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Scenario Development for the Waste Isolation Pilot Plant:

Building Confidence in the Assessment

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ABSTRACT

Scenario development is part of the iterative performance assessment (PA) process for the Waste Isolation Pilot Plant (WIPP). Scenario development for the WIPP has been the subject of intense external review. and is certain to be the subject of continued scrutiny as the project proceeds toward regulatory compliance. The principal means of increasing confidence in this aspect of the PA will be through the use of a systematic and thorough procedure toward developing the scenarios and conceptual models on which the assessment is to be based. Early and ongoing interaction with project reviewers can assist with confidence building. Quality of argument and clarity of presentation in PA will be of key concern. Appropriate tools are required for documenting and tracking assumptions, through a single assessment phase, and between iterative assessment phases. Risks associated with future human actions are of particular concern to the WIPP project, and international consensus on the principles for incorporation of future human actions in assessments would be valuable.

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DISCLAIMER

PREFACE

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SCENARIO DEVELOPMENT FOR THE WASTE ISOLATION PILOT PLANT: BUILDING CONFIDENCE IN THE ASSESSMENT

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ABSTRACT

Scenario development is part of the iterative performance assessment (PA) process for the Waste Isolation Pilot Plant (WIPP). Scenario development for the WIPP has been the subject of intense external review, and is certain to be the subject of continued scrutiny as the project proceeds toward regulatory compliance. The principal means of increasing confidence in this aspect of the PA will be through the use of a systematic and thorough procedure toward developing the scenarios and conceptual models on which the assessment is to be based. Early and ongoing interaction with project reviewers can assist with confidence building. Quality of argument and clarity of presentation in PA will be of key concern. Appropriate tools are required for documenting and tracking assumptions, through a single assessment phase, and between iterative assessment phases. Risks associated with future human actions are of particular concern to the WIPP project, and international consensus on the principles for incorporation of future human actions in assessments would be valuable.

I. INTRODUCTION

Assessments of the long-term safety of radioactive waste disposal sites rely on a combination of qualitative judgements and quantitative modelling. The ultimate aim of these assessments is an evaluation of the performance of a particular site or disposal concept against a regulatory measure, such as individual dose or risk, or cumulative releases of radionuclides. An important aim of site characterisation is to provide the data required for the development, evaluation and use of the conceptual models and corresponding mathematical models required for a quantitative assessment of long-term performance.

Various methods have been used to progress from the site and system understanding achieved during site characterisation to a well-structured performance assessment (PA). All radioactive waste disposal programmes face the problem of determining exactly what phenomena and components of the disposal system can and should be dealt with in the quantitative PA. In the radioactive waste disposal literature, this problem is normally referred to as 'scenario development', and the phenomena and components of the system - or the 'things' to be modelled - have sometimes been referred to as features, events and processes (FEPs). 'Scenarios' themselves can be considered as broad descriptions of alternative futures of the waste disposal system. Multiple scenarios have been used where it is not possible or convenient to describe the system using a single integrated model.

An international review of scenario development methodologies is being undertaken on behalf of Sandia National Laboratories (SNL), within the context of the performance assessment programme for the Waste Isolation Pilot Plant (WIPP). The purpose of the review is to evaluate approaches to scenario development, and to compare methods used recently with those used in the WIPP PA, with the aim of improving the basis for the screening of events and processes in WIPP PAs.

An important aspect of the review was the organisation of an informal international seminar with participants from many of the national programmes active in scenario development[1]. Previous discussions at an international level were held in the period 1987-1989, by a working group of the Nuclear Energy Agency of the Organisation for Economic Co-operation and Development (OECD/NEA).[2] However, new work has been reported since then in many of the countries with disposal programmes for long-lived radioactive wastes.

Additional input for the review came from study of recent performance assessment documents from countries active in the field.[3-12]

Scenario development for the WIPP is reviewed in Section II of this paper. An analysis of several key issues in scenario development and an explanation of the relevance of these issues to the WIPP project is provided in Section III. Based on this analysis, recommendations relating to documentation and integration of the scenario development process are provided in Section IV.

II. SCENARIO DEVELOPMENT FOR THE WIPP

A. Regulatory Background

The WIPP has been developed by the United States Department of Energy (DOE) to demonstrate the safe disposal of transuranic wastes (TRU) generated by DOE defense programmes since 1970. The WIPP is located 42 km east of Carlsbad, in southeastern New Mexico. The proposed repository is in bedded salt about 655 m below the land surface (Figure 1). Prior to disposing of waste at the WIPP, the DOE must evaluate compliance with applicable long-term regulations and, in particular, those promulgated by the United States Environmental Protection Agency (EPA), including 40 CFR Part 191 (Subparts B and C) and 40 CFR Part 268.6.[13-15]

The Containment Requirements of 40 CFR 191, Subpart B (§191.13) set limits on the probability that cumulative releases of radionuclides to the accessible environment for 10,000 years after disposal will exceed certain limits.[13] The accessible environment is defined to be (1) the atmosphere, (2) land surfaces, (3) surface waters, (4) oceans, and (5) all of the lithosphere that is beyond the controlled area (§ 191.12[k]).[13] The controlled area for the 1992 WIPP PA was the 41-km^2 land-withdrawal area.

The Land Disposal Restrictions (40 CFR 268) of the Resource Conservation and Recovery Act (RCRA) regulate releases of specified nonradioactive hazardous materials from the repository to the disposal-unit boundary.[15] For the WIPP, these hazardous materials include heavy metals and semivolatile and volatile organic compounds. The disposal unit for the WIPP has been defined to be the entire volume of the Salado Formation within the WIPP land-withdrawal area, and it is assumed that the same lateral spatial scale applies as for the accessible environment defined in 40 CFR 191, Subpart B.[16] The length of the regulatory period will be a waste-specific and site-specific determination, and is assumed to be 10,000 years for the purpose of interim analyses.[16]

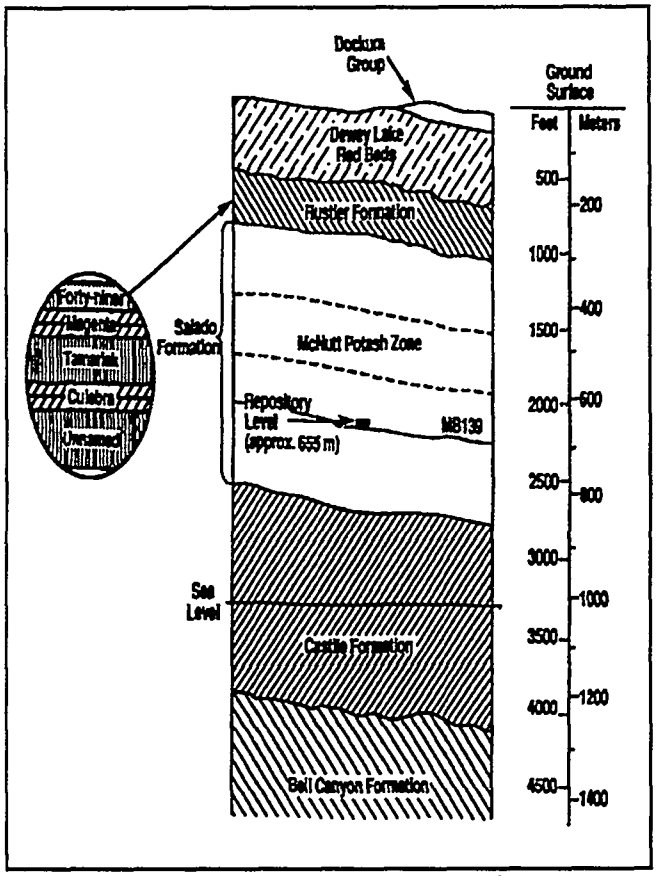

Figure 1 : Generalised WIPP stratigraphy.[16]

B. Performance Assessment Overview

System performance assessments will form an important basis for evaluating compliance with the applicable regulations. The SNL/WIPP Performance Department (PA) Department is responsible for performing iterative performance assessments of the WIPP, to provide guidance to the project while preparing for final compliance evaluation.

Long-term containment of wastes at the WIPP is provided by a multibarrier system that comprises three principal components:

(i) Engineered barriers such as the waste form, repository backfill, and shaft and panel seal systems. The waste containers themselves are assumed to lose their integrity almost immediately. However, for the base case, long-term performance of the shaft seal systems is important in limiting releases.

