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The Second Iteration of the Systems Prioritization Method: A Systems Prioritization and Decision-Aiding Tool for the Waste Isolation Pilot Plant

Volume I: Synopsis of Method and Results

N. H. Prindle, F. T. Mendenhall, D. M. Boak, W. Beyeler, D. Rudeen, R. C. Lincoln, K. Trauth, D. R. Anderson, M. G. Marietta, J. C. Helton

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The Second Iteration of the Systems Prioritization Method: A Systems Prioritization and Decision-Aiding Tool for the Waste Isolation Pilot Plant

Volume I: Synopsis of Method and Results

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ABSTRACT

Systems Prioritization Method (SPM) is a decision-aiding tool developed by Sandia National Laboratories for the U.S. Department of Energy Carlsbad Area Office (DOE/CAO) to provide an analytical basis for programmatic decision making for the Waste Isolation Pilot Plant (WIPP). SPM integrates decision-analysis techniques, performance and risk-assessment tools, and advanced information technology. Potential outcomes of proposed activities and combinations of activities (activity sets) are used to calculate a probability of demonstrating compliance (PDC). The results are presented in a decision matrix showing cost, duration, and maximum PDC for all activities in a given cost and duration category. This is the first volume in the series *The Second Iteration of the Systems Prioritization Method: A Systems Prioritization and Decision-Aiding Tool for the Waste Isolation Pilot Plant*, a three-volume report on the second iteration of SPM (SPM-2). SPM-2 analyzed the most viable combinations of scientific investigations, engineered alternatives (EAs), and waste acceptance criteria (WAC) for supporting the final compliance application for WIPP. The scope of SPM-2 was restricted to evaluating the predicted performance of the disposal system with respect to selected portions of the applicable EPA long-term performance regulations, 40 CFR 191.13(a) (radionuclide containment requirements) and 40 CFR 268.6 (hazardous constituent concentration requirements). Stakeholders, oversight groups, interdisciplinary technical staff teams, and DOE/CAO were involved in the development of technical baseline position papers. The SPM-2 baseline was based on existing information on the disposal system and the technical baseline position papers.

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Interdisciplinary technical teams were elicited for information on scientific activities that would increase the PDC. A screening based on viability and relevance resulted in 21 scientific investigations, three EAs, and two WACs. The evaluation of the SPM-2 baseline predicted release of radionuclides in violation of 40 CFR 191.13(a), and indicated compliance with respect to 40 CFR 268.6. In the final analysis, approximately 30% of the activity sets resulted in a PDC of 1.0. These activity sets contained one of two EAs, one that adds a backfill with a pH buffer to control actinide solubility and one that, in addition to backfill, adds a waste form modification (such as clay or grout). These EAs were effective only in combination with one or more scientific investigations. The WAC that would replace steel drums for waste storage with noncorrodible materials resulted in additional expense to the program and a slightly reduced PDC. The other WAC had no discernible impact on the PDC. SPM-2 results indicate that there are numerous cost-effective paths with a high probability of successfully demonstrating compliance based solely on scientific investigations.

ACKNOWLEDGMENTS

SPM was a team effort that required the dedicated commitment of many people. To acknowledge everyone that made essential contributions to this analysis would take pages. However, we would like to gratefully acknowledge the efforts of all the SNL WIPP program staff, including the principal investigators and PA analysts, for defining the SPM-2 baseline and activity sets models, developing the technical input, and performing the SPM-2 calculations. We would like to thank Peter Swift for his careful review and coordination with the SNL WIPP compliance efforts, Mel Marietta for leading the WIPP PA team, and Hong-Nian Jow for his leadership and support in getting the calculations completed. We appreciate the WID staff for supplying the RCRA models and source term, Dr. H. V. Ravinder and Dr. Sul Kassecieh for conducting the elicitations, SAIC for documenting many of the meetings, Tech Reps, Inc., for documentation support, LATA for development of the decision matrix visualization tools and the CD-ROM product, and Informatics Corporation for invaluable scientific and administrative support.

We would also like to thank Paul Davis for having the initial vision of SPM and supporting its use in this application. We want to acknowledge Dori Ellis and Wendell Weart for their strong commitment and personal guidance to the SPM management team. And finally, we wish to thank Bob Bills of DOE/CAO for his contributions both in terms of guidance and support to the SPM effort.

EXECUTIVE SUMMARY

In March 1994, the U.S. Department of Energy Carlsbad Area Office (DOE/CAO) embarked on an effort to design and implement a performance-based decision-aiding tool to provide an analytical basis for planning, prioritizing, and selecting programmatic options for the Waste Isolation Pilot Plant (WIPP). This tool, called Systems Prioritization Method (SPM) defines the most viable combinations of scientific investigations, engineered alternatives (EAs), and waste acceptance criteria (WAC) for supporting the final WIPP compliance application. The scope of SPM is restricted to selected portions of applicable Environmental Protection Agency (EPA) long-term performance regulations. SPM calculates the probabilities of certain sets of activities demonstrating compliance with portions of 40 CFR 191.13(a) (radionuclide containment requirements) and 40 CFR 268.6 (hazardous constituent concentration requirements). SPM provides results in the form of a decision matrix to identify cost-effective programmatic paths with a high probability of successfully demonstrating compliance.

This is Volume 1 of the final report of the second iteration of SPM (SPM-2). With consideration of issues outside the scope of SPM, it is intended for programmatic decision making. The first iteration of SPM (SPM-1), the prototype of SPM, was completed September 1994. It served as a benchmark and a test bed for developing the tools needed for SPM-2. SPM-2 was completed in March 1995.

SPM has eight key steps. They are: the development of a technical baseline (step 1); the specification of the SPM compliance indicator (CI), a binary measure of whether the WIPP disposal system is predicted to succeed or fail in meeting the selected performance requirements (step 2); the evaluation of the baseline CI for the WIPP disposal system using models and data from the technical baseline (step 3); the identification of activities available to the WIPP Project that, if implemented, have the potential to impact the system's CI (step 4); the elicitation of information from the project about what might evolve if specific activities are implemented (potential outcomes) (step 5); the evaluation of the performance of the disposal system using the potential outcomes of the activities and combinations of activities (activity sets) to calculate a probability of demonstrating compliance (PDC) (step 6); the performance of a decision analysis and the creation of the decision matrix (step 7); and the implementation of selected activities (step 8). Steps one through eight are iterated as necessary until the baseline calculations indicate compliance. When the baseline calculation does indicate compliance, the preparation of a formal performance assessment (PA) for compliance can begin.

SPM-2 used technical position papers with the associated involvement of stakeholders, oversight groups, interdisciplinary technical staff teams, and DOE/CAO as a starting point for establishing a baseline. In order to accurately evaluate the value of the activities proposed for the WIPP program, realistic conservatisim was used as the basis for the SPM-2 baseline. The SPM-2 baseline also contains technical positions that require substantiation by side investigations.

Interdisciplinary teams were formed to write the technical position papers and define the SPM-2 baseline. They also provided a major portion of the information on activities considered in SPM-2, and were elicited for the outcomes of those activities. Elicitors external to the WIPP Project worked with these teams to provide a consistent and structured process for eliciting the parameters and models for the activity outcomes and the probabilities of those outcomes. To complete each activity description, incremental cost and duration estimates were provided for each activity. Westinghouse Waste Isolation Division (WID) and DOE/CAO provided material with regard to EAs, WACs, and other programmatic guidance. Potential outcomes for 37 scientific investigations, 18 EAs, and three WACs were elicited. These were screened to 26 discrete activities for the final SPM-2 analysis, which consisted of 21 scientific investigations, three EAs, and two WACs.

The SPM-2 used the existing WIPP PA computer codes, with modifications required by the SPM-2 baseline and the activity sets, to calculate required complementary cumulative distribution functions (CCDFs) for radionuclide releases. The SPM-2 analysis examined over 600,000 possible activity sets. Several of the analyzed activities had no impact on the CI, and were thus removed from the decision matrix. This reduced the number of activity sets to roughly 46,700. Because each activity set had multiple outcomes, the number of CCDFs needed to complete the SPM-2 analysis was approximately 1,300,000. Due to the vast amount of information in the SPM-2 decision matrix, only a very brief overview of some features of the results are presented in this report. The fully-populated decision matrix and visualization tools are contained on a compact disk - read only memory (CD-ROM) designed to assist the user in fully analyzing the results. The CD-ROM allowed DOE/CAO to review all of the SPM-2 information and assisted in understanding the results.

SPM-2 succeeded in providing DOE/CAO with a decision matrix for the WIPP disposal system containing multiple cost-effective paths with a high probability of demonstrating compliance with the selected regulations. Additional benefits to the WIPP Project were realized as a result of SPM-2. Three major benefits that will have far-reaching significance as the WIPP Project moves forward are that: 1) SPM-2 successfully brought the WIPP Project participants, stakeholders, oversight groups, and regulators together to define the relevant issues to be addressed in a compliance application, 2) the SPM-2 effort brought together interdisciplinary teams to fundamentally change the way that scientific information is integrated between experimental programs and WIPP PA analysis, and 3) SPM-2 realized rapid inclusion of new conceptual models and focused streamlining of the calculational methods for WIPP PA.

There are assumptions and uncertainties inherent in SPM-2. Final programmatic decisions should consider the SPM-2 results along with broad technical and compliance issues and existing information from such documents as the 1992 WIPP PA Sensitivity Analysis (WIPP PA, 1993). When available, the results of side investigations should also be considered.

Issues that must be considered when using the SPM-2 results are that: 1) the technical baseline is conservative, for decision-aiding only, and not necessarily an indication of the final

Project Technical Baseline (PTB) that will be used to prepare the WIPP compliance application; 2) SPM-2 results are based on calculations using mean values, and are valid for discriminating between activities intended to shift a mean value for a parameter, but not for discriminating between activities intended to reduce uncertainty about a mean; and 3) some conceptual models called for in the SPM-2 technical baseline were not implemented in the SPM-2 analysis: these are being evaluated in side investigations.

The first observation from SPM-2 results is that, given the assumptions and modeling of the SPM-2 baseline, the baseline analysis indicates a predicted noncompliance with respect to 40 CFR 191.13(a). The SPM-2 baseline analysis did, however, indicate compliance with 40 CFR 268.6. All but a few of the activity sets for SPM-2 also predicted compliance with respect to 40 CFR 268.6. The activity sets that did not indicate compliance included both the SPM-2 baseline seals and the WAC that eliminated the corrodible metal waste drums. This predicted failure to comply with 40 CFR 268.6 is believed to be caused by reduced gas generation that would allow brine to enter the disposal room and travel out of the disposal system through the main shaft seals to the top of the Salado.

Approximately 30% of the SPM-2 activity sets were at 1.0 PDC. These activities are associated with EAs. About 40% of the activity sets were near 0.0 PDC. These activity sets are not likely to lead to a successful demonstration of compliance. The remaining 30% of the activity sets were scattered between 0.0 and 1.0 PDC.

Note that the EAs and WACs were assumed to be optimally effective, and were assigned a 100% probability of yielding the desired performance. The EAs that have a PDC near 1.0 were those that add a backfill with a pH buffer to control actinide solubility, and those that add an engineered backfill (such as clay) in combination with a waste form modification. These EAs by themselves had a PDC of 0.0, and it is only in combination with other activities that they become effective. A third EA, passive markers, is also ineffective without the support of experimental activities.

SPM-2 analyzed two WACs. WAC-1 replaces the steel drums used to store the waste with noncorrodible materials. This WAC resulted in additional expense to the program and a slightly reduced PDC. The implication is that some generated gas may be desirable. However, this conclusion may be premature until an outstanding issue relating to the impact of stratigraphic dip is resolved by side investigations. Preliminary examination indicates that WAC-2, which eliminates all high-molecular weight organic compounds (HMWOCs) (such as soils) from the waste, has no discernible impact on the PDC.

Because the EAs generated a series of results with PDCs near 1.0, they tend to mask the effects of the scientific program. To determine the impact of the scientific program, the EAs and WACs were filtered out of the analysis. The results are shown in the 3-D bar chart in Figure ES-1. This figure shows the scientific investigations in terms of cost increment, duration, and maximum PDC for a given cost/duration category. The general trend is that the PDC tends to increase with increasing cost or increasing duration. Another observation is that there are

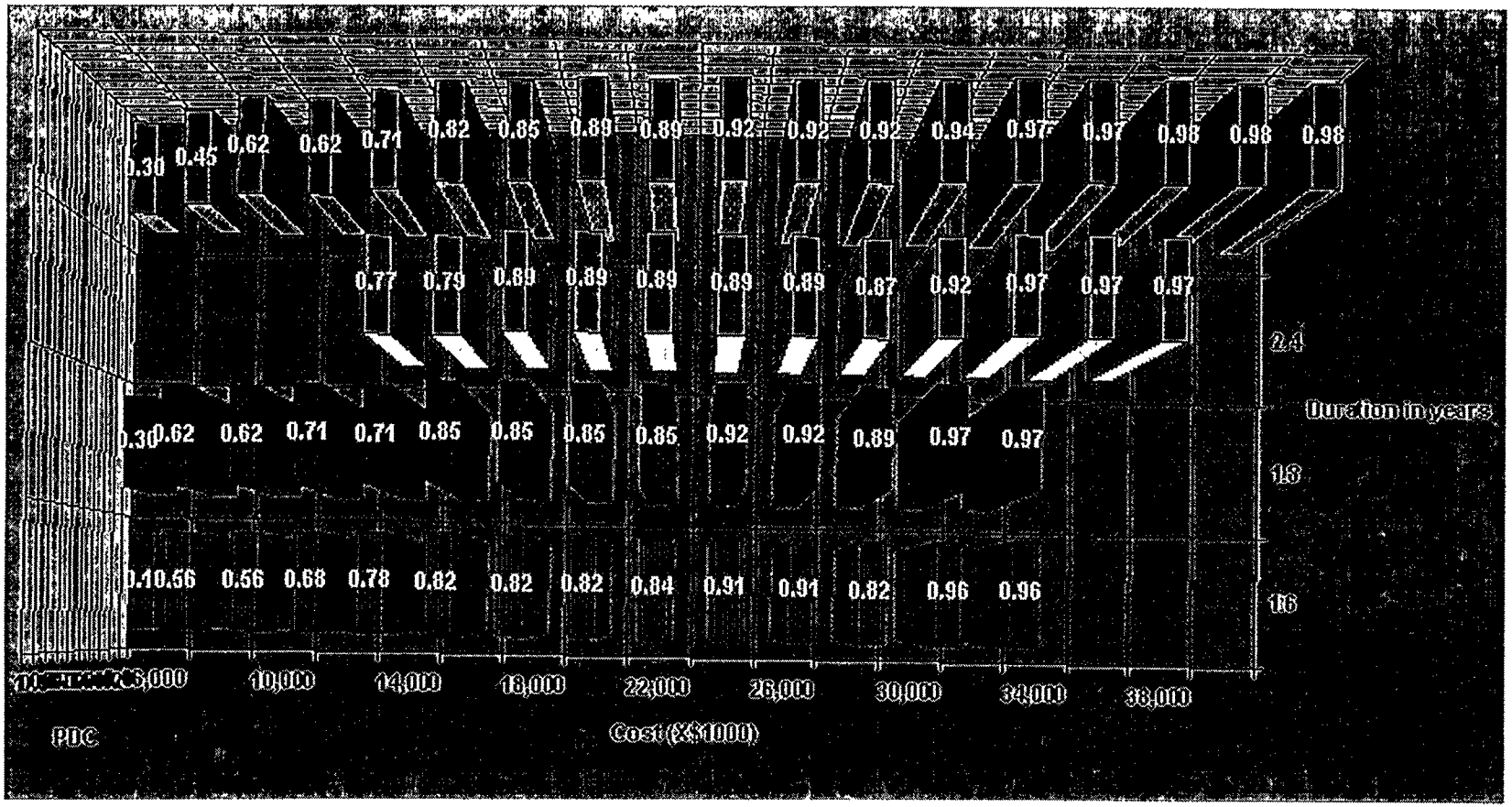

Figure ES-1. SPM-2 decision matrix: 3-D bar chart for scientific investigations (PDC versus cost and duration).

numerous cost-effective paths with a high probability of demonstrating compliance. Further analyses of the decision matrix (such as statistical regression analyses), in conjunction with an understanding of the activity sets, will yield more details of the cost/benefit relationship for the elements of the scientific program inherent in these SPM-2 results.

Although the results have yet to be fully analyzed, and need to be interpreted with consideration of the assumptions and uncertainties, it is clear that the SPM-2 decision matrix contains valuable information for identifying:

1) activity sets necessary for a given PDC,
2) activity sets that give the maximum PDC, and
3) activities that have minimal impact on the PDC.

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ACRONYMS

CAO	Carlsbad Area Office
CCDF	Complementary Cumulative Distribution Function
CD-ROM	Compact Disk-Read Only Memory
CH-TRU	Contact-Handled Transuranic (Waste)
CI	Compliance Indicator
DDP	Disposal Decision Plan
DOE	U.S. Department of Energy
DRZ	Disturbed Rock Zone
EA	Engineered Alternative
EATF	Engineered Alternatives Task Force
EMR	Elicitation Meeting Record
EPP	Experimental Program Plan
EPA	Environmental Protection Agency
FCCA	Final Compliance Certification Application
FEP	Features, Events, and Processes
HMWOC	High-Molecular Weight Organic Compounds
LHS	Latin Hypercube Sampling
MD	Multimechanism Deformation
MDCF	Multimechanism Deformation Coupled Fracture
PA	Performance Assessment
PDC	Probability of Demonstrating Compliance
PDE	Partial Differential Equation
PI	Principal Investigator
PTB	Project Technical Baseline
QA	Quality Assurance
RCRA	Resource Conservation and Recovery Act
RH-TRU	Remotely Handled Transuranic Waste
RPM	Reaction-Path gas generation model
SNL	Sandia National Laboratories
SPM	Systems Prioritization Method
SPM-1	Systems Prioritization Method - Iteration 1
SPM-2	Systems Prioritization Method - Iteration 2
SSA	Specific Surface Area
TEC	Total Estimated Cost
TRU	Transuranic Waste
TZ	Transition Zone
VOC	Volatile Organic Compound
WAC	Waste Acceptance Criteria
WID	Westinghouse Waste Isolation Division
WIPP	Waste Isolation Pilot Plant

CODES

BRAGFLO	BRine And Gas FLOw
NUTS	NUclide Transport System

1. INTRODUCTION

The Systems Prioritization Method (SPM) is a decision-aiding tool developed by Sandia National Laboratories (SNL) for the U.S. Department of Energy Carlsbad Area Office (DOE/CAO). SPM provides an analytical basis for supporting programmatic decisions for the Waste Isolation Pilot Plant (WIPP) to meet selected portions of the applicable Environmental Protection Agency (EPA) long-term performance regulations (40 CFR 191.13(a) and 40 CFR 268.6). The first iteration of SPM (SPM-1), the prototype for SPM, was completed in September 1994. It served as a benchmark and a test bed for developing the tools needed for the second iteration of SPM (SPM-2). SPM-2, completed in March 1995, is intended for programmatic decision making. This is Volume I of the SPM-2 final report.

SPM was designed to assist DOE/CAO in identifying which activities to implement to support the WIPP compliance process. SPM generates a decision matrix that shows the probability of sets of programmatic options of a specified cost and duration that, if implemented, will support compliance with selected EPA long-term performance regulations (referred to as the probability of demonstrating compliance (PDC)). In addition, SPM generates a technical baseline for WIPP by using interdisciplinary teams with broad technical and stakeholder input. Stakeholder comments on the SPM-2 baseline received on or before January 9, 1995 were considered. All those that were applicable were incorporated into the SPM baseline (see A. Reiser, "Examples of Actions in Response to Stakeholder Comments," Sandia National Laboratories memorandum to N. H. Prindle, March 10, 1995, in Appendix C).

The programmatic options considered in SPM are those activities that could affect selected quantitative aspects of regulatory compliance, such as scientific investigations, engineered alternatives (EAs), and policy decisions, e.g., defining certain waste acceptance criteria (WAC). For each discrete set of programmatic options considered, the SPM decision matrix shows the functional relationship between the PDC, incremental costs, and duration.

SPM is not a detailed scheduling tool, and it should not be confused with compliance calculations. It provides the ability to technically evaluate the benefits of tradeoffs between credible combinations of programmatic options in a process that involves stakeholders, WIPP managers, and the technical community. Assumptions, simplifications, and resulting uncertainties are an inherent part of any analysis, and are particularly relevant to computer modeling of a complex system such as WIPP. Decisions based on SPM should carefully consider the limitations and assumptions of the models and parameters used in the analysis and the programmatic constraints under which the analysis was conducted.

The SPM-2 final report consists of three volumes. Section 2 of Volume I presents the overview of SPM and the evolution of SPM-2. Section 3 of Volume I describes how the SPM-2 input was developed. Section 4 provides a synopsis of the SPM-2 decision analysis. Section 5 discusses the assumptions, simplifications, and uncertainties of SPM-2. The results of the SPM-2 decision analysis are discussed in Section 6, and Section 7 presents conclusions drawn from the

SPM process. Volume II provides a technical summary of the SPM-2 baseline and the SPM-2 activities. Volume III presents the results of the sensitivity and uncertainty analyses performed in the final evaluation of the SPM-2 results to support programmatic recommendations to DOE/CAO.

2. OVERVIEW OF SPM AND SPM-2

The SPM uses existing WIPP Performance Assessment (PA) computational tools, or modifications of these tools, to estimate the WIPP disposal system performance as a basis for programmatic decisions. An overview of SPM is illustrated in Figure 2-1. The steps of SPM are as follows:

Step 1. The SPM technical baseline was defined by WIPP Project participants (SNL, Westinghouse Waste Isolation Division (WID), and DOE/CAO) using existing technical knowledge on the WIPP disposal system. It reflects input from DOE/CAO, the National Academy of Sciences (NAS), and stakeholders. For SPM-2, stakeholder viewpoints were obtained in the form of comments on technical baseline position papers prepared by the WIPP Project scientists (see Section 3.3) and on the SPM-2 baseline itself. The SPM-2 baseline incorporates some technical positions that require corroboration through side investigations, discussed in Section 3.4.1 and listed in Appendix A. With the exception of these side investigations, all technical positions incorporated into the baseline are based on existing data, knowledge, and completed, documented work. As such, they are more conservative than previous PA analyses of WIPP performance, which tested models and codes, performed sensitivity studies, and provided estimates of compliance—but did not establish a baseline.

Step 2. A Compliance Indicator (CI) is used in SPM to provide a binary measure of whether the WIPP disposal system is predicted to succeed or fail in meeting selected post-closure performance requirements in 40 CFR 191.13(a) and 40 CFR 268.6. Compliance is indicated when the CI equals the value 1. If the CI equals 0, compliance is not indicated. If the SPM baseline CI shows compliance with the quantitative standards, the WIPP Project can begin preparing a formal PA to support a WIPP compliance application. If the CI does not indicate compliance, the WIPP Project participants will identify activities that, if implemented, have the potential to impact the system's CI. These activities may include additional scientific investigations, design changes to the facility, or changes to the waste form and WAC.

Step 3. Step 3 models and analyzes the performance of the SPM baseline using existing or modified WIPP methods and codes. If the CI shows compliance with quantitative standards (CI = 1), the WIPP Project can begin preparation for a formal PA to support a compliance application. If the CI = 0, the process proceeds to step 4.

Step 4. Step 4 identifies activities available to the WIPP Project that, if implemented, have the potential to impact the system's CI. The basis for identifying activities includes the current state of knowledge gained from field and laboratory investigations, sensitivity studies conducted by PA, and requests for more information from project scientists. Activities may include additional experiments, design changes to the facility, or changes to the WAC.

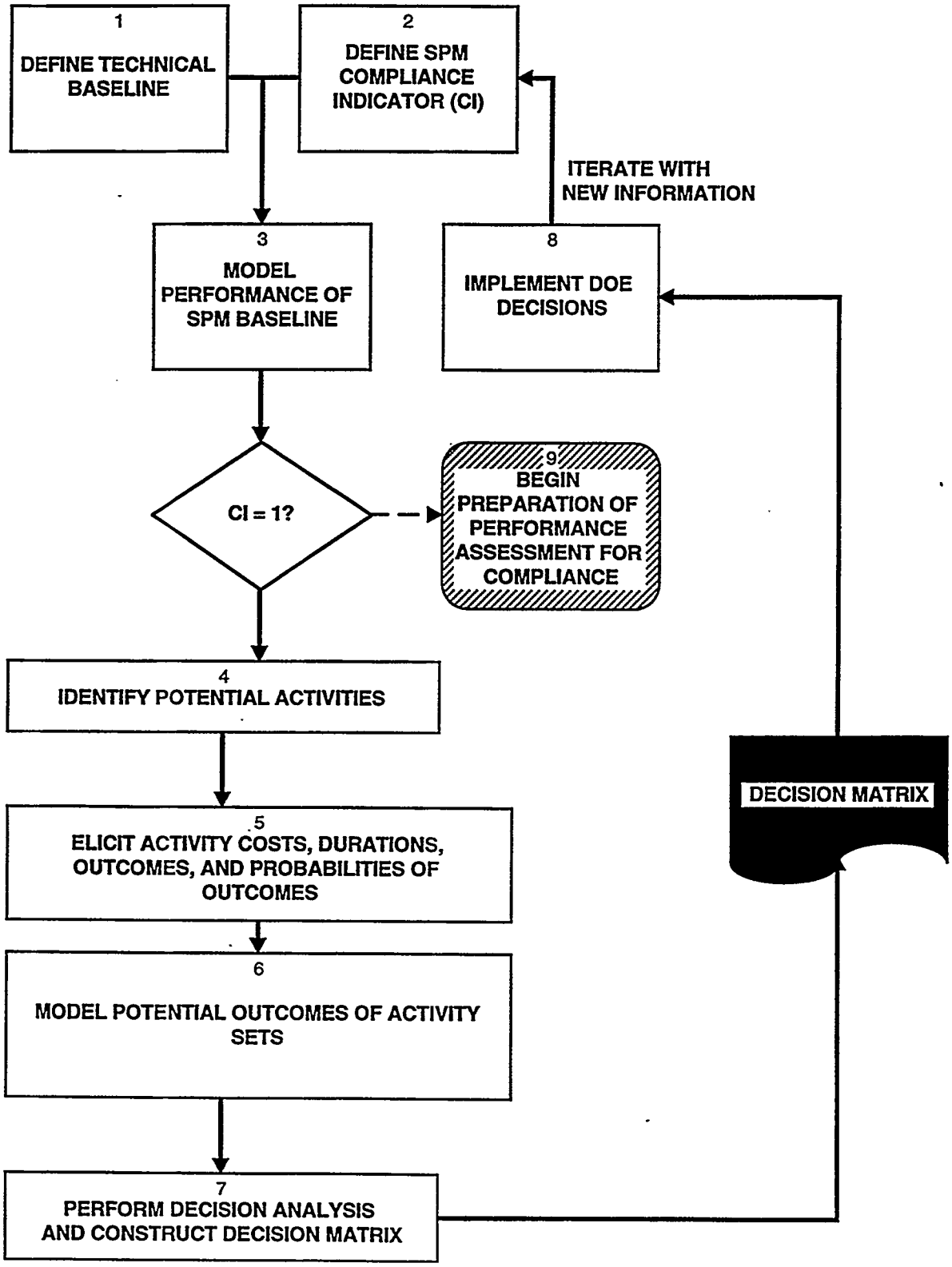

Figure 2-1. Overview of SPM.

Step 5. For each activity, predictions of potential outcomes are elicited from the project participants. These elicitations include identifying what new information or changes to existing information might be gained if specific activities are implemented. Every attempt is made by the elicitors and the project scientist to ensure the predictions are as realistic and unbiased as possible. These predictions of potential outcomes, hereafter referred to as "potential outcomes," are essentially informed estimates that are provided before the activity has actually been implemented.

Step 6. Potential outcomes of activities are modeled using WIPP codes and data. For SPM-2, this means calculating Complementary Cumulative Distribution Functions (CCDFs) for radionuclide releases along the possible pathways, and estimating potential releases of regulated Volatile Organic Compounds (VOCs) and heavy metals. A PDC is calculated and analyzed from these results for combinations of potential outcomes of activities and the probabilities of their occurrence. These are compiled into PDCs for activity sets.

Step 7. A decision matrix is constructed that includes the PDC, incremental cost, and duration for all activity sets. The decision matrix condenses the analysis of thousands of combinations of activity outcomes and displays those activity set results that lead to the highest PDC within given cost and duration categories. The fully populated decision matrix and visualization tools are contained on a compact disk - read only memory (CD-ROM) designed to assist the user in understanding the SPM-2 process and analyzing the results. The design specifications for the CD-ROM capabilities are given in Appendix D.

Step 8. Using the information presented in the decision matrix and other programmatic factors, the DOE/CAO decides which activities to implement. This decision is implemented by the WIPP Project, and the baseline is updated after the activities have been completed.

Step 9. When the baseline calculations indicate that the CI equals one, a full suite of formal PA calculations is prepared for a compliance application with all necessary Quality Assurance (QA) requirements. The formal PA calculations will follow a more prescriptive process than SPM calculations because they will adhere to all regulatory QA requirements applicable to the WIPP compliance application. In particular, all calculations will be performed to QA Level "A."

2.1 SPM-2 Background

2.1.1 Development of SPM-1

The SPM prototype, SPM-1, was completed September 30, 1994. The purposes of SPM-1 were to test the feasibility of SPM and to provide a design basis for carrying out SPM-2. Where SPM-1 was a prototype, and not to be used for decision-making, SPM-2 results may be used as the basis for programmatic decisions. SPM-1 proved to be a useful testing ground that resulted in important lessons learned. SPM-2 design and implementation addressed many of these lessons learned, as described below.

Important lessons learned from SPM-1 were: the need for consistency between costs, durations, and potential outcomes of activities; the need to confirm embedded assumptions; the need for a structured elicitation process; computational efficiency (including code automation); the need for post-closure design information and configuration control; and the need for decision analysis post-processing. The approaches used in SPM-2 to address each of these issues are discussed below. In addition, SPM-1 showed that a less extreme and more realistic baseline was necessary in order to meet the objective of showing meaningful discrimination between program options to DOE. The management review of the SPM-2 technical baseline operated upon this lesson learned as described in Section 3.4.

2.1.1.1 CONSISTENCY BETWEEN COST, DURATION, AND ACTIVITY OUTCOMES

In SPM-1, there was neither sufficient nor consistent information on activity cost and duration. At the time the activity outcomes were defined, the planning basis for the activities was the prevalidated SNL five-year plan. At the time of inputting cost and duration information and building the decision matrix, the WIPP Project was directed to bring all cost and duration scenarios into alignment with the WIPP Disposal Decision Plan (DDP). This resulted in some discrepancies between the assumption basis for the activity outcomes and the assumption basis for the costs and durations entered into the decision matrix for those activities.

SPM-2 adhered to the cost and duration assumption basis described in Section 3.5.2. In principle, neither cost nor duration were allowed to constrain the information elicited for the activities. Many of the activities that were planned as part of the WIPP Project prior to SPM-2 are consistent with the DDP schedule. However, the SPM-2 decision matrix (see Section 6) does show the duration of some activities extending beyond the final decision date on the current WIPP DDP.

