-water flow in the Culebra Dolomite (LaVenue et al., 1988) shows that water above WIPP generally flows southward. This flow is controlled by a high-permeability zone. Because transport of solutes through this zone is of concern (Reeves et al., 1987) tracer tests should address this sensitive portion of the site. Computer analysis of the data will estimate fracture porosity and other factors for use in solute-transport modeling. The distribution of transmissivities and storativities resulting from the analysis will guide the two-dimensional numerical modeling of Culebra Dolomite flow (Activity S.4.2.1).

2. Methodology

A combination multipad pumping and tracer test was performed at the H-11 hydropad. Different tracers were injected into the three other wells on the hydropad and their breakthroughs to the pump well were monitored to allow characterization of the flow paths. Water levels were also monitored in surrounding observation wells to define the water recovery trends. Analysis of this data will be input to the modeling activities to better define the high-permeability zone in the Culebra Dolomite.

3. Information Needs Addressed

Culebra Dolomite Member (1.3.2.2)

Activity S.4.3.2
RUSTLER RESPONSE TO AIR INTAKE SHAFT

1. Focus

Monitoring and interpretations of the hydrologic response as a result of the installation and grouting of the Air Intake Shaft are necessary to develop the final Culebra model (Activity S.4.2.1) and to support the near-field, mechanistic, flow and transport model (Activity S.3.2.5). The drawdown cone caused by leakage from the Culebra into the shafts extends at least 2 mi (3.2 km) outward (Haug et al., 1987). Field data will be interpreted and simulated using computer models to estimate transmissivity and storativity for Rustler members at the WIPP facility. These data will allow calculation of potential leakage rates to the shafts, better design of shaft seals, and more defensible undisturbed performance calculations.

2. Methodology

Because the storativity and transmissivity within the Rustler can only be clarified by long-term testing, a specific borehole (H-16) was drilled and instrumented to monitor the hydrologic regime, both during construction and after construction of the Air Intake Shaft. Pressures in all five Rustler members were monitored, and water level measurements in nearby observation wells were monitored (Beauheim, 1987b). These data will provide support in developing the final Culebra model.

3. Information Needs Addressed

Disturbed Rock Zone and Fluid-Flow Characteristics (1.2.4.3)
Culebra Dolomite Member (1.3.2.2)
Rustler Formation (1.3.2.4)
Rustler/Dewey Lake Red Beds (1.3.2.6)

Activity S.4.3.3
SINGLE-HOLE HYDRAULIC TESTS OF THE RUSTLER FORMATION

1. Focus

Additional single-hole hydrologic data on the Rustler Formation are needed to reduce uncertainties in the hydrologic data bases. A reliable numerical model of ground water flow and mass transport through the Culebra Dolomite must be completed. Previous tests and modeling have identified areas where Culebra Dolomite observation wells would be useful (LaVenue et al., 1988).

2. Methodology

Seven boreholes located in response to previous tests and modeling have been drilled and tested (Beauheim, 1987b). The data from these tests will be interpreted from pump tests or slug tests and transmissivity in high-uncertainty locations in the Culebra Dolomite will be estimated. Data will be incorporated into the appropriate Culebra Dolomite models (Activity S.4.2.1). If unacceptable areas of uncertainty still exist, additional boreholes may be required. It is likely that a new Culebra-depth hole south of the WIPP facility and a shallow hole into the Dewey Lake Red Beds will be required.

3. Information Needs Addressed

Culebra Dolomite Member (1.3.2.2)
Rustler Formation (1.3.2.4)
Rustler/Dewey Lake Red Beds (1.3.2.6)

Activity S.4.3.4
SINGLE-PAD INTERFERENCE TESTS OF THE CULEBRA DOLOMITE

1. Focus

A reliable and defensible numerical model of ground-water flow and transport through the Culebra Dolomite is required for final interpretation of the local variability of fracturing effects and storativity on ground-water flow. Results to date identify the existence of fracturing in several boreholes and demonstrate the complex relationship between fracturing and transmissivity (Beauheim, 1987a; Saulnier, 1987). Test results were previously interpreted assuming the Culebra Dolomite acts hydraulically as a single-porosity medium. However, recent interpretations show it acts as a double-porosity medium over much of the WIPP site (Beauheim, 1987a, 1987b, 1987c). Hydraulic interference tests are the only source of information on storativity of the Culebra Dolomite. Storativity is a key parameter governing the response of a water-bearing unit to transient stresses and needed as input to the two-dimensional Culebra Dolomite model (Activity S.4.2.1).

2. Methodology

To provide the required information, existing data from appropriate boreholes will be reinterpreted using analytical techniques incorporating both single and double-porosity formulations. Determinations of which borehole locations in the Culebra Dolomite behave as a single-porosity medium and which behave as a double-porosity medium will be made. These data will be input to the model to support regional scale interpretations.

3. Information Needs Addressed

Culebra Dolomite Member (1.3.2.2)

Activity S.4.3.5
CONCEPTUAL HYDROGEOLOGIC MODEL OF THE RUSTLER FORMATION

1. Focus

   A conceptual hydrogeologic model is needed to estimate hydrogeologic properties where point data are not available. Models have relied on hydraulic property measurements made at discrete points, but this fails to consider nonnumerical information (LaVenue et al., 1988). Because transmissivity of the Culebra Dolomite is closely related to fracturing in a geologic model, explaining the origin of the fractures and predicting their geographic occurrence is desirable. Establishing a relationship between geology, fractures, and geophysical measurements would enhance the model.

2. Methodology

   Cores from the Rustler Formation, the geology of the Air Intake Shaft, nearby outcrops of the Rustler, and geophysical data will be examined to define factors that correlate with transmissivity and define causal relationships. A conceptual model will be developed integrating geologic, hydrologic, and geophysical data to allow predictions of Rustler hydraulic properties or potential for vertical flow paths.

3. Information Needs Addressed

   Culebra Dolomite Member (1.3.2.2)
   Rustler/Salado Formation (1.3.2.3)
   Rustler Formation (1.3.2.4)
   Rustler/Dewey Lake Red Beds (1.3.2.6)

Activity S.4.3.6
BELL CANYON HYDROLOGIC INFORMATION

1. Focus

   Accurate information on Bell Canyon hydrologic properties is needed to define scenarios involving connection of the Bell Canyon with other water-bearing units (Activity S.4.2.3). Some scenarios postulate connecting the Rustler with the Bell Canyon by a drillhole through the repository. Evaluation of the flow and transport properties of the Bell Canyon is needed. The formation has been tested in five boreholes in the past. However, early interpretations, particularly hydraulic gradients, are inconsistent with the two most recent test interpretations (Beauheim et al., 1983; Beauheim, 1986).

2. Methodology

   The data from the three early interpretations will be reevaluated to obtain new estimates of transmissivity and hydraulic head in the Bell Canyon. If the data from all five boreholes and the subsequent numerical modeling indicate that transport through the Bell Canyon is a concern in the event of human intrusion, it will be necessary to compile and assess data on the composition of Bell Canyon brines.

3. Information Needs Addressed

   Rustler/Salado Formation (1.3.2.3)
   Bell Canyon Flow and Geochemistry (1.3.2.9)

Activity S.4.3.7
DEWEY LAKE RED BEDS HYDROLOGY

1. Focus

In the event of any breach involving upward fluid flow from the WIPP facility, contaminated brine might be injected into either saturated or unsaturated portions of the Dewey Lake Red Beds. This activity also supports limited evaluation of Dewey Lake Red Beds hydrology and transport behavior (Activity S.4.2.3). No continuous zone of saturation has been evident in holes drilled at the site. However, there are permeable zones as evidenced by loss of drilling fluid in some holes. A locally significant freshwater aquifer is present along the southern boundary of the WIPP site (Mercer, 1983). Therefore the Dewey Lake Red Beds could, under certain breach scenarios, provide a path to the accessible environment.

2. Methodology

Three phases will be implemented to resolve this concern:

a. All drilling records and borehole histories from WIPP boreholes will be reviewed and assessed for pertinent Dewey Lake Red Beds hydrologic information.

b. A Dewey Lake Red Beds well will be installed to evaluate the nature and properties of the Dewey Lake Red Beds aquifer along the southern WIPP boundary.

c. A brine injection test will be performed at a well that has a known fracture zone in the Dewey Lake Red Beds to assess the transport properties.

3. Information Needs Addressed

Rustler/Salado Formation (1.3.2.3)
Dewey Lake Red Beds (1.3.2.5)
Rustler/Dewey Lake Red Beds (1.3.2.6)
Pressurized Brine Hydrofracturing and Transport (1.3.2.8)

Activity S.4.3.8
SURFACE GEOPHYSICS

1. Focus

Delineation and interpretation of lateral variation in the Rustler Formation as observed in the changes in apparent resistivity across the WIPP site will help determine the flow field and interrelationship of the spatially separated boreholes for use in the two dimensional Culebra Dolomite model (Activity S.4.2.1). Geophysical methods can also assess the effectiveness of borehole plugs and determine the effects of shafts on the Rustler Formation hydrology.

2. Methodology

Geophysical methods proposed are primarily electric or electromagnetic and will measure subsurface resistivities which is the geophysical property most sensitive to changes in the hydrologic system. Small-scale controlled source audio-magnetotelluric surveys will be conducted as needed. A remotely monitored high-resolution transient electromagnetic array will be designed and installed to monitor the site and large-scale tests.

3. Information Needs Addressed

Culebra Dolomite Member (1.3.2.2)
Dewey Lake Red Beds (1.3.2.5)
Pressurized Brine Hydrofracturing and Transport (1.3.2.8)

Activity S.4.3.9
REGIONAL GEOCHEMICAL STUDIES: Solute Chemistry and Mineralogy

1. Focus

Recent interpretation of the geochemical and hydrologic setting of the WIPP facility has emphasized that the overall behavior is transient (Siegel et al., 1988). Evidence suggests a major recharge regime about 10,000 to 20,000 years ago that differs notably from the modern one (Hunter, 1985). Available models are based on a few reliable analyses of the isotopic, chemical, and mineralogic character of the Ochoan system. Reliable predictions of the fate of radionuclides emplaced in the WIPP facility require a better understanding of the histories of rocks and ground water. The resolution of differences among various conceptual models of the evolution of the ground-water system is necessary (e.g., Haug et al., 1987; LaVenue et al., 1988; Chapman, 1988; Lambert, 1988; Siegel et al., 1988). Also, previous studies of Rustler mineralogy have focused on intact core which tends to bias the sampling. Sampling of less cohesive core is required to characterize mineralogies actually in contact with water recovered during pump tests.

2. Methodology

   a. The mineralogical aspect of this activity will be covered by a review of core descriptions to compare with hydrologic test results. Then mineral assemblages that are probably related to solutes in the fluids will be compiled. Finally, trace-isotope and trace-element studies of key mineral constituents will be performed.

   b. Laboratory analyses of water samples from the Water Quality Sampling Program will be continued to support the solute chemistry program. Additional solutes will be quantified if needed. Data bases on solutes and isotopes will be expanded.

3. Information Needs Addressed

Recharge (1.3.1.6)
Extent of Dissolution (1.3.1.7)
Culebra Dolomite Member (1.3.2.2)

Activity S.4.3.10
REGIONAL GEOCHEMICAL STUDIES: DISSOLUTION

1. Focus

Additional petrographic and isotopic measurements are needed to confidently estimate rock/water ratios and determine the origin of water that interacted with the minerals. The degree and timing of rock/water interactions resulting in evaporate dissolution govern the changes in permeability of water-bearing brittle interbeds in the evaporate section. Therefore, the degree of vertical and lateral water movement within the Rustler and Dewey Lake Red Beds zones that are now carrying or have carried water must be determined. This will allow areas to be identified in which permeabilities may have changed as a result of postdepositional rock/water interactions and evaporite dissolution. It may also determine the time scale over which dissolution has occurred, and the mechanisms and pathways of ground water movement that have resulted in changes in rock properties and major and minor solute distribution.

2. Methodology

Ongoing laboratory studies related to evaporate dissolution will be completed. Concurrently, the characterization of gypsiferous rocks in the Ochoan evaporates at and near the WIPP facility with emphasis on characterizing the last major fluids in contact with these rocks will be completed. The rock/water interactions that took place in the Rustler Formation and Dewey Lake Red Beds at the WIPP site and the upper Salado Formation in Nash Draw will be described.

3. Information Needs Addressed

Extent of Dissolution (1.3.1.7)
Culebra Dolomite Member (1.3.2.2)

Activity S.4.3.11
REGIONAL GEOCHEMICAL STUDIES: PALEOCLIMATE

1. Focus

Recent interpretation of the geochemical and hydrologic setting of the WIPP facility has emphasized that the overall behavior is transient. There is evidence of a major recharge regime 10,000 to 20,000 years ago that is notably different from the modern one. The timing and magnitude of extremes in transient behavior of the hydrologic system probably correlate with magnitude and periodicity of geologic events such as climatic fluctuations. To support scenario screening and long-term performance calculations, information on the paleoclimate is needed.

2. Methodology

A bibliography of the paleoclimate will be compiled. Based on mineralogical and element analysis, an estimate of the annual precipitation to the Ochoan/Triassic/Cenozoic hydrologic system during the late Pleistocene in southeastern New Mexico will be determined. Paleoflow patterns in the Dewey Lake Red Beds and Rustler Formation associated with the Pleistocene will be obtained by analyzing faunal remains from Pleistocene deposits and cellulosic material from old trees. Finally, the water budget calculations will be revised and flow models made consistent with wetter climatic conditions for a 10,000-year simulation of WIPP performance under such hydrologic conditions.

3. Information Needs Addressed

Recharge (1.3.1.6)
Extent of Dissolution (1.3.1.7)
Culebra Dolomite Member (1.3.2.2)

2.7 ACTIVITY SCHEDULES

A series of schedules for the performance assessment activities and supporting activities appears on Figures 2-10 through 2-14. These schedules were developed to identify the data and models necessary to support the final consequence analysis. Thus the final analysis is anticipated to be performed with the minimal model and parameter uncertainties reasonably achievable at that time.

Each schedule contains key milestones and reports. More detailed schedules showing the relationship of activities to each other will be prepared. Thus a critical path can be identified to ensure completion of the Draft EPA Compliance Report by September 1992 and a Final EPA Compliance Report by September 1993.

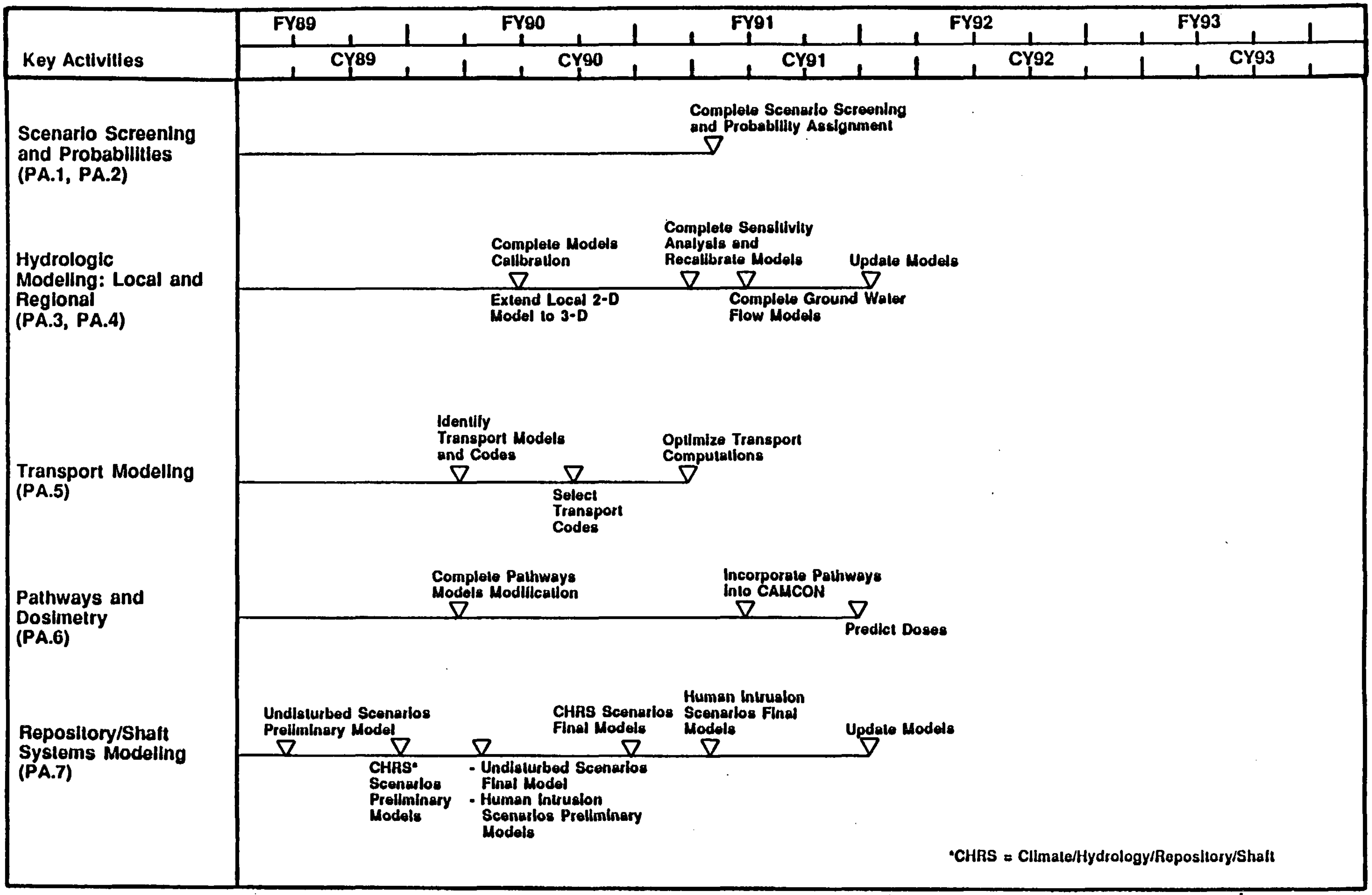


Figure 2-10. Schedule for Performance Assessment Activities

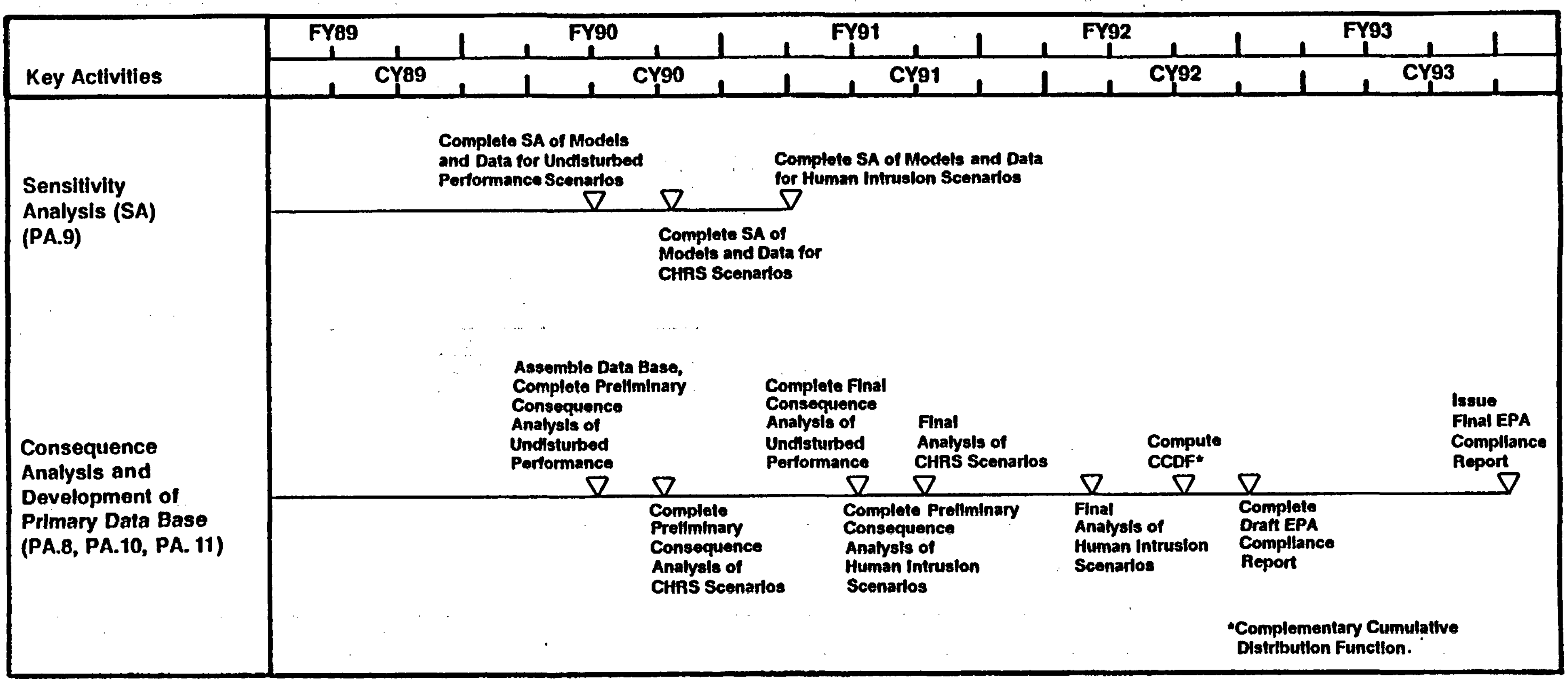


Figure 2-10. Schedule for Performance Assessment Activities (Concluded)

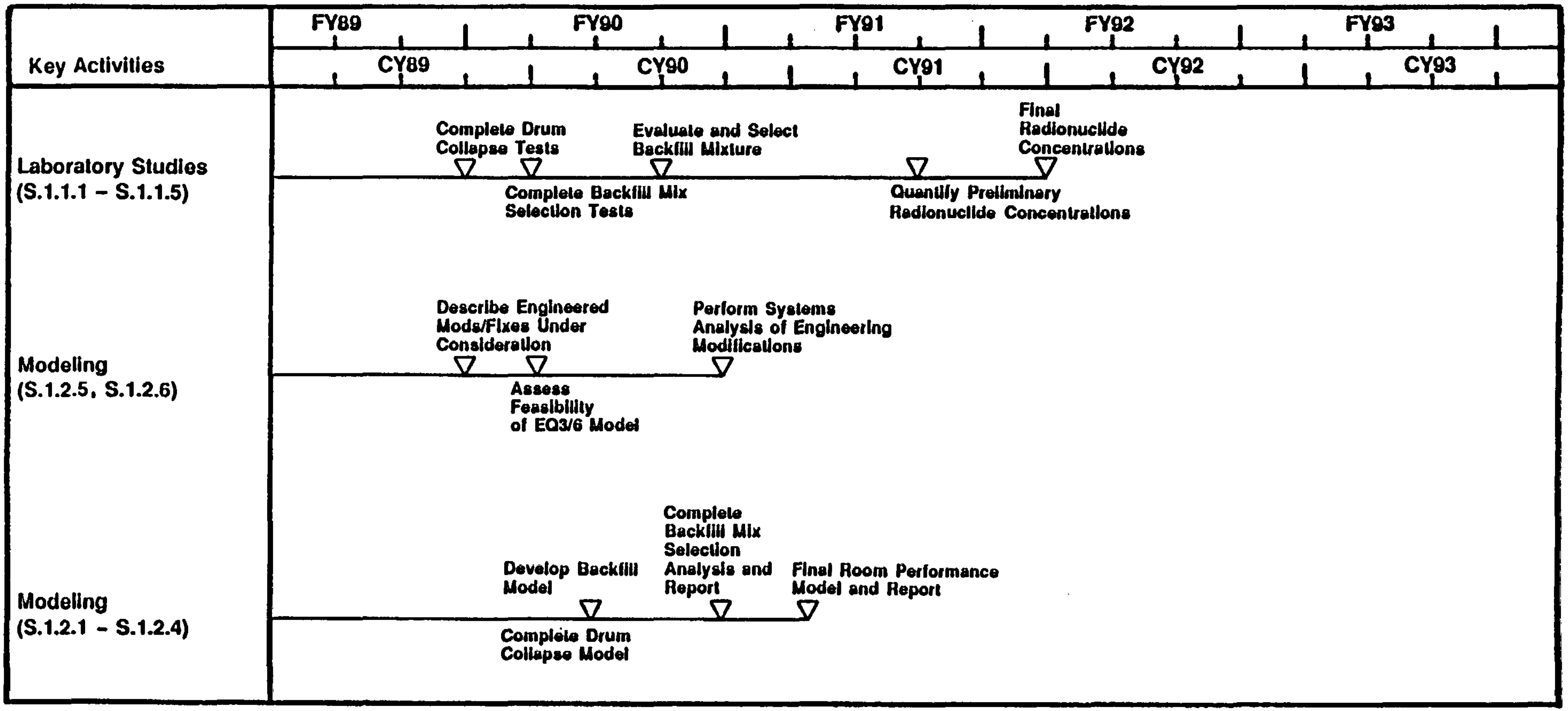


Figure 2-11. Schedule for Disposal Room and Drift System Activities

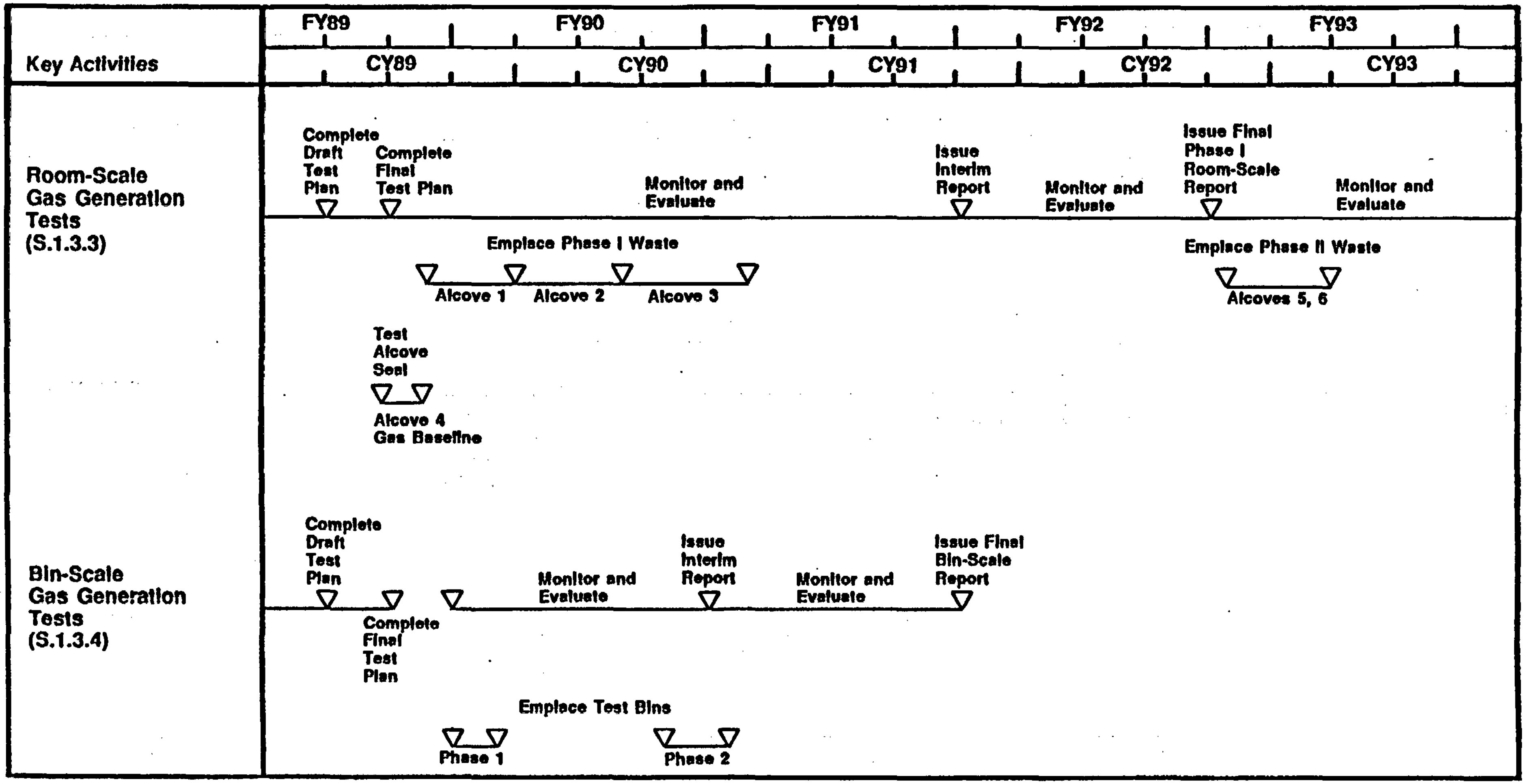


Figure 2-11. Schedule for Disposal Room and Drift System Activities (Concluded)

