ENVIRONMENTAL EVALUATION GROUP

AN EQUAL OPPORTUNITY / AFFIRMATIVE ACTION EMPLOYER

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ENTERED

FINAL AGENDA

48TH DOE/EEG/EMNRD/NMED QUARTERLY REVIEW MEETING

October 20, 1994

TIME	TOPIC	PRESENTER
9:00	Resolution of Action Items	Neill/Dials
9:30	SPM-1 Overview	Mike McFadden, CAO
10:00	Caveats	~~Paul Davis,~~ SNL Dick Lincoln
10:30	Break	
10:45	Decision Analysis Method	Nancy Prindle, SNL
11:45	Lunch	
1:00	SPM-1 Baseline/Activity Sets	Fred Mendenhall, SNL
2:00	Results and Conclusions	Richard Lincoln, SNL
3:00	Discussion/Action Items	All participants

10/20/94

48th Quarterly Meeting
WIPP

Bill Lee — Action items - waste characterization existing, RH-TRU)
Question of inventory - 30% or 60% generated today?
" " PBWMC - will this be a real document? What are the critical parameters/characteristics of waste?
DOE will revise engineered barrier, treatment studies. DOE is in process of identifying senior mgrs at each generator site who are responsible for TRU waste to NTPO.
Discussion of disagreement over EEG "suggestions" to modify FSAR by DOE. Appears to be communication breakdown - DOE ignores or belittles EEG suggestions, rejection of probabilistic risk assessment for short term items - fire, etc)

George Diaz — Stakeholders still perceive transportation as major risk. Need to ~~set~~ deal adequately with concerns - more of a marketing challenge. Not all stakeholders are equal (Indian sovereign nations). Don Hancock said many people concerned over RH waste transportation - have false impression that all waste will be CH in TRUPACT's. George said RH is lagging behind, but is no more dangerous than spent fuel.
Cleary supports agressive schedule, despite objections from many outside. Many concerned about what goes into compliance appl. Will have complete compliance application in by 12/96

Mike McFadden, Dick Lincold

Bill Lee's Top 10 Prioritization by Cut Feel

Source Term Testing Program at LANL
Enhanced Lab Pgm @ INEL
Retardation Exp's @ SNL
Spalling Exps @ SNL
Tuff tracer test
Colloids Transp Characteristics
New Engineered Alter. Study
Borehole Seals (full scale) testing
Anhydrite Fracture Exp
VOC Transport Model Exp

48th QUARTERLY, Albuquerque, October 20, 1994

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48th QUARTERLY, Albuquerque, October 20, 1994

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48th QUARTERLY, Albuquerque, October 20, 1994

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According to DOE

QUARTERLY MEETING ACTION STATUS

DATE	SUBJECT	ITEM	STATUS
04/13/94	46th Quarterly Action 1	Furnish truck vs rail study to EEG	Complete
04/13/94	46th Quarterly Action 2	Provide EEG the draft design for RH TRU Transportation Cask	Complete
04/13/94	46th Quarterly Action 3	Provide response to Multiple Confinement in the Underground to EEG	Complete, entered into interactive meetings on confinement.
07/21/94	47th Quarterly Action 1	Address actions from previous meeting (April 13, 1994) and actions in G. Dials presentation.	Complete
		15) EEG recommends CAO establish a Carlsbad document collection center for generator site WAC compliance documents	Center is being considered with plans for larger CAO office building.
07/21/94	47th Quarterly Action 2	Provide EEG any comments or responses submitted to BLM on 59 applications for drilling	Complete. BLM provided requested data to M. Silva, EEG.
07/21/94	47th Quarterly Action 3	Obtain and Forward to EEG a copy of BLM's 1992 comments on EEG-50, Implications of Oil and Gas Leases	In progress.
07/21/94	47th Quarterly Action 4	Provide EEG copies of all waste characterization analysis and data available to date on waste drums destined for WIPP.	Same as 8/24/94 and 9/20/94 letters from EEG. The requested data was provided to Dr. R. Weiner, EEG, on 9/26/94.
07/21/94	47th Quarterly	Provide EEG and other interested parties hands on training	Training provided in three seperate sessions, most recently in

QUARTERLY MEETING ACTION STATUS

DATE	SUBJECT	ITEM	STATUS
	Action 5	on computer programs (codes) used in the WIPP Performance Assessment Report	August, 1994 meeting. Attendies included representatives from EEG and EPA.
07/21/94	47th Quarterly Action 6	Provide EEG access to the help files on the SECO2D/SECO_TP and BRAGFLO computer codes.	Training and information provided in sessions discussed in item 5.
07/21/94	47th Quarterly Action 7	Provide briefing to EEG on the SPM Baseline currently under development.	On-going activity. Information is continuously provided in stakeholder meetings. Additional information to be provided in 48th quarterly review meeting.
07/21/94	47th Quarterly Action 8	DOE/CAO provide indepth briefing on performance based waste acceptance criteria at a near future quarterly review meeting.	Date of meeting open for discusion.

EEG/NMED OPEN ACTION STATUS

DATE	SUBJECT	ITEM	STATUS
04/13/94	Engineered Alternatives	Arrange workshop with SNL/DOE/WID/EEG on engineering alternatives and engineered barriers. Committed at 46th Quarterly Review Meeting.	On hold.
06/01/94	Oil and Gas EEG 55	EEG-55, Implications of the Presence of Petroleum Resources on the Integrity of the WIPP	Being evaluated, response expected April, 1995
06/06/94	QA Level C Codes	EEG requests immediate access to codes identified at QA Level C.	In progress.
07/01/94	Network Support for Site NMED	Connect Site NMED to Network	All hard wiring is complete. Training and software installation to be completed by 12/30/94.
07/01/94	Raptor Reports	Provide 92 and 93 DOE/BLM Annual Raptor Reports to the Site NMED	Report being re-written. It will be transmitted upon completion - 4/95
07/22/94	Intrusion Rates	Impact of different human intrusion rates on long term compliance calculations.	In progress.
08/03/94	Anomolous Water Levels	Anomolous water levels in the Rustler formation in the vicinity of the WIPP.	In progress.
08/24/94	Land Management Plan	Respond to EEG comments on the draft Land Management Implementation Plan, Revision 1.	CAO will resolve comments with the EEG and incorporate appropraite modifications in the next revision of the plan.