SPM evaluates the utility of three activity types: scientific investigations, EAs, and WACs. In SPM-1, only scientific investigation costs were input to the decision matrix. EAs and WACs were implemented on a zero-cost basis giving a skewed representation of their utility. This issue was resolved in SPM-2 by using the three cost categories described in Section 3.5.2: WIPP, WAC, and Combined.

2.1.1.2 EMBEDDED ASSUMPTIONS

SPM is not designed to test or validate assumptions embedded in the conceptual or mathematical models. SPM shows the utility of only those activities that provide new information resulting in changes to baseline parameters of models. For example, the utility of some Salado activities evaluated in SPM-1 were calculated to be zero because the outcomes of the activities did not change the parameters or models in the baseline; they were intended to confirm baseline assumptions.

In SPM-2, all activity outcomes changed either models or parameter distributions. An example of an activity excluded from the SPM-2 analysis because its potential outcome was to confirm, not change, model assumptions, is the Room Q activity. The purpose of the Room Q activity is to confirm existing flow representations. Other confirmatory evaluations being studied as part of the SPM-2 side investigations are described in Section 3.4.2.

2.1.1.3 ELICITATION PROCESS

In the course of completing SPM-1, the need for a structured elicitation process was recognized. The SPM-2 elicitation process was designed to involve principal investigators (PIs), allow necessary time, set and follow specific guidelines, and employ trained elicitors familiar with the concepts of probability elicitations and bias in judgment. The elicitation process for SPM-2, described in Section 3.5.1, adhered as closely to these objectives as was feasible.

2.1.1.4 COMPUTATIONAL NEEDS

SPM-1 showed that the computational needs for SPM-2 would require streamlining the calculation procedures. The streamlining done for SPM-2 advanced the ability of the WIPP Project to meet the required performance-related deliverables for the DDP. Several modifications were developed for generating the CCDFs, implementing conceptual models, interpolating of performance-related results, and performing decision analysis. The additional WIPP PA computational capabilities that were developed are summarized in Section 6.3. The additional decision analysis post-processing capabilities that were developed appear in an executable form on the SPM-2 CD-ROM product.

2.1.1.5 POST-CLOSURE DESIGN NEEDS

Post-closure design needs were highlighted by SPM-1. In response, DOE/CAO guidance for SPM-2 specified:

- the soil volume to use for calculating the hazardous constituent concentrations for compliance with 40 CFR 268.6, which implements the requirements of the Resource Conservation and Recovery Act (RCRA);
- the reference for RCRA soil-based standards and the RCRA source term;
- that no addition to metals or cellulosics will be made in the waste panels;
- that all underground areas other than panels will be rockbolted;
- a design basis of 6.2 million cubic feet of waste;
- a design basis of no backfill in the SPM-2 baseline; and
- a steel cased salt plug for remotely handled transuranic waste (RH-TRU).

2.1.1.6 CONFIGURATION MANAGEMENT AND INFORMATION FLOW

When the configuration management and information flow needs for SPM-2 were identified, it was anticipated that codes would be run on a variety of computer platforms. SPM-1 had required the use of multiple operating systems (UNIX, VMS) and multiple platforms (SUN Workstations, CRAY, PARAGON, ALPHAs, and HP Workstations). In actuality, the need for configuration management across different platforms was not an issue for SPM-2.

2.1.1.7 DECISION ANALYSIS POST-PROCESSING CAPABILITIES

Significant effort went into developing decision analysis post-processing capabilities for SPM-2 as a result of the lessons learned in SPM-1. The final decision matrix, available in fully executable form on a CD-ROM, allows the user to explore the decision matrix. Considerable effort was made to ensure that the final product was user-friendly and would enable the stakeholders and regulators to fully investigate the SPM-2 process and results. The design specifications for the SPM-2 CD-ROM appear in Appendix D.

2.1.2 Relation of SPM-2 to the WIPP Compliance Strategy

The goal of SPM-2 is to provide a thorough and systematic analysis of the programmatic options available to DOE/CAO with respect to their contribution to a demonstration of compliance of the WIPP facility with selected regulations. The results of SPM-2 are to be used to guide DOE/CAO decisions, but are not appropriate for use in a WIPP compliance application.

The results of the 1992 WIPP PA showed the sensitivity of the long-term performance measures to parameters based on best estimates of data and models at that time. The Final Compliance Certification Application (FCCA) for WIPP will use data and models from the WIPP Project Technical Baseline (PTB). In contrast, the SPM-2 technical baseline, developed in the interim for the purpose of guiding WIPP programmatic decisions, was based on existing technical knowledge of the WIPP disposal system. The actual results of activities that are implemented as a result of SPM-2 are expected to be incorporated into PTB models and data to be used to prepare the FCCA.

3. INPUT TO SPM-2

This section shows how the input to SPM-2 was developed. Sections 3.1 through 3.5 discuss the processes that were used to obtain this input. Detailed information on the conceptual models, input parameters, and activity cost and duration information used in SPM-2 can be found in Volume II of this report.

3.1 Programmatic Guidance

The SPM-2 analysis was based on the following guidance from DOE/CAO (M. H. McFadden, "Systems Prioritization Method Information Needs and Product Requirements," U.S. Department of Energy memorandum to Richard Lincoln, December 19, 1994):

- "Assume no backfill for the baseline."
- "Average the soil concentration over the thickness of the marker beds and the cross sectional area of the shaft at the top of the Salado."
- "Assume no hazardous constituents other than waste will be in the underground."
- "Assume for the Remote-Handled Waste that a steel cased salt plug will be used."
- "Use the drilling frequency and time of drilling (random in time and space) to determine if E1E2 *occurs or not*, and [u]se 25 boreholes per square kilometer per 10,000 years. All other parameters will be as from 40 CFR 191."

In addition, DOE/CAO directed that SPM-2 should:

- Address 40 CFR 191.13(a) and 40 CFR 268.6, but not 40 CFR 194.
- Use source term information for heavy metals from the November 1994 release of the *Waste Isolation Pilot Plant Transuranic Waste Baseline Inventory Report* (U.S. DOE, 1995) as the inventory for SPM-2.

As the *Waste Isolation Pilot Plant Transuranic Waste Baseline Inventory Report* was not yet released at the time the SPM-2 analysis began, SPM-2 used information in P. Drez, "Waste Material Parameter and Radionuclide Inventories for SPM-2 Calculations Derived from Draft WTWBIR Rev. 1 and IDB Rev. 10 Databases," Drez Environmental Associates memorandum to File, January 3, 1995, for the waste inventory (see Appendix C). The source term for each VOC is the initial headspace gas concentration of the VOC in the repository, as documented in M. Fewell and P. Sanchez, "Soil-Based VOC and Semi-VOC Concentration in the Gas Phase for SPM-2," Sandia National Laboratories memorandum to F. Mendenhall and N. Prindle, March 29, 1995 (see Appendix C).

3.2 Performance Measures (Regulatory Requirements)

The scope of SPM-2 was to address the post-closure period of WIPP. The operational period of the WIPP was not considered. The performance measures addressed were the radionuclide containment requirements of 40 CFR 191.13(a), and the hazardous constituent concentration requirements of 40 CFR 268.6 with health-based levels as defined in 55 F.R. 30865 through 55 F.R. 30868.

Radionuclide Containment Performance Measure. Agreement with the radionuclide containment regulatory requirements was assumed when the mean CCDF met the regulatory requirements of 40 CFR §191.13(a), i.e., the mean CCDF did not exceed the values specified in the regulation.

Hazardous Constituent Concentration Performance Measure. Agreement with post-closure hazardous constituent concentration regulatory requirements was assumed when the hazardous constituent concentration at the unit boundary was less than the heath-based level for soil (as defined in 55 F.R. 30865 through 55 F.R. 30868) for each hazardous constituent. Hazardous constituents transported to the unit boundary by gas were compared with the health-based levels.

For SPM-2, bounding calculations showed that for the VOC source term model used, there would be no violations even in the room, so that actual calculations for these hazardous constituent concentrations were not done. For purposes of SPM-2, any brine leaving the disposal room and reaching the unit boundary was assumed to cause a violation with regard to heavy metals. This very conservative assumption is based on the lack of detailed information on the solubility for heavy metals in repository brine.

3.3 The Position Paper Process and Stakeholder Interaction

In June 1994, the WIPP Project identified a need to develop a complete set of WIPP technical positions, conceptual models, computer models, and parameter ranges and distributions for the draft compliance application. An effort was initiated to consolidate these efforts by creating a single source of information for each key technical area for various WIPP Project needs. The key areas were defined as: Seals, Rock Mechanics, Gas Generation, Disposal Room Actinide Source Term, Salado, Non-Salado, Scenario Screening, and Performance Assessment. The information would be contained in a technical position paper for each key area. The information was considered important enough that the DOE/CAO asked the WIPP stakeholders to review and comment on the technical position papers.

Early in October 1994, it became evident that the position paper process was not going to provide timely input to SPM-2, nor was there enough detail in the position papers for the SPM-2 models. A simultaneous process that would meet the information needs for the SPM-2 baseline was created. In this process, every attempt was made to use the most current information from

the position papers, and to incorporate stakeholder concerns communicated to DOE/CAO. The information developed for the SPM-2 baseline was incorporated into the technical position papers. The SPM-2 baseline is summarized in Section 2 of Volume II of this report.

3.4 SPM-2 Baseline Development and Review

3.4.1 SPM-2 Technical Baseline

In an October 17, 1994, Sandia National Laboratories memorandum to Distribution, titled "Systems Prioritization Method - Iteration 2 (SPM-2) Baseline and Activity Set Outcome Elicitation," W. Weart defined the initiation of the SPM-2 baseline development process. In this memorandum, the scope and objectives of the SPM-2 baseline were defined:

"With the completion of Systems Prioritization Method - Iteration 1 (SPM-1) analysis and documentation, Sandia is now concentrating on the SPM-2 work effort. I would like to provide my personal emphasis that the SPM-2 process will be viewed as a direct reflection on Sandia's credibility and our ability to carry out this intensive, potentially Project-directing effort, on a very difficult time scale. Our customer and the stakeholders who have contributed to this process will be examining the product and the assumptions in detail. The WIPP Project has no more important task in the next few months than assuring the SPM process gets the required support of all parties and that the job is done to the best of our ability. One of the keys to our credibility will be to assure that we are neither too optimistic nor too conservative as we establish the baseline and contribute to the elicitations. We must be able to provide sound arguments for our positions but that does not mean we must be able to disprove all alternatives if the preponderance of evidence favors our position <u>or</u> if the position is unequivocally conservative when adequate information is unavailable."

A series of meetings were held in October and November 1994 with members of the technical position paper teams, WIPP managers, and members of the WIPP PA Department to define the SPM-2 baseline models, parameters, and parameter distributions and ranges. In parallel, computer models were modified or developed as new features were identified for the SPM-2 calculations. SPM-2 baseline meetings with SNL technical staff were completed, and a complete suite of SPM-2 baseline models was presented to the SNL WIPP management team for review. The basis for the management review is contained in the memoranda, W. Weart, "Direction for Completion of the Programmatic Review of the SPM-2 Baseline and Activities," Sandia National Laboratories memorandum to SNL WIPP Managers, December 14, 1995, and W. Weart, "Process for SNL WIPP Programmatic Review of SPM-2 Baseline and Activities," Sandia National Laboratories memorandum to SNL WIPP Managers and Principal Investigators, December 1, 1995 (see Appendix C).

The management review raised concerns about the appropriate level of conservatism in the baseline. SNL WIPP management decided that the project could take credit for issues that it

understood, but that had not yet been analyzed completely or documented, as long as a side investigation could be defined that would clearly demonstrate the technical justification for the position taken. Since the objective of SPM-2 is to determine which activities have the most value with respect to achieving compliance, the conduct of side investigations was agreed to by DOE/CAO in order to more clearly differentiate between a need for new knowledge and the documentation of existing knowledge. A detailed discussion of side investigations can be found in Section 3.4.2.

Concerns raised in the management review process resulted in some changes to the preliminary SPM-2 baseline models. These changes were incorporated, and the SPM-2 baseline models were frozen on January 11, 1995. In the future, the PTB will be based on refinements or changes to the SPM-2 baseline resulting from additional information about system behavior from new sensitivity analysis, calculations focused on addressing specific technical and compliance issues, and new information generated as a result of activities implemented after SPM-2. A detailed description of the SPM-2 baseline can be found in Volume II of this report.

All the models requested for the SPM-2 technical baseline described in Volume II were incorporated into codes for SPM-2. However, during systems testing, some of the models did not function as expected. Section 6.3 contains a list of the models that were called for in the SPM-2 technical baseline, but that could not be implemented in a timely fashion. Problematic codes were removed, and resolution of the associated technical issues was added to the list of side investigations needed to support the SPM-2 baseline, as discussed below. The final model implementation of the SPM-2 technical baseline, the SPM-2 calculational baseline, is presented in Section 4 of Volume II.

3.4.2 Side Investigations

Side investigations are supplementary and confirmatory evaluations required to 1) fully address certain technical positions taken in the SPM-2 baseline, 2) investigate the impact of potential activities where the cost and expense of carrying an activity outcome all the way through the formal SPM decision process was not warranted, and 3) investigate the impact of the calculational models chosen for SPM-2, such as two-dimensional versus three-dimensional models for both baseline and activity outcomes. These side investigations include certain scenario screening, literature searches, analysis of existing data, bounding calculations, and computer modeling. The predicted outcomes of the side investigations were used in SPM-2 calculations because of the high probability of completing the work as expected. There remains some nonzero probability that the outcome of a given evaluation will be significantly different than the predicted outcome.

One example of a baseline technical position that presumed the results of a side investigation is isothermal fluid flow. Thermally driven flow could have been included in computer codes for SPM-2 calculations, but the additional uncertainty was already considered to be captured within the uncertainties in calculated brine inflow values (Nowak et al., 1988). Isothermal flow was

therefore an embedded technical assumption in both the SPM-2 baseline and all SPM-2 activities. Work remains to validate this technical position.

SPM is a decision-aiding tool designed to assist DOE/CAO in planning, prioritizing, and selecting programmatic options for the WIPP Project. Planning methods, by their very nature, must find ways to make useful predictions in light of uncertainties introduced by incomplete information and necessary assumptions and simplifications to make problems tractable. It was not appropriate to incorporate all outstanding uncertainties directly into SPM-2 calculations. Some were better dealt with as side investigations or in scenario screening studies. For example, stakeholders have raised numerous questions about the formations surrounding the Salado, including the effects of shallow drilling, pumping, potash mines, time-varying rock properties, fluid injection, brine density effects, and climate change. Non-Salado issues are being addressed through regional 3-D modeling as part of scenario screening. The side investigations have been incorporated into the scenario screening endeavor to eliminate duplication of efforts and to bring in new concerns to the scenario screening effort. This work will be completed prior to submitting the FCCA. Therefore, these studies, unlike the SPM-2 activities, were not considered programmatic options.

Most side investigations to support the SPM-2 technical baseline had not been completed by March 31, 1995, when the final SPM-2 product was delivered to DOE/CAO. Side investigations will be prioritized and conducted based on their potential impact on the compliance application. The programmatic impact of side investigation results will be assessed as the work is completed. If results of a side investigation do not support the SPM-2 baseline, actions will be defined to address the results, and the DOE/CAO will be informed of potential programmatic impacts. See Appendix A for SPM-2 side investigations that are necessary to support the SPM-2 technical baseline and scenario screening.

3.4.3 SPM-2 Calculational Baseline

Modeling the SPM-2 technical baseline required implementing computer codes using a calculational baseline. This required modifying existing WIPP PA codes. Many of these modifications were realized within the time frame of SPM-2, but some were not. Some conceptual models that could not be incorporated into the SPM-2 calculational baseline were:

- mechanical effects of gas generation on the Salado Formation;
- the effects of stratigraphic dip on the repository; and
- dynamic dependence of threshold displacement pressure with permeability in anhydrite interbeds.

The impacts of not including these conceptual models on SPM-2 results cannot be determined at this time, and, therefore, these models will also be studied as side investigations (see

Appendix A for side investigations necessary to reconcile the calculational baseline with the technical baseline for SPM-2).

3.5 SPM-2 Activity Development and Review

The development of activities for evaluation in the SPM-2 decision analysis followed directly upon the development of the SPM-2 baseline. Activities were defined that would reduce the uncertainties that existed in the baseline. The identification of activities began during the development of the baseline and continued during the elicitation sessions.

The SPM-2 activities for scientific investigations were defined using the elicitation process described in Section 3.5.1. The EA and WAC input, described in Section 3.5.2, was derived from WIPP Project documents and from the DOE National Transuranic Waste Program. Section 3.5.3 describes the formation of activity sets and derivation of activity set outcomes. The basis for the cost and duration for the activity sets is described in Section 3.5.4.

3.5.1 SPM-2 Elicitation Process

The purpose of the SPM-2 elicitation effort was to provide a consistent and structured process for collecting information from the appropriate WIPP staff on: 1) scientific investigation activities to undertake to support a showing of compliance with selected regulations, 2) predictions of the potential outcomes of those activities, 3) the basis for belief in those outcomes, and 4) the probability of their success or failure. This information-gathering effort took advantage, to the extent possible, of a formal expert elicitation process (see, for example, Hora and Iman, 1989). Although it did not technically follow a formal expert elicitation process, a number of important benefits were realized from the SPM-2 elicitation.

The major benefits included: 1) bringing together an interdisciplinary team of technical staff for focused technical discussions on issues important to the WIPP PA (e.g., appropriate conceptual models, the representation of conceptual models in PA computational models, and representation of the experimental data), 2) the participation of outside elicitors to guide the discussions and ask questions without preconceived ideas or expectations, 3) the documentation of elicited information, and 4) providing a forum for raising and addressing questions about the basis upon which the judgments for SPM-2 should be made, and upon which a compliance application should eventually be based.

Some technical positions identified during the elicitation process could not be incorporated into SPM-2 calculations. These positions will be addressed in the side investigations discussed previously.

3.5.1.1 PREPARATION FOR THE ELICITATIONS

Preparation for the elicitation involved assembling the appropriate staff members and elicitors, developing issues to be addressed, and preparing the participants for the elicitation process. DOE/CAO directed that, for the purposes of the SPM-2, only individuals within the WIPP Project would be elicited for the activity outcome information. This included staff members responsible for each of the particular technical areas as they were deemed the most familiar with the experiments currently planned and those currently in place. In addition, the WIPP PA team leader ensured that the appropriate PA staff participated in the elicitation sessions to provide input on how the elicited information could be modeled. The participants were provided with guidance memos about the elicitation process, the objectives, and their roles in the process. (S. Goldstein, N. Prindle, K. Trauth, "Guidance on the SPM-2 Elicitation Process," Sandia National Laboratories memorandum to Distribution, November 3, 1994).

3.5.1.2 CONDUCT OF THE ELICITATIONS

Three elicitors, professors from the University of New Mexico, Albuquerque, New Mexico, and the University of Hawaii, at Hilo, Hawaii, conducted the elicitations. The number of technical areas required using multiple elicitors. They were trained in the decision analysis process to work with experts to develop the required information in each technical area, while recognizing and attempting to reduce bias. In an effort to provide consistency in the elicitation, the first two sessions were conducted by one elicitor (who had considerable experience with the WIPP Project), with the other two elicitors present as observers. The elicitors also met with PA staff for background information.

The elicitation sessions consisted of two parts: 1) defining activities, and 2) developing the activity outcomes and associated probabilities. A minimum of two potential outcomes were elicited for each activity. An interdisciplinary team of experimentalists and analysts were present for discussions of conceptual models and data uncertainties and their implementation in the SPM-2 calculations, although the required information was actually elicited from the experimental staff. It was not uncommon for several staff members to consult on an activity because of the complexity of the technical areas. The integration among technical staff was necessary to coordinate experimental results and modeling methods and provide confidence in the results. This integration was key to SPM-2. SPM team members were also present at the elicitation sessions to answer questions on programmatic issues. Recorders were present to take notes of the discussion, which they used to prepare meeting records.

3.5.1.3 PROCESSING THE ELICITED INFORMATION

Each elicitation was designed to occur in a single meeting, rather than as an iterative process. The recorders present during the elicitation sessions prepared EMRs that were distributed to the meeting participants, as well as other staff who would be using the information. The EMRs contain a summary of the activities and their outcomes elicited during the sessions. They were

available for review and comment by the participants and their managers. Follow-on was conducted with SNL SPM team leaders and WIPP technical staff on a one-to-one basis, using the elicitation meeting records (EMRs).

The elicitation process required an analysis of the elicited information. This analysis included a review by the SNL management in which questions were raised about the basis for the baseline formulated prior to the elicitations. Specifically, the SNL WIPP Project questioned what level of confidence in the existing information should be considered when making judgments. During the SNL management review, it was determined that the basis should be conservative, but not the extreme conservatism evident in the preliminary SPM-2 baseline (see W. Weart, "Direction for Completion of the Programmatic Review of the SPM-2 Baseline and Activities," Sandia National Laboratories memorandum to SNL WIPP Managers, December 14, 1995, and W. Weart, "Process for SNL WIPP Programmatic Review of SPM-2 Baseline and Activities," Sandia National Laboratories memorandum to SNL WIPP Managers and Principal Investigators, December 1, 1995, in Appendix C). The resulting baseline modifications necessitated refinements in some of the activities and their outcomes.

The elicited activities and activity outcomes were refined in management reviews, meetings, and individual interviews. Any changes and the rationales behind them were recorded in a parallel effort.

In summary, the formalized information-gathering process used for SPM-2, its trained elicitors, discussions among WIPP technical staff, and its documentation, provided multiple benefits. It also raised issues important for the WIPP Project to resolve, such as appropriate conceptual models, the representation of conceptual models in computational models, the representation of the experimental data in the computational models, and the basis upon which to judge information.

3.5.2 EA and WAC

The Engineered Alternatives Task Force (EATF) was established by DOE in 1989 to evaluate the relative effectiveness and feasibility of implementing selected design enhancements (referred to as EAs) for the WIPP. The primary goal of the EATF was to develop and evaluate EAs that could substantially enhance the containment performance of the WIPP repository. The SPM-2 drew heavily on the results and recommendations of the EATF to define EAs and their performance. In addition to EAs, WAC were formulated to evaluate potential improvements in WIPP performance gained by selectively emplacing waste based on performance characteristics.

The SPM-2 evaluation of EA and WAC alternatives considered how implementation of a given alternative (or combination of alternatives) affects WIPP performance in terms of the CI, the order of magnitude cost, and the estimated implementation time. Three EAs and two WAC alternatives were defined. A rigorous screening of EAs and WACs was not performed to select these examples. These cases were chosen to evaluate the improvements gained by backfill,

backfill with waste form modification, passive markers, elimination of soils, and reduction of corroding metal inventory. A WAC to limit VOCs was determined to be insignificant, after consideration of the results for the RCRA source term (described in Section 4.4.5), which showed VOCs to be a nonissue for the source term prescribed.

SPM-2 analyzed an EA (EA 1) that provides a backfill with an added pH buffer. This EA provides for improved repository performance by emplacing a backfill that will reduce brine inflow and subsequent gas generation. The backfill will have a pH buffer additive to control pH to 6.4 ± 1.0, which will reduce actinide solubility. Overall actinide mobilization is reduced by both the reduction in brine inflow and reduced solubility due to pH control.

A second EA (EA 2) provides a backfill (such as clay) with a pH buffer and waste form modification (such as clay or grout injection into drums of waste). This EA provides an optimally effective barrier to brine inflow and thereby reduces gas generated by inflowing brine. Actinide mobilization is also reduced when brine inflow is reduced. The pH buffer additive controls pH to a range of 6.4 ± 1.0 to reduce actinide solubility. The clay or grout injection into the waste drums will provide additional waste strength to reduce spallings releases.

The third EA (EA 3) takes credit for passive makers which reduce the effective human intrusion drilling rates. This effective rate includes the probability of failures of markers.

Two WAC alternatives were defined. These are the use of noncorroding waste containers for all future wastes (WAC 1) and the elimination of humic-containing waste drums to reduce small colloid formation (WAC 2).

Table 3-1 identifies the key characteristics of the EAs and WACs evaluated in SPM-2. Table 3-2 provides cost and schedule data for comparing alternatives.

3.5.3 Activity Sets and Activity Set Outcomes

After the elicitations were complete, the activities were combined into activity sets, collections of activities that constitute coherent program options. Figure 3-1 shows an example of an activity set, $A \cup B$, consisting of the two activities A and B. There are six unique potential activity set outcomes for the activity set. These are derived from all possible unique combinations of outcomes for the two activities. One activity set outcome is A1 + B1.

Performance results were generated for each activity set outcome. The probability of an activity set outcome is the product of the probabilities for the corresponding individual activity outcomes in the set. SPM associates a PDC and cost and duration information with each activity set. The PDC is calculated from the probabilities associated with each activity set outcome that has a CI equal to one.

Table 3-1. Characteristics of EAs and WACs for SPM-2

Characteristic	EA 1	EA 2	EA 3	WAC 1	WAC 2
Porosity Surface	1992 WIPP PA porosity surface	Range = 0.1 to 0.4	No change	No change	No change
Gas Generation	Reduced due to less brine	Reduced due to less brine	No change	Reduced due to less corrosive metal	No change
Actinide Mobilization	Solubility reduced due to pH buffer	Solubility reduced due to pH buffer	No change	No change	Reduced colloids
Spalling Release	Reduced due to less gas	Reduced due to less gas	Reduced due to less intrusion	No change	No change

Table 3-2. Cost and Schedule Data for EAs and WACs in SPM-2

EA/WAC	Cost Data	Schedule Data
EA 1 Backfill (w/ pH buffer)	TEC* ≅ $2M	No anticipated schedule impact
EA 2 Backfill (clay w/pH buffer) and waste form modification (inject drums w/clay or grout)	TEC ≅ $25M	No anticipated schedule impact
EA 3 Passive markers	Average Cost ≅ $65M	No anticipated schedule impact
WAC 1 Reduce corrosive drum inventory	TEC ≅ $23M	No anticipated schedule impact
WAC 2 Eliminate humic material	No anticipated cost impact	No anticipated schedule impact

*TEC = Total Estimated Cost

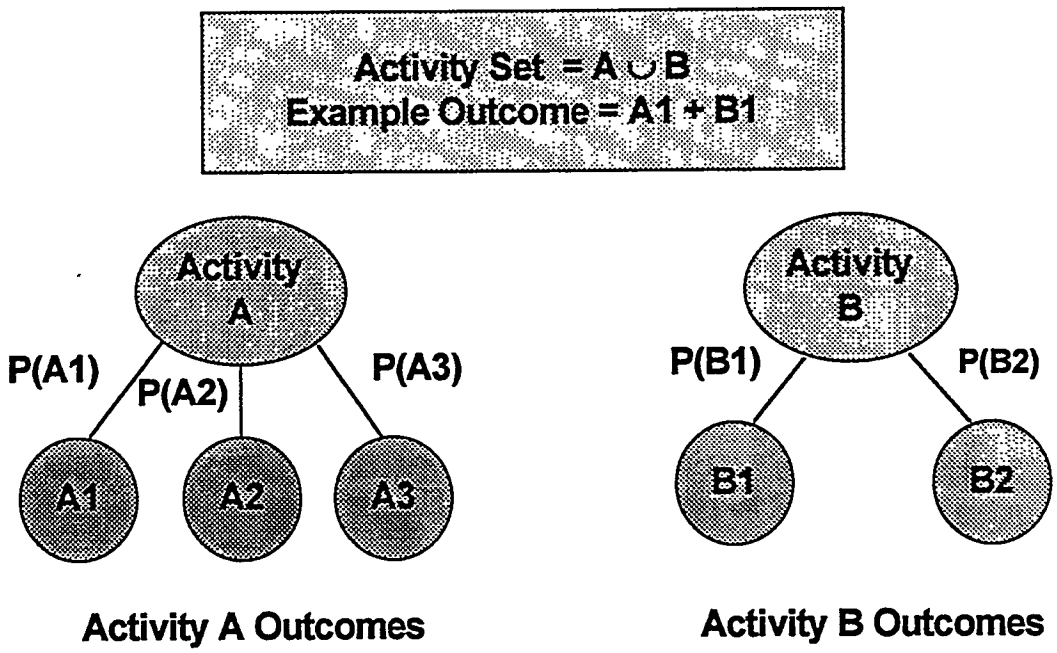

Figure 3-1. Activity set A∪B and an example activity set outcome.

3.5.4 Cost/Duration Basis for Activity Sets

Activity set cost and duration were calculated from the cost and duration information for each of the component activities. The activity set cost represents the estimated incremental cost of an activity set, and does not include the total programmatic costs of implementing the WIPP Project. The activity set duration represents the estimated duration of implementing an activity set, and should not be confused with an activity set schedule.

Activity set durations and end dates were calculated from the total duration of each activity and the date at which all results from component activities would be available for use in a compliance application. The activity set duration is the difference between the start date of the earliest activity and the end date of the latest activity. The completion date of the latest activity is the end date of the activity set. The activity duration represents the total time to complete the activity; an activity that takes one month of effort over a five-month period has a five-month duration. An activity set may be composed of activities that do not run concurrently.

Activity set costs are a simple sum of the incremental costs of the activities in the activity set. For activity sets that include scientific activities, costs represent expenditures that would be necessary for collecting data and developing and documenting models and parameters that would be used in evaluations for the WIPP PA compliance application. Costs do not include actual implementation of this information in PA. For activity sets with EAs, costs represent expenditures that would be necessary to comply with engineering requirements, such as the cost of backfilling waste in the repository. Costs for activity sets with WAC represent expenditures

that would be incurred by waste generator sites to comply with the waste acceptance requirements. EA and WAC costs are accurate to a rough order of magnitude.

Cost and duration data are presented at the activity set level. For SPM purposes, this assumes that activities can be completed at any time within the time frame of the activity set. That is, there are no dependencies between technical activities or conflicts over requirements for common resources.

Three costs categories are found in the SPM-2 decision matrix. These categories are WIPP, WAC, and Combined. WIPP costs include Experimental Program Plan (EPP) costs and EA costs; that is, the incremental costs of implementing scientific activities plus incremental costs incurred by WIPP facility to meet EA requirements. WAC costs include only those incremental costs that would be incurred by the WIPP Project and waste generator sites to meet the WAC. Combined costs are the sum of EPP, EA, and WAC costs.

Activity costs may be added as a simple sum to find the activity set cost. There are no EPP or EA costs incurred by implementing a WAC. Nor are EPP costs incurred by implementing an EA. CD-ROM reports generated by a user list the costs for each activity, as well as the EPP, EA, WAC, WIPP, and Combined costs (see Appendix E for examples of CD-ROM reports).

4. SYNOPSIS OF SPM-2 DECISION ANALYSIS

This section summarizes the SPM-2 decision analysis. Section 4.2 presents an overview of the activities considered in the SPM-2 analysis. The tree diagram showing the calculation structure for the analysis is presented in Section 4.3. Section 4.4 summarizes the conceptual models incorporated into the codes for the SPM-2 analysis. Brief descriptions of the SPM-2 codes appear in Section 4.5. Complete summaries of the SPM-2 baseline and activities can be found in Volume II of this report.