(ii) The 600-m thick halite host rock (Salado Formation). This unit has an extremely low permeability, and is not expected to provide a

pathway to the accessible environment in the 10,000-year time frame of concern, unless it is breached by inadvertent future human actions, such as exploration for natural resources that are known to exist in the region.

(iii) The geologic units underlying and overlying the Salado Formation. In particular, given a breach of the Salado Formation by a future borehole, it is expected that significant delay and retardation of radionuclides will occur in the principal aquifer of concern, the Culebra Dolomite Member of the Rustler Formation.

Annual assessments have been conducted and published by SNL in the period 1989-1992.[16] Assessment structure is linked to the representation of risk in response to three questions:[17]

(i) What can happen? (scenarios)

(ii) How likely are things to happen? (likelihood of occurrence of scenarios)

(iii) What are the consequences of these things (scenarios) happening?

Systematic scenario development techniques have been employed to answer the first question. A formal elicitation procedure using expert panels has been used to answer the second question.[18] Monte-Carlo simulation is used to examine uncertainties in consequence assessments and to perform sensitivity analyses that provide guidance to the project.

C. Scenario Development Procedure

Although early scenario development for the WIPP used an event-tree approach, in recent years the systematic five-step procedure developed by Cranwell et al. has been used, as outlined below:[19]

(i) Compilation or adoption of a comprehensive set of features, events and processes that potentially could affect the disposal system. The current WIPP list is based on that in Cranwell et al. (ibid), which itself reflects the discussions of an expert group that met in the late 1970s. The list is restricted to potential 'disruptions' that arise externally to the disposal system, or that are caused by human activity - including emplacement of the radioactive wastes. The term 'features' has not been used in scenario development for WIPP PAs, and is omitted from the discussion that follows.

(ii) Classification of the events and processes to aid in completeness arguments.

(iii) Screening the events and processes to identify those that can be eliminated from consideration in the performance assessment. Screening criteria include low probability, negligible consequence, physical reasonableness, and regulatory guidance on the treatment of future human actions.

(iv) Developing scenarios by combining events and processes that remain after screening. A logic diagram is used to illustrate the possible combinations (Figure 2). At each junction within the diagram, a yes/no decision is made as to whether the next event or process is added to the scenario. Parameter values, time of occurrence, and location of occurrence are not used to define the events and processes, and parameter uncertainty is incorporated directly into the assessment database. Thus, each scenario consists of a combination of occurrence and non-occurrence of all events and processes that survive screening.

(v) Screening scenarios to identify those that have little or no effect on the performance estimate. Screening criteria are similar to those used in screening events and processes.

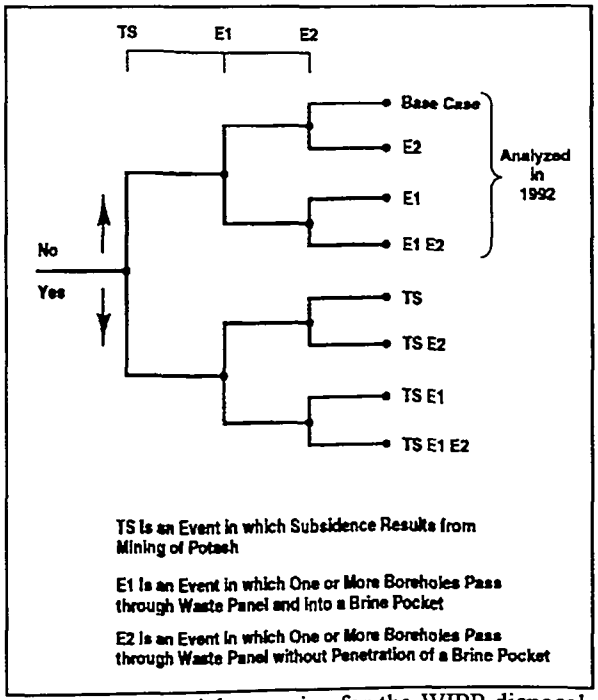

Figure 2 : Potential scenarios for the WIPP disposal system.[16] Each scenario is a set of similar occurrences and a subset of all possible 10,000-year histories beginning at decommissioning of the WIPP.

This process is structured and provides an auditable and documented means for identifying and screening events and processes of concern. Potentially disruptive events and processes are combined to form a mutually exclusive and representative set of scenarios for consequence analysis. The likelihood of occurrence of a scenario may be estimated directly, or by combining the likelihood of occurrence and non-occurrence of its constituent events and processes.

D. Application to the WIPP

For the WIPP, the 'base-case' represents expected behaviour of the natural and engineered systems, including consideration of variability in these systems and uncertainties in characterising them. The base-case scenario does not take into account disruptions caused by future human actions or the occurrence of 'unlikely' natural events. Thus, all naturally occurring events and processes retained for scenario development have been considered to form part of the base-case scenario. Simulations conducted to date indicate that this scenario is not expected to give rise to any releases to the accessible environment in the time frame of concern.[16]

Future human actions are currently judged to be the only disruptive events requiring additional system assessment outside the base-case scenario. These events are combined with the base case to form additional scenarios that could give rise to releases within the 10,000-year regulatory time frame. In the scenario development work conducted to date, three events have been retained for scenario development, leading to the construction of eight scenarios (Figure 2). The three events are:

E1 - The inadvertent drilling of one or more exploratory boreholes that intersect a waste-filled room or drift and a hypothetical pressurised brine reservoir in the underlying Castile Formation; the borehole(s) forms a flow path to the overlying Culebra Dolomite.

E2 - The inadvertent drilling of one or more exploratory boreholes that intersect a waste-filled room or drift but not a brine reservoir in the underlying Castile Formation; the borehole(s) forms a flow path to the overlying Culebra Dolomite.

TS - Mining for potash by either conventional or solution methods in areas beyond the boundaries of the waste panels; the mining leads to subsidence, with potential for degraded performance of the geosphere system.

The scenario leading to the largest consequences is E1E2, in which two boreholes, one of each type, penetrate a single waste panel, creating a flow path for Castile brine through the waste from one hole to the other and then upward to the Culebra Dolomite. Scenarios involving TS have not yet been modelled within the assessment, but are not expected to affect significantly the final evaluation of compliance with the EPA regulations.

Many judgements and assumptions are required in order to assess the potential risks associated with future human actions. These judgements are clearly required for modelling of the intrusion activity; they are, however, also required in considering the transport of radionuclides from the repository through the surrounding geology and to the accessible environment.

E. Peer Review of WIPP Scenario Development

Because assessments are being conducted and documented iteratively, external reviewers have had several opportunities to provide input to the performance assessment. Reviewers have expressed concern about the logic behind various screening arguments:[20]

- Certain events and processes have been screened out owing to low consequence, with insufficient attention paid to a quantitative demonstration that this was indeed the case.

- Existing site information has not always been fully considered in screening events and processes, and in framing the models used in performance assessment.

- Not all potentially significant interactions between features, events and processes have been considered in screening arguments.

Reviewers have also questioned the comprehensiveness of the initial list of features, events and processes, and the documentation of the screening process. For example, the initial list of FEPs cannot be considered comprehensive in the sense that many FEPs which form part of the base case are not included on the list (e.g., hydrological and geochemical processes). The result is that there is no clear discussion in one place in the assessment documentation of what FEPs are included in the base case, the reasoning behind this selection of FEPs, and the linkages between them.

Despite these criticisms, the work to date does have the advantage of having been submitted to continuous and rigorous peer review. Many of the reviewers' concerns have pertained more to the presentation of the available information, rather than to the broad selection

of scenarios to model or to the basic methodology for developing scenarios.

The WIPP review process indicates that external reviewers will focus on the comprehensiveness of the scenario development exercise, and the arguments used to exclude particular events and processes from the quantitative system assessment. Thus, decisions to exclude particular events and processes need to be well defended, with quantitative argument whenever possible. The methodology used for forming scenarios is likely to be of secondary importance to the quality of the argument used in developing the assessment basis.

III. INTERNATIONAL COMPARISON OF SCENARIO DEVELOPMENT METHODOLOGIES: PRELIMINARY ANALYSIS

A. Previous Reviews

Assessments must both demonstrate regulatory compliance and be clearly presented. The importance of clearly identifying the phenomena to be included in an assessment was already recognised more than a decade ago, when the first syntheses of approaches to scenario development appeared.[21] Since then, summaries of approaches to scenario development have appeared regularly, and such reviews are becoming increasingly fashionable. In large part, the recent reviews seem to be motivated by the desire to ensure that programmatic lists of FEPs are as comprehensive as possible.

Recent reviews have been conducted on behalf of TVO (Finland), SKI (Sweden), NAGRA (Switzerland) and the SNL Greater Confinement Disposal (GCD) project (United States).[3-6] Several of these projects have compiled master lists of FEPs based on review of a large range of other studies. The master lists were then screened, for example to remove duplicate entries, and were used as a basis for the ensuing scenario selection and modelling exercises. It is interesting to note, however, that the basic starting lists used by these projects have not been identical, because the researchers involved in these studies have had access to different lists, not all of which are yet publicly available. In addition to these studies, FEP lists have also been compiled at an international level, and work is continuing in this direction.[22]

These studies show that almost all of the important events and processes were already identified in the earliest assessments. Improvements in assessments pertain more to increased realism in process models, better understanding of linkages between FEPs, and better treatment of uncertainties and presentation of results.

This analysis builds on the earlier reviews, discussions at an informal international seminar, and review of recently published performance assessments.[1-12, 19, 21]

B. Overall Performance Assessment Methodology and Importance of Judgement

There has been discussion within the assessment community over the past 15 or more years concerning approaches for treatment of uncertainty related to evolution of a disposal system. Many of the early performance assessments were characterised by an ad hoc procedure to arrive at decisions on what events and processes to consider, and the decision bases were sometimes not well documented. Approaches to model formulation have become increasingly more systematic and increasing attention is being paid to formal methods for the use of expert judgement for event and process screening, model development and parameter selection.

Many apparent methodological differences between performance assessment programmes are a result of differences between sites, repository design concepts, and national regulatory requirements. In addition, apparent differences arise from decisions on which processes ought to be considered within the main system assessment model, and which should be treated through separate analyses outside the system model (e.g, for reasons of clarity or convenience). Such decisions have led to a distinction between so-called scenario-based and simulation-based approaches to assessment. This distinction is more apparent than real, as the aim of both approaches is to produce a model of the system.[23] Both approaches require reasoned argument and extensive use of expert judgement to arrive at this goal. In addition, the most important part of any methodology will be the quality of the judgements made (i) in determining which features, events and processes to consider in the assessment, and (ii) in linking them together in an overall conceptual model of the system.

C. Documentation

The screening of events and processes will be an important focus for external review, including that by regulatory agencies. Review will be facilitated by providing sufficient information in one place in the assessment documentation for reviewers to understand the decision bases on assessment structure. The inevitable focus of reviewers on this part of the assessment leads to high demands for clear documentation. Catalogues of FEPs and influence diagrams have been developed and used to good effect in many programmes. Such tools can assist with tracking decisions and assumptions through

an assessment, as well as from one assessment phase to the next.

Relevance to WIPP: In documentation for the WIPP PAs, screening of potentially disruptive events and processes has been discussed under the heading of 'scenario development'. However, numerous other assumptions have been made concerning evolution of the system under both normal and disruptive conditions. Documentation of these assumptions is found in several places in recent assessments, and some assumptions may have been undocumented.

D. Comprehensiveness

A great deal of duplication has occurred in developing comprehensive lists of FEPs that may be relevant to system safety, with many national programmes developing their own supposedly comprehensive lists of FEPs as a basis for making screening decisions for assessments. Some of these lists have been developed internally; some have been compiled based on comparison with lists available in other programmes.

Work underway at an international level will reduce this duplication of effort in the future, and will help ensure that FEP lists are as comprehensive as possible. The OECD/NEA has recently initiated a working group to establish an international database of features, events and processes of concern to long-term performance assessments of deep geological disposal systems. The international FEP list is supposed to be developed as a relational database that represents the sum of national experience in identifying, classifying and screening FEPs. The database, when available in late 1994 or early 1995, will be of value to all assessment programmes.

Relevance to WIPP: The WIPP performance assessment programme has developed its own 'comprehensive' list of FEPs, which focuses on potential disruptions. The lists of other programmes are substantially longer, and include a great deal of detail concerning the modelling of disposal system evolution in undisturbed (as well as disturbed) conditions.

E. Screening and Combining FEPs

For practical reasons, there is a need to screen out many events and processes early on, but this should be done whenever possible using quantitative arguments. Important early screening criteria may relate to particular characteristics of the site and disposal concept, regulation (or ground rules for the assessment), probability, and consequence.

Scenarios and conceptual models should be formulated initially on the basis of current understanding of the disposal system. Development of a representative set of scenarios for consequence analysis will be influenced, however, by mathematical and numerical modelling capability, as well as by the overall approach to assessment. As already noted, experience with reviews, particularly within the WIPP project, shows that the overall methodologies for forming scenarios are likely to be of secondary importance to the quality of the argument used in screening events, processes and scenarios.

Relevance to WIPP: Criticism of the WIPP scenario development work has focused on the quality of the argument behind various screening decisions that have been made. For example, assumptions used in the assessment concerning the treatment of future human actions have been questioned. Future WIPP PAs will consider in detail the range of comments received and modify the argumentation as needed to account for them. This will be an ongoing process as the project moves through the regulatory process, in so far as the scenario development work remains a focus of external review. Interaction between the project staff and its reviewers will be a vital step in building confidence in the quality of the argument used throughout the assessment.

F. Treatment of Conceptual Model Uncertainty

The process of forcing experts to undertake a conscious sorting of alternative assumptions concerning evolution of the disposal system - and appropriate documentation of this sorting process - is a time-consuming effort. Nonetheless, the results of this process can provide a useful tool for evaluating progress within assessment programmes and for providing an accessible source of information for reviewers. Reviewers need to be able to understand what decisions and assumptions were made in an assessment, why they were made, what alternative assumptions might also have been made, and the potential affect on assessment results of these alternative assumptions. These issues were discussed at a recent OECD/NEA Workshop on conceptual model uncertainty.[24] Systematic approaches are being actively developed in several countries.

Relevance to WIPP: There has been no formal use of expert judgement aimed at systematically identifying alternative plausible assumptions relating to conceptual models, and considering their relative importance in the WIPP PA. Emphasis has however been placed on submitting the iterative PAs to a broad range of formal and informal peer review, and in responding to reviewers'

concerns. It is considered that an iterative approach to PA and external review is a good means of developing confidence in the assessment.

IV. CONCLUSIONS AND RECOMMENDATIONS

Recommendations are provided below concerning scenario development in general, and scenario development for the WIPP PA in particular.

Alternative assumptions and decisions in the modelling process need to be addressed systematically to build confidence in the assessment. In particular, all key assumptions should be systematically compiled and kept under review for each iterative assessment. A documented systematic methodology for this is fundamental to the rational review and acceptance of an assessment.

Comprehensiveness of the scenario development and conceptual modelling activities is an important issue in all programmes. Uncertainty over comprehensiveness can be addressed by development of clear documentation concerning the translation from site and system information to the predictive models used in PA.

Tools - such as relational databases for FEPs and influence diagrams at an appropriate level of detail - are required for documenting and tracking decisions and assumptions made in assessments, through a single assessment phase, and between iterative assessment phases. Even though an international FEP database will be available soon, in-house site-specific databases also will be beneficial. Such in-house databases could serve as a useful tool for communication within the project, as well as with all reviewers and stakeholders in the assessment process.

The need to undertake PAs iteratively and to use the results of these assessments in providing guidance to other project staff is well recognised. These iterative PAs provide an opportunity for ongoing critical interaction between the PA project and its reviewers. Such interaction should be initiated early within a disposal project, as it can be a vital step in building confidence in the quality of the argument used throughout the assessment.

All programmes concerned with the disposal of long-lived radioactive wastes have addressed to a greater or lesser extent the issue of future human actions. An international consensus on the methodologies and principles for quantitative assessment would build confidence in the way in which future human actions are considered in PAs.[22] Such consensus would be of particular value to the WIPP project because of the importance of human intrusion in the PA.

Developing the bases for an assessment is a multidisciplinary task, placing high demands on management and requiring appropriate organisational structures to overcome the tendency for individual experts to focus on the particular problems in their own disciplines. The recommendations outlined here may seem mundane, but review of national assessment programmes shows that they have not yet been fully implemented. Additional effort needs to be applied to improve the documentation and presentation of assessments, but any additional resource requirements will be relatively small in view of the overall costs of waste disposal programmes.

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Trevion II
Washington, DC 20585-0002

US Department of Energy
Office of Environmental Restoration and Waste Management
Attn: S. Schneider, EM-342,
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US Department of Energy (2)
Office of Environment, Safety and Health
Attn: C. Borgstrom, EH-25
R. Pelletier, EH-231
Washington, DC 20585

US Department of Energy (2)
Idaho Operations Office
Fuel Processing and Waste Management Division
785 DOE Place
Idaho Falls, ID 83402

US Environmental Protection Agency (2)
Radiation Protection Programs
Attn: M. Oge
ANR-460
Washington, DC 20460

US Nuclear Regulatory Commission
Division of Waste Management
Attn: H. Marson
Mail Stop 4-H-3
Washington, DC 20555

Boards

Defense Nuclear Facilities Safety Board
Attn: D. Winters
625 Indiana Ave. NW, Suite 700
Washington, DC 20004

Nuclear Waste Technical Review
Board (2)
Attn: Chairman
S.J.S. Parry
1100 Wilson Blvd., Suite 910
Arlington, VA 22209-2297

Advisory Committee on Nuclear Waste
Nuclear Regulatory Commission
Attn: R. Major
7920 Norfolk Ave.
Bethesda, MD 20814

State Agencies

Attorney General of New Mexico
P.O. Drawer 1508
Santa Fe, NM 87504-1508

Environmental Evaluation Group (3)
Attn: Library
7007 Wyoming NE
Suite F-2
Albuquerque, NM 87109

NM Energy, Minerals, and Natural
Resources Department
Attn: Library
2040 S. Pacheco
Santa Fe, NM 87505

NM Environment Department (3)
Secretary of the Environment
Attn: J. Espinosa
1190 St. Francis Drive
Santa Fe, NM 87503-0968

NM Bureau of Mines and Mineral
Resources
Socorro, NM 87801

NM Environment Department
WIPP Project Site
Attn: P. McCasland
PO Box 3090
Carlsbad, NM 88221

Laboratories/Corporations

Battelle Pacific Northwest Laboratories
Attn: R.E. Westerman, MSIN P8-44
Battelle Blvd.
Richland, WA 99352

INTERA, Inc.
Attn: G.A. Freeze
1650 University NE, Suite 300
Albuquerque, NM 87102

INTERA, Inc.
Attn: J.F. Pickens
6850 Austin Center Blvd., Suite 300
Austin, TX 78731

INTERA, Inc.
Attn: W. Stensrud
PO Box 2123
Carlsbad, NM 88221

Los Alamos National Laboratory
Attn: B. Erdal, INC-12
PO Box 1663
Los Alamos, NM 87544

RE/SPEC, Inc.
Attn: W. Coons
4775 Indian School NE, Suite 300
Albuquerque, NM 87110-3927

RE/SPEC, Inc.
Attn: J.L. Ratigan
PO Box 725
Rapid City, SD 57709

Southwest Research Institute (2)
Center for Nuclear Waste Regulatory Analysis
Attn: P.K. Nair
6220 Culebra Road
San Antonio, TX 78228-0510

Tech Reps Inc. (4)
Attn: J. Chapman
C. Crawford
T. Peterson (2)
5000 Marble NE, Suite 222
Albuquerque, NM 87110

Westinghouse Electric Corporation (5)
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C. Cox
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Atlanta, GA 30350

Christopher G. Whipple
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Oakland, CA 94612-3430

Universities

University of New Mexico
Geology Department
Attn: Library
141 Northrop Hall
Albuquerque, NM 87131

University of Washington
College of Ocean & Fishery Sciences
Attn: G.R. Heath
583 Henderson Hall HN-15
Seattle, WA 98195

Libraries

Thomas Brannigan Library
Attn: D. Dresp
106 W. Hadley St.
Las Cruces, NM 88001

Government Publications Department
Zimmerman Library
University of New Mexico
Albuquerque, NM 87131

New Mexico Junior College
Pannell Library
Attn: R. Hill
Lovington Highway
Hobbs, NM 88240

New Mexico State Library
Attn: N. McCallan
325 Don Gaspar
Santa Fe, NM 87503

New Mexico Tech
Martin Speere Memorial Library
Campus Street
Socorro, NM 87810

WIPP Public Reading Room
Carlsbad Public Library
101 S. Halagueno St.
Carlsbad, NM 88220

Foreign Addresses

Studiecentrum Voor Kernenergie
Centre d'Énergie Nucléaire
Attn: A. Bonne
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Atomic Energy of Canada, Ltd.
Whiteshell Laboratories
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Postfach 200 706
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