EEG/NMED OPEN ACTION STATUS

DATE	SUBJECT	ITEM	STATUS
09/01/94	RH Disposal EEG 56	EEG-56, Unresolved Issues for the Disposal of Remote Handled Transuranic Waste in the WIPP	Recently received, in review by the CAO.
09/01/94	Performance Assessment EEG 57	EEG-57, An appraisal of the 1992 Preliminary Performance Assessment for the WIPP.	Recently received, in review by the CAO.
09/08/94	Performance Assessment Models	Provide Technical Details on extensions to the 1992 Performance Assessment Models.	In progress.
09/19/94	Performance Assessment Code	Request for supplementary Session on code CCDF-Perm in October and Request a definition list for internal variables in SECO codes.	In progress.
10/05/94	GET Training	EEG Suggests including material on 40 CFR 191 (performance assessment) and RCRA compliance requirements in General Employee Training	This is a follow-up to previous letter (June 22, 1994) on this subject. Is being evaluated for inclusion.
10/07/94	Stakeholder Meeting	EEG's comments to statements made during the September 28-29, 1994 stakeholders meeting concerning the analysis of the undisturbed performance of the WIPP.	Recently received, in review by CAO.
10/10/94	Actinide Source Term	Review of the Environmental Assessment for the actinide source term waste test program.	Recently received, in review by CAO.
10/11/94	FSAR	EEG FSAR Issues	Recently received, in review by CAO-WPSO. Draft detailed

EEG/NMED OPEN ACTION STATUS

DATE	SUBJECT	ITEM	STATUS
	Issues/Meetings		implementation plan for disposal phase FSAR has been reviewed by CAO and will be provided to EEG when CAO comments are addressed. November, 1994.
10/11/94	Performance Assessment Codes	EEG follow-up letter to CAO's June 10, 1994 letter providing access to some performance assessment computer codes. Not all requested codes have been released to EEG.	In progress.

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48th Quarterly Meeting

USDOE/NMED/NME&MD/EEG

October 20, 1994

Providing an independent technical analysis of the Waste Isolation Pilot Plant (WIPP), a federal transuranic nuclear waste repository.

Outstanding Issues at WIPP

- **Waste Characterization**

  Radioactivity and VOC content in existing waste

  What about pre-1970 waste?

  How much and what is in RH-TRU?

  Other wastes

- **Site Characterization**

  Nature of Brine Migration to the repository still don't know

  Nature of flow in the Rustler "

  Retardation Mechanisms in the Rustler

- Potential for **Engineered Treatments and Additional Barriers**

  Treatment to reduce gas generation and mobile toxicity

  Performance of borehole seals, plugs and panel seals

- **FSAR**

  No Resolution of EEG-initiated Issues

  Need Technical Review of Disposal-Phase FSAR

- **Performance Assessment: What will be done for the certification application?**

◇ **What combination of scenarios will be considered?**

◇ **What will be the period of intrusion? 1900 or 10,000 years?**

◇ **How will probabilities of human intrusion be determined?**

◇ **What waste inventory will be used?**

◇ **How will emplacement strategy be considered?**

◇ **How will release rates of radionuclides be calculated?**

◇ **Will you calculate fully coupled brine flow, gas generation and creep closure?**

◇ **Will gas fracturing of anhydrite interbeds be included as a new radionuclide migration pathway?**

◇ **What assumptions about institutional control, from closure to 10,000 years?**

◇ **What assumptions will be made about the intruders drilling practice and well-plugging efficiency?**

◇ **Will spalling be considered in direct surface discharge in the certification application?**

◇ **What radionuclide retardation mechanisms will be considered in Culebra transport, and what data is used to justify them?**

◇ **How will you calculate committed effective dose for compliance with the Individual Protection Requirement of 40 *CFR* 191?**

48th Quarterly Meeting

ENVIRONMENTAL EVALUATION GROUP
NEW MEXICO ENVIRONMENT DEPARTMENT
NEW MEXICO ENERGY, MINERALS, AND NATURAL RESOURCES DEPARTMENT

GEORGE DIALS, MANAGER
CARLSBAD AREA OFFICE

VISIT BY ENERGY SECRETARY HAZEL O'LEARY

- CAO provided program review
- Report on Stakeholder Forum (September 26–27)
- Stakeholders provided perspectives
  - Don Hancock (Southwest Research and Information Center), interest groups' representative
  - John Heaton, city of Carlsbad representative
  - Gary King, New Mexico Governor's representative
- Secretary O'Leary reconfirmed commitment to June 1998 opening date

1094L:6609a

WIPP STAKEHOLDER FORUM

- Held September 26–27 in Albuquerque
- Invited 170 individuals
  - 70 persons attended

- Environmental Protection Agency
- Local governments
- Oversight groups
- Media
- Congressional representatives
- State governments
- Tribal governments
- Environmental groups
- Citizen groups
- Regional government groups

- Stakeholders presented issues
  - DOE listened

1094L:6609b

ISSUES IDENTIFIED

- Lack of national nuclear waste policy
- Disposal decision schedule too aggressive
  - May impact science
- Need to continue training emergency responders
- Lack of program integration
  - National Transuranic Program
  - Other DOE waste shipments
- Working wrong issues
  - Look at pre-1970 and liquid wastes
- Waste inventories, characterization, quantities uncertain

1094L:6609c

ISSUES IDENTIFIED

(cont.)

- Recognition of Native Americans as sovereign nations
- Regulatory compliance and risk assessment lacking
  - Human intrusion
  - Uncertainty of long-range predictions
  - Engineered alternatives and waste form modifications
  - Site suitability and characterization
- Involvement process lacking
  - Timely notice of meetings and document review opportunities
  - Evening meetings
  - Interactive TV
  - Videoconferencing
  - Toll-free number

1095L:6609d

UPDATE: SOURCE TERM PROGRAM

- CAO sent EA out for 14-day review
  - Tribal governments
  - New Mexico Environment Department
  - Environmental Evaluation Group
- Only EEG commented
  - Los Alamos reviewing EEG's comments
- Facilities, procedures, personnel in place to start
- Next steps:
  - Comment resolution
  - Issuance of Finding of No Significant Impact
  - Start-up: November 1994

1094L:6609e

UPDATE: GAS GENERATION PROGRAM

- Idaho notified CAO start-up date has slipped from May to October 1995
- Long-lead item, lack of management priority causing problems
- CAO has asked Argonne West to survey availability of needed resource at Lockheed
- CAO going to Idaho early November to develop "get well" schedule