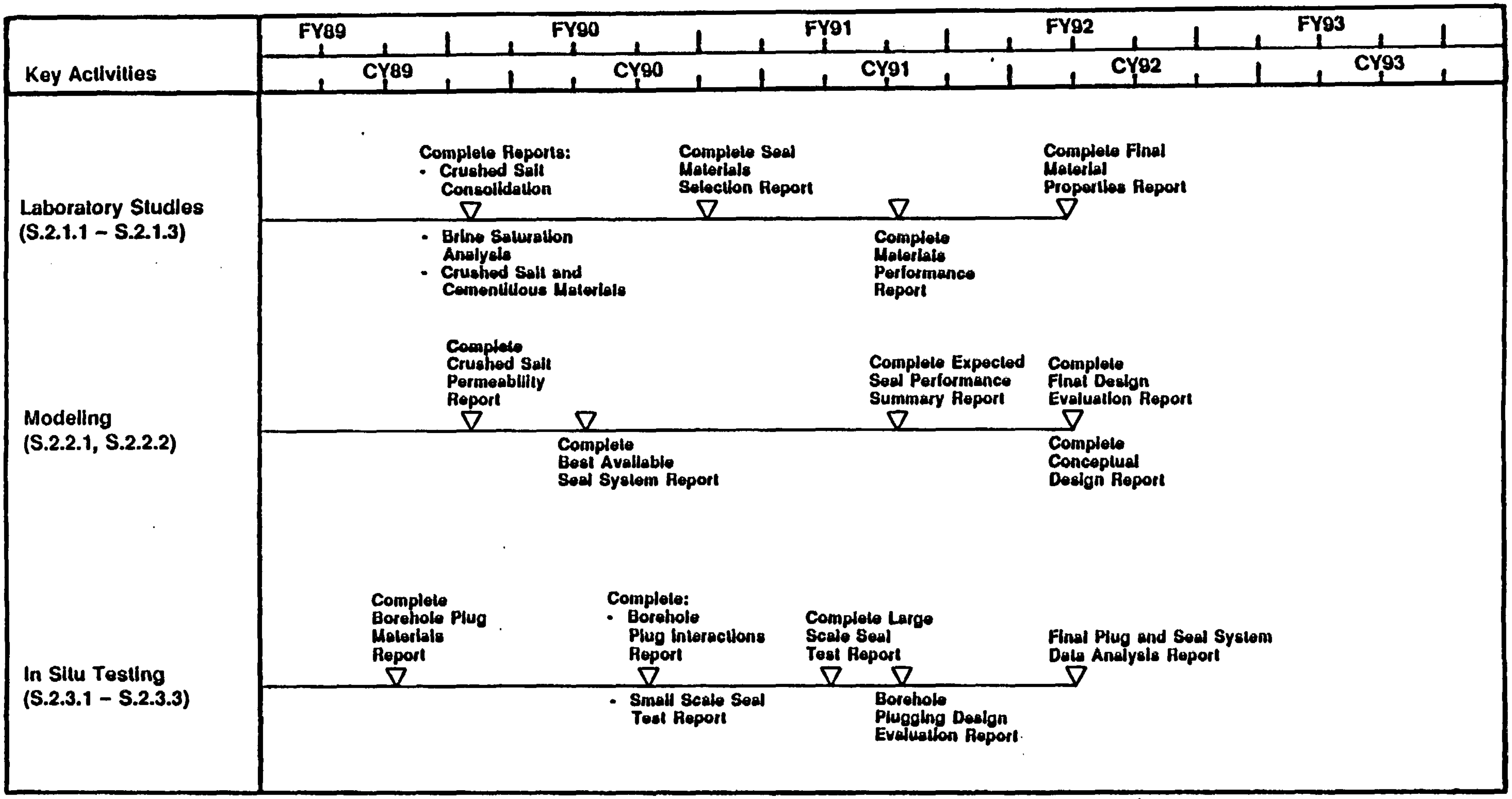


Figure 2-12. Schedule for Sealing System Activities

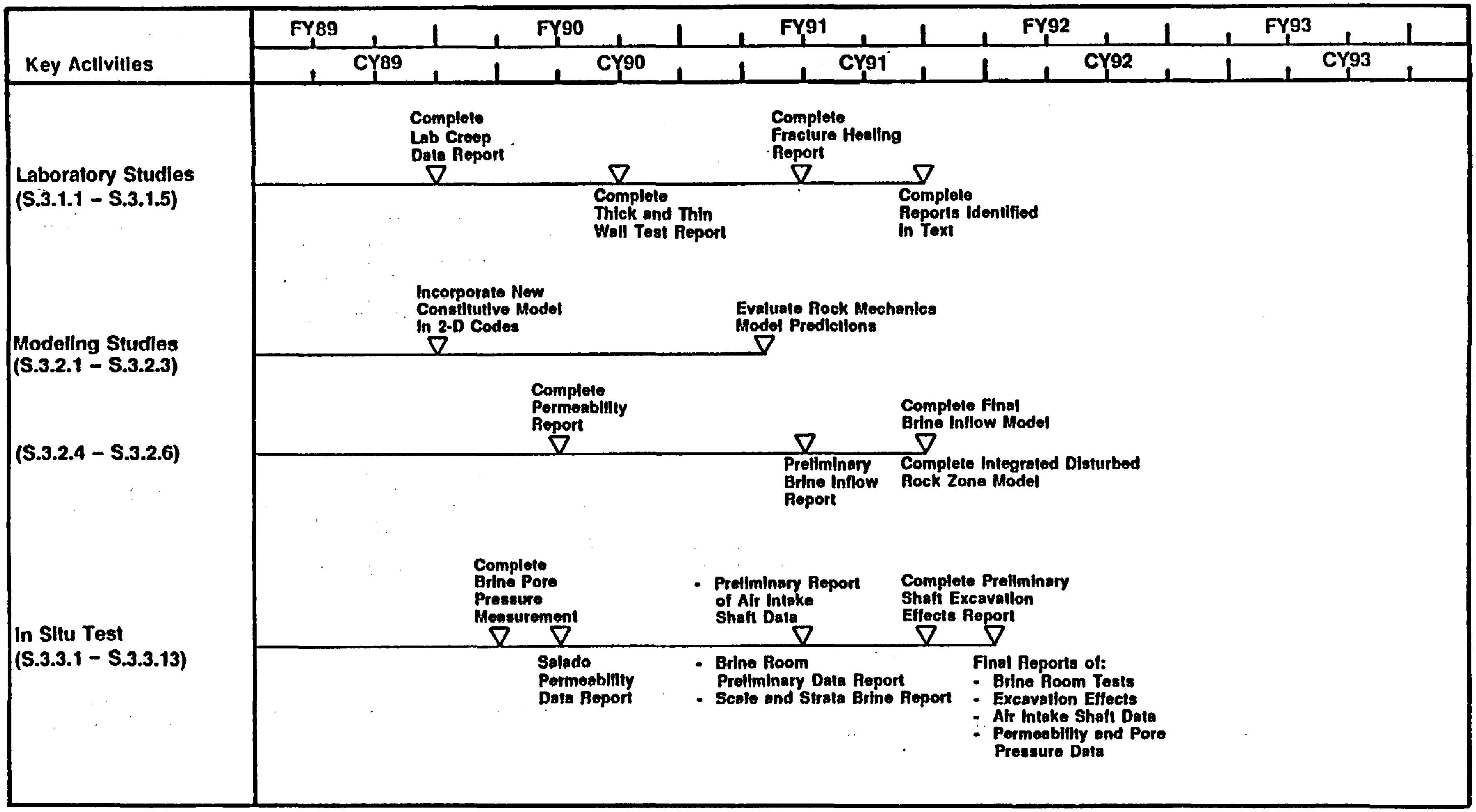


Figure 2-13. Schedule for Structural Behavior and Fluid-Flow Activities

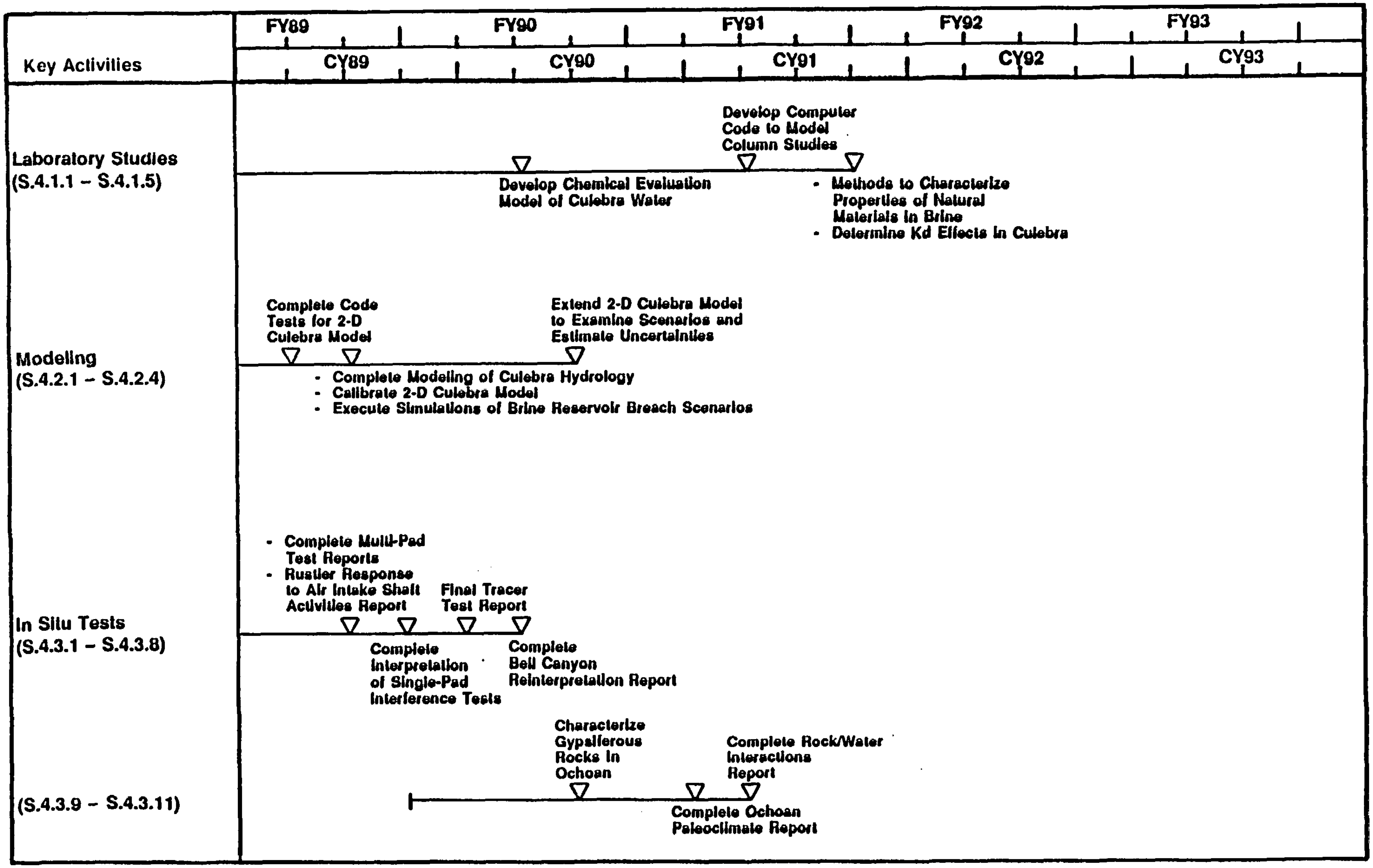


Figure 2-14. Schedule for Non-Salado Hydrology and Nuclide Migration Activities

3.0 OPERATIONS DEMONSTRATION

During the Test Phase, a second program will be implemented before the decision whether to designate WIPP a TRU waste disposal facility can be made. This program will be used to evaluate whether the WIPP facility and associated TRU waste management activities can be safely and effectively operated as intended by Congress in PL 96-164. The WIPP facility is unique in that it will be the country's first deep geologic disposal facility for radioactive waste. As such, there is no body of knowledge to guide such activities; pertinent operational data can best be developed by operating the DOE TRU waste management system with actual waste. This would be achieved by an integrated Operations Demonstration during the Test Phase, which includes all aspects of the TRU waste management system. The Operations Demonstration will initiate waste receipt at the WIPP facility with small quantities of waste for the underground gas generation tests and increase to anticipated design throughput rates as is appropriate based on experience gained. During the Test Phase, TRU waste management system performance will be assessed against prior estimates. Fulfilling the scope of the Operations Demonstration is a prudent precursor to full system operation and will provide increased assurance that the WIPP facility and the balance of the DOE TRU waste management system can support safe design throughput disposal operations.

The Operations Demonstration is planned in two parts. The first part will be completed in late FY92. At that time approximately 4.4 percent of the WIPP disposal area design capacity will have been emplaced. A holdpoint will be initiated at the end of the first part of the Demonstration to evaluate the ability of the WIPP disposal system to satisfy the EPA Standard, 40 CFR 191, and to assess the TRU waste management system operations up to that time. This assessment will be a major factor in determining whether to proceed to the second part of the Operations Demonstration.

This program has three elements:

1. Waste Generating/Storage Sites: Waste management activities at TRU waste generating/storage sites include waste certification and waste packaging for shipment to the WIPP facility. The sites will certify TRU waste to ensure that it meets the WIPP Waste Acceptance Criteria for emplacement in the WIPP facility. Careful waste packaging and loading into the shipping containers will ensure compliance with applicable U.S. Department of Transportation (DOT) regulations and the appropriate Safety Analysis Report for Packaging.

2. Transportation System: Transportation of TRU waste to the WIPP site includes shipping container and trailer operations, shipment tracking using the TRANSportation COMmunication System (TRANSCOM) satellite tracking system, and regulatory compliance monitoring.

3. WIPP Facility: Operation of WIPP with TRU waste includes demonstration of emplacement rates up to those representative of design throughput disposal operations. This entails waste receipt and handling, waste emplacement in the underground facility, environmental compliance activities, and facility support operations.

These elements form the basis for the Operations Demonstration planned activities. While a decision to establish WIPP as a disposal facility could be based on nonradioactive, simulated operational demonstrations and other appraisals completed to date, it is apparent from past public concerns that the lack of operational tests with radioactive materials at the WIPP facility and the TRU waste management system could be an impediment to full confidence in the decision-making process. It is prudent to establish an operational data base which can address questions that might be raised. The Operations Demonstration, described herein, will address these concerns and provide information needed for the performance assessment process.

The Operations Demonstration is an integral part of the thorough, phased approach to the development of the WIPP facility. Since the Record of Decision in 1981, significant progress has been made within the DOE TRU waste management system in providing a sound basis for continuing toward the primary objective of fully demonstrating disposal of defense TRU waste. Table 3-1 summarizes the primary milestones of the TRU waste management system, which provide a framework for evaluation of the more detailed activities presented in succeeding sections of this chapter.

The Operations Demonstration is designed to provide operational experience, using limited quantities of radioactive waste, to substantiate the safety and effectiveness of WIPP operations and associated waste management system activities under realistic conditions. The safety of the waste management system operations will be demonstrated, first using newly generated waste from those DOE sites lacking on-site storage capabilities, including the Rocky Flats Plant near Denver and other sites, and stored waste from the Idaho National Engineering Laboratory. During this period, the WIPP facility will comply with the EPA Standard, 40 CFR 191, Subpart A, per agreement with the State of New Mexico. The waste brought to the WIPP site during the Test Phase, including both CH- and RH-TRU wastes, will remain retrievable.

Included in the Operations Demonstration are those activities necessary to provide TRU waste for the gas generation tests described in Chapter 2 and Appendix A of this Plan. These operations will include the phased receipt of CH-TRU test waste. The Operations Demonstration is constrained by test requirements and the caution that appropriately accompanies the start-up of a first-of-a-kind nuclear facility.

The Operations Demonstration will begin with the first shipment of waste to the WIPP facility, and proceed to expected throughput rates for CH-TRU waste, including the phased receipt of RH-TRU waste (which is not required for the Performance Assessment Program). CH- and RH-TRU waste handling operations will be conducted concurrently after each waste handling process has been separately performed. These operations are intended to show that the TRU waste management system can operate safely and effectively at increasing waste throughput rates up to the design operating rates representative of disposal operations.

There are four main Operations Demonstration objectives:

1. Continue with phased approach toward satisfying Congressional intent regarding the purpose and function of WIPP to demonstrate safe disposal of TRU radioactive waste resulting from U.S. defense programs.

TABLE 3-1. TRU WASTE MANAGEMENT SYSTEM SUMMARY CHRONOLOGY

Waste Generating/Storage Sites		
1970	•	Initiate retrievable storage of TRU waste at Idaho National Engineering Laboratory.
1982	•	Definition of TRU waste revised by DOE Order 5820.2.
1984	•	Initial WIPP Waste Acceptance Criteria Certification Program approved for CH-TRU waste.
1985	•	Idaho National Engineering Laboratory Stored Waste Examination Pilot Plant on-line.
	•	Storage of certified CH-TRU waste at Idaho National Engineering Laboratory initiated.
1988	•	Initial WIPP Waste Acceptance Criteria Certification Program approved for RH-TRU waste.
1990	•	Compacted waste to be packaged at Rocky Flats Plant.
1991	•	Storage of certified RH-TRU waste at Idaho National Engineering Laboratory to be initiated.
Transportation System		
1987	•	TRUPACT I design (rectangular package) superceded.
	•	TRUPACT II design initiated.
1988	•	RH-TRU Waste Cask Safety Analysis Report for Packaging completed.
	•	Prototype TRUPACT II delivered for training.
	•	TRANSCOM mock demonstration completed.
1989	•	Testing of TRUPACT II completed.
	•	TRUPACT II Safety Analysis Report for Packaging submitted to Nuclear Regulatory Commission.
	•	TRUPACT II to be certified by Nuclear Regulatory Commission.
	•	Initial TRUPACT IIs to be delivered.
	•	RH-TRU Waste Cask Safety Analysis Report for Packaging to be submitted to Nuclear Regulatory Commission.
1990	•	Final TRUPACT IIs to be delivered.
	•	RH-TRU Waste Cask to be certified by Nuclear Regulatory Commission.
	•	RH-TRU Waste Cask to be delivered.
Waste Isolation Pilot Plant (WIPP)		
1979	•	WIPP established by Public Law 96-164.
1980	•	WIPP Final Environmental Impact Statement issued.
1981	•	WIPP Record of Decision.
	•	WIPP groundbreaking for Site and Preliminary Design Validation.
	•	Initial WIPP Waste Acceptance Criteria issued.
1983	•	Site Preliminary Design Validation Program completed.
	•	Facility construction initiated.
1987	•	Waste Handling and Exhaust Filter Buildings completed.
1988	•	Panel 1 mining completed.
	•	Air Intake Shaft construction initiated.
1989	•	Facility construction to be completed.
	•	RCRA No Migration Variance to be obtained.
	•	Final Safety Analysis Report to be issued.
	•	WIPP operational readiness to be established.
	•	Plan for Test Phase issued.
	•	Supplement to the Environmental Impact Statement to be issued.
	•	Panel 1 alcoves to be mined.

2. Incorporate, within the demonstration of safe operations, the handling of waste to support the TRU waste gas generation tests.

3. Complete the demonstration of safe waste management system operations at rates representative of design throughput operations, including both CH- and RH-TRU wastes.

4. Demonstrate WIPP facility compliance with the requirements of DOE Orders, RCRA, and the EPA Standard, 40 CFR 191, Subpart A, as well as other applicable state and federal regulations, during the Operations Demonstration Program. Compliance with Subpart A of the Standard will be demonstrated per agreement with the State of New Mexico.

A documented Quality Assurance Program will be developed, implemented, and maintained in accordance with DOE Order 5700.6B. The QA Program will provide control over activities affecting quality commensurate with their importance.

Throughout these operations tests, all waste emplaced in the WIPP facility will be retrievable. In accordance with the Consultation and Cooperation Agreement with the State of New Mexico, planning information relative to the actual retrieval of emplaced waste will be prepared consistent with the decision to retrieve, if required.

The succeeding sections of this chapter address the scope of the Operations Demonstration. Section 3.1 provides a summary description of the TRU waste management system, including the waste generating/storage sites, the transportation system, and the WIPP facility. The current status of preparations at WIPP to demonstrate readiness for TRU waste operations is presented in Section 3.2. Section 3.3 is a description of the integrated Operations Demonstration, including the waste-related operations that will be conducted in support of the gas generation tests. Section 3.4 discusses the evaluation of operations.

3.1 WASTE MANAGEMENT SYSTEM DESCRIPTION

The following sections provide descriptions of the DOE TRU waste management system, along with some historical information to provide continuity.

3.1.1 Waste Generating/Storage Sites

Ten DOE sites have been identified as TRU waste generating/storage sites that may ship waste to WIPP over the duration of the Test and Disposal Phases of the Project. Table 3-2 identifies these sites, and the category of TRU waste originating at each. It also identifies the first sites that will ship waste to WIPP for the Operations Demonstration.

In addition to meeting the requirements of the National Environmental Policy Act, each site that will ship waste to WIPP has developed, or will develop, plans and procedures for certifying the waste in accordance with the WIPP Waste Acceptance Criteria. This activity has been phased, initially directed at stored CH-TRU waste at Idaho National Engineering Laboratory and newly generated CH-TRU waste at other sites, followed by RH-TRU waste. After extensive review

TABLE 3-2. TRU WASTE TO BE SHIPPED TO WIPP FOR TEST AND DISPOSAL PHASES

	Waste Types		
	CH-TRU		RH-TRU
Sites	Stored Waste	Newly Generated	
Argonne National Laboratory	No	Yes	Yes
Hanford Reservation	Yes	Yes	Yes
Idaho National Engineering Laboratory	Yes*	Yes	Yes*
Lawrence Livermore National Laboratory	No	Yes	No
Los Alamos National Laboratory	Yes	Yes	Yes
Mound Laboratory	No	Yes	No
Nevada Test Site	Yes	No	No
Oak Ridge National Laboratory	Yes	Yes	Yes
Rocky Flats Plant	No	Yes*	No
Savannah River Plant	Yes	Yes	No

*Sites initially shipping waste during the Test Phase

stored CH-TRU waste at Idaho National Engineering Laboratory and newly generated CH-TRU waste at other sites, followed by RH-TRU waste. After extensive review by the Waste Acceptance Criteria Certification Committee, all sites have been authorized to implement their certification procedures which, together with other records, provide documented evidence that only waste meeting the WIPP Waste Acceptance Criteria will be emplaced at WIPP. The current status of the certification process, covering both CH- and RH-TRU wastes, is shown in Table 3-3. The DOE sites are also periodically audited to ensure continuing adherence to their certification procedures. These audits include representatives of the State of New Mexico's Environmental Evaluation Group.

Shipping TRU waste to WIPP in TRUPACT IIs requires all shipping sites to meet the requirements of the TRUPACT II Certificate of Compliance, Safety Analysis Report for Packaging (NUPAC, 1989), and the TRUPACT II Approved Method for Payload Control. The shippers are preparing implementation plans, similar to those required for waste certification, to control these additional loading parameters. These plans are approved prior to use and are also audited before the first shipment and periodically thereafter.

Personnel at each site are being trained in the opening, loading, closing, and leak testing of TRUPACT II shipping containers. To date, qualified WIPP operators have trained Rocky Flats Plant, Idaho National Engineering Laboratory, Mound Laboratory, Los Alamos National Laboratory, and Lawrence Livermore National Laboratory personnel in these operations. These activities have been performed with a full-scale prototype TRUPACT II and will be followed by training with actual TRUPACT IIs. The readiness of each site to ship TRU waste to WIPP will be confirmed by its formal Operational Readiness Review documentation before operations begin. An overview of each site follows.

TABLE 3-3. SITE CERTIFICATION PLAN STATUS*

	Waste Types		
	CH-TRU		RH-TRU
Sites	Stored Waste	Newly Generated	
Argonne National Laboratory	N/A	Complete	Complete
Hanford Reservation	Future	Complete	Future
Idaho National Engineering Laboratory	Complete	Complete	Future
Lawrence Livermore National Laboratory	N/A	Complete	FY89
Los Alamos National Laboratory	Future	Complete	FY89
Mound Laboratory	N/A	Complete	N/A
Nevada Test Site	Complete	N/A	N/A
Oak Ridge National Laboratory	Future	Complete	Future
Rocky Flats Plant	N/A	Complete	N/A
Savannah River Plant	Future	Complete	N/A

*As of March 1989

IDAHO NATIONAL ENGINEERING LABORATORY (INEL) - The Radioactive Waste Management Complex at Idaho National Engineering Laboratory is used for interim storage of CH- and RH-TRU wastes. This complex includes the Stored Waste Examination Pilot Plant, which became operational in 1985. This facility provides capabilities for radiographic examination, assay of container contents, container integrity examination, and data management resulting in certification and segregated storage of waste containers.

Idaho National Engineering Laboratory has a significant volume of waste that is not certifiable in present form. The Process Experimental Pilot Plant is not expected to be operational prior to 1992. In this facility, solid waste that is not otherwise certifiable as TRU waste in accordance with the WIPP Waste Acceptance Criteria would be shredded, incinerated, and the ash immobilized in concrete.

HANFORD - The Transuranic Storage and Assay Facility began operation in 1985 and is used to assay, inspect, certify, and store newly generated CH-TRU waste, pending shipment to WIPP. This system has established an inventory of CH-TRU waste. In 1996, the Waste Receiving and Processing Facility will be operational. This facility will be used to certify additional CH-TRU waste. Hanford has a limited amount of RH-TRU waste in interim storage and additional RH-TRU waste will be generated.

OAK RIDGE NATIONAL LABORATORY (ORNL) - Oak Ridge National Laboratory has used the Waste Examination and Assay Facility, operational since 1982, to certify its CH-TRU waste inventory. Additional CH-TRU waste is expected to be certified when a new facility is available. Oak Ridge National Laboratory is the largest source of RH-TRU waste in interim storage. Due to the large volume of stored waste, Oak Ridge National Laboratory has been designated the central processing site for all RH-TRU waste.

SAVANNAH RIVER PLANT (SRP) - CH-TRU waste will be certified at the Waste Certification Facility. A new facility will be operational in 1996 to certify additional CH-TRU waste. Savannah River Plant is not a source of RH-TRU waste.

LOS ALAMOS NATIONAL LABORATORY (LANL) - Los Alamos National Laboratory will use existing facilities to certify CH-TRU waste. Additional waste will be certified with new facilities that will become operational during the next five years. Los Alamos National Laboratory is the source of a nominal amount of RH-TRU waste.

NEVADA TEST SITE (NTS) - The Nevada Test Site has an inventory of CH-TRU waste and receives a small volume each year from the Lawrence Livermore National Laboratory. After WIPP begins accepting waste for disposal, Lawrence Livermore National Laboratory will ship directly to WIPP. The Nevada Test Site is a storage site and does not generate any CH-TRU waste; it has no RH-TRU waste.

ROCKY FLATS PLANT (RFP) - The Rocky Flats Plant currently generates about 50 percent of the total annual volume of the DOE TRU waste management system's CH-TRU waste. Limited quantities of newly generated CH-TRU waste are stored at Rocky Flats Plant. In 1988, all the CH-TRU waste that was generated and shipped to Idaho National Engineering Laboratory for interim storage was certified prior to shipment. Once WIPP is operational, the Rocky Flats Plant will ship TRU waste directly to WIPP. In FY90, the Rocky Flats Plant will initiate use of a compactor to process its waste. The compactor will be used to process both soft and hard wastes and will effectively reduce the end point volume of these wastes by approximately a factor of five.

3.1.2 Transportation System

The transportation system for the shipment of TRU waste to the WIPP facility from the DOE generating/storage sites is significant to the overall waste management system operations. It is highly visible and involves the interstate movement of TRU wastes. The transportation system includes newly designed waste packaging systems and trailers for CH- and RH-TRU wastes. The waste shipping containers will meet Department of Transportation Type B packaging requirements for safe transportation of nuclear materials, and will be certified by the Nuclear Regulatory Commission. The transportation system will include the use of satellite tracking to monitor the shipments during transit to and from the WIPP site. Figure 3-1 shows the potential routes for transporting waste to WIPP from each of the TRU waste generating/storage sites. This transportation system spans 23 states and 46 Indian reservations.

The DOE has a long-standing relationship with the State of New Mexico and has consulted and cooperated with the State on transportation matters. In addition to interactions with New Mexico, discussions have been conducted with 22 other states through which TRU waste shipments will be made. The major topics of discussion included shipment routing, emergency response training, and advance shipment information.

Routes within New Mexico were agreed to in 1982, at which time the State and the DOE defined the most likely routes to be used (see Figure 3-1). Prenotification

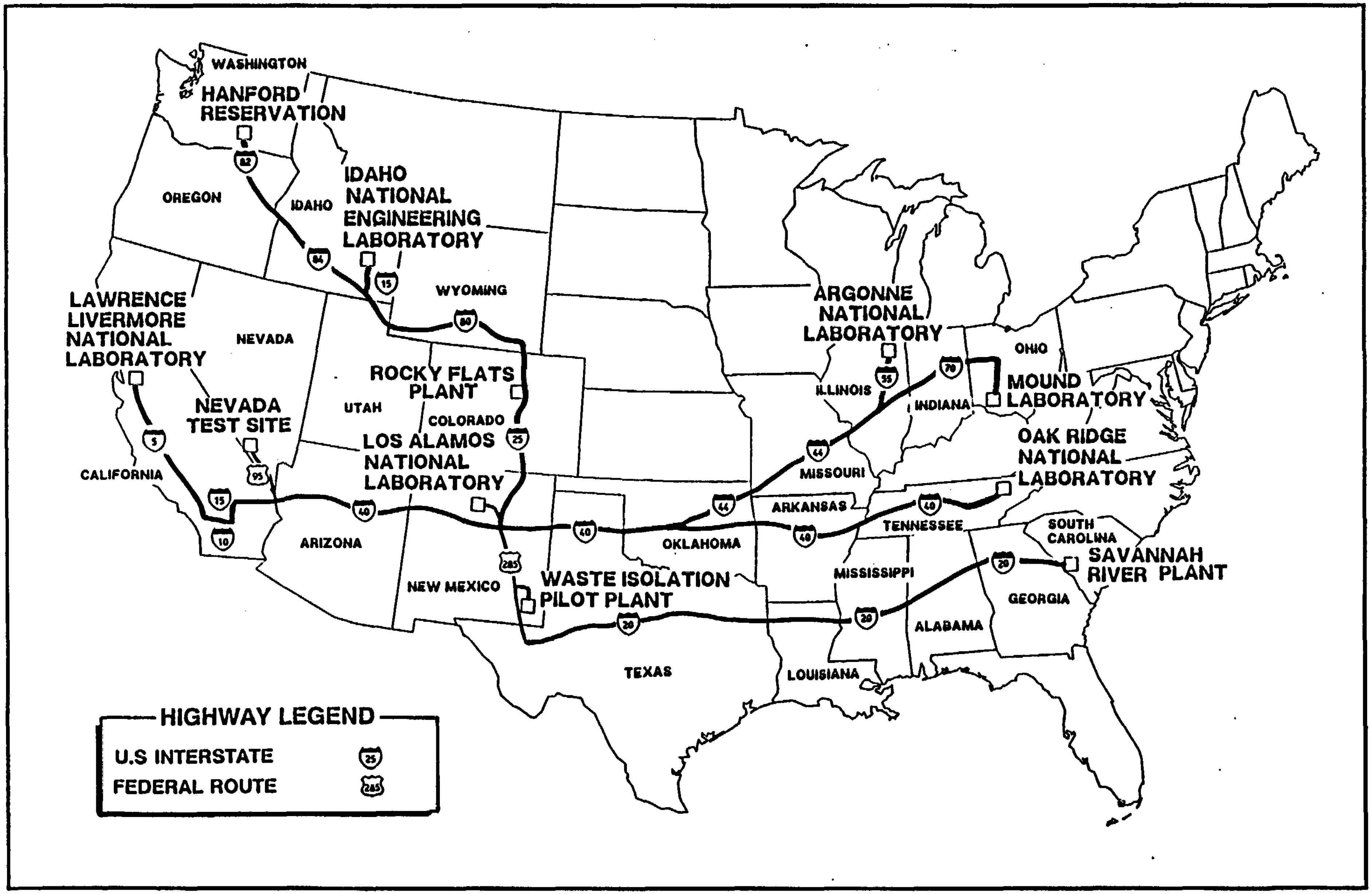


Figure 3-1. Transportation Routes

will be implemented by providing New Mexico, other corridor states, and Indian Tribes/Pueblos access to TRANSCOM. Emergency response training to emergency responders and state officials is being provided in New Mexico and corridor states, as well as to Indian Tribe/Pueblo agencies. As part of a familiarization program, a full-scale mock-up of the TRUPACT II is being used for emergency response training, and to aquaint officials and the public along WIPP shipment routes with the TRU waste management program. These training programs are being sequentially implemented using a corridor approach. The initial shipment corridor is from the Idaho National Engineering Laboratory to the WIPP site and involves the states of Idaho, Utah, Wyoming, Colorado, and New Mexico. Training programs in these five states were completed in 1988.

The two segments of this program are Emergency Response Training and Public Awareness. All work is coordinated through state, reservation, or pueblo officials and relies heavily upon their active participation.

The Emergency Response Training portion consists of three separate courses targeting different groups:

1. Mitigation Course: a one-day course taught to a few state level radiation protection specialists. The purpose of this course is to provide information on the characteristics of TRU waste to individuals who would be involved in assuring that proper clean-up procedures are followed in the event of an accident. These individuals would be the official interface between their state and the DOE.

2. Command and Control Course: a three-day course prepared for a select group of law enforcement and regulatory officers that could be in charge of an accident scene. A wide variety of subjects, from waste characterization to evacuation procedures, are covered in this course.

3. First Responder Course: a one-day course taught to a large number of law enforcement, regulatory, and emergency personnel located along the transportation route. Its purpose is to disseminate basic information on the nature of TRU waste, provide training for initial response to an accident scene, and establish procedures for notification of designated command individuals and organizations.

Work is beginning on a second corridor, from the Savannah River Plant to the WIPP site. This route covers an additional six states: South Carolina, Georgia, Alabama, Mississippi, Louisiana, and Texas. All training within this corridor will be completed prior to shipment of waste along this route. First corridor state training statistics are summarized in Table 3-4.

3.1.2.1 TRUPACT II Shipping Container

CH-TRU waste will be transported in the TRUPACT II shipping container certified by the Nuclear Regulatory Commission. This lightweight container has been developed to enable maximum waste transport per shipment without compromising public or operator safety during loading, unloading, and transport operations. Maximizing the amount of waste transported per shipment is a significant safety factor as it minimizes the total number of shipments. The TRUPACT II (Figure 3-2) can transport up to fourteen 55-gallon drums (assembled as two 7-packs) or up to two Standard Waste Boxes, and is designed for truck transport. Three

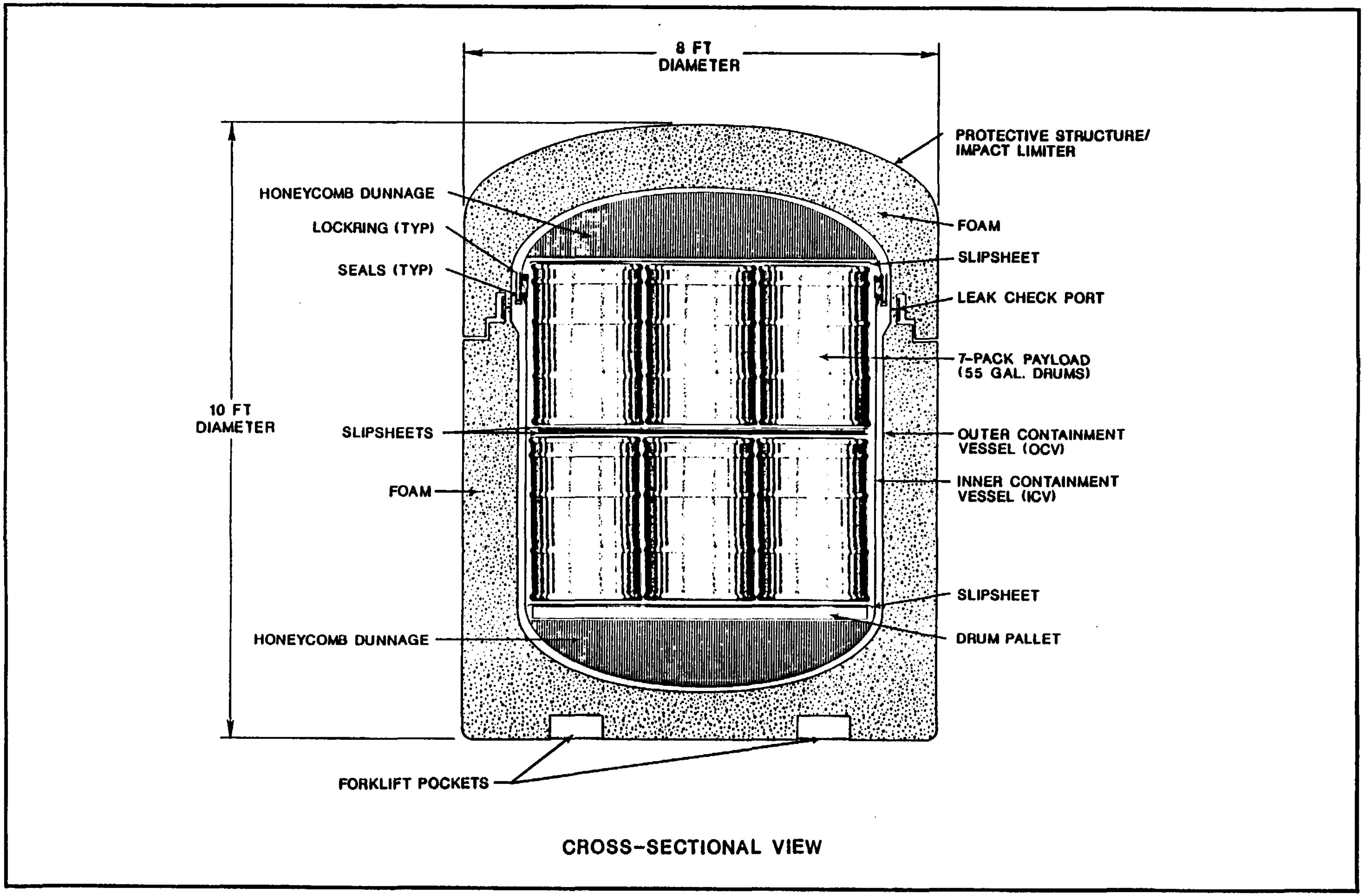


Figure 3-2. TRUPACT II Shipping Container

TABLE 3-4. FIRST CORRIDOR STATES TRAINING STATISTICS

State	Idaho	Utah	New Mexico	Colorado	Wyoming
Dates (1988)	April	April	June/Sept.	May	Sept./Oct.
First Responder Course Students	111	179	663	339	324
Command and Control Course Students	26	21	276	161	245
Mitigation Course Students	17	16	8	17	45

TRUPACT II shipping containers will be transported on each trailer. The TRUPACT II has a payload of about 7,000 pounds; the containers in combination with the tractor and trailer constitute a legal weight shipment with a gross weight not exceeding 80,000 pounds. To achieve this total weight limitation, a specially designed lightweight trailer is used as part of the TRUPACT II transportation system. The TRUPACT II fleet is expected to consist of 17 transport trailers with three TRUPACT II shipping containers per trailer.

3.1.2.2 <u>RH-TRU Waste Shipping Cask</u>

Because RH-TRU waste contains significant gamma radiation, specially designed shielded casks will be used to transport these wastes to WIPP. As with the TRUPACT II shipping container, these containers will be designed to meet 10 CFR 71, Type B packaging requirements and will be certified by the Nuclear Regulatory Commission. The general configuration of the cask is shown in Figure 3-3. As with the TRUPACT II container, a specially designed trailer will be used. RH-TRU waste is placed in canisters for shipment and subsequent emplacement at the WIPP facility. The RH-TRU waste cask, trailer, and tractor constitute a legal-weight shipment. The initial production fleet is expected to consist of three RH-TRU waste cask/trailers.

3.1.2.3 <u>TRANSCOM Tracking System</u>

All waste shipments will be tracked using land based positioning and satellite based two-way digital communication equipment. This tracking concept, TRANSportation COMmunication System (TRANSCOM), is a new system developed under DOE direction to ensure that shipment locations are known at all times. As a result, the system provides invaluable information should an emergency situation be encountered during shipment of waste to the WIPP facility.