4.1 SPM-2 Decision Analysis

4.1.1 Measures of Value

SPM-2 decision analysis evaluated the relative value of activity sets with respect to cost, duration, and PDC. The objective function for the decision analysis thus has three variables: incremental dollars, time (duration), and PDC. The SPM-2 decision analysis derived the functional relationship between these three variables for each activity set.

4.1.2 The CI

SPM uses a binary measure called the CI. The SPM-2 CI indicated whether the WIPP disposal system is predicted to succeed or fail in meeting the selected radionuclide containment requirements of 40 CFR 191.13(a) and the health-based requirements of 40 CFR 268.6, which limit hazardous constituent concentrations in soil. The SPM-2 WIPP disposal system CI was equal to 1 if, and only if, the performance measures (defined in Section 3.2) for radionuclide containment and hazardous constituent concentration compliance were met; otherwise, the CI was equal to 0.

For the SPM-2 analysis, the final CCDF for radionuclide containment was calculated by combining three separate distributions for integrated releases from the possible pathways: direct releases during drilling, groundwater release through the Salado anhydrite layers, and groundwater release through the Rustler formation. The hazardous constituent concentrations of heavy metals were assumed to be in violation of 40 CFR 268.6 if any contaminated brine crossed the regulatory boundary. For SPM-2, scoping calculations for VOCs showed that, using an initial concentration based on headspace gas concentrations in the repository, no VOC will produce a regulatory violation under any credible scenario for undisturbed performance (see M. Fewell and P. Sanchez, "Soil-Based VOC and Semi-VOC Concentration in the Gas Phase for SPM-2," Sandia National Laboratories memorandum to F. Mendenhall and N. Prindle, March 29, 1995, in Appendix C).

4.1.3 Building the Decision Matrix

Information was fed into the SPM-2 decision matrix by the process shown in Figure 4-1. The four categories of input data to the decision analysis were: cost and duration of activities, elicited outcomes and their probabilities for each activity, baseline technical information, and programmatic guidance for the selected regulatory criteria. The cost and duration for activities were entered into a database and simply carried along until the final stage of building the decision matrix. The process for calculating the PDC is more complicated, and is summarized briefly in the subsection below. Once calculated for each activity set, the PDC was entered into the database. The decision matrix was constructed by compiling the appropriate cost and duration information for each activity set on the basis of each component activity's cost and duration with the PDC for the set.

4.1.3.1 PDC

A PDC was calculated for each activity set. When an activity set leads to a CI equal to 0 for the WIPP disposal facility, the PDC is also equal to 0. When the CI equals 1 for the WIPP disposal facility, the PDC is calculated by multiplying together the elicited probabilities of each of the required outcomes. The probability of each outcome of each activity in the set was derived from the elicitations of the scientific investigators.

4.1.3.2 EXAMPLE SPM-2 CALCULATION OF PDC

The following example illustrates the PDC calculations for one SPM-2 activity set. Consider the activity set that consists of the following six activities, their outcomes, and their outcome probabilities, set forth in Table 4-1: experiments to determine actinide source term solubilities (AST 1.1), seals tests (SL 4), laboratory and field tests for properties of anhydrites (SAL 1), the multi-well tracer test (NS 4), Culebra chemical retardation tests (NS 7), and colloid studies (NS 8.1).

Suppose that results from the SPM-2 performance calculations show that the calculated value for the CI for this activity set is equal to 1 only when outcome 2 is achieved for AST 1.2, SL 4, SAL 1, NS 7, and NS 8.1, and for any of the outcomes of NS 4. The algorithm for calculating the PDC for this activity set would then be:

$$\begin{aligned} PDC = {} & P[AST\ 1.2(2)] \times P[SL\ 4(2)] \times P[SAL\ 1(2)] \times \{P[NS\ 4(1) + \\ & P[NS\ 4(2)] + P[NS\ 4(3)] + P[NS\ 4(4)]\} \times P[NS\ 7(2)] \times \\ & P[NS\ 8.1(2)] \end{aligned}$$

Using values for the probabilities of the outcomes shown in Table 4-1, the PDC for this activity set would be calculated as:

$$PDC = (1.00) \times (0.9025) \times (0.85) \times (1.00) \times (0.80) \times (1.00) = 0.6137.$$

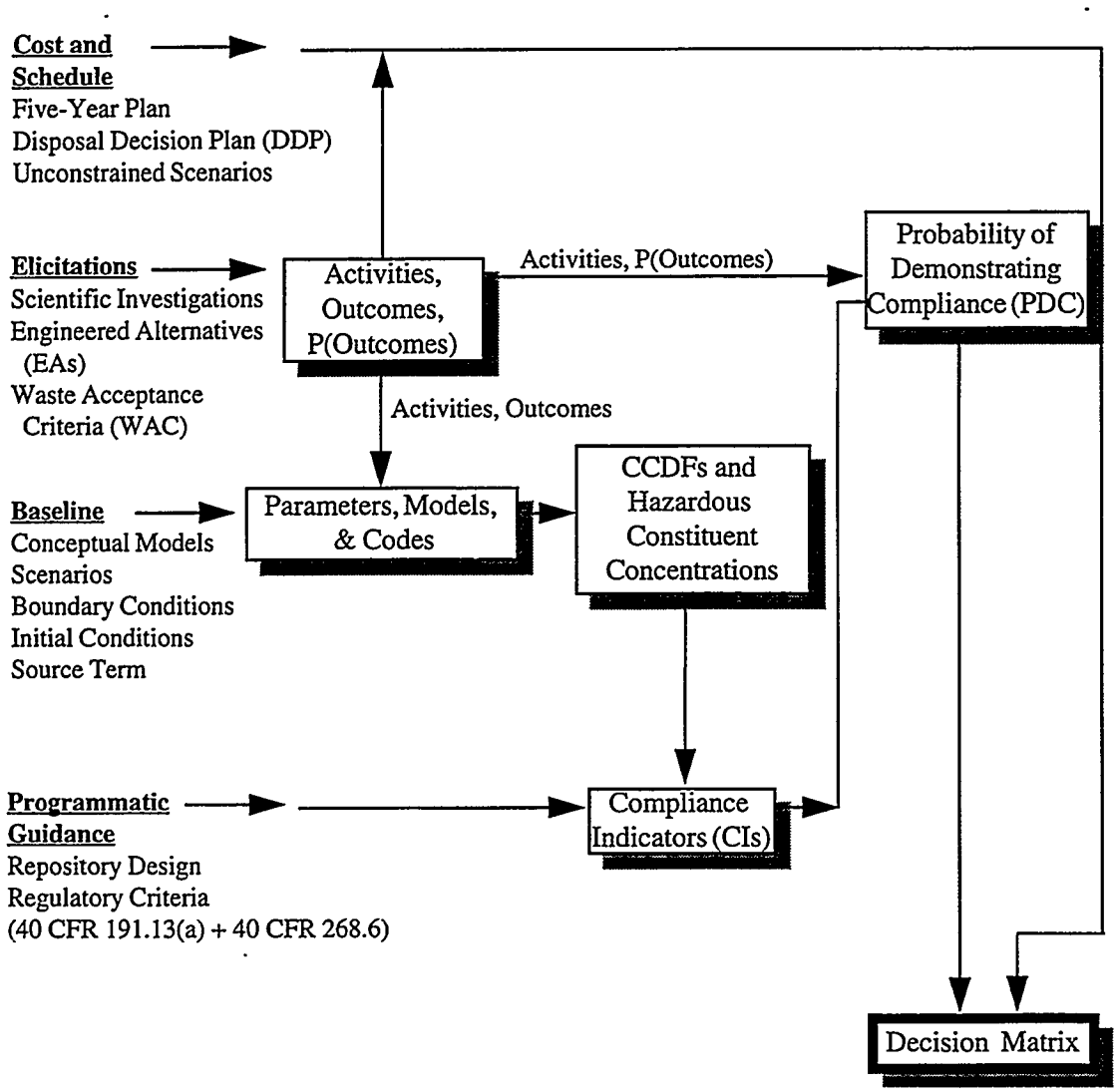

Figure 4-1. Schematic of SPM-2 decision analysis.

Table 4-1. Six Activities and Their Potential Outcomes and Outcome Probabilities for Example Activity Set

Activity	Description	Outcomes	P(Outcomes)
Dissolved Actinide Solubilities (AST 1.2)	Actinide solubility in oxidation states +III, +IV, +V, and +VI	1) Baseline distributions	0.0
		2) New solubility distributions	1.0
Short- and Long- Term Seal Component Studies using Multimechanism Deformation Coupled Fracture (MDCF) Rock Mechanics Model (SL 4 + RM 1)	Time-dependent permeability of upper (short-term) and lower (long-term) shaft seals	1) Baseline distributions	0.0975
		2) New permeability distributions	0.9025
Laboratory and Field Properties of Anhydrite Layers (SAL 1)	(porosity, permeability, critical gas and brine saturation, intrinsic permeability, C_{min} storage parameter)	1) Baseline distributions	0.15
		2) New parameter distributions	0.85
Multi-well Tracer Test (NS 4)	Specific surface area (SSA) for matrix diffusion in the Culebra	1) SSA = 0.52 - 1.04	0.02
		2) SSA = 1.04 - 2.08	0.08
		3) SSA = 2.08 - 4.16	0.45
		4) SSA = 4.16 - 20.78	0.45
Chemical Retardation in the Culebra (NS 7)	K_d distribution	1) Baseline ($K_d = 0$)	0.20
		2) New K_d distributions	0.80
Colloid Concentrations and Transport (NS 8.1)	Colloid concentrations formed for humic and microbial materials, physical and chemical retardation of each	1) Baseline distributions	0.0
		2) New parameter distributions	1.0

In other words, DOE/CAO could expect that if this activity set were implemented, there would be a 61% probability that the results from actual experimental data would lead to performance assessments that quantitatively demonstrate compliance with the selected long-term post-closure regulatory criteria.

The PDC was calculated for all SPM-2 activity sets in this way, using the calculated results for the CI to discriminate which activity outcomes are necessary to demonstrate compliance. The probabilities for those outcomes were then multiplied together to get the PDC for the activity set.

4.2 SPM-2 Activities

Table 4-2 presents the final list of 26 activities considered in the SPM-2 analysis. Not all activities elicited are included on this list. A screening of activities for the SPM-2 decision analysis eliminated activities that:

1) could not be implemented in the codes at this time (i.e., Gas Generation);
2) has been eliminated from consideration in SPM-2 during management review or upon reconsideration by the PIs (e.g., certain seals activities);
3) were determined to have insignificant consequences based on knowledge from prior results (e.g., the impact of decomposed waste properties on brine inflow); and
4) were determined by DOE/CAO to be impractical to implement (e.g., an EA calling for reconfiguration of waste emplacement).

This screening eliminated two Disposal Room activities (moved to side investigations), four Seals activities, three Salado activities (moved to side investigations), and five Non-Salado activities (two moved to side investigations). The cost and duration information used for these final activities is contained in the database, and is available for review on the CD-ROM. The number of outcomes and specific parameters for each of these activities, and the probability of the outcomes for these activities, appear in Volume II of this report.

4.3 Computational Structure (Tree Diagram)

This section describes the structure of the analyses used to calculate the PDC for SPM-2. The factors controlling the number of required analyses are described, along with an overview of the information flow used between the codes. The procedure used to define the computational structure is then discussed, and the resulting case structure for SPM-2 is summarized.

The 26 activities in SPM-2 produced approximately 600,000 credible combinations. Each activity had two or more possible outcomes. Activity set outcomes were defined by the combinations of activity outcomes; some sets had more than 50,000 possible outcomes. Each possible outcome of each activity set considered in SPM-2 potentially led to a separate calculation, which produced a composite of CCDF and RCRA results. Although the number of activities and the number of outcomes for each activity were not large, the number of possible

Table 4-2. SPM-2 Final Activity List

Activity	SPM-2 Indicator	Number of Outcomes	Probabilities of Outcomes	Parameters Influenced by Success or Failure of Outcomes	Activity Constraints	SPM-2 Modeling Codes
Actinide Source Term						
Dissolved Actinide Solubilities for Oxidation States +III - +VI	AST 1.1	2	0, 1	Solubility in (+III), (+IV), (+V), (+VI)	AST 1.1 and 1.2 are mutually exclusive	PANEL
Dissolved Actinide Solubilities for Oxidation States +III - +V	AST 1.2	2	0, 1	Solubility in (+III), (+IV), (+V)	AST 1.1 and 1.2 are mutually exclusive	PANEL
Gas Generation[a]						
RPM and Supporting Data	GG 1	2	0.33, 0.67	Model and data	NA	BRAGFLO
Disposal Room						
Decomposed Waste Properties	DR 1	2	0, 1	Waste strength, k	None	CUTTINGS/ SPALLINGS
Blowout Releases	DR 2	10	See Volume II, Table 4-4	Release reduction factor	None	CUTTINGS/ SPALLINGS
Non-Blowout Releases	DR 3	6	See Volume II, Table 3-6	Release reduction factor	None	CUTTINGS/ SPALLINGS
Seals and Rock Mechanics						
Rock Mechanics	RM 1	2	0.05, 0.95	Model and Data	Must be done with SL 4	SANCHO
Studies of Short- and Long-Term Components	SL 4	2	0.05, 0.95	Seals Permeability	Must be done with RM 1	BRAGFLO

[a] This activity was elicited, but not modeled for the SPM-2 analysis.

Table 4-2. SPM-2 Final Activity List (Continued)

Activity	SPM-2 Indicator	Number of Outcomes	Probabilities of Outcomes	Parameters Influenced by Success or Failure of Outcomes	Activity Constraints	SPM-2 Modeling Codes
Salado						
Lab/Field Properties of Anhydrite	SAL 1	2	0.15, 0.85	k, n, S_{gc}, S_{br}, P_{th}, C_{min}	None	BRAGFLO
Halite Far-Field Pore Pressure	SAL 2	2	0.20, 0.80	Field Pore Pressure	None	BRAGFLO
Halite Lab/Field Properties	SAL 3	2	0.25, 0.75	P_{th}, k, n, S_{bf}, S_{go}	None	BRAGFLO
Fingering/Channeling Studies - Existing Data	SAL 4.1	2	0.20, 0.80	C_{min}	None	Post-Processing
Fingering/Channeling Studies - New Data	SAL 4.2	2	0.05, 0.95	C_{min}	Requires SAL1	Post-Processing
Anhydrite Fracture Studies	SAL 4.3	2	0.30, 0.70	C_{min}	Requires SAL 1	Post-Processing
Non-Salado						
Dewey Lake - Paper and Low-Effort Field Studies	NS 1	2	0, 1	Minimum K_ds	None	Scaled SECO-TP
Culebra Fracture/Matrix/Flow - Lab	NS 2	4	See Volume II, Table 3-21	Diffusion surface area	None	Scaled SECO-TP
Culebra Fracture/Matrix/Flow - Field	NS 3	4	See Volume II, Table 3-21	Diffusion surface area	None	Scaled SECO-TP
Multi-Well Tracer Test	NS 4	4	See Volume II, Table 3-21	Diffusion surface area	None	Scaled SECO-TP
Sorbing Tracer Test	NS 5	2	See Volume II, 0.05, 0.95	K_ds in Culebra	None	Scaled SECO-TP

Table 4-2. SPM-2 Final Activity List (Continued)

Activity	SPM-2 Indicator	Number of Outcomes	Probabilities of Outcomes	Parameters Influenced by Success or Failure of Outcomes	Activity Constraints	SPM-2 Modeling Codes
Non-Salado (Continued)						
Chemical Retradation for Th, Np, Pu, U, and Am	NS 7	2		K_ds in Culebra	Requires NS 6	Scaled SECO-TP
Concentrations and Transport of Colloid Carriers: HMWOC and Microbes	NS 8.1	2	0, 1	Concentrations and retardation mechanisms	None	Scaled SECO-TP
Enhanced Colloid Experimental Program	NS 8.2	2	0, 1	Concentrations and retardation mechanisms	None	Scaled SECO-TP
EAs						
Passive Markers	EA 3	1	1	Drilling Rates	None	BRAGFLO and PANEL
Backfill with pH Buffer	EA 1	1	1	Room Porosity, Actinide Solubilities	None	BRAGFLO and PANEL
Backfill with pH Buffer and Waste Form Modification	EA 2	1	1	Room Porosity, Waste Strength, Solubilities	None	BRAGFLO and PANEL
WAC						
Non-Corroding Waste Containers	WAC 1	1	1	Reduce Gas Potential	None	BRAGFLO
Elimination of Humic-Containing Waste Drums (Not Funded)	WAC 2	1	1	No humic colloids	None	Scaled SECO-TP

calculations grew geometrically with the number of activities and outcomes. It was thus important to carefully design and organize the calculations to make the analysis tractable.

The SPM-2 modeling system was a sequence of linked simulation codes. Figure 4-2 shows the primary simulation codes used for the calculations, the processes simulated by each code, and the information flow between the codes.

The SPM-2 process used a modeling approach similar to that used by the WIPP PA. The SPM-2 computational structure was based on three observations:

1) For a given code there were a finite number of model configurations and input parameter values (computational cases) that could occur based on WIPP containment implications associated with activity outcomes. Each activity set outcome required specification of the exact model configuration and use of each code in the modeling system.

2) The direction of the information flow created the potential for reusing intermediate results. The number of simulations performed by each code depended on both its own computational case structure and on the number of different input cases from upstream codes. The number of input cases from upstream codes, in turn, depended on the number of computational cases defined for the upstream codes. For example, the number of calculations for the computational code PANEL depended on the number of cases defined for PANEL, and on the number of cases defined for the computational model BRAGFLO (BRine And Gas FLOw), which provided input to PANEL. Two activity set outcomes could require different PANEL cases, but might use a common BRAGFLO result. This potential for reusing intermediate results made it possible to construct the number of CCDFs and RCRA results required by the SPM-2 analysis.

3) The final CCDF depends on the releases calculated for three potential release pathways that are separable: direct release during drilling, groundwater release through the Rustler formation, and groundwater release through the Salado anhydrite layers. This composite CCDF depends on the configuration and parameter values (computational cases) used for each code in the analysis along all pathways. However, the release along each pathway only depends on the computational cases for the codes that model those portions of the pathway. For example, direct releases only depend on the BRAGFLO and CUTTINGS cases, but not on the PANEL or SECO/TP cases.

These observations were used to develop the computational structure for SPM-2. An overview of this structure is discussed below.

For each code in the modeling system, a series of indices were defined to specify the computational case (code configuration and parameter values) for that code. An index was defined for each element of the overall system model that is affected by activity outcomes. A unique value for that index was defined for each distinct code configuration or set of parameter

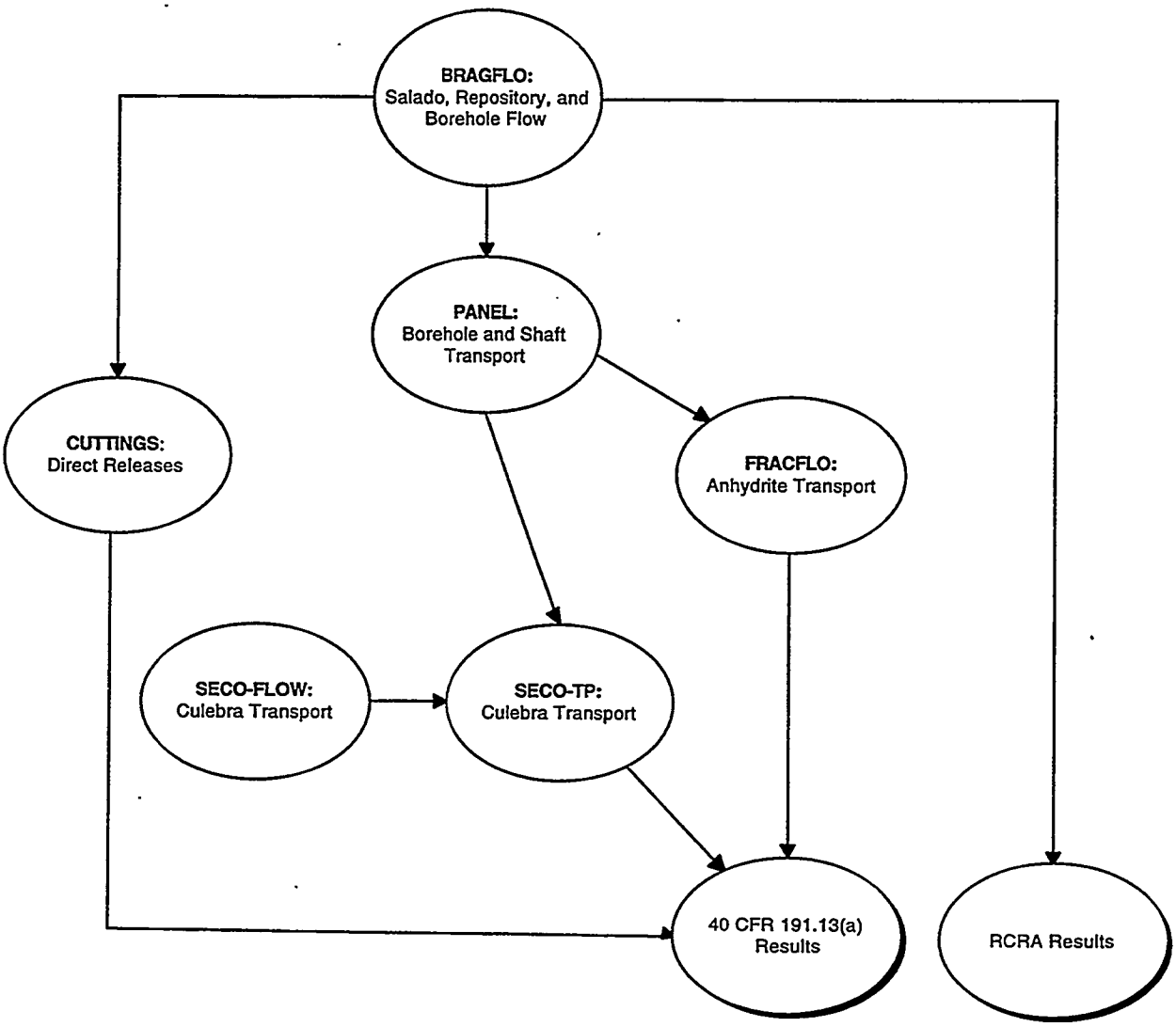

Figure 4-2. Major modeling steps in the SPM-2 calculations.

values that could be used to model that element. For example, the BRAGFLO case structure shown in Figure 4-3 used four indices: IENG identified the set of waste properties to use for each EA, ISHAFT identified the shaft seal permeability, IANHY defined the anhydrite layer permeability, and IHAL defined various properties of the Salado halite. The table in Appendix B presents a complete list of the case indices used in SPM-2 with the codes that directly use each index, and a brief description of the index values.

The indices defined above, along with the information flow through the codes, were used to identify all of the calculations required in the analysis. Figure 4-4 shows the information flow between the codes, the indices defined to describe the computational cases for each code, and the number of values defined for each index (shown in parenthesis). The results for each calculation performed by each code can be described by specifying values for each of the indices used for that code and for all of the other codes that provided input to the code. For example, a BRAGFLO calculation was identified by values for IENG, ISHAFT, IANHY, and IHAL; a PANEL result was identified by values for ICHMSOL and ICOLSOL, as well as the BRAGFLO indices ISHAFT, IANHY, and IHAL, because PANEL derives its input from BRAGFLO.

The component CCDF for release along a particular pathway was uniquely specified by values for all indices along the pathway. For example, the CCDF for direct releases was identified by IENG, ISHAFT, IANHY, IHAL, IBLW, and NOBLW. The composite CCDF for total release due to all pathways was identified by values for all of the indices. The number of CCDFs required in the entire SPM-2 analysis was determined by the number of possible combinations of values for each index that identified the CCDF. RCRA results depend only on the computational case for BRAGFLO, and its post-processor, NUclide Transport System (NUTS). Table 4-3 shows the number of component CCDFs of each type, and the number of RCRA results required for SPM-2.[1]

The total number of composite CCDFs was much larger than the sum of the number of component CCDFs. This is because, in general, the number of composite CCDFs depends on the product of the number of possible index values for all indices in the analysis, while the number of component CCDFs does not include the product of indices that pertain only to models of other pathways. For example, the number of direct release CCDFs does not depend on the number of values of IBUCKET.

Each component CCDF can be calculated by randomly generating 1,000 drilling intrusion histories. Each component CCDF can be constructed quickly, but because of the large number of

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[1] In general, the number of result types is determined by the product of the number of values defined for each index that identifies the result. The numbers of CCDFs in Table 4-3 are smaller than this product because the indices are not entirely independent; the possible values of ICHMSOL depend on the value of IENG.

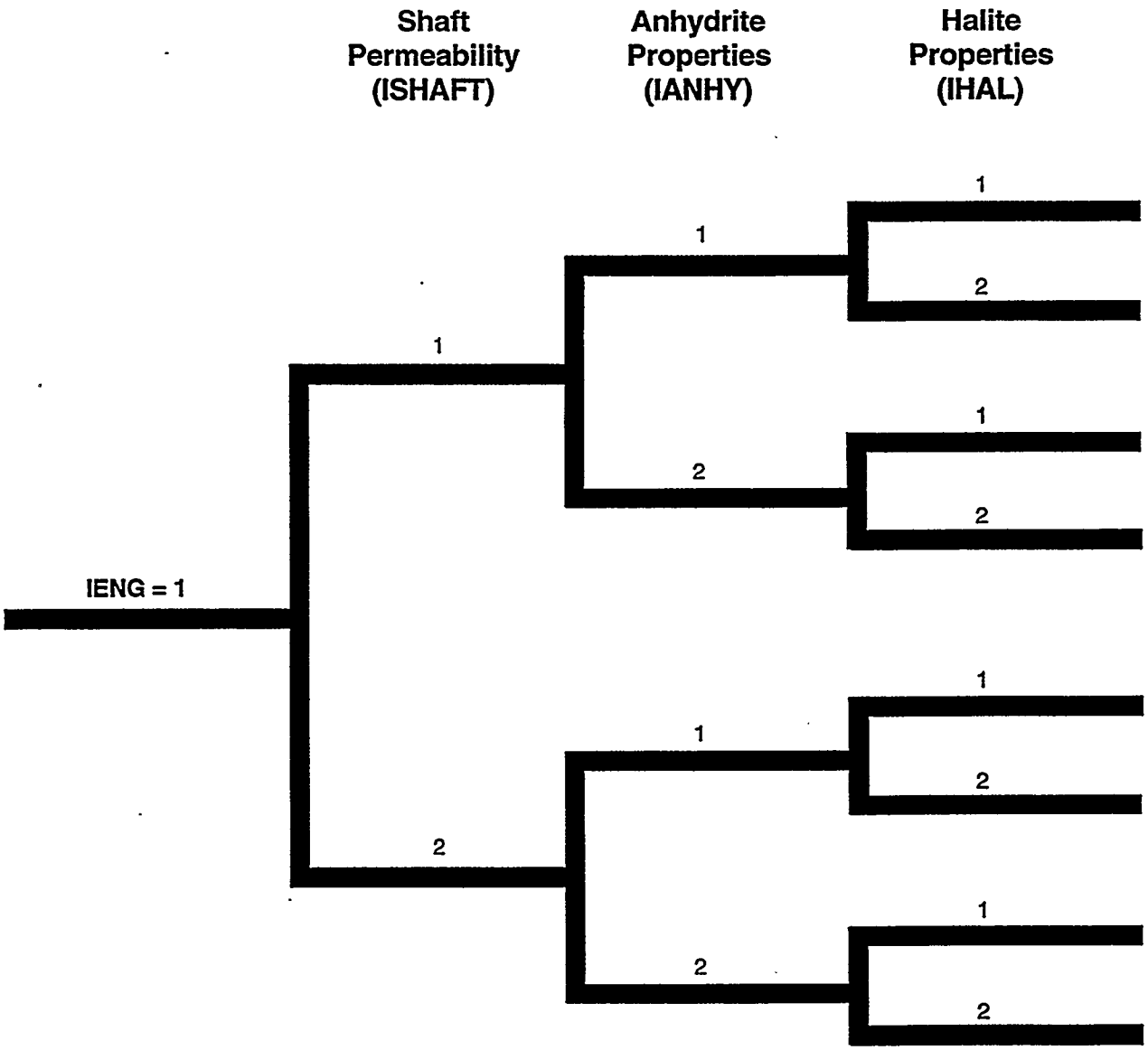

Figure 4-3. Schematic representation of BRAGFLO case structure. (A description of the indices and their values is presented in Appendix D.)

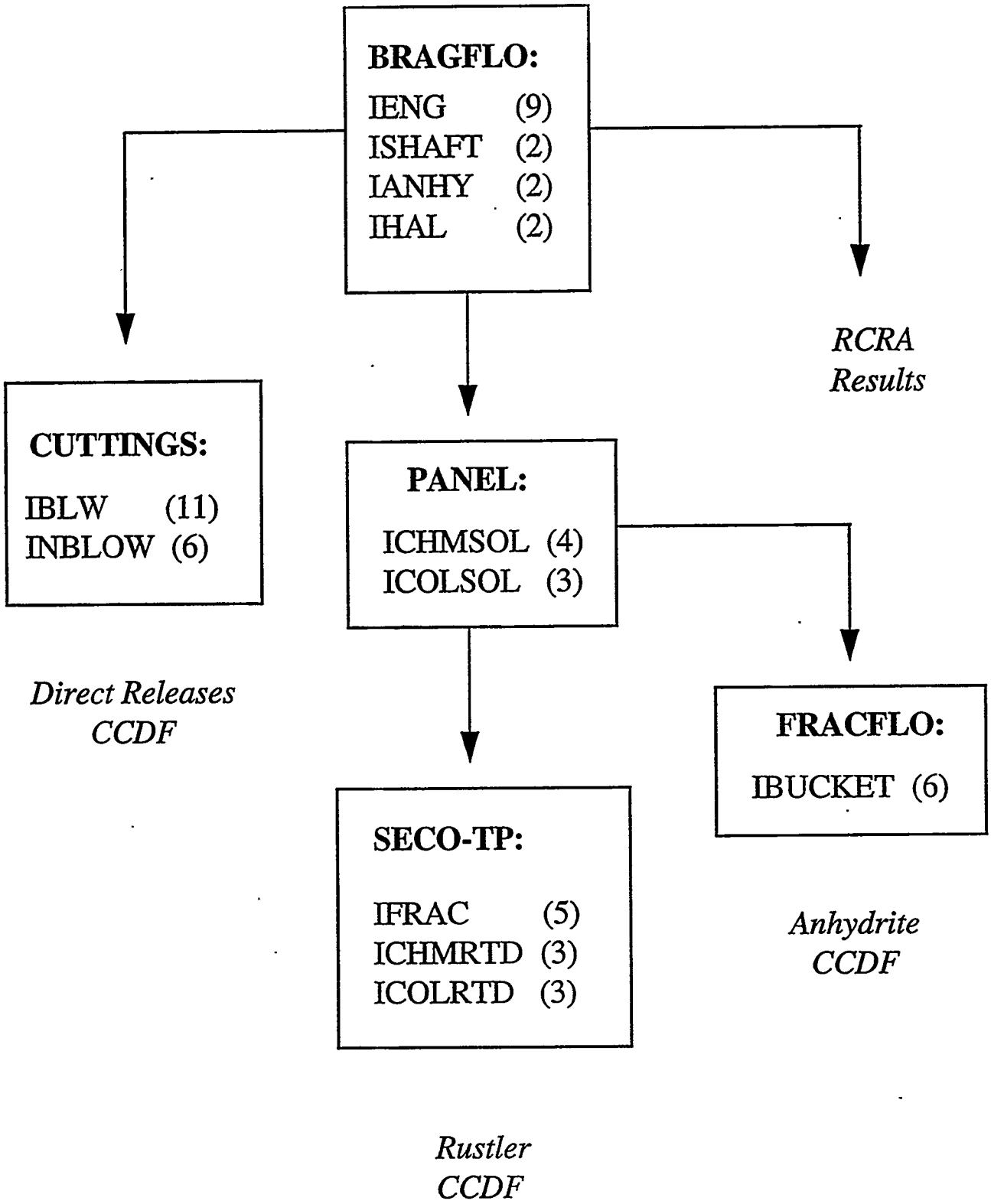

Figure 4-4. Information flow diagram, computation case index names, and number of computational case index values for the SPM-2 calculations.