1094L:66091

UPDATE: FINAL SAFETY ANALYSIS REPORT

- CAO is preparing Implementation Plan for Disposal Operations Update to the FSAR
  - Objectives of Disposal Operations FSAR
  - Proposed modifications to safety analysis documentation to support disposal operations
  - Major milestones
  - Schedule
- Working draft of Implementation Plan in final stages
- Scheduled for completion in November 1994
- Following EEG review of the Implementation Plan, CAO invites meeting with EEG to discuss concerns or recommendations

1094L:6609g

UPDATE: PA CODES

- Archived '92 PA codes
  - Commitment: release copy of archived codes
  - Status: available on CD ROM (for IBM compatible PCs); delay largely due to emplacing licensing agreement
  - Plan: conversion software within a week for EEG MacIntosh
- Current PA codes
  - Commitment: all codes accessible on "TINA"; all to QA Level A by 1/1/95
  - Status: all major codes accessible on "TINA"
  - Plan: all codes to QA Level A by 9/30/95; delay due to demands of System Prioritization

1094L:6609h

UPDATE: COMPLIANCE

- Revised Part B Application chapters submitted to NMED
  - B -- Facility Description
  - E -- Groundwater Monitoring
  - F -- Procedures to Prevent Hazards
  - G -- Contingency Plan
  - H -- Personnel Training
  - J -- Corrective Actions for SWMUs
  - K -- Other Federal Laws

1094L:66091

UPDATE: COMPLIANCE
(cont.)

- Remaining sections to be submitted
  - A -- Part A Permit Application, 3/2/95
  - C -- Waste Analysis Plan, 3/2/95
  - D -- Facility and Process Description, 1/6/95
  - I -- Closure and Post-closure Plans, 1/6/95
  - L -- No-Migration Determination, 3/2/95
  - M -- Certification, 3/2/95

1094L:6609J

UPDATE: DISPOSAL DECISION MILESTONES

- Preliminary baseline assumptions for PB–WAC
  - To be completed in October 1994
  - Supports Fleet Optimization Study
- Biennial Environmental Compliance Report
  - To be submitted to EPA, NMED 10/27/94
  - Meets Land Withdrawal requirement

1094L:6609k

The Waste Isolation Pilot Plant (WIPP) Systems Prioritization Method - Iteration One (SPM-1): A Prototype Decision Analysis

Final

EXTERNAL DRAFT

EXECUTIVE SUMMARY

The System Prioritization Method (SPM) is a decision analysis tool developed to provide an analytical basis for programmatic decisions regarding activities undertaken in support of a compliance application for the Waste Isolation Pilot Plant (WIPP) to meet selected portions of applicable Environmental Protection Agency (EPA) long-term performance regulations. SPM will calculate the probabilities of certain sets of activities demonstrating compliance with portions of 40 CFR 191 Subpart B and 40 CFR 268.6. SPM will provide this information in the form of a decision matrix to identify low risk and/or cost-effective paths for demonstrating this compliance.

SPM has eleven key steps. They are: 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 selected performance requirements in 40 CFR 191 and 40 CFR 286.6 (step 1); the development of a baseline consisting of models and data necessary to evaluate the CI (step 2); the evaluation of the baseline CI for the WIPP disposal system using models and data developed in step 2 (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) (step 6); the performance of a decision analysis and the creation of a decision matrix that includes the probability of demonstrating compliance, cost, and duration for the activity sets (step 7); the selection by DOE of activities to implement (step 8); the implementation of selected activities (step 9); the reiteration of steps 2 through 8 as necessary (step 10); and, when the baseline calculations indicate compliance, the execution of PA calculations with the Quality Assurance (QA) requirements necessary to prepare a compliance application (step 11).

The SPM uses existing WIPP Performance Assessment (PA) methods and computational tools, or modifications of these tools, to estimate disposal system performance. Unlike previous WIPP PAs, which used models based on best estimates of the natural processes or properties, SPM assumptions and parameters are based on existing information that is believed to be defensible in a regulatory environment.

A prototype of the WIPP SPM was successfully completed on a tight schedule. The time constraints imposed on the SPM-1, and the fact that it was a prototype, required modifying and condensing the SPM steps in several ways: 1) Models and data were based on the 1992 PA, stakeholder concerns received in writing prior to May 1994 that could be easily implemented as simple code modifications, and some new PA models developed in 1993. 2) System

performance was estimated using the baseline prescribed by the SPM team. The baseline for subsequent iterations of SPM will be documented in the WIPP Project Technical Baseline (PTB) report. 3) Potential outcomes of activity sets and their probabilities were prescribed by the SPM team (as opposed to formal elicitations on a project-wide reference basis).

To implement SPM-1, it was necessary to make several assumptions and decisions, and to use several processes that limit the prototype's applicability. As a result, the reader of this report is cautioned that the results of the SPM-1 are unsuitable for making programmatic decisions. The principal caveats are listed below.

Caveat 1. The SPM-1 baseline is an estimate of the future Project Technical Baseline (PTB) used for the purposes of prototyping the SPM and reflects only the beliefs of members of the SPM team at Sandia National Laboratories (SNL). It does not include sufficient SNL, Westinghouse Waste Isolation Division (WID), DOE-CAO, regulator, or stakeholder involvement to represent a full range of concerns and therefore is not useful for drawing programmatic conclusions.

Caveat 2. Only conceptual models that could readily be incorporated into the modeling structures used in the 1992 PA analysis were considered for the SPM-1 baseline and the activity set outcomes.

Caveat 3. Possible outcomes of the SPM-1 activities were defined in part using information obtained in limited and informal elicitation of the Principal Investigators (PI). These activity outcomes are estimates for the purposes of prototyping the SPM. The interpretation of these outcomes and their use in SPM-1 are the sole responsibility of the SNL SPM team.

Caveat 4. The tie between activity sets and cost and schedule for SPM-1 is an estimate for the purposes of prototyping the SPM.

Caveat 5. While in general the SNL SPM team believes that the decision matrix information correctly reflects the results of the computer modeling, there may be isolated errors in results because of insufficient time to check the output and behavior of each run of each code in detail, due to the large amount of information handled.

Caveat 6. SPM-1 analysis is limited to evaluating the ability of the WIPP disposal system to meet selected post-closure regulatory requirements. Any other requirements from the regulator are not covered in this analysis.

Based on prior PA results, SPM-1 does not address 40 CFR 191.15 (individual protection requirements), and 40 CFR 191, Subpart C (environmental standards for groundwater protection).

The SPM-1 team implemented steps 1-7 of the SPM. The results of the evaluation of the CI for the SPM-1 baseline indicated that radionuclide containment and hazardous consituent concentration requirements were not both met. The results of modeling the potential outcomes

of identified activities were compiled into a three dimensional plot representing a "decision matrix" showing the probability of demonstrating compliance of the activity set that leads to the highest probability of demonstrating compliance, against each associated cost and schedule category.

SPM-1 has successfully shown that the SPM is computationally feasible and that the type of information desired can be generated given sufficient resources. The results of the SPM prototype will serve both as a benchmark and as a test bed for developing the tools needed for the anticipated requirements of the second iteration of SPM (SPM-2). The SPM-1 effort has demonstrated: 1) The ability to reconfigure the original 1992 PA codes in a timely fashion to contain or approximate altered conceptual models for both a baseline calculation and a suite of activity sets. 2) The development of databases and the execution of decision analysis software to handle large files of information. 3) The ability to handle a large number of input vectors to the PA systems models, computations, and PA output files. 4) The ability to reduce a very large amount of information into a decision matrix.

A number of lessons were learned during SPM-1. One was that the SPM-1 decision matrix for compliance probability as a function of program duration and total costs resulted in no schedule discrimination because the SNL five-year plan had been modified to make all currently planned activities consistent with the WIPP Disposal Decision Plan (DDP). SPM-2 will analyze multiple potential outcomes corresponding to different total costs and durations for selected activities to allow duration to impact compliance probability. Another lesson learned was that SPM can measure only the "regulatory compliance worth" of activity sets that will change the baseline information. This means that the regulatory compliance worth of activity sets with potential outcomes that are the same as the baseline will be calculated to be zero.

The SPM-1 prototype has demonstrated the ability to supply a decision maker with important information to aid in directing a program as complex as WIPP. The tool, however, is only as useful as the quality of the input data including cost and schedule information. Although the SNL SPM team has just started to fully analyze the results from the SPM-1 prototype, it is clear (given activity cost, schedule, and potential outcomes) that SPM is a viable tool for identifying:

1) activity sets necessary for a given probability of demonstrating compliance (Caveat 6),

2) activity sets that give the maximum probability of demonstrating compliance (Caveat 6),

3) activities that have minimal impact on probability of demonstrating compliance (Caveat 6), and

4) the potential worth, with respect to demonstrating compliance (Caveat 6), of new activities.

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1. INTRODUCTION

The System Prioritization Method (SPM) is a decision analysis tool developed at Sandia National Laboratories (SNL) to provide an analytical basis for programmatic decisions regarding activities undertaken in support of a compliance application for the Waste Isolation Pilot Plant (WIPP) to meet selected portions of the applicable Environmental Protection Agency (EPA) long-term performance regulations. SPM is designed to calculate the probabilities of certain sets of activities demonstrating compliance with portions of 40 CFR 191 Subpart B and 40 CFR 286.6. SPM provides this information in the form of a decision matrix for identifying low risk and/or cost-effective paths for demonstrating this compliance.

SPM involves an eleven-step process that uses existing WIPP Performance Assessment (PA) methods and computation tools, or modifications of these tools, to estimate the WIPP disposal system performance. The first iteration of the WIPP SPM (SPM-1) was successfully completed at the close of September 1994. The results of this prototype will serve both as a benchmark and as a test bed for developing the tools needed for the anticipated requirements of the second iteration of SPM (SPM-2).

Section 2 of this report provides an overview of the SPM and describes the key steps of the WIPP SPM, the modifications that were made for SPM-1, and the differences in modeling between SPM-1 and the 1992 PA. Section 3 discusses the caveats associated with the SPM-1. The modeling codes used in SPM-1 and the SPM-1 Compliance Indicator (CI) are described in Sections 4 and 5, respectively. Section 6 reviews the SPM decision analysis methods, including the computation approaches, the method of calculating the probability of demonstrating compliance using the CI, and the construction and analysis of the decision matrix. The results and conclusions of SPM-1 are presented in Section 7 with an overview of the SPM-1 lessons learned.

2. SPM OVERVIEW

The SPM is a decision analysis tool developed to provide an analytical basis for programmatic decisions regarding activities undertaken in support of a compliance application for the WIPP to meet applicable EPA long-term performance regulations. SPM will calculate the probabilities of certain sets of activities leading to a demonstration of compliance with portions of 40 CFR 191 and 40 CFR 268.6 (see Section 3, Caveat 6, and Section 5). The SPM calculations will provide information for identifying low risk and/or cost-effective paths for demonstrating this compliance.

As currently defined, the activities considered are those managed by the Department of Energy (DOE) that have the potential to affect selected quantitative aspects of regulatory compliance, such as experimental and other information-gathering programs, engineered alternatives to current repository design or waste form, and possible modifications to the waste acceptance criteria. Non-quantitative aspects of regulatory compliance will require consideration of other activity sets. SPM-1 includes activities from experimental programs at SNL and selected potential performance-based waste acceptance criteria (PB-WAC).

The SPM uses existing WIPP Performance Assessment (PA) methods and computational tools, or modifications of these tools, to estimate the WIPP disposal system performance, but it uses a fundamentally different approach to iterative analyses than those used in past PAs. In previous WIPP PAs, Principal Investigators (PIs) were asked what they believed about the current state of knowledge and data in their area of expertise. PIs typically provided the PA analysts with models or data distributions that were their informal best estimates of the natural processes or properties. There was no explicit constraint that assumptions and parameters used in the PA be based on existing information believed to be defensible in a regulatory environment. Each iteration of these PAs used increasingly refined models and data as they became available, but the responsibility of establishing the suitability of the models and data with respect to existing information was essentially outside the PA process. In contrast to these previous PA analyses, the PA calculations of the baseline in future SPM iterations will use only information that can withstand significant scrutiny. As such, the SPM PA is more conservative than the 1992 PA.

The SPM requirement to use only defensible information as a starting point is derived from the following premise: information that is used in a compliance application must ultimately be acceptable to the regulator for the application to be successful. This premise drives the key steps of the SPM process illustrated in Figure 1 and described below.

2.1 Key Steps of the WIPP SPM

1. Specify the SPM(CI).

The CI provides a binary measure of whether the WIPP disposal system is predicted to succeed or fail in meeting the specific post-closure performance requirements in 40 CFR 191.13(a) and 40 CFR 286.6. Compliance with the requirements in Section 5 is indicated when CI equals the value 1 (see Caveat 6). If the CI equals 0, compliance is not indicated. The first step in SPM is to specify how the CI will be evaluated.

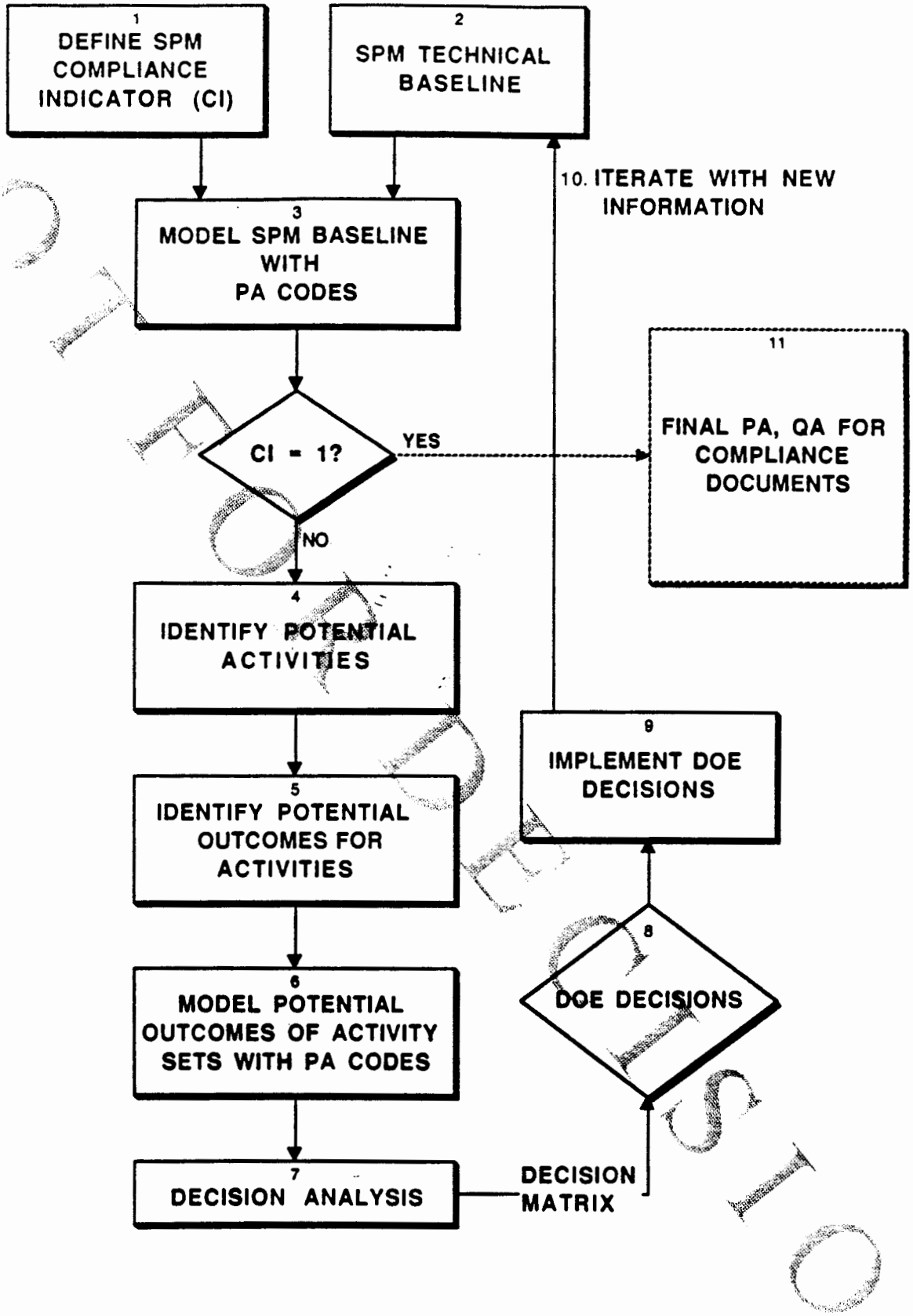

Figure 1. Overview of the SPM. Steps 1-7 were implemented in SPM-1; steps 1-10 will be implemented in all subsequent iterations.

2. Identify the models and data that are necessary for evaluating the baseline CI, and that are defensible based on existing information.

Models and data identified in this step are used to analyze the SPM baseline. For SPM-1, the baseline was developed by the SNL SPM team. The baseline for subsequent iterations of SPM will be documented in the WIPP Project Technical Baseline (PTB) report.

3. Evaluate the CI for the WIPP disposal system using models and data from the baseline.

If the baseline CI shows compliance with quantitative standards (CI = 1), prepare a compliance application. This involves implementing a full PA with appropriate Quality Assurance (QA) (step 11). If the CI does not indicate potential compliance (CI = 0), proceed to SPM step 4.

4. Identify activities available to the WIPP project that, if implemented, have the potential to impact the system's CI.

The activities may include experimental program elements or design changes to the facility, such as changes to the waste acceptance criteria.

5. Elicit from the project participants their beliefs about what new information, or changes to existing information, might evolve if specific activities are implemented.

These "potential outcomes" should be as realistic and unbiased as possible, but all parties must recognize that they are essentially informed estimates that are provided before the activity has been implemented.

The process for eliciting information from the PIs and other project participants includes answering four basic questions:

1) What is the purpose of the activity with respect to demonstrating compliance with quantitative standards (CI = 1)?

2) What do you expect to be the potential outcomes (or outcome categories) of your activity with respect to PA models and/or parameters that are important for assessing compliance with quantitative standards (CI=1)?

3) In your best judgment, what do you think are the probabilities of these possible outcomes?

4) What are the appropriate PA parameters and/or models for each of these outcomes?

6. Model potential outcomes of activities using PA codes.

PA results are calculated assuming that the specific activities are implemented and the results of the activities match their potential outcomes. For SPM-1, this means calculating Complementary Cumulative Distribution Functions (CCDFs) for radionuclide releases and concentrations of Volatile Organic Compounds (VOCs) in soil. Other iterations of SPM could address additional quantitative regulatory standards.

7. Create a decision matrix that includes the probability of demonstrating compliance (see Caveat 6), cost, and duration for all activity sets.

The probability of demonstrating compliance is calculated from the PA results in step 6 for combinations of activity outcomes and the probabilities of those potential outcomes. These are compiled into probabilities of demonstrating compliance for activity sets with the associated cost and schedule. These analyses of thousands of combinations of activity outcomes are condensed into a decision matrix displaying those activity sets leading to the highest probability of compliance within given cost and schedule categories.

8. DOE-CAO decides which activities to implement.

The decision matrix will provide information for selecting activities to implement.

9. Implement the selected activities.

Update the PTB after the activities have been completed. Note that the results of the selected activities may or may not match their potential outcomes.

10. Repeat step 2, and iterate as necessary until the baseline CI equals 1.

11. When the baseline calculations indicate that the CI equals one, rerun a full suite of PA calculations for a compliance application with the corresponding QA requirements.

The calculations performed in step 11 will follow a different process than those in other SPM steps, and will adhere to all applicable regulatory QA requirements. Some work getting the PA codes and models used in SPM up to QA Level A is expected, especially where new conceptual and numeric models have been added to the SPM baseline.

There are two important concepts integrated into the SPM: first, the QA level required for SPM is different than the level required for a compliance application; and second, DOE is the customer for SPM, and ultimately the sole decision maker of which activities to implement.

Note that calculations using the PA computational system are performed three times in Figure 1. PA calculations occur first in step 3, which consists of an analysis using the current baseline. PA calculations occur a second time in step 5, where multiple analyses are performed using the activity sets' potential outcomes. The PA calculations occur a third time in step 11, for the compliance application. The calculations in steps 3 and 5 are for DOE's internal use for making programmatic budget decisions, and cannot be used in a compliance application. Neither the calculations for making programmatic budget decisions nor the data used in these calculations are at the QA level necessary for a compliance demonstration. The data used in step 3 is based on the current state of knowledge as contained in the PTB. It will be of whatever QA level the PTB has available. The data used in step 5 is, by definition, hypothetical. Only the data and calculations used in step 11, which take place outside of the SPM loop (steps 2 through 10) (see Figure 1), will be at the QA level appropriate for a compliance demonstration.

Also note that the decision about which activities to perform, in step 7, is a decision made by DOE. There is always some risk that the activities will not actually yield the anticipated outcomes. If the actual outcomes do not support an acceptable compliance application, DOE may need to implement additional activities and iterate the SPM as necessary.

2.2 Implementation in SPM-1

The SPM overview above describes the ideal process. The time constraints imposed on SPM-1, and the fact that it is a prototype process, required modifying and condensing the SPM steps in the following ways:

1) For the most part, models and data were based on the 1992 PA. Only those stakeholder concerns received in writing prior to May 1994 and that could be easily implemented as simple code modifications were addressed. Some new PA models developed in 1993 were implemented.

2) System performance was estimated using the baseline prescribed by the SPM team (as opposed to the PTB), as described in Appendix A.

3) Potential outcomes of activity sets and the probabilities of these outcomes were prescribed by the SPM team (as opposed to formal elicitations on a project-wide basis), as described in Appendix B.

4) The performance of the system was estimated using a "Selective Brute Force" approach described in Section 6.1.

2.3 SPM-1 and 1992 PA Modeling Differences

Table 1 summarizes the differences between the models for the 1992 PA, SPM-1 baseline, and SPM-1 activity sets. Table 2 summarizes the regulatory requirements addressed in the 1992 PA, SPM-1 baseline, and SPM-1 activity sets.

3. CAVEATS

SPM-1 is the prototype of a complex set of conceptual and numeric models and computer calculations performed on a tight schedule. As such, it was necessary to make several assumptions and decisions, and use several processes, that limited the scope of SPM-1, in order to complete the analysis within the desired time frame. As a result, the reader is cautioned that the results of SPM-1 are not suitable for making programmatic decisions. To understand the SPM-1 results and their range of applicability, it is important to understand the caveats associated with this prototype. The high-level caveats are listed below. A complete list of SPM-1 caveats appears in Appendix C.

Caveat 1. The SPM-1 baseline is an estimate of the future PTB used for the purposes of prototyping the SPM and reflects only the beliefs of members of the SPM team at SNL. It does not include sufficient SNL, Westinghouse Waste Isolation Division (WID), DOE-CAO, regulator, or stakeholder involvement to represent a full range of concerns and therefore is not useful for drawing programmatic conclusions.

To measure the potential value of the data from the WIPP Experimental Program, the SPM must use a "technical baseline" as a starting point. The technical baseline is a compendium of scenarios, conceptual models, numerical models, experimental data, parameter ranges and distributions, and computer codes that the WIPP project is willing to defend to the regulator as appropriate for demonstrating the performance of the repository. The technical baseline includes both the repository design and a baseline inventory. Defining the SPM-2 technical baseline is an ongoing process that entails the consideration of input from the stakeholder meetings and the production of the PTB document.

Caveat 2. Only conceptual models that could readily be incorporated into the modeling structures used in the 1992 PA analysis were considered for the SPM-1 baseline and the activity set outcomes.

This results from a need to rapidly explore the feasibility of SPM technology.

Table 1. Model Differences Between the 1992 PA, SPM-1 Baseline, and SPM-1 Activity Sets

Processes and Parameters	Model and Parameter Values		
	1992 PA	SPM-1 Baseline	SPM-1 Activity Sets
Salado - Anhydrite Relative Permability Curve	Brooks Corey used 66% of the time/Parker Van Genuchten used 33% of the time	Brooks Corey used 50% of the time/Parker Van Genuchten used 50% of the time	Either Brooks Corey or Parker Van Genuchten depending on Salado activity outcome (see Appendix B.1)
Salado - Anhydrite Gas Flow Model	Two-phase flow with constant permeability and porosity	Instant gas transport to boundary when repository pressure reaches 12.5 MPa	Either baseline model or pressure-dependent permea-bility with preferential gas flow model depending on Salado activity outcome (see Table B-1)
Shaft Seals Permeability	Sample range: 10^{-20} to 10^{-21} m^2	0-100 years, sample range: 10^{-12} to 10^{-14} m^2 100-10,000 years, sample range: 10^{-13} to 10^{-15} m^2	Sample range depends on Seals activity outcome (see Table B-2)
Panel Seals Permeability	Zero	10^{-12} to 10^{-14} m^2	10^{-12} to 10^{-14} m^2
Initial Room Moisture	Sample range: 0.0 to 14.0% Mean: 7.0%	Sample Range: 0.04 to 5.2% Mean: 0.44%	Sample Range: 0.04 to 5.2% Mean: 0.44%
Waste Inventory	Used the 1990/91 Integrated Database	Used the 1994 BIR w/limits on U_{235}	Used 1994 BIR w/limits on U^{235}
Plastic and Rubber Degradation	50% available for gas production	100% available for gas production	100% available for gas production
Actinide Solute Concentrations	Limited by actinide solubility	Actinide inventory limited	Solubility sample range depends on Actinide Source Term activity outcome (see Table B-3)

Table 1. Model Differences Between the 1992 PA, SPM-1 Baseline, and SPM-1 Activity Sets (Continued)

Processes and Parameters	Model and Parameter Values		
	1992 PA	SPM-1 Baseline	SPM-1 Activity Sets
Colloid Concentration	Not modeled	Actinide inventory limited	Solubility sample range depends on Actinide Colloid activity outcome (see Table B-7)
Colloid Transport	Not modeled	No chemical or physical retardation	No chemical or physical retardation
Culebra Physical Retardation of Solute	Both dual and single porosity cases	Not modeled	Fracture spacing sample range depends on Culebra Physical Retardation activity outcome (see Table B-4)
Culebra Chemical Retardation of Solutes	Modeled (see Appendix B.5)	Not modeled	Retardation sample range depends on Culebra Chemical Retardation activity outcome (see Table B-5)
Groundwater Level in Recahrge Area	Sample range: Present depth to land surface	Fixed at land surface for 10,000 years	Fixed at land surface for 10,000 years
Human Intrusion - Spallings	Not modeled	Modeled	Sample range depends on Spalling activity outcome (see Table B-9)
Human Intrusion - Borehole Intrusion Rate	Sampled as Poisson process with sampled rate: 0-30/km^2	Fixed at 30/km^2	Fixed at 30/km^2
Human Intrusion - Earliest Intrusion Time	1000 years	101 years	101 years
Borehole Plugs	All flow diverted into Culebra	Degraded (approximates the permeability of silty sand)	Degraded (approximates the permeability of silty sand)
PB-WACs	Not considered	Not considered	Considered (see Section B.8)

NOT FOR DECISION

Table 2. Regulatory Requirements Addressed in the 1992 PA, SPM-1 Baseline, and SPM-1 Activity Sets

Regulatory Requirements	1992 PA	SPM-1 Baseline	SPM-1 Activity Sets
40 CFR 191.13(a) Radionuclide Containment	Yes	Yes	Yes
40 CFR 268.6 Hazardous Constituents	No	Yes	Yes
40 CFR 191.15 Individual Protection	No	No	No
40 CFR 191 Subpart C Groundwater Protection	No	No	No

Caveat 3. Possible outcomes of the SPM-1 activities were defined in part using information obtained in limited and informal elicitation of the PIs. These activity outcomes are estimates for the purposes of prototyping the SPM. The interpretation of these outcomes and their use in SPM-1 are the sole responsibility of the SNL SPM team.

In addition to the technical baseline, the SPM process requires the elicitation of possible future states of knowledge based on possible activities. "Activity" here has a broad definition, and could include things as diverse as field experiments, lab experiments, novel analyses, changes in the engineering design, changes in the waste acceptance criteria, discussions with the regulator, and literature searches of existing information bases. The limited and informal elicitation of the PIs, as in the case of the conceptual models, resulted from the need to rapidly explore the feasibility of SPM technology.

Caveat 4. The tie between activity sets and cost and schedule for SPM-1 is an estimate for the purposes of prototyping the SPM.

Information required for the SPM analysis also includes the cost and duration necessary to accomplish the activity sets. For the purposes of SPM-1, the cost and duration figures were obtained from the SNL portion of the budget only, and are therefore incomplete. Also note that the definition of the potential outcomes of the activity sets occurred before the recent budget validation exercise, which may lead to mismatches between the potential future states of knowledge and the associated budget and schedule.

Caveat 5. While in general the SNL SPM team believes that the decision matrix information correctly reflects the results of the computer modeling, there may be isolated errors in results because of the insufficient time to check the output and behavior of each run of each code in detail, due to the large amount of information handled.

SPM-1 required hundreds of runs of complex codes such as BRAGFLO (BRine And Gas FLOw), NUTS (NUclide Transport System), and SECO/TP (Sandia ECOdynamics TransPort). Normally the output of each of these codes is carefully examined to ensure that the code behaved appropriately. In addition, a number of new codes were developed to process PA results for decision analysis. While in general the SNL SPM team has confidence in the codes and their execution, the large amount of information generated in a short time frame did not allow the PA analysts to check each run of each code for normal behavior. This leads to the need, as discussed in Section 6.2.5, to automate the analysis of the output of some codes, allowing reviews of key indicators to quickly determine if the code ran as expected.

Caveat 6. SPM-1 analysis is limited to evaluating the ability of the WIPP disposal system to meet specific regulatory requirements as defined in Section 5. Any other requirements from the regulator are not covered in this analysis.

The SPM-1 concerns itself only with post-closure regulatory compliance. As such, regulations related to the operational period of WIPP are not considered. Furthermore, based on prior modeling results, the SPM-1 does not address 40 CFR 191, Subpart B, 191.15 (individual protection requirements), and 40 CFR 191, Subpart C (environmental standards for groundwater protection). Compliance with the radionuclide containment regulation requirements is assumed when the mean CCDF meets the requirements of 40 CFR Part 191, Subpart B, 191.13 (a), i.e., below the values specified in the regulation.

Compliance with the post-closure hazardous constituents concentration regulatory requirement is assumed in SPM-1 when the hazardous constituent concentration calculated at the Resource Conservation and Recovery Act (RCRA) unit boundary is less than the health-based level for soils for each hazardous constituent. For SPM-1, the anhydrite interbed pathway uses from the top of marker bed 138 to the bottom of marker bed 139, the shaft pathway uses the model shaft diameter, and both pathways use gas-available porosity for concentration calculations. The hazardous constituent concentrations are calculated from the mean of the multiple deterministic concentrations calculations to include the effect of parameter uncertainty. For SPM-1, only five VOCs were looked at, and values for the VOC source term and for the health-based level for soils were assumed.

SPM-1 was run to demonstrate that the SPM is computationally feasible and that the type of information desired could be generated. None of these caveats should thus cause any concern, as long as the SPM-1 results are not interpreted for the purpose of making programmatic decisions.

4. MODELING CODES USED IN SPM-1

The PA process for the SPM-1 prototype required the modeling of the repository shaft system for the undisturbed scenario, and either one or two boreholes for the E1, E2, and E1E2 human intrusion scenarios (see Appendix D for definitions of the three scenarios). BRAGFLO was used to model two-phase flow in the repository shaft system, boreholes, and in the Salado Formation. The PANEL code used the borehole flow to mobilize radionuclides and transport them to the Culebra. SECO2D and SECO/TP were used to model radionuclide flow and transport in the Culebra.

The VAST code used the BRAGFLO flow fields to model transport of VOCs in the gas phase for the RCRA CI determination. The NUTS code was used to model transport of a non-reactive tracer in brine to allow the determination of the potential for contaminated brine flow. The CUTTINGS code was used to model three separate physical processes causing direct releases to the surface, including cuttings, cavings, and spallings.

SPM-1 required the development of new software for assembling and post-processing PA results, storing activities and activity set data (cost, duration, connection to PA results), performing the decision analysis, and displaying and exploring the decision analysis results. The new codes developed for SPM-1 are briefly summarized below:

MIXMASTER: combines and re-scales output from PANEL, SECO/TP, and Cuttings for each CCDF construction case.

CONREL: uses MIXMASTER output to calculate CCDFs for histories of random drilling intrusions.

CI191B: compares CONREL mean CCDF for each calculational case to the 40 CFR 191.13(a) performance requirements.

CIRCRA: compares VOC concentrations calculated by VAST to evaluate compliance with RCRA health-based soil concentrations.

CISET: uses the results of CI191B and CIRCRA to update the activities database.

CPROB: calculates probability of demonstrating compliance using the activities, activity sets, outcomes, and compliance results in the activities database.

Database queries and macros were also developed for:

1) generating activity sets
2) calculating costs and durations for activity sets
3) exploring and displaying decision analysis results

5. THE SPM-1 CI

The scope of the system prioritization effort has been defined as post-closure regulatory compliance. Activities that are to take place during the operational period of the WIPP are not considered. Results of prior modeling of undisturbed performance have indicated that radionuclide releases without human intrusion are very small. Based on these prior modeling results, the system prioritization analysis does not address 40 CFR Part 191, Subpart B, 191.15 (individual protection requirements), and 40 CFR Part 191, Subpart C (environmental standards for groundwater protection).

The CI addressed by the system prioritization effort is based on the radionuclide containment requirements of 40 CFR Part 191, Subpart B, 191.13(a), and the hazardous constituent concentration requirements of 40 CFR 286.6 with health-based levels for soil.

5.1 Radionuclide Containment

Compliance with the radionuclide containment regulatory requirements is assumed when the mean CCDF meets the requirements of 40 CFR Part 191, Subpart B, 191.13(a), i.e., below the values specified in the regulations.

5.2 Hazardous Constituent Concentration

Compliance with post-closure hazardous constituent concentration regulatory requirements is assumed when the hazardous constituent concentration calculated at the unit boundary is less than the health-based level for soil for each hazardous constituent.

Hazardous constituents transported to the RCRA unit boundary by gas are compared with the health-based levels. This focus on transport by the gas phase is based on the results of prior

modeling of undisturbed performance, which indicated that contaminated brine does not reach the unit boundary. The anhydrite interbed pathway model uses from the top of marker bed 138 to the bottom of marker bed 139; the shaft pathway uses the model shaft diameter; and both pathways use gas-available porosity, for concentration calculations. The hazardous constituent concentrations are calculated from the mean of the multiple deterministic concentration calculations to include the effect of parameter uncertainty.

5.3 SPM-1 WIPP Disposal System CI

The SPM-1 WIPP disposal system CI is equal to 1 if, and only if, the assumptions on radionuclide containment and hazardous constituent concentration compliance (as defined in Sections 5.1 and 5.2) are met; otherwise, the CI is equal to zero.

6. DECISION ANALYSIS METHODS

6.1 Computational Approaches

The following computational approaches were considered as potential ways to implement the SPM-1 analysis: Straight Brute Force, Selective Brute Force, Median/Median Calculations, and Interpolation Approaches.

Straight Brute Force: This potential computational approach involves the direct calculation of CCDFs for radionuclide releases and soil concentrations for hazardous constituents for every projected outcome of each combination of activities. Previous PA analyses have used this Straight Brute Force method, treating all input parameters and scenarios probabalistically, and generating about 70 different vectors for CCDFs to compare with the applicable 40 CFR 191 requirements. However, for the SPM-1 analysis, the Straight Brute Force would have required the calculation of many thousands of CCDFs and VOC concentrations to calculate the CI for each activity set combination.

Selective Brute Force: This computational approach involves the direct calculation of CCDFs for radionuclide releases and/or post-closure VOC soil concentrations for only the potential outcomes that are expected, on the basis of prior calculations or an understanding of the isolation system, to significantly impact the CI. For example, once compliance is indicated for chemical retardation above a certain threshold, there is no need for additional calculations of related activities with higher chemical retardation.

Median/Median Calculations: This computational approach involves the direct calculation of CCDFs for radionuclide releases and post-closure VOC concentrations using the single valued median of each parameter distribution instead of current PA methodology (i.e., Latin Hypercube sampling of each parameter distribution with multiple Monte Carlo calculations).

Interpolation Approaches: These potential computational approaches (there are as many of these approaches as there are interpolation algorithms) involve approximating the results for CCDFs and VOC concentrations associated with a given set of conceptual models and parameters by interpolating between previously calculated results created with the Straight Brute Force method.

Straight Brute Force was not used for the SPM prototype because of the large computational resources needed to implement this alternative. Median/median calculations were not used for the SPM prototype because of the unknown nature of potential systematic errors due to nonlinear models resulting in the median of the input distributions not resulting in the median of the output distribution. Interpolation approaches were not used for the SPM prototype because of the unknown extent of potential random errors associated with these alternatives prior to benchmarking.

The Selective Brute Force computational approach was chosen for the SPM prototype. As discussed in the definition above, once compliance is indicated for chemical retardation above a certain threshold, there is no need for additional calculations of related activities with a higher chemical retardation. Therefore, for SPM-1, the SNL SPM team elected not to overtly calculate the CCDF for cases above the threshold. We did, however, account for the probability that these cases will occur and will lead to a favorable demonstration of compliance in the decision matrix. In preparation for SPM-2, we plan to use the results from the SPM-1 PA calculations as a library for rerunning SPM-1 with alternative interpolation computational approaches to benchmark the interpolation approaches. The benchmarking information, along with the results of rerunning SPM-1 with the median/median technique, will be used to select a computational approach for SPM-2.

6.2 Construction of Decision Matrix

6.2.1 Definition of Measure of Value and Discriminators

The SPM involves the evaluation of whether the CI that was calculated using the baseline indicates compliance of the WIPP disposal system (see Caveat 6). If the answer is no, the goal of the SPM decision analysis is to predict the value to DOE-CAO of implementing different activities or activity sets on the basis of increasing the probability of demonstrating compliance.

The probability of demonstrating compliance, as indicated by the CI, is the sole measure of value used by SPM-1.[1] In the terminology of decision analysis, the probability of demonstrating compliance is the utility function for the analysis.

For the different activity sets, the SPM decision analysis derives the functional relations among the three discriminators: the probