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Carlsbad Area Office

Disposal Phase
Experimental Program Plan

January 31, 1997
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PREFACE

This Disposal Phase Experimental Program Plan outlines the current United States Department of Energy (DOE) approach to disposal phase experimental work in support of the overall objectives of the Waste Isolation Pilot Plant (WIPP) Program and the national transuranic (TRU) radioactive waste management system. The DOE will conduct experimental activities to: (1) support WIPP operations, by maintaining compliance certification and enhancing WIPP and national TRU system operations; and (2) support future TRU waste management needs, by establishing a focused international nuclear waste disposal research and development program and by enhancing proactive responses to emerging DOE TRU waste management needs.

The experimental activities outlined in this Plan are designed to meet WIPP Program and TRU system objectives during the initial 5-year WIPP re-certification period, and to form the basis for longer-term activities to be carried out throughout the 35-year disposal phase. Brief summaries of the DOE's technical positions are included in this Plan to facilitate understanding of the general technical program.

This Plan is not intended to be a "stand-alone" document. It is supported by the DOE Quality Assurance Program Document, the Compliance Certification Application, the Ten-Year Plan, the Resource Conservation and Recovery Act Part B Permit Application, and numerous other detailed planning documents for the activities described herein. The reader is referred to these documents for more detailed program technical positions.

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1.0 INTRODUCTION AND OBJECTIVES

1.1 Introduction

The Waste Isolation Pilot Plant (WIPP) is a project of the U.S. Department of Energy (DOE) and is administered through the Carlsbad Area Office (CAO). The WIPP facility comprises surface and subsurface facilities, including a repository mined in a bedded salt formation at a depth of 2150 feet (650 meters). It has been developed to safely and permanently isolate transuranic (TRU) radioactive wastes in a deep geological disposal site. The WIPP is located 26 miles (42 kilometers) east of Carlsbad, New Mexico.

On April 12, 1996, the DOE submitted a revised Resource Conservation and Recovery Act (RCRA) Part B permit application to the New Mexico Environment Department (NMED). The DOE anticipates receiving an operating permit from the NMED; this permit is required prior to the start of disposal operations.

On October 29, 1996, the DOE submitted a Compliance Certification Application (CCA) to the U.S. Environmental Protection Agency (EPA) in accordance with the WIPP Land Withdrawal Act (LWA) of 1992 (Public Law 102-579) as amended, and the requirements of Title 40 of the Code of Federal Regulations (40 CFR) Parts 191 and 194. The DOE plans to begin disposal operations at the WIPP in November 1997 following receipt of certification by the EPA. The disposal phase is expected to last for 35 years, and will include recertification activities no less than once every five years. This Disposal Phase Experimental Program (DPEP) Plan outlines the experimental program to be conducted during the first 5-year recertification period. It also forms the basis for longer-term activities to be carried out throughout the 35-year disposal phase.

1.2 Objectives of the Disposal Phase Experimental Program

Once the WIPP has been shown to be in compliance with regulatory requirements, the disposal phase gives an opportunity to affirm the compliance status of the WIPP, enhance the operations of the WIPP and the national TRU system, and contribute to the resolution of national and international nuclear waste management technical needs. The WIPP is the first facility of its kind in the world. As such, it provides a unique opportunity to advance the technical state of the art for permanent disposal of long-lived radioactive wastes. Therefore, the DOE has developed this DPEP Plan to describe the future experimental program, which is designed to achieve two main objectives.

<u>Objective 1:</u> **Support WIPP and national TRU system operations.** Experimental activities supporting WIPP operations will be designed to accomplish two goals:

- **Maintain compliance certification.** This will be accomplished by monitoring and verifying performance of the system's sensitive parameters, evaluating the information, and performing recertification calculations at five-year intervals or as directed by the EPA in accordance with the requirements of 40 CFR § 194.4 and the WIPP LWA.

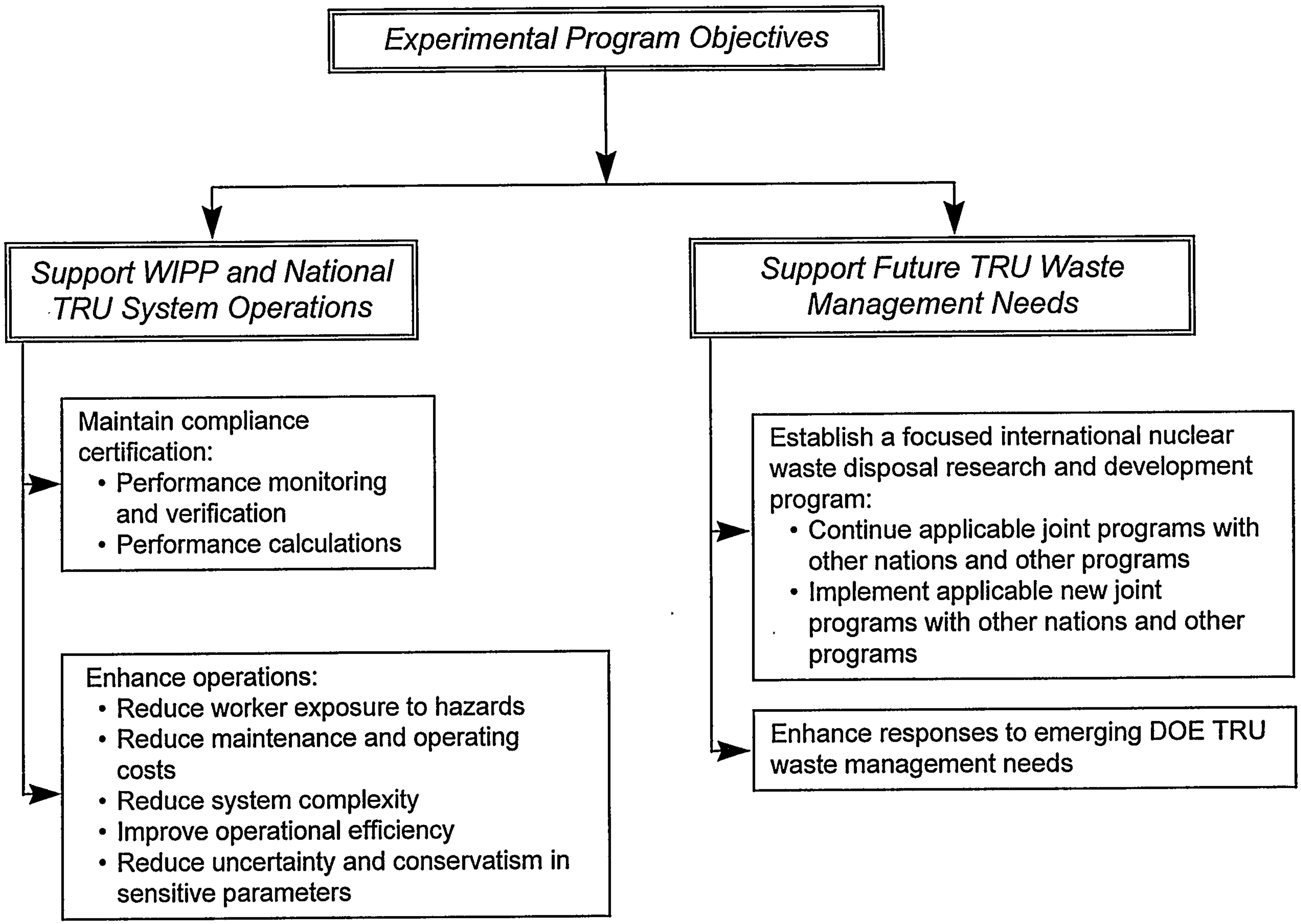

Figure 1. Objectives of the Disposal Phase Experimental Program

- **Enhance operations.** This will be accomplished through focused efforts to refine knowledge and develop new methods and procedures which will reduce worker exposure to radiation and other hazards, enhance operational efficiency, reduce design and operational complexity of the WIPP and the national TRU system, reduce uncertainty and conservatism in sensitive parameters, and reduce costs. These goals are inter-related (for example, reducing complexity of operations is likely to reduce worker exposure to hazards and also reduce costs).

Objective 2: **Support future TRU waste management needs.** Experimental activities supporting future waste management needs will be designed to accomplish two goals:

- **Establish a focused international nuclear waste disposal research and development program by continuing and implementing applicable joint programs with other nations and other programs.**
  This will be accomplished through the CAO's implementation of focused experimental activities to address Objective 1 in cooperation with other national and international waste management programs and efforts. Through synergistic activities with other nations and other programs, the DOE will gain access to relevant information from other programs, will provide information to other programs, and will share costs.

- **Enhance proactive responses to emerging DOE TRU waste management needs.** This will be accomplished by providing guidance and support to generators of TRU waste, particularly in the area of waste characterization. The CAO, as the national TRU program leader, will develop and provide technical information for the DOE's use in formulating radioactive waste management policies.

1.3 Organization of this Plan

A brief history of the WIPP experimental programs and the current repository understanding are included in Section 2.0 of this Plan. The DOE's plan for meeting the objectives outlined above is described in Section 3.0.

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2.0 BACKGROUND AND SUMMARY OF CURRENT UNDERSTANDING

2.1 WIPP Background

One of the fundamental reasons for selecting bedded salt deposits for a geological repository for TRU waste is that the salt will creep and thus close around the waste, thereby entombing and isolating it. Beginning with siting studies in the 1970s, a number of scientific programs have been conducted to obtain information about the WIPP site. The siting phase ended in 1980 with the completion of the WIPP Final Environmental Impact Statement.

The WIPP site-construction-and-design-validation phase occurred between 1980 and 1990. During this time, the underground site characteristics and the underground repository design were validated. Construction of the surface facility began in 1983. The experiments and other activities conducted during the 1980s were undertaken primarily to: (1) develop a general understanding of selected natural phenomena, as deemed prudent by WIPP Project scientists and/or scientists on the WIPP Panel of the National Academy of Sciences (NAS) and the New Mexico Environmental Evaluation Group (EEG); and (2) satisfy negotiated agreements with the State of New Mexico. In the late 1980s, the WIPP Project began developing and refining the tools needed to assess the long-term performance of the disposal system, including the performance assessment process (Section 2.2).

The pre-disposal phase began in 1990. The activities conducted during this time period focused on collecting additional data and performing the analyses to demonstrate compliance with the disposal system performance regulations. The performance assessment process is the DOE's method for demonstrating the safe long-term containment of the TRU waste, and is supported by information from the experimental program. The results of the performance assessment process are a critical element of the CCA. The EPA will use the CCA as the basis for determining the WIPP's compliance with the disposal system performance regulations in 40 CFR Part 191.

During the 35-year disposal (operating) phase, which will begin in November 1997, TRU waste will be emplaced in the WIPP. The disposal phase will be followed by a 10-year decommissioning phase (during which the repository will be sealed), a 100-year active institutional control phase, and the remaining 9,900 years of the 10,000-year post-decommissioning (post-closure) phase.

Further details regarding the information in this chapter are available in the CCA and numerous additional reports and documents. The reader is directed to the CCA in particular for additional information.

2.2 Assessing System Performance

To assess the WIPP's performance over the 10,000-year post-closure phase and to demonstrate a reasonable expectation of compliance (as required by 40 CFR Part 191), the CAO has developed a modeling system which incorporates the physical features of the repository, the surrounding geologic formations, and the TRU waste forms to predict long-term disposal system performance. Conceptual models are implemented in numerical code to estimate the effects and outcomes of credible future processes and events (both natural and human-induced processes and events). Performance assessment is the central part of the overall process for estimating long-term disposal system performance in a probabilistic format; in this case, the performance criteria are the EPA's release limits specified in 40 CFR § 191.13(a). The CAO also used a formalized decision methodology, the System Prioritization Method (SPM), in 1995 to define a suite of experimental activities whose results were highly likely to reduce uncertainty about some important parameters for performance assessment. The results of these experiments were incorporated into CCA performance assessment calculations.

A great deal of information has been acquired and used to develop an understanding of the processes and events that affect long-term isolation of the TRU wastes at the WIPP. This information can be divided into two main categories:

- Detailed knowledge of the ambient site characteristics, the repository design, and the characteristics of the wastes destined for disposal; and
- An understanding of the events and processes that may affect the disposal system during the 10,000-year post-closure regulatory period, the probabilities they will happen, and their consequences.

The information in the first category has been obtained through a number of sources: field observations and tests, laboratory experiments and evaluations, scientific literature, professional technical judgement (for those features and processes where data were not obtainable), and programmatic policies (such as the types and specifications of waste destined for disposal at the WIPP). The information in the second category has been acquired over time through a formal screening and evaluation process and is a result of the iterative approach to performance assessment.

2.2.1 Performance Assessment Methodology

In developing the mathematical system used to assess disposal system performance, the disposal system's features, events, and processes (FEPs) are developed using the information described above. This body of information is combined into scenarios; these are sets of naturally occurring, waste-induced, and human-induced conditions that represent realistic potential future states of the repository, the geologic setting, and the groundwater flow systems that could affect the migration and transport of radionuclides from the repository to the accessible environment, as defined in 40 CFR § 191.12(k). The FEPs and scenarios are evaluated; then either they are incorporated into the suite of conceptual and mathematical models of the disposal system that are used to calculate disposal system performance, or they are screened from the analysis. Screening decisions are supported by one of the following criteria: (1) low probability; (2) low consequence, or (3) regulatory criteria. Additional information can be found in the CCA.

Uncertainty is inherent in the events and processes used to determine performance; some uncertainty is also inherent in disposal system features. Uncertainty is incorporated into these conceptual models and parameter distributions where appropriate to represent the intrinsic variability due to the heterogeneity of the system (such as hydrologic properties of the undisturbed Salado Formation). For processes that are important to disposal system performance, but for which uncertainty cannot otherwise be reasonably treated, conservative choices are made in selecting modeling assumptions and parameter values (for example, all waste containers are assumed to be breached at the time of facility closure, allowing the contents to be immediately available for reactions which could generate gas).

The performance assessment calculations performed over the past several years, combined with uncertainty analyses and sensitivity analyses, have given the DOE a good understanding about which processes and events are most important to repository performance.

2.2.2 Systems Prioritization Method

In 1994 and 1995, the CAO developed and used a formalized decision methodology, called the systems prioritization method (SPM), to provide an analytical basis for evaluating programmatic decisions. SPM was used to: (1) identify programmatic options (activities), their costs, and duration; (2) analyze the potential combinations of activities in terms of predicted contributions to long-term performance and demonstrating compliance with the regulatory performance criteria in 40 CFR § 191.13(a); and (3) analyze cost, duration, and performance tradeoffs with the objective of identifying combinations of scientific activities, sets of waste characteristics, and engineered alternatives with the most favorable performance indicators (i.e., combinations with a high probability of demonstrating compliance, minimal activity duration, and minimal cost.) The DOE evaluated 21 sets of scientific activities, three engineered alternatives, and two sets of waste characteristics singularly and in various combinations. For each activity set (i.e., a combination of activities), the DOE calculated the probability of demonstrating compliance if the activity set was selected, and the projected cost and duration of the activity set. Preliminary performance assessment models were used to estimate the long-term performance of the WIPP repository if selected activities were implemented.

The CAO analyzed the SPM results to determine the most favorable activity sets for meeting the CAO's objectives. The CAO reviewed potential sources of uncertainty, quantified the potential impact of these uncertainties, and implemented a specific suite of experimental activities to build the scientific baseline used for supporting the final performance assessment calculations. These activities included: (1) colloid chemistry investigations; (2) dissolved actinide solubility studies; (3) specific activities associated with rock mechanics and shaft seals; (4) a multi-well tracer test in the Culebra; (5) studies of chemical retardation and fracture-matrix flow in the Culebra; and (6) direct releases to the surface. Results from each of these experimental efforts were incorporated into the final performance assessment calculations completed for the CCA.

2.3 Experimental Activities

The WIPP pre-disposal experimental program, including the SPM-identified activities and other supporting experiments, was organized into four major areas: three areas addressing undisturbed performance (rock mechanics and shaft seals, disposal room interactions, and fluid flow and transport); and a fourth area specifically addressing direct releases to the surface that are part of a disposal system disturbed by human intrusions (disturbed performance).

2.3.1 Rock Mechanics and Seal System

Rock mechanics processes are important to repository performance, as they are a key element of the disposal room model. Rock mechanics assessments have provided information on processes including salt creep closure of underground openings, development of a disturbed rock zone (DRZ) around underground openings, and healing of the DRZ by creep closure around rigid inclusions. The DRZ, which is present around the repository openings and around the shafts, provides a potential pathway for migration of brine containing radionuclides.

The rock mechanics program has included laboratory measurements of the creep and fracture properties of rock salt at the WIPP site, development of detailed models for creep and for fracture development in the salt, and room-scale verification of the predictive capabilities of these models. Thus the DOE has sufficient understanding of the processes to incorporate them into the performance assessment models and calculations.

There are four shafts, 12 to 18 feet (3.6 to 5.5 meters) in diameter, connecting the repository to the surface. These shafts are potential pathways for fluid flow and contaminant transport. Thus, shaft seals play a fundamental role in isolating the waste. Although shaft seals will not be emplaced until the decommissioning phase, their predicted performance is very important to overall system performance. Key properties affecting shaft seal performance include the permeability of the seal materials and characteristics of the DRZ around each shaft. The pre-disposal shaft seals program included measurements of component properties and performance, shaft seal design, and shaft behavior characterization (including measurements of creep closure and DRZ development around the shaft). The seal system design includes several materials (crushed salt, salt-saturated concrete, clay, grout, asphalt, and earthen fill). These materials are incorporated into multiple independent seal components that are designed to be emplaced using adaptations of currently available construction methods and equipment and to meet the system performance requirements. The redundant components provide additional assurance of seal performance. The shaft seal system is incorporated into the performance assessment models and calculations using appropriate assumptions to address uncertainties.

2.3.2 Disposal Room Interactions

The long-term processes inside the closed disposal room are complex and control the mobilization of radionuclides and their migration. The processes include creep closure of the room, consolidation of the waste, and chemical interactions among the waste, the host rock, and brine that may flow into the room from the surrounding Salado Formation (or from the Castile Formation, under certain human-intrusion scenarios).

The potential for mobilization of the actinides which could be contained in the wastes into the WIPP brines has, in part, been characterized through the actinide chemistry program. The actinide source term directly affects radionuclide releases for scenarios that involve the transport of brine to overlying geological units or to the surface (Section 2.3.4). The pre-disposal experimental activities included determination of actinide solubilities, the stable oxidation states of the actinides in brines present at the WIPP site, and the quantities of actinides mobilized in stable colloidal forms in the WIPP brines. The relevant transport models and related parameters used in the performance assessment calculations are based on the extensive set of experimental measurements that have been made in the laboratory chemistry program. The CAO's understanding of the chemical processes is sufficient for conceptual model development and performance assessment calculations. The CAO has identified the components and characteristics of the TRU wastes that are important to the models and calculations of disposal system performance. Conservatism has been incorporated into the performance assessment models as needed to account for remaining uncertainties in the chemical processes and future events.

Gas may be generated in the closed repository through two primary processes: (1) anoxic corrosion of metals in the disposal areas (the resulting gas is primarily hydrogen); and (2) anaerobic microbial degradation of cellulosic materials in the waste (the gas generated is primarily carbon dioxide).

Radiolysis of the brine can also generate gas, but the volume is negligible compared to the two aforementioned gas-generation processes.

The gas generated in the closed repository can have both mechanical and chemical effects. Mechanically, the gas may pressurize the repository, thus retarding closure, reducing brine inflow, and perhaps fracturing the nearby brittle anhydrite layers. Carbon dioxide will dissolve in the brine; this will affect the acidity of the brine, and thus the solubility of actinide species. Experimental measurements of parameters for gas generation by corrosion and microbial action have provided sufficient basis for calculations that evaluate the effects of gas generation.

In order to provide additional performance assurance, the DOE will use magnesium oxide as backfill in the disposal rooms to stabilize the chemical conditions in the repository. The magnesium oxide will react with the carbon dioxide gas formed by microbial degradation; the carbonate formed will buffer the acidity of the brine present in the repository, thereby controlling actinide solubility. The chemical reactions which provide the control are well understood at the laboratory scale. The current model includes conservative assumptions to bound the uncertainties. The specifications for packaging and placement of the backfill have been developed.

2.3.3 Fluid Flow and Transport

To characterize the processes that most significantly affect predicted repository performance, it is necessary to understand the presence and flow of brines in the Salado Formation, in the overlying Rustler and Dewey Lake Formations, and in the Castile Formation that underlies the repository (these are the only significant water-bearing units at the WIPP site). Brines entering the repository would support gas-generating reactions and would provide a medium for mobilizing actinides in the waste. The brines may come from the Salado Formation, or from the Castile Formation (in the case of human intrusion into an area of the Castile Formation containing pressurized brine). The Culebra Member of the Rustler Formation forms a potential release pathway under certain conditions. The Dewey Lake Formation contains potable water, but is not considered a pathway to the accessible environment because its sorptive capacity is believed to be much greater than would be needed to sorb and effectively immobilize radionuclides releases over 10,000 years.

A series of measurements within and adjacent to the WIPP site has provided extensive data on the hydrologic properties of Salado halite and anhydrite units near the repository level; these properties (with their spatial variability) have been incorporated into the performance assessment models and parameters.

Pressurized brine reservoirs have been encountered locally in the Castile Formation, and may underlie the repository. Thus, the Castile Formation is important for human-intrusion scenarios, and the possibility that a human-intrusion borehole might penetrate through the repository and encounter a Castile brine reservoir is included in the performance assessment models (see Section 2.3.4 of this plan). The properties of the Castile brine reservoir used in the performance assessment calculations have been derived using hydrologic measurements at boreholes that have penetrated Castile brine reservoirs.

The Culebra Member is important to repository performance and is most important in the case of human intrusion. Brine containing dissolved and colloidal actinides may flow through a human-intrusion borehole or through a sealed shaft to the Culebra Member. A human-intrusion borehole intercepting a

Castile brine reservoir may also provide a pathway for brine from the Castile Formation to flow through the repository and up to the Culebra Member.

The Culebra Member exhibits complex flow properties with significant observed spatial variability. There is considerable variability in the structure and size of porous features through which flow (and potential radionuclide transport) occurs, and the transmissivity varies over six orders of magnitude in the area around the WIPP site. A higher transmissivity zone, located in the southeastern area of the WIPP site, could provide the preferred path for radionuclide transport in the Culebra Member. The properties of this zone have been characterized and incorporated into performance assessment models with uncertainty that represents the spatial variability. Field measurements have also characterized Culebra transport properties (including both diffusion and fracture-flow properties) at multiple locations near the repository, and these measured properties have been used to develop parameter values which incorporate the spatial variability for the performance assessment calculations.

In addition, the chemical- and physical-retardation mechanisms affecting transport of actinides in the Culebra Member have been determined experimentally. Because the potential interactions are complex, not all retardation processes have been fully investigated. However, the DOE has sufficient understanding of the processes to incorporate them into performance assessment models and calculations, with allowance for uncertainties in the physical and chemical processes.

2.3.4 <u>System Response to Human-Initiated Activities</u>
The natural phenomena and processes described in the previous sections are considered when assessing the performance of: (1) the undisturbed system, and (2) the system when disturbed through human-initiated activities specified in 40 CFR § 194.32(a).

In the disturbed-performance scenarios, direct releases to the surface can contribute significantly to the total releases of radionuclides. In the performance assessment, these direct releases are the primary source of releases to the accessible environment. Direct releases include material brought to the surface during the drilling process: the drill cuttings themselves; material eroded from the borehole wall by circulating drill fluid; material spalled or forced into the borehole by pressurized fluid in the disposal room; and dissolved radionuclides contained in releases of pressurized brine. Calculations and experimental measurements have addressed heterogeneity and uncertainty in the properties of the consolidated wastes and disposal room, and have provided conservative bounds on the processes involved in direct releases. Waste characteristics are discussed further in Section 3.2.2 of this plan.

The presence and characteristics of brine pockets in the Castile Formation are important to disposal system response to human intrusion, as the pressurized brine could provide a driving force for both direct releases and long-term releases of brine carrying dissolved and colloidal radionuclides through the intrusion boreholes. The DOE's models for actinide solubility and colloid stability in Castile brine include conservatism as needed to address uncertainties in the models and variability in composition of Castile brines. The models also incorporate conservative assumptions to bound the spatial variability in the properties of Castile brine reservoirs (Section 2.3.3), as these properties are important in performance assessment calculations.

Indirect releases may also occur as a result of human-initiated activities as radionuclides migrate to the accessible environment using pathways and conditions created by the human-intrusion boreholes. Many Culebra properties related to physical transport and chemical retardation are important in predicting the magnitude and time of indirect releases (these are discussed in Section 2.3.3). In addition, the properties of an intrusion borehole will change over time as plugs placed after abandonment degrade. The borehole and plug properties that are incorporated into the performance assessment models are based on current borehole plugging practices in the Delaware Basin in New Mexico. As the plugs degrade, the borehole permeability will increase, affecting fluid flow. The DOE's understanding of the material properties and processes is sufficient for developing a conceptual model of the boreholes, and for performing calculations.

Passive institutional controls to reduce the probability of inadvertent human intrusion are incorporated into the performance assessment calculations. The current system of passive controls includes multiple and redundant elements (multiple sets of markers and records) to provide performance assurance.

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3.0 DISPOSAL PHASE EXPERIMENTAL PROGRAM

As described in Section 1.0, the DPEP is designed to meet two main objectives:

- Support of WIPP and national TRU system operations through
  - maintaining compliance certification and
  - enhancing operations.

- Support of future TRU waste management needs through
  - establishing a focused international nuclear waste disposal research and development program, by continuing and implementing applicable joint programs with other nations and other programs, and
  - enhancing proactive responses to emerging DOE TRU waste management needs.

The activities outlined here are designed to meet these objectives in the short term (nominally five years), and to form a basis for longer-term activities to be carried out throughout the 35-year disposal phase.

This Plan provides an overview of the DPEP and thus does not include detailed descriptions of each anticipated experimental program or individual activity. Detailed activity plans will be prepared as needed in accordance with CAO procedures and quality assurance (QA) requirements. DOE QA requirements will be followed in execution and documentation of the work. 40 CFR § 194.22 also contains QA program requirements which will be adhered to as applicable while conducting the experimental program.

The DOE has developed a preliminary program for achieving the objectives described above; it is outlined in Tables 1 and 2, and is described in the following sections. The program is described in terms of the two objectives stated above, i.e., those activities aimed at providing support to WIPP operations and the national TRU system (Section 3.1), and those activities aimed at supporting future TRU waste management needs (Section 3.2).

3.1 Support of WIPP and National TRU System Operations

Providing support to the operations of the national TRU system, including the WIPP, will be a major component of the activities during the disposal phase. As indicated in Table 1, this support is needed to: (1) maintain compliance certification for operating the WIPP (which requires recertification every five years by the EPA); and (2) increase the efficiency of these operations through savings in cost, improvements in safety, improvements in operational efficiency, reductions in system complexity, and reductions in uncertainty and conservatism in sensitive parameters. The DOE has used the results of previous experimental studies and performance assessment calculations (discussed in Section 2.0) in developing the set of experimental activities to achieve these objectives.

3.1.1 Maintain Compliance

To maintain certification for operating the WIPP, the DOE will: (1) monitor and verify predicted disposal system performance; and (2) perform calculations no less frequently than once every five years or as requested by the EPA in accordance with the requirements of 40 CFR § 194.4 and Section 8(f) of the LWA. These activities are shown in Table 1 and discussed below.

3.1.1.1 System Performance Monitoring

The DOE is required by 40 CFR § 191.14(b) to develop and maintain a post-closure monitoring program "to detect substantial and detrimental deviations from expected performance. This monitoring shall be done with techniques that do not jeopardize the isolation of the wastes and shall be conducted until there are no significant concerns to be addressed by further monitoring." The requirement for monitoring significant parameters during the disposal (pre-closure) phase is included in 40 CFR § 194.42(c), which notes that a "disposal system parameter shall be considered significant if it affects the system's ability to contain waste or the ability to verify predictions about the future performance of the disposal system." Post-closure monitoring, as specified in 40 CFR § 194.42(d) is to be complementary to monitoring conducted under RCRA.

As discussed in the CCA, the DOE has performed an analysis to identify parameters that are significant to disposal system performance, and has designed a monitoring program which addresses both the pre-closure and post-closure periods. The monitoring program described in the CCA consists of the following elements:

- Geomechanical monitoring (disposal phase);
- Monitoring airborne volatile organic compounds (disposal phase);
- Groundwater surveillance (disposal phase and post-closure);
- Radiological environmental monitoring (disposal phase and post-closure);
- Observation of drilling practices in the Delaware Basin (disposal phase and post-closure); and
- Subsidence monitoring (disposal phase and post-closure).

The geomechanical monitoring program is an integral part of the DOE's routine ground-control program in the mine. In the program, the disposal rooms, drifts, air intake shaft, and operations area will be monitored during repository operations to confirm the structural integrity of the underground openings.

In the volatile organic compound monitoring program (included in the Part B permit application), the DOE will collect gas samples from the mine air upstream and downstream of the first panel during operations and for at least six months after the panel closure is installed.

The DOE has collected samples from wells installed in the Culebra for several years and will monitor Culebra hydrology on a regional scale. These monitoring results will allow the DOE to observe deviations from expected conditions. The DOE's proposed monitoring network is identified in the RCRA Part B permit application; it includes six wells installed in the Culebra Member and one well in the Dewey Lake Member. The DOE will collect samples annually from the suite of monitoring wells and will analyze them for radionuclides and for chemical constituents that indicate water quality as specified for hazardous waste management facilities in 40 CFR Part 264.

In accordance with DOE Order 5400.1, General Environmental Protection Program, the DOE has collected soil, surface water, vegetation, and animal tissue samples from the accessible environment around the WIPP for several years in a program developed under the Agreement for Consultation and Cooperation (C&C) between the DOE and the State of New Mexico. In continuing this radiological environmental monitoring program, the DOE will collect samples of soil, surface water, vegetation, and animal tissue; these samples will be analyzed for specific radionuclides associated with the TRU waste. The DOE will also monitor meteorological conditions at the WIPP site.

For performance assessment calculations, the DOE has developed a database of parameters related to drilling activities, the location and properties of brine reservoirs in the Castile Formation, and the properties of the intrusion borehole, including plugging practices. The DOE will maintain this database and will add information as it is obtained from future Delaware Basin drilling activities. The updated database will be used, as appropriate, in the calculations for re-certification.

During the operational and post-closure periods, the DOE will perform surveys to detect any surface subsidence attributable to the repository. These surveys will be conducted at 10-year intervals after final closure in accordance with the disposal system monitoring program schedule. The total subsidence due to repository closure is expected to be less than 2 feet at the surface.

3.1.1.2 Performance Assessment

The DOE will maintain the capability to execute performance assessment calculations to meet several objectives:

- Supporting recertification, including assessments of applicable monitoring and testing results to meet the five-year recertification requirement;
- Maintaining the capability for conducting sensitivity analyses to verify the parameters previously shown to be significant to performance as the disposal system evolves;
- Evaluating the effects of proposed future TRU waste inventory changes (see Section 3.2.2 of this Plan);
- Evaluating operations enhancements that involve conceptual models (such as chemical control); and
- Providing support for major project decisions relative to the national TRU system, including the WIPP.

The DOE will maintain the suite of WIPP computer codes in accordance with applicable QA requirements. To assure operability of the performance assessment system through the disposal phase, the codes and performance assessment parameter database will be moved from the current VAX operating system and hardware to operating systems and hardware that can be more readily maintained.

Upgrades of software to take advantage of improvements in hardware and programming are anticipated on a value-added basis. The software will also be updated as needed to facilitate modifications to conceptual and numerical models used in performance assessment.

3.1.2 Enhance System Operations

Focused efforts are planned to enhance system operations by developing new methods and procedures for reducing worker exposure to radiation and other hazards, increasing operational efficiency, reducing system complexity, reducing uncertainty and conservatism in sensitive parameters, and reducing costs. The planned experimental efforts fall into a number of technical areas, which are discussed in the following sections.

3.1.2.1 Rock Mechanics and Seal Systems

Work during the disposal phase will focus on refining and optimizing the seals design and construction-related technologies, and on verifying those modeling parameters shown to be important to system performance. As noted in Section 2.3.1, the seals design included in the CCA is one which can be constructed with current technology, and which will demonstrably fulfill its required function. The current cost estimate for design and construction of the seals systems is $40 million. Uncertainties in material properties, or in construction methodology, have been accounted for in this design by including multiple components (crushed salt, salt-saturated concrete, clay, grout, asphalt, and earthen fill). Each component is designed to contribute to the effectiveness of the shaft sealing system over the 10,000-year regulatory period, and the overall design includes appropriate redundancy to accommodate material and construction uncertainties. Activities during the disposal phase are designed to reduce these uncertainties through:

- Acquisition of additional data on material properties and construction/emplacement technologies;
- Periodic reevaluation of the design, based on these new data; and
- Periodic reevaluation of the construction methodology to allow optimization of the properties of the emplaced materials.

Since the requirements for the seals systems are to function at full scale, and the seals are to be installed using practical field construction methods and controls, much of the disposal-phase work will be aimed at obtaining and evaluating data under field conditions.

Specific activities to be initiated will include:

- Optimizing crushed salt specifications (for example, by adjusting moisture content and size distribution) to enhance compaction;
- Evaluating construction methodology for clay components. The current design calls for emplacing clay as pre-compacted blocks. The efficiency of this needs further investigation, as do the potential efficiencies of alternative emplacement methodologies;

- Optimizing the performance of clay seal elements in field applications and tailoring the specifications for clay mixtures;

- Evaluating the potential longevity of concrete materials under the conditions at the WIPP. If concrete can be demonstrated to have a long life and uncertainty can be reduced, then efficiencies in design can be achieved;

- Evaluating the emplacement methodology of asphaltic seals; and

- Monitoring the development/healing of the DRZ around the WIPP shafts (specifically the air intake shaft).

The potential savings in design and construction of the seals systems are estimated to be as much as $15 million. The savings are primarily associated with fewer materials and use of simplified emplacement and construction technologies that are proven to be successful through application of civil construction techniques and conduct of experimental activities described above. The current cost estimate for these experimental activities is $2.6 million. This cost estimate does not include large-scale field activities to evaluate emplacement technologies. Because of the costs involved in such activities, the DOE plans to conduct these field evaluations through joint programs at both the national and international level, as described in Section 3.2.

The DOE will maintain an ongoing program at the WIPP to measure the extent and nature of the DRZ surrounding the air intake shaft. The DRZ is an important element in performance of the seal systems, as it provides a potential pathway for fluid flow adjacent to seal components. The effective permeability of each seal component is determined by the permeability of the seal material and the properties of the DRZ surrounding the component. The DOE will continue to obtain measurements from the monitoring equipment in place in the air intake shaft and will periodically make direct measurements of flow in boreholes adjacent to the shaft to evaluate interface and DRZ permeability. The data will be used to verify the seals and shaft DRZ performance predictions, and will also be used in the analyses of seal design and construction.

3.1.2.2 Disposal Room Interactions

The DOE's current understanding of the chemical and physical processes which govern conditions in the closed disposal room and the repository is adequate to allow the DOE to develop conceptual and numerical models and calculate long-term disposal system performance in the CCA. The models and calculations incorporate the uncertainties in the processes expected to occur in the closed disposal room (such as brine inflow, creep closure, waste heterogeneity - both physical and chemical, actinide solubility, microbial degradation, and gas generation). As noted in Section 2.3.2, backfill has been incorporated into repository design to provide additional assurance. The current design for the backfill includes conservatism to account for the uncertainties listed above, particularly uncertainties in actinide solubility and in the quantity of gas generated through microbial degradation.

In support of the CCA, the DOE has performed analyses of waste characteristics and components and identified those that affect disposal room interactions and are therefore important to system performance. These results, together with issues associated with safety and waste transportation, form the basis for the waste acceptance criteria (WAC) detailed in the CCA.

There are several areas wherein additional experimental activities may bring increased efficiencies and reduced costs: the actinide source term (actinide solubilities); gas generation (quantity and composition of gas generated); backfill (quantity and placement specifications); and waste characterization (reducing characterization requirements). These are discussed in the following sections.

Actinide Source Term

The actinide source term is important to system performance, as it defines the actinides that are available for transport to the accessible environment. Further evaluation of the source term utilizing real waste tests may allow the level of conservatism in backfill design to be reduced (for program savings, see Backfill). These model evaluations are in progress through the ongoing source term test program (STTP) at Los Alamos National Laboratory (LANL), in which samples of TRU waste are inundated in WIPP brine under controlled conditions. Sampling of the brine in the test containers in the STTP will be continued until the concentrations of key components in the brine approach equilibrium. The maximum measured concentrations will be compared to the results of the actinide solubility model used in performance assessment.

Gas Generation

The model used to predict gas generation in the repository is currently being evaluated through the ongoing gas generation experiments at Idaho National Engineering Laboratory (INEL). The INEL tests are designed to evaluate the effects of the major waste constituents that contribute to gas generation. These include: organic materials (cellulosics, plastics, rubbers, and leaded rubber); iron-base metal; and sludges (particularly sludges that contain potential nutrients for microbial degradation). In the test, the waste has been inundated with simulated WIPP brine and the test containers are initially pressurized with nitrogen to the WIPP lithostatic pressure. The container pressure, temperature, and gas composition are being periodically measured. The measured pressure will be compared with the pressure calculated by the gas-generation model. The additional data regarding gas generation may allow a reduction in the conservatism in backfill design, since the backfill is designed to react with carbon dioxide produced by microbial action (for program savings, see Backfill).

Backfill

The DOE will perform additional laboratory tests to enhance magnesium oxide chemical control, focusing on aspects that are important to long-term disposal system performance and to backfill emplacement. The objective is to optimize the amount of magnesium oxide required to assure the modeled solubility of key radionuclides in Salado and Castile brines (thereby reducing backfill material costs and placement requirements). The DOE has developed a design for packaging the backfill. The magnesium oxide will be contained in bags that are designed to prevent contact with mine air until the repository is decommissioned, and the magnesium oxide will then be released into the disposal room during creep closure. The DOE's placement specifications require placing the bags of magnesium oxide over and between the drums and waste boxes in each room. The current cost estimate for backfill material and placement is $40 million, based on 85,600 tons of backfill.

The DOE is considering laboratory studies to further characterize magnesium oxide and enhance its performance. The DOE is also considering room-scale studies designed to optimize procedures for placing the bags of magnesium oxide over and around the waste containers in the disposal rooms. The benefits of these tests and analyses include:

- Potentially reducing the amount of magnesium oxide required to achieve long-term chemical control in the repository, thereby reducing backfill material costs and operating costs associated with backfill placement;

- Enhancing the ease and efficiency of the backfill placement process, which will reduce operating costs associated with placement, and may also reduce material handling requirements and thereby reduce the potential for worker exposure to powdered backfill, and;

- Refining the backfill packaging specifications to enhance package performance and reduce cost. This will also reduce potential worker exposure through reduced handling, enhance chemical delivery and performance (by providing assurance that the magnesium oxide will be available soon after repository closure), and reduce packaging materials and their associated costs.

The potential savings in design and emplacement of the backfill are estimated to be up to $20 million. These savings are primarily associated with optimizing the amount and cost of the magnesium oxide and use of simplified emplacement operations that are proven to be successful through the activities described above. The current cost estimate for these experimental activities is $2 million.

In conjunction with these efforts, the DOE is also considering development of robotic systems to improve processes for waste emplacement and backfilling and to further reduce the potential for worker exposure.

Waste Characteristics

Waste characterization will be a major cost throughout the national TRU program (the current cost estimate is $4,675 million), and significant cost savings may be realized if the characterization requirements can be reduced. In conjunction with the CCA, the DOE assessed waste components and characteristics to identify those that are significant to performance. Those identified are:

- Specific activity of the five radionuclides that account for a significant portion of the regulatory limits and modeled releases;

- Waste components that affect solubility of plutonium and americium, including complexing agents, plutonium and americium nitrate, and solution reactions of other metals present in the waste;

- Organic compounds (cellulosic and plastic materials) that could be subject to biodegradation, as these reactions will generate carbon dioxide that will react with the magnesium oxide backfill; and

- Physical characteristics and properties of the waste that would affect long-term permeability in the closed repository.

These waste characteristics and components are currently incorporated into the PA models with some conservatism to account for uncertainty and heterogeneity in the wastes. The DOE may perform additional evaluations and laboratory tests to assess the degree of uncertainty and thereby provide greater confidence in the manner in which waste characterization should be applied. Also, characterization techniques, equipment, and instrumentation may be evaluated to develop faster and less expensive processes and equipment (see Section 3.2.2 for additional information). The potential savings in waste characterization costs are estimated to be as much as $2,338 million (based on items that are proven to be successful through the activities described above). The current cost estimate for these experimental activities is $9 million.

3.1.2.3 System Response to Human-Initiated Activities

Passive institutional controls are an integral (though minor) part of reducing human intrusion into the disposal facility during the 10,000-year regulatory time frame. The DOE will implement passive institutional controls that involve multiple types and multiple levels of passive controls to make human intrusion into the disposal site unlikely. Such controls, once established, are expected to remain effective with no human surveillance and maintenance; however, in the PA calculations, the DOE only takes credit for 700 years of performance, in accordance with 40 CFR § 194.43(c). Components of the passive controls system include: (1) physical markers that warn of the presence of buried nuclear waste and identify the boundary of the disposal area footprint and the controlled area; (2) external records about the WIPP repository; and (3) continued federal ownership. The DOE intends to use several types of monuments and markers, land ownership, and written notations in land records in numerous locations. The current DOE cost estimate for the passive institutional control system is $70 million.

With respect to passive institutional controls, the DOE will continue to improve upon the current strategies for archiving and disseminating records. The DOE will also evaluate the markers system (for example, assessing different materials and their properties such as durability). The current cost estimate for these experimental activities is $1.5 million, and the potential savings are estimated to be as much as $35 million.

The speculative nature of future human intrusion and repository conditions requires conservative estimates of sensitive parameters controlling direct radionuclide releases to the surface to properly bound uncertainty in the probabilistic performance assessment calculations. Activities being considered as part of the disposal room interactions (backfill studies and gas generation modeling) during the disposal phase will be used to reduce the uncertainty associated with sensitive parameters such as those which affect spallings and other direct releases. Additional laboratory studies and modeling calculations will also be conducted as needed to provide additional information.

The DOE has a good understanding, and defensible conceptual models, of the properties of boreholes over time and borehole plugging practices in the Delaware Basin in New Mexico. As noted in Section 3.1.1.1, the DOE monitors ongoing drilling and plugging practices as part of the WIPP environmental monitoring program. The DOE also obtains information on the occurrence of Castile brine reservoirs that are sometimes encountered during deep drilling activities.

3.2 Support of Future TRU Waste Management Needs

As the lead for the national TRU Waste Program, the CAO is responsible not only for the WIPP but for developing guidance on all TRU waste issues. Following certification, the WIPP will be a unique facility for disposal of long-lived TRU radioactive waste. As such, the CAO should play a major role as a technical leader in the development of strategies and methods for safe and cost-effective operations of the national TRU waste system. In taking this lead role, the CAO will: (1) establish an international nuclear waste disposal research and development program; (2) become a focus for national and international interactive efforts; (3) potentially realize significant operational benefits and cost savings from these efforts; and (4) provide proactive responses to emerging TRU waste management needs. The DOE has designed a set of experimental activities to utilize the full potential of the WIPP, as shown in Table 2. The experimental program and planned activities fall into two primary areas:

- Establishing future collaborative efforts and continuing ongoing efforts as appropriate with other countries and other material programs; and

- Providing a technical focus for activities in radioactive waste management, including maintaining a key capability to readily provide proactive responses to emerging waste management needs.

The focused international program in radioactive waste management at the CAO will provide the DOE with the opportunity to maintain a technical leadership role in national and international experimental programs. By doing so, the DOE will gain access to relevant information from other programs, provide nuclear waste management information to other programs, and share costs.

In order to provide proactive response to emerging waste management needs, the CAO will also develop technical guidance and support for generators of TRU waste, and will provide technical information for the DOE's use in formulating radioactive waste management policies.

3.2.1 Maintain DOE's Leadership Role by Establishing a Focused National and International Nuclear Waste Disposal Research and Development Program

Developing an international nuclear waste disposal research and development program at CAO offers a unique opportunity to expand the areas of international cooperation. This cooperation would extend to joint development and evaluation of technologies and methods in other areas relevant to radioactive waste disposal, including monitoring technologies, waste characterization, transportation, and operations. Further planning will be required to identify appropriate topics and venues for such future cooperative ventures.

3.2.1.1 Collaboration in National and International Programs

The CAO has designed the disposal phase experimental program to maintain compliance certification and enhance WIPP and national TRU system operations. The CAO will continue to engage in joint activities with other countries that lead to the development and evaluation of new waste management technologies, methods, and designs in areas described in Section 3.1.

The CAO's main focus will continue to be joint programs specifically addressing the needs of the DPEP. Through joint endeavors, the expertise and resources of other countries will enable the DOE to leverage its own expertise and resources and maximize the return on its investment. Joint activities allow the

DOE to address more areas of interest and possibly achieve more expedient results. The DOE will not initiate joint efforts unless experimental data are required and the effort is cost effective.

Thus, the CAO's joint ventures are and will continue to be a cost-effective means of providing assurance that the CAO's TRU waste management program remains consistent with international scientific understanding and processes in key disciplines. In addition, the joint ventures provide a means of generating specific data of value to the WIPP (such as experience with large concrete seal emplacements) with minimal costs. In return, CAO will transfer the WIPP's experience to other projects around the world.

In order to develop and maintain a coherent, comprehensive, and iterative approach to other national and international radioactive waste management experimental programs, the CAO will develop an international research and development program plan by May 1997. The plan will include a summary of experimental areas and specific programs which the CAO believes may be relevant to the WIPP project; these programs will be pursued and will become elements of an active, vigorous, and productive international experimental program for the U.S. The international research and development plan will also include a summary of activities which have only limited interest to the U.S.; the CAO will establish links with countries performing these activities to monitor progress, but will not fund joint programs in these areas. However, maintaining limited interfaces through attending symposia and workshops will enable the CAO to maintain general knowledge of progress in areas which may, at a future date, be relevant to the DOE's evolving research needs.

Countries with active radioactive waste management and repository programs include Argentina, Belgium, Brazil, Canada, Finland, France, Germany, Israel, Italy, Japan, Korea, Netherlands, Spain, Sweden, Switzerland, republics in the former Soviet Union (e.g., Kazakhstan, Russia, Ukraine), the United Kingdom, and others. These programs are developing information which may be used to enhance the DOE's understanding of the processes and parameters that contribute to the long-term performance of the WIPP disposal system, thereby increasing public confidence. Other U.S. activities in radioactive waste management include the Yucca Mountain Project under the DOE Office of Civilian Radioactive Waste Management (OCRWM).

The CAO currently participates in the Site Evaluation and Design of Experiments (SEDE) Group for Radioactive Waste Disposal, as well as the Performance Assessment Advisory Group (PAAG), both of which are international information-exchange forums coordinated by the Nuclear Energy Agency of the Organization for Economic Cooperation and Development (NEA/OECD). Each group conducts an annual information-exchange meeting and periodic workshops dealing with topics of widespread interest within the international waste-management community. These exchanges are both valuable in themselves and useful as venues to identify topics of common interest that may be fruitful subjects for joint ventures. These exchanges will continue during the disposal phase.

The CAO has also participated in a third NEA/OECD group: GEOTRAP (Geological Transport of Radionuclides Predictions). GEOTRAP's predecessor, the INTRAVAL (International Project to Study Validation of Geosphere Transport Models), provided a detailed international technical review of plans for Culebra tracer tests. This input not only provided for extensive review of the plans for these experiments but also assured that the international community would reap the full benefit of advances in understanding that came out of these experiments.

The CAO will continue to participate in GEOTRAP in order to enhance interpretation of experimental results and understanding of flow and radionuclide transport. As a result of careful integration of physical-transport and chemical-transport studies in the Culebra Member, the CAO anticipates the WIPP will play a lead role in the upcoming GEOTRAP workshop, which will focus on scaling issues associated with interpreting experimental results.

In addition, fracture-flow experimental programs are underway or planned in such countries as Sweden, Switzerland, and Japan. These international programs are designed to develop a better understanding of radionuclide migration and retention in fractured rock, and to evaluate different concepts and models for modeling this behavior. The CAO will evaluate participation in these programs, as they may be useful in enhancing the understanding of flow and transport in the Culebra.

The role of two-phase flow in geological formations and other materials (such as shaft seals and other engineered barriers) associated with radioactive waste disposal facilities is a topic of increasing interest in the international community. A working group is presently being developed within SEDE (at the behest of NEA/OECD) to investigate this area. The potential for two-phase flow (brine and gas) in the Salado Formation has been addressed in assessments of disposal system performance. The presence of a gas phase is not currently assessed to have a strong effect on WIPP facility compliance for hazardous constituents (these hazardous constituents would potentially be present in the gas phase). However, it does affect direct releases of radionuclides during some drilling events.

The CAO may continue to participate in a cooperative effort to examine the role of two-phase flow in radioactive waste disposal. The participants in this effort are the CAO, Japan, and Russia. This effort provides a cost-effective opportunity to assure that the WIPP project stays current with international developments in this area.

As part of the Canadian Nuclear Fuel Waste Management Program and in concert with other international waste management organizations, a major tunnel-sealing experiment is to be completed over the next five years. The tunnel-sealing experiment's objectives are: (1) to develop and study clay- and concrete-sealing technologies; and (2) to evaluate the performance of a sealing system using these technologies. Although this seal will be emplaced in granite in an environment somewhat different than WIPP brines, the WIPP Project will benefit from participation in this project by developing experience in important shaft-sealing technologies. These technologies include: (1) placing, modeling, and measuring clay seal components; (2) experience in the large-scale placement and performance of concrete; and (3) experience in large-scale flow testing of seals. The total funding for this effort is approximately $8.1 million; the DOE is providing approximately $3.6 million.

Field evaluations of sealing technologies for shafts and drifts in evaporite (salt) formations are being conducted in the German radioactive waste program. The WIPP Project will collaborate in applying, analyzing, and evaluating the technologies being applied in this program in order to further enhance the performance and credibility of the WIPP's seal designs in a cost-effective manner. The DOE is providing approximately $1.65 million of the total $11.2 million cost of this project.

This project does not address the large-scale field activities that would be required to evaluate emplacement technologies.

In the U.S., seals or plugs are being emplaced in oil and gas wells in the Delaware Basin, in caverns in salt formations, and in other shafts in salt formations. Shaft seals will also be emplaced in Delaware Basin potash mines. The DOE will continue to monitor and evaluate these activities and incorporate information as appropriate into the WIPP program.

There are also other ongoing international programs of potential interest. These offer the opportunity to jointly develop understanding of coupled chemical processes that may affect chemical retardation of radionuclide transport, which is of importance to assessing radionuclide flow and transport in the Culebra Member.

3.2.1.2 Test Site for Experimental Activities

The CAO will not only collaborate in experimental programs being conducted at other facilities, but will also serve to attract other parties to the WIPP for experimental programs. The WIPP facilities may be offered under prescribed conditions as an international test site for experiments since the focused international program in radioactive waste management at CAO will encompass world-class facilities and expertise associated with the WIPP. CAO will provide a focus for activities and maintain expert capabilities to support key scientific areas in radioactive waste management.

The technical focus will be developed based upon the existence of the facility and the availability of key personnel to address emerging technical issues in the waste management area. Any experimental activities will be conducted in accordance with the WIPP permit conditions, and will not be allowed to interfere with ongoing WIPP operations. By maintaining this technical focus and key capabilities for operations and disposal system performance assessment, the CAO will be in a position to maintain a lead role in international studies, providing maximum benefit in cost sharing and technology development. The infrastructure for additional tests by other countries will be made available by CAO, and these international experimental activities will provide additional information to the CAO.

3.2.2 <u>Enhance Proactive Responses to Emerging DOE TRU Waste Management Needs</u>

TRU wastes generated by the DOE must currently undergo comprehensive testing and characterization prior to shipment to the WIPP. The operational characterization criteria include real-time radiography (RTR), radioassay, and headspace gas sampling on all waste, and detailed characterization of some statistically adequate portion of the waste. These requirements are time-consuming and costly. The requirement for detailed characterization involves the potential for significant worker exposure to hazardous components of the waste. Additional costs would be incurred for any treatment of the waste.

To reduce the potential for worker exposure and treatment costs, CAO will support the waste generators to evaluate three aspects of the current waste characterization requirements:

- The need for the types of information that will be provided by the current characterization program. For example, continued analyses of waste behavior under repository conditions as described above are designed to confirm the radionuclide releases that are predicted in performance assessment; these results would then be used to optimize characterization requirements.

- The need for operational characterization of each drum of the incoming waste. Complete characterization of each drum of the same waste stream may not be required for wastes being generated now and in the future. As an alternative, the DOE may monitor the historically stable waste-generating processes to ensure there are no deviations.

- Alternative methods for characterizing the wastes. For example, improvements in non-destructive assay (NDA) and non-destructive examination (NDE) methods may provide suitable information at lower cost than the current RTR and radioassay procedures.

When evaluating these aspects of the characterization requirements, CAO will consider both the current waste forms and compatibility with the properties of future TRU wastes.

The CAO is developing guidance for DOE TRU waste generators to assure that future TRU waste will be acceptable for disposal at the WIPP. This guidance will translate the significant calculational assumptions related to waste characteristics and components into a form that can be used by waste generators in developing their waste-generating and/or waste-treatment processes. The guidance will be based on the analyses performed in support of the CCA and the experimental activities described in Section 3.1.2.2. It will address waste characteristics and components such as radionuclide specific activity, waste components that affect actinide solubility, organic compounds (cellulosic and plastic materials) that could be subject to biodegradation, and physical characteristics and properties of the waste that affect long-term permeability in the closed repository.

Sources of future (to be generated) TRU waste for the WIPP include decontamination and decommissioning (D&D) activities at nuclear weapons complex facilities. Other sources may include waste processing or treatment at TRU waste generator sites such as INEL, Oak Ridge National Laboratory, and Savannah River Site, in addition to the defense processes that have produced TRU waste in the past. The characteristics of these TRU wastes may differ from the current waste inventory. The DOE may perform laboratory tests to evaluate the density, strength, porosity, and other physical, mechanical, and hydrologic properties of vitrified wastes and other future waste forms that differ from the current wastes. In particular, the CAO plans to provide support to the TRU waste generators to verify that the properties of future TRU wastes destined for the WIPP fall within the range of properties that are the bases for the calculations of WIPP disposal system performance, as described above.

3.2.3 Summary

This Plan represents the current DOE approach to future disposal-phase experimental work in support of the overall objectives of the CAO mission. The DOE will evaluate, select, design, and conduct experimental activities to meet the objectives stated in Section 1.2: (1) support WIPP operations by maintaining certification and enhancing facility operations; and (2) support future waste management needs by establishing a focused international nuclear waste disposal research and development program and by enhancing proactive responses to emerging DOE TRU waste management needs. The experimental activities outlined in this Plan are intended to support WIPP Program objectives in the short term (five years), and to form the basis for longer-term activities to be carried out throughout the 35-year disposal phase.

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Table 1. Summary of Experimental Activities in Support of WIPP and National TRU System Operations

Experimental Area	Current Status	Future Plans	Objective
SYSTEM PERFORMANCE MONITORING (Section 3.1.1.1)			
· Geomechanical monitoring · VOC monitoring · Groundwater surveillance in Culebra · Radiological environmental monitoring · Observation of drilling practices in the Delaware Basin · Subsidence monitoring	· Programs are specified in compliance certification	· Programs will be implemented as detailed in the CCA	· Maintain compliance and obtain information for re-certification
PERFORMANCE ASSESSMENT (Section 3.1.1.2)			
· Assessment capability	· Current capability is acceptable for CCA calculations, and is dependent on hardware.	· Maintain complete capability.	· Use as needed in re-certification.

Table 1. Summary of Experimental-Activities in Support of WIPP and National TRU System Operations (continued)

Experimental Area	Current Status	Future Plans	Objective
ROCK MECHANICS AND SEAL SYSTEMS (Section 3.1.2.1)			
• Seal materials, design, and emplacement	• Understanding of material properties is sufficient for conceptual model development and performance assessment calculations. • Multiple components provide redundancy and assurance, but increase material and construction costs.	• Evaluate concrete longevity and large-scale performance. • Optimize crushed salt specifications. • Tailor specifications for clay mixtures. Optimize clay seal performance in field applications. • Evaluate emplacement of asphaltic component.	• Reduce costs. • Verify performance and refine model assumptions. • Simplify design and construction processes.
• Shaft DRZ properties and behavior	• Measuring properties of DRZ around the air intake shaft without a rigid seal element in place	• Continue monitoring DRZ development around air intake shaft.	• Verify performance, verify simulation capability, and refine model assumptions. • Incorporate future seal design changes.

Table 1. Summary of Experimental Activities in Support of WIPP and National TRU System Operations (continued)

Experimental Area	Current Status	Future Plans	Objective
DISPOSAL ROOM INTERACTIONS (Section 3.1.2.2)			
• Actinide solubility • Gas generation	• Understanding is sufficient for conceptual model development and performance assessment calculations; includes conservatism to address uncertainty in processes.	• Perform laboratory tests of waste components and characteristics that are significant in performance assessment.	• Refine model assumptions and verify model predictions and potentially reduce conservatism in backfill design. • Reduce waste characterization costs.
		• Complete source term test program (STTP) at LANL.	• Refine model assumptions and verify model predictions.
		• Complete gas generation test program at INEL.	
• Backfill (chemical control)	• Understanding of chemistry is sufficient for conceptual model development and performance assessment calculations; includes conservatism to address uncertainty.	• Perform laboratory tests to refine the conceptual model of actinide solubility with magnesium oxide and to optimize amount of magnesium oxide required to maintain conditions.	• Reduce backfill material and packaging costs. • Reduce operating costs. • Reduce worker exposure to hazards.
• Backfill specifications	• Understanding of process is sufficient for conceptual model development and packaging specifications; includes conservatism to address uncertainty.	• Perform laboratory tests of packaging properties and performance in simulated repository conditions.	
		• Perform room-scale tests of backfill placement.	

Table 1. Summary of Experimental Activities in Support of WIPP and National TRU System Operations (continued)

Experimental Area	Current Status	Future Plans	Objective
SYSTEM RESPONSE TO HUMAN-INITIATED ACTIVITIES (Section 3.1.2.3)			
• Passive institutional controls	• Understanding of system performance is sufficient for conceptual model development and performance assessment calculations. • Multiple components provide redundancy and assurance, but increase material and construction costs.	• Study system for archiving and disseminating records. • Test durability and performance of proposed marker materials.	• Reduce costs.
• Direct releases	• Understanding of processes is sufficient for conceptual model development and performance assessment calculations. Models include uncertainty and conservatism to address uncertainty in future conditions.	• Utilize information from other experimental areas (such as gas generation and backfill) to reduce uncertainty in parameters controlling spallings and other direct releases. Perform laboratory studies and modeling as needed.	• Reduce uncertainty and conservatism in sensitive parameters.

Table 2. Summary of Experimental Activities in Support of Future TRU Waste Management Needs

Experimental Area	Current Status	Future Plans	Objective
COLLABORATION WITH NATIONAL AND INTERNATIONAL PROGRAMS (Section 3.2.1.1)			
• SEDE and PAAG information-exchange forums	• WIPP Project currently participates.	• Continue participation.	• Exchange relevant information.
• GEOTRAP (and previous INTRAVAL) participation in Culebra studies	• Provided input to Culebra hydrological studies.	• Continue participation while interpreting results.	• Exchange relevant information. • Obtain technical input for verifying model predictions and refining model assumptions.
• Various fractured-flow programs	• Developing understanding of transport in fractured rock.	• Evaluate participation as an observer.	
• SEDE working group to examine 2-phase flow in rock formations and engineered materials	• 2-phase flow occurs at the WIPP and is addressed in performance assessment models and calculations.	• Participate in working group.	• Obtain technical input for verifying model predictions and refining model assumptions.
• Japan and Russia cooperative effort to study 2-phase flow		• Keep current on results of studies.	
• Canadian tunnel-sealing experiment	• Will evaluate emplacement and performance of materials.	• Participate.	• Enhance WIPP seal-emplacement specifications.
• German shaft sealing evaluation			
• DOE and other sealing programs	• Monitoring various seal designs and seal-emplacement specifications.	• Keep current on results of programs.	

Table 2. Summary of Experimental Activities in Support of Future TRU Waste Management Needs (continued)

Experimental Area	Current Status	Future Plans	Objective
PROACTIVE RESPONSES TO TRU WASTE MANAGEMENT NEEDS (Section 3.2.2)			
• Requirements for operational characterization of incoming TRU waste: RTR; radioassay; and headspace gas sampling.	• Current characterization requirements are 100% of waste.	• Consider coupling emerging technologies, WIPP performance, and waste-generating processes. Determine whether requirements can be refined.	• Respond to emerging needs. • Reduce costs.
• Detailed characterization requirements for incoming TRU waste	• Current requirement is percentage of wastes.		
• TRU waste components and characteristics	• Conceptual models and performance assessment calculations indicate certain radionuclides, waste characteristics, and waste components are important to system performance.	• Specify minimum technical acceptance requirements in conjunction with performance assessment. • Perform laboratory tests as needed to determine and verify chemical and physical properties of new TRU waste forms.	• Assure continued performance of the WIPP. • Reduce costs. • Assure compatibility with DOE TRU waste generators.