The TRANSCOM software accepts positioning data from the Long Range Navigation-C (LORAN-C) positioning system and displays the information on a computer-generated mapping system. Two-way digital communication between the WIPP site

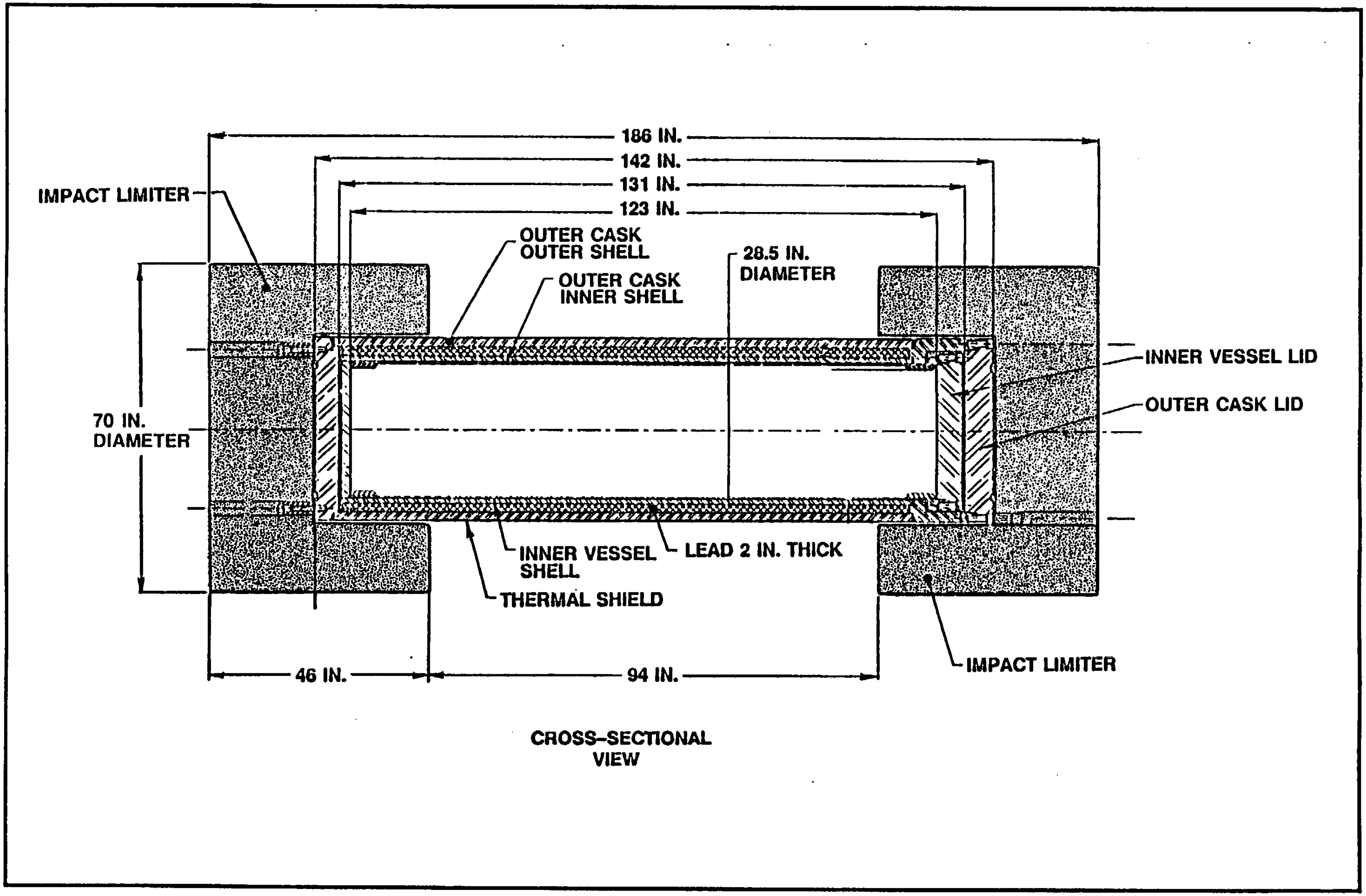


Figure 3-3. RH-TRU Waste Shipping Cask

and the vehicle operators will be accomplished by satellite communications through the TRANSCOM system. The components of this system are shown in Figure 3-4. Access to the TRANSCOM system and its data has been provided to the State of New Mexico, other corridor states, and Indian Tribes/Pueblos.

3.1.2.4 TRUPACT Transportation System Demonstration

The shipment of waste from the waste generating/storage sites to the WIPP facility is an important facet of overall operations. To ensure that personnel at the WIPP facility, the sites, and the commercial contract carrier are prepared to make these shipments safely and efficiently, several trial runs are being made. The first includes a full-size mock-up of the TRUPACT II and simulated waste, including TRANSCOM satellite tracking of the shipment; the second with actual TRUPACT IIs.

The first trial run was successfully performed in January 1989. The trial was based on a round trip between the WIPP facility and the Idaho National Engineering Laboratory. The purpose of the trial was to:

- Simulate preparation for shipment of the TRUPACT IIs to the WIPP facility.
- Conduct all dispatching requirements.
- Train operators at Idaho National Engineering Laboratory to load and unload the TRUPACT II.
- Communicate with drivers and monitor the location of shipments using the TRANSCOM satellite tracking system.
- Establish base transit times between the WIPP facility and Idaho National Engineering Laboratory.

During the transit phase of the trial, several simulated off-normal conditions were reported by the drivers and responded to by WIPP. All operations at WIPP, Idaho National Engineering Laboratory, and in transit were conducted without incident.

When the actual TRUPACT IIs become available, further trials will be conducted, including contacts with appropriate authorities along the routes. The results of the first trial run will be used to modify the conduct of subsequent trial runs and influence the final transportation operations procedures.

3.1.3 Waste Isolation Pilot Plant

3.1.3.1 WIPP Facility Description

The WIPP facilities include surface facilities, shafts and hoists, and the underground or mined facilities. WIPP surface facilities are shown in Figure 3-5. Figure 3-6 shows the underground facilities, including the four shafts.

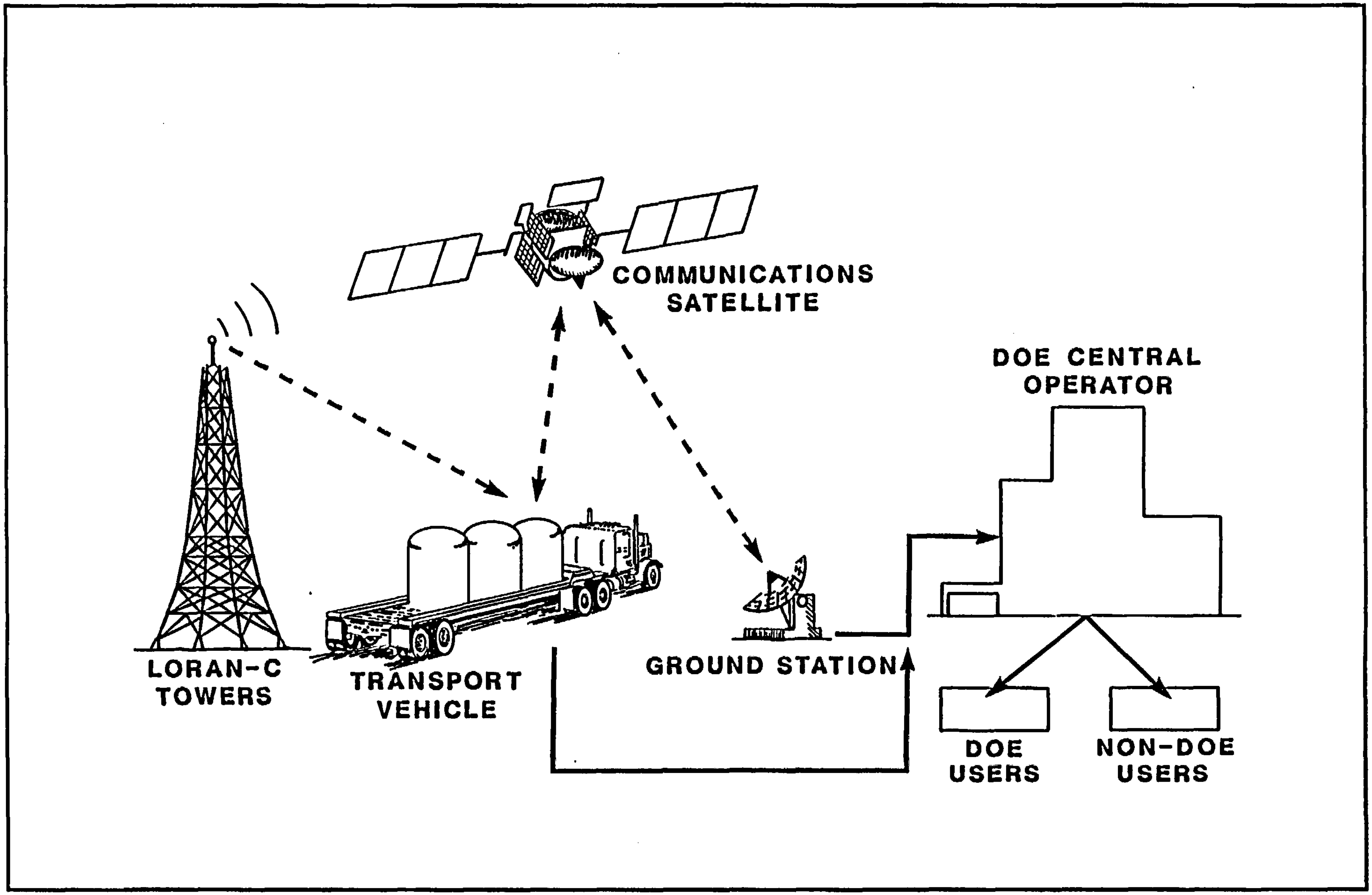
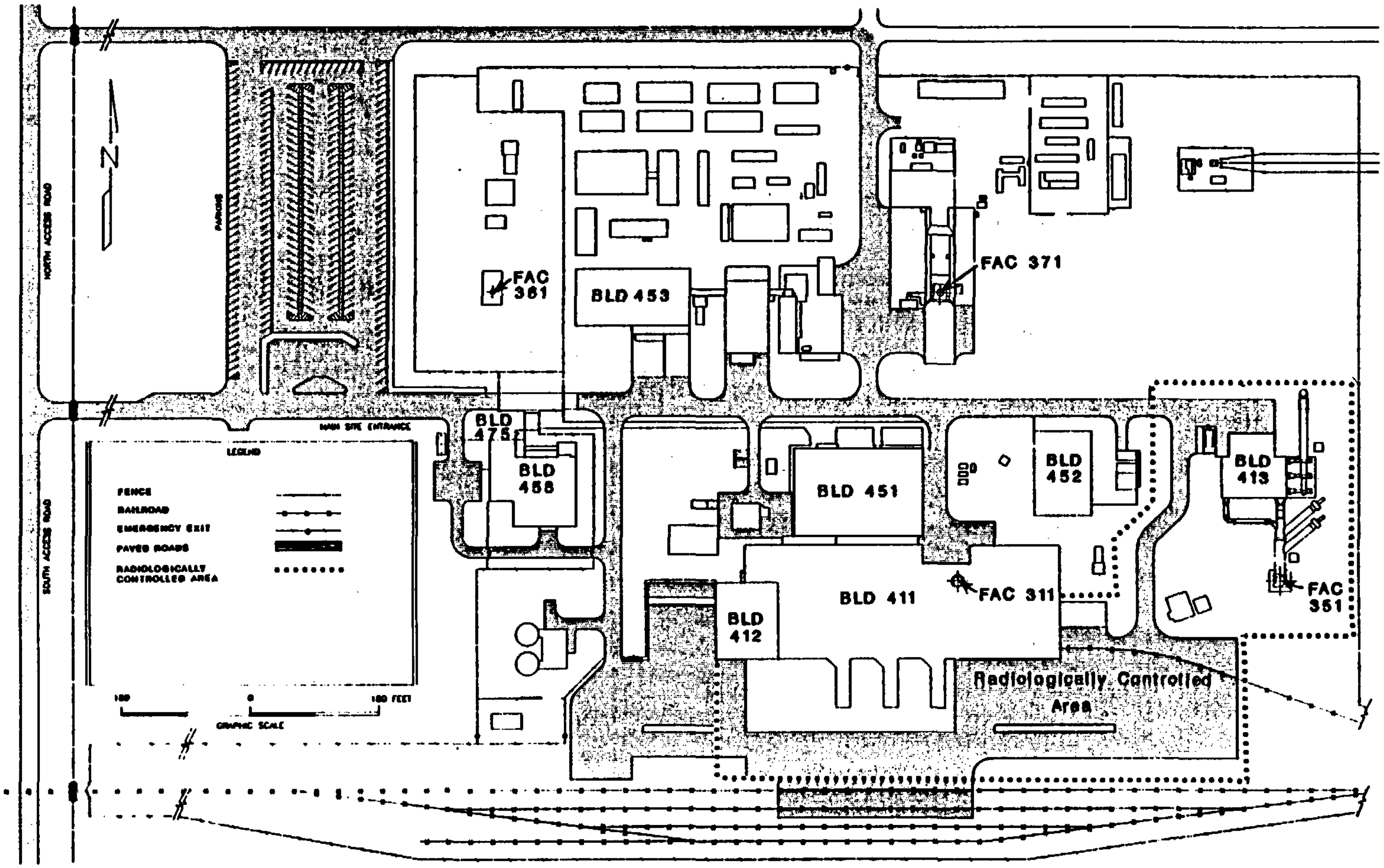


Figure 3-4. TRANSCOM System



WASTE SHAFT	FAC 311	EXHAUST SHAFT FILTER BUILDING	BLD 413
EXHAUST SHAFT	FAC 351	SUPPORT BUILDING	BLD 451
AIR INTAKE SHAFT	FAC 361	SAFETY & EMERGENCY SERVICE FACILITIES	BLD 452
SALT HANDLING SHAFT	FAC 371	WAREHOUSE/SHOPS BUILDING	BLD 453
WASTE HANDLING BUILDING	BLD 411	GUARD AND SECURITY BUILDING	BLD 458
TRUPACT MAINTENANCE BUILDING	BLD 412	GATEHOUSE	BLD 475

Figure 3-5. WIPP Surface Facilities

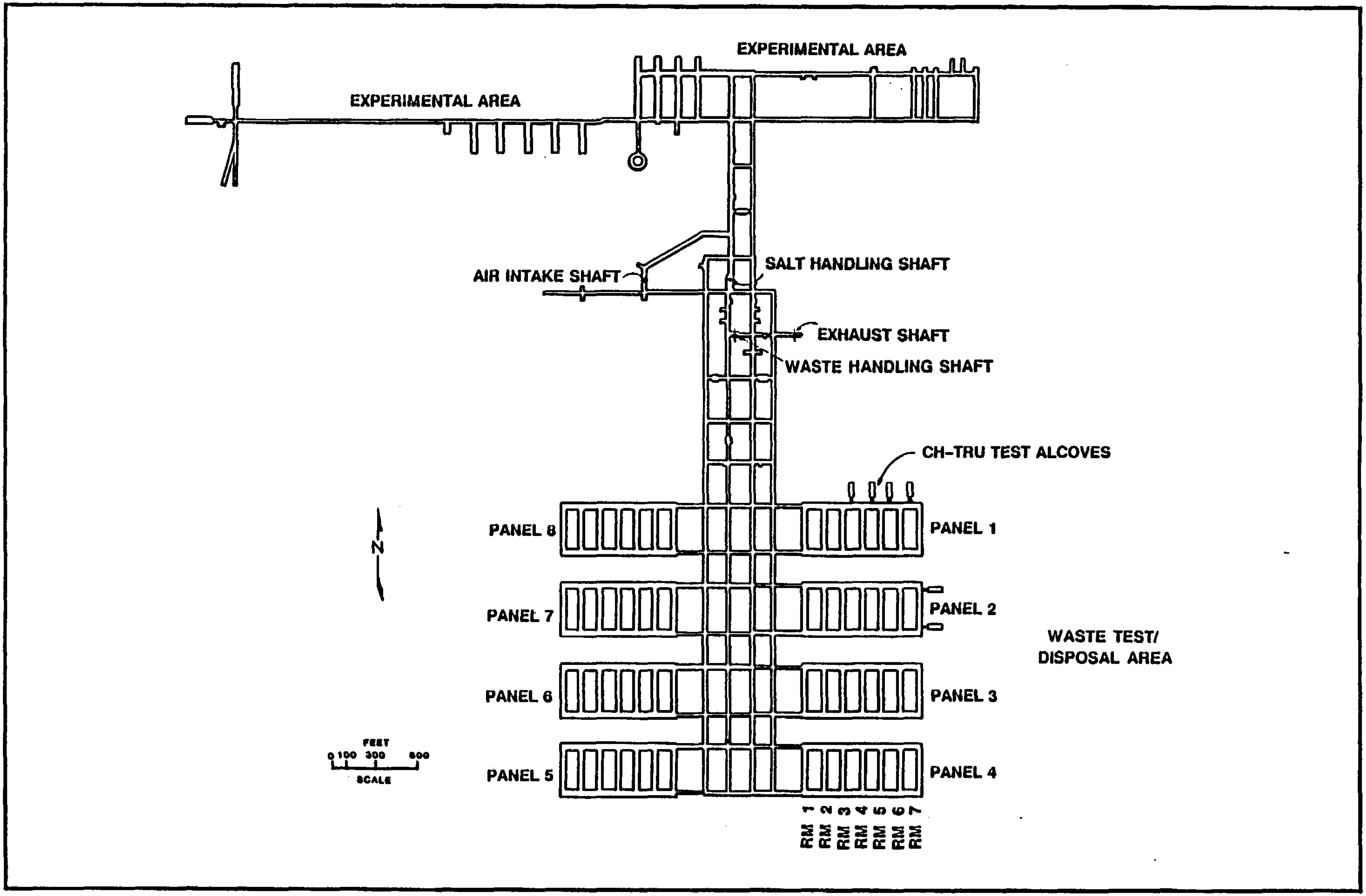


Figure 3-6. WIPP Underground Facility

Surface Facilities

Surface facilities directly associated with waste receipt consist of the Security Inspection Area, the trailer exchange area, the Radiologically Controlled Area, and the Waste Handling Building, which constitutes the surface portion of the Radioactive Materials Area. Major surface support facilities include the Support Building, the Central Monitoring System, the Exhaust Filter Building, on-site backup power systems, and an Emergency Operations Center.

Both CH- and RH-TRU wastes will be transported to the WIPP site by truck on public highway systems. Transportation vehicles enter the fenced perimeter by way of the Security Inspection Area where the waste is checked for radioactive contamination, external radiation, and proper documentation. The shipment is then routed to the trailer exchange area where the driver exchanges a loaded trailer for an empty trailer. When ready to conduct unloading operations, waste handling technicians move the loaded trailers inside the fenced Radiologically Controlled Area to just outside the Waste Handling Building. Shipping containers are not opened until they are inside the Waste Handling Building.

WASTE HANDLING BUILDING - The primary function of the Waste Handling Building and its associated systems is to provide a controlled facility to unload waste from incoming shipping containers and transfer the waste to the underground by way of the waste hoist (elevator). The general floor plan of the building is shown in Figure 3-7. The Waste Handling Building is divided into four functional areas: (1) CH-TRU waste handling; (2) RH-TRU waste handling, which includes the hot cell; (3) support; and (4) waste hoist. The CH-TRU waste area includes an Overpack and Repair Room which is used for unloading operations in the event a TRUPACT II container shows evidence of high internal contamination levels. Because the Waste Handling Building acts as a confinement barrier to control the release of radioactive material, the building has been designed to resist a design basis earthquake and design basis tornado. In addition, the building is maintained at a negative pressure relative to the outside, with a pressure distribution inside the building such that the leakage air flows toward areas of increased contamination potential. Air locks are included at key points in the building to control air flow. Exhaust air from the building flows through high efficiency particulate air (HEPA) filters to a stack outfitted with an Effluent Monitoring System.

CENTRAL MONITORING SYSTEM - The continuously manned Central Monitoring System is located in the Central Monitoring Room of the Support Building. The Central Monitoring Room is the primary monitoring point for the WIPP facility and WIPP TRU waste shipments. It houses the TRANSCOM vehicle tracking system, the Central Monitoring System computer and its ancillary equipment, and provides access to all of the plant's communications systems. From the Central Monitoring Room, operators have access to a variety of plant operating conditions and parameters, including, but not limited to:

- Radiation Monitoring System status,
- Effluent Monitoring System status,
- Building pressures,
- Electrical power distribution system status,
- Fire alarm and suppression system status,
- Meteorological data,
- Heating, ventilation, and air conditioning modes and status,

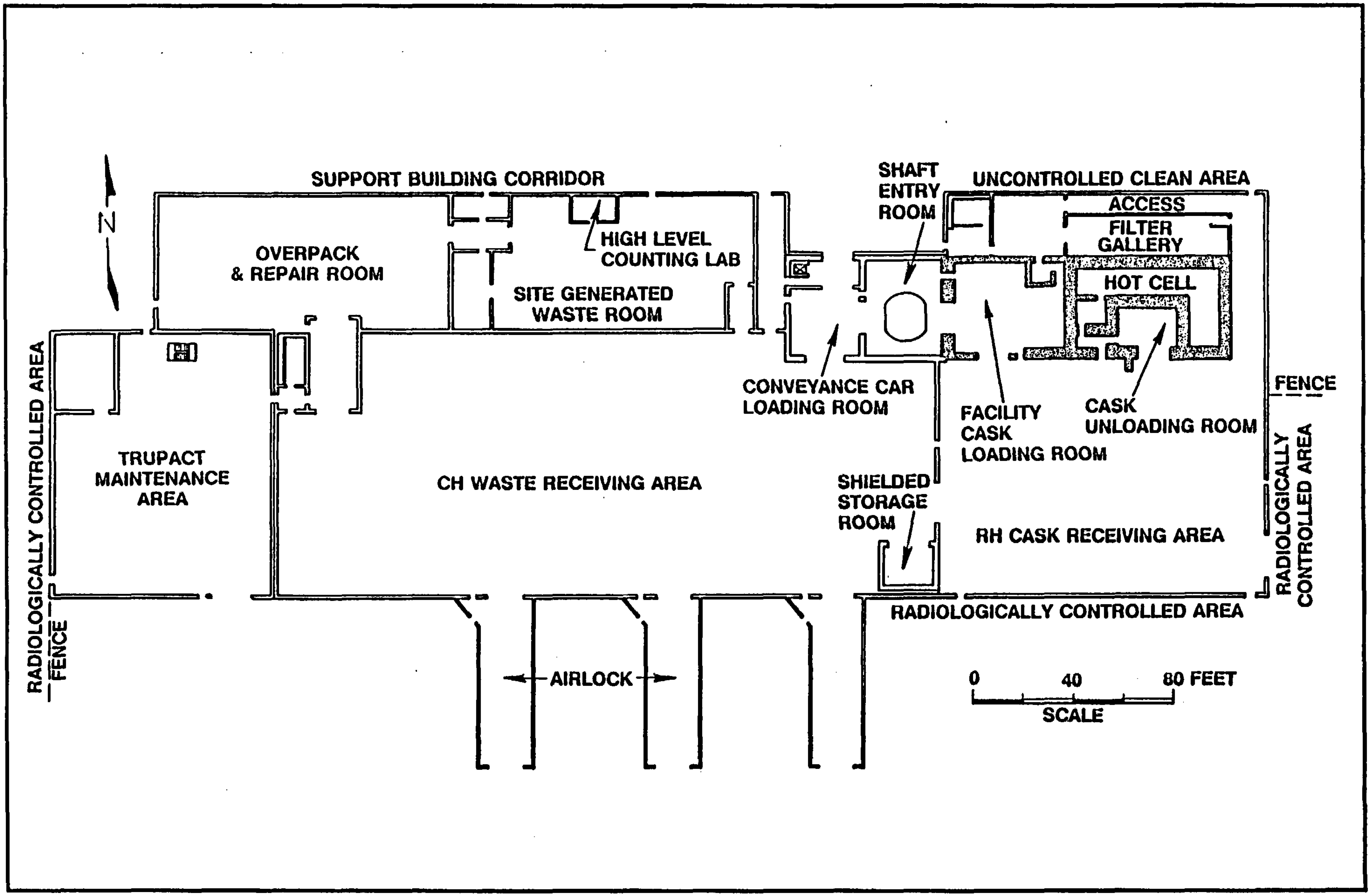


Figure 3-7. Waste Handling Building Floor Plan

- Exhaust Filter Building status,
- Security door positions, and
- TRU waste vehicle shipment status.

The Central Monitoring System has a limited control capability including start-up of the on-site backup power system, realignment of critical electrical loads, and operation of the Exhaust Filter Building diversion valves.

POWER DISTRIBUTION - The basic design philosophy of the WIPP facility electrical system is to use normal utility power supplied by Southwestern Public Service. In the event of loss of normal utility power, on-site diesel generators will provide AC power to important facility electrical loads. Start-up of the diesel generators is not automatic; however, they can be started remotely from the Central Monitoring Room. Uninterruptible power supply units are also on-line to provide DC battery power to critical monitoring systems including radiation monitoring systems, the Central Monitoring System, local processing units, and the Effluent Monitoring System. These uninterruptible power supply units provide power for a minimum of 30 minutes during which time the on-site diesel generators can be brought on-line. With respect to electrical supply, the WIPP facility design is fail-safe; critical systems are uninterruptible. Upon loss of either utility or diesel generator power, the Exhaust Filter Building goes into the high efficiency particulate air filter mode and waste handling and other operations cease; therefore, there will be no significant impact to public or operator safety in the event of a power outage.

RADIATION MONITORING SYSTEM - A radiation monitoring system is in place at WIPP to supplement the personnel and area radiation survey provisions of the plant radiological control program to assure that radiation exposures are maintained as low as reasonably achievable (ALARA). The Radiation Monitoring System includes area radiation monitors, airborne particulate radioactivity monitors, and effluent monitors, which are described separately below. The equipment gives visual and/or audible signals that annunciate locally and in the Central Monitoring Room. Critical Radiation Monitoring System units are powered by the uninterruptible power supply system in the event of a power outage. Except for the automatic underground filtration system operation, these alarms require operator response and corrective action.

Area radiation monitors are located in normally accessible areas to provide indications of changes in the immediate operational environment of the plant. These monitors, which sense gamma radiation, are located throughout appropriate areas of the surface and underground facilities. Occupied areas on the surface and in the underground with potential for contamination are monitored by continuous air monitoring equipment, including beta-gamma and alpha sensitive detectors. Fixed air samplers are used in areas where personnel occupancy will be low.

EXHAUST FILTER BUILDING - The Exhaust Filter Building is adjacent to the Exhaust Shaft. This building houses the filtration equipment associated with the underground ventilation system as well as elements of the Effluent Monitoring System. The boundary of the Exhaust Filter Building is a Radioactive Materials Area. Ventilation fans are located adjacent to the building. Under normal conditions, fans draw air from the underground and, because normally there is no measurable contamination in this stream, the air is exhausted through the stack, bypassing the high efficiency particulate air filters. In the event of an underground radiological release which exceeds the setpoint, air flow from the underground is automatically reduced to about one-seventh of normal flow and is diverted through the high efficiency particulate air filtration units located in this building to remove airborne radioactive particulates from the air stream. Since the building structure and the ducting from the Exhaust Shaft perform a primary containment function, these items are designed to resist a design basis earthquake as well as a design basis tornado.

EFFLUENT MONITORING SYSTEMS - The Effluent Monitoring Systems are used to monitor airborne release points from the WIPP facility. These points are continuously monitored to ensure that off-site releases do not exceed safe regulatory limits as defined by 40 CFR 191, Subpart A, and 40 CFR 61, Subpart H. The WIPP Project will demonstrate compliance with both of these regulations by continuously sampling the airborne effluent and then modeling the release and dispersion of any detected radionuclides through the environment to the maximally exposed individual. With respect to both regulations, the purpose of the effluent monitoring program will be to show that doses to the public will be as low as reasonably achievable.

EMERGENCY OPERATIONS CENTER - The WIPP facility includes an Emergency Operations Center to be used in the event of on-site or off-site emergencies resulting from WIPP-related activities. The primary function of the Emergency Operations Center is to provide a command and control function. This facility has several redundant means of communication including radio, telephone, a separate dedicated telephone line to the DOE Albuquerque Operations Office satellite, and personal computer. The Emergency Operations Center can communicate with an equivalent Emergency Operations Center located at the DOE-Albuquerque Operations center and with other DOE sites, as well as with State and local government agencies. The Emergency Operations Center is provided with emergency power from batteries and a backup generator. The Emergency Operations Center would be activated and manned to provide the requisite level of management and technical expertise to successfully control, mitigate, and recover from emergency events. Should it be required, a backup Emergency Operations Center is located in Carlsbad, New Mexico.

Shafts and Hoists

WASTE HOIST - The primary interface between the surface and the underground is the Waste Hoist which is located in the Waste Handling Shaft. This conveyance is used primarily to transfer waste to the underground. It has a rated capacity of 45 tons, which is sufficient to transport loaded CH-TRU waste pallets or the loaded RH-TRU waste facility cask. The waste hoist is also used to transport personnel and large items to the underground, but not concurrent with waste transfers. It is located at the juncture of the RH-TRU and CH-TRU portions of the Waste Handling Building to serve each area independently.

AIR INTAKE SHAFT - The Air Intake Shaft is the major ventilation air source for the underground. Figure 3-8 shows the normal underground ventilation flow. There are three primary flowpaths in the underground. Separate ventilation flow is provided to the experimental area, the active waste handling portion of the test/disposal area, and the active mining portion of the disposal area. To preclude the potential for contamination spread, the ventilation path for the waste handling portion of the test/disposal area is maintained at a negative pressure relative to the other flowpaths. Return air from each of these areas flows up the Exhaust Shaft.

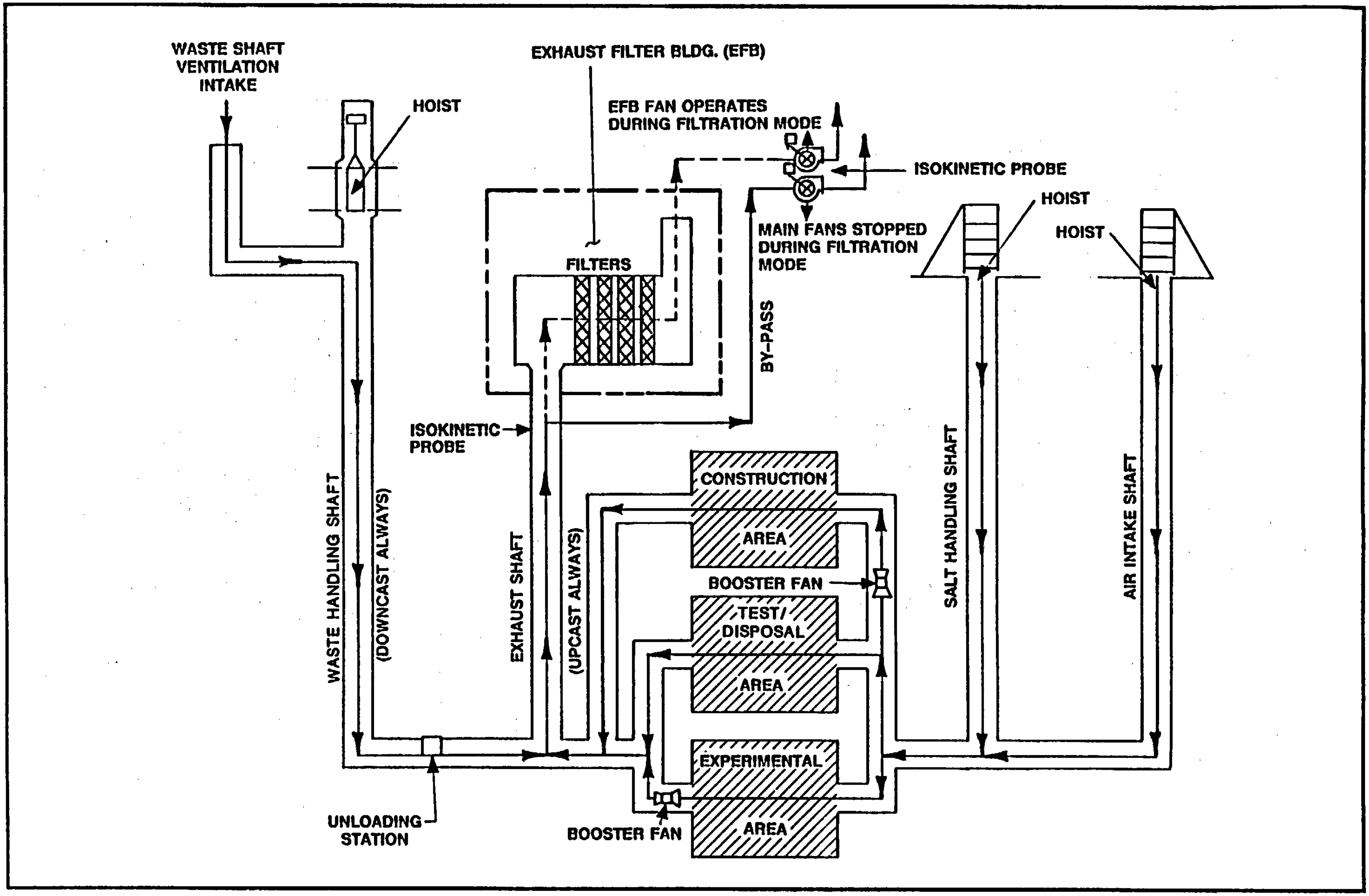


Figure 3-8. Underground Ventilation Diagram

EXHAUST SHAFT - The Exhaust Shaft is the only exhaust airflow path from the underground facility. Two ventilation exhaust fans provide the normal driving force for underground ventilation. The Exhaust Shaft is also instrumented for monitoring the effluent air for radioactive contamination. If a high airborne activity is detected at the Exhaust Shaft, equipment at the Exhaust Filter Building automatically, or on command from the Central Monitoring System, shifts the ventilation exhaust air through two high efficiency particulate air filter trains prior to release to the atmosphere through a stack. The Exhaust Filter Building system incorporates two Effluent Monitoring Systems.

SALT HANDLING SHAFT - This shaft is used to carry mined salt to the surface and can be used to transfer mining personnel to and from the underground workings.

Underground Facilities

The underground is divided into three major areas (see Figure 3-6): the experimental area, where various nonradioactive experiments are performed; a shaft pillar area, which encompasses the various shafts and is characterized by a low extraction ratio to ensure shaft stability; and the waste test/disposal area. The disposal area is designed in an eight-panel array, with each panel containing seven rooms. Mining is required to support continued excavation of additional waste disposal panels. Waste handling operations are conducted in the underground Radioactive Materials Area, which is separated from the other two areas by bulkheads and airlocks. The Radioactive Materials Area contains the transport routes between the waste hoist underground station and the waste disposal panel. The underground ventilation flows are designed and adjusted to maintain the Radioactive Materials Area pressure negative with respect to the balance of the mine. This ensures that any radioactive materials that may potentially become airborne cannot leave except by way of the Exhaust Shaft.

3.1.3.2 WIPP Operations

The WIPP operations described in this subsection are intended to supplement the previous facility descriptions and provide a more thorough functional description of the WIPP facility.

Waste Handling Operations

CH-TRU WASTE - The basic CH-TRU waste handling process, including surface and underground operations, is outlined in Figure 3-9. Following unloading from the transport trailer, individual TRUPACT IIs are brought into the CH-TRU waste receiving bay of the Waste Handling Building through an airlock system. Electric forklifts are used for this transfer operation. The TRUPACT II is placed in an unloading position in one of the two unloading docks. Following radiological and operational checks, a five-ton capacity overhead bridge crane removes the lids of the TRUPACT II. The palletized contents are then removed and placed on an adjacent facility pallet. The facility pallet, capable of holding the contents of two TRUPACT IIs, is transferred by electric forklift onto the conveyance loading car inside the conveyance loading room adjacent to the waste hoist. The conveyance loading car is an electric driven railcar with a bed that can be raised and lowered. It is driven with its load onto the waste hoist conveyance materials deck where it deposits the facility pallet. The conveyance loading car is returned to the conveyance loading room, leaving the loaded waste hoist free to transport the facility pallet and cargo underground.

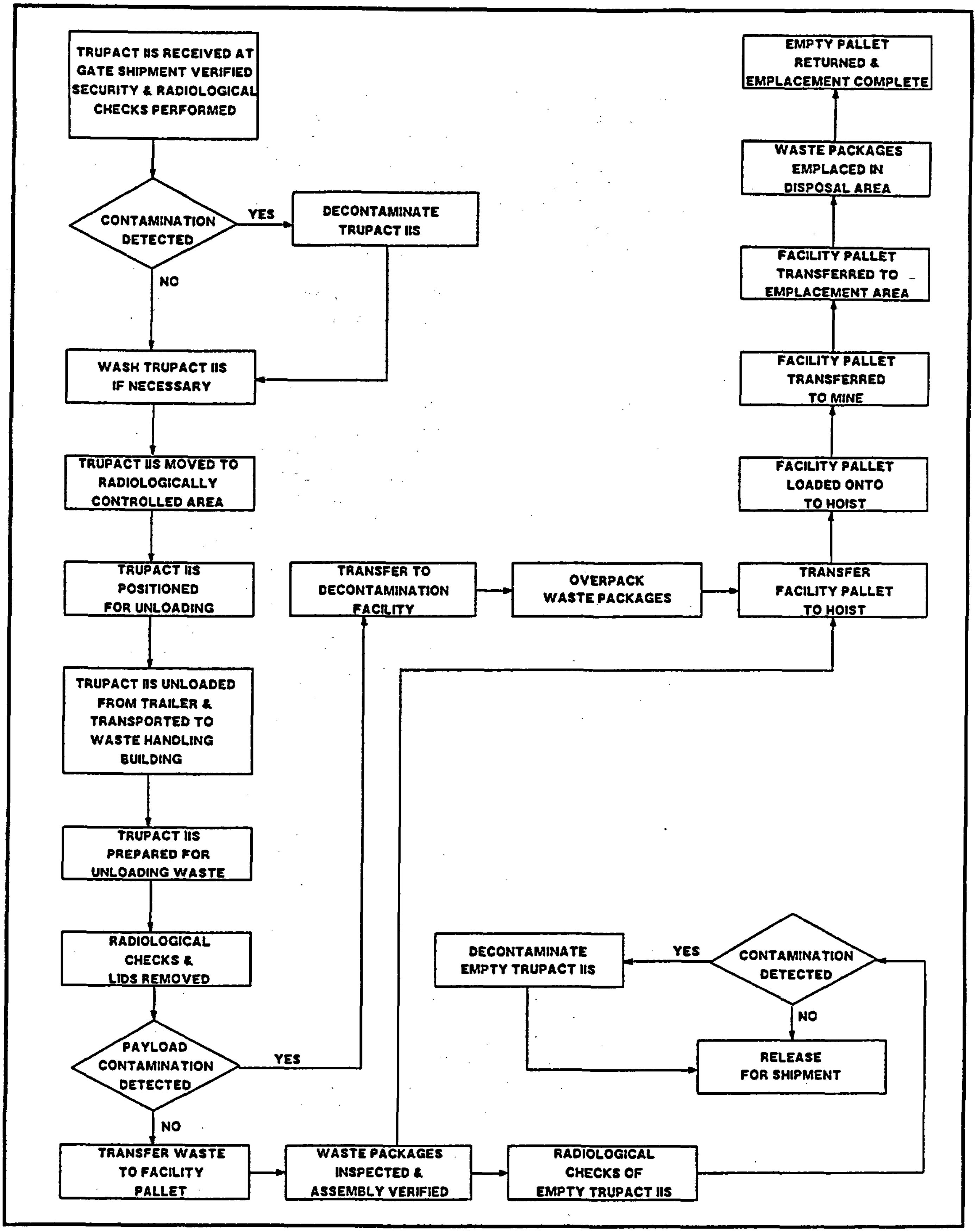


Figure 3-9. CH-TRU Waste Process Diagram

CH-TRU waste arrives underground via the waste hoist on facility pallets. An underground transporter offloads the pallet from the conveyance and transports it to the waste disposal panel. In the disposal panel the waste is unloaded from the transporter by a lift truck outfitted with a slip sheet attachment and placed in the waste stack. The typical emplacement configuration is shown in Figure 3-10. This configuration provides adequate clearance between the waste stack and the walls and roof of the room such that creep closure of the salt formation does not result in salt contact with the emplaced waste. Once placed in the waste stack in the disposal room the waste package location is recorded either manually or with the use of the bar coding system. This information is then transferred to the WIPP Waste Information System (WWIS) for retention as a permanent record.

RH-TRU WASTE - The RH-TRU waste arrives in a shielded shipping cask and is taken directly into the RH receiving high bay on the east end of the Waste Handling Building (see Figure 3-11 for the process steps). RH-TRU waste is contained in canisters, nominally 26 in. in diameter by approximately 10 ft long. The canister is outfitted with a pintle which is used for remote handling operations. Waste handling technicians upright and place the shipping cask on a transfer car utilizing the 140-ton capacity overhead bridge crane. While on the transfer car, radiological and operational checks are completed and the cask outer lid is removed and the inner lid is prepared for removal. The transfer car is then driven into the cask unloading room and positioned beneath a removable shielded port in the floor of the hot cell. The cask unloading room shield door is closed, providing shielding during the balance of the unloading sequence. A 15-ton overhead bridge crane inside the hot cell is used to remove the shielded floor port plug, the cask inner lid, and finally the RH-TRU waste canister. Once inside the hot cell, the canister is inspected and checked for surface contamination. The canister leaves the hot cell via another floor port shield valve and is transferred via a shuttle car to a position beneath the facility cask loading room. The facility cask, carried by a transfer car, is positioned in a vertical orientation over the shield port and a grapple transfers the canister into the facility cask. End shield valves on the facility cask and a shield bell are used to maintain shielding during the transfer operation. During the process of moving the facility cask to the hoist, the cask is rotated to a horizontal orientation for transfer underground.

Single RH-TRU waste canisters contained within the shielded facility cask arrive underground on the facility cask transfer car. The car is driven off the waste hoist to an area accessible by a 41-ton capacity diesel forklift. The forklift removes the facility cask from the transfer car and transports the cask to the waste disposal panel where the horizontal emplacement and retrieval equipment has been prepositioned at the desired disposal location. To ensure retrievability during the Test Phase, the RH-TRU waste canister is emplaced in a horizontal, steel-sleeved hole in the wall (rib) of the disposal room (Figure 3-12). The sleeve is designed to withstand lithostatic pressure resulting from salt creep. Emplacement is accomplished by a hydraulic ram in the machine that pushes the canister out of the cask and into the borehole. Personnel are shielded from the canister by a shield plug which is similarly emplaced in the location between the emplaced canister and the room. The horizontal emplacement and retrieval equipment is then moved to the next borehole in preparation for emplacement of the next canister. The canister's location is retained as a permanent record.

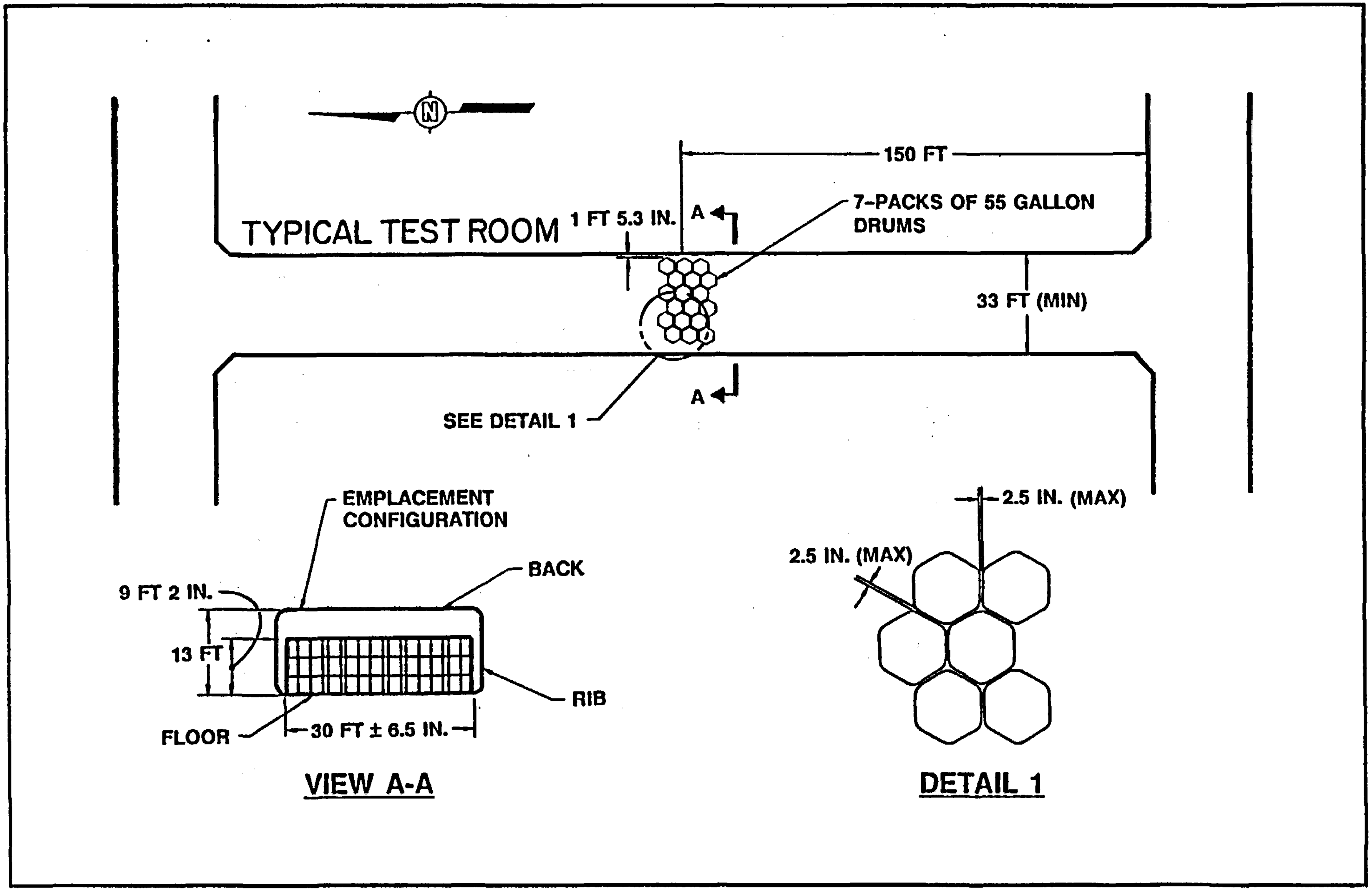


Figure 3-10. Typical CH-TRU Waste Stack Configuration

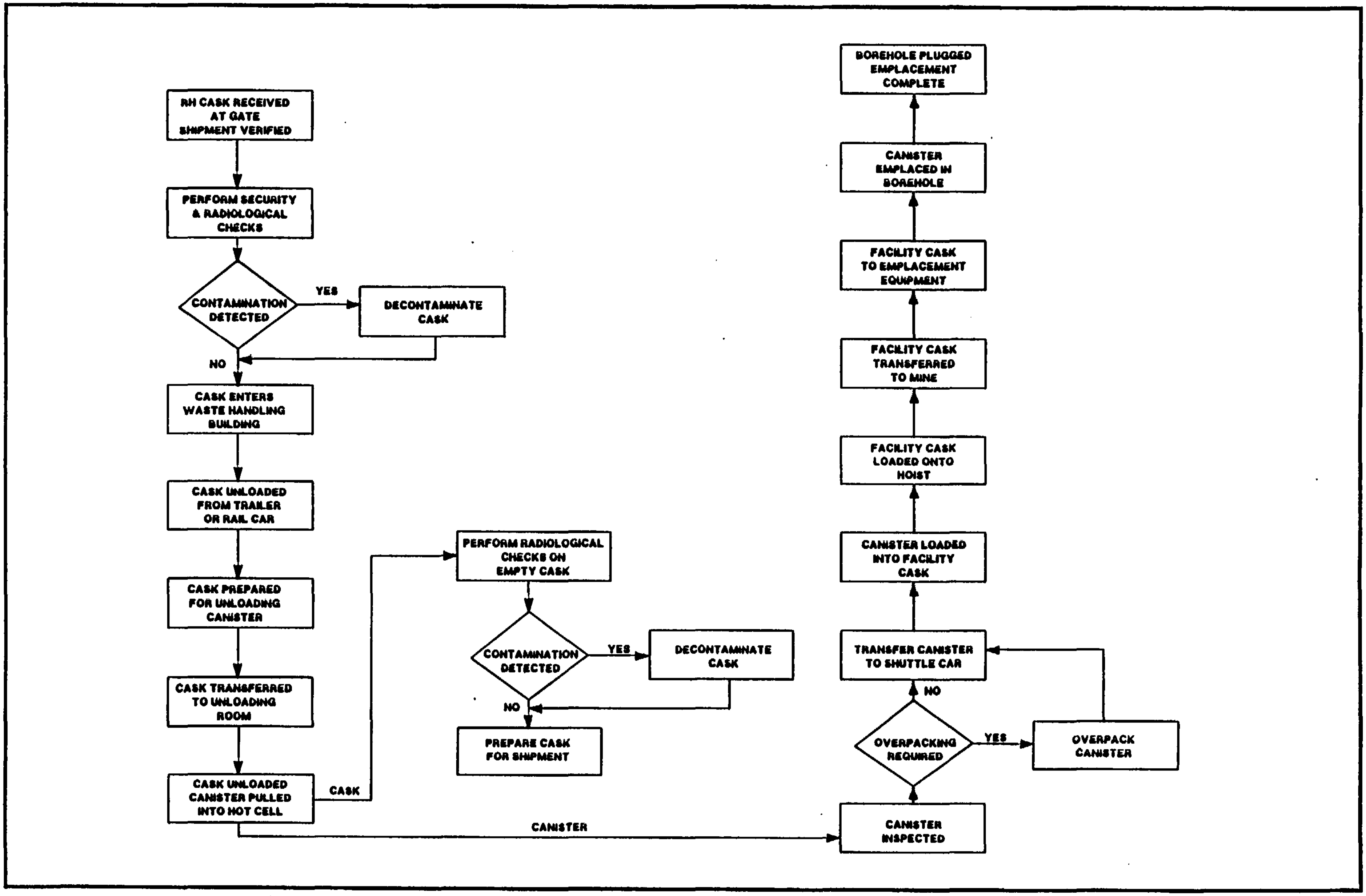


Figure 3-11. RH-TRU Waste Process Diagram

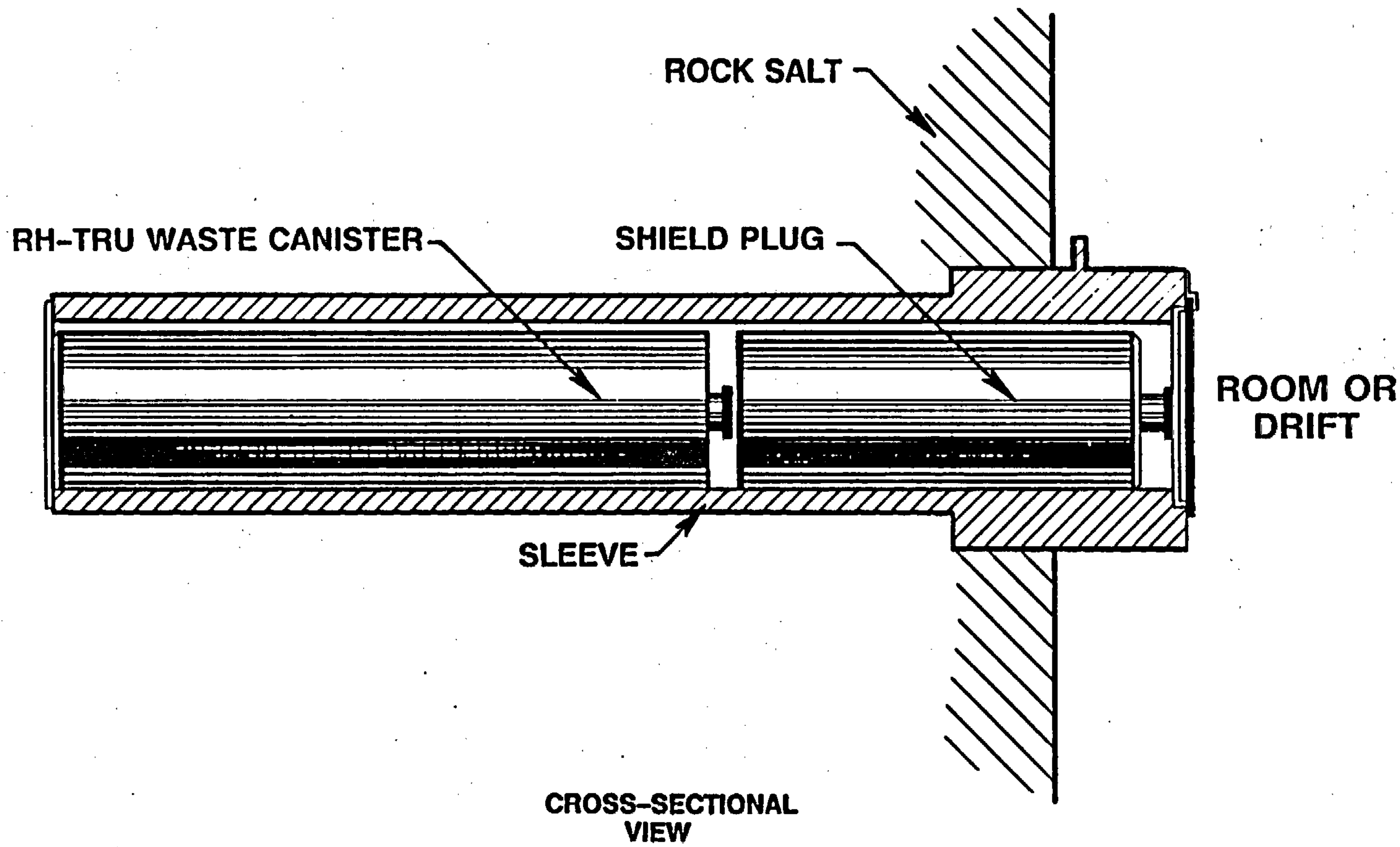


Figure 3-12. RH-TRU Waste Emplacement

Facility Operations

The facilities operations consist of the operation of supporting facilities, equipment, systems, and structures. Facility operations are conducted with the prime objective of supporting waste handling functions, experimental activities, and mining operations. These operations include:

- Heating, ventilation, and air conditioning systems,
- Electrical distribution system,
- Water and sewage system,
- Fire main system,
- Surface compressed air systems,
- Surface portion of the mine ventilation system, and
- Central Monitoring System.

These systems are continuously monitored by operations personnel to assure the proper functioning of the equipment and facilities. In addition to recording equipment operating parameters, operators notify maintenance personnel if abnormalities are noted. The Central Monitoring System is operated around the clock to monitor facility performance and status.

Functions monitored through the Central Monitoring System include personnel access to critical surface and underground working areas, waste handling operations, heating, ventilation, air conditioning, diesel generator operations, electrical distribution breakers, hoist status, underground facility ventilation, radiation monitoring, facilities equipment operations, fire protection, and plant security. Should the Central Monitoring System become disabled, equipment to monitor and maintain the plant in a safe condition can be operated and monitored from appropriate local control panels.

Mining Operations

Mining is accomplished by continuous mining machines. A separate mining ventilation circuit is maintained by temporary and permanent bulkheads. Air pressure in the mining side is maintained higher than in the waste side to ensure that any leakage results in air flow to the waste side. The mining sequence must progress such that a full panel is completed, including outfitting with utilities and appropriate bulkheads, before the next panel is started and waste emplacement can commence in the fully mined and outfitted panel.

Prior to mining in new areas, probe holes are drilled into the mining face to ensure that brine and gases are not present. During and immediately after mining, a survey of the roof (back) of all drifts is made to identify areas of safety or stability concerns. Remedial work is accomplished immediately, as required. Rock bolts are commonly used throughout the underground for safety and openings stability.

The mined salt is transferred from the mining area to the salt handling hoist by diesel powered haul trucks. The salt handling hoist, with a capacity of eight tons, transfers the salt to the surface where it is moved to the salt storage pile located just north of the perimeter fence.

3.2 WIPP READINESS

Before waste is transported to WIPP, all activities necessary to ensure that the WIPP facility and transportation system function as designed will have been performed. Many have been completed, including construction of the WIPP facility, waste handling demonstrations, waste retrieval demonstrations, personnel training without radioactive waste, transportation preoperational checkouts, emergency preparedness training and drills, and interactions with corridor states and Indian reservations through which waste will be shipped. The remainder will be complete before waste is shipped to WIPP, including an Operational Readiness Review and a Preoperational Appraisal.

The following sections present a summary status of WIPP's preparations for and readiness to operate with radioactive waste and thereby perform the Operations Demonstration. These sections will address readiness in two categories. The first, Section 3.2.1, Facility and System Readiness, covers hardware and completed or planned operational demonstrations. The second category, described in Section 3.2.2, Readiness Assessment, includes those significant and pertinent management and oversight reviews that have been conducted or are scheduled. This readiness assessment initially addresses CH-TRU waste, to be followed by a separate assessment addressing RH-TRU waste.

3.2.1 Facility and System Readiness

3.2.1.1 Start-Up Testing

Upon completion of construction, a formal start-up program was implemented for critical systems and subsystems with the primary objective to verify proper operation with emphasis on the integration of these systems with other interfacing systems previously completed. This process employed formal start-up procedures and required documentation, tracking, and resolution of discrepancies or deficiencies identified during the start-up tests. The satisfactory completion of start-up testing is a prerequisite for implementation of routine operations with waste.

The general scope of this program is extensive and covers all critical operating systems. The start-up testing program is being conducted in two discrete phases which are related to the two TRU waste types. Since CH-TRU waste will be received at WIPP before RH-TRU waste, the critical CH-TRU waste related systems were addressed first. A total of 56 critical systems relating to CH-TRU waste were identified. A partial listing of these critical systems includes:

- Waste handling facility, including the Waste Handling Building and Exhaust Filter Building;
- Shaft and hoist systems, including Waste Handling, Salt Handling, Exhaust, and Air Intake Shafts;
- CH-TRU waste handling system and equipment;
- Mine equipment;
- Monitoring systems, controls and instrumentation, including Radiation Monitoring and Alarm Systems, Central Monitoring System and Communications Systems;

- Utilities, including electrical, water, and fire protection systems; and

- Underground ventilation system, including environmental controls.

By the end of April 1989, all tests applicable to the critical CH-TRU waste operating systems are expected to be completed.

Completion of CH-TRU waste start-up testing also includes many systems that are critical to RH-TRU waste emplacement operations. The equivalent preoperational testing for RH-TRU waste has essentially been completed, except for a limited number of RH-TRU waste specific start-up tests and formal documentation required by the start-up process. This will be completed prior to receipt of RH-TRU waste.

3.2.1.2 Operational Testing

Subsequent to completion of appropriate elements of the start-up testing program, the WIPP project conducted a series of operational demonstrations focusing on the retrievability of both CH- and RH-TRU waste and preoperational demonstrations of the full waste handling processes to be used for waste emplacement. These demonstrations were conducted using nonradioactive mockups of CH- and RH-TRU waste packages. While these demonstrations were part of the planned WIPP phased approach to demonstrate readiness for operations with actual waste, the successful completion of these specific demonstrations was also identified in the Consultation and Cooperation Agreement with the State of New Mexico as prerequisites to the start of WIPP operations with actual waste.

Each of these demonstrations was completed with equipment, personnel, procedures, and methods to be used with actual waste. The demonstrations included the participation of each applicable organizational entity within the WIPP Management and Operating Contractor (Westinghouse Waste Isolation Division), including: Waste Handling Operations, Safety, Security, Radiation Safety, and Quality Assurance. For all of these demonstrations, the projected radiation dose to workers was estimated from time-line data and remained within the requirements of DOE Order 5480.11. Oversight of these demonstrations was provided by the DOE Albuquerque Operations Office, and the State of New Mexico Environmental Evaluation Group.

MOCK CH-TRU WASTE RETRIEVAL DEMONSTRATION

A demonstration of CH-TRU waste retrievability was conducted in September 1987. The demonstration was structured to include a worst-case retrieval scenario (simulated contaminated waste packages and crushed drums) as off-normal events. These off-normal events are not expected; however, they were included to demonstrate the use of appropriate waste handling and as low as reasonably achievable techniques.

The demonstration was completed in Room 1 of Panel 1 of the WIPP underground area. The area was configured to simulate underground conditions expected to be encountered late in the retrieval period. The retrieval period is coincident with the Test Phase and will be extended for up to 10 years beyond the Test Phase if retrieval of waste is required. The effects of salt creep were simulated in establishing the room dimensions, including the effects of floor heave. Even though salt creep is not projected to contact the waste stack, as a worst case scenario the demonstration included use of retrieval techniques that would be employed should stack/salt contact be encountered. A contamination control barrier was installed upstream of the waste stack. This barrier incorporated a pass through system which was used to overpack simulated contaminated waste packages. The percentage of simulated contaminated containers in the demonstration greatly exceeded that which would reasonably be expected if waste retrieval becomes necessary. Of 132 drums and 4 waste boxes installed in the stack, 57 drums and 4 boxes were retrieved. Simulation of contamination on the exterior of some of the waste packages was achieved with fluorescent powder. As a result, the projection of operator exposures is higher than would be expected.

The WIPP CH-TRU waste retrieval operations demonstrated (Westinghouse, 1988j) that:

- Operating personnel responded to a range of conditions in a safe and effective manner.

- Operating procedures, equipment, and operating techniques are acceptable.

- If required, 15 percent of WIPP design capacity waste volume can be safely retrieved while satisfying the radiological requirements of DOE Order 5480.11.

- Retrieval of this quantity can be achieved within 10 years after a decision to retrieve.

- Control of potential contamination can be achieved while retrieving waste from a disposal room environment representative of actual conditions.

The CH-TRU waste retrieval demonstration identified several "lessons learned" that have been incorporated into WIPP operations:

- Equipment used within the retrieval area must be mobile and offer enhanced operator vision.

- Operators wearing anticontamination clothing need to be rotated to avoid loss of concentration and the subsequent adverse effects on the conduct of safe and effective operations.

CH-TRU WASTE PREOPERATIONAL CHECKOUT

The CH-TRU waste handling preoperational demonstration was completed at WIPP in June 1988 (Westinghouse, 1988h). The demonstration, using nonradioactive waste packages, confirmed the acceptability of WIPP waste handling equipment and operations to safely receive and emplace CH-TRU waste at WIPP.

During a one-week period, 10 TRUPACT II shipping containers were processed beginning with preparatory activities outside the Waste Handling Building, progressing through TRUPACT II unloading operations in the Waste Handling Building, and ending with emplacement operations in the underground area. One TRUPACT II was processed through a sequence which simulated a condition of internal contamination. This occurred in the controlled environment of the Overpack and Repair Room.

Five objectives were defined to evaluate the acceptability of the demonstration results:

- Demonstrate that WIPP waste handling personnel are capable of safely handling CH-TRU waste packages, including unloading an internally contaminated TRUPACT II.

- Demonstrate satisfactory operation of WIPP waste handling equipment.

- Demonstrate that WIPP operating procedures are comprehensive and sufficiently detailed to allow performance of normal waste handling operations, and to recover from off-normal occurrences encountered during waste handling operations.

- Establish the aggregate time estimate for WIPP waste handling operations.

- Provide the bases for estimating the doses to be received by WIPP waste handling personnel.

The CH-TRU waste handling demonstration was completed without incident. Based on the demonstration results and computer simulation of the normal waste handling process, the WIPP facility single shift throughput capability for the normal waste handling process is 273,000 cubic feet per year. This compares favorably with an anticipated receival rate of 230,000 cubic feet per year. By conducting two waste handling shifts, the WIPP facility can process the design throughput of 500,000 cubic feet per year.

At the anticipated CH-TRU waste receipt rate of 230,000 cubic feet per year for normal waste handling operations, the combined CH-TRU waste annual operator exposure and the average individual exposure are conservatively projected to be within the requirements of DOE Order 5480.11. These exposure levels are based on a minimum operating crew size. It is expected that actual exposures will be lower due to inherent conservatisms in the analytical methods and models, learning curve effects, and anticipated procedural and process improvements.

MOCK RH-TRU WASTE RETRIEVAL DEMONSTRATION

In May 1987, RH-TRU waste retrieval was demonstrated, using two simulated RH-TRU waste canisters consisting of the same materials (nonradioactive), size, and weight as the actual radioactive canisters. The objectives of this demonstration were similar to those for the CH-TRU waste retrieval demonstration. A major difference between the two demonstrations is the more complex equipment required to handle RH-TRU waste. In addition to demonstrating operating procedures, techniques, and personnel performance, the operability of heavy shielded equipment such as the facility cask and the waste emplacement/retrieval machine had to be verified. Another difference between CH- and RH-TRU waste retrieval is the need to retrieve RH-TRU waste from horizontal sleeved boreholes.

The effects of salt creep on RH-TRU waste canister retrieval are more pronounced than on CH-TRU waste drum or box retrieval due to the inherent size of the emplacement and retrieval equipment. To simulate the minimum dimensions expected after trimming the floor and roof (back) of a room that has experienced 15 years of creep closure, markers were added to the retrieval demonstration room. Equipment was operated within these markers.

The demonstrations included retrieval of a simulated canister and of a simulated overpacked canister. The retrieval sequence consisted of the following basic steps:

- Setting up the emplacement/retrieval equipment at the borehole, including the facility cask.

- Removing the shield plug and canister from the borehole.

- Removing the facility cask and setting up the equipment at the next borehole.

The demonstration was completed without incident and no unanticipated or abnormal conditions developed (Westinghouse, 1987b). The cumulative time required to retrieve the canisters was approximately 72 percent of the estimated time. The total simulated exposure to personnel was well within the requirements of DOE Order 5480.11. No unsafe conditions were encountered during the operations.

RH-TRU WASTE PREOPERATIONAL CHECKOUT

The RH-TRU waste handling demonstrations were successfully completed in March 1988 (Westinghouse, 1988j). As with the CH-TRU waste demonstrations, these operations were conducted with simulated waste packages. A total of five RH-TRU waste canisters were handled and emplaced during this demonstration.

The objectives of this demonstration were similar to those for the CH-TRU waste handling demonstrations. The following operations were performed:

- RH-TRU waste receipt and shipping cask preparations.

- Hot cell operations, including transfer of canisters from the road cask to the facility cask.

- Facility cask movement to and from the underground emplacement area.

- RH-TRU waste emplacement machinery setup, emplacement, and disassembly.

- Canister overpacking to demonstrate the procedure if a canister is received damaged or highly contaminated.

The full sequence of operations was completed without incident and in full accordance with the demonstration procedure and applicable waste handling procedures. Based on timeline data taken during these operations, the WIPP throughput capability was determined to be 286 canisters of RH-TRU waste per year, which exceeds the specified design throughput rate of 250 canisters per year. The projected total operator dose satisfies the requirements of DOE Order 5480.11.

3.2.1.3 Personnel Training

Training of WIPP personnel is an ongoing activity. Since the WIPP Project is a first-of-a-kind endeavor, minimum training requirements are not considered adequate. The training program in place at WIPP is an in-depth program intended to provide safe and efficient operation of the facility.

Training is conducted by a combination of in-house and subcontracted instructors. Areas addressed by the program include initial placement, developmental, and requalification training as applicable for each of the following areas:

General Employee Training: Designed to provide an in-depth look at the operations of the WIPP Project, this training contains sessions on waste handling operations, site security information, general site safety requirements, quality assurance, and an overview of radiation control and protection.

Emergency Response: Site personnel are trained to respond to internal emergencies, such as radiological accidents, personnel injuries, fires, hazardous material spills, simulated system failures, and underground accidents, as well as emergencies external to the WIPP facility.

Safety: This program is designed for all personnel working in waste handling or underground areas, and provides detailed radiation worker and health physics training. It also includes a health physics technician, underground safety, rigging safety, and standard occupational safety training.

Maintenance: A complete maintenance training program is provided for personnel maintaining manipulators, cranes, and hoists, as well as for ventilation and air handling systems. Instrument maintenance, computer maintenance, and general training programs for welding and mechanical maintenance are also included.

Specific System and Facility Operations: Operator training constitutes a large portion of the overall training program. Training is provided for hot cell operations, surface and subsurface waste handling equipment and operations, hoist and crane operations, mining operations, and facility operations.

3.2.2 Readiness Assessment

Assurance that the WIPP facility is ready to receive waste results from the step-by-step review of all project aspects, including previous design reviews, construction, system start-up, operations demonstrations with simulated waste, and waste retrieval demonstrations. Two additional comprehensive reviews are being conducted to establish WIPP's readiness: an Operational Readiness Review (ORR) and a Preoperational Appraisal. The Operational Readiness Review is conducted by the WIPP Management and Operating Contractor while the Preoperational

Appraisal is conducted by an independent group within the DOE. The Operational Readiness Review results are a significant input to the Preoperational Appraisal. These reviews are intended to establish that the WIPP facility is operationally ready to accept waste in a safe and efficient manner. After completion of these reviews, approval of the Final Safety Analysis Report and other prerequisite activities, the DOE Acquisition Executive, with the advice of the Energy System Acquisition Advisory Board, will decide whether the WIPP facility is ready to start operations (Key Decision #4 in Figure 1-4).

3.2.2.1 Operational Readiness Review

The Operational Readiness Review, implemented by the WIPP Management and Operating Contractor, provides a comprehensive overview of safety, administrative, and operational aspects of the WIPP Project. The review provides an evaluation and verification of the operational readiness of critical systems and activities to support waste receipt at WIPP.

The Operational Readiness Review Program was implemented by an Operational Readiness Review Committee and a supporting Operational Readiness Review Team. The Operational Readiness Review Team included technically proficient individuals chosen for their expertise in operations, safety, engineering, security, construction, and administration. The Committee plans and directs the Operational Readiness Review program and is responsible for:

- Implementation of a systematic method to define all critical systems and activities associated with start-up, waste receipt, and program requirements.

- Development of criteria to assess readiness of the critical systems and activities.

- Assuring that all comments resulting from the readiness review are resolved in a timely manner.

- Issuing a recommendation to the General Manager of the Management and Operating Contractor regarding facility readiness.

The Operational Readiness Review Team's responsibilities include:

- Developing a Management Oversight Risk Tree with a corresponding dictionary that defines all basic events required to satisfy readiness.

- Identifying readiness criteria and assessing readiness.

- Maintaining a data base for all readiness activities and resolution of comments and concerns.

- Performing statistical analyses on the data base.

- Preparing required readiness documentation for use by the DOE in the readiness determinations.

The team has several analytical tools at its disposal. The Management Oversight Risk Tree is an analytical logic diagram designed to prevent safety-related oversights, errors, and omissions using fault tree analysis techniques. The Project Requirements Implementation Matrix is a management tool that identifies WIPP requirements, WIPP documents that describe the requirements, plans, and procedures that implement the requirements, and the current status. The team uses these tools as a means of determining the adequacy of systems and facilities relative to WIPP operating requirements.

Requirements documents contain 1,300 criteria against which readiness is assessed. Fault tree analyses and failure mode effects analyses techniques were used in selected systems to identify potential risks. Early in the Operational Readiness Review process, WIPP was represented as a series of overall systems which included plant facilities, handling systems, monitoring systems, control and instrumentation, utilities, and ventilation. Subsystems were defined at two or three levels below each major system. A total of 56 systems and 13 activities were identified as critical to waste receipt. The following criteria, taken from "Operational Readiness Review Verifications," WP 12-004, were established to define critical systems and essential equipment.

Those systems whose continued integrity and/or operability are essential to ensure:

- Confinement or measure of the release of radioactive materials to the accessible environment.

- Continued receipt and/or emplacement of TRU waste without an interruption greater than one month according to the shipping plan schedule.

- That the environmental and occupational safety of personnel meets the established site programs.

- The physical security of the WIPP facilities.

From the established 56 critical systems and 13 critical activities a total of 11,324 Acceptance Criteria and 954 Verification Records have been identified for document validation.

3.2.2.2 Preoperational Appraisal

The Preoperational Appraisal is a comprehensive and independent review of the critical systems, facilities, and activities required to operate the WIPP facility. The appraisal includes an in-depth review of the environmental, safety, health, security, and operational aspects of the Project. The appraisal covers hardware, equipment, demonstrations, and documentation. Since WIPP is a new facility, the appraisals are being conducted to determine the first time readiness of the physical systems and administrative practices.

The Preoperational Appraisal is being conducted by the DOE Albuquerque Operations Office, independent of the DOE WIPP Project Office. The results of the Operational Readiness Review will provide significant input to the appraisal. A successful Preoperational Appraisal and an approved Final Safety Analysis Report are required before WIPP is authorized to receive waste. These are significant inputs into the decision making process of determining operational readiness (Key Decision #4 of the Major System Acquisition process).

The Preoperational Appraisal Team uses the DOE-Headquarters "Performance Objectives and Criteria for Technical Safety Appraisals" as the basis for measuring acceptability. The appraisal also includes review of specific sections of the WIPP Safety Analysis Report which is compared with the facility, operations, and environmental, health, and safety programs, as well as operational plans and selected procedures.

The appraisal is being conducted in two phases. The first phase focused primarily on the nonnuclear aspects of the facility and operations. The scope of Phase I included inspection of facilities, the underground, equipment/systems, and review of site operations and environmental, safety, and health programs. Also included were auxiliary systems and services at the site which have safety related significance to facility and site operations. The areas addressed during the first phase were:

Organization and Management	Experimental Activities
Criticality Safety Program	Fire Protection Program
Maintenance Program	Safety/Security Interface
Electrical Power	Technical Support
Industrial Safety/Mine Safety	Training and Certifications

A demonstration of the loss of electrical power and a fire in the Waste Handling Building was conducted during this phase of the appraisal.

Phase I was conducted by technical experts from the DOE Albuquerque Operations Office, including the Safety Programs Division, Facilities and Project Management Division, Non-Weapons Quality Assurance Staff, and the Environmental and Health Division. Additional members included representatives from the U.S. Mine Safety and Health Administration, consultants, and DOE Headquarters Defense Program observers. During the first phase of the appraisal there were no significant findings or recommendations that would hinder a decision to bring waste to the WIPP facility.

The second phase of the appraisal will focus on the critical radiological systems and activities. These include:

Waste Handling Building and Underground	Environmental Program
Waste Handling Operations	Emergency Preparedness
Waste Packaging	Quality Assurance
Industrial Hygiene Program	Maintenance
Health Physics Program	Training and Certification
Underground Air Handling	Air Intake Shaft

This phase will also include a demonstration and drill involving waste emplacement in the waste disposal rooms, a release of contamination underground, and a contaminated TRUPACT II whose contents require overpacking to prevent the spread of contamination. An underground fire drill involving mine rescue may also be performed. In addition to the review of abnormal events, the appraisal team will evaluate demonstrations and drills to validate operations in major functional areas. These demonstrations and drills will be conducted with all support systems and operations functional. Phase II of the appraisal is scheduled to be completed during the first quarter of CY89.

3.3 OPERATIONS DEMONSTRATION DESCRIPTION

The integrated Operations Demonstration reflects the necessary next step in the stepwise progression from construction, start-up testing, facility readiness, training, and nonradioactive operational demonstrations to demonstrations with radioactive wastes. As presented in this Plan, waste management system operations will progress in a stepwise fashion from initial waste shipment to quantities representative of WIPP design throughput rates. The Operations Demonstration will encompass CH-TRU waste, RH-TRU waste, CH-TRU waste for gas generation tests, and the concurrent emplacement of CH- and RH-TRU wastes at the WIPP facility. Operation of the DOE TRU waste management system includes waste certification and packaging at DOE sites and transportation to the WIPP site. The first waste will be shipped to initiate the gas generation tests.

Throughout the Operations Demonstration, there are designated checkpoints for analysis and review of safety, environmental, and operational (procedural or administrative) factors and reporting of monitoring activities. These checkpoints are part of a continuous evaluation of operations and will apply to each element of the waste management system. The purpose of these checkpoints is to provide a basis for WIPP management to determine whether to proceed as planned, or to modify plans based on experience gained up to that time.

The Operations Demonstration includes those activities needed to provide as-received, prepared, and compacted waste in drums and bins for the gas generation tests. These tests will use less than one percent of the WIPP design capacity TRU waste. As for all waste received during the Test Phase, retrievability is ensured by design.

In addition to the waste needed for gas generation tests, the Operations Demonstration will include CH-TRU waste as well as RH-TRU waste to provide the operating data that will ensure that the TRU waste management system activities can be performed safely and effectively. Consistent with the phased and progressive approach, data collected during the initial ramp-up will be used to establish that follow-on operations can proceed. To acquire sufficient data for input to the decision whether the WIPP facility should become a waste disposal facility, a period of sustained design throughput operations is planned. This sequence of operations is analogous to those used in the nuclear and nonnuclear industries after preoperational testing but before full operations begin. Although individual parts of the system have been tested to ensure that they function as designed, industrial practice suggests that the entire system be tested in phases with increasing waste receipt rates and culminating in a sustained demonstration period at expected waste receipt rates including the concurrent handling of CH- and RH-TRU waste. The Operations Demonstration includes provisions for such an operational sequence, one which will effectively exercise the waste management system thereby ensuring that adequate data are available for the decision process.

Figure 3-13 provides a summary schedule applicable to the Operations Demonstration. The first part of the operating tests will be completed in late FY92, at which time approximately 4.4 percent of the WIPP total capacity of 6,200,000 cubic feet of waste will be emplaced. Upon completion of the first part, a holdpoint will be instituted to evaluate conclusions previously obtained from: (1) the Performance Assessment Program regarding EPA compliance, and (2) evaluation of the Operations Demonstration Program. If at that time, there is

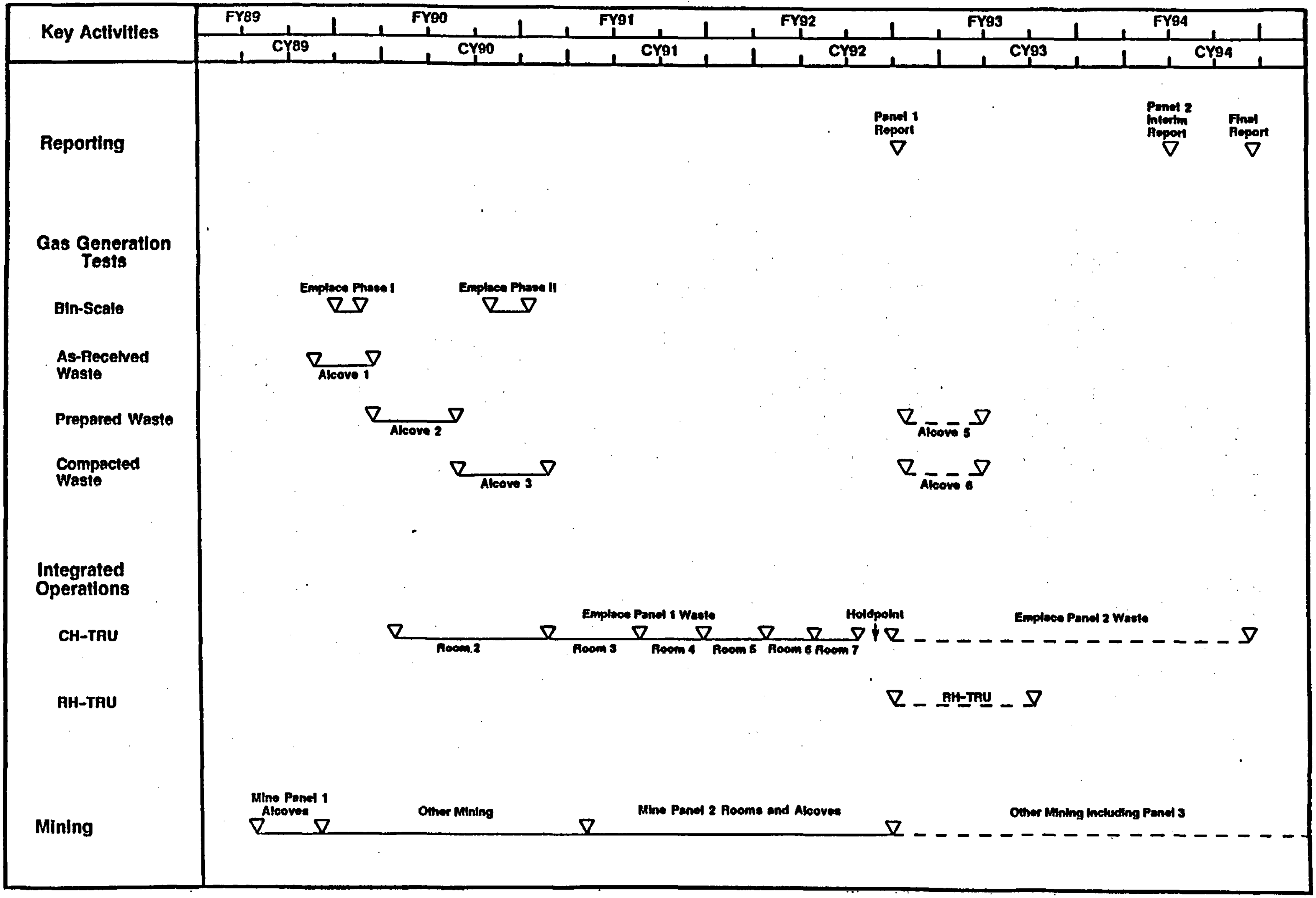


Figure 3-13. Schedule for Operations Demonstration

sufficient confidence that the WIPP facility will comply with the Standard and the TRU waste management system operations are functioning as planned, the Operations Demonstration will be continued by emplacing waste in Panel 2, including RH-TRU waste. This extension could include shipments from additional CH-TRU waste generating/storage sites upon completion of their National Environmental Policy Act requirements and other appropriate documentation. During this continuation of the Operations Demonstration all waste will be emplaced in a manner to ensure easy retrieval. This does not preclude the possibility that special backfill tests in alcoves may be conducted during this period. The details for including backfilling in the operation are dependent on the backfill to be selected as a result of the experimental and performance assessment activities.

3.3.1 Waste Emplacement Sequence

As presented in Chapter 2 and in Appendix A of this Plan, the bin-scale tests will include approximately 100 bins with each bin containing up to the equivalent of 6 drums of selected waste types. A number of these bins will include additives, including brines, backfills, and getters as determined by laboratory tests. Each of these sealed bins is instrumented and outfitted with appropriate gas and liquid sampling ports. The special bins will be prepared at the Rocky Flats Plant; brine addition will be performed at the WIPP facility. It is expected that these bins will be received in two distinct phases. Phase I bins will be received early in the Operations Demonstration. The Phase II bins will be received about one year later since the waste and additive compositions of the bins are dependent on results of ongoing laboratory testing. As shown in Figure 3-14, the bin-scale tests will be emplaced in Room 1 of Panel 1.

The room-scale tests, discussed in Chapter 2 and in Appendix A, will be similarly phased. Due to the unique sealing requirements of these tests, single-entry alcoves which incorporate a special seal will be used. The room-scale tests require a total of six such alcoves. The first phase will include a gas baseline alcove, an as-received waste alcove, and two alcoves, one containing prepared waste and the other compacted waste, without backfill around the drums. These alcoves will be located off the S-1600 drift of Panel 1 (Figure 3-14). An important prerequisite to initiating these Phase I room-scale tests is the satisfactory demonstration of seal performance. This demonstration will be conducted using a test alcove.

As with the bin-scale tests, the second phase of the room-scale tests is dependent on data resulting from laboratory and bin-scale tests. This second phase will be implemented in Alcoves 5 and 6 in Panel 2; one alcove will include drums of prepared waste and the other drums of compacted waste. Initiation of the second phase of the room-scale tests will not begin until satisfactory seal performance and operating techniques have been demonstrated via the Phase I alcoves. Also, Phase II may include backfill tests in Alcoves 5 and 6 and therefore appropriate retreival demonstrations will precede this second phase.

A summary of the waste required by the tests is presented in Table 3-5, including the waste source, emplacement location in the WIPP test area, and quantities of drums.

An element of the Operations Demonstration will be the completion of a backfill emplacement demonstration. This element will be incorporated in this Plan at a

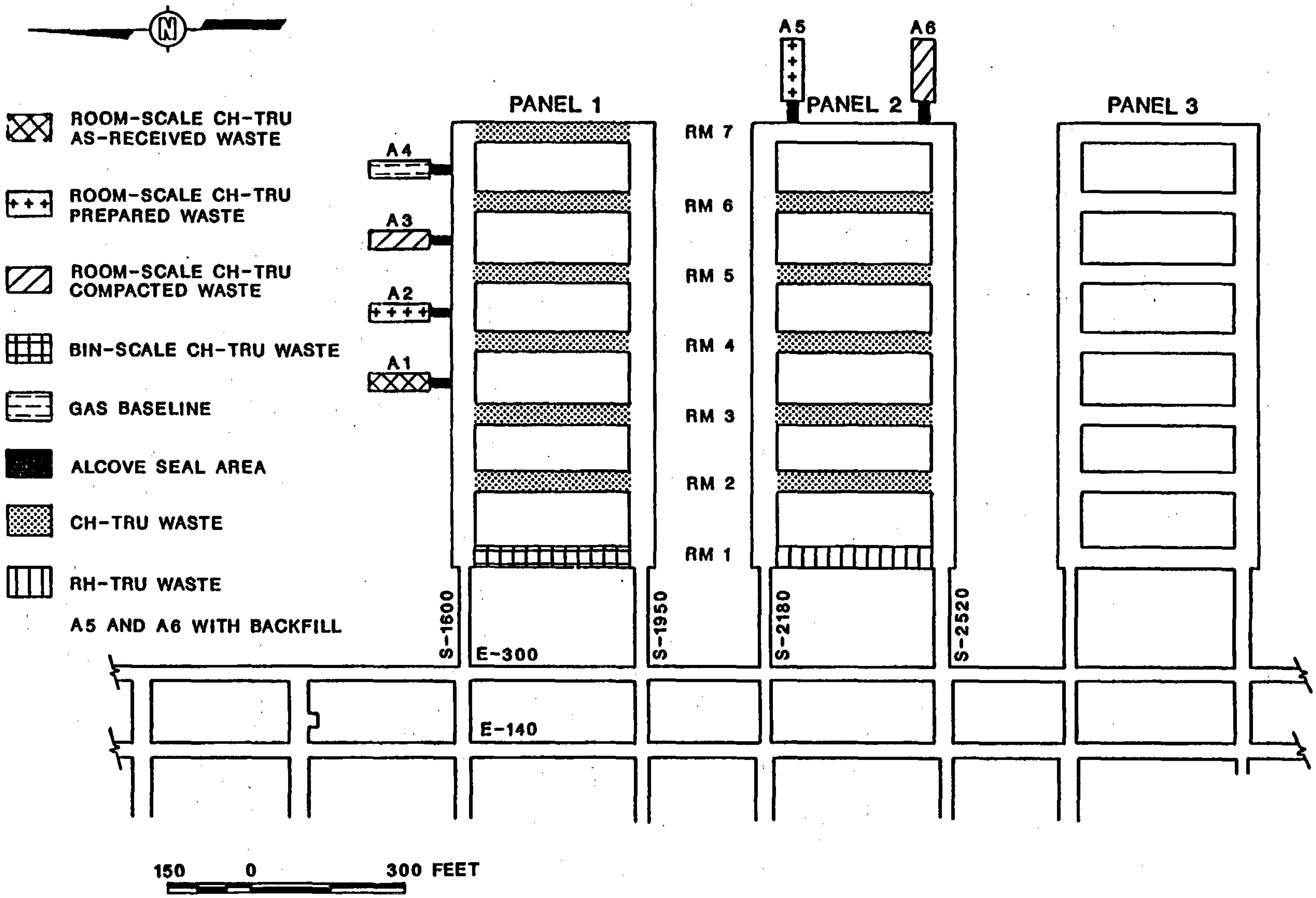


Figure 3-14. TRU Waste Test/Disposal Area (Panels 1 and 2)

TABLE 3-5. GAS GENERATION TEST SUMMARY

Description	Quantity of Drums (Approximate No.)	Test Location	Waste Source
Bin-Scale, bins	600	Room 1/Panel 1	RFP, INEL
Room-Scale, as-received	1,100	Alcove 1	INEL, RFP
Room-Scale, compacted	1,600*	Alcove 3	RFP
	1,600	Alcove 6	RFP
Room-Scale, prepared	1,100	Alcove 2	RFP, INEL
	1,100	Alcove 5	RFP, INEL

*Equivalent drums of waste, total of about 700 drums containing compacted waste.
INEL - Idaho National Engineering Laboratory
RFP - Rocky Flats Plant

later date when the actual backfill has been selected and the required mock retrieval demonstration has been successfully completed.

To achieve a sufficient data base for evaluation of the full system, the operations test includes a structured, stepwise progression in the receipt of both CH- and RH-TRU wastes, including receipt of CH-TRU waste required for the gas generation tests, and culminating in the concurrent receipt of both waste types at rates typical of design throughput operations. For CH-TRU waste, the expected single shift receipt rate is 230,000 cubic feet per year (a total of 45 TRUPACT IIs or 15 shipments per week). For RH-TRU waste, the equivalent rate is 250 canisters per year or 5 shipments per week. Figure 3-15 provides a pictorial representation of the waste receipt scenario included in the integrated Operations Demonstration. As previously noted, this process includes designated checkpoints which will be used to verify that all operations are safely progressing as anticipated. In the event that any abnormal occurrences are encountered, their impact on the process will be assessed and appropriate corrective action implemented before the process is resumed. Specific criteria will be established, reflecting regulatory and other appropriate requirements, as applicable to waste generating/storage site operations, transportation system operations, and WIPP operations.

The waste quantities to be used for operations testing include:

- Approximately 33,000 drums (3.9 percent of WIPP design capacity) of CH-TRU waste to be emplaced in 6 rooms of Panel 1.

- Approximately 27,500 drums (3.3 percent of WIPP design capacity) of CH-TRU waste to be emplaced in 5 rooms of Panel 2, and approximately 50 canisters of RH-TRU waste to be emplaced in Room 1 of Panel 2.

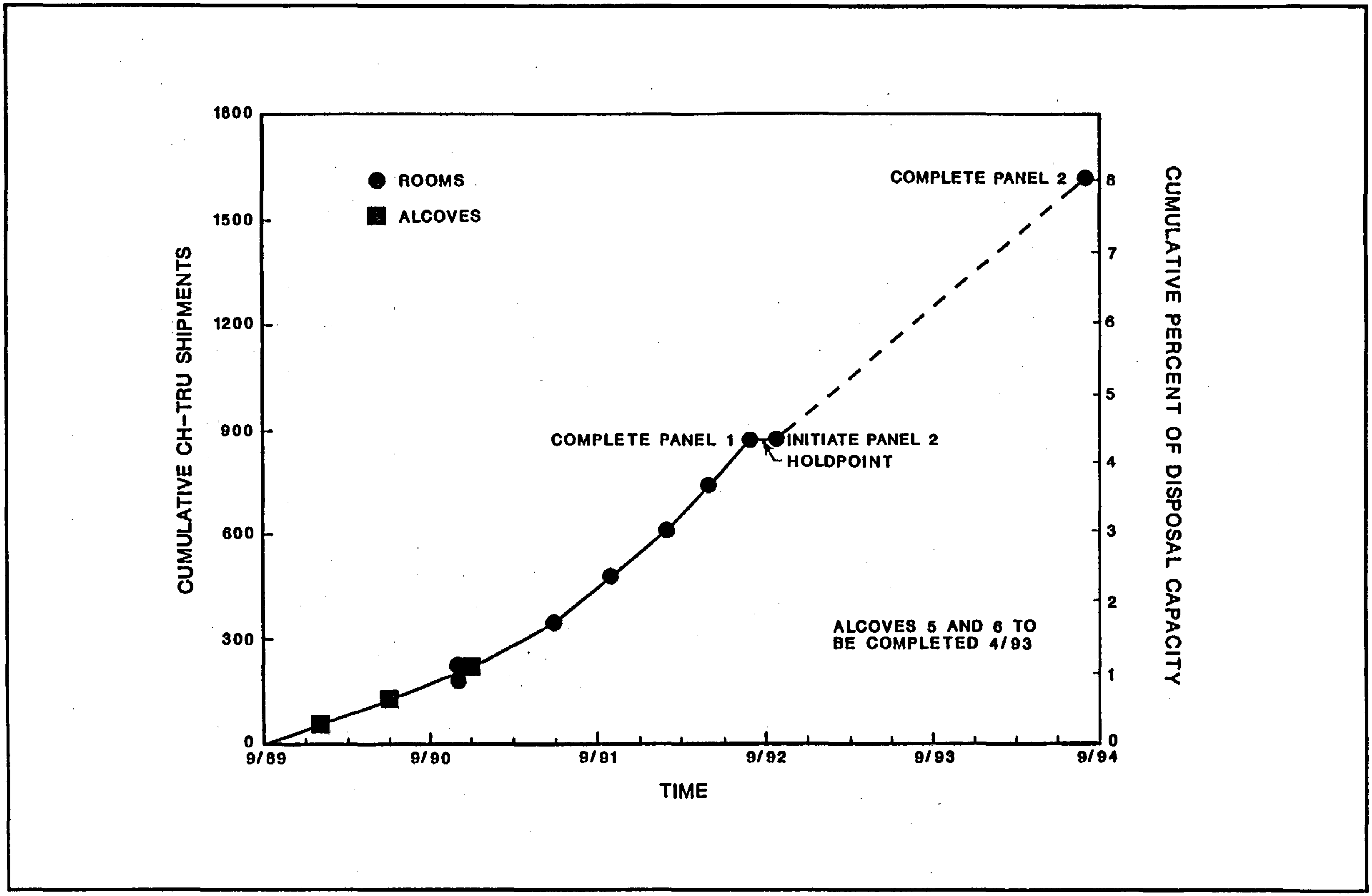


Figure 3-15. Schedule for TRU Waste Test Phase Emplacement

- Approximately 7,100 drums (0.8 percent of WIPP design capacity) to be emplaced for the gas generation tests.

The data presented in the Plan are in drum equivalents. Waste will also be transported and emplaced in larger Standard Waste Boxes. A more detailed description of these waste quantities is provided in Chapter 1, Table 1-1.

During the Test Phase, waste will be emplaced in two panels (the test/disposal area); approximately 1,600 shipments of CH-TRU waste and about 50 shipments of RH-TRU waste will be required. The quantity of waste emplaced in the WIPP facility in Panels 1 and 2 during the Test Phase will equal about eight percent of capacity. Waste will be shipped from the Rocky Flats Plant and the Idaho National Engineering Laboratory and will provide a basis for transferring experience to the remaining sites. This will provide evidence and confidence that the waste generating/storage sites, the transportation system, and the WIPP facility can be operated safely and effectively.

While some changes in the details of the waste shipments are expected to accommodate future developments, the following description establishes the methodology to be implemented in this process. The initial wastes to be shipped will be the as-received CH-TRU waste in support of the gas generation test program. These wastes will be shipped from the Rocky Flats Plant and the Idaho National Engineering Laboratory, and will be emplaced in Panel 1, Alcove 1, of the WIPP test/disposal area (see Figure 3-14). It is expected that the initial campaign to transport and emplace approximately 1,100 drums of as-received CH-TRU waste will require about 25 shipments over a 4-month period. A checkpoint will be instituted immediately following the initial shipment. This checkpoint, of up to two weeks duration, will allow a detailed review of critical elements of the operation, including those applicable to the waste generating/storage sites, the transportation system, and the WIPP facility. During this period, the shipments for the first phase of the bin-scale tests will also be completed. From this initial shipment, the shipping schedule will be increased incrementally up to four shipments per week and at the same time the duration of these increments will increase from one week to three weeks.

Following completion of the as-received waste shipments, the stepwise progression of waste shipments will continue. The progression includes both an increase in the number of shipments per week as well as an increase in the duration of shipments at specific levels. In general terms, the sequence includes operations at shipping levels of 4, 7, 10, and 15 shipments per week. During this sequence, prepared and compacted waste required for Panel 1, Alcoves 2 and 3, will be emplaced, as will the remainder of the bin-scale waste (Panel 1, Room 1) and the waste to fill the balance of the Panel 1 rooms. No RH-TRU waste will be received while Panel 1 is being filled. This sequence includes checkpoints at various stages of the demonstration, as summarized in Table 3-6.

As shown in Figure 3-13, the initial Operations Demonstration (Panel 1) would last about three years and would conclude in late FY92. At the conclusion of Panel 1 waste emplacement, a major holdpoint will be instituted. The holdpoint will allow an assessment of the TRU waste management operations to date and an assessment of the ability of the WIPP disposal system to satisfy the EPA Standard, 40 CFR 191. If the judgment at that time indicates that operations are proceeding safely, and sufficient confidence can be established in the

TABLE 3-6. SUMMARY OF PANEL 1 CHECKPOINTS

Emplacement Location	Number of Shipments	Anticipated Shipment Rate Shipments/Week	Number of Checkpoints
Alcove 4	Gas Baseline Alcove - contains no waste		
Alcove 1	25	2	3
Room 1	17	1	0*
Alcove 2	17	0.5	0*
Room 2	131	3.5	4
Alcove 3	17	0.5	0*
Room 3	131	6.5	3
Room 4	131	10	2
Room 5	131	10	2
Room 6	131	14.5	2
Room 7	131	14.5	2

*Included in other checkpoints.

ability to demonstrate compliance with the Standard, it is anticipated that the holdpoint will be discontinued and waste emplacement operations resumed to install Alcoves 5 and 6 tests, and perform concurrent emplacement of CH- and RH-TRU wastes in Panel 2. This holdpoint is scheduled to last up to two months.

In completing the remainder of the Operations Demonstration, RH-TRU waste shipments will be received in addition to CH-TRU waste shipments. During this period, the receipt of RH-TRU waste will be interspersed among the continuing CH-TRU waste shipments. During the ramp-up of RH-TRU waste shipments, the concurrent receipt of CH- and RH-TRU wastes at the WIPP facility will not be in effect. Once the operational throughput rates for CH- and RH-TRU wastes have been individually determined, the concurrent handling operations of both waste types will be conducted. Due to the limited shipping capacity of the three RH-TRU waste casks and with the Idaho National Engineering Laboratory being the only source of RH-TRU waste available for the tests, it will be necessary to accumulate RH-TRU waste canisters in the WIPP hot cell such that the concurrent handling of CH- and RH-TRU wastes at maximum rates can be performed.

3.3.2 TRU Waste Management System Operations

The integrated Operations Demonstration will commence with the initial shipment of CH-TRU waste to the WIPP site in September 1989. This initial shipment establishes the need for the waste management system to demonstrate compliance with applicable regulatory, technical, institutional, industrial, and managerial requirements. Operations that comply with these requirements will form the basis for the waste management system operational data base. This data base provides the information necessary for the disposal decision. To this end, a requirements hierarchy has been established, which includes:

1. Federal Regulations, such as Environmental Protection Agency, Department of Transportation, Nuclear Regulatory Commission, and other applicable regulations.

2. DOE Orders, which implement the federal regulations and impose additional requirements.

3. Other program-specific requirements.

These requirements are limited to those of primary significance to operations and are not intended to be all inclusive. However, operations will be performed in accordance with all applicable regulations and DOE Orders. The intent is to ensure that data acquired during the Test Phase show that the TRU waste management system complies with these requirements.

The following sections provide a brief description of the scope of operations to be accomplished for each part of the DOE TRU waste management system in support of the Operations Demonstration. These sections also summarize the primary requirements which must be satisfied for completing these operations. The requirements included are organized according to the hierarchy previously described and have been limited to those which are of primary operational significance. When viewed from an overall perspective, the demonstration of compliance with the federal regulations and DOE Orders addresses the primary safety concerns while the program specific requirements address both safety and primary operational concerns.

3.3.2.1 Waste Generating/Storage Site Operations

Transuranic waste is being generated or stored at ten DOE sites nationwide. These sites have been fully operational for a number of years and may eventually ship TRU waste to WIPP for disposal on a regular basis if the WIPP facility is designated a permanent TRU waste disposal facility. Prior to shipment of wastes to WIPP, management of TRU waste is the responsibility of the individual waste generating/storage site. The TRU waste shipping sites routinely manage and ship wastes in accordance with applicable DOE Orders and Department of Transportation regulations as part of their current operations. However, these operations are based on use of the current shipping container which is a specially designed ATMX rail car. In addition, Idaho National Engineering Laboratory operations have been limited to the receipt of waste from those other sites which have no permanent on-site storage capacity. The inclusion of Idaho National Engineering Laboratory as a shipper using TRUPACT IIs is an important activity. There are specific site operations pertaining to waste transportation and disposal at the WIPP facility that are unique and are included in the Operations Demonstration so that overall safety and effectiveness can be evaluated.

These operations include the certification of newly generated waste and stored CH- and RH-TRU wastes, as applicable to each site. Waste certification is accomplished in accordance with site-specific plans that have been prepared and approved in accordance with the WIPP Waste Acceptance Criteria (DOE, 1989a) and ensures that the waste is suitable for emplacement in the WIPP facility. In addition, the Waste Acceptance Criteria have established specific requirements for the data package that accompanies the TRU waste. These DOE site operations are subject to periodic audit by the WIPP Waste Acceptance Criteria Certification Committee Audit Team to ensure compliance with approved procedures.

DOE site operations will also include loading waste packages or transporters (the TRUPACT II and the RH-TRU waste shipping cask). Loading operations will be accomplished in accordance with site specific operating procedures, and the Nuclear Regulatory Commission's Certificate of Compliance issued for each transporter as reflected in the Safety Analysis Report for Packaging.

The scope of the Operations Demonstration includes shipment of newly generated CH-TRU waste from DOE's Rocky Flats Plant near Denver, and stored waste from the Idaho National Engineering Laboratory. Other sites may also ship waste to WIPP during operations testing. The Idaho National Engineering Laboratory, is expected to ship RH-TRU waste, which includes waste from Argonne National Laboratory (west). These sites are representative of the waste generating/storage sites that comprise the TRU waste management system; they include both large and small quantity shippers. Their activities during the Operations Demonstration will provide a basis for evaluating site certification and transportation operations and allow acquired data to be applied throughout the TRU waste management system.

Requirements applicable to the waste generating/storage site operations include the following:

10 CFR 71 - Packaging and Transport of Radioactive Material.

> This Nuclear Regulatory Commission regulation establishes requirements for packaging, preparation for shipment, and transport of licensed material. Nuclear Regulatory Commission regulations are not in themselves legally applicable to DOE nuclear shipment operations; however many of the provisions of the Nuclear Regulatory Commission regulations are specifically incorporated as required by reference in DOE Orders. Specifically, DOE will design the TRUPACT II and the RH cask to comply with the Type B packaging requirements of 10 CFR 71.41-71.47, 71.51, and 71.73.

40 CFR 261 - Identification and Listing of Hazardous Waste.

> This regulation identifies those solid wastes that are subject to regulation as hazardous waste.

49 CFR 100-178 - Other Regulations Relating to Transportation: Chapter I - Research and Special Programs Administration, Department of Transportation.

> This regulation prescribes the requirements of the U.S. Department of Transportation governing the transportation of hazardous material.

DOE Order 5820.2A - Radioactive Waste Management, September 1988.

> This Order establishes policies and guidelines for managing TRU waste starting with its generation, and continuing through closure of the WIPP facility. TRU wastes that are also mixed wastes are subject to the requirements of the Atomic Energy Act and the Resource Conservation and Recovery Act (RCRA). Included by reference in this Order are the requirements of the following DOE Orders:

DOE Order 1540.1, Materials Transportation and Traffic Management of May 3, 1982, establishes the DOE's policies for management of materials transportation activities, including traffic management.

DOE Order 5480.3, Safety Requirements for the Packaging and Transportation of Hazardous Materials, Hazardous Substances, and Hazardous Wastes of July 9, 1985, establishes requirements for the packaging and transportation of hazardous materials, hazardous substances, and hazardous wastes.

DOE Order 5700.6B, Quality Assurance of September 23, 1986, sets forth principles and assigns responsibilities for establishing, implementing, and maintaining programs of plans and actions to assure quality achievement in DOE's programs.

Transuranic Waste Acceptance Criteria for the Waste Isolation Pilot Plant January 1989 (DOE, 1989a).

The WIPP Waste Acceptance Criteria specify basic requirements for disposal of CH- and RH-TRU waste at WIPP including those specified in DOE Order 5820.2A. Criteria are established for the waste form, nuclear characteristics including criticality limits, waste containers, and radiation doses. These criteria establish limits that allow waste generating/storage sites to develop their own procedures and specifications for preparation of TRU waste for shipment to the WIPP facility.

These criteria are discussed further in the following implementing documents:

TRU Waste Certification Compliance Requirements for Newly Generated Contact-Handled Wastes for Shipment to WIPP, WIPP-DOE-114 (DOE, 1989b).

Quality Assurance Requirements for the Certification of TRU Waste for Shipment to the Waste Isolation Pilot Plant, WIPP-DOE-120 (DOE, 1988b).

TRU Waste Certification Compliance Requirements for Contact-Handled Wastes Retrieved From Storage for Shipment to WIPP, WIPP-DOE-137 (DOE, 1989c).

TRU Waste Certification Compliance Requirements for Remote-Handled Wastes For Shipment to WIPP, WIPP-DOE-158 (DOE, 1989d).

WIPP-DOE-114, 137, and 158 have been established to assure that wastes shipped to the WIPP facility meet the requirements of the WIPP Waste Acceptance Criteria and amplify the requirements found in the WIPP Waste Acceptance Criteria. WIPP-DOE-120 provides the basic quality assurance requirements that will be included in the quality assurance programs established by the DOE sites that ship waste to WIPP. These requirements are modeled after ANSI/ASME NQA-1-1986.

Safety Analysis Report for Packaging.

The Safety Analysis Report for Packaging forms the basis for issue of the Nuclear Regulatory Commission Certificate of Compliance for the individual shipping containers. The Safety Analysis Report for Packaging also establishes specific requirements applicable to the loading and maintenance of the shipping containers.

Waste Isolation Pilot Plant - Waste Transportation Manual (Westinghouse, 1988c).

The requirements described in the WIPP Waste Transportation Manual that affect the DOE site operations include preparation of shipping papers in accordance with 49 CFR 172, packaging and transportation equipment inspection, planning and schedule coordination with the WIPP site, equipment maintenance, and record keeping.

3.3.2.2 Transportation System Operations

This element of the waste management system includes the portal to portal shipment of wastes required for the integrated Operations Demonstration, including waste required for the gas generation tests. The transport of TRU wastes will use newly designed shipping containers which will be certified by the Nuclear Regulatory Commission, including specially designed trailers, for both CH- and RH-TRU wastes. This activity is necessary to demonstrate the safety of and determine the capacity and adequacy of the transportation system, specifically addressing transportation system reliability and availability. Although forecasts of transportation capabilities of the TRUPACT II and the RH-TRU waste cask fleet have been made, it is important to test these capabilities at increasing rates up to anticipated shipping steady-state rates. In this way evaluations can be performed of tracking system performance; radiation dose commitments to transportation support personnel; delays due to impediments such as weather, road construction, and rerouting; equipment breakdown; regulatory compliance; transportation system cost; and institutional considerations.

Several factors make transportation system operations testing prudent. These include: (1) the new designs for the waste shipping containers (TRUPACT II and RH-TRU waste casks); (2) the need to address institutional concerns that may develop concerning state and local government entities along the designated transportation routes; (3) the unprecedented provision of shipment tracking and information access to states and Indian Tribes/Pueblos (Oak Ridge National Laboratory, TRANSCOM responsibilities document, to be issued); and (4) the need to demonstrate safe and effective system operations to mitigate the public's safety concerns. The WIPP shipment tracking system is a pilot for all DOE shipments and potentially for the entire hazardous-waste shipping industry. Further, due to the unique design of the TRUPACT II shipping container and the transportation trailers there is a need to evaluate compliance with Nuclear Regulatory Commission maintenance requirements for the shipping containers lifetime and maintenance criteria applicable to the trailers themselves.

Requirements applicable to the transportation system include the following:

49 CFR 177 - Carriage by Public Highway.

Part 177 describes the requirements for motor vehicle transport of hazardous materials, including radioactive materials, and the regulations covering shipping papers, routing of shipments, and loading and unloading of containers.

49 CFR 350-399 - Federal Motor Carrier Safety Regulations.

Parts 350-399 prescribe regulations, standards, and requirements for the operations by a motor carrier in commerce. The regulations cover driver qualifications, training and testing, motor vehicle maintenance and safety, and general carrier operations.

DOE Order 5820.2A - Radioactive Waste Management.

DOE Order 5820.2A establishes DOE's policies, guidelines, and minimum requirements by which the DOE manages its radioactive and mixed waste and contaminated facilities. The requirements of DOE orders 1540.1, 5480.3, and 5700.6B are included by reference:

Safety Analysis Report for Packaging.

The Safety Analysis Report for Packaging prescribes maintenance programs which must be implemented to ensure continued performance of the packagings, i.e., TRUPACT II and the RH-TRU waste shipping container.

Waste Isolation Pilot Plant - Waste Transportation Manual (Westinghouse, 1988c).

This manual defines the guidelines, policies, and requirements necessary to accomplish the TRU waste shipping objectives of the DOE waste generating/storage sites, as well as receipt objectives of the WIPP facility, in a safe and efficient manner including requirements of DOE Order 5820.2A. The guidelines and requirements include procedure compliance, equipment inspection and staging, transportation monitoring and scheduling, equipment maintenance and storage, and record keeping. Preparation of transportation plans and schedules, shipment control, and receiving and inspection are also included.

3.3.2.3 WIPP Operations

At the WIPP facility, the Operations Demonstration will be used to evaluate overall safety and operational effectiveness, to ensure that operations are consistent with environmental considerations, and to demonstrate compliance with regulations and DOE Orders. The WIPP is a unique first-of-a-kind facility and the interaction and integration of surface, hoist, and underground operations will be evaluated while handling radioactive wastes. Further, this evaluation will include the concurrent handling of both CH- and RH-TRU waste types at rates up to those representative of design throughput rates.

WIPP operations will encompass a broad range of activities. The operating functions at the WIPP facility involve the handling of radioactive waste for emplacement in the underground test area, the operation of surface facilities, and mining operations. Waste management consists of shipping container receipt and unloading, waste handling from the surface to emplacement in the underground test area, and maintenance of required records. In support of waste management activities, the surface and underground facilities will be operated in a manner to ensure operator and public safety. This requires maintaining the required ventilation pressure differentials in the Waste Handling Building and in the underground to ensure radiological control; that critical support systems are operational, including the Radioactive Monitoring System and Central Monitoring System; that procedures for responding to off-normal events that may be encountered during radioactive waste handling operations are effective; and that the effluent monitoring systems, in the Waste Handling Building and the Exhaust Filter Building, are effective and reliable. Following the first waste receipt, the facility will be continuously monitored, i.e., three shifts a day, seven days a week.

Waste received during the Operations Demonstration will include waste required in support of the gas generation tests. The general arrangement of the underground test area through the completion of the demonstration is shown in Figure 3-14. Waste received for the bin-scale tests will be located in Panel 1, Room 1. The room-scale test waste will be emplaced in specially mined single-entry alcoves located off Panel 1, S-1600 drift; a gas baseline room will be similarly located. The remaining waste will be emplaced in the balance of Panel 1 and into Panel 2 as shown in the Figure 3-14, with the second phase of the room-scale waste to be emplaced in the alcoves in Panel 2. While waste is being emplaced in Panel 1, Panel 2 will be mined. The gas generation test alcoves incorporate a special seal to control the interchange of gases between the alcoves and the general mine environment. With the exception of the bin tests, it is expected that normal waste handling techniques will be employed throughout the test phase. During this period, retrievability of emplaced waste will be ensured by design.

RH-TRU waste will also be emplaced in Panel 2. Approximately 50 canisters of RH-TRU waste will be emplaced in steel-sleeved boreholes (which ensure retrievability) in Panel 2, Room 1. Panel 3 will be excavated and outfitted on a schedule that supports the continuation of waste receipt once the determination or decision regarding the disposal phase has been made.

The operational tests at WIPP will be used to:

- Receive, handle, and emplace TRU waste in accordance with approved operating procedures and safety requirements to test the WIPP waste handling process, personnel, and equipment and confirm the capability to concurrently emplace CH- and RH-TRU wastes at required rates.

- Provide a sound basis for projecting occupational radiation exposures resulting from the full scope of WIPP operations. These data are required for normal as well as off-normal operating conditions.

- Test the ability to maintain the required ventilation pressure differentials in the surface and underground Radioactive Materials Areas thereby ensuring control of potential contamination spread.

- Refine operating procedures to increase the efficiency of waste handling, facility, and mining operations. An important element of this process is to verify a radiation safety program which has as a basic principle: the limitation of occupational exposures to "as low as reasonably achievable."

- Test the effectiveness of administrative controls for personnel, equipment, and materials. A significant part of this effort will be to establish a data base for the effectiveness of preventative maintenance and responsive corrective maintenance programs as they relate to establishing and maintaining plant availability.

- Confirm the reliability of key WIPP operating systems including: power systems, radiation monitoring systems, effluent monitoring systems, the Central Monitoring System, supporting mining systems, hoist systems, surface and underground ventilation systems, and back-up power systems.

- Test the effectiveness of responses to actual off-normal events that might be encountered including: Emergency Operations Center operations, emergency response procedures under actual radioactive waste handling conditions such as potential spills, and the receipt of shipments requiring decontamination or overpacking operations.

- Develop an operational data base relating to high efficiency particulate air filter changeout in the Waste Handling and Exhaust Filter Buildings. Additionally, operational data are required to demonstrate the ability to maintain the WIPP facility in a radiologically "clean" status.

- Evaluate and assess the interactions between mining and waste handling operations, with particular emphasis on maintaining radiological controls and ensuring a complete assessment of the impact of room, panel, and drift closure on the safety of underground operations.

- Demonstrate compliance with Federal Regulations and DOE Orders and revisions thereof as applicable to WIPP operations.

Requirements applicable to WIPP facility operations include the following:

40 CFR 191 - Environmental Radiation Protection Standards for Management and Disposal of Spent Nuclear Fuel, High-level, and Transuranic Radioactive Wastes, Subpart A - Environmental Standards for Management and Storage. (WIPP will meet the intent of this regulation per agreement with the State of New Mexico.)

40 CFR 61, Subpart H - National Emission Standards for Hazardous Air Pollutants; Standards for Radionuclides.

The EPA Standard, 40 CFR 191, Subpart A, requires that during the management and disposal phase, WIPP operations shall provide reasonable assurance that the combined annual dose equivalent to any member of the public in the general environment shall not exceed 25 mrem to the whole body and 75 mrem to any critical organ from all release pathways. The 40 CFR 61 regulation is similar except that it applies to the airborne emission of radionuclides only. In each case, all direct or secondary pathways must be considered in assessing compliance with the dose equivalent limits of the regulation.

40 CFR 260-280 - Various titles all of which are the Environmental Protection Agency's codification of the Resource Conservation and Recovery Act (RCRA).

RCRA provides for the cradle to grave management of hazardous wastes. The standards issued by the EPA under this act apply to the WIPP facility in a number of ways. The most significant application is the regulation of the WIPP as a treatment, storage, or disposal facility for the hazardous waste components of radioactive mixed wastes that will be shipped from the various DOE generator/storage locations and Subpart X, Performance Standards for Miscellaneous Hazardous Waste Units. In addition, the DOE must provide information regarding the specific hazardous waste constituents in the containers.

40 CFR 1500-1508 - Regulations for Implementing the Procedural Provisions of the National Environmental Policy Act (NEPA).

This regulation promulgates Council on Environmental Quality (CEQ) guidelines requiring that environmental impacts be considered in the decision-making process regarding major projects. DOE implementing guidance is found in the Environmental Compliance Guide, DOE/EV-0132.

30 CFR - Federal Mine Safety and Health Act of 1977.

This regulation, more commonly known as MSHA, establishes specific requirements that must be adhered to in the conduct of underground operations. Significant parts of the regulation and their areas of applicability include:

Part 32 - Mobile diesel-powered equipment
Part 48 - Training and retraining of miners
Part 49 - Mine rescue teams
Part 57 - Safety and health standards - underground metal and nonmetal mines

DOE 5480.11 - Radiation Protection for Occupational Workers, draft.

While this order has established a whole body dose of 5 rem/year, WIPP is required to operate at an Administrative Dose Control Level of 1 rem/year. This Order further establishes specific requirements for monitoring and documenting personnel external exposure, internal exposure, air monitoring, radiation monitoring, contamination control and monitoring, and as low as reasonably achieveable (ALARA) requirements.

DOE Order 5400.1 - General Environmental Protection Program.

DOE Order 5484.1 - Environmental Protection, Safety and Health Protection Information Reporting Requirements.

> These orders establish requirements for an Environmental Monitoring Program designed to monitor the various pathways which could lead to environmental impacts including areas of potential radiological and ecological concern and to document program results.

DOE Order 5400.3 - Hazardous and Radioactive Mixed Waste Program.

> This order establishes DOE hazardous and radioactive mixed waste policies and requirements and implements the requirements of the Resource Conservation and Recovery Act within the framework of environmental programs established under DOE Order 5408.1.

DOE Order 5632.6 - Physical Protection of DOE Property and Unclassified Facilities.

DOE Order 5632.7 - Protective Forces.

> These orders establish baseline physical protection requirements and standards for the WIPP site and other specific requirements to be satisfied by the Protective Force.

DOE Order 5480.1B - Environment, Safety, and Health Program for Department of Energy Operations.

> This order establishes the requirement to define the Operational Safety Requirements for WIPP operations. These Operational Safety Requirements define the Safety Limits, Limiting Conditions for Operation, and Administrative Controls unique to the WIPP facility.

DOE Order 5500.2 - Emergency Planning, Preparedness, and Response for Operations.

> This order prescribes criteria applicable to a plan of action and a centralized facility for command and control in the event of an emergency.

WIPP Final Safety Analysis Report (FSAR).

> This Report describes a systematic analysis of the hazards and risks associated with the operation of WIPP as required in DOE Order 5481.1B, Safety Analysis Reporting. This report also contains a description of the structures, systems, and programs to be implemented to minimize and mitigate the risks and hazards.

WIPP Project Plan (DOE, 1988h).

> The WIPP mission statement, contained in the WIPP Project Plan, requires that safe and efficient operations be demonstrated.

Consultation and Cooperation Agreement (DOE and State of New Mexico, 1981).

> The Agreement for Consultation and Cooperation with the State of New Mexico, Article IV - L, requires that, prior to making the disposal facility determination, the WIPP Project must complete a Facility Performance Evaluation.

3.4 EVALUATION OF OPERATIONS DEMONSTRATION

As currently planned, the integrated Operations Demonstration will be continuously evaluated and will include checkpoints in the operational sequence. The checkpoints are included to establish specific times when the conduct of the demonstration will be evaluated. These evaluations will address each element of the DOE TRU waste management system, the waste generating/storage sites, the transportation system, and WIPP, and will be used to make operational system changes, if required. In addition, a holdpoint has been identified to occur when Panel 1 rooms and alcoves have been filled and the initial 4.4 percent of waste has been received. This holdpoint is expected to last approximately two months and will consist of a review of conclusions from all previous operations checkpoints based on the requirements presented in Table 3-7. The holdpoint will remain in effect until a judgment can be made that there is sufficient confidence that WIPP will satisfy the requirements of 40 CFR 191, Subpart B, and that the Operations Demonstration in Panel 1 has been safely conducted. The intent is to ensure that operations have been sufficiently acceptable for WIPP DOE management to recommend to DOE upper management that the Panel 2 Operations Demonstration should proceed.

A set of criteria will be applied throughout the test phase for evaluating the conduct of the Operations Demonstration. These criteria, as applicable, will be used to assess the operation at the various checkpoints included in the operational sequence as well as the specified holdpoint at the conclusion of waste emplacement in Panel 1. These criteria will be based on the applicable regulations, DOE Orders, and program-specific documents shown in Table 3-7. The table identifies those significant documents that form the basis for establishing checkpoint and holdpoint criteria and identifies to which program element these will be applied. The table also shows the applicability of these data to the final disposal facility decision process. In general, the DOE Orders and program specific documents reflect the requirements of the federal regulations and will form the basis for the evaluations. The criteria to be chosen will focus on the safety of operations, including operating personnel, and the public; operating efficiency; and environmental considerations.

More specifically, criteria for waste generating/storage site operations, transportation system operations, and WIPP site operations applicable to both CH- and RH-TRU waste operations will be developed as follows:

Waste Generating/Storage Sites - The primary operations to be addressed at the waste generating/storage sites include waste certification activities, shipping container preparations and loading activities, and other operations preparatory to shipping.

Certification of waste will be evaluated based on adherence to the WIPP Waste Acceptance Criteria, other supporting WIPP documents, and the site-specific

TABLE 3-7. APPLICATION OF REQUIREMENTS TO CHECKPOINTS, THE HOLDPOINT, AND THE DISPOSAL PHASE DECISION

Requirement	Program Elements									Description of Requirement
	Waste Generating/ Storage Sites			Transportation			WIPP			
	C	H	D	C	H	D	C	H	D	
10 CFR 71	X	X	X							Nuclear Regulatory Commission Packaging Requirements
30 CFR							X	X	X	Mining Safety Requirements
40 CFR 191-A & 61-H								X*	X	Environmental Radiation Protection
40 CFR 261	X	X	X							Hazardous Waste Identification
40 CFR 260-280							X	X	X	
49 CFR 100-178	X	X	X	X	X	X				Transportation Regulations
40 CFR 1500-1508							X	X	X	
49 CFR 350-399				X	X	X				Motor Carrier Requirements
DOE Orders 5400.1 & 5484.1							X	X	X	Environmental Protection, Safety, and Health
DOE Order 5400.3	X	X	X				X	X	X	Hazardous and Mixed Waste Program
DOE Order 5480.1B							X	X	X	Environmental, Safety, and Health
DOE Order 5480.11							X	X	X	Radiation Protection Requirements
DOE Order 5500.2							X	X	X	Emergency Planning, Preparedness, Response
DOE Order 5820.2A	X	X	X	X	X	X	X	X	X	Radioactive Waste Management
DOE Orders 5632.6 & 5632.7							X	X	X	Physical Protection of DOE Property
WIPP Final Safety Analysis Report							X	X	X	Final Safety Analysis Report

C - Checkpoint H - Holdpoint D - Decision * - Annual

TABLE 3-7. APPLICATION OF REQUIREMENTS TO CHECKPOINTS, THE HOLDPOINT, AND THE DISPOSAL PHASE DECISION (CONCLUDED)

Requirement	Program Elements									Description of Requirement
	Waste Generating/ Storage Sites			Transportation			WIPP			
	C	H	D	C	H	D	C	H	D	
WIPP Project Plan										Top Level WIPP Project Planning
Surface Facility Operations							X	X	X	
Occupational Exposures							X	X	X	
CH-TRU Waste Process/ Procedures							X	X	X	
RH-TRU Waste Process/ Procedures							X	X	X	
Ventilation Control							X	X	X	
Contamination Control							X	X	X	
Central Monitoring System							X	X	X	
Mine Operations							X	X	X	
Hoist Operations							X	X	X	
Emergency Response							X	X	X	
Maintenance							X	X	X	
WWIS							X	X	X	
WIPP-DOE-069										WIPP Waste Acceptance Criteria
Certification	X	X	X							
Data Package	X	X	X							
Exceptions	X	X	X							
Safety Analysis Report for Packaging (Both Containers)										Packaging Certificate of Compliance (NRC)
TRAMPAC	X	X	X							
Procedures	X	X	X				X	X	X	
Maintenance	X	X	X				X	X	X	
WP 06-2										Waste Transportation Requirements
TRANSCOM				X	X	X				
Trailer Life				X	X	X				

C - Checkpoint H - Holdpoint D - Decision * - Annual waste certification plans and procedures. In addition to the certification process, the operations will be evaluated to ensure compliance with the National Environmental Protection Policy Act, the quality assurance requirements for certification, data package completeness and transmission to the WIPP facility, and proper processing of any exceptions to the WIPP Waste Acceptance Criteria.

Shipping container preparations will be evaluated based on the operations and maintenance requirements of the Safety Analysis Report for Packaging, including adherence to the TRUPACT II Authorized Method for Payload Control requirements; approved loading procedures, seal inspections, and tests; acceptability and completeness of any maintenance operations completed on site; required trailer and tractor inspections; radiological survey results; and completeness and accuracy of required shipping papers.

Transportation System - The foremost criteria for evaluation of transportation system operations will be adherence to Department of Transportation regulations for highway route controlled quantities of nuclear materials, shipping container and tractor/trailer maintenance, and the effectiveness of the TRANSCOM tracking system.

As reflected in DOE Orders and program-specific documents, the Department of Transportation criteria to be addressed include shipping papers, adherence to specified routing, driver qualifications, motor vehicle maintenance and safety, and general carrier operations. The effectiveness of the TRANSCOM tracking system will be evaluated, considering both normal and off-normal operations. In addition, the effectiveness of the institutional programs in effect for the corridor states will be evaluated. Shipping container and tractor/trailer maintenance will be assessed to determine effectiveness and to project these data to full disposal operations.

WIPP Facility Operations - The overriding criteria for evaluating WIPP operations will be based on public and operating personnel safety, and the projections of pertinent operating data obtained during the Operations Demonstration to address the ability of the WIPP facility to support effective operations.

The full suite of WIPP operations will be critiqued during the checkpoints to assess procedural compliance; occupational and public radiation exposures; function and availability of critical facility systems including the Central Monitoring System, Radioactive Monitoring System, Effluent Monitoring Systems, power systems, hoists, waste handling equipment, mining equipment, surface and underground ventilation systems, etc.; contamination incidents/control; compatibility of waste handling (both CH- and RH-TRU wastes) and mining operations; effectiveness of waste handling, maintenance, security, mining, radiation safety, quality assurance and transportation operations; compliance with the Final Safety Analysis Report, including Limiting Conditions for Operations, and compliance with the Resource Conservation and Recovery Act.

In evaluating waste emplacement rates for the individual waste forms, as well as for the concurrent handling of both waste forms, statistical techniques will be used to project WIPP's ability to satisfy design capacity requirements as well as projected personnel exposures. The influence of actual off-normal events on design capacity determinations and projected personnel exposures will be important in evaluating WIPP operations.

Checkpoint evaluations will be completed by the WIPP DOE management for WIPP operations and by a combination of the WIPP DOE management and the specific site operational/DOE personnel for transportation system operations and applicable waste generating/storage site operations. In the case of the holdpoint for Operations Demonstration, this judgment will be made by WIPP DOE management with approval from the DOE Albuquerque Operations Office, based on a compilation and evaluation of checkpoint data. The results of this process will be documented in a Panel 1 Operations Demonstration Report. In assessing checkpoints, it is anticipated that any discrepancies or deficiencies that may be encountered will be appropriately mitigated thereby allowing continuation of the demonstration process. Procedures and processes will be refined as experience increases and the results of the demonstration are evaluated. An Interim and a Final Operations Demonstration Report will be prepared to document test results as input to the Disposal Phase decision-making process.

REFERENCES

Beauheim, R.L., 1987a. Analysis of Pumping Tests of the Culebra Dolomite Conducted at the H-3 Hydropad at the Waste Isolation Pilot Plant (WIPP) Site, SAND86-2311; Sandia National Laboratories, Albuquerque, NM.

Beauheim, R.L., 1987b. Interpretations of Single-Well Hydraulic Tests Conducted at and Near the Waste Isolation Pilot Plant (WIPP) Site, 1983-1987, SAND87-0039; Sandia National Laboratories, Albuquerque, NM.

Beauheim, R.L., 1987c. Interpretation of the WIPP-13 Multipad Pumping Test of the Culebra Dolomite at the Waste Isolation Pilot Plant (WIPP) Site, SAND87-2456; Sandia National Laboratories, Albuquerque, NM.

Beauheim, R.L., 1986. Hydraulic-Test Results for Well DOE-2 at the Waste Isolation Pilot Plant (WIPP) Site, SAND86-1364; Sandia National Laboratories, Albuquerque, NM.

Beauheim, R.L., B.W. Hassinger, and J.A. Klaiber, 1983. Basic Data Report for Borehole Cabin Baby-1 Deepening and Hydrologic Testing, Waste Isolation Pilot Plant (WIPP) Project, Southeastern New Mexico, WTSD-TME-020; U.S. Department of Energy, Albuquerque, NM.

Bechtel National, Inc., 1986a. Interim Geotechnical Field Data Report, DOE-WIPP-86-012; Waste Isolation Pilot Plant, Carlsbad, NM.

Bechtel National, Inc., 1986b. Design Validation Final Report, DOE-WIPP-86-010; San Francisco, CA.

Bechtel National, Inc., 1983. Preliminary Design Validation Report; San Francisco, CA.

Bertram-Howery, S.G. and R.L. Hunter, 1989a (in preparation). Plans for Evaluation of the Waste Isolation Pilot Plant's Compliance with EPA Standards for Radioactive Waste Management and Disposal, SAND88-2871; Sandia National Laboratories, Albuquerque, NM.

Bertram-Howery, S.G. and R.L. Hunter, 1989b (in preparation). Plan for Disposal System Characterizations and Long-Term Performance Evaluation of the Waste Isolation Pilot Plant, SAND89-0178; Sandia National Laboratories, Albuquerque, NM.

Borns, D.J., 1987. Rates of Evaporite Deformation: The Role of Pressure Solution, SAND85-1599; Sandia National Laboratories, Albuquerque, NM.

Borns, D.J. and J.C. Stormont, 1988. An Interim Report on Excavation-Effects Studies at the Waste Isolation Pilot Plant: The Delineation of the Disturbed Rock Zone, SAND87-1375; Sandia National Laboratories, Albuquerque, NM.

Bredehoeft, J.D., 1988. Will Salt Repositories be Dry?; in EOS, Trans. Am. Geoph. Union, March 1, 1988.

Brinster, K.F., 1989 (in preparation). Three Dimensional Los Medanos Regional Flow Model; Sandia National Laboratories, Albuquerque, NM.

Brush, L.H., 1989 (in preparation). Test Plan for Laboratory and Modeling Studies of Repository and Radionuclide Chemistry; Sandia National Laboratories, Albuquerque, NM.

Brush, L.H. and D.R. Anderson, 1988a. Potential Effects of Chemical Reactions on WIPP Gas and Water Budgets; Sandia National Laboratories Memorandum; Sandia National Laboratories, Albuquerque, NM.

Brush, L.H. and D.R. Anderson, 1988b. First Meeting of the WIPP Performance Source Term Group; Sandia National Laboratories Memorandum; Sandia National Laboratories, Albuquerque, NM.

Brush, L.H. and D.R. Anderson, 1988c. Second Meeting of the WIPP PA Source Term Group; Sandia National Laboratories Memorandum; Sandia National Laboratories, Albuquerque, NM.

Chapman, J.B., 1988. Chemical and Radiochemical Characteristics of Ground water in the Culebra Dolomite, Southeastern New Mexico, EEG-39; New Mexico Environmental Evaluation Group, Santa Fe, NM.

Christensen, C.L., C.W. Gulick, and S.J. Lambert, 1981. Sealing Concepts for the Waste Isolation Pilot Plant, SAND81-2195; Sandia National Laboratories, Albuquerque, NM.

Christensen, C.L. and E.W. Peterson, 1981. The Bell Canyon Test Summary Report, SAND80-1375; Sandia National Laboratories, Albuquerque, NM.

Clements, T.L., Jr. and D.E. Kudera, 1985. TRU Waste Sampling Program: Volume 1--Waste Characterization, EGG-WM-6503-Vol. 1; EG&G Idaho, Inc., Idaho Falls, ID.

Costin, L.S. and W.R. Wawersik, 1980. Creep Healing of Fractures in Rock Salt, SAND80-0392; Sandia National Laboratories, Albuquerque, NM.

Deal, D.E. and J.B. Case, 1987. Brine Sampling and Evaluation Program, Phase I Report, DOE-WIPP 87-008; U.S. Department of Energy, Carlsbad, NM.

Earth Technology Corporation, 1988. Final Report for Time Domain Electromagnetic (TDEM) Surveys at the WIPP Site, SAND84-7144; Sandia National Laboratories, Albuquerque, NM.

Gulich, C.W. and L.D. Wakeley, 1988 (in preparation). Reference Properties of Cement-Based Plugging and Sealing Materials for the Waste Isolation Pilot Plant, SAND87-2817; Sandia National Laboratories, Albuquerque, NM.

Haug, A., V.A. Kelley, A.M. LaVenue, and J.F. Pickens, 1987. Modeling of Ground-Water Flow in the Culebra Dolomite at the Waste Isolation Pilot Plant (WIPP) Site: Interim Report, SAND86-7167; Sandia National Laboratories, Albuquerque, NM.

Huerta, M., G.H. Lamoreaux, L.E. Romesberg, H.R. Yoshimura, B.J. Joseph, and R.A. May, 1983. Analysis, Scale Modeling and Fullscale Tests of Low-Level Nuclear Waste Drum Response to Accident Environments, SAND80-2517; Sandia National Laboratories, Albuquerque, NM.

Hunche, U., 1984. Fracture Experiments on Cubic Rock Salt Samples; Proceedings 1st International Conference on the Mechanical Behavior of Salt, Transtech Publications, Clausthal, Germany, pp. 169-179.

Hunter, R.L., 1989 (in preparation). Final Scenarios for Analysis of the Release of Transuranic Waste From a Repository at the WIPP Site, Southeastern New Mexico, SAND88-0050; Sandia National Laboratories, Albuquerque, NM.

Hunter, R.L., and D. Mann, 1989 (in preparation). Techniques for Determining Probabilities of Events and Process Effects on the Processes of Geologic Events, SAND86-0196; Sandia National Laboratories, Albuquerque, NM.

Hunter, R.L., 1988. Two Scenarios for the Exercise of Codes for the WIPP Performance Assessment; Internal Memorandum, Sandia National Laboratories, Albuquerque, NM.

Hunter, R.L., R.M. Cranwell, and M.S.Y. Chu, 1986. Assessing Compliance with the EPA High-Level Waste Standard: An Overview, SAND86-0121, NUREG/CR-4510; U.S. Nuclear Regulatory Commission, Washington, DC.

Hunter, R.L., 1985. A Regional Water Balance for the Waste Isolation Pilot Plant (WIPP) Site and Surrounding Area, SAND84-2233; Sandia National Laboratories, Albuquerque, NM.

INTERA Environmental Consultants, Inc., 1981. Consequence Assessment of Hydrological Communications Through Borehole Plugs, SAND81-7164; Sandia National Laboratories, Albuquerque, NM.

Kelley, V.A. and J.F. Pickens, 1986. Interpretation of the Convergent-Flow Tracer Tests Conducted in the Culebra Dolomite at the H-3 and H-4 Hydropads at the Waste Isolation Pilot Plant (WIPP) Site, SAND86-7161; Sandia National Laboratories, Albuquerque, NM.

Labreche, P.A. and L.L. Van Sambeek, 1988. Analysis of Data from Expansive Salt-Water Concrete Seals in Series B Small-Scale Seal Performance Tests, SAND87-7155; Sandia National Laboratories, Albuquerque, NM.

Lambert, S.J., 1988. Isotopic Constraints on the Rustler and Dewey Lake Groundwater Systems; in M.D. Siegel, S.J. Lambert, and K.L. Robinson, eds., Hydrogeochemical Studies of the Rustler Formation and Related Rocks in the WIPP Area, Southeastern New Mexico, SAND88-0196; Sandia National Laboratories, Albuquerque, NM.

Lambert, S.J., 1987. Feasibility Study: Applicability of Geochronologic Methods Involving Radiocarbon and other Nuclides to the Groundwater Hydrology of the Rustler Formation, SAND86-1054; Sandia National Laboratories, Albuquerque, NM.

Lambert, S.J. and J.A. Carter, 1987. Uranium-Isotope Systematics in Ground waters of the Rustler Formation, Northern Delaware Basin, Southeastern New Mexico, SAND87-0388; Sandia National Laboratories, Albuquerque, NM.

Lambert, S.J. and D.M. Harvey, 1987. Stable-Isotope Geochemistry of Ground waters in the Delaware Basin of Southeastern New Mexico, SAND87-0138; Sandia National Laboratories, Albuquerque, NM.

Lappin, A.R., 1988. Summary of Site-Characterization Studies Conducted from 1983 Through 1987 at the Waste Isolation Pilot Plant (WIPP) Site, Southeastern New Mexico, SAND88-0157; Sandia National Laboratories, Albuquerque, NM.

LaVenue, A.M., A. Haug, and V.A. Kelley, 1988. Numerical Simulation of Ground-Water Flow in the Culebra Dolomite at the Waste Isolation Pilot Plant (WIPP) Site: Second Interim Report, SAND88-7002; Sandia National Laboratories, Albuquerque, NM.

Matalucci, R.V. and T.O. Hunter, 1982. Geomechanical Applications for the Waste Isolation Pilot Plant (WIPP) Project, SAND81-1203; Sandia National Laboratories, Albuquerque, NM. [Also appears in The Mechanical Behavior of Salt: Proceedings of the First Conference held at the Pennsylvania State University, University Park, Pennsylvania, November 9-11, 1981, pp. 791-881.]

Matalucci, R.V., C.L. Christensen, T.O. Hunter, M.A. Molecke, D.M. Munson, 1982. Waste Isolation Pilot Plant (WIPP) Research and Development Program: In Situ Testing Plan, SAND81-2628; Sandia National Laboratories, Albuquerque, NM.

Matalucci, R.V., H.S. Morgan, and R.D. Krieg, 1981. The Role of Benchmarking in Assessing the Capability to Predict Room Response in Bedded Salt Repositories, SAND81-1293; Sandia National Laboratories, Albuquerque, NM.

McTigue, D.F. and E.J. Nowak, 1987. Brine Transport in the Bedded Salt of the Waste Isolation Pilot Plant (WIPP): Field Measurements and a Darcy Flow Model; Scientific Basis for Nuclear Waste Management XI, Materials Research Society Symposium Proceedings, Vol. 112, Materials Research Society, Pittsburgh, PA.

Mercer, J.W., 1983. Geohydrology of the Proposed Waste Isolation Pilot Plant Site, Los Medanos Area, Southeastern New Mexico, U.S. Geological Survey, Water-Resources Investigations Report 83-4016; U.S. Geological Survey, Albuquerque, NM.

Morgan, H.S., R.D. Krieg, and R.V. Matalucci, 1981. Comparative Analysis of Nine Structural Codes used in the Second Benchmark Problem, SAND81-1389; Sandia National Laboratories, Albuquerque, NM.

Morgan, H.S., C.M. Stone, and R.D. Krieg, 1985. The Use of Field Data to Evaluate and Improve Response Models for the Waste Isolation Pilot Plant (WIPP); Proceedings 26th U.S. Symposium on Rock Mechanics, A.A. Balkema, Boston, MA, pp. 769-776.

Munson, D.E., R.L. Jones, D.L. Hoag, and J.R. Ball, 1987. Heated Axisymetric Pillar Test (Room H) In Situ Data Report (February 1985 - April 1987), SAND87-2488; Sandia National Laboratories, Albuquerque, NM.

Munson, D.E. and A.F. Fossum, 1986. Comparison Between Predicted and Measured South Drift Closures at the WIPP using a Transient Creep Model for Salt; Proceedings 27th U.S. Symposium on Rock Mechanics, Society of Mining Engineers, Littleton, CO, pp. 931-939.

Munson, D.E. and H.S. Morgan, 1986. Methodology for Performing Parallel Design Calculations (Nuclear Waste Repository Application), SAND85-0324; Sandia National Laboratories, Albuquerque, NM.

Munson, D.E., T.M. Torres, and D.A. Blankenship, 1986. Early Results from the Thermal/Structural In Situ Testing Series at the WIPP; Proceedings 26th U.S. Symposium on Rock Mechanics, Society of Mining Engineers, Littleton, CO, pp. 923-930.

Munson, D.E., and P.R. Dawson, 1982. A Transient Creep Model for Salt During Stress Loading and Unloading, SAND82-0962; Sandia National Laboratories, Albuquerque, NM.

National Academy of Sciences, 1983. Review of the Scientific and Technical Criteria for the Waste Isolation Pilot Plant (WIPP); National Academy of Sciences - National Research Council, Washington, D.C.

Nowak, E.J., 1988. Assessment of Brine Inflow to WIPP Disposal Rooms, Sandia National Laboratories Memorandum; Sandia National Laboratories, Albuquerque, NM.

Nowak, E.J., D.F. McTigue, and R. Beraun, 1988. Brine Inflow to WIPP Disposal Rooms: Data, Modeling, and Assessment, SAND88-0112; Sandia National Laboratories, Albuquerque, NM.

Nowak, E.J. and D.F. McTigue, 1987. Interim Results of Brine Transport Studies in the Waste Isolation Pilot Plant (WIPP), SAND87-0880; Sandia National Laboratories, Albuquerque, NM.

Nowak, E.J. and J.C. Stormont, 1987. Scoping Model Calculations of the Reconsolidation of Crushed Salt in WIPP Shafts, SAND87-0879; Sandia National Laboratories, Albuquerque, NM.

Nowak, E.J., 1981. Composite Backfill Materials for Radioactive Waste Isolation by Deep Burial in Salt; Scientific Basis for Nuclear Waste Management, Vol. 3, Plenum Press, New York, NY.

Nowak, E.J., 1980. Radionuclide Sorption and Migration Studies of Getters for Backfill Barriers, SAND79-1110; Sandia National Laboratories, Albuquerque, NM.

NUPAC, 1989 (in preparation). TRUPACT II Safety Analysis Report for Packaging; Nuclear Packaging, Inc., Auburn, WA.

Peterson, W.W., P.L. Lagus, and K. Lie, 1987. WIPP Horizon Free Field Fluid Transport Characteristics, SAND87-7164; Sandia National Laboratories, Albuquerque, NM.

Pfeifle, T.W., 1987. Backfill Material Specification and Requirements for the WIPP Simulated DHLW and TRU Waste Technology Experiments, SAND85-7209; Re/Spec, Inc., Albuquerque, NM.

Popielak, R.S., R.L. Beauheim, S.R. Black, W.E. Coons, C.T. Ellingson, and R.L. Olsen, 1983. Brine Reservoirs in the Castile Formation, Southeastern New Mexico, TME 3153; U.S. Department of Energy, Albuquerque, NM.

Powers, D.W., S.J. Lambert, S.E. Shaffer, L.R. Hill, W.D. Weart, eds., 1978. Geological Characterization Report, Waste Isolation Pilot Plant (WIPP) Site, Southeastern New Mexico, 2 Vols., SAND78-1596; Sandia National Laboratories, Albuquerque, NM.

Public Law 96-164, 1979, Department of Energy National Security and Military Applications of Nuclear Energy Authorization Act of 1980.

Pusch, R., 1980. Swelling Pressure of Highly Compacted Bentonite, KBS Project 15:05, Technical Report 80-13; Division Soil Mechanics, University of Lulea, Lulea, Sweden.

Rechard, R.P., 1989 (in preparation). Code Linkage and Data Flow in Performance Assessment, SAND87-2833; Sandia National Laboratories, Albuquerque, NM.