Table 4-3. Number of Results for Each CCDF Type and RCRA Concentration

Result Type	Indices Used to Identify Result	Number of Results
Direct Release CCDF	IENG, ISHAFT, IANHY, IHAL, IBLW, NOBLW	4,752
Rustler Release CCDF	IENG, ISHAFT, IANHY, IHAL, ICHMSOL, ICOLSOL, IFRAC, ICHMRTD, ICOLRTD	20,520
Anhydrite Release CCDF	IENG, ISHAFT, IANHY, IHAL, ICHMSOL, ICOLSOL, IBUCKET	2,736
Composite CCDF	IENG, ISHAFT, IANHY, IHAL, IBUCKET, IBLW, INOBLW, ICHMSOL, ICOLSOL, IFRAC, ICHMRTD, ICOLRTD	8,125,920
RCRA Concentration	IENG, ISHAFT, IANHY, IHAL	72

composite CCDFs, there is considerable computational savings in constructing only the component CCDFs. By using the same series of random drilling histories to construct each component CCDF, the composite CCDF can be rapidly calculated by combining the components when it is required in the decision analysis or in the visualization system.

4.4 SPM-2 Conceptual Models

A detailed discussion of the conceptual models used in the SPM-2 analysis can be found in the appropriate SPM-2 technical position papers. This section provides a general description of the key features of the conceptual models found in the SPM-2 analysis, in particular, conceptual models not used in previous WIPP analyses. For ease of reference, this section is organized according to the technical position paper topics.

4.4.1 Scenario Screening

The technical baseline position paper, "Systems Prioritization Method - Iteration 2 Baseline Position Paper: Scenario Development for Long-Term Performance Assessments of the WIPP," identifies features, events, and processes (FEPs) that either need to be considered or that may be ruled out of the analysis. For example, meteor impact at the WIPP can be ruled out because the probability of its occurrence is extremely low. On the other hand, inadvertent human intrusion

cannot be ruled out, and should be analyzed. One particular FEP, borehole connections to units above the repository other than the Culebra, was included in the SPM-2 analysis, and had not been studied before. Several FEPs were identified as appropriate for side investigations (see Section 3.4.2).

4.4.2 Gas Generation

Gas Generation in the WIPP is caused by three mechanisms: 1) anoxic corrosion (corrosion in the absence of oxygen) of metals left underground either as part of the waste, or part of the repository facility (e.g., rock bolts in the ceilings), 2) degradation of organic materials that are part of the waste, generally assumed to occur through microbial actions (microbes eat waste and create gas in the process), and 3) radiolysis (radioactive particles break chemical bonds in waste materials or WIPP brine, and create gas in the process).

The SPM-2 baseline and activity records discuss two types of models for gas generation: the average-stoichiometric gas generation model, and the reaction-path gas generation model (RPM). The average-stoichiometric gas generation model samples on the rate of reaction for anoxic metallic corrosion and organic degradation, for both humid and brine inundated conditions. Once the rates are sampled, the gas generation for these processes remains fixed as long as the appropriate reactants are available. The RPM, on the other hand, has a library of many possible chemical reactions that can occur. The model determines from chemical conditions in the repository at any give time which reactions are favored, and allows only those reactions to proceed.

As discussed in Section 2.13 in Volume II of this report, neither the RPM nor the model of radiolysis could be implemented in the SPM-2 analysis. SPM-2 simply modeled the gas generation as defined for the baseline as described in Section 2 of Volume II (excluding radiolysis).

4.4.3 Actinide Source Terms

The actinides considered in SPM-2 analysis were uranium, neptunium, plutonium, americium, and thorium. The source term is concerned with the mobilization of the actinides; that is, what processes, and in what chemical or physical form, must the actinides be in, to leave the WIPP and move into the accessible environment. For example, a solid chunk of uranium is not going to leave the WIPP. However, if that uranium contacts WIPP brine (water with dissolved salt), some of the uranium could dissolve in the brine and leave the WIPP if the brine is forced out of the room. The dissolved uranium is considered mobilized. The same argument is valid for the other actinides.

In addition to dissolution, actinides can be mobilized by forming or becoming attached to a colloid. For transport, the difference between a dissolved actinide and an actinide in colloidal

form is size. Colloids can be one to four orders of magnitude larger in size than a single actinide ion dissolved in brine. The size difference between a colloid and dissolved ion can have a major impact on how the actinide moves in the WIPP underground environment. Several types of colloids are considered in the SPM-2 analysis (see Section 2 in Volume II of this report for more detailed information).

For SPM-2, the uncertainty in the effects of colloids includes both uncertainty in the formation of colloids, and uncertainty in chemical and physical retardation that may affect their transport. For the SPM-2 baseline analysis, the full range of chemical conditions (a large range of potential pH and Eh conditions) that result in a large range in the potential actinide mobilization must be considered. However, for the EA analysis, it is expected that the pH in the waste region of the repository can be controlled by adding a buffer to the backfill, which is expected to result in a significant reduction in actinide mobility.

4.4.4 Seals

In order to place waste in WIPP, several shafts were drilled into the Salado Formation. After the repository is filled, these shafts will be sealed in order to isolate the waste. The SPM-2 models two types of seals, one made up of short-term components, and the other of long-term components. The long-term seal component is typically made from Salado salt. Ideally, creep closure of the salt will compress and consolidate the salt seal element near to the undisturbed permeability of the Salado Formation. The short-term component is typically a material like concrete that will protect the long-term component while it is consolidating. The short-term component is expected to be effective for 100 years. The long-term component, once consolidated, is expected to be effective for over 10,000 years.

For SPM-2, the effectiveness of the long-term seal is directly tied to the effectiveness of the short-term seal. That is, if the short-term component doesn't work as expected, the long-term component's performance may be delayed or may be degraded from its optimal value. If the short-term component works well, the long-term component will function near its optimal value. In SPM-2, the uncertainty in seal permeability ranges from 10^{-20} to 10^{-12} m^2 for the baseline.

4.4.5 RCRA Source Term

Transuranic mixed waste is transuranic waste (TRU) contaminated with hazardous waste constituents regulated under Subtitle C of RCRA. Assessment of the ability of the WIPP facility to comply with the RCRA no-migration standards, codified at 40 CFR 268.6, is referred to as a no-migration demonstration. Hazardous constituents contained in the waste at repository closure will exist in one or more physical states (solid, liquid, vapor) within solidified liquids and sludges or sorbed onto cellulosics and other waste materials.

Heavy metals, like the actinides, can be dissolved in brines and then transported out of the repository. SPM-2 conceptually assumes that all hazardous heavy metals are dissolved in WIPP brines at their saturation limit. The saturation limits for most heavy metals in WIPP brines, however, is not known. Therefore, for SPM-2, RCRA-regulated metals and volatile and semi-volatile organic compounds in the liquid phase were not modeled directly. Rather, a very conservative assumption was made that the transport of brine is an indicator to assess demonstration of no-migration relative to the 40 CFR 268.6 disposal unit boundary. For volatile organic and semi-volatile organic compounds in the gas/vapor phase, SPM-2 compared the repository source term (corrected for gas-available porosity) to health-based soil levels at the disposal unit boundary. This conservative iteration is expected to result in a subset of constituents appropriate for detailed PA modeling at a later date. A key element of the SPM-2 RCRA analysis was the assumption of undisturbed conditions. RCRA regulations allow credit to be taken for long-term passive institutional controls to reduce the likelihood of human intrusion.

VOCs can be transported in the brine as dissolved gases or as liquids. They tend to transport more quickly in the gas phase. The VOC source term for SPM-2 gas concentrations was the average gas concentration for a given compound, based on measurements of the headspace in existing waste drums. The SPM-2 analysis conservatively assumed that the VOC source term does not degrade with time. For details, see Section 2.6 in Volume II of this report.

A bounding calculation has shown that, when using the SPM-2 VOC source term based on headspace concentration in the repository, the RCRA soil-based limits are never exceeded for VOCs (see M. Fewell and P. Sanchez, "Soil-Based VOC and Semi-VOC Concentration in the Gas Phase for SPM-2," Sandia National Laboratories memorandum to F. Mendenhall and N. Prindle, March 29, 1995, in Appendix C). Because of regulatory considerations unique to the RCRA no-migration demonstration, no formal elicitation process is presented in the discussions of SPM-2 activities in Section 3 of Volume II. Because of the deterministic nature of RCRA SPM-2 analysis, the discussion in Section 4 of Volume II on computer code implementation is also not considered pertinent to this activity. For SPM-2, conservative assumptions were used to bound uncertainties for the RCRA analysis. Uncertainty analyses will need to be conducted in future modeling.

4.4.6 Rock Mechanics

Rock Mechanics refers to the mechanical behavior of the host halite and anhydrite marker beds found in the Salado formation (the formation containing the WIPP repository) under load. Results from Rock Mechanics modeling were used as input to the models that predict the behavior of the sealing system discussed in Section 4.4.4 above, the Disposal Room systems behavior as discussed in Section 4.4.7, and the conditions necessary for performing the Salado fluid flow analysis in Section 4.4.8.

4.4.7 Disposal Room

The disposal rooms are areas in the repository mined out for disposal of waste materials. For the SPM-2 analysis, the disposal rooms are assumed to contain both contact-handled transuranic waste (CH-TRU) and RH-TRU.

Immediately after excavation, the stress field caused by the weight of the overlying rock causes the room to begin creep closure; that is, the walls and floors of the room begin to move toward each other at a very slow rate. At the same time, the reduced pressure in the room causes brine from the Salado formation to move toward, and eventually enter, the disposal room. The brine can then interact with the waste, causing gas generation (see Section 4.4.2), and mobilizing actinides (see Section 4.4.3). The creep closure continues until the combination of closure, brine inflow, and/or gas generation raises the pressure in the room sufficient to slow and eventually stop both the creep closure and/or the fluid inflow to the disposal room. If the pressure continues to rise (due to continued gas generation), the room may begin to expand, and brine and gases in the room could be pushed out into the anhydrite rock layers or up the shaft seals.

In the SPM-2 baseline analysis, room closure is modeled using the Multimechanism Deformation (MD) model relationships (see the discussion under Rock Mechanics in Section 2.7 of Volume II) that define the halite creeping process. Once brine enters the room, only 50% is allowed to leave the room. This prevents the gas generation processes from slowing down unless the brine is totally consumed by the generation of gas. Prior to conducting the analysis, it was not obvious what the effect of brine saturation would be. Therefore, the value of 50% was selected as the mean of the possible range (1-99%) to not bias the room response.

In addition to its effect on room pressure, room closure can cause the consolidation and compaction of the waste and backfill. For SPM-2, the baseline analysis assumes no backfill; the waste is simply placed in the room. The EAs considered for SPM-2 add a pH-buffered backfill material like crushed salt or clay between and over the waste, which removes some of the initial void space and therefore accelerates the closure of the disposal room. Besides affecting room closure, EAs may reduce gas generation, the mobile brine fraction, and/or actinide mobility.

Furthermore, SPM-2 evaluated the effect of room closure on the permeability of the waste for human intrusion. The SPM-2 model altered the permeability of the waste as a function of room closure and void space reduction. During the modeling of a human intrusion, when a borehole is drilled through the repository from the land surface, the permeability of the waste as well as the gas pressure in the repository helps determine how much of the waste material is likely to be released to the accessible environment during a blowout. Thus, SPM-2 assumed that room closure changes the waste permeability, which then impacts how much waste is released during a human intrusion blowout event.

4.4.8 Salado Flow and Transport

The flow and transport of fluids in the Salado Formation is complex and is addressed in detail in " Systems Prioritization Method - Iteration 2 Baseline Position Paper: Salado Formation Fluid Flow and Transport Containment Group." There is a major conceptual change in SPM-2 from previous analyses of WIPP performance.

Because of uncertainties in preferential flow issues (such as fingering, heterogeneity of properties, and flow up-dip), and because it is not clear if these uncertainties are adequately represented in the uncertainties of the parameter ranges/distributions of the existing models, the analysis for SPM-2 treated fluid flow out of the repository in a new, albeit very conservative, fashion. The new analysis model defined two fluid storage volumes: one for gases, and one for liquids. These storage volumes were based on the expected storage available in the anhydrite marker beds. The storage volume could be a small fraction of the expected volume in the marker beds to approximate highly channelized flow, or larger than the expected volume in the marker beds to approximate the condition where some fluids may leave the anhydrite layers and be stored to a small extent in the adjacent halite layers. All fluid leaving the repository and entering the marker beds, as modeled by the two-phase flow codes used in the Salado, was assumed to go into the storage volumes. For flow out of the repository that is larger in volume than the assigned storage volume, the excess fluid was assumed to reach the accessible environment.

4.4.9 Non-Salado Flow and Transport

As with the Salado Flow and Transport, Non-Salado Flow and Transport is complex. The reader is referred to " Systems Prioritization Method - Iteration 2 Baseline Position Paper: Non-Salado Flow and Transport." Some interesting features of the SPM-2 Non-Salado modeling include additional flow layers above the repository, matrix diffusion of some of the colloidal species, and a depleting Castile Reservoir.

In SPM-2, flow in an intrusion borehole was partitioned into three locations: the Culebra, the Magenta, and the top surface of the Rustler. Releases from the Culebra were calculated as in previous calculations. Radionuclides that enter the Magenta were assumed to not reach the accessible environment during the 10,000 year analysis. Radionuclide releases from the top of the Rustler were assumed to be regulatory releases of varying percent, and are set by the SPM-2 baseline and activities.

Three types of colloids were considered in SPM-2. Of these, two types, the soft-sphere carrier colloids and the actinide-intrinsic colloids, were considered small enough to undergo some matrix diffusion. The amount of matrix diffusion for these actinide-bearing colloids was assumed to be less than that for dissolved actinides due to the large particle size of the colloids, as discussed in " Systems Prioritization Method - Iteration 2 Baseline Position Paper: Non-Salado Flow and Transport."

In SPM-2, the Castile brine reservoir was modeled as a depleting reservoir. This means that, in the event of a human intrusion through the repository and into the Castile brine pocket, the flow up through the repository will show a decreasing rate of fluid flow with decreasing pressure. It is also noteworthy that the SPM-2 analysis called for multiple reservoirs in the Castile formation under the repository so that one human intrusion did not necessarily deplete the Castile for the remainder of the analysis.

4.5 SPM-2 Modeling Codes

SPM-2 required modeling the repository and shaft system for the undisturbed scenario and also either one or two boreholes for the E1, E2, and E1E2 human intrusion scenarios (see Glossary, Section 9, for definitions). BRAGFLO was used to model gas generation and two-phase flow in the repository, the shaft system, and the boreholes. Deformation of the waste-filled repository due to halite creep was modeled with the SANCHO code. The effect on waste porosity was coupled to the BRAGFLO simulations via a porosity surface. The porosity surface was a fit to the effective porosity of the waste-filled room as a function of time and total moles of gas generated. The NUTS code was used as a post-processor to the BRAGFLO simulations with a unit source concentration in order to determine the volume of brine originating in the repository that reached the Rustler formation. The PANEL code used the borehole and shaft brine flow rates and volumes to mobilize radionuclides and transport them in both dissolved and colloidal forms to the Culebra, Magenta, and Dewey Lakes formations above the repository. SECO/TP was used to simulate the transport of nuclides and small (humic) colloids in the Culebra based on a "mean" flow field calculated by SECO2D.

BRAGFLO. The computational model BRAGFLO (WIPP PA, 1992) was used to model gas generation and brine and gas flow within the Salado Formation and the repository, including a representation of the shaft system for undisturbed performance and an intrusion borehole(s) for disturbed performance. The Culebra Dolomite Member of the Rustler Formation and a hypothetical pressurized brine reservoir in the Castile Formation were also included in the model because of their potential as a sink and a source, respectively, for fluid flow.

BRAGFLO is capable of describing three-phase (e.g., water, gas, and oil) fluid flow through porous media in one, two, or three dimensions. Only two phases (brine and gas) needed to be modeled for SPM-2, and calculations were performed in two dimensions. The code uses spatially varying meshes, and solves the coupled nonlinear partial differential equations (PDE) using nonlinear Newton-Raphson iteration, automatic time-stepping, and direct or iterative solvers.

SANCHO. (WIPP PA, 1992) Halite creep and resulting repository deformation and room closure was modeled using the SANCHO finite element program. The resulting effective waste porosity surface was supplied to the BRAGFLO simulations. SANCHO solves problems of quasi-static large-deformation inelastic response of 2-D solids. This program numerically solves the general, nonlinear PDEs that govern relaxation to equilibrium between stresses and applied loads in a solid body. Because the general equations are an under-determined system, they must

be supplemented with constitutive equations. The choices were: a finite strain, elastic-plastic strain-hardening; a volumetric plasticity model; and a metallic creep model.

PANEL. (WIPP PA, 1992) Following an intrusion, flow of brine through a collapsed WIPP panel and up an intrusion borehole may result in transport of mobilized radionuclide-bearing compounds towards the ground surface. Similar behavior can also occur in the shafts under failed seal conditions. The consequence model that simulated the process was implemented in a computer code called PANEL. The mathematical model on which PANEL is based represents an extreme simplification of a potentially complex situation that involves a mixture of waste forms with widely varying physical and chemical compositions in contact with heterogeneous flows of brine. The primary simplifying assumptions were as follows:

1) A WIPP panel is idealized as a single, connected cavity of constant volume.
2) Waste and backfill are treated as a homogeneous porous medium with infinite permeability. Radionuclide-bearing compounds are uniformly distributed.
3) Steady state discharge of brine is assumed at all time (i.e., flow in equals flow out).
4) Pore space is fully saturated with brine, i.e., mobilization of nuclides in the gas phase is ignored.
5) Chemical equilibrium and uniform mixing is assumed.

NUTS. NUTS is a multicomponent radionuclide contaminant transport code, with single-porosity, dual-porosity, and dual-permeability capabilities. The code can also handle temperature-dependent solubility and precipitation. BRAGFLO output can feed directly into NUTS. The NUTS code was used as a post-processor to the BRAGFLO simulations with a unit source concentration to determine the volume of brine originating in the repository that reached the Rustler formation. It is also used to partition the flow between the different layers in the Rustler.

CUTTINGS. The CUTTINGS computer program (WIPP PA, 1992) estimates the direct removal of waste that would result if an exploratory drill bit inadvertently penetrated a waste storage room. Three separate physical processes that could mix waste with the drilling fluid and transport it to the ground surface were modeled:

1) Cuttings: waste contained in the cylindrical volume created by the cutting action of the drill bit through the waste.

2) Caving: waste that erodes from the borehole in response to the upward-flowing drilling fluid within the annulus. The borehole erosion is caused when the magnitude of the fluid shear stress acting on the borehole wall exceeds the effective shear strength for erosion of the wall material.

3) Spallings: waste surrounding the eroded borehole that is transported by waste generated gas escaping to the lower pressure borehole. The escaping gas may compromise the stability of the borehole wall. The response is dependent on the constitutive nature of the compacted composite waste and the interaction of the waste impressed against the drill string.

SECO2D. SECO2D (WIPP PA, 1992) simulates groundwater flow in two dimensions at both regional and local scales. Given appropriate initial and boundary conditions, it calculates a potentiometric head field, which can be used to compute specific discharge (Darcy velocity) using Darcy's Law. Climate effects are simulated in SECO2D by including time-dependent head boundary conditions on a user-specified portion of the boundary of the regional computational domain. A single "mean" flow field was used for all Culebra transport simulations.

SECO/TP. SECO/TP calculates multicomponent radionuclide contaminant transport with either the dual- or single-porosity conceptual models using flow fields calculated by SECO2D. It solves the general advective/dispersive transport equation where hydrodynamic dispersion is modeled using Fick's law. SECO/TP also has the capability of modeling adsorption of solutes using a linear equilibrium isotherm with constant partitioning coefficients. Chemical retardation in the fractures can be modeled by either a "thin skin" fracture retardation factor or by actually modeling diffusion into the clay fracture lining. In the second case, the thin clay layer was modeled as part of a two-layer matrix.

Solute transport and fluid flow can be uncoupled, i.e., modeled separately with SECO2D and SECO/TP, because solute concentrations are assumed to be small enough that they do not affect fluid densities.

5. SPM-2 ASSUMPTIONS, SIMPLIFICATIONS, AND UNCERTAINTIES

Assumptions, simplifications, and resulting uncertainties are an inherent part of any analysis and are particularly relevant to the computer modeling of a complex system such as WIPP. In modeling such a system, experimental data and scientific knowledge are translated into conceptual models, which are then represented by mathematical models and computer codes. Simplifications made to retain a computationally tractable problem introduce uncertainties. Decisions based on the results of an analysis such as SPM-2 require the user to be cognizant of these assumptions, simplifications, and uncertainties.

Key assumptions, simplifications, and uncertainties in SPM-2 were:

1) A mean value approach was used to generate a single vector from parameter distributions for input to SPM-2 modeling. This approach produced a first order approximation to the mean of a family of CCDFs that would result from Latin Hypercube Sampling (LHS) of the parameter distributions. Activities and activity sets were discriminated on the basis of their corresponding shift in mean parameter values. The value of reducing the range of uncertainty in parameter distributions was therefore not captured in SPM-2.

2) CCDFs and RCRA concentrations were conditioned on the assumptions of the SPM-2 analysis and the choice of conceptual models. For SPM-2, very conservative assumptions were used to bound uncertainties for the RCRA analysis. Uncertainty analyses will need to be conducted in future modeling to quantify inherent uncertainty in parameter distributions assumptions that are not bounding. No decision has been made regarding assumptions inherent in the headspace-concentration limited conceptual model for the VOC source term. The scope of required uncertainty analyses will be decided in future PA modeling, and is not considered in SPM-2.

3) The SPM-2 baseline is not identical to the Project Technical Baseline (PTB), and is only intended for use in SPM-2 calculations.

4) While the authors believe that the decision matrix information correctly reflects the results of the computer modeling, there may be isolated errors in results due to limited verification of computer codes and calculation results.

5) SPM-2 results are limited to evaluating the ability of the WIPP disposal system to meet selected post-closure regulatory requirements (40 CFR 191.13(a) and 40 CFR 268.6).

6) SPM-2 results are based on the predicted outcome of activities (i.e., the anticipated possible result of implementing scientific investigations, EAs, and WAC) that have not yet been implemented. The actual outcome may therefore be different from the predicted outcome.

7) Some activities were modeled using a relatively small number of predicted outcomes.

8) Cost and duration data were presented at the activity set level. For SPM-2 modeling purposes, this assumes that activities can be completed at any time within the time frame of the activity set. That is, there are no dependencies between technical activities or conflicts between requirements for common resources. In actuality, these assumptions need to be tested by redesigning the WIPP DDP around a selected activity set to examine dependencies and true costs and schedule.

9) Cost and duration data for EAs and WAC were accurate to a rough order of magnitude. Cost and duration information for these activities should be verified prior to implementation.

10) Important programmatic information, such as the relevance of portions of scientific activities to other aspects of the WIPP program, or interdependencies between activities, was not fully captured by SPM-2. This information will only become available during the detailed evaluation of an activity set.

11) Completion of side investigations will provide information to substantiate certain technical positions taken in the SPM-2 baseline. There is some small but nonzero risk that these evaluations will not support one or more baseline positions.

6. SPM-2 RESULTS

The purpose of SPM-2 is to aid DOE in making programmatic decisions for the WIPP Project. The CAO final decisions are outside of the scope of this report. This section discusses preliminary observations of the SPM-2 decision matrix, completed on March 23, 1995. The vast amount of information in the decision matrix made it possible to give only a very brief overview of some features in the matrix. To assist DOE/CAO in understanding the matrix, a CD-ROM containing the matrix and software tools was transmitted to DOE/CAO with this document. The figures shown in this section were generated on the CD-ROM.

The SPM-2 analysis examined over 600,000 possible combinations of activities, called activity sets. Several of the analyzed activities had no impact on the CCDFs or the RCRA concentrations, which allowed their removal from the decision matrix, reducing the number of activity sets to roughly 46,700. Because each activity set had multiple outcomes, the number of CCDFs needed to complete the SPM-2 analysis was roughly 1,300,000. Each activity set is an element in the decision matrix, i.e., each activity set has an associated PDC, cost, and duration.

As stated above, after the performance calculations were completed, several activities showed no impact on the CCDFs or the RCRA concentrations. The activities that had no impact on the CI and that were removed from the decision matrix were SAL 4.1, SAL 4.2, SAL 4.3, and NS 1. Most noteworthy were the several Salado activities. No brine releases were shown to occur through the Salado Formation. Because of this, no Salado activity that specified only a value for C_{min} (SAL 4.1, SAL 4.2, SAL 4.3) affected any of the CCDFs and, therefore, these Salado activities would have no effect if entered into the decision matrix. Therefore, Salado activities were not included in the decision matrix. The CD-ROM does list these activities for completeness, but results are not in the matrix proper, and cannot be selected from the activities panels. As expected, disconnecting nonimpactive activities from decision matrix software resulted in marked improvement of the performance of the software.

It is important to understand that, while these Salado activities showed no releases in the SPM-2 analysis, this may be a direct result of using a mean calculation and not the full LHS approach. The difference between the calculational models used to generate these results and the SPM-2 technical baseline conceptual models could conceivably lead to different results. These differences, as mentioned earlier, will be analyzed in side investigations. Prior analyses have shown that the impact of Salado releases on the CCDF can be quite large. Other Salado activities that impact more than the anhydrite storage term are included in the decision matrix.

6.1 SPM-2 Baseline Results

With the given assumptions and modeling of the SPM-2 baseline, the analysis showed a violation with respect to 40 CFR 191.13(a). The SPM-2 baseline analysis, however, showed compliance with respect to 40 CFR 268.6.

This result is based on performance calculations for the movement of contaminated brine from the room and a bounding calculation of the VOC source term in the room. The brine flow calculations for the SPM-2 baseline show that no contaminated brine reached the RCRA boundary, indicating compliance with respect to liquid. Similarly, compliance for the gas phase was indicated by the bounding VOC calculations. These bounding calculations for VOCs (see M. Fewell and P. Sanchez, "Soil-Based VOC and Semi-VOC Concentration in the Gas Phase for SPM-2," Sandia National Laboratories memorandum to F. Mendenhall and N. Prindle, March 29, 1995, in Appendix C), however, did show calculated carbon tetrachloride soil-based concentrations approaching the health-based limit in both the anhydrite and upper shaft. In the anhydrite at the disposal unit boundary, the soil-based concentration for carbon tetrachloride and the health-based limit are essentially equivalent (5.33 mg/kg for the soil-based concentration versus 5.38 mg/kg for the health-based limit). The calculated soil-based concentration for carbon tetrachloride within the upper shaft seals is lower than the health-based limit, but is of the same order of magnitude (2.43 mg/kg for the soil-based concentration versus 5.38 mg/kg for the health-based limit).

Using a minimum porosity of 1% for the anhydrite yields a soil-based concentration more than an order of magnitude lower than the health-based limit for carbon tetrachloride (0.18 mg/kg for soil-based concentrations versus 5.38 mg/kg for the health-based limit). No porosity range is documented for upper shaft materials. Carbon tetrachloride was, therefore, retained for further analysis as the sole indicator for chemical gas-phase organic constituents.

6.2 SPM-2 Activity Results

A detailed analysis of the SPM-2 decision matrix is beyond the scope of this report. Such an analysis requires post-processing using the CD-ROM visualization software and other sensitivity and uncertainty studies. The CD-ROM software is designed to answer questions such as:

1) Which activities have the greatest influence on compliance probability?

2) What is the effect of removing activities from, or adding activities to, selected sets?

The solution sets are too numerous to report here (there are over 46,000 viable solution sets); the CD-ROM, however, provides the capability to determine the component activities that make up the activity sets for selected categories of cost, duration, and PDC. In particular, using the CD-ROM, one can list the activity sets that correspond to the surfaces appearing in Figures 6-1 through 6-5 (discussed below) for the maximum PDC. There are multiple activity set solutions in each category, too numerous to list here, that, for given cost and duration categories, result in the maximum PDC.

In addition, the CCDFs and RCRA results are provided on the CD-ROM for each activity set. These performance results were valuable in developing an understanding of the uncertainties and

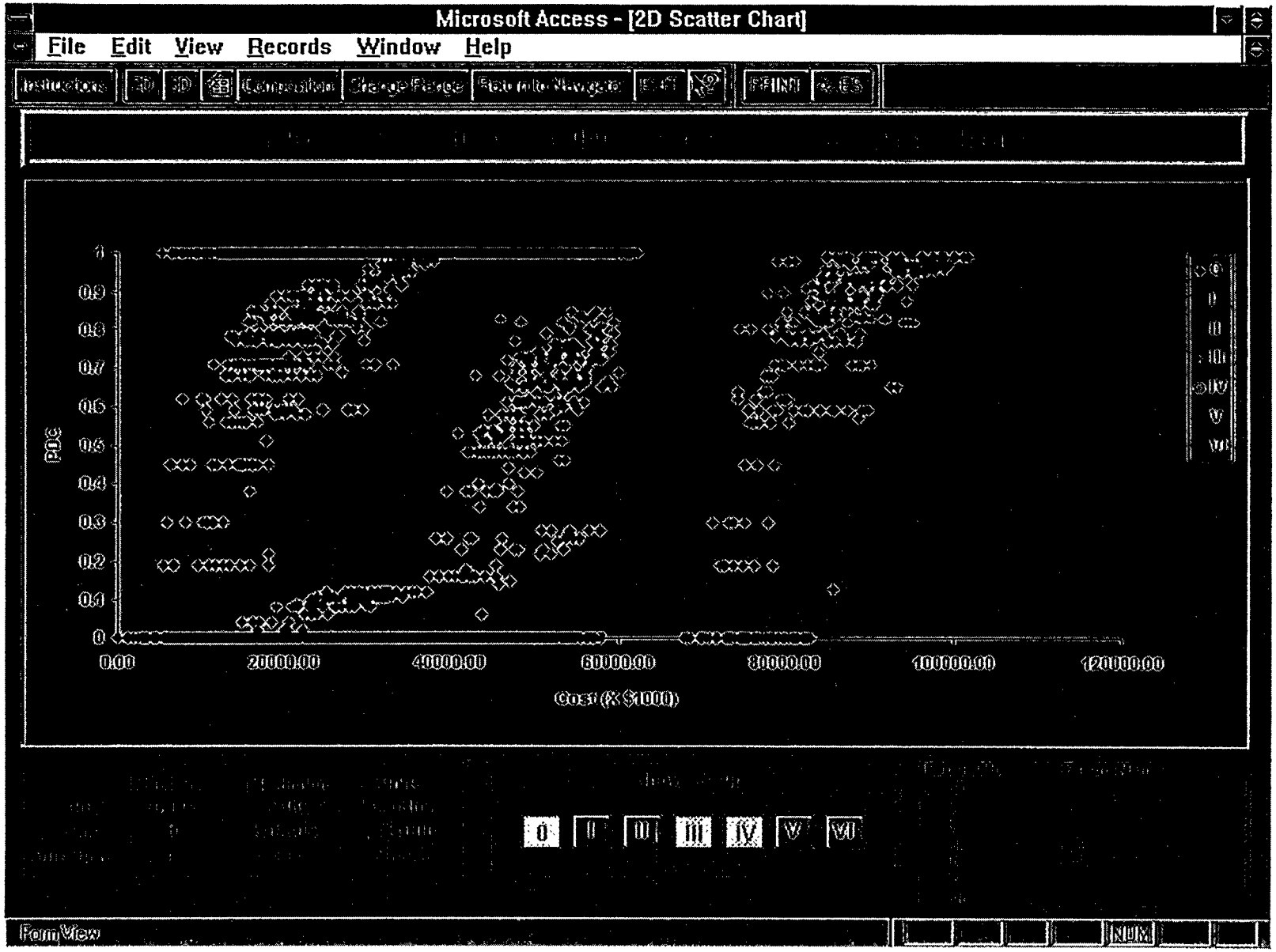

Figure 6-1. 2-D scatter chart of 4,000 sampled activity sets.

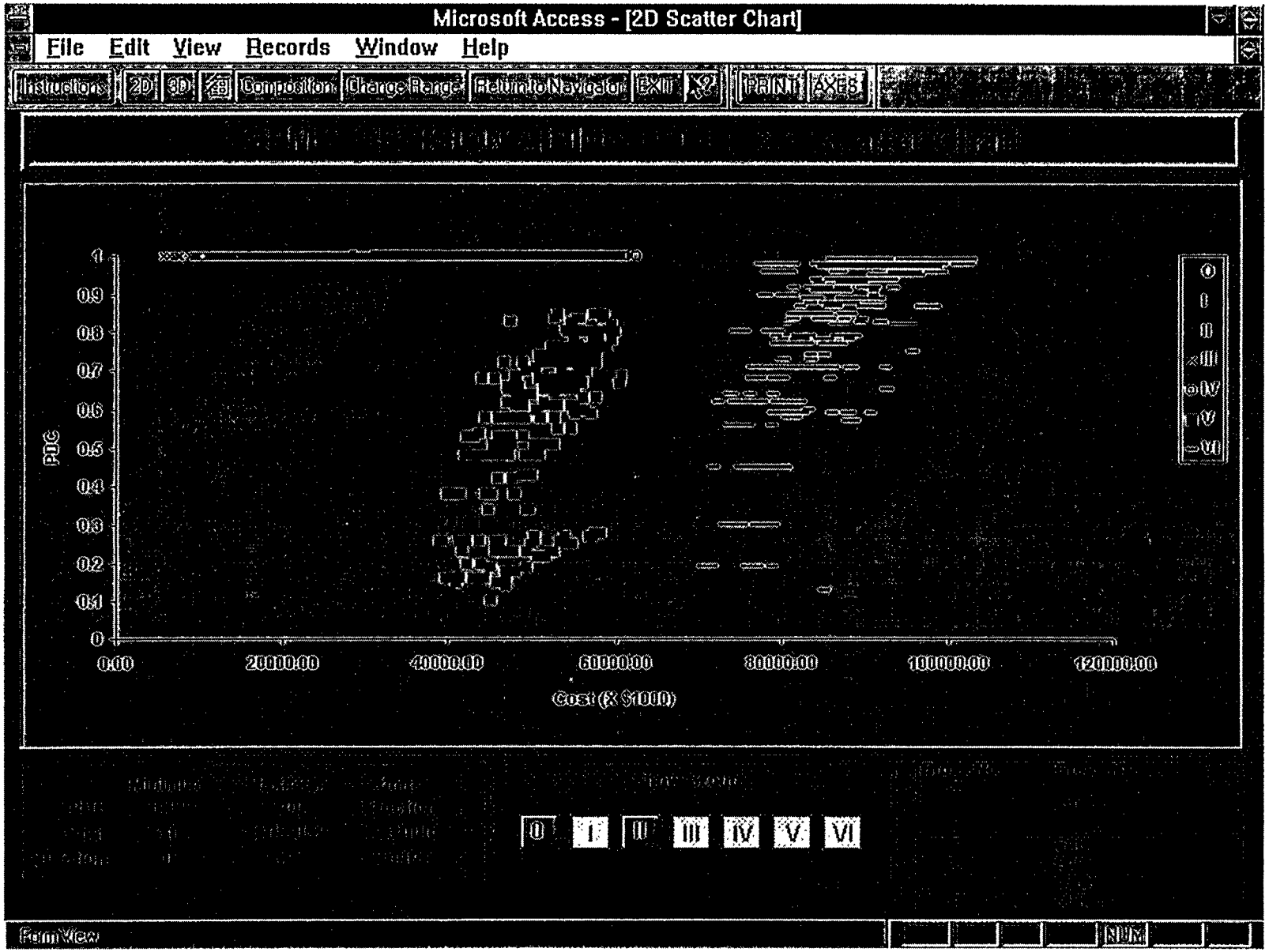

Figure 6-2. 2-D scatter chart mapping location of EA, WAC, and EPP activities.

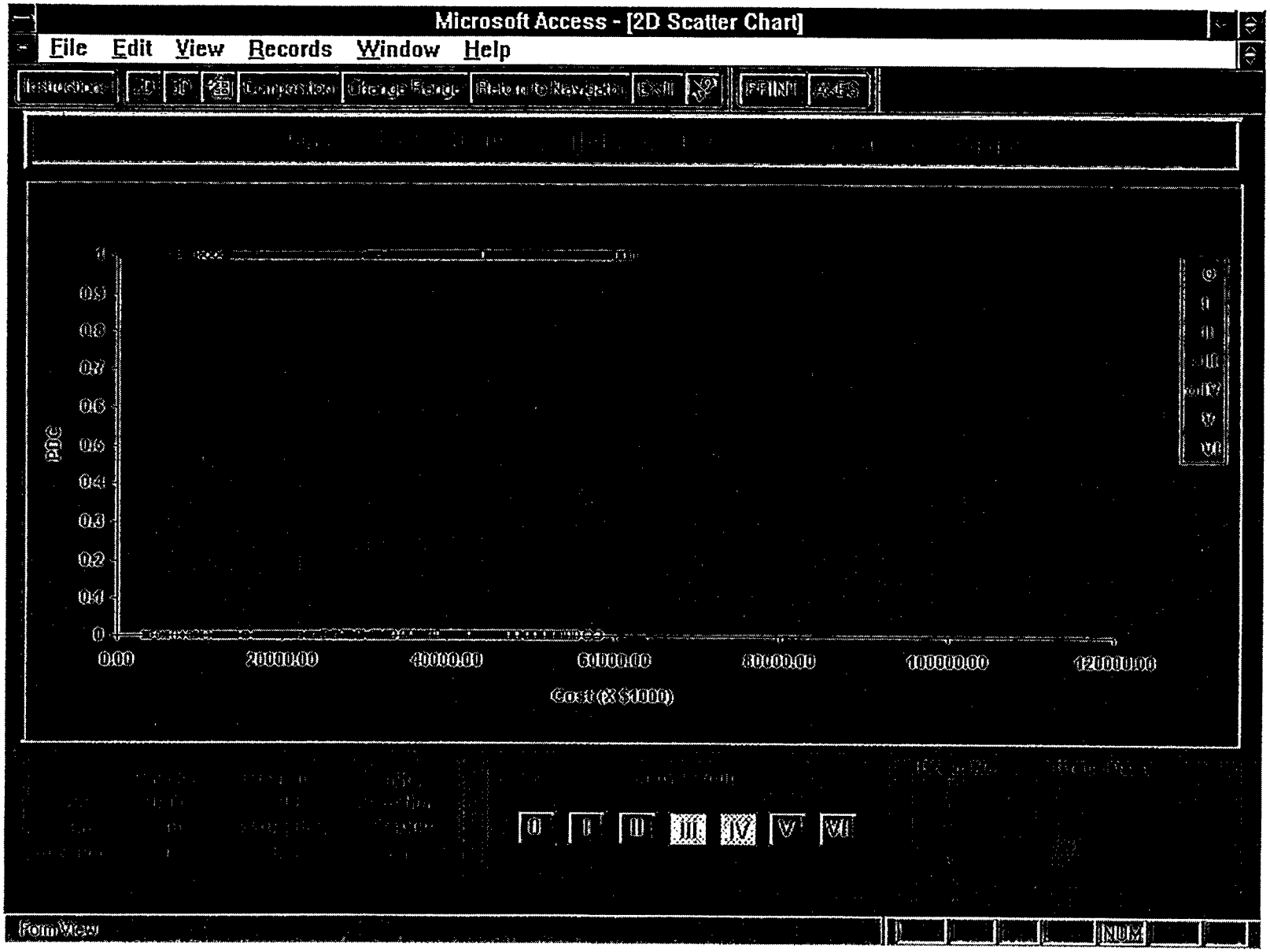

Figure 6-3. Scatter chart showing location of only EA 1 and EA 2.

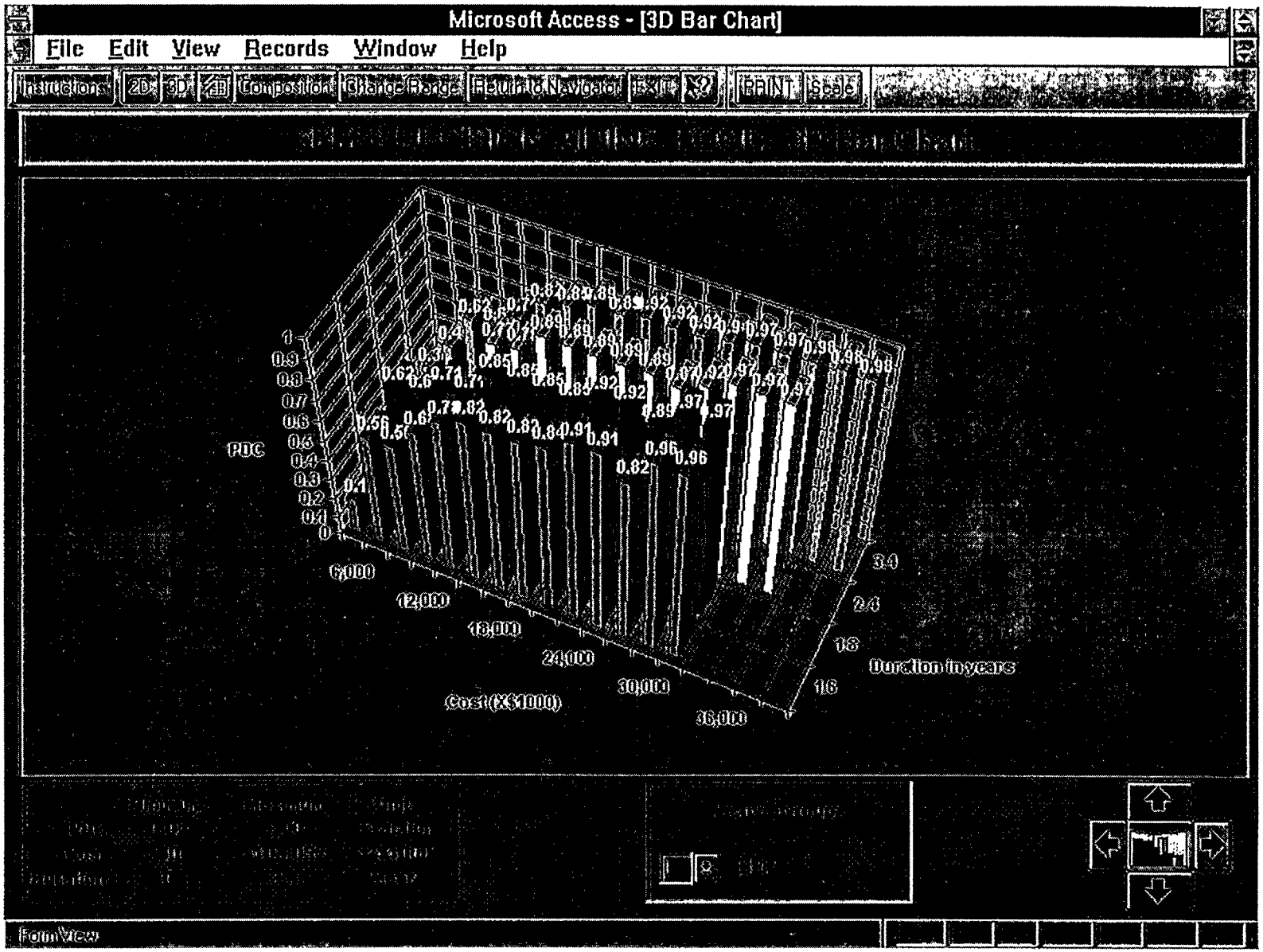

Figure 6-4. 3-D plot of the EPP portion of SPM-2 decision matrix.

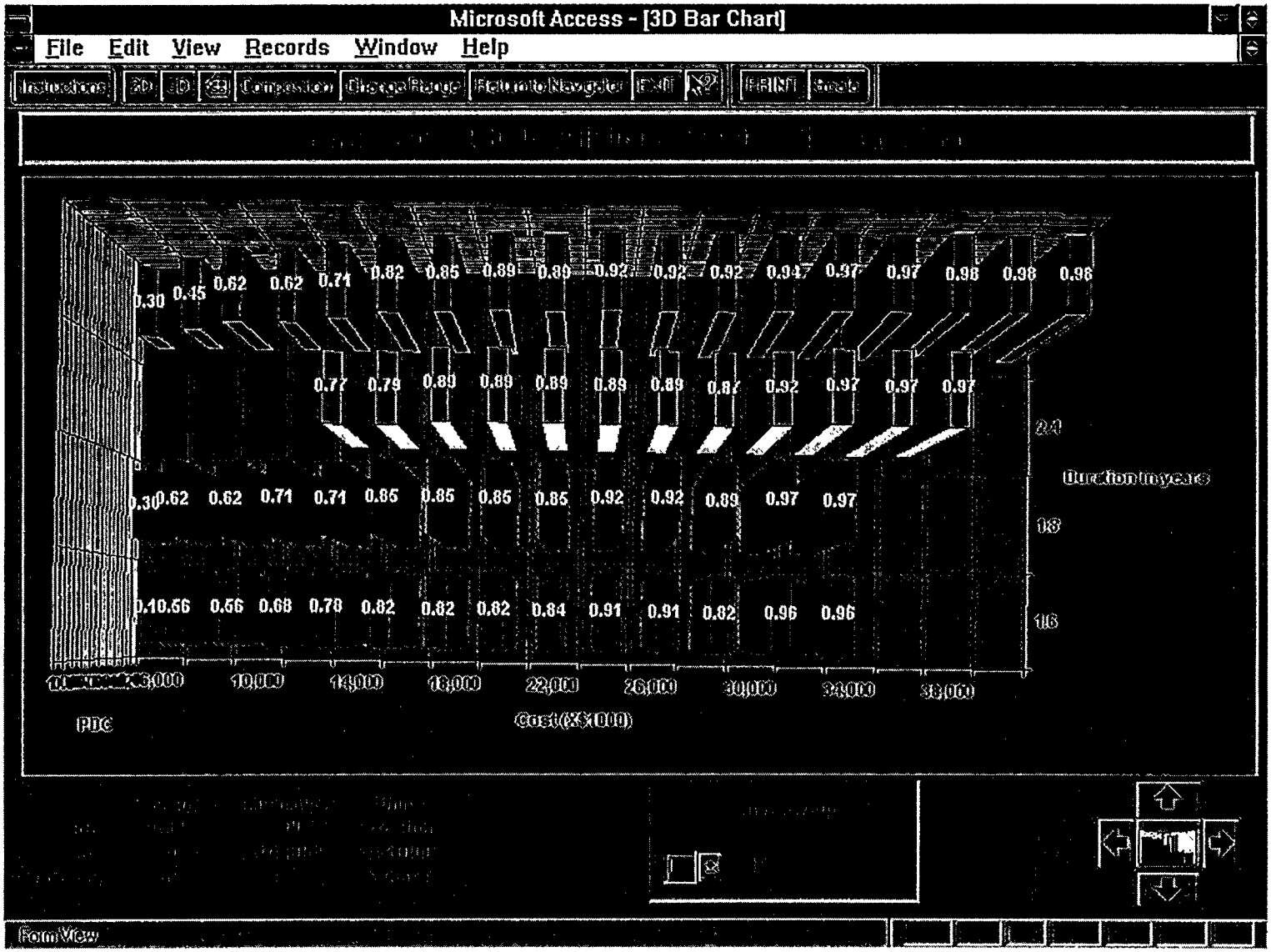

Figure 6-5. SPM-2 decision matrix: 3-D bar chart for scientific investigations (PDC versus cost and duration).

the significance of the simplifications and assumptions made in SPM-2 before making programmatic recommendations, as described in Volume III of this report. The detailed cost and duration information for activities that comprise activity sets are also provided on the CD-ROM, including a breakdown between WIPP costs, EAs, and Combined costs for WIPP and the waste generator sites. The following sections summarize initial observations of the SPM-2 activity results, as they appeared on the CD-ROM prior to the post-processing analysis.

6.2.1 RCRA Results

As mentioned above, no violations were shown with regard to VOCs in the bounding calculation for either the baseline or activities (see M. Fewell and P. Sanchez, " Soil-Based VOC and Semi-VOC Concentration in the Gas Phase for SPM-2," Sandia National Laboratories memorandum to F. Mendenhall and N. Prindle, March 29, 1995, in Appendix C). With regard to heavy metals, if any brine leaves the repository and crosses the unit boundary, a RCRA violation is assumed. Several activity sets showed brine leaving the repository and moving through the seals to the top of Salado, causing an assumed violation. Specifically, only those activity sets that had both the baseline seals values and the WAC that replaced the waste drums with noncorroding materials had brine leaving the repository and crossing the unit boundary.

6.2.2 General Decision Matrix

Figure 6-1 shows a random sampling of roughly 4,000 activity sets of the decision matrix on a scatter plot of PDC versus cost. This plot shows the basic structure of the decision matrix. First, the plot shows about 40% of the activity sets near 0.0 PDC. These consist of activities that, by themselves, cannot lead to a successful demonstration of compliance. Second, the plot shows approximately 30% of the activity sets at 1.0 PDC. These activities, as will be shown later, are associated with specific EAs. Third, the remaining 30% of the activity sets are scattered between 0.0 and 1.0 PDC. Note that there appears to be a generally positive correlation between cost and PDC for the activity sets scattered between the PDC extremes.

Figure 6-2 shows a mapping for the general decision matrix. In this figure, diamond points represent the EPP, Xs represent EA 1, open squares represent EA 2, solid squares represent WAC 1, and minus signs represent passive markers. This is discussed below.

6.2.3 EAs

Figure 6-3 shows a segment of the decision matrix containing only activity sets that include EA 1 or EA 2. The striking characteristic of the map is that EA 1 and EA 2 only populate activity sets that have PDCs that equal 0.0 or 1.0. The implication is that while the EAs by themselves are insufficient, in combination with other activities they become effective. Note that the EAs

assumed that only one outcome had a 100% probability of the desired results, which contributes to their appearance at the top of the matrix

The mapping in Figure 6-2 also shows that the only activities having a PDC equal to 1.0 contain EA 1 or EA 2. Figure 6-2 also shows activity sets that contain EA 3, passive markers. The cost of this activity causes a shift of the matrix along the cost axis, with little observable increase in PDC.

6.2.4 WACs

Figure 6-2 shows activity sets containing WAC 1, which replaced corrodible steel drums with noncorrodible material. This WAC reduces both gas generation rates and potentials inside the repository. The implication is that gas generation is desirable to a certain extent because removal of the corrodible drums seems to reduce the PDC. However, this conclusion may be premature. The PIs clearly identified a need to account for stratigraphic dip that may significantly impact this conclusion.

WAC 2, the elimination of all high-molecular weight organic compounds (HMWOCs) (such as soils) from the waste, has had no discernible impact on the results. If side investigations support this result, the implication would be that colloid releases from the repository are dominated by the large-sized colloids.

6.2.5 Scientific Investigations

Because the EAs generate a series of results with PDCs fixed at 1.0, they tend to mask the effects of the scientific program. Therefore, to determine the impact of the scientific program, the EAs and WACs were filtered out of the analysis. Figures 6-4 and 6-5 show two 3-D bar charts of the scientific activities in terms of incremental cost, duration, and the largest PDC for a given cost/duration category. The general trend, as one would expect, is that the PDC tends to increase with either increasing cost or increasing duration. It is by considering the 3-D bar chart and determining which activities result in the highest PDC for a given cost or duration that the paths with low cost and a high probability of success may be found for the WIPP.

A question remaining after the preliminary observations of the SPM-2 results was: In the absence of EA 1 and EA 2, what scientific programs should be undertaken to achieve a high PDC? The answer to this question was important, because EA 1 and EA 2 were assumed to be optimally effective and tended to mask the value of the scientific program. Further analyses of the decision matrix (such as statistical regression analyses), in conjunction with an understanding of the activity sets, yielded the cost/benefit relationship for the elements of the scientific program inherent in the SPM-2 results. The results of these further analyses are described in Volume III of this report.

6.3 Performance Assessment Modifications

The inherent challenges of integrating a multidisciplinary technical team were met by focusing on team building and communication between WIPP analysts and scientific investigators. This enhanced communication changed the fundamental way the project integrates scientific information into WIPP PA analysis. As a result, significant improvements in the WIPP PA capabilities were realized. The capability for rapid inclusion of conceptual models (computational subroutines) requested by the scientific investigators was realized. The code changes listed below were included within a two-month period with sufficient confidence for making programmatic decisions.

- An additional stratigraphic unit was added to allow releases to the surface and through the Dewey Lake, the Magenta, and the anhydrite interbeds.
- The Klinkenberg Effect was incorporated.
- New characteristic curves (modified van Genuchten/Parker Model, fixed relative permeability model) were incorporated.
- Shaft seal properties were varied on different time intervals, so that concrete elements were assumed to degrade after 100 years, and different shaft seal thicknesses were used.
- A modified repository scale was used.
- Water-tracking capability in the repository was incorporated.
- A new porosity surface for no backfill was used with disposal room creep consolidation described by the MD Model.
- A five-year waste-emplacement dewatering period was used.
- Puddling "sponge" parameter in the waste was incorporated.
- A new Disturbed Rock Zone/Transition Zone (DRZ/TZ) was used as a high-permeability connection between the repository and the anhydrite layers MB 139 a and b, and MB 138 via an extended DRZ.
- A Mass-Storage ("bucket") for brine in the anhydrite post processor was incorporated.
- Post-processing reduction factors for colloid releases through Dewey Lake and Culebra were used.
- Additional file-management software for the CRAY and the Paragon was developed.

- An altered Anhydrite Model for anhydrite interbed fracturing was applied to the DRZ and TZ material regions for both halites and anhydrites.

In addition, some of the conceptual models described in Volume II of this report for the SPM-2 baseline are being evaluated through side investigations for incorporation into the WIPP PA codes. These include:

- The effects of repository dip.
- Gas generation from radiolysis.
- Multiple closure surfaces (one for the north end, one for the south end).
- Dynamic changes in waste permeability.
- Wicking in the waste.
- Gas dissolution in brine (Henry's Law).
- Multicomponent gas transport.
- The RPM within BRAGFLO and an option to use the Ideal Gas Law.

Finally, through focused streamlining of the calculational methodology, the number of calculations that can be compiled per unit time has dramatically increased. This improvement will be beneficial for the final compliance analyses, which will require a very large number of calculations.

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7. CONCLUSIONS

SPM-2 has succeeded in providing DOE/CAO with a decision matrix for aiding in programmatic direction for WIPP. Although the results have yet to be fully analyzed and need to be interpreted with consideration of the assumptions and uncertainties, it is clear that the SPM-2 decision matrix contains valuable information for identifying:

1) activity sets necessary for a given PDC,
2) activity sets that give the maximum PDC,
3) activities that have minimal impact on the PDC, and
4) the potential worth, with respect to demonstrating compliance, of individual activities.

Because of the assumptions and uncertainties inherent in SPM-2, final programmatic decisions should also consider existing information from the 1992 WIPP PA Sensitivity Analysis (WIPP PA, 1993), broad technical and compliance issues, and the available results of side investigations.

The key issues that must be considered in the use of the SPM-2 results are that

1) the technical baseline is conservative, for decision-aiding only, and not necessarily an indication of the PTB, which will be used to prepare the WIPP FCCA,
2) the results based on calculations using mean values are valid for discriminating between activities intended to shift a mean value for a parameter, but not for discriminating between activities intended to reduce uncertainty about a mean, and
3) the impacts on SPM-2 results of not including all conceptual models called for in the SPM-2 technical baseline cannot be determined at this time, and, therefore, these impacts are to be studied as side investigations.

The first issue is only a reminder of SPM's intended use, which does not include compliance calculations. With respect to the second issue, virtually all of the elicited values for potential outcomes of activities moved the parameter distributions instead of narrowing them. The full impact in SPM-2 of using mean values can only be ascertained by using LHS on all of the SPM-2 calculations. An appropriate way to confirm the calculation for the activity set selected for implementation is to perform an LHS calculation for that set. Finally, side investigations are being planned and prioritized to address the most pressing concerns of WIPP Project scientists with respect to conceptual models that could not, at this time, be implemented. Results from these investigations will be communicated immediately to DOE/CAO upon completion.

Multiple benefits accrued to the WIPP Project as a result of SPM in addition to the production of the information contained in the SPM-2 decision matrix. Major benefits that will have far-reaching significance as the WIPP Project moves forward are that SPM-2 successfully:

1) brought the project participants and stakeholders together to define relevant issues to be addressed in a compliance application,

2) advanced the suite of conceptual models that could be used for a WIPP PA,

3) advanced the state-of-the-art speed in calculating a WIPP CCDF,

4) advanced the state-of-the-art in managing input information into a large suite of PA calculations,

5) developed visualization tools to study large decision matrixes, and

6) performed analyses showing the contribution of major WIPP activities, including EAs and WAC, towards a successful demonstration of compliance with selected EPA long-term performance regulations.

8. REFERENCES

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Nowak, E. J., D. F. McTigue, and R. Beraun. 1988. *Brine Inflow to WIPP Disposal Rooms: Data, Modeling, and Assessment*. SAND88-0112.

U.S. DOE (Department of Energy). 1995. *Waste Isolation Pilot Plant Transuranic Waste Baseline Inventory Report*. CAO-94-1005, Revision 1. [Carlsbad, NM]: WIPP Technical Assistance Contractor for U.S. Department of Energy. Vols. 1-2.

WIPP PA (Performance Assessment) Department. 1992. *Preliminary Performance Assessment for the Waste Isolation Pilot Plant, December 1992. Volume 2: Technical Basis*. SAND92-0700/2. Albuquerque, NM: Sandia National Laboratories.

WIPP PA (Performance Assessment) Department. 1993. *Preliminary Performance Assessment for the Waste Isolation Pilot Plant, December 1992. Volume 4: Uncertainty and Sensitivity Analyses for 40 CFR 191, Subpart B*. SAND92-0700/4. Albuquerque, NM: Sandia National Laboratories.

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9. GLOSSARY

Activity - A field experiment, lab experiment, novel analysis, change in the engineering design, change in the WAC, discussion with the regulator, literature search of existing information bases, or other option available to the WIPP Project that has the potential to influence CIs.

Activity Set - A collection of activities that constitutes a coherent program option. SPM associates a PDC with each activity set.

Compliance Indicator (CI) - The binary measure that indicates whether the WIPP disposal system is predicted to succeed or fail with respect to meeting the selected post-closure performance requirements in 40 CFR 191.13(a) and 40 CFR 268.6.

Dual Permeability - A conceptualization of flow and transport through a fractured porous media where flow, advective transport, and mechanical dispersion take place simultaneously through both the fractures and pore space. Exchange of fluid and solute between the two continua are also modeled.

Dual Porosity - An idealized conceptualization of contaminant transport through a fractured, porous media where advective transport is assumed to take place only in the fracture, and there is a local exchange of solute between the fracture and matrix controlled by one-dimensional diffusion. No transport is assumed to take place in the matrix. The dual-porosity model results in physical retardation of solute. There is also an equivalent dual-porosity conceptualization for fluid flow that is not modeled in SPM-2.

E1 Intrusion Scenario - A characterization of an alternative future state of the WIPP disposal system that models an inadvertent exploratory borehole intersecting the repository and a hypothetical pressurized brine reservoir in the underlying Castile formation.

E2 Intrusion Scenario - A characterization of an alternative future state of the WIPP disposal system that models an inadvertent exploratory borehole intersecting the repository and missing the hypothetical brine reservoir.

E1E2 Intrusion Scenario - A characterization of an alternative future state of the WIPP disposal system that models two inadvertent exploratory boreholes intersecting the repository, only one of which hits an underlying brine reservoir. With robust panel seals, both boreholes must intersect a panel; panels are isolated. With degraded or failed seals, any two such boreholes must intersect the repository.

Potential Outcome - The predicted result of implementing an activity. If the result is uncertain, two or more outcomes are defined to represent the range of possible results of an activity. Each outcome is associated with a specific activity, and is characterized by a description, a probability of occurrence if the activity is conducted and the effect of the outcome on performance evaluation.

Performance Assessment (PA) - Models, data, codes, calculations, and modeling results that are intended to be used in WIPP compliance documents.

Probability of Demonstrating Compliance (PDC) - The probability that sets of programmatic options of a specified cost and duration, if implemented, will support compliance with selected EPA long-term performance regulations.

Project Technical Baseline (PTB) - The conceptual models and data for the WIPP disposal system that will be used to prepare the FCCA. The PTB will be based on refinements and changes to the SPM-2 technical baseline that arise from additional information about system behavior from new sensitivity analyses, calculations focused on addressing specific technical and compliance issues, and new information generated as a result of WIPP Project activities implemented after SPM-2.

SPM-2 Calculational Baseline - The calculational implementation of the conceptual models and data called for by the SPM-2 technical baseline.

SPM-2 Technical Baseline - The conceptual models and data for the WIPP disposal system based on existing knowledge, data, and documented work as established by the WIPP scientific investigators for SPM-2.

APPENDIX A:
TABLE OF SYSTEMS PRIORITIZATION METHOD - ITERATION TWO (SPM-2) SIDE INVESTIGATIONS

APPENDIX A:
TABLE OF SYSTEMS PRIORITIZATION METHOD - ITERATION 2 (SPM-2) SIDE INVESTIGATIONS

Side Investigation	Rationale*
Brine storage in the anhydrite and surrounding halite	1
Mechanical effects of gas generation on the Salado Formation	2
Applicability of using 2-D/pseudo 3-D calculations including dynamic alteration of disturbed rock (transition) zone	1, 2
Effect of DRZ and TZ	1
Gas exsolution effects on brine inflow	2
The effects of 1degree dip in the repository	1, 2
Dynamic dependence of threshold displacement pressure with permeability in anhydrite interbeds	1, 2
Detailed 3-D room flow model (including dip) with detail at the drum scale to support	1, 2
Circulation of fluid in repository during drilling and after abandonment	1
Reevaluation of gas entrainment	1
Wicking, mobile brine saturation, and two-phase flow properties of the waste	2
Dynamic closure of unfilled excavations (north end)	1
Dynamic dependence of permeability on porosity during creep consolidation	1
Red Bed retardation and the role of the Dewey Lake in regional hydrologic behavior	1, 2
Radiolysis	3
RPM	3
Calculations related to thermal effects on fluid flow	3
Salado near misses, flow to surface during drilling, and flow through abandoned boreholes	3
Nuclear criticality	3
Evaluation of borehole connections to units below repository	3
Non-Salado/Regional 3-D modeling	3
Screening of minor FEPs	3

* 1 = Investigation is required to substantiate a technical position taken in the SPM-2 technical baseline.
2 = Conceptual models in the SPM-2 technical baseline that were not incorporated into the SPM-2 codes.
3 = Investigation is required to support scenario screening.

APPENDIX B:
TABLE OF SYSTEMS PRIORITIZATION METHOD - ITERATION TWO (SPM-2) CALCULATION CASE IDENTIFIERS AND CODES

APPENDIX B:
TABLE OF SYSTEMS PRIORITIZATION METHOD - ITERATION 2 (SPM-2) CALCULATION CASE IDENTIFIERS AND CODES

Case Identifier	Code	Value	Description	Related Activities
IENG	BRAGFLO	1	Base case (as received)	None
	PANEL	2	Backfill with pH buffer and waste-form modification	EA 2
		3	Backfill with pH buffer	EA 1
		4	Non-corroding waste containers for future waste	WAC 1
		5	Eliminate humic materials from waste	WAC 2
		6	Eliminate humic materials from waste; backfill with pH buffer and waste-form modification	WAC 2, EA 2
		7	Eliminate humic materials from waste; backfill with pH buffer	WAC 2, EA 1
		8	Eliminate humic materials from waste; non-corroding waste containers for future waste	WAC 2, WAC 1
		9	Passive markers	EA 3
ISHAFT	BRAGFLO	1	Baseline shaft permeability	None
		2	Shaft permeabilities associated with successful completion of RM 1+ SL 4	RM 1, SL 4
IANHY	BRAGFLO	1	Baseline anhydrite permeability	None
		2	Anhydrite permeabilities associated with successful completion of SAL 1	SAL 1
IHAL	BRAGFLO	1	Baseline halite properties	None
		2	Halite properties associated with successful completion of SAL 2 + SAL 3	SAL 2, SAL 3

Table of SPM-2 Calculation Case Identifiers and Codes (Cont.)

Case Identifier	Code	Value	Description	Related Activities
IBLW	CUTTINGS	1	Baseline blowout release factor	None
		$1+i$	Blowout release factor associated with ith binned outcome of DR 2, where $i = 1$ to 10	DR 2
INOBLW	CUTTINGS	1	Baseline non-blowout release factor	None
		$1+i$	Non-blowout release factor associated with ith binned outcome of DR 3, where $i = 1$ to 5	DR 3
ICHMSOL	PANEL	1	Baseline actinide solubilities	None
		2	Actinide solubilities associated with successful outcome of AST 1.1	AST 1.1
		3	Actinide solubilities associated with successful outcome of AST 1.2	AST 1.2
		4	Actinide solubilities associated with pH buffer	EA 1, EA 2
ICOLSOL	PANEL	1	Baseline colloidal solubilities and retardation factors	None
	SECOTP	2	Colloid concentrations associated with successful outcome of NS 8.1	NS 8.1
		3	Colloid concentrations associated with successful outcome of NS 8.2	NS 8.2
IFRAC	SECO-TP	1	Baseline Culebra fracture spacing (7.7 m)	None
		2	Culebra fracture spacing = 3.0 m	NS 2, NS 3, NS 4
		3	Culebra fracture spacing = 1.5 m	NS 2, NS 3, NS 4
		4	Culebra fracture spacing = 0.75 m	NS 2, NS 3, NS 4
		5	Culebra fracture spacing = 0.30 m	NS 2, NS 3, NS 4

Table of SPM-2 Calculation Case Identifiers and Codes (Cont.)

Case Identifier	Code	Value	Description	Related Activities
ICHMRTD	SECO-TP	1	Baseline sorption coefficients	None
		2	Sorption coefficients associated with successful outcome of NS 6, or of NS 5 + NS 6	NS 5, NS 6
		3	Sorption coefficients associated with successful outcome of NS 7, or of NS 5 + NS 7	NS 5, NS 7
ICOLRTD	SECO-TP	1	Baseline colloid diffusion coefficients and retardation factors	None
		2	Colloid diffusion coefficients and retardation factors associated with successful outcome of NS 8.1	NS 8.1

APPENDIX C:
MEMORANDA AND LETTERS REGARDING REFERENCE DATA

Drez, January 3, 1995 ..... C-5
Fewell and Sanchez, March 29, 1995 ..... C-13
Fitch, March 21, 1995 ..... C-27
Goldstein, Prindle, and Trauth, November 3, 1994 ..... C-33
McFadden, December 19, 1994 ..... C-41
Reiser, March 10, 1995 ..... C-45
Weart, December 1, 1994 ..... C-49
Weart, December 14, 1994 ..... C-55

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APPENDIX C:
MEMORANDA AND LETTERS REGARDING REFERENCE DATA

Drez, January 3, 1995

Date: 1/3/95
To: File
From: P. Drez
Subject: Waste Material Parameter and Radionuclide Inventories for SPM-2 Calculations Derived from Draft WTWBIR Rev. 1 and IDB Rev. 10 Databases.

Fewell and Sanchez, March 29, 1995

Date: 3/29/95
To: F. Mendenhall and N. Prindle
From: M. Fewell and P. Sanchez
Subject: Soil-Based VOC and Semi-VOC Concentration in the Gas Phase for SPM-2

Fitch, March 21, 1995

Date: 3/21/95
To: M. McFadden
From: Fitch
Subject: Future Inadvertent Intrusion Rates

Goldstein, Prindle, and Trauth, November 3, 1994

Date: 11/3/94
To: Distribution
From: S. Goldstein, N. Prindle, and K. Trauth
Subject: Guidance on the SPM-2 Elicitation Process

McFadden, December 19, 1994

Date: 12/19/94
To: R. Lincoln
From: M. McFadden
Subject: Systems Prioritization Method Information Needs and Product Requirements.

Reiser, March 10, 1995

Date: 3/10/95
To: N. Prindle
From: A. Reiser
Subject: Examples of Actions in Response to Stakeholder Comments

Weart, December 1, 1994

Date: 12/1/94
To: SNL WIPP Managers and Principal Investigators
From: W. Weart
Subject: Process for SNL WIPP Programmatic Review of SPM-2 Baseline and Activities

Weart, December 14, 1994

Date: 12/14/94
To: SNL WIPP Managers
From: W. Weart
Subject: Direction for Completion of the Programmatic Review of the SPM-2 Baseline and Activities

Drez, January 3, 1995

Date: 1/3/95
To: File
From: P. Drez
Subject: Waste Material Parameter and Radionuclide Inventories for SPM-2 Calculations Derived from Draft WTWBIR Rev. 1 and IDB Rev. 10 Databases.

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Date: January 3, 1995

From: Paul E. Drez PED

To: File

Subject: Waste material parameter and radionuclide inventories for SPM2 calculations derived from DRAFT WTWBIR Rev. 1 and IDB Rev. 10 databases

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Waste Material Parameter Data

The waste material parameter data for CH-TRU and RH-TRU wastes are reported in the attached Tables 1 and 2. These tables replace Tables 6-2 and 6-3 of Rev. 0 of the WTWBIR and subsequent internal revisions supplied to Sandia/NM on September 27, 1994 and November 29, 1994. Sandia/NM should assume for the attached tables the design basis volumes for CH-TRU (1.75E+05 $m^3 \approx$ 6.2E+06 ft^3) and RH-TRU (7080 $m^3 \approx$ 7955 canisters x 0.89 m^3/canister) wastes. Estimates of waste container materials have been provided at the bottom of the tables.

The stored and projected CH-TRU volumes for WIPP CH-TRU wastes from the Rev. 1 WTWBIR (due out 1/31/95) database has now increased to approximately 1.6E+05 m^3 (from 1.27E+05 m^3 in WTWBIR Rev. 0), requiring only a small amount of scaling to the WIPP design volume. One of the main reasons for this is the large projected volume of CH-TRU waste from the Savannah River Site (SRS).

Radionuclide Inventory Data

The WTWBIR effort has been aimed at deriving an inventory on a waste stream basis, rather than reporting "upper level" waste volumes as published in the IDB. For the Rev. 1 data submitted by the TRU waste generator/storage sites, we still do not have closure between the volume data in the IDB and the WTWBIR, that is, the volumes for the waste streams at some sites do not add up to the "total" volumes in the IDB. This closure should be achieved with the Rev. 2 WTWBIR data call due out by March 1995. Therefore, we have used the volume data from the DRAFT Rev. 10 IDB database to make the estimates of stored and projected volumes used in deriving the radionuclide information. By using the volume and radionuclide data from the IDB database, we have one internally consistent set of data for estimating the radionuclide inventory.

Table 3 represents the <u>total</u> radionuclide inventory for CH-TRU and RH-TRU wastes as derived from the Rev. 10 IDB database (to be published in the Spring of 1995). Sandia should use these numbers for the <u>total</u> design inventory for CH-TRU and RH-TRU as earlier defined in this memo. No calculations are necessary.
A few points of note about the inventory are included below:

- The total radionuclide inventory for CH-TRU waste is much higher than that included in the Rev. 0 of the WTWBIR. This is primarily due to two changes:

- The SRS has reported a large volume of CH-TRU projected waste in the IDB (~5.1E+04 m^3), which was previously reported as "unknown." With the historically high Pu-238 content, this considerably raises the total curies in the CH-TRU inventory.

- During the calculations for the Rev. 0 inventory, the "projected" part (1993-2022) of the CH-TRU radionuclide inventory was accidently left out of the totals reported, causing the inventory numbers to be low (~25%). This has been corrected in this inventory definition.

- The total radionuclide inventory for RH-TRU waste is also much higher than that included in the Rev. 0 of the WTWBIR. During calculation of the RH-TRU inventory the volume defined by the sites included more waste than the repository could hold. I did not realize that the IDB radionuclide numbers only covered the "stored" part of the inventory. This made the WTWBIR reported RH-TRU inventory low by a factor of approximately 3-4. This has been corrected in this inventory definition.

- Considerably more RH-TRU waste has been reported in the Rev. 1 data submittals from the TRU waste generator/storage sites than the design capacity of WIPP. This is due to a very large submittal of RH-TRU waste from Hanford and a much smaller amount from SRS. The two sites were unable to define a radionuclide inventory for these waste streams. Therefore, these projected waste streams have been "set aside" and the calculations included in this memo use only those stored RH-TRU waste streams for which radionuclide data was submitted in the IDB. These stored volumes of RH-TRU waste, and the associated radionuclide inventories, have been use to correct for projected volumes and then scaling (as defined in Rev. 0 of the WTWBIR) of the RH-TRU volumes and radionuclide inventories to the design basis for WIPP (7955 canisters).

- Oak Ridge National Laboratory (ORNL) has not revised their ultra conservative estimate for U-235 in RH-TRU waste. Therefore, the U-235 number included in this data package is the same calculated number that was reported in the memo to file dated September 27, 1994, previously provided to Sandia.

The number is derived from the anticipated initial transportation limit in the RH-TRU cask of 325 grams of Pu-239 fissile gram equivalent (FGE). Assuming a 1:1 equivalence of U-235 FGE (as required by the TRUPACT-II SARP) to Pu-239, this provides a bounding limit of 325 grams of U-235/canister X 7955 canisters x 2.19E-06 curies/gram = 5.66 curies of U-235 in RH-TRU waste inventory. This number has been substituted in Table 3 to replace the overly conservative data reported by ORNL.

cc: Jimmy Dyke, DOE-CAO
John Suermann, DOE-CAO
J. Williams, DOE-EM-30
R. Lincoln, SNL/NM
D. Schafer, SNL/NM
F. Mendenhall, SNL/NM

DRAFT

Table 1. CH-TRU WIPP Matrix Waste Parameter Profile Data for SPM-2

	Materials	(Kg/m3)		
		Maximum	Average	Minimum
Inorganics	Iron Based	2.5E+03	1.4E+02	0.0E+00
	Aluminum Based	1.3E+03	2.1E+01	0.0E+00
	Other Metals	1.4E+03	4.7E+01	0.0E+00
	Other Inorganics	2.1E+03	2.7E+01	0.0E+00
Organics	Cellulose	9.6E+02	1.3E+02	0.0E+00
	Rubber	6.8E+02	1.6E+01	0.0E+00
	Plastics	8.9E+02	5.1E+01	0.0E+00
Solidified Materials	Inorganic	2.2E+03	2.1E+02	0.0E+00
	Organic	1.4E+03	4.0E+00	0.0E+00
Soils		1.6E+03	7.9E+00	0.0E+00
Container Materials	Steel		1.4E+02	
	Plastic/Liners		3.2E+01	

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Table 2. RH-TRU WIPP Matrix Waste Parameter Profile Data for SPM-2

	Materials	(Kg/m3)		
		Maximum	Average	Minimum
Inorganics	Iron Based	2.5E+03	1.3E+02	0.0E+00
	Aluminum Based	6.1E+02	3.1E+01	0.0E+00
	Other Metals	9.1E+02	4.9E+00	0.0E+00
	Other Inorganics	2.0E+03	3.3E+00	0.0E+00
Organics	Cellulose	4.8E+02	1.1E+01	0.0E+00
	Rubber	1.9E+02	3.1E+00	0.0E+00
	Plastics	5.5E+02	1.9E+01	0.0E+00
Solidified Materials	Inorganic	1.1E+03	1.3E+01	0.0E+00
	Organic	3.0E+00	6.4E-04	0.0E+00
Soils		1.9E+02	1.9E+00	0.0E+00
Container Materials	Steel		4.5E+02	
	Plastic/Liners		1.0E+00	
	Lead		4.7E+02	
	Steel Plug		2.2E+03	

Table 3. CH-TRU and RH-TRU Radionuclide Inventory for SPM 2 Calculations

Radionuclide	CH Curies	RH Curies
Ac-227	1.17E+00	3.35E-03
Am-240	1.61E-02	0.00E+00
Am-241	2.40E+05	2.21E+02
Am-243	3.57E+01	3.90E-03
Ba-137M	1.59E+04	3.77E+05
Bi-214	4.80E-02	0.00E+00
Bk-249	5.88E+02	6.70E-04
C-14	5.42E-04	7.91E+01
Cd-109	6.68E+03	0.00E+00
Ce-144	1.42E+04	3.58E+05
Cf-249	5.33E-02	4.52E-02
Cf-250	5.40E-01	6.09E-01
Cf-251	4.03E-03	0.00E+00
Cf-252	2.96E+03	2.01E+02
Cm-242	6.73E+01	0.00E+00
Cm-243	1.59E+00	1.22E+03
Cm-244	1.38E+04	7.73E+03
Cm-245	4.25E+01	0.00E+00
Cm-246	1.08E-01	0.00E+00
Cm-248	2.46E-02	00.0E+00
Co-58	2.04E+03	2.58E+05
Co-60	3.02E+02	1.61E+04
Cr-51	1.84E+02	2.30E+04
Cs-134	3.69E+02	1.48E+04
Cs-137	2.07E+04	5.53E+05
Es-253	1.02E+01	0.00E+00
Es-254	1.99E-02	0.00E+00
Es-254M	1.40E+01	0.00E+00
Eu-150	4.50E-05	0.00E+00
Eu-152	8.96E+01	3.76E+04
Eu-154	8.86E+01	2.29E+04
Eu-155	5.84E+01	6.71E+03
Fe-55	6.11E-04	1.99E+01
Fe-59	2.32E+01	2.31E+03
H-3	2.07E+00	4.66E+01
Kr-85	4.00E-01	4.83E+01
Mn-54	1.40E+03	1.78E+05
Nb-95	2.75E+03	6.52E+04
Ni-59	8.45E-03	0.00E+00
Ni-63	1.16E+00	1.90E+01
Np-237	6.67E+01	9.18E-03
Np-239	1.82E-02	0.00E+00
Pa-231	3.30E-03	0.00E+00
Pa-233	1.97E-03	0.00E+00
Pb-210	2.10E-02	0.00E+00

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Table 3. CH-TRU and RH-TRU Radionuclide Inventory for SPM 2 Calculations (continued)

Radionuclide	CH Curies	RH Curies
Pb-214	4.80E-02	0.00E+00
Pm-147	5.25E+02	1.81E+03
Po-209	2.56E-06	0.00E+00
Po-210	2.52E-03	0.00E+00
Po-214	4.80E-02	0.00E+00
Po-218	4.80E-02	0.00E+00
Pr-144	1.42E+04	3.37E+05
Pu-236	5.76E-02	0.00E+00
Pu-238	4.24E+06	2.22E+03
Pu-239	3.92E+05	4.44E+03
Pu-240	6.93E+04	1.05E+03
Pu-241	1.93E+06	6.06E+04
Pu-242	4.91E+04	1.09E+01
Pu-244	1.00E-06	0.00E+00
Pu-245	0.00E+00	3.35E-03
Ra-226	5.57E+00	1.42E+01
Ra-228	2.75E-01	0.00E+00
Rh-106	6.20E+03	1.47E+05
Rn-222	4.80E-02	0.00E+00
Ru-106	6.20E+03	1.50E+05
Sb-125	2.84E+03	6.72E+04
Sb-126	1.56E-01	0.00E+00
Sm-151	1.07E+02	2.52E+03
Sr-90	9.85E+03	5.48E+05
Ta-182	0.00E+00	3.79E+00
Tc-99	4.22E+01	4.59E+02
Te-125M	7.09E+02	1.67E+04
Th-228	1.12E+00	1.34E-01
Th-230	2.08E-02	0.00E+00
Th-232	6.11E-01	1.51E-02
Th-234	9.50E-05	0.00E+00
U-232	3.02E+01	6.70E+00
U-233	1.31E+03	4.80E+02
U-234	1.75E+01	0.00E+00
U-235	1.15E+00	5.66E+00
U-236	2.98E-01	0.00E+00
U-238	2.01E-01	7.28E+00
Y-90	7.55E+03	1.79E+05
Zn-65	7.00E+00	8.83E+02
Zr-95	1.30E+03	3.25E+04

Radionuclide	CH Curies	RH Curies
Total	7.05E+06	3.47E+06

Fewell and Sanchez, March 29, 1995

Date: 3/29/95
To: F. Mendenhall and N. Prindle
From: M. Fewell and P. Sanchez
Subject: Soil-Based VOC and Semi-VOC Concentration in the Gas Phase for SPM-2

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Sandia National Laboratories

Albuquerque, New Mexico 87185-1328MS1328

date: March 29, 1995

to: Fred Mendenhall, MS-1335 (6705)
and Nancy Prindle, MS-1335 (6705)

Mert Fewell Mert Fewell for Paul Sanchez

from: Mert Fewell, MS-1328 (6749)
and Paul Sanchez, MS-1395 (6700)

subject: Soil-based VOC and Semi-VOC Concentrations in the gas phase for SPM-2

The WID model for the VOC and semi-VOC source term is used to calculate upper bounds for the soil based concentrations of VOC's and semi-VOCs in the upper shaft seal and in the anhydrite layers at the land withdrawal boundary.

The soil-based concentration of hazardous constituent i in the gas phase is given by

$$c_{sb}^{i}=\frac{M_i}{M}=\frac{1000\rho_i\phi s_g V}{\overline{\rho}_{sd}V}=\frac{1000\rho_i\phi s_g}{\overline{\rho}_{sd}} \qquad (1)$$

where

$$\overline{\rho}_{sd}=\left[\rho_{gr}(1-\phi)+\rho_b(1-s_g)\phi+\overbrace{\rho_m\phi s_g}^{\sim 0}\right], \qquad (2)$$

$$\rho_i=\frac{P_i\hat{M}_i}{\Re T}, \text{ and} \qquad (3)$$

$$s_g=1-s_b, \qquad (4)$$

c_{sb}^{i} ≡ the soil based concentration of hazardous constituent i in volume V (mg/kg),

M_i ≡ the mass of hazardous constituent i contained in the gas phase in volume V (mg),

M ≡ the combined mass of the solid, brine, and gas phases in volume V (kg),

ρ_i ≡ the mass of hazardous constituent i per volume of the gas phase in volume V (g/m^3),

ϕ ≡ the porosity of the solid (-),

s_g ≡ the saturation of the gas phase(-),

V ≡ the formation (rock) volume (m^3),

$\overline{\rho}_{sd}$ ≡ the combined mass of the solid, brine, and gas phases in volume V (kg/m^3),

ρ_{gr} ≡ the grain density of the solid in volume V (kg/m^3),

ρ_b ≡ the brine density (kg/m^3),

ρ_m ≡ the density of the gas phase (kg/m^3)

Note: the density of the gas mixture is assumed to be negligible in comparison to the anhydrite and brine density,

P_i ≡ the partial pressure of hazardous constituent i in the gas phase (Pa),

$\hat{M}_i$ ≡ the molecular weight of hazardous constituent i (g),

$\Re$ ≡ the universal gas constant, (Nt-m/gmole/K),

T ≡ the temperature of the gas phase in volume V (K), and

s_b ≡ the brine saturation (-).

From Equations 1 through 4, soil-based concentrations of hazardous constituents increase with porosity, gas saturation, and the partial pressure of the hazardous constituents in the gas phase. Thus, substitution of upper bounded values for porosity, gas saturation, and partial pressure yields upper bounds for soil-based concentrations of hazardous constituents in the gas phase. Values for the parameters needed to calculate upper bounds for soil-based concentrations are displayed in Table 1.

VOCs

The WID hazardous constituent source term for VOCs in the gas phase is based on the assumption that no post-closure release mechanisms will elevate concentrations of VOCs in the gas phase above those measured in drum headspaces. Using this assumption, the concentrations of VOCs in the gas phase at the regulatory boundaries are bounded by the headspace concentrations; these bounds can be calculated by transferring the headspace concentrations to the boundaries as depicted in Figure 1. In so doing, the maximum partial pressure is given by

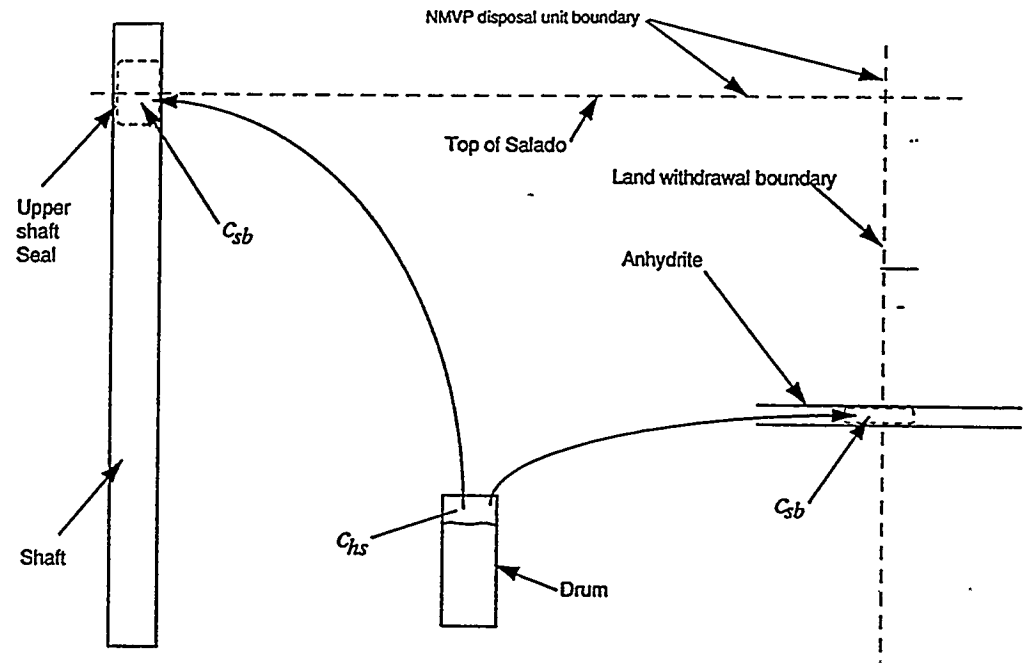
$$P_i = c^i_{hs} P, \tag{5}$$

where

c^i_{hs} ≡ the concentration of VOC i in drum headspaces (-), and

P ≡ the maximum pressure of the gas phase in the repository (PA).

Note: The maximum pressure of the gas phase is assumed to be the lithostatic stress at the repository horizon.



MEF01-30-95

Figure 1. Bounding soil-based VOC concentrations at the regulatory boundaries.

Upper bounds for soil-based concentrations of VOCs in the anhydrite at the land withdrawal boundary and in the upper shaft seals are compared to the health-based soil levels in Table 2 and 3. These values were calculated by substituting the bounding parameter values in Table 1b and the headspace concentration and molecular weight values from Tables 2 and 3 into Equations 1 through 5.

Semi-VOCs

The WID hazardous constituent source term for semi-VOCs assumes that the concentrations are vapor pressure limited.. This means that

$$P_i = P_v^i \qquad (6)$$

where

$P_v^i \equiv$ the vapor pressure of hazardous constituent i at the gas mixture temperature T.

The upper bounds for soil-based concentrations of semi-VOCs in the anhydrite at the land withdrawal boundary and in the upper shaft seals are compared to the health-based soil levels in Table 4 and 5. These values were calculated by substituting the bounding parameter values in Table 1b, the vapor pressure and molecular weight values from Tables 4 and 5, and Equation (6) into Equations 1 through 4.

Conclusions

Based on the WID source term model, upper-bounds of soil-based concentrations in the gas phase are, with the exception of carbon tetrachloride, two orders or more below the health-based levels. The upper-bounds of the soil-based concentration of carbon tetrachloride is at the health-based level in anhydrite and is below, but of the same order of magnitude as, the health-based soil level in the upper shaft seals (Tables 2 through 5). The soil-based concentration of carbon tetrachloride is more than an order of magnitude less than the health-based soil level for the lower limit of porosity in the anhydrite.

While concentrations in the repository may exceed those calculated by the WID source term model during the 10,000 year post-closure period, the results presented here do not consider transport, dilution of waste generated gas, degradation, and other processes that could lower hazardous constituent concentrations.

Table 1. WIPP values for parameters required in the calculation of soil-based concentrations of hazardous constituents

a. Parameters values

Parameter	Value		Source
Lithostatic pressure	14.8	(mPa)	SPM-2 database
Universal gas constant	8.317	(Nt-m/gmole K)	—
Repository temperature	300	(K)	-
Anhydrite porosity	0.1-3%		SPM-2 database
Residual brine saturation in the anhydrite	0-60%		SPM-2 database
Upper shaft seal porosity	5%		SPM-2 database
Residual brine saturation in the upper shaft seal	20%		SPM-2 database
Anhydrite grain density	2.96E+03	(kg/m3)	SPM-2 database
Brine density	1.23E+03	(kg/m3)	1992 PA
Upper shaft seal grain density	2.16E+03	(kg/m3)	SPM-2 database

b. Bounding values.

Parameter	Value
Anhydrite porosity	3.00%
Maximum gas saturation in anhydrite	100.00% *
Local soil density of anhydrite	2.87E+03
Upper shaft seal porosity	5.00%
Maximum gas saturation in upper shaft seal	80.00% *
Local soil density of the upper shaft seal	2.10E+03

* The maximum gas saturation corresponds to the minimum brine saturation, i.e. the residual brine saturation.

Table 2. Upper Bounded Headspace Concentration Limited Soil Based VOC Concentrations in Anhydrite

VOCs	C_{hs}^{i} (ppmv)	$\hat{M}_i$ (g)	C_{hbs}^{i} (mg/kg)	C_{sb}^{i} (mg/kg)
Acetone	92.6	58.08	0.33	8,000.
Benzene	9.18	78.11	0.04	24.14
Bromoform	9.09	252.7	0.14	88.61
1-Butanol	101	74.12	0.46	8,000.
2-Butanone/Methyl ethyl ketone	76.2	72.1	0.34	4,800.
Carbon disulfide		76.13		8,000.
Carbon tetrachloride	560	153.8	5.33 *	5.38
Chlorobenzene	12.1	112.6	0.08	1,600.
Chloroform	15.5	119.4	0.11	114.75
Cyclohexane	15.4	84.15	0.08	Note 7.
Cyclohexanone		98.15		400,000.
1,1-Dichloroethane	9.26	98.96	0.06	Note 7.
1,2-Dichloroethane	9.07	98.96	0.06	7.69
1,1-Dichloroethylene (ene)	11.1	96.94	0.07	11.67
(Z)-1,2-Dichloroethylene (ene)	9.05	96.94	0.05	Note 7.
Ethyl acetate		88.11		72,000.
Ethyl benzene	10.1	106.2	0.07	8,000.
Diethyl ether	12.1	74.12	0.06	16,000.
2-Ethoxyethanol		90.12		Note 7.
Formaldehyde		30.03		16,000.
Hydrazine		32.05		0.23
Isobutanol		74.12		24,000.

* = 0.18 mg/kg for .1% porosity (the lower limit from Table 1)

Notes:

1. Blanks indicate that data are not available.
2. The list of VOCs were compiled from the union of the target compounds identified for waste characterization in *Resource Conservation and Recovery Act Part B Permit Application.* DOE/WIPP 91-005, Rev. 3 and the list of VOCs found in letter WD:95:0214 from L. R. Fitch, Manager, Environment, Safety, Health, and Regulatory Compliance, Westinghouse Isolation Division, Westinghouse Electric Corporation to Dr. J. A. Mewhinney dated January 25, 1995.
3. C_{hs}^{i} is the headspace concentration for constituent i found in letter WD:95:0214 from L. R. Fitch, Manager, Environment, Safety, Health, and Regulatory Compliance, Westinghouse Isolation Division, Westinghouse Electric Corporation to Dr. J. A. Mewhinney dated January 25, 1995.
4. $\hat{M}_i$ is the molecular weight of constituent i.
5. C_{hbs}^{i} is the headspace limited health-based soil level for constituent i.
6. C_{sb}^{i} is the health-based soil level for constituent i. These levels represent the most stringent limits for either carcinogenic or systemic risk from oral exposure. See memorandum from Paul Sanchez to Peter Swift and Mert Fewell dated January 24, 1995.
7. No health-based standard in IRIS 2 database.

Table 2. Upper Bounded Headspace Concentration Limited Soil Based VOC Concentrations in Anhydrite (conc.)

VOCs	C_{hs}^{i} (ppmv)	$\hat{M}_i$ (g)	C_{hbs}^{i} (mg/kg)	C_{sb}^{i} (mg/kg)
Methanol	261	32.04	0.52	40,000.
Methylene chloride	739	50.49	2.31	93.33
Methyl isobutyl ketone	97.9	100.2	0.61	4,000.
2-Nitropropane		105.1		Note 7.
1,1,2,2-Tetrachloroethane	9.11	167.9	0.09	35.
Tetrachloroethylene (ene)	9.09	165.8	0.09	13.73
Toluene	25.1	92.14	0.14	16,000.
1,1,2-Trichloroethane		133.4		122.81
1,1,1-Trichloroethane	492	133.4	4.06	7,200.
Trichloroethylene (ene)	21.2	131.4	0.17	63.64
Trichlorofluoromethane		137.4		24,000.
1,3,5-Trimethylbenzene	8.96	120.2	0.07	Note 7.
1,2,4-Trimethlybenzene	12.1	120.2	0.09	Note 7.
1,1,2-Trichloro-1,2,2-trifluoroethane	52.4	187.4	0.61	2,400,000.
Vinyl chloride		62.5		Note 7.
p/m-xylene	12.6	106.2	0.08	160,000.
0-Xylene	15.3	106.2	0.10	160,000.

Notes:

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5. C_{hbs}^{i} is the headspace limited health-based soil level for constituent i.
6. C_{sb}^{i} is the health-based soil level for constituent i. These levels represent the most stringent limits for either carcinogenic or systemic risk from oral exposure. See memorandum from Paul Sanchez to Peter Swift and Mert Fewell dated January 24, 1995.
7. No health-based standard in IRIS 2 database.

Table 3. Upper Bounded Headspace Concentration Limited Soil Based VOC Concentrations in the Upper Shaft Seals

VOCs	C_{hs}^{i} (ppmv)	$\hat{M}_i$ (g)	C_{hbs}^{i} (mg/kg)	C_{sb}^{i} (mg/kg)
Acetone	92.6	58.08	0.15	8,000.
Benzene	9.18	78.11	0.02	24.14
Bromoform	9.09	252.7	0.06	88.61
1-Butanol	101	74.12	0.21	8,000.
2-Butanone/Methyl ethyl ketone	76.2	72.1	0.15	4,800.
Carbon disulfide		76.13		8,000.
Carbon tetrachloride	560	153.8	2.43	5.38
Chlorobenzene	12.1	112.6	0.04	1,600.
Chloroform	15.5	119.4	0.05	114.75
Cyclohexane	15.4	84.15	0.04	Note 7.
Cyclohexanone		98.15		400,000.
1,1-Dichloroethane	9.26	98.96	0.03	Note 7.
1,2-Dichloroethane	9.07	98.96	0.03	7.69
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Ethyl acetate		88.11		72,000.
Ethyl benzene	10.1	106.2	0.03	8,000.
Diethyl ether	12.1	74.12	0.03	16,000.
2-Ethoxyethanol		90.12		Note 7.
Formaldehyde		30.03		16,000.
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Isobutanol		74.12		24,000.

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Table 3. Upper Bounded Headspace Concentration Limited Soil Based VOC Concentrations in the Upper Shaft Seals (conc.)

VOCs	C_{hs}^{i} (ppmv)	$\hat{M}_i$ (g)	C_{hbs}^{i} (mg/kg)	C_{sb}^{i} (mg/kg)
Methanol	261	32.04	0.24	40,000.
Methylene chloride	739	50.49	1.05	93.33
Methyl isobutyl ketone	97.9	100.2	0.28	4,000.
2-Nitropropane		105.1		Note 7.
1,1,2,2-Tetrachloroethane	9.11	167.9	0.04	35.
Tetrachloroethylene (ene)	9.09	165.8	0.04	13.73
Toluene	25.1	92.14	0.07	16,000.
1,1,2-Trichloroethane		133.4		122.81
1,1,1-Trichloroethane	492	133.4	1.85	7,200.
Trichloroethylene (ene)	21.2	131.4	0.08	63.64
Trichlorofluoromethane		137.4		24,000.
1,3,5-Trimethylbenzene	8.96	120.2	0.03	Note 7.
1,2,4-Trimethlybenzene	12.1	120.2	0.04	Note 7.
1,1,2-Trichloro-1,2,2-trifluoroethane	52.4	187.4	0.28	2,400,000.
Vinyl chloride		62.5		Note 7.
p/m-xylene	12.6	106.2	0.04	160,000.
0-Xylene	15.3	106.2	0.05	160,000.

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7. No health-based standard in IRIS 2 database.

Table 4. Saturation Pressure Limited Soil Based Semi-VOC Concentrations in Anhydrite

Semi-VOCS	P_v^i (atm)	$\hat{M}_i$ (g)	C_{vbs}^i (mg/kg)	C_{sb}^i (mg/kg)
Cresols (o, m, p)	4.77E-04	108	0.02	Note 6.
ortho-Dichlorobenzene		146.9		7,200.
1,4-Dichlorobenzene		146.9		Note 6.
2,4-Dinitrotoluene	6.71E-06	182	0.00	1.03
Hexachloroethane	1.00E-03	236.7	0.10	80.
Nitrobenzene	4.03E-04	123	0.02	40.
Polychlorinated biphenyls (PCBs)	1.01E-07	291.8	0.00	0.09
Pyridine	3.04E-02	79	1.02	80.

Notes:

1. Blanks indicate that data are not available.
2. The list of VOCs were compiled from the union of the target compounds identified for waste characterization in *Resource Conservation and Recovery Act Part B Permit Application.* DOE/WIPP 91-005, Rev. 3 and the list of VOCs found in letter WD:95:0214 from L. R. Fitch, Manager, Environment, Safety, Health, and Regulatory Compliance, Westinghouse Isolation Division, Westinghouse Electric Corporation to Dr. J. A. Mewhinney dated January 25, 1995.
3. $\hat{M}_i$ is the molecular weight of constituent i.
4. C_{vbs}^i is the vapor pressure limited health-based soil level for constituent i.
5. C_{sb}^i is the health-based soil level for constituent i. These levels represent the most stringent limits for either carcinogenic or systemic risk from oral exposure. See memorandum from Paul Sanchez to Peter Swift and Mert Fewell dated January 24, 1995.
6. No health-based standard in IRIS 2 database.

Table 5. Saturation Pressure Limited Soil Based Semi-VOC Concentrations in Upper Shaft Seals

Semi-VOCS	P_v^i (atm)	$\hat{M}_i$ (g)	C_{vbs}^i (mg/kg)	C_{sb}^i (mg/kg)
Cresols (o, m, p)	4.77E-04	108	0.01	Note 6.
ortho-Dichlorobenzene		146.9		7,200.
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Hexachloroethane	1.00E-03	236.7	0.05	80.
Nitrobenzene	4.03E-04	123	0.01	40.
Polychlorinated biphenyls (PCBs)	1.01E-07	291.8	0.00	0.09
Pyridine	3.04E-02	79	0.46	80.

Notes:

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2. The list of VOCs were compiled from the union of the target compounds identified for waste characterization in *Resource Conservation and Recovery Act Part B Permit Application.* DOE/WIPP 91-005, Rev. 3 and the list of VOCs found in letter WD:95:0214 from L. R. Fitch, Manager, Environment, Safety, Health, and Regulatory Compliance, Westinghouse Isolation Division, Westinghouse Electric Corporation to Dr. J. A. Mewhinney dated January 25, 1995.
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6. No health-based standard in IRIS 2 database.

Distribution:
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MS-1395, P. Sanchez (6700)
MS-1328, M. Fewell (6749)
SWCF-A: 1.1.2.7;SPM; RCRA; NQ: SBSP2M1.DOC(2 cys)

Fitch, March 21, 1995

Date: 3/21/95
To: M. McFadden
From: Fitch
Subject: Future Inadvertent Intrusion Rates

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Westinghouse
Electric Corporation

Government Operations

WD:95:03113
DA:95:11026
Waste Isolation Division

Box 2078
Carlsbad New Mexico 88221

March 21, 1995

Mr. M. H. McFadden, Assistant Manager
Office of Regulatory Compliance
Carlsbad Area Office
U.S. Department of Energy
P.O. Box 3090
Carlsbad, NM 88221-3090

Subject: FUTURE INADVERTENT INTRUSION RATES

Dear Mr. McFadden:

Per your verbal request, we suggest that you use the following drilling rates for disturbed case, repository performance assessment calculations:

- complete one set of calculations using a rate of 25 events/square kilometer
- complete one set of calculations using a rate of 17.5 events/square kilometer
- complete one set of calculations using a rate of 10 events/square kilometer
- complete one set of calculations using a rate of 3 events/square kilometer
- complete one set of calculations using a rate of 1 event/square kilometer

These calculations will result in the identification of an expected number of inadvertent intrusions into the repository over the 10,000 year performance assessment period at several assumed rates of future drilling. The resultant numbers of calculated, expected intrusions at each of these assumed future drilling rates coupled with an analysis of the consequences of these intrusions will be used to develop permanent marker system design goals. These system design goals will allow the WIPP project to develop a concept that is "effective enough" to deter future inadvertent human intrusion during the 10,000 year regulatory time frame based on the expected level of repository performance.

The justification for, and logic behind such an approach is as follows:

- The WID has initiated research of drilling activities in the Delaware Basin. This assessment is limited to those activities occurring during the last 50 years as recorded in a Petroleum Information Corporation database (received on February 1, 1995), and additional information from the State Engineer's office. We have identified some other potential sources of information that may be useful. We will acquire whatever information that is available to ensure that the resulting expected drilling rate is defensible and that the DOE has shown due diligence in an attempt to include all relevant information. Until we complete this drilling research activity we have no technical or statistical basis for any future inadvertent intrusion rate to be used in assessments of long-term repository performance.

- We are required to design a permanent markers system for compliance with 40 CFR 191. Our intent is to design the permanent marker system to be effective in rendering future inadvertent intrusion events unlikely for the 10,000 year regulatory period of interest. A permanent marker system must be designed to ensure that future generations are warned of the presence of the repository, the wastes, and the associated hazards posed. In the required 10,000 year predictive exercise embodied in repository performance assessment one must consider the affect of future inadvertent intrusions into the repository. These two requirements, when coupled in the same long term performance assessment, make it clear that the impacts of future inadvertent intrusion events can be extremely impactive. The logical conclusion we have reached is that the permanent marker system must be solid.

  When the calculations of repository performance are completed and we have finished the consequence analysis we will be in a position to conclude one of two things. Either the markers must be effective to some degree demonstrate compliance, or that compliance can be demonstrated with a zero level of effectiveness from the markers system and they are therefore a part of fulfilling the assurance requirements. If we conclude that the markers must be effective to demonstrate compliance, we must bear in mind that it will be impossible to quantify with statistical certainty, exactly how effective such a marker system will be, and/or for exactly how long the system can be expected to remain effective. One could conduct a detailed, probablistic assessment of effectiveness on such a marker system in an attempt to quantify such a probability for success. The results of such an assessment would undoubtedly have a substantive level of uncertainty associated with

the result. The applicable regulations require that the markers be effective enough. Exactly what mechanism is best suited for the task of bringing the ideas of "probability" for successful markers and "effective enough" together can be debated at length. However, since we will attack this problem in a regulatory arena, we have concluded that convincing the regulator that the markers are "effective enough" will require that we provide as much evidence as possible and allow him to make his decision judiciously. The use of expert panels and/or peer reviews may also add some value. In the final analysis, the regulator's decision relative to marker system effectiveness, should it be required, will be one based purely on judgement.

When our research of the drilling activity in the Delaware Basin is complete, we will provide you with an intrusion rate for use in future decision making. In the meantime, the approach we have recommended to you here is a sound, logical way to address this important information need. Should you have any questions, contact Mr. B. A. Howard at (505) 234-8380.

Sincerely,

L. R. Fitch, Manager
Environment, Safety, Health, and Regulatory Compliance

BAH:kds

cc: R. A. Bills, CAO
G. T. Basabilvazo, CAO
J. H. Maes, CAO
J. A. Mewhinney, CAO
N. H. Prindle, SNL
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P. N. Swift, SNL

bcc: WID Distribution

C. E. Conway
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Goldstein, Prindle, and Trauth, November 3, 1994

Date: 11/3/94
To: Distribution
From: S. Goldstein, N. Prindle, and K. Trauth
Subject: Guidance on the SPM-2 Elicitation Process

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Sandia National Laboratories

Albuquerque, New Mexico 87185-1341

date: November 3, 1994

to: Distribution

from: S.A. Goldstein, Org. 6305; N.H. Prindle, Org. 6308; K.M. Trauth, Org. 6347

subject: Guidance on the SPM-2 Elicitation Process

This memo is intended to provide you with information about the upcoming elicitation process, including a proposed schedule, what must take place prior to the official elicitation session, and roles and responsibilities (described below). If you have conflicts with how this schedule impacts your work and your priorities, see Steve Goldstein or Nancy Prindle. If you have questions about the process, see Kate Trauth.

Steve Goldstein--SNL WIPP Project Management--Handle policy decisions; resolution of schedule conflicts.

Nancy Prindle--SPM Management Team--Define scope, requirements, constraints, and schedule; provide technical support to and review of process design and issue statements; participate in elicitation sessions.

Kate Trauth--PI for Elicitation Process--Design and document SPM-2 elicitation process; place required contracts; implement and participate in elicitation sessions; arrange for facilities; document results.

The process of developing information is not an activity with which most scientists are familiar or comfortable. In order to make this process run as smoothly as possible, training (described below) will be provided. There are also several ground rules that are intended to delineate the process and how you will be treated. (1) The expectation is to work with you to develop your best judgment about the outcomes and likelihoods of your experiments or activities and then to translate that into parameters necessary for computational codes, including probabilities. Cost and schedule information is also requested, and the link to 40 CFR 191.13 or 40 CFR 268.6 needs to be established. (2) You will be asked to provide some rationale for your judgments in a verbal format. Other individuals will document the rationales for your review and approval. (3) The expectation for the level of effort that you apply to this process is that it needs to be consistent with the schedule that we have been given for this task and your other commitments. (4) The expectation for the adherence of this process with a formal elicitation process results is that it needs to

be consistent with the time allotted for development of the issue statements and preparation for the elicitation sessions.

The SPM-2 elicitation process follows immediately upon the development of the baseline and is intended to develop further information about activities to look at models and data that are not part of the baseline. Only when the baseline has been established for the SPM-2 process can the detailed actions for the elicitation sessions be undertaken.

A formal elicitation process involves a series of steps. The SPM-2 elicitations will be conducted in accordance with the standard elicitation process in the decision analysis literature, modified for the constraints of the SPM-2 process. The elicitation process described below will be discussed in the framework of a standard elicitation.

Selecting the Issues

The first step in the process is to decide upon the issues which require elicitation. The white papers describe the general issue area to be addressed. The baseline meeting in which you have or will participate will identify (through a consensus between the PI(s) and the PA personnel) the specific information that should be elicited.

Participants

(a) The elicitation session is directed by a trained elicitor. For this process you will be working with Professor H.V. Ravinder from UNM, Professor Sul Kassicieh from UNM, or Professor Steve Hora from the University of Hawaii at Hilo.

(b) The lead PI(s) for each topic area or experimental area is the individual from whom information will be elicited during this process. The PI is free to invite no one or anyone they believe would be able to assist them during the elicitation session.

(c) PA personnel knowledgeable about the computational code(s) that will use the information generated by the PI. The PI and the PA personnel will have the opportunity during the session to discuss the development of the required information to ensure that what is provided is consistent with the required input for the computational codes.

(d) A member of the SPM-2 management team will be present to answer questions regarding how the information required fits into the SPM-2 process and to ensure that all of the SPM-2 needs are met.

(e) Also present at the session will be one or two individuals to record the process, the results and the rationales.

If any stakeholder requests to observe the proceedings, this will be accomplished in a non-intrusive fashion, i.e., providing them with a tape or transcript. Observers will not be allowed in the sessions.

Development of the Issue Statement

The development of the issue statement is intended to be a joint effort between the PI (s) and the PA personnel in order to include both the experimental and the modeling perspectives.

The issue statement attempts to clearly define the information that must be elicited. This definition ensures that when a parameter value is elicited, for example, it is understood what is included in that parameter value. It is prepared prior to the elicitation session in order to have the opportunity to discuss it with both the PI and the appropriate PA personnel to resolve any questions and to make the elicitation session a more effective use of time. While every effort will be made to have the issue statement prepared ahead of time, it is subject to final modification at the elicitation session.

The types of information to be elicited include outcomes of experiments, probabilities of outcomes of experiments, and conditional parameter or model outcomes and probabilities given each experimental outcome.

Kate will work to set up interviews with the PI(s) and the PA personnel to obtain the information necessary to write the issue statement. You will also be asked to review and comment on the draft issue statement.

In the interview, you will be asked questions directed at more specifically defining the issues identified in the baseline meeting. In this way, we hope any implicit assumptions that could impact the outcome or the probability will be identified. The issues from each white paper area are different, and thus the specific questions asked will vary. The issues should be defined, for example, in terms of the scale and time factors for both the experiment and PA parameter, any initiating events (e.g., pressure) that may impact the parameter, room chemistry or backfill assumptions, or any averaging of the parameter (over a drum, a room, a panel, or the entire repository).

Engineered alternatives are to be considered in the elicitation process and their specification may impact information to be elicited within other topic or experimental areas. On November 7th, Andrew Orrell will provide the information needed to determine what models and parameters would be impacted. Elicitations are thus expected to address two sets of assumptions--considering currently assumed conditions at the WIPP and considering the existence of specified engineered alternatives.

Training

Training in the elicitation process, including a discussion of the development of probabilities will be provided. Professor Steve Hora, who is one of the trained elicitors involved in the process, will discuss the elicitation of probabilities at the November 8 SPM Brown Bag lunch. Please see Steve Goldstein's email of November 3 regarding attendance. This discussion will to be supplemented by written materials on the elicitation process.

Preparation for the Elicitation Session

In order to achieve the most efficient use of time, preparation for the session is necessary. All parties must have attended the training session and read the written training materials. All parties must also be familiar with the issue statement, and bring any questions to the session.

The PI(s) must be prepared to discuss their planned experiments or activities, the nature of the expected results, any consideration of other experiments that could be conducted or time and resources changes that could be made to existing experiments or activities. The PA personnel must be prepared to discuss modeling different conceptual models with existing codes, as well as parameter usage in the computational codes. Also be prepared to answer questions from the elicitor in order for them to improve their understanding of the issues.

Elicitation Session

The SPM-2 process is intended to indicate which experiments and other activities may be able to increase the probability of compliance over the baseline. Thus there must be a direct connection between experimental outcomes and the PA parameters used in the computational codes (the results of which indicate compliance or non-compliance). This connection is to be elicited during the session.

In the elicitation sessions, actual experimental outcomes and their likelihoods must be elicited. It is only at this point that PA parameters and the probabilities associated with them can be elicited.

Documentation developed during the session will be returned to the participants for their review and approval.

Schedule

Please reserve 8:30 to 4:30 for the day assigned to you. This is necessary in order to clear up any issue statement concerns that may result from the short turn around time between the baseline meeting and the elicitation session. The locations for these sessions will be communicated in the Baseline/Elicitation meetings table that is being circulated and is updated periodically.

Elicitation sessions

Rock Mechanics	November 10
Gas Generation	November 11
Engineering Alternatives	November 11
Disposal Room (including spallings)	November 15
Seals	November 15
Non-Salado	November 17
RCRA Source	November 17
Salado	November 18
Actinide Source	November 22

Follow-up information meetings

PBWAC	December 1
Scenario Screening	December 2

Distribution:

All SNL WIPP Project Participants

SWCF CO/SP WBS 1.1.7.2

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McFadden, December 19, 1994

Date: 12/19/94
To: R. Lincoln
From: M. McFadden
Subject: Systems Prioritization Method Information Needs and Product Requirements

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DOE F 1325.8

United States Government | Department of Energy

memorandum

Carlsbad Area Office
Carlsbad, New Mexico 88221

DATE: DEC 19 1994

REPLY TO ATTN OF: CAO:EPB:RAB: 94-2936

SUBJECT: Systems Prioritization Method Information Needs And Product Requirements

TO: Richard Lincoln, MS #1341, SNL/NM

The Systems Prioritization Method (SPM) Steering Committee has reviewed your memorandums of December 2 and 7, 1994, explaining your information requirements and product requirements. An important point is that the SPM Steering Committee will be responsible for abridging or eliminating any activities or activity sets. Please address, in writing, any request to consider eliminating activities to the committee.

The answers to the questions asked in the memorandum of December 2, 1994 are:

- Average the soil concentrations over the thickness of the marker beds and the cross sectional area of the shaft at the top of the Salado,

  Use the Resource Conservation and Recovery Act (RCRA) source term in the "White Paper",

  Assume no hazardous constituents other than waste will be in the underground, and

  R. Kehrman of Westinghouse will supply soil-based standards information prior to February 1995

- R. Bills will obtain this information from the National Transuranic Program Office as soon as he receives the detailed request from you

- Assume no addition to metals or cellulosics will be made in the waste panels,

  Assume that all underground areas other than panels are rockbolted,

  Information will be provided shortly,

  Assume that there are 6.2 million cubic feet of waste,

  Assume no backfill for the baseline.

Information will be provided shortly, and

Assume for the Remote-Handled Waste that a steel cased salt plug will be used. (Contact R. Kehrman for location of design information). A concrete plug should be an activity.

- Use the drilling frequency and time of drilling (random in time and space) to determine if E1E2 *occurs or not,*

Use 25 boreholes per square kilometer per 10,000 years. All other parameters will be as from 40 CFR 191. R. Kehrman will supply data regarding efficacy of passive markers for an activity, and

Assess current modelling capability to analyze shallow wells with the assumption that the wells do not affect the hydraulic gradient (i.e:, they exist only as a zone of reduced permeability).

In response to the memorandum of December 7, 1994, your assumptions are essentially correct except that George Dials stated at the December 12,1994, meeting that there would only be one CD-ROM and that the stakeholders would get the exact same material as the Carlsbad Area Office (CAO). It was also decided during this meeting that it may be appropriate to address certain side issues (e.g., criticality) in side bar calculations/studies, but that all issues to be addressed in this fashion are to be agreed to by the SPM Steering Committee. We additionally request that you also provide, on the CD-ROM, a copy of the second iteration SPM paper reports.

Michael H. McFadden
Branch Chief
Experimental Programs Manager

cc:
B. Bills, CAO
J. Mewhinney, CAO
B. Kehrman, WID

Reiser, March 10, 1995

Date: 3/10/95
To: N. Prindle
From: A. Reiser
Subject: Examples of Actions in Response to Stakeholder Comments

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Sandia National Laboratories

Albuquerque, New Mexico 87185-

date: March 10, 1995

to: Nancy H. Prindle

Anita

from: Anita S. Reiser

subject: Examples of Actions in Response to Stakeholder Comments

Actinide Source Term Paper

Started with three models:

- Inventory limits
- Chemical model for mobile Actinide concentrations
- Expert panel model

Considered three more models in response to comments:

- Inventory limits with sorption (EEG)
- Inventory limits with realistic conservatism in maximum concentrations (CAO, EPA, stakeholder meeting 12/94)
- Fresh waster estimates (EEG)

Salado Paper

Started with three competing conceptual models for brine inflow that were posed as being in competition.

In response to comments, the three models are now included as mechanisms in a single conceptual model.

Scenario Paper

Started with minimal discussion on certain features, events and processes (FEPs):

- Meteorite impact
- Deep dissolution
- Shallow dissolution

Gave these further consideration in response to EPA comments.

Considered two additional FEPs per EPA and EEG:

- Hydrocarbon storage in boreholes in the Delaware Basin
- Rinsing and transporting radionuclides in particulate form from the waste

Are currently considering two additional FEPs per EPA:

- Dissolution of borehole bottom

- Consideration of human activities for undisturbed performance

Other notes:
The drilling rate from proposed 40 CFR 194 has not been incorporated into the Scenario paper. It has been incorporated into SPM-2.

SWCF-A 1.1.7.2 co/SPM-2 (Stakeholder/Baseline)

Weart, December 1, 1994

Date: 12/1/94
To: SNL WIPP Managers and Principal Investigators
From: W. Weart
Subject: Process for SNL WIPP Programmatic Review of SPM-2 Baseline and Activities

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Sandia National Laboratories

Albuquerque, New Mexico 87185

date: December 1, 1994

to: SNL WIPP Managers and Principal Investigators

from: Wendell Weart 12/01/94

subject: PROCESS FOR SNL WIPP PROGRAMMATIC REVIEW OF SPM-2 BASELINE AND ACTIVITIES

I will assure a programmatic review of the proposed SPM-2 baseline and activities prior to initiation of performance assessment (PA) calculations for SPM-2. The purpose of the review is to ascertain whether the information received to date on the proposed SPM-2 baseline and activities represents a balanced total package. Specifically, the review will be conducted to assure a) modeling feasibility, b) that an appropriate balance exists between technical defensibility and credibility, and c) that sufficient resources exist to complete proposed calculations on schedule. The review will include supporting calculations (sometimes called "side bar calculations") and draft documents proposed as references for the baseline. The product of the review will become the SNL-approved input for SPM-2 calculations. See Attachment 1 for the review schedule.

In order to accommodate schedule constraints of the SPM-2 process, additional SNL WIPP personnel will be designated to provide support to me in this review. Because baseline meetings have largely been completed and activity elicitations are still being conducted, I will first review the baseline and then review activities and activity combinations. Details of the process follow:

1) Using information from the baseline meetings, a team of appropriate PA and SPM representatives will review the proposed SPM baseline and baseline references.

   a) The PA/SPM team will identify all items that are considered mutually acceptable to PA, SPM, and the white paper team leaders.

   b) The PA/SPM team will also identify any baseline items which they believe cannot be feasibly modeled in the time allowed for SPM-2, or which may not be defensible (as defined November 11, 1994), or which are apparently inconsistent with other items. If a mutually acceptable solution cannot be identified, the basis for the concern will be documented and elevated to me for resolution.

   c) Both a description of any unresolved concerns and appropriate documentation for items that are acceptable as is will be provided to me and appropriate white paper team leader(s) for their independent review.

2) Based on input from review team members, an agenda will be set for items to be presented in more detail. Appropriate team leaders or principal investigators will be invited to be present when any unresolved concerns are discussed.

3) If changes to the proposed baseline are made, both the original technical position and the logic for the change will become part of the public record. A final decision on the baseline to be modeled for SPM-2 will be made no later than December 15, 1994.

4) If changes to the proposed baseline are made in the review, the white papers will be revised to reflect the changes (prior to submittal to CAO) by December 23, 1995.

5) The same process will be followed for activities following the completion of elicitations. In addition, I will also review a) the consistency between activities and baseline and b) PA and SPM recommendations for final activity sets.

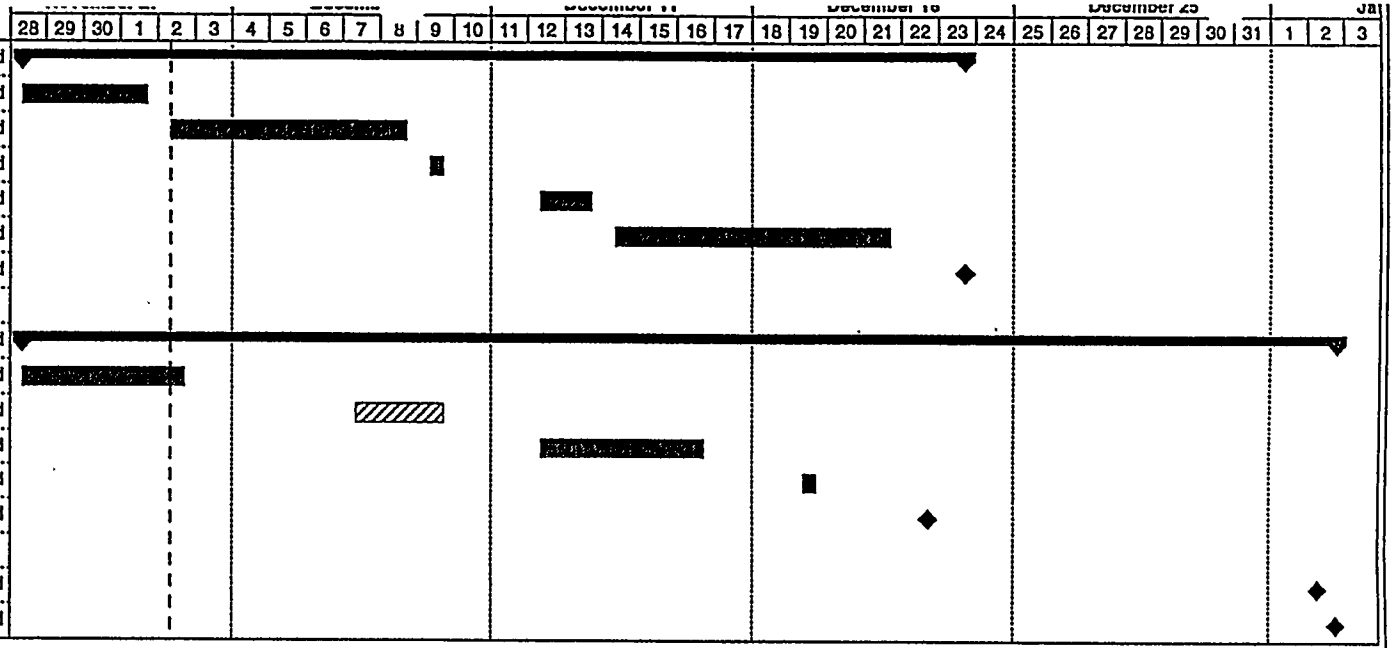
Note that PA systems testing work is scheduled to begin 12/1/94. There is some risk that significant changes to either the baseline or activities which are identified during the review process could result in a schedule slip. Also, keep in mind that this is not a review of the white papers. The white papers will be formally reviewed by WID, CAO, and stakeholders *after* completion of this programmatic review; again, there is some risk that significant comments will be received which could affect the SPM-2 schedule.

Development of the baseline and activity sets for SPM-2 will be a team-oriented process which must balance multiple views and constraints. While there is no guarantee that the final project technical position will be fully satisfactory to everyone, all viewpoints will be acknowledged through formal documentation and inclusion in the public record. Concerns which are not resolved to your satisfaction may be elevated to the WIPP Program Manger, Dori Ellis.

Attachment 1: Review Schedule

SWCF-A: 1.4.2: SPM; QA NA; Programmatic Review

ID	Name	Duration
1	SNL Mgmt Approve Baseline	20d
2	PA/SPM Review Baseline	4d
3	MGMT Review PA/SPM Input & set Agenda	5d
4	Present Additional Items to Mgmt	1d
5	Mgmt Approval of Baseline	2d
6	PIs Revise White Papers for Changes to Base	6d
7	White Papers Due to CAO	1d
8		
9	SNL Mgmt Approve Activities & Activity Sets	22d
10	Complete Activity Elicitations	5d
11	PA/SPM Review Activities & Activity Sets	3d
12	MGMT Review PA/SPM Input & set Agenda	5d
13	Present Additional Items to Mgmt	1d
14	Mgmt Approval of Activities & Activity Sets	3d
15		
16	Baseline & Activity Sets for SPM-2 Frozen	0d
17	Begin SPM-2 Calculations	0d



Attachment 1

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Weart, December 14, 1994

Date: 12/14/94
To: SNL WIPP Managers
From: W. Weart
Subject: Direction for Completion of the Programmatic Review of the SPM-2 Baseline and Activities

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Sandia National Laboratories

Albuquerque, New Mexico 87185

date: December 14, 1994

to: SNL WIPP Managers

Wendell D. Weart

from: Wendell D. Weart

subject: DIRECTION FOR COMPLETION OF THE PROGRAMMATIC REVIEW OF THE SPM-2 BASELINE AND ACTIVITIES

As you know, the management review of the baseline and activities for SPM-2 calculations is in progress. To date we have developed a very conservative baseline, partly because of a requirement to reflect stakeholder concerns and partly because of ground-rules that we can take credit for only knowledge that can be fully supported without any further work. This approach has value in that it is an indicator of what could currently be presented to the regulator in the form of a compliance application. A regulator is, however, always willing to accept the most extreme assumptions as long as they are conservative.

Our DOE customer and the technical community which reviews our efforts wishes to see a realistically conservative but not an extreme baseline. I would like the SPM-2 baseline to reflect this view and I will take what ever heat may result from this position. It is possible that the results from the activity sets may (but not likely) be less favorable than assumed in the baseline. However, our customer would also like to be able to use the SPM-2 tool to set priorities for the remaining experimental program. To do that properly (i.e. to avoid inflating the value of remaining work), we must identify and segregate those high probability activities which, if funded, could move us rapidly towards a more realistic baseline.

I would like the review to identify these high probability activities and represent them as a single "consolidated" activity. Suggested ground-rules for defining and documenting this activity follow:

1. Include activities currently identified as very high probability (and short duration) activities for which the outcome is not expected to have a significant negative impact on the baseline. Examples are simple bounding calculations, literature searches, or items previously discussed as possible side calculations. The category might also contain issues (such as deep hydrology) for which we have such limited information and unclear regulatory guidelines that treating them as separate activities would be inefficient. Include items for which your conclusion would be clear if you had time to fully document your work.

2. The final criteria for including activities in this category must be documented.

3. Document the rationale for including specific activities in this category.

4. Define and document the technical work scope and associated budget for activities in this category.

CAO will review the content of the consolidated activity. If particular portions are unacceptable to CAO, they will be removed and represented in SPM-2 calculations as discrete activities.

Steve Goldstein will be my representative during the week of December 19; I will be available by phone as needed to resolve specific issues. The review will end, on schedule, by December 23, 1994. Please see me if you need assistance in addressing conflicting priorities during the next two weeks.

DMB

cc:

CAO	R. A. Bills
6305	S. A. Goldstein
6300	D. E. Ellis
6308	D. M. Boak
6308	N. H. Prindle
6308	F. T. Mendenhall
6347	K. Trauth

SWCF-A: 1.4.2: SPM; QA NA; SPM-2 Programmatic Review

APPENDIX D:
DESIGN SPECIFICATION FOR CD-ROM DATA VISUALIZATION SUBSYSTEM

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Specification for SPM-2 Data Visualization Subsystem
January 13, 1995

The following requirements for the Data Visualization Subsystem (DVS) were developed through a series of review meetings held at Sandia National Laboratories between January 6 and January 13, 1995. The goal of the review was to produce a clear definition of the appearance and operation of the DVS. The resulting requirements represent a consensus among the SPM-2 Product Team members:

1/13/95

Deirdre Boak, 6305, SPM Product Team leader

1/13/95

Curt Harris, LATA

1/13/95

Walt Beyeler, SAIC

1/13/95

Al Schenker, LATA

I. Introduction

The electronic deliverable for SPM-2 will have three major components, in order of priority:

1) A Data Visualization Subsystem (DVS) which provides convenient access to the SPM-2 decision matrix and the data used to produce it. The Data Visualization subsystem will include on-line documentation (including context-sensitive help) to assist the user in accessing and displaying data.

2) An Electronic References Subsystem (ERS) which will provide indexed and sequential access to key references associated with SPM-2, including the SPM-2 final report, technical position (white) papers, and the baseline and activities summaries. A tentative list of references in included as an attachment to this report.

3) A Navigation and Online Help System (NOHS) which will provide high-level information on the SPM process and SPM-2, and will provide integrated access to the two subordinate sub-systems described above.

This report provides specifications for the Data Visualization Subsystem by describing the information content and functionality of the main display screens available to the user. Specifications for on-line help supporting the Data Visualization Subsystem, for the Electronic Reference Subsystem, and for the Navigation and Online Help System will be addressed in subsequent documents.

Algorithms for identifying compositional features of activity groups are highly desirable. If implementing tools can be developed to support SPM-2, the feasibility of including these tools in the electronic deliverable will be considered. Specifications for a separate interface to the analysis tools will be developed as needed.

II. SPM-2 Information Accessed through the Data Visualization Subsystem

The purpose of the DVS is to present the results of the SPM decision analysis, and the data used in the analysis, in an easily understandable form. The primary data types, and their inter-relationships, are presented in this section as a basis for specifications for the DVS.

There are four principle data types used in the SPM decision analysis calculations:

1. Activities - individual WIPP disposal system program elements which the DOE may or may not elect to implement and fund. Activities include experimental programs, engineering modifications to the waste, or policy decisions (such as waste acceptance criteria) which affect the ability of the disposal system to meet regulatory compliance criteria. Activities are characterized by expected cost at three separate scales: Experimental Program, WIPP, and TRU (national disposal system) and by expected duration. Activities are also characterized by one or more possible outcomes, as described below.

2. Activity Outcomes - possible results of implementing an activity. If the result of implementing an activity is uncertain, two or more outcomes are defined to represent the range of possible results of an activity. Each outcome is associated with a specific activity, and is characterized by a description, by a probability of occurrence if the activity is conducted, and by a description of the effect of the outcome on performance assessment.

3. Activity sets - technically credible combinations of activities. Activity sets are defined by: 1) their component activities; 2) total cost and duration, and 3) a probability of demonstrating compliance (PDC) if the activity set is implemented. The probability of demonstrating compliance is derived from the combinations of outcomes for the component activities, from the probabilities of those outcome combinations if the activity set is implemented, and from the binary compliance indicator associated with each outcome combination.

4. Performance Assessment Results - the results of performance assessment calculations performed for specific model configurations, PA Input Parameters , and PA input parameter values. Performance assessment calculations for SPM-2 will produce two separate results: CCDFs for comparison against the standards of 40 CFR 191, and soil-based concentrations for comparison against RCRA soil standards (40 CFR 268.6). Each performance assessment result, when compared to regulatory criteria, produces a binary compliance indicator.

III. Variables and Data Stored in the SPM-2 (ACCESS) Database

The DVS draws from a database which stores all relevant information as described in section II. The various screens in the DVS (described in section IV)

display data and their inter-connections. This database is intended to support both the DVS and the calculation of probability of demonstrating compliance. Because of this dual purpose, not all information is accessible through the DVS. Critical information needed to support the DVS is described in this section. This description is intended to clarify the information content of screens described in section IV, and is not a complete specification of the database contents.

A. Technical Program Areas

- Program name (~10 characters)
- Program description (~500 characters providing an overview of the program, i.e. what system elements and processes are involved)

B. Activities

- Activity name (~10 character identifier)
- Activity description (~500 characters)
- Activity abbreviation (a short identifier for "dense" screens)
- Technical Program Area (identifier of one of the Technical Program Areas defined in the White Papers)
- Activity cost. Three costs will be stored: experimental program costs, WIPP program costs, and National TRU program costs. Only the National TRU program costs will be available as a cost discriminator for ranking activity sets; all others will be presented as information items in hard-copy report options.
- Activity duration
- References for Activity cost, duration, and technical description

C. Activity Components

- Activity identifier, indicating the Activity containing the component
- Component description (~100 characters)

D. Activity Outcomes

- Outcome description (~20 character description of an outcome type)
- Activity identifier, indicating the Activity corresponding to the outcome
- Number of Outcome Values for the Activity

E. Outcome Values

- Outcome Value description (~20 character description of a particular outcome value, e.g. Measured solubility = 10^{-x})
- Probability of obtaining the Outcome Value
- PA Code(s) whose input or configuration is influenced by the outcome (~10 characters).
- Outcome implication for PA (~50 character description of the assumed influence of obtaining this value on PA, e.g. Solubilities for Am, Pu, Th, U sampled from distributions centered around 10^{-x}). This information may include graphical representations of parameter distributions.
- References for probability of obtaining the Outcome Value and the Outcome implication

F. Performance Assessment Compliance Indicators - 40 CFR 191

- PA case identifier (size and format to be determined by PA calculation structure)
- RCRA Compliance Indicator
- 40 CFR 191 Compliance Indicator
- Overall Compliance Indicator

G. Performance Measure Values - 40 CFR 191

- PA case identifier (size and format to be determined by PA calculational structure)
- Table of paired values of integrated normalized release and exceedance probability

H. Performance Measure Values - RCRA

- PA case identifier
- Table of paired values of VOC identifier and soil-based concentration

I. Performance Assessment Case Element Descriptive Text

Description of the performance assessment assumptions, parameter distributions, and simulation codes utilized in PA calculations corresponding to the possible values of each element of the PA case identifier

- Case identifier element value (size and format compatible with the above table)
- Description (~50 character description of a key aspects of the PA calculation, e.g. "No chemical retardation in the Culebra."
- Performance assessment simulation codes used in the PA calculation
- Corresponding performance assessment input parameter names and their associated values or distributions. This information may include graphical representations of parameter distributions.

J. Activity Sets

- Cost (for EPP, WIPP, and National TRU programs)
- Duration
- Probability of demonstrating compliance given completion of the activity set. Three values will be stored: PDC with RCRA, PDC with 40 CFR 191.B , and PDC with both regulations.

IV. Specifications for the Data Visualization Subsystem

The SPM decision aiding tool is intended to assist the decision maker in identifying an activity set which best satisfies competing objectives regarding duration, cost, and the probability of demonstrating compliance. The tool is not a decision *making* tool in that the decision maker may wish to base a final decision on factors which either cannot or will not be incorporated into this decision framework.

Each activity set is described by a cost, a duration, and a probability of demonstrating compliance. The number of activity sets will be on the order of thousands. The central purpose for the DVS is to assist users in comparing activity sets, both through the decision matrix and through other displays. A second purpose is to clarify the logical process underlying the computations. Final, the tool is intended to present descriptive data and the results of performance assessment (PA) calculations corresponding to activities and activity sets in a relevant and understandable way.

The DVS should allow the user to focus on a sub-set of the thousands of activity sets so that a detailed understanding of important sets is possible. In general, activity sets can be selected based on one of two types of criteria:

Ranges in values for cost, duration, and PDC;

The composition of the activity set.

Figure 1 outlines the display screens and possible display sequences designed to accomplish the goals of the DVS. Each screen will have a unique identifying subtitle.

The purpose and information content for each of the displays is described below:

Screen 1 of the DVS will contain appropriate introductory text, and lead to Screen 2. Screen 1 may be implemented as part of the Navigation and Online-Help System.

Screen 2 has two functions: it will allow the user to define a 'master' filter for selecting activity sets to be available in all subsequent displays, and will allow the user to select from 5 subordinate displays (Screens 3 through 7) for an initial display of selected activity sets. This screen will allow the user to select cost, duration, and PDC ranges by specifying minimum and maximum values for each selection criterion. All activity sets outside the box will be excluded from display in subsequent screens. By default, the limits for each discriminator will be set to include all activity sets.

Screens 3 through 7 will provide different views of the activity sets in Screen 2. To allow the user additional focus within the 'master' selection, a floating pop-up screen (Screen 8) will be available for creating activity set groups based on composition. This screen will allow the user to display and edit the criteria for a manageable number of groups (e.g. 6). Composition criteria will be specified using a selection panel similar in appearance and arrangement to the activity set composition display in Screen 3 (see below). Each group will contain only those activity sets that meet both the master filter cost/duration/PDC criteria and the group composition criteria. The user should be alerted of no activity sets meet the specified criteria (e.g. because of pairing exclusion conditions).

Activity set groups will be distinguished by number, and one of the groups will be designated as the 'active' group. A visibility flag can be independently set for each group by means of a check-box. For displays that accommodate multiple groups (Screens 5 and 7), visible groups will be consistently distinguished by color based on the group number. For displays that accommodate only one group (Screens 3, 4, 6), only the 'active' group will be displayed. For single-group screens (3,4,6), the active group will be displayed regardless of the setting of the visibility flag for the active group.

Screen 3 displays summary information for the active activity set group including composition, cost, duration, and PDC as a table. The table rows correspond to activity sets in the group. Table columns will be provided for all technical program elements, and the composition of each set will be indicated by symbols in the appropriate columns denoting the presence of activities belonging to the technical program element. Additional columns will be provided for the cost, duration, and overall PDC of the activity sets. The user will be able to sort the activity sets in the group according to cost, duration, or compliance probability.

Screen 4 contains the SPM-2 decision matrix as a 3-D bar chart with the cost and duration axes divided into intervals. For each combination of cost and duration intervals, the height of the bar indicates the maximum compliance probability over all activity sets in the active group that fall within the intervals. The interval endpoints for both cost and duration can be defined by the user from pop-up screens, allowing either uniform interval sizes or arbitrary interval sizes to be specified. By default, a duration corresponding to the Disposal Decision Plan will be used as an interval endpoint. The color of the bars will be determined by the active group number.

Screen 5 has been removed.

Screen 6 has been removed.

Screen 7 contains a 2D scatter plot of activity sets. The x and y axes can each be set to one of the three activity set discriminators (cost, duration, or compliance probability). The colors of activity set symbols are defined by the (first) group to which the activity set belongs. By default, the x axis displays cost and the y axis overall PDC. When one of the axes displays duration, the duration corresponding to the Disposal Decision Plan will be indicated.

Controls will be provided to allow the user to switch between Screens 3 through 7, and to return to Screen 1 for re-specification of the master filter. In addition, controls will be provided to 'expand' certain areas in Screens 3 through 7, allowing the user to access information on activity set composition. If possible, this control should be available by double-clicking active areas of each screen.

Screen 9 contains a description of each activity and of the outcomes associated with the activity. The activity name and description will appear as a header; the remainder of the screen will contain a table describing the activity outcomes. Each outcome will appear on a separate row; columns will be provided for an outcome domain identifier, an outcome identifier, a description of the outcome, and a probability of obtaining the outcome. Screen 9 may be accessed from Screen 3 by selecting an activity column header.

Screen 10 contains a description of the outcomes associated with all activities in an activity set. This screen will display a table similar to the Screen 9 table, with outcomes grouped by activity. The total number of outcome combinations for the activity set should be computed and displayed as a header or footer to the table.. Screen 10 may be accessed by selecting a particular set in Screen 3, or by selecting an 'expansion' function in Screen 6.

Screen 10 contains a description of the outcomes associated with all activities in an activity set. This screen will display a table similar to the Screen 9 table, with outcomes grouped by activity. The total number of outcome combinations for the activity set should be computed and displayed as a header or footer to the table. Screen 10 will allow access to individual performance measures by complete specification of the activity set outcome, by automatic selection of the most probable outcome, or by random selection of a possible outcome. Access to the performance assessment results corresponding to the specified outcome (Screens 12 and 13 below) will be provided. Screen 10 may be accessed by selecting a particular set in Screen 3.

Screen 11 has been removed.

Screen 12 displays the CCDF for a particular PA case identifier. The CCDF will be displayed on a log/log plot, with the EPA containment requirement limits indicated. The screen header will include the activity set identifier and the activity set outcome identifier associated with the CCDF, along with the outcome probability. Screen 12 is accessed through Screen 11

Screen 13 displays the RCRA performance measures for a particular PA case identifier, and contains a table of hazardous constituent names, calculated concentrations, regulatory limits, and the minimum and maximum solid concentration values over the sample vectors. The screen header will include the activity set identifier and the activity set outcome identifier associated with the soil concentrations, along with the outcome probability. Screen 13 is accessed through Screen 11.

V. Report Specification

The DVS will provide the ability to print key information about selected activity sets. The report can be initiated from screens 3 and 10. Two levels of report detail will be provided: 1) a single page summary, and 2) a multi-page summary. The multi-page summary will include the single page summary, as well as summary pages for each of the activities in the set. Each report page will include a date stamp, user name, and a unique version identifier for the electronic deliverable. Appropriate references will be provided for all information appearing on

the report. Publication references should be used for cost and duration data, outcome definitions and probabilities, and PA inferences. The CD ROM may be referenced for compliance probabilities and PA results.

Example report formats are attached, illustrating the desired content and general layout of the report forms. The numbers and descriptions in these forms are only for illustration.

The single page summary will be divided into three sections. The upper section will summarize the selection criteria (cost/duration/probability and composition) defining the group from which the activity set was selected, and the total number of activity sets in the group. The center section will contain the activity set ID and values for cost, duration, and compliance probability, along with other useful summary measures. These measures will include the values for cost, duration, and compliance probability, and might include the value of a 'global' utility function. The ranks of these values, among the group defined be the selection criteria, will also be provided. The bottom section will provide details of the composition of the activity set as a list of technical programs represented in the set and a table of component activities. The table will contain the activity name, cost, and duration, and the number of outcome values for the activity. A final, summary row will repeat the total cost and duration for the activity set, and show the total number of outcomes for the activity set, and the number of outcomes for which the overall compliance index is greater than zero.

The multi-page summary will include the single-page activity set summary, along with more detailed activity descriptions on separate pages. The activity summary pages will include a header containing the activity name, technical program name, cost, and duration, followed by a description (~1 paragraph) of the activity, including relevant references (e.g. the Experimental Program Plan). The activity components will be listed following the description. The activity outcome domains, outcome values, and PA implications (along with associated probabilities) will be tabulated following the description. The PA implication may include both text and graphics illustrating parameter distribution.

Systems Prioritization Method II
Activity Set Summary

Cost/Duration/PDC selection criteria:

	Cost	Duration	PDC
Minimum	$4315	0.5 Y	0.51
Maximum	$8132	3.5Y	0.99

Composition selection criteria:

Disposal Room	Rock Mechanics	Gas Generation
+SPL	-MDF	+RPM

Number of Activity Sets meeting selection criteria: 15

Activity Set No. 435

	Estimated Cost	Estimated Duration	PDC	PDC (191)	PDC (RCRA)	Utility
Value	$4315	3.7 Y	0.51	0.79	.60	0.7
Rank within activity sets meeting criteria	3	2	1	2	4	3

Activity Set Composition:

Technical Programs Represented:

Sealing
Source Term
Culebra Hydrology
Room Mechanics

Activity	*Cost (K)*	*Duration (Y)*	*Number of Possible Outcomes*
Seals Program	$3500	1.2	8
Actinide source-term	$500	1.4	3
Colloid studies	$300	3.7	5
Multi-well tracer test	$700	2.5	4
Spallings studies	$200	1.5	4
Total for the set	$5200	3.7	1920
Number of outcomes with CI > 0			321

References:

Systems Prioritization Method II
Activity Summary

Activity:	Halite-related Experiments
Technical Program Area	Salado Flow and Transport
Estimated Cost:	$313 K
Estimated Duration	2.7 Y

Description:

The Salado flow and transport experimental program is designed to resolve outstanding questions about the suitability of a conceptual model based on darcy's law, and to provide refined estimates of parameter values.

Components:

- Field and laboratory tests to obtain values for far-field halite pore pressure
- Laboratory tests on intrinsic permeability of halite, laboratory tests on halite porosity for stressed samples, and curve-fit modeling (halite lab tests, gas and brine under different stresses, and two-phase flow

Activity Outcomes:	PA Code	PA Input	Probability of Activity Outcome
Halite Permeability Measurement:			
No information	BRAGFLO	Baseline	0.01
Average $k < 10^{-12}$ m/s	BRAGFLO	Salado $k \sim N(10^{-12},1)$	0.49
Average $k < 10^{-10}$ m/s	BRAGFLO	Salado $k \sim N(10^{-10},1)$	0.50
Halite Specific Storage Measurement:			
No information	BRAGFLO	Baseline	0.05
Average $S < 10^{-8}$ m^{-1}	BRAGFLO	Salado $S \sim U(10^{-9},10^{-7})$	0.80
Average $S < 10^{-7}$ m^{-1}	BRAGFLO	Salado $S \sim U(10^{-8},10^{-6})$	0.15

References:

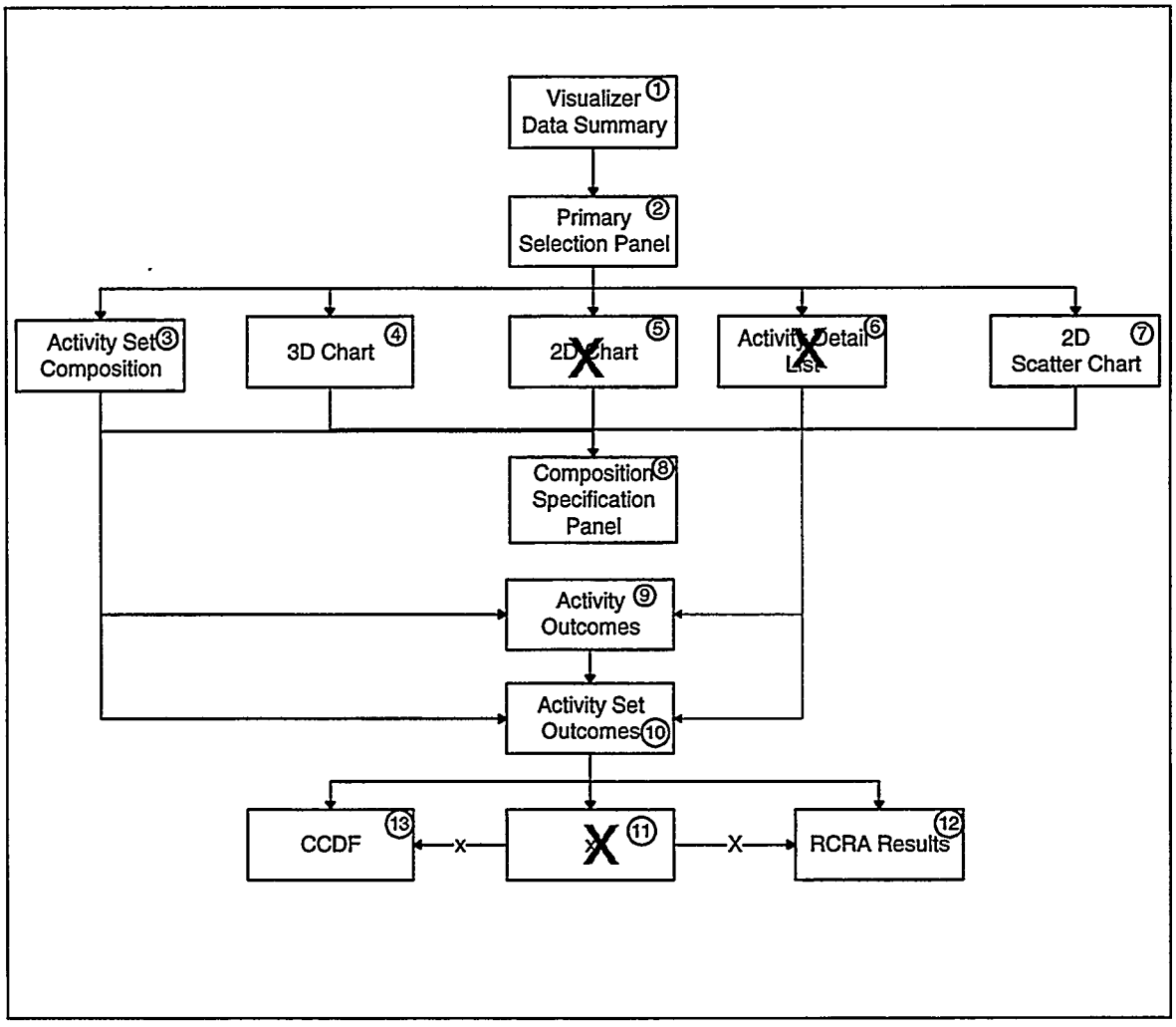

Figure 1 SPM-2 Visualization Subsystem Screen Structure

Attachment

The following is a tentative list of references to be included in the Electronic Reference Subsystem:

a. Summary of SPM-2 Activities
b. Summary of the SPM-2 Baseline
c. SPM-2 Final Report
d. SPM-1 Final Report
e. 40 CFR 191 and 40 CFR 268.6 text
f. BIR
g. Engineered Alternatives Memo
h. CAO Guidance (McFadden to Lincoln, 12/19/94)
i. White Papers

APPENDIX E:
EXAMPLE CD-ROM REPORTS

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APPENDIX E:
EXAMPLE CD-ROM REPORTS

The following examples illustrate the two types of reports that can be generated and printed after a session with the SPM-2 Decision-Aiding Tool CD-ROM. The first example report, *Activity Set Summary*, shows the user-defined selection criteria for the session, statistics on activity sets that satisfy the selection criteria, and selected cost and duration information. The second example report, *Activity Set Components*, gives technical summaries of user-specified activities and activity sets.

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WIPP Systems Prioritization Method
Report #1: Activity Set Summary

ACTIVITY SET NO. 27190

Combined Cost (x1000)	Duration (years)	Composite PDC
$29,250	1.6	0.96

PRIMARY SELECTION CRITERIA:

	Combined (Cost x $1000)	Duration (in Years)	PDC
Minimum	$0	0	0.02
Maximum	$30,000	1.7	0.96

COMPOSITION SELECTION CRITERIA:

The following activities are included in the activity set:

None

The following activities are excluded from the activity set:

None

Activity sets meeting selection criteria: 646

Total number of activity sets in SPM-2: 46655

ACTIVITY SET COMPOSITION:

Technical Program Area	Activity Designator	Cost Type	Cost (x1000)	Duration (years)
Actinide S. T.	AST 1.2	EPP	$4,304	1.5
Disposal Rm.	DR 2	EPP	$250	0.5
Non-Salado	NS 8.1	EPP	$3,242	1.6
	NS 7	EPP	$7,200	1.6
	NS 4	EPP	$3,113	1.4
	NS 2	EPP	$816	1.3
Rock Mech.	RM 1	EPP	$3,660	1.4
Seals	SL 4	EPP	$6,665	1.4

Date/Time:	18-Apr-95	15:33
User ID:	Randy	
SPM-2 Version:	3/31/95	

WIPP Systems Prioritization Method
Report #1: Activity Set Summary

Activity Set No: 27190

Totals for the set: $29,250

ACTIVITY SET COST SUMMARY:

EPP Costs:	$29,250
EA Costs:	$0
WAC Costs:	$0
WIPP (EPP + EA) Costs:	$29,250
Combined (EPP + EA + WAC) Costs:	$29,250

COMMENTS:

Assuming an understanding of the goals of the SPM process, along with its key assumptions, simplifications, and uncertainties, SPM results are appropriate for use in programmatic decisions for WIPP. However, a detailed evaluation of specific results is necessary to fully define programmatic implications and should be conducted prior to final programmatic selections.

Key areas of uncertainty:

1. SPM results are based on the expected outcome of activities (potential scientific work, engineered alternatives, and waste acceptance criteria) that have not yet been implemented.

2. Cost and duration data are presented at the activity set level; this assumes that activities can be completed at any time within the time frame of the activity set.

3. Cost and duration data for engineered alternatives and waste acceptance criteria are at best rough order-of-magnitude estimates.

4. A mean value approach was used to generate a single vector from parameter distributions for input to performance assessment modeling. This approach produces a first order approximation to the mean of a family of CCDFs that would result from of Latin Hypercube Sampling of the parameter distributions.

Date/Time:	18-Apr-95	15:33
User ID:	Randy	
SPM-2 Version:	3/31/95	

WIPP Systems Prioritization Method (SPM)
Report #2: Activity Set Components

Activity Set ID: **27190**

SPM ACTIVITY:	AST 1.2: Dissolved Actinide Solubilities - for Oxidation States +III, +IV, +V
TECHNICAL PROGRAM AREA:	Actinide Source Term
ACTIVITY COST (x1000$:)	$4,304
COST TYPE:	EPP
ACTIVITY DURATION (Years):	1.5

SPM-2 ACTIVITY DESCRIPTION:

Develop an expanded model for determining the solubilities of oxidation states +III, +IV, and +V for the actinides Am, Np, Pu, Th, and U as a function of brine composition, pH, and other independent variables. This effort includes experiments, a literature search, data reduction, and translation of data into a form usable in future compliance assessment codes.

Activity AST 1.2 is similar to Activity AST 1.1 but differs from Activity AST 1.1 in that it does not investigate solubilities for actinides in oxidation state +VI. Assumptions regarding oxidation state +VI for SPM-2 analysis for Activity AST 1.2 are to be based on information on partitioning U and Pu into oxidation state +VI obtained from the Los Alamos Source Term test program.

Refer to the activity summary in Volume II of the SPM-2 report for a more complete description of the activity, outcomes, and parameters used in SPM-2 calculations.

SPM-2 ACTIVITY OUTCOME DESCRIPTION:

There are two potential outcomes for Activity AST 1.2: success and failure. The probability of success is 1; the probability of failure is 0. The parameters to be used to model the outcomes for Activity AST 1.2 are those described in Volume II (the activity summary) of the SPM-2 report.

SPM-2 ACTIVITY OUTCOMES:

Outcome Type	Outcome Number	Outcome Description	PA Code	Probability of Activity Outcome
1	0	Failure: baseline defined dissolved actinide solubilities	PANEL	0
	1	Success: AST 1.2 defined dissolved actinide solubilities	PANEL	1

Date/Time:	18-Apr-95	15:33
User ID:	Randy	
SPM-2 Version:	3/31/95	

WIPP Systems Prioritization Method (SPM)
Report #2: Activity Set Components

Activity Set ID: **27190**

COMMENTS:

Assuming an understanding of the goals of the SPM process, along with its key assumptions, simplifications, and uncertainties, SPM results are appropriate for use in programmatic decisions for WIPP. However, a detailed evaluation of specific results is necessary to fully define programmatic implications and should be conducted prior to final programmatic selections.

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1. SPM results are based on the expected outcome of activities (potential scientific work, engineered alternatives, and waste acceptance criteria) that have not yet been implemented.

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4. A mean value approach was used to generate a single vector from parameter distributions for input to performance assessment modeling. This approach produces a first order approximation to the mean of a family of CCDFs that would result from of Latin Hypercube Sampling of the parameter distributions.

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SPM-2 Version:	3/31/95	

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9 May 1996

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