Reeves, M., D.S. Ward, N.D. Johns, and R.M. Cranwell, 1986a. Theory and Implementation for SWIFT II, the Sandia Waste-Isolation Flow and Transport Model, Release 4.84, SAND83-1159 NUREG/CR-3328; Sandia National Laboratories, Albuquerque, NM.

Reeves, M., D.S. Ward, N.D. Johns, and R.M. Cranwell, 1986b. Data Input Guide for SWIFT II, the Sandia Waste-Isolation Flow and Transport Model for Fractured Media, Release 4.84, SAND84-1586 NUREG/CR-3925; Sandia National Laboratories, Albuquerque, NM.

Reeves, M., V.A. Kelley, and J.F. Pickens, 1987. Regional Double-Porosity Solute Transport in the Culebra Dolomite: An Analysis of Parameter Sensitivity and Importance at the Waste Isolation Pilot Plant (WIPP) Site, SAND87-7105; Sandia National Laboratories, Albuquerque, NM.

Reith, C.C. and G. Daer, 1985. Radiological Baseline Program for the Waste Isolation Pilot Plant: Program Plan, WTSD-TME-057; U.S. Department of Energy, Carlsbad, NM.

Saulnier G.J., Jr., 1987. Analysis of Pumping Tests of the Culebra Dolomite Conducted at the H-11 Hydropad at the Waste Isolation Pilot Plant (WIPP) Site, SAND87-7124; Sandia National Laboratories, Albuquerque, NM.

Saulnier, G.J., Jr. and J.D. Avis, 1988. Interpretation of Hydraulic Tests Conducted in the Waste-Handling Shaft at the Waste Isolation Pilot Plant (WIPP) Site, SAND88-7001; Sandia National Laboratories, Albuquerque, NM.

Siegel, M.D., S.J. Lambert, and K.L. Robinson, eds., 1988. Hydrogeochemical Studies of the Rustler Formation and Related Rocks in the WIPP Area, Southeastern New Mexico, SAND88-0196; Sandia National Laboratories, Albuquerque, NM.

Sjaardema, G.D. and R.D. Krieg, 1987. Constitutive Model for the Consolidation of WIPP Crushed Salt and Its Use in Analysis of Backfilled Shaft and Drift Configurations, SAND87-1977; Sandia National Laboratories, Albuquerque, NM.

Skokan, C., J. Starrett, and H.T. Anderson, 1988. Final Report: Feasibility Study of Seismic Tomography to Monitor Underground Pillar Integrity at the WIPP Site, SAND88-7096; Sandia National Laboratories, Albuquerque, NM.

Stormont, J.C., and J.G. Arguello, 1988. Model Calculations of Flow Through Shaft Seals in the Rustler Formation, SAND87-2859; Sandia National Laboratories, Albuquerque, NM.

Stormont, J.C., 1988a. Preliminary Seal Design Evaluation for the Waste Isolation Pilot Plant, SAND87-3083; Sandia National Laboratories, Albuquerque, NM.

Stormont, J.C., 1988b. Test Plan: WIPP Horizon Gas Flow/Permeability Measurements; Sandia National Laboratories, Albuquerque, NM.

Stormont, J.C., 1987. Small Scale Seal Performance Test Series "A" Thermal/ Structural Data through the 180th Day, SAND87-0178; Sandia National Laboratories, Albuquerque, NM.

Stormont, J.C., 1985. Test Plan: Small Scale Seal Performance Tests; Sandia National Laboratories, Albuquerque, NM.

Stormont, J.C., 1984. Plugging and Sealing Program for the Waste Isolation Pilot Plant (WIPP), SAND84-1057; Sandia National Laboratories, Albuquerque, NM.

Stormont, J.C. and C.L. Howard, 1986. Development and Implementation: Test Series B of the Small-Scale Seal Performance Tests, SAND86-1329; Sandia National Laboratories, Albuquerque, NM.

Sutherland, H.J. and S. Cave, 1978. Gas Permeability of SENM Rock Salt, SAND78-2287; Sandia National Laboratories, Albuquerque, NM.

Tyler, L.D., R.V. Matalucci, M.A. Molecke, D.E. Munson, E.J. Nowack, and J.C. Stormont, 1988. Summary Report for the WIPP Technology Development Program for Isolation of Radioactive Waste, SAND88-0844; Sandia National Laboratories, Albuquerque, NM.

U.S. Department of Energy, 1989a. TRU Waste Acceptance Criteria for the Waste Isolation Pilot Plant, Revision 3, DOE-WIPP-069-Rev.3; Waste Isolation Pilot Plant, Carlsbad, NM.

U.S. Department of Energy, 1989b. TRU Waste Certification Compliance Requirements for Newly-Generated Contact-Handled Wastes for Shipment to WIPP, WIPP-DOE-114; Waste Isolation Pilot Plant, Carlsbad, NM.

U.S. Department of Energy, 1989c. TRU Waste Certification Compliance Requirements for Contact-Handled Wastes Retrieved From Storage for Shipment to WIPP, WIPP-DOE-137; Waste Isolation Pilot Plant, Carlsbad, NM.

U.S. Department of Energy, 1989d. TRU Waste Certification Compliance Requirements for Remote-Handled Wastes for Shipment to WIPP, WIPP-DOE-158; Waste Isolation Pilot Plant, Carlsbad, NM.

U.S. Department of Energy, 1989e. Waste Isolation Pilot Plant Compliance Strategy for 40 CFR Part 191, DOE-WIPP 86-013; Waste Isolation Pilot Plant, Carlsbad, NM.

U.S. Department of Energy, 1988a (in preparation). Final WIPP Safety Analysis Report; Waste Isolation Pilot Plant. Carlsbad, NM.

U.S. Department of Energy, 1988b. Quality Assurance Requirements for the Certification of TRU Waste for Shipment to the Waste Isolation Pilot Plant, WIPP-DOE-120; Waste Isolation Pilot Plant, Carlsbad, NM.

U.S. Department of Energy, 1988c. General Environmental Protection Program, DOE Order 5400.1; U.S. DOE, Washington, DC.

U.S. Department of Energy, 1988d (Draft). Radiation Protection for Occupational Workers, DOE Order 5480.11; U.S. DOE, Washington, D.C.

U.S. Department of Energy, 1988e. Radioactive Waste Management, DOE Order 5820.2A; U.S. DOE, Washington, D.C.

U.S. Department of Energy, 1988f. Physical Protection of DOE Property and Unclassified Facilities, DOE Order 5632.6; U.S. DOE, Washington, D.C.

U.S. Department of Energy, 1988g. Protective Forces, DOE Order 5632.7; U.S. DOE, Washington, D.C.

U.S. Department of Energy, 1988h. WIPP Project Plan, DOE-WIPP 88-010, draft; Waste Isolation Pilot Plant, Carlsbad, NM.

U.S. Department of Energy, 1987a. Project Management Orders; DOE Order 4700.1; U.S. DOE, Washington, D.C.

U.S. Department of Energy, 1987b. Environmental Protection, Safety and Health Protection Information Reporting Requirements, DOE Order 5484.1; U.S. DOE, Washington, D.C.

U.S. Department of Energy, 1986a. Hazardous Materials Packaging for Transport-Administrative Procedures, DOE Order 1540.2, modified December 1988; U.S. DOE, Washington, DC.

U.S. Department of Energy, 1986b. Environmental Protection, Safety and Health Protection Program for DOE Operations, DOE Order 5480.1B; U.S. DOE, Washington, D.C.

U.S. Department of Energy, 1986c. Safety Analysis and Review System, DOE Order 5481.1B; U.S. DOE, Washington, DC.

U.S. Department of Energy, 1986d. Quality Assurance, DOE Order 5700.6B; U.S. DOE, Washington, D.C.

U.S. Department of Energy, 1985. Safety Requirements for the Packaging and Transportation of Hazardous Materials, Hazardous Substances, and Hazardous Wastes, DOE Order 5480.3; U.S. DOE, Washington, D.C.

U.S. Department of Energy, 1983. Summary of the Results of the Evaluation of the WIPP Site and Preliminary Design Validation Program, WIPP-DOE-161; Waste Isolation Pilot Plant, Carlsbad, NM.

U.S. Department of Energy, 1982. Materials Transportation and Traffic Management, DOE Order 1540.1; U.S. DOE, Washington, D.C.

U.S. Department of Energy, 1981a. Emergency Planning, Preparedness, and Response for Operations, DOE Order 5500.2; U.S. DOE, Washington, D.C.

U.S. Department of Energy, 1981b. Record of Decision - Waste Isolation Pilot Plant (WIPP); Federal Register Vol. 48, pg. 9162, January 28, 1981.

U.S. Department of Energy, 1980. Final Environmental Impact Statement, Waste Isolation Pilot Plant, DOE/EIS-0026; Washington, D.C.

U.S. Department of Energy and State of NM, 1981, as modified. Agreement for Consultation and Cooperation Between the U.S. Department of Energy and the State of NM on the Waste Isolation Pilot Plant, modified 11/30/84, 8/4/87, and 3/22/88.

U.S. Department of Energy, U.S. Department of the Interior, and State of NM, 1981. Stipulated Agreement in the Case of State of New Mexico, ex rel. Jeff Bingaman, Attorney General of the State of New Mexico, vs. The United States Department of Energy et al., Civil Action No. 81-0363 JB, in the United States District Court for the District of NM.

U.S. Department of Labor, 1977. Federal Mine Safety and Health Act of 1977; Code of Federal Regulations, Title 30, Parts 32 to 57.

U.S. Department of Transportation. Carriage by Public Highway; Code of Federal Regulations, Title 49, Part 177.

U.S. Department of Transportation. Federal Motor Carrier Safety Regulations; Code of Federal Regulations, Title 49, Parts 350 to 399.

U.S. Department of Transportation, Hazardous Materials Tables and Hazardous Materials Communications Regulations; Code of Federal Regulations, Title 49, Part 172.

U.S. Department of Transportation, Other Regulations Relating to Transportation; Code of Federal Regulations, Title 49, Parts 100 to 178.

U.S. Department of Transportation, Shippers - General Requirements for Shipments and Packagings; Code of Federal Regulations, Title 49, Part 173.

U.S. Environmental Protection Agency. Standards Applicable to Generators of Hazardous Wastes; Code of Federal Regulations, Title 40, Part 262.

U.S. Environmental Protection Agency. Subpart H - National Emission Standards for Hazardous Air Pollutant: Standards for Radionuclides; Code of Federal Regulations, Title 40, Part 61.

U.S. Environmental Protection Agency. Identification and Listing of Hazardous Waste; Code of Federal Regulations, Title 40, Part 261.

U.S. Environmental Protection Agency, 1985. Environmental Radiation Protection Standards for the Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes; Final Rule; Code of Federal Regulations. Title 40, Part 191, pp. 38066-38089. Federal Register, Vol. 50, No. 182 (Sept. 19, 1985).

U.S. Environmental Protection Agency. Regulations for Implementing the Procedural Provisions of the National Environmental Policy Act (NEPA); Code of Federal Regulations, Title 40, Parts 1500 to 1508.

U.S. Nuclear Regulatory Commission, Packaging and Transport of Radioactive Material; Code of Federal Regulations, Title 10, Part 71.

Vandekraats, J., 1987. Quarter-Scale Modeling of Room Convergence Effects on CH TRU Drum Waste Emplacements Using WIPP Reference Design Geometries, DOE/WIPP 87-012; Westinghouse Electric Corporation.

Van Sambeek, L.L. and J.C. Stormont, 1987. Thermal/Stuctural Modeling of the Small Scale Seal Performance Tests, SAND87-7037; Sandia National Laboratories. Albuquerque, NM.

Westinghouse Electric Corporation, 1989. WIPP Operational Environmental Monitoring Plan, DOE-WIPP 88-025; Waste Isolation Pilot Plant, Carlsbad, NM.

Westinghouse Electric Corporation, 1988a. Operational Readiness Review Verification, WP 12-004; Waste Isolation Pilot Plant, Carlsbad, NM.

Westinghouse Electric Corporation, 1988b. Waste Transportation Manual, DOE-WIPP-88-002; Waste Isolation Pilot Plant, Carlsbad, NM.

Westinghouse Electric Corporation, 1988c. Waste Transportation Manual, WP 06-2; Waste Isolation Pilot Plant, Carlsbad, NM.

Westinghouse Electric Corporation, 1988d. WIPP Operations Ground Control Procedure, WP 04-220; Waste Isolation Pilot Plant, Carlsbad, NM.

Westinghouse Electric Corporation, 1988e. WIPP Radiation Safety Manual, WP 12-5; Waste Isolation Pilot Plant, Carlsbad, NM.

Westinghouse Electric Corporation, 1988f. WIPP Operational Safety Requirements Administration Plan, WP 04-7 Rev. 4; Waste Isolation Pilot Plant, Carlsbad, NM.

Westinghouse Electric Corporation, 1988g. WIPP Emergency Plan, WP 12-7 Rev. 4; Waste Isolation Pilot Plant, Carlsbad, NM.

Westinghouse Electric Corporation, 1988h. Final Report for the WIPP CH-TRU Waste Preoperational Checkout, DOE-WIPP 88-012; Waste Isolation Pilot Plant, Carlsbad, NM.

Westinghouse Electric Corporation, 1988i. Final Report for the WIPP RH-TRU Waste Preoperational Checkout, DOE-WIPP 88-013; Waste Isolation Pilot Plant, Carlsbad, NM.

Westinghouse Electric Corporation, 1988j. Final Report for the CH-TRU Mock Retrieval Demonstration, DOE-WIPP 88-006; Waste Isolation Pilot Plant, Carlsbad, NM.

Westinghouse Electric Corporation, 1987a. A Plan for the Implementation of Assurance Requirements in Compliance with 40 CFR 191.14 at the Waste Isolation Pilot Plant, DOE-WIPP 87-016; Waste Isolation Pilot Plant, Carlsbad, NM.

Westinghouse Electric Corporation, 1987b. Report of the RH-TRU Mock Retrieval Demonstration, DOE-WIPP 87-005; Waste Isolation Pilot Plant, Carlsbad, NM.

APPENDIX A
TESTS WITH CH-TRU AND SIMULATED WASTES

APPENDIX A
TESTS WITH CH-TRU AND SIMULATED WASTES

A.1.0 INTRODUCTION

Because of the special interest in those components of this Plan that will use CH-TRU waste or simulated (nonradioactive) and spiked (radioactive) wastes in tests, this appendix has been prepared as a supplement to Activities S.1.1.4 (Laboratory Studies of Repository Chemistry), S.1.1.5 (Radionuclide Chemistry), S.1.3.2 (Room-Scale Gas Generation Tests), and S.1.3.3 (Bin-Scale Gas Generation Tests). These activities are described here in more detail for completeness emphasizing gas generation, consumption, and transport. This appendix discusses the acquisition, understanding, and refinement of data necessary for performance assessment using drum-scale tests in the laboratory with simulated wastes, and bin-scale and room-scale tests with CH-TRU waste. This testing program will reduce uncertainty in the performance assessment by confirming predictions of gas generation. Data sets resulting from these tests will be used to check the predictions.

The laboratory tests will use only simulated waste (nonradioactive) or spiked waste containing a single radionuclide to examine radiolysis and effects of compaction. The bin-scale tests will use CH-TRU waste specially prepared and modified to study the synergism between waste types, backfill and getter materials, metals, and injected brines. The room-scale tests will use a mix of both unmodified (as-received) and specially prepared CH-TRU wastes to obtain information on initial, operational phase conditions and on longer term, postoperational phase conditions representative of a partially closed room. Both CH-TRU waste tests will be conducted underground.

A.1.1 BACKGROUND

The TRU waste to be disposed of at the WIPP facility is a mixture of standard 55-gallon (208-liter) drums and a lesser number of TRUPACT II CH-TRU Standard Waste Boxes, which are filled with waste from nuclear weapons production facilities. This waste is comprised of laboratory hardware such as ring stands, other metal structures, and glassware; cleaning materials such as Kimwipes, tissues, and towels; protective clothing; chemicals, many of which are stabilized with cement; plastics and resins of all types; and worn out or contaminated engineering equipment and tools. When these materials are placed in the WIPP facility, and generally as soon as they are placed in the drums and boxes, they begin to generate gases. These gases range from by-products of bacterial action (mainly carbon dioxide or methane and potentially nitrogen), gaseous by-products of anoxic metal corrosion (mainly hydrogen), to the volatile products of waste radiolysis (mainly hydrogen, oxygen, carbon oxides, and low molecular weight organic compounds).

WIPP waste emplacement operations for ultimate disposal will include several steps. Containers (drums and boxes) shipped to the WIPP facility will be placed in one of eight panels, and the rooms will be backfilled with an appropriately designed backfill. After filling the panel with drums or boxes of waste, the panel will also be backfilled. Subsequently, the panel will be sealed from the rest of the underground facility. Any gas generated by the waste after a panel is sealed must be considered in the long-term performance assessment calculation. The performance of the WIPP disposal system includes not only the room behavior but also the individual and coupled behaviors of the panel seals, access drifts, shaft seals, damaged zones in the rock around the shaft seals, and potential radionuclide transport through the upper water-bearing units to the accessible environment.

A.1.2 RATIONALE

The gas and water content of waste disposal rooms could affect long-term performance, especially in the event of human intrusion. Available estimates of the rates of gas production by CH-TRU waste are based on laboratory studies of processes such as radiolysis, microbial activity, corrosion, and thermal degradation (Molecke, 1979), and field studies of head-space gases in drums (Clements and Kudera, 1985b). The extreme heterogeneity of CH-TRU waste resulting from the variety of waste streams exacerbates the difficulty of obtaining gas production data representative of the total waste mix. To do so requires large numbers of experiments and, in the large-scale tests, a significant and representative sample of the inventory.

Previously, gas generation did not seem to be critical to the long-term performance of WIPP. Calculations of the diffusive transport of gas out of the repository and into the surrounding Salado Formation (DOE, 1980; Sandia Laboratories, 1979) implied that even if the high gas production rates estimated by Molecke (1979) were correct, the permeability of the surrounding rock was high enough to allow gas to escape without a significant increase in repository pressure. Recent, more definitive, far-field permeability measurements (Tyler et al., 1988), however, imply that high gas production rates may significantly pressurize the repository. Thus, it has become necessary to resolve the differences between gas production estimates to establish a realistic range of gas production rates for WIPP.

Recently, Brush and Anderson (1988a) calculated that processes such as drum corrosion, microbial decomposition of cellulosic materials, and reactions between drum corrosion products and microbially generated gases could affect the gas budget of the repository. These processes could consume or produce quantities of water similar to quantities of brine recently predicted to seep into the repository from the Salado Formation (Activities S.3.3.6 through S.3.3.13).

Laboratory-, bin-, and room-scale tests with CH-TRU and simulated wastes are thus necessary to acquire the data for predictions of the long-term gas and water content of WIPP disposal rooms, and to assess their impact on repository performance. It has become evident during the last year that a proper understanding of gas evolution rates is critical to addressing the behavior and ultimate state of the repository. The TRU waste tests described in more detail in this appendix will provide that understanding and establish an acceptable level of confidence in predictions of performance.

A.1.3 APPROACH

Gas generated from the TRU waste emplaced in the WIPP could pressurize the disposal room during room closure and waste entombment. The assessment of gas concerns must consider three elements: gas production, gas transport, and gas consumption. Gas is produced by radiolytic, chemical, and biological reactions between the waste, waste containers, engineered backfill, brine, and salt. Gas transport depends on the ability of the salt formation to accept the gas and allow it to disperse. The primary parameter controlling gas transport is gas permeability of the formation, which differs for different gases. Gas consumption is dependent upon the backfill composition. Backfills are being considered to include gas getters as backfill components. Gas transport can be addressed without waste, but gas production and consumption are strong functions of the waste itself. To measure gas production and consumption, actual CH-TRU waste is needed. The data needed for the performance assessment models will be obtained from laboratory-scale, bin-scale, and room-scale tests. These data, coupled with model development, will be used to assess the importance of gas in the repository. The lab-scale tests will provide detailed information on each type of gas that may be generated and on which getter materials are effective. The bin-scale tests will provide data on gas generation and getter effectiveness on a much larger scale. The bin-scale tests will bound the laboratory tests and address synergistic effects and unknowns identified by the laboratory tests. The room-scale tests will provide data to confirm the assessment of the importance of gas in the repository. These assessments will determine the gas generation rates for the times of interest and how the gases will either be consumed or transported from the disposal room.

Liter-sized laboratory tests will address all expected repository conditions for each gas. The tests will bracket the generation rates and times of interest. The tests will also identify, screen, and test gas getters. For carbon dioxide and nitrogen, the conditions will include wet and dry environments, with and without oxygen, with and without salt, and all appropriate combinations. For each set, both halophilic and nonhalophilic bacteria will be considered. Radiolysis of water and the wastes inside the drums can generate oxygen, carbon oxides, hydrogen, and low molecular weight organic compounds. CH-TRU waste simulants spiked with radionuclides will be used to assess the effects of radiolysis in all potential environments.

Hydrogen can also be generated by anoxic corrosion of the metal in the drums if excess brine is present. Corrosion tests have been designed. Getters will be added to some test environments to provide the data needed for getter selection. Additional tests can be conducted using simulated wastes in drum-size containers to aid in determining generation rates and getter effectiveness.

In the bin-scale tests, the test bins will be large enough to contain a mixture of about six drum volumes of actual CH-TRU waste, drum metals, backfill materials, brine, and salt. The tests will bound the laboratory studies and provide a scaled evaluation and confirmation of the synergistic impacts of waste-degradation, modes of gas generation, and the effectiveness of the getter backfill components. The tests will address wet and dry environments with salt and with and without oxygen, and backfills with and without getters. Halophilic, halotolerant, and nonhalophilic bacteria will be present for bacterial gas generation. Drum and waste metals will provide the source for corrosion gas. The waste and the brine will be the sources of radiolysis gas. The bin-scale tests also provide an environment in which various types of gas generation may occur simultaneously. Therefore, the bin-scale tests will provide a realistic, credible, and synergistic test for gas generation rates and interaction with backfill and getters.

Room-scale tests will confirm the results of the laboratory and bin tests. These underground tests will allow a larger, synergistic test of gas generation, waste compaction impacts, and getter material effectiveness. These tests will be conducted in the WIPP underground to provide a realistic environment of brine, bacterial contamination, naturally occurring gases, and salt contaminated by bacteria. One alcove will contain about 1,050 drums of as-received CH-TRU waste to define initial operational phase gas generation. Two alcoves will contain about 1,050 drums each of prepared waste, one with backfill over the waste drums, and one without the backfill. The prepared waste will contain CH-TRU waste, drum metal, salt, brine, and backfill to simulate postoperational conditions during room closure. Two other rooms will contain lesser amounts of compacted waste. As with the prepared waste test alcoves, one will be with backfill, the other without. The drums are vented to allow exchange of the gases between drums and the ambient atmosphere of the room within the rock salt. The alcoves will require a degree of sealing to limit air exchange with the access drifts.

A.2.0 LABORATORY TESTS OF REPOSITORY AND RADIONUCLIDE CHEMISTRY

A.2.1 RATIONALE

Laboratory studies are planned to develop a mechanistic understanding of repository and radionuclide chemistry because they can: (1) quantify the effects of significant processes under conditions that isolate each process from the complex effects of other processes, yet are nevertheless realistic; (2) determine the effects of variations in repository conditions on these processes.

Several processes could affect the repository gas and water budgets. The air trapped in WIPP disposal rooms at the time they are filled and sealed will be comprised of mainly nitrogen and oxygen. The Salado Formation will release brine and will initially release gas, mostly nitrogen, possibly with some methane. Eventually, the Salado Formation might serve as a sink for all gases, except perhaps nitrogen. Microbial activity, either aerobic or anaerobic, halophilic, halotolerant, or nonhalophilic, will oxidize cellulosic materials and perhaps other materials in the waste such as plastics and rubbers. Microbial degradation of the waste will produce carbon dioxide in potentially significant amounts, as well as potentially significant quantities of other gases under certain conditions. These other gases could include hydrogen sulfide, methane, and nitrogen. Microbial activity could also affect the water budget of the repository, but the net effect is unclear at present. Corrosion, either oxic or anoxic, of drums, metal boxes, and metallic constituents of the waste will consume significant quantities of water and (in the case of anoxic corrosion) produce significant quantities of hydrogen in the presence of excess brine. Hydrogen gas may be removed by microbial sulfate reduction, and hydrogen sulfide may be removed by reacting with iron or iron oxides to form pyrite. The formation of pyrite, however, will release the hydrogen consumed during sulfate reduction and perhaps produce additional hydrogen, as well as release any water consumed during oxic or anoxic corrosion. Radiolysis of brine, cellulosics, plastics, and rubbers will consume water and produce carbon dioxide, carbon monoxide, hydrogen, and oxygen. Radiolysis could also increase the microbial gas production potential by transforming plastics and rubbers into more biodegradable materials. Brush and Anderson (1988a, 1988b, 1988c) have described these reactions in detail.

Brush and Anderson (1988a, 1988c) proposed several backfill additives to remove or prevent the production of gas. Calcium carbonate, calcium oxide, potassium hydroxide, and sodium hydroxide might remove carbon dioxide. Calcium oxide might also remove water. The addition of manganese dioxide, an electron acceptor, might prevent microbial sulfate reduction; the concomitant production of hydrogen sulfide; the reaction of hydrogen sulfide with drums, metal boxes, metallic constituents of the waste and their corrosion products to form pyrite; and the concomitant production of hydrogen. Copper sulfate, an oxidant, might corrode metal containers and metallic constituents of the waste without producing hydrogen. It is unclear at present, however, whether these proposed backfill additives will be effective, affect other aspects of repository chemistry deleteriously, or inhibit the closure of WIPP disposal rooms by increasing the strength of the materials in the rooms.

Reactions between any brine present in the WIPP disposal rooms and backfill additives, drums, boxes, and nonradioactive constituents of the waste could change the Eh (oxidation potential) and pH of the brine significantly. Microbial activity and corrosion of drums, metal boxes, and metallic constituents of the waste would decrease the Eh. However, radiolytic production of oxygen or peroxides would tend to increase Eh. Microbial activity, for example, could decrease the Eh to values characteristic of denitrification or nitrate reduction, the reduction of manganese(IV) oxides or hydroxides, the reduction of iron(III) oxides or hydroxides, or even sulfate reduction. (Numerical values of Eh for any of these processes values depend on pH, which cannot be predicted yet.) Microbial production of carbon dioxide could decrease the pH of the brine to acidic values. Reactions between brine and the cements used to grout some of the drums and used in seals, could increase the pH to basic values. Reactions between brine and three of the backfill additives proposed for the removal of carbon dioxide (calcium oxide, potassium hydroxide, and sodium hydroxide) could increase the pH to very basic values.

Because the possible ranges of Eh and pH for any brine after the reactions described above are so wide, the speciation, solubilities, and sorptive behavior of the important radionuclides in TRU waste could vary significantly. Unfortunately, there are no thermodynamic data for the actinide elements in solutions with ionic strengths of likely WIPP brines (see Activity S.1.1.4). Laboratory studies of radionuclide chemistry will therefore be necessary over a wide variety of conditions.

A.2.2 OBJECTIVES

1. Quantify the effects of microbial degradation of the nonradioactive constituents of TRU waste on the gas and water budgets of WIPP disposal rooms, the Eh and pH of any brine present, and the chemical behavior of radionuclides.

2. Determine the effects of radiolysis on the bioavailability of plastics and rubbers.

3. Quantify the production of hydrogen by anoxic corrosion of drums, metal boxes, and metallic constituents of the waste under various conditions.

4. Quantify the chemical effects of proposed backfill additives to remove gas or prevent its production.

5. Quantify the chemical behavior of the important radionuclides in TRU waste in likely WIPP brines.

A.2.3 DESCRIPTION

Brush (1989) describes the laboratory studies of repository and radionuclide chemistry discussed below in much greater detail.

Laboratory Studies of Microbial Degradation of Nonradioactive Simulated Waste

Microbial degradation of nonradioactive constituents of the waste will produce potentially significant quantities of gas. Based on an extensive literature review and experimental program, Molecke (1979) concluded that the "most probable overall average" gas production rate for TRU waste under expected WIPP conditions will be 0.3 to 1.4 moles per drum per year, and that microbial degradation will be the most important component of this gas production rate. Furthermore, Sandia National Laboratories (1979) concluded that the microbial gas production potential of an average TRU waste drum is 2,000 moles. Although Brush and Anderson (1989) estimated a lower microbial gas production potential of 589 moles per drum, they found no reason to lower Molecke's (1979) estimate of the microbial gas production. Microbial degradation is therefore one of the two processes of most concern from the standpoint of the repository gas budget. The other process, anoxic corrosion of drums, metal boxes, and metallic constituents of the waste, is discussed below.

The experimental program directed by Molecke (1979) yielded valuable data on the overall microbial gas production rate under expected repository conditions. Subsequently, however, an increased awareness by geochemists of the role of microorganisms in mediating diagenetic oxidation-reduction (redox) reactions has led to the development of a conceptual model of the effects of microbial activity on low temperature geochemical systems. Froelich et al. (1979) and Berner (1980) have described this model in detail; Brush and Anderson (1988a) applied it to the microbial degradation of TRU waste in WIPP disposal rooms. From the perspective of the long-term performance of the WIPP disposal system, the most important results obtained from this model have been: (1) a method for identifying microbial processes that could affect the gas and water budgets of the repository significantly; (2) the understanding that microbially mediated reactions can determine the Eh and pH of low temperature geochemical systems, and hence the speciation, solubilities, and sorptive behavior of radionuclides in these systems (see, for example, Sholkovitz et al., 1983).

Based on a review by the WIPP Performance Assessment Source Term Group, it was concluded that the following microbial processes could significantly affect repository and radionuclide chemistry: (1) denitrification (the use of nitrate as an electron acceptor, and the concomitant production of carbon dioxide and nitrogen) under saline conditions; (2) sulfate reduction (the use of sulfate as an electron acceptor, and the concomitant production of carbon dioxide and hydrogen sulfide) under saline conditions; and (3) fermentation and methanogenesis (the consumption of carbon dioxide and hydrogen, or acetate, and the concomitant production of methane) under asaline conditions (prior to rupture of drums and boxes, and resaturation of the repository with brine) and saline conditions. It was also concluded that aerobic respiration, the reduction of manganese(IV) oxides and hydroxides, and the reduction of iron(III) oxides and hydroxides will not be important in the repository. (Brush, 1989, provides detailed justification for these conclusions.)

The objectives of the laboratory microbiological studies are to: (1) determine whether the potentially significant processes identified above occur under saline conditions or, in the case of fermentation and methanogenesis, under asaline conditions as well; (2) quantify under realistic, not overtest, conditions the effects on the repository gas and water budgets of those potentially significant processes that actually occur; (3) quantify under realistic, not overtest, conditions the effects on the chemical behavior of the important radionuclides in TRU waste of those potentially significant processes that actually occur; and (4) determine whether or not the microorganisms responsible for any significant processes are likely to survive for periods sufficient to affect the long-term performance of the WIPP disposal system.

Laboratory Studies of Radiolysis

Molecke (1979) concluded from simulated waste experiments that the rate of radiolytic gas production by TRU waste under expected WIPP conditions will be significantly lower than either the potential long-term microbial gas production or the production of hydrogen by anoxic corrosion of drums, metal boxes, and metallic constituents of the waste estimated by Brush and Anderson (1989) assuming excess brine.

The Rocky Flats Plant plans to compact newly generated waste. Thus a laboratory study of the effects of compaction on the radiolytic gas production rate is planned.

Estimates of the total gas production potential of TRU waste, however, are very sensitive to assumptions of the extent to which microorganisms will degrade cellulosic materials, plastics, and rubbers in the WIPP inventory. Brush and Anderson (1989) calculated a total gas production potential of 1,480 moles per drum (589 moles per drum from microbial activity, 894 moles per drum from anoxic corrosion) by assuming that microorganisms convert 100 percent of the cellulosics, 50 percent of the rubbers, but none of the plastics in the WIPP inventory to gas. Their estimate of the microbial component of the gas production potential would have been much higher, however, if they had assumed that microorganisms will degrade plastics significantly. Conversion of all the plastics could increase the total gas production potential to a value close to that estimated by Sandia National Laboratories (1979), 2,000 moles per drum.

Microorganisms will almost certainly consume cellulosic materials in preference to plastics and rubbers. Radiolysis of plastics and rubbers, however, could transform them into more bioavailable materials. A laboratory study of the effects of radiolysis on the bioavailability of plastics and rubbers is therefore necessary to determine the gas production potential of TRU waste.

Radiolysis may also produce oxidants such as oxygen and hydrogen peroxide that may have important effects on the oxidation state of the repository and hence the ability of anaerobic microbes to survive.

Laboratory Studies of Anoxic Corrosion

Brush and Anderson (1989) used recent estimates of the quantities of metallic constituents in the WIPP inventory to calculate that anoxic corrosion of drums, metal boxes, and metallic constituents of the waste will produce 1.70 moles of hydrogen per drum per year, and that the hydrogen production potential from anoxic corrosion is 894 moles per drum. Anoxic corrosion is thus the process of greatest concern from the standpoint of the gas budget of the repository, assuming that excess brine will be available for corrosion reactions.

Brush and Anderson (1989) based their estimate of the hydrogen production rate on anoxic corrosion data from Molecke (1979) and Haberman and Frydrych (1988). Molecke (1979) reviewed data from a laboratory study of the corrosion of 1018 mild steel (the same alloy used for the drums) in sodium chloride-saturated brine at 25°C. Haberman and Frydrych (1988) studied the corrosion of A216 Grade WCA mild steel in Permian Basin brines at 90, 150, and 250°C; Brush and Anderson (1988a) then extrapolated these data to the expected WIPP temperature of about 30°C and the lower magnesium concentrations of intergranular brines from the Salado Formation.

Although it seems virtually certain that anoxic corrosion will produce large quantities of hydrogen if magnesium-bearing brine resaturates the repository, it is unclear whether anoxic corrosion will occur in the presence of water vapor, or of water previously absorbed by bentonite in contact with drums, metal boxes, and metallic constituents of the waste. Additional laboratory studies are therefore necessary to: (1) measure anoxic corrosion rates for relevant iron and steel alloys in likely WIPP brines at 30°C, if possible; (2) determine whether anoxic corrosion occurs using water vapor and, if so, measure its rate; (3) determine whether anoxic corrosion occurs using water absorbed by bentonite and, if so, measure its rate; and (4) determine whether anoxic corrosion of other metals in the WIPP inventory occurs and, if so, measure rates for these metals. After iron-bearing alloys, aluminum is probably the metal of greatest concern.

Laboratory Studies of Proposed Backfill Additives

Carbon dioxide will probably be the most abundant microbially produced gas under most conditions. Brush and Anderson (1988a) proposed the use of four backfill additives to remove carbon dioxide from WIPP disposal rooms: calcium carbonate, calcium oxide, potassium hydroxide, and sodium hydroxide. Calcium carbonate would remove carbon dioxide only if brine were present; calcium oxide, potassium hydroxide, and sodium hydroxide would remove carbon dioxide in the absence of brine. Brush and Anderson (1988a) calculated that about 87,000 kg of potassium hydroxide or 62,000 kg of sodium hydroxide per room would be required to remove all of the microbially produced carbon dioxide, but did not calculate the required quantities of calcium carbonate or calcium oxide because the stoichiometry of carbon dioxide uptake by these compounds has not been defined for expected WIPP conditions. Because the required quantity of any backfill additive for the removal of carbon dioxide depends critically on how much of the microbially produced gas is in fact carbon dioxide, which is unknown at present, the required quantities of any of these backfill additives cannot be estimated yet. Because the required quantities of these backfill additives cannot be calculated at this time, the pH of brine after it reacts with these compounds or their carbon dioxide-bearing reaction products cannot be predicted yet, but it could increase to extremely basic values. This could in turn hasten anoxic corrosion of drums, metal boxes, and metallic constituents of the waste, as well as increase the concentrations of dissolved radionuclides.

Addition of manganese dioxide, an electron acceptor, to the backfill might prevent microbial sulfate reduction, the concomitant production of hydrogen sulfide, the reaction of hydrogen sulfide with drums, metal boxes, metallic constituents of the waste, and their corrosion products to form pyrite, and the concomitant production of hydrogen. The use of manganese dioxide as a backfill additive, however, has three potential problems: (1) it must be demonstrated that there are halophilic or halotolerant microorganisms that can use manganese dioxide as an electron acceptor under expected WIPP conditions; (2) it must be demonstrated that these microorganisms would survive in the repository until conditions conducive to manganese(IV) reduction occurred, and throughout the period during which manganese(IV) reduction would be required; (3) manganese dioxide is very insoluble and thus might not migrate through any brine fast enough to prevent significant sulfate reduction in isolated locations in WIPP disposal rooms.

Finally, the proposed backfill additive, copper sulfate, an oxidant, might corrode drums, metal boxes, and metallic constituents of the waste without producing hydrogen. Copper sulfate would only be effective if brine were present, but anoxic corrosion might not occur in the absence of brine anyway. Brush and Anderson (1989) estimated that 878,000 kg of copper sulfate per room would be required to corrode all of the metal containers and metallic constituents of the waste without producing hydrogen.

The objectives of laboratory studies of proposed backfill additives are to: (1) determine whether these compounds remove gas or prevent its production and (2) quantify their effects on repository chemistry. (Studies of possible effects of proposed backfill additives on the closure of WIPP disposal rooms are described in Activity S.1.1.1).

<u>Laboratory Studies of Radionuclide Chemistry</u>

Predictions of the concentrations of radionuclides in any brine present in WIPP disposal rooms, along with the volume and rate of brine release from the repository, constitute the source term for performance assessment modeling. The speciation, solubilities, and sorptive properties of radionuclides will determine their concentrations in any brine present.

The speciation, solubilities, and sorptive properties of the important actinide elements in TRU waste are very sensitive to Eh and pH, which will vary significantly with time and over short distances in WIPP disposal rooms (see Activity S.1.1.5). It is therefore necessary to quantify the chemical behavior of the actinide elements over a wide range of expected repository conditions. Unfortunately, there are no thermodynamic data (stability constants for organic or inorganic actinide complexes, solubility products for actinide-bearing solids, or distribution coefficients for the sorption of actinides by bentonite or iron oxides) for solutions with ionic strengths as high as likely WIPP brines (I = 6 to 8 M).

Initially, stability constants, and perhaps solubility products, will be measured for the important actinide elements in likely WIPP brines under conditions expected prior to reactions between these brines and nonradioactive constituents of the waste. (Microbial degradation of nonradioactive constituents of the waste, anoxic corrosion of drums, metal boxes, and metallic waste constituents, and reactions between brine and proposed backfill additives could change the Eh and pH of these brines significantly.)

Later, after laboratory studies of repository chemistry indicate the possible ranges of Eh and pH following reactions between these brines and nonradioactive constituents of the waste, stability constants, and perhaps solubility products, will also be measured for the important actinide elements under other conditions.

An ongoing sensitivity study is examining the relative effects of solubility and sorption on the concentrations of radionuclides in any brine that resaturates WIPP disposal rooms. This study will identify actinide sorption data necessary for predictions of the source term.

Finally, transport of actinide elements by colloidal or other suspended particles could be significant. Studies of colloid formation will begin once sensitivity studies identify the conditions under which this form of transport could be significant.

A.2.4 <u>SEQUENCE</u>

The sequence of each category of laboratory studies appears separately below.

<u>Laboratory Studies of Microbial Degradation of Nonradioactive Simulated Waste</u>

1. Determine whether or not potentially significant microbial processes occur under expected repository conditions. (Begin mid-FY89)

2. Quantify, under realistic conditions, the effects on the repository gas and water budgets of those potentially significant processes that actually occur. (Begin mid-FY89)

3. Determine whether or not the microorganisms responsible for significant processes are likely to survive for periods sufficient to affect the long-term performance of the WIPP disposal system. (Begin mid-FY89)

4. Quantify, under realistic conditions, the effects on the chemical behavior of the important radionuclides in TRU waste of any potentially significant microbial processes that actually occur under expected repository conditions. (Begin late FY89)

<u>Laboratory Studies of Radiolysis</u>

1. Quantify the effect of waste compaction on the radiolytic gas production rate. (Begin late FY89)

2. Determine whether radiolysis increases the bioavailability of plastics and rubbers. (Begin late FY89)

Laboratory Studies of Anoxic Corrosion

1. Measure anoxic corrosion rates for relevant iron and steel alloys in likely WIPP brines at 30°C, if possible. (Begin mid-FY89)

2. Determine whether anoxic corrosion of iron and steel alloys occurs in the presence of water vapor and, if so, measure its rate. (Begin mid-FY89)

3. Determine whether anoxic corrosion of iron and steel alloys occurs in the presence of water absorbed by bentonite and, if so, measure its rate. (Begin mid-FY89)

4. Determine whether anoxic corrosion of other metals in the WIPP inventory occurs and, if so, measure rates for these metals. (Begin mid-FY89)

Laboratory Studies of Proposed Backfill Additives

1. Determine whether proposed backfill additives remove gas or prevent its production effectively. (Begin mid-FY89)

2. Quantify the effects of proposed backfill additives on repository chemistry. (Begin mid-FY89)

Laboratory Studies of Radionuclide Chemistry

1. Measure stability constants, and perhaps solubility products, for the important actinide elements in likely WIPP brines under conditions expected prior to reactions between these brines and nonradioactive constituents of the waste. (Begin mid-FY89)

2. Measure stability constants, and perhaps solubility products, for the important actinide elements in likely WIPP brines under conditions expected following reactions between these brines and nonradioactive constituents of the waste. (Begin mid-FY90)

3. Measure any necessary sorption data for the important actinide elements for predictions of the source term. (To be scheduled at a later date)

4. Determine the conditions under which colloids form. (To be scheduled at a later date)

A.3.0 BIN-SCALE GAS GENERATION TESTS

A.3.1 RATIONALE

Gases generated by radioactive waste and generation rates as a function of time in the repository may significantly affect releases from the repository. Evaluation of gas effects on potential release scenarios requires data that define the chemical reactions and the amounts and rates of gases generated. Several kinds of data on the potential in situ behavior of CH-TRU waste are needed. Examples are gas speciation, generation, and depletion rates as a function of time and several other waste condition parameters; definition of dissolved or mobilized chemical and radiochemical species for the source term; and systems interactions and synergisms. The impacts of radiolytic, bacterial, and chemical degradation can be adequately analyzed and evaluated in bin-scale tests with TRU wastes. The added degree of experimental control and the multiple test conditions planned for the bin-scale tests allow simpler and more straightforward data interpretation. Test data are necessary for both analytical calculations and performance assessment predictions and for confirmation of smaller scale laboratory data on simulated wastes. The full spectrum of required data can be obtained from bin-scale tests combined with room-scale tests (Activity S.1.3.2) and supporting laboratory tests (Activities S.1.1.4 and S.1.1.5).

A.3.2 OBJECTIVES

1. Quantify gas composition, generation, and depletion rates from CH-TRU waste as a function of waste type and other conditions, with a high degree of control. The conditions of the waste will be representative of both the operational phase and the longer term, postoperational phase of the repository.

2. Provide a large-scale confirmation of the laboratory-scale test results under repository conditions.

3. Measure solution leachate radiochemistry from saturated CH-TRU waste as a function of many credible environmental variables.

4. Evaluate the synergistic impacts of bacterial action, potential saturation, waste compaction, degradation product contamination, etc., on the gas generation capacity and radiochemical environment of CH-TRU waste.

5. Evaluate (gas and/or radionuclide) getter effectiveness in a controlled series of bin-scale tests.

6. Provide necessary gas generation and depletion data and source term information for performance assessment analyses and predictive modeling.

A.3.3 DESCRIPTION

Bin-scale tests are being designed to provide gas production and radiochemical source term data from CH-TRU waste. The degradation and interaction behavior of several representative classifications and types of waste will be tested under aerobic and anaerobic conditions representative of the operational phase and long-term, postoperational phase of the repository. Impacts of several types and quantities of intruding brines; impacts on gas production and consumption of waste interactions with salt, container metals, backfill, and gas getter materials; and gas production resulting from synergisms between the various degradation modes will be evaluated. The tests will be controlled so that radiological safety of personnel is maintained.

The tests will be conducted in multiple, large, instrumented metal "bins" with specially prepared CH-TRU waste. The "prepared" waste includes approximately six drum volume-equivalents of CH-TRU waste, with added granular backfill materials (including salt), metals, and brine (to be injected at the WIPP facility). Each bin will be specially prepared and filled at the waste generator site and shipped to the WIPP site for testing. Each bin will also function as a nominally independent, isolated, and controlled test system, although all the test bins will be isolated within one underground test room. The leak tight test bins will have a closely controlled and sealed internal atmosphere. Each bin will have an inner, high density polyethylene liner. Each will be equipped with remote reading thermocouples, pressure gages, and redundant gas sampling and relief valves that are equipped with integral, carbon-composite high efficiency particulate air (HEPA) filters. Bins also will have multiple brine injection and sampling valves and, possibly, materials sampling ports.

These "bins" are being designed to fit within a TRUPACT II Standard Waste Box for transportation to the WIPP site. The test bin is not to be regarded as a transportation or terminal disposal container: it is to be used for testing purposes only.

The bin-scale test matrix includes combinations of four representative CH-TRU waste material classifications (waste types), two levels of waste compaction, four backfill materials, and four brine moisture conditions. The waste types selected are high organic/newly generated waste (HONG), both uncompacted and compacted; low organic/newly generated waste (LONG), both uncompacted and compacted; high organic/old waste (HOOW); and prepared or standard processing sludge (PS). Most high organic ("soft") and low organic ("hard," primarily metals and glasses) newly generated waste will be compacted at the Rocky Flats Plant starting in 1990; these wastes will constitute a major fraction of TRU wastes to be shipped to the WIPP facility in the future. The advantage of testing the in situ degradation behavior of compacted wastes is that such wastes are similar to noncompacted wastes that have been crushed/compacted in situ by the expected long-term closure of repository rooms. Compaction impacts on gas generation can thus be realistically evaluated during the course of these tests and factored into the performance assessment.

Other bin-scale test parameters are described here. The moisture conditions are dry (expected short-term); moistened with Salado brine (expected case within several years); saturated with Salado brine (probable in the long-term); and saturated with Castile brine (possible in the case of human intrusion). The selected backfill material combinations are (representing the postoperational phase, when drums are no longer expected to be intact): none, rock salt and bentonite clay (70 percent/30 percent), salt/bentonite and getter additives (gas and/or radionuclide), and salt/others (i.e., grouts). The test bin internal atmosphere will be representative of CH-TRU waste in the postemplacement and later period. The CH-TRU HONG waste will generate its own anoxic hydrogen and carbon dioxide atmosphere by means of radiolysis, primarily, and therefore require no gas flushing. No flushing is necessary for the PS waste for the same reason. HOOW waste will be purged with carbon dioxide, nitrogen, or (preferably) argon gas until anoxic. During repackaging of HOOW waste, the previously established anoxic environment will be replaced by air; purging with an inert gas will reestablish the original environment, presumably generated by microbial degradation. The CH-TRU LONG waste will be purged with nitrogen or argon until anoxic.

These bin-scale tests will take place in two phases. Phase I will incorporate the simpler system tests, mostly applicable to the operational phase time period. Approximately 32 bins of different waste compositions, including replicates, will be included in Phase I; there will also be four other, empty test bins used for gas baseline reference purposes. Phase II will use another 68 waste bins, with more moisture conditions, and will include the compacted high organic and low organic wastes. Phase II will be mostly geared to the expected, postoperational phase repository conditions. In total, there are 100 waste filled test bins (plus a contingency of eight more waste filled bins included in Phase II) for the entire test program. This results in approximately 600 drum-equivalents of CH-TRU waste plus the eight contingency bins. Initiation of Phase II depends on obtaining supporting laboratory definition of the composition of gas getter or other backfill material components. Phase II tests are anticipated to start not sooner than approximately eight months after initiation of Phase I.

The WIPP bin-scale tests are being formulated. A test plan is being developed. The extent and preliminary order of test emplacements are summarized in Tables A-1 and A-2. The current conceptual design of the test incorporates the following assumptions:

1. Waste Packaging: Newly generated wastes can be loaded directly into the WIPP test bins at the generator site, or previously packaged (drummed) wastes can be emptied into the bins (without the original drums). Sludges could be filled directly into the bins.

2. Bin Waste Filling, Backfill, and Metal Mixing: Before wastes are placed in the preinstrumented and prepared test bin, two necessary additions to the bin can be made nonremotely: about a half-drum volume of appropriate backfill material (0.1 m^3) must be placed on the bottom of the test bin and about six drum equivalents of bare, unpainted steel sheet (cut into strips or other shapes) are then arranged along the bottom and side walls of the bin. The bin is then remotely filled with about six drum-volume equivalents of CH-TRU wastes. Another half-drum volume of backfill material is sprinkled on top of the waste materials. The mated bin-lid/liner-lid combination is then attached and sealed. The filled bin is checked for surface contamination and decontaminated using standard practices at the waste generator facility.

3. Waste Shipping: Waste filled test bins are inserted into Standard Waste Boxes at the generating/storage site for transportation to the WIPP facility for testing. The upper gas valves on the test bin (with integrated carbon-composite HEPA filters) are left in the open (gas release) position during transportation; any generated gas then vents through the Standard Waste Box HEPA filters.

4. Bin Waste - Bag Puncturing System: Internal bags of waste (usually multiple, taped poly-bags) will be punctured, ripped, or sliced so that internal gases can be released, backfill materials can contact/interact with waste materials, and (injected) brines can moisten the wastes. Bag piercing must be accomplished to accelerate long-term interactions so that they will occur during the test observation period.

5. Bin Gas - Tightness and Pressurization: The test bins will be gas tight during testing; there will be no permeable gaskets. The bin will be designed to safely hold an internal pressure of <2 psi (to be determined). A pressure relief valve will be attached to one of the top gas valves during

TABLE A-1. NUMBER OF BINS TO BE TESTED

	Phase I	Phase II	Contingency
High Organic/Newly Generated (HONG)	12	16	2
Low Organic/Newly Generated (LONG)	10	6	2
Prepared Sludges (PS)	10	20	2
High Organic/Old Waste (HOOW)	0	26	2
	32	68	8
	Total = 108		

TABLE A-2. ORDER OF BIN TEST EMPLACEMENTS

PHASE I*

Batch 1: HONG-dry (4), LONG-dry (4), PS-dry (4)
Total = 12

Batch 2: HONG-Salt/Bentonite (8), PS-Salt/Bentonite (6), LONG-Salt/Bentonite (6)
Total = 20

PHASE II**

Batch 3: HOOW-dry (4), HOOW-Salt/Bentonite (8)
Total = 12

Batch 4: HONG-Salt/Bentonite and Getters (8), HOOW-Salt/Bentonite and Getters (8), PS-Salt/Bentonite and Getters (6)
Total = 22

Batch 5: HONG-Compacted (8), LONG-Compacted (6), PS-Salt/Other (6), HOOW-Salt/Other(6)
Total = 26

Batch 6: PS/HONG-Salt/Bentonite (8), All Contingencies (8)
Total = 16

* Phase I = 32 Bins
** Phase II = 68 Bins, 8 Contingencies

testing. When the maximum allowed pressure is reached the valve will release excess gas into the test room (through the HEPA filter); the volume of released gases will be remotely monitored with the data acquisition system.

6. Schedules and Gas Analyses: Schedules for the bin-scale tests are being prepared. Activities to be included are waste receipt schedules, brine-injection schedules, gas sampling and analyses schedules, brine sampling schedules, etc. Samples of internal bin gases will be obtained on a periodic basis.

7. Posttest Waste Disposal: Free liquids will be removed from the bins via the bottom liquid sampling ports; these liquids can then be concentrated and/or immobilized and disposed of as TRU waste. Additional brine within the bin could be further reduced by flushing the bin with warmed air, or by injecting sorbant materials. Potentially hazardous gases within the bin could also be purged with air or other gases. The posttest prepared bins would be repackaged in Standard Waste Boxes as TRU waste.

A.4.0 ROOM-SCALE GAS GENERATION TESTS

A.4.1 RATIONALE

Data on production, depletion, and composition of gases resulting from in situ degradation of CH-TRU waste are needed to support performance assessment of long-term repository behavior (Activity S.1.2.4). Representative data are needed on TRU waste degradation rates, and must be representative of time periods from emplacement to the long-term, postoperational phase. Data must be obtained in a controlled research mode, not simply as a monitoring function, to allow multiple degradation mechanisms and impacts to be assessed.

Because of uncertainties introduced by extrapolating laboratory, small-scale, or even bin-scale results to the full-scale disposal configuration, it is necessary to confirm gas generation models and predicted consequences by conducting room-scale tests with CH-TRU waste in the WIPP facility. In addition to eliminating scaling factor effects, the room-scale tests are the only experiments planned that incorporate the impacts of the repository environment on the waste. For example, gases released from the rock salt (such as nitrogen and methane) intermix with waste degradation gases, possibly influencing bacterial degradation of the waste. Effects of the repository environment also include brine intrusion, long-term waste compaction and encapsulation of waste drums by backfill and getter materials.

This large-scale, underground test will identify unexpected phenomena or problems, which can then be technically resolved, and thus eliminate most "what if" questions or concerns. There is no credible alternative to conducting room-scale tests underground (in situ) at the WIPP facility in such a manner as to fully support the confidence level required of performance assessment. The full spectrum of gas data needed to address performance assessment concerns can be obtained when data from the room-scale tests are combined with the parallel laboratory (Activities S.1.1.4 and S.1.1.5) and bin-scale (Activity S.1.3.3) tests. The room-scale, in situ data will be acquired from the first CH-TRU waste to be emplaced in the WIPP facility.

A.4.2 OBJECTIVES

1. Determine baseline gas generation, composition, and depletion for as-received CH-TRU waste under representative, operational phase, repository room conditions.

2. Determine gas generation, composition, and depletion for specially prepared mixtures of CH-TRU wastes (with and without compaction), backfill materials, gas getters, and brine under representative, postoperational phase, repository conditions.

3. Confirm on a room scale, the gas generation results and interpretations of the laboratory- and bin-scale tests of CH-TRU waste degradation and gas production.

4. Provide sufficient confidence in the performance assessment calculations for those scenarios that include gas generation and depletion and help validate assumptions used in modeling.

A.4.3 DESCRIPTION

The tests to be conducted underground will use as-received, compacted, and specially prepared CH-TRU waste. Waste types, representative of the majority of waste to be isolated at WIPP, include high organic/newly generated (both standard and compacted from Rocky Flats Plant), low organic/newly generated (i.e., metals, glasses, etc., both standard and compacted from Rocky Flats Plant), prepared sludges, and high organic/old (stored) wastes from Idaho National Engineering Laboratory.

These wastes will be emplaced within five sealed, atmosphere controlled test alcoves. A test alcove is tentatively defined as being about one-fourth the size of a full-size disposal room. The first four test rooms or alcoves in Panel 1 are planned for waste emplacement and initial gas testing in September 1989. The remaining two test alcoves in Panel 2 will be available for testing at a later date.

The planned room-scale tests will be conducted in two test phases. Phase I will include emplacing and monitoring CH-TRU waste in three test alcoves in Panel 1 and using a fourth alcove for testing the sealing concept and obtaining gas baseline measurements. This empty gas baseline room, Alcove 4, will provide gas composition data (i.e., trapped atmosphere and gases released from the rock salt) necessary for comparison to the waste filled test alcoves. Alcove 1 will contain a mixture of about 1,050 drum volume-equivalents of as-received CH-TRU waste with no special preparation. This waste will be packaged at the generating/storage site into standard 55-gallon drums or Standard Waste Boxes, transported to the WIPP site, and emplaced in the underground test alcove for gas measurements. Alcove 1 will provide data on gas generation under in situ conditions (oxic, dry, with no salt, backfill, or getter materials in contact with the wastes) representative of the short-term, operational phase of the disposal facility. These two Alcoves, 1 and 4, will provide the "proof of concept" that gas measurements can be successfully conducted in the underground facility. Alcove 1 will also provide the initial data for the follow-on tests.

Alcoves 2 and 3 in Panel 1 will include specially prepared, noncompacted waste and compacted waste, respectively. Alcoves 2 and 3 will provide the major data confirmation and model validation for gas generation, consumption, and transport when results of the preceding, smaller scale laboratory and bin-scale tests are incorporated. The tests are to be conducted under conditions typical of the long-term, postoperational phase of the repository. The waste in each test drum will be specially prepared and packaged. Within each drum there will be layers of CH-TRU waste (either poly-bagged/noncompacted wastes or compacted wastes), container metals, and backfill and getter materials. Small amounts of brine will be injected into the drums (at WIPP) to simulate long-term brine intrusion.

Phase II of the room-scale tests will be conducted in Panel 2. Alcoves 5 and 6 will include the same waste types as Alcoves 1 and 3, but will also include backfill and getter materials that encapsulate the waste and its containers. The sealed test alcove atmospheres will be initially purged with nitrogen, to be representative of the expected atmosphere in the sealed repository.

The following information describes these tests is more detail; the tests are still in the design and development phase. A WIPP CH-TRU Room-Scale Test Plan is being drafted and will include specific details.

Test Rooms and Sealing

Four of the six test alcoves will be located along the northern edge of Panel 1; the other two alcoves will be located on the east end of Panel 2. Each conventionally mined test alcove is planned to be 13 ft (4 m) high by 25 ft (7.6 m) wide by 100 ft (30.5 m) long, with a smaller 13 ft (4 m) wide by 12 ft (3.7 m) wide access entry drift, to facilitate easier sealing. The smaller access entry drift will be about 50 ft (15.2 m) long. The access drift will be large enough to accommodate a mining machine, but can be sealed with an appropriately shaped inflatable seal containing instrumentation and access ports for the gas recirculation system. Alternative sealing plugs and concepts are also under consideration.

The inflatable plug must be adequate to control leakage rates to less than approximately 1 percent of the test room's air volume per week, corresponding to a rate of less than 0.04 ft^3/min, and have the capability to withstand a maximum of approximately 1 psi of differential pressure. Each sealed test alcove will be operated under a slight positive pressure (about 0.25 to 0.5 psi), similar to a glove box. Testing of the room seal and pressurization system is to be done in Alcove 4, by injecting compressed air and measuring the pressure drop. Alcove 4 should be mined, prepared, and equipped with an inflatable seal apparatus by late FY89.

Waste Preparation

The specified test alcove length is designed to contain either 150 7-packs of drums or 150 Standard Waste Boxes, both stacked (on average) 4 across and 3 high. Alcoves 2 and 5 will contain a mixture of specially prepared and packaged wastes that are not compacted. Alcoves 3 and 6 will contain similar wastes that have been compacted. Reasons for including the compacted waste are described in the bin-scale tests program. Test alcoves with compacted waste will contain about 350 drums of compacted waste per alcove (1,630 drum-equivalents per alcove).

The prepared and compacted waste drums require some preliminary preparation at the waste generating/storage facility before they are shipped to the WIPP site. Only drums will be used in these test alcoves. Extra metal strips will be arranged on the sides of the drums. Waste and backfill (salt 70 percent/ bentonite 30 percent) will be layered within each drum. A small amount of moistening brine (essentially all to be sorbed by the waste matrix) will be injected into the drums through injection ports in the drum lid.

The test drums will not contain any significant over-pressure (each drum has a gas permeable filter gasket ring at the top of the drum). These drums will also contain an integral HEPA filter for gas release; the composite filter-gasket ring of the drum is known to be nonpermeable to particulates. The gases released from each drum, plus those released from the rock salt, will collect and be mixed in the test room. All the test drums will effectively "breathe" en masse, in a "shared" atmosphere, just as they would in a disposal room.

Backfill and Gas Getter Differences

The Phase II Alcoves 5 and 6 will contain backfill and getter materials external to the drums, essentially surrounding and encapsulating them. These tests will be initiated after the most appropriate WIPP backfill has been selected. The backfill and getter materials will be emplaced over the preemplaced 7-packs, totally covering them on the sides, top, and throughout the gaps between the drums. Backfilling of alcoves will only be performed after a successful mock waste retrieval demonstration. The proposed technique uses room stand-off walls or barriers at the edges, so that room creep closure pressures will not be transmitted to the waste stack. In this manner, not only are the effectiveness and impacts of gas getters measured and demonstrated in situ, but an operational demonstration is provided for the waste backfilling concept. Backfilling of all waste is planned for disposal operations after the WIPP Test Phase has ended.

Test Room Preparation, Gas Flushing

Each gas test alcove will be equipped with remote reading thermocouples, pressure gages, and HEPA-filtered gas relief and gas volume monitoring gages. All instruments will be connected to a computerized Data Acquisition System. Appreciably elevated gas pressures will not be allowed in the test alcoves. A gas recirculation system will also be installed in each alcove to ensure that gases are adequately mixed for sampling. The gas recirculation system will include inlet and outlet ducting penetrating through the inflatable seal with gas sampling ports or septa. All instrumentation and hardware access will be through a sealed access port in the alcove seal. After all the waste, backfill, instruments, hardware, and seal plugs are installed, there will be no manned access to the test alcoves.

The two initial test alcoves for Phase I, Alcoves 4 (gas baseline) and 1 (as-received waste), will have no initial atmosphere control. These alcoves are representative of the initial, oxic environment in the early operational phase of the disposal facility, and gas and moisture content/humidity will be measured as a function of time. The other test alcoves for Phases I and II are representative of the postoperational phase of the repository. As such, their initial atmosphere (after filling and sealing) will be flushed with nitrogen, which is anoxic.

Gas Sampling and Analyses

Gases periodically collected from each test alcove will be analyzed using a gas chromatography/mass spectrometer to determine major and minor gas concentrations, and changes in those compositions as a function of time (Table A-3). This allows rates of generation and/or depletion to be determined. The major gases are: (a) generated or consumed by various waste degradation mechanisms, (b) contained in the room atmosphere, or (c) released by the host rock. The other gases may be sorbed in/on the wastes and eventually can be volatilized.

TABLE A-3. GASES TO BE MEASURED ALONG WITH THE NEON AND ARGON ISOTOPIC RATIOS*

Hydrogen*	Neon*	Dichloromethane
Oxygen*	Argon*	Trichloroethylene
Carbon Dioxide*	Nitrous Oxide	Carbon Tetrachloride
Carbon Monoxide*	Hydrogen Sulfide	1,1,1-Trichloroethane
Nitrogen*	Hydrogen Chloride	1,2 Dichloroethane
Methane*	Freon-113	Cyclohexane
	Xylene, Mixed	Other Organics, Tracers

*Major Gases

Nonradioactive tracer gases, such as isotopically-spiked neon, will be injected into the alcoves to monitor the potential leakgage of gases out of the alcoves through the seals and gas relief valves. For example, a quantity of neon-22 will be injected and the neon-20/neon-22 ratio monitored to quantify leakage. Because neon-20 is the most abundant isotope of neon in the air, a change in the neon isotope ratio will reflect a change in the air sealed in the room. A different organic tracer gas may be also used in each separate alcove to monitor potential leakage through cracks in the host rock from one test alcove to the next.

Posttest Waste Disposal (Options)

The estimated test duration of both phases of the room-scale tests is estimated to be three to five years. At the conclusion of the room-scale tests, the gas atmosphere inside each room may require purging into the normal mine ventilation system; all gases would be filtered through a HEPA filter. The seal on each room would then be removed. The waste drums in Phase I could then be: (1) backfilled in place, with the test alcove being converted to a waste disposal room; (2) moved to a waste disposal room at the WIPP for disposal; (3) temporarily stored at WIPP until transport to another DOE facility is possible; or (4) inspected, overpacked if necessary in 80-gallon drums, and transported to another DOE facility. The options for waste drums used in Phase II of the test program are similar, except for the backfill around the containers. If the backfilled waste containers from the Phase II Alcoves 5 and 6 are retrieved, the installed backfill materials could be removed by vacuuming. The drums could then be inspected and overpacked if necessary. Preliminary details for removing backfills from test wastes are described elsewhere (Molecke, 1988).

A.5.0 SEQUENCE FOR BIN-SCALE AND ROOM-SCALE TESTS

The laboratory portion of the testing program has been initiated and will soon be followed by the bin-scale tests. These two tests will proceed concurrently with appropriate sequencing to permit the early laboratory results to have some impact on the configuration of the bin tests. For example, backfill additives to be evaluated for gas and brine sorption capability will be selected in laboratory tests and subsequently evaluated in bin-scale tests.

Additional laboratory tests will be initiated throughout the second quarter of FY89. The tests will provide data within one year, but some laboratory testing will continue for an additional year or until sufficient data and technical understanding of the phenomena are gained. At specific periods within the testing program, data will be analyzed and evaluated for input to ongoing performance assessment studies. At appropriate test intervals, data will be evaluated and documented in topical reports.

Detailed test planning for the bin-scale tests will continue through mid- to late FY89, followed by procurement actions in late FY89. Test installation will begin in the early part of FY90. Early data acquisition for these tests will start during the early part of FY90. These tests will continue for about two years, or until the data acquired are sufficient to provide confidence in the reliability of the information being obtained. Data and analyses will be incorporated into the performance assessment.

Detailed test planning for the room-scale tests will also continue through mid- to late FY89. Preliminary engineering design has been started and will continue throughout FY89. Phase I of the room-scale tests will be initiated in September 1989, using as-received wastes. Phase II of the room-scale tests would be initiated in early FY93.

The analysis of all data obtained from laboratory, bin-scale, and room-scale tests will be documented in periodic data evaluation and topical reports (approximately on a yearly basis) as appropriate for each phase of the experiments. These reports will contain reduced data and interpretations, evaluations, and conclusions about the results of the tests and the technical issues addressed. These reports will form part of the primary data base use in the performance assessment process.

A.6.0 SUMMARY

WIPP is a first-of-a-kind facility for disposal (10,000 years) of TRU waste in a deep geologic environment. The WIPP Project is committed to compliance with the EPA Standard, 40 CFR 191, Subpart B. To understand and reasonably predict long-term disposal system behavior in this complex arena of high uncertainty, it is necessary to acquire data and a technical understanding of this heterogeneous system by performance of tests under conditions existing only in the WIPP underground environment. Numerous in situ tests have already been performed at WIPP; however, additional tests are required, one of which is the determination of gas generation effects associated with the TRU waste and the geologic environment.

Before data on gas permeability of the Salado Formation at the WIPP were available, calculations of gas buildup in the rooms at the WIPP using an estimated permeability of 10^{-6} darcy and a gas generation rate of 5 moles/drum/year indicated that gas generation would not impair repository performance. Current, measured gas permeabilities of the rock salt are of the order of 10^{-9} darcy. Calculations using these new values indicate that gas buildup in the rooms and panels could impair repository performance. Performance assessment must, therefore, acquire better data to assure that realistic conditions are evaluated and modeled.

Performance of these gas generation tests with actual TRU waste materials is required to accurately characterize the behavior of the repository under very complex conditions. The tests consist of laboratory studies using radioactive and nonradioactive simulated wastes, bin-scale tests with CH-TRU waste, and room-scale or alcove tests with CH-TRU waste. These tests will provide the data and models to be used to evaluate the effects of gas generated by the waste in actual, realistic environments for both the operational (short-term) period and the postoperational (long-term) period. Collection of this information is necessary for application to the performance assessment process to obtain results with a sufficient level of confidence to demonstrate compliance with the EPA Standard.

REFERENCES

Berner, R.A., 1980. Early Diagenesis: A Theoretical Approach; Princeton University Press, Princeton, NJ.

Brush, L.H., 1989, (in preparation). Test Plan for Laboratory and Modeling Studies of Repository and Radionuclide Chemistry; Sandia National Laboratories, Albuquerque, NM.

Brush, L.H., and D.R. Anderson, 1989. Estimates of Gas Production Rates, Potentials, Periods and Disolved Radionuclide Concentrations for the WIPP Supplemental Environmental Impact Statement, Sandia National Laboratories Memorandum; Sandia National Laboratories, Albuquerque, NM.

Brush, L.H., and D.R. Anderson, 1988a. Potential Effects of Chemical Reactions on WIPP Gas and Water Budgets, Sandia National Laboratories Memorandum; Sandia National Laboratories, Albuquerque, NM.

Brush, L.H., and D.R. Anderson, 1988b. First Meeting of the WIPP Performance Assessment Source Term Group, Sandia National Laboratories Memorandum; Sandia National Laboratories, Albuquerque, NM.

Brush, L.H., and D.R. Anderson, 1988c. Second Meeting of the WIPP PA Source-Term Group, Sandia National Laboratories Memorandum; Sandia National Laboratories, Albuquerque, NM.

Clements, T.L., Jr., and D.E. Kudera, 1985. TRU Waste Sampling Program: Volume II - Gas Generation Studies, EGG-WM-6503; Idaho National Engineering Laboratory, Idaho Falls, ID.

Froelich, P.N., G.P. Klinkhammer, M.L. Bender, N.A. Luedtke, G.R. Heath, D. Cullen, P. Dauphin, D. Hammond, B. Hartman, and V. Maynard, 1979. Early Oxidation of Organic Matter in Pelagic Sediments of the Eastern Equatorial Atlantic: Suboxic Diagenesis; Geochimica et Cosmochimica Acta, Vol. 43, pp. 1075-1090.

Haberman, J.H., and D.J. Frydrych, 1988. Corrosion Studies of A216 Grade WCA Steel in Hydrothermal Magnesium-Containing Brines; in Scientific Basis For Nuclear Waste Management XI. Materials Research Society Proceedings, Vol. 84, Materials Research Society, Pittsburgh, PA, pp. 761-772.

Molecke, M.A., 1989. Memo Of Record: Conceptual Design Details for WIPP CH TRU Waste Bin-Scale Tests, to distribution, January 18, 1989; Sandia National Laboratories, Albuquerque, NM.

Molecke, M.A., 1988. Memo Of Record: Concept for Testing Actual CH TRU Wastes With Backfill Materials in the WIPP, to W. D. Weart, April 18, 1988; Sandia National Laboratories, Albuquerque, NM.

Molecke, M.A., 1979. Gas Generation from Transuranic Waste Degradation: Data Summary and Interpretation, SAND79-1245; Sandia National Laboratories, Albuquerque, NM.

Sandia National Laboratories, 1979. Summary of Research and Development Activities in Support of Waste Acceptance Criteria for WIPP, SAND79-1305; Sandia National Laboratories, Albuquerque, NM.

Sholkovitz, E.R., J.K. Cochran, and E. Carey, 1983. Laboratory Studies of the Diagenesis and Mobility of $^{239,240}Pu$ and ^{137}Cs in Nearshore Sediments; Geochimica et Cosmochimica Acta, Vol. 47, pp. 1369-1380.

Tyler, L.D., R.V. Matalucci, M.A. Molecke, D.E. Munson, E.J. Nowak, and J.C. Stormont, 1988. Summary Report for the WIPP Technology Development Program for Isolation of Radioactive Waste, SAND88-0844; Sandia National Laboratories, Albuquerque, NM.

U.S. Department of Energy, 1980. Final Environmental Impact Statement, Waste Isolation Pilot Plant, Vol. 1 of 2, DOE/EIS-0026; Washington, D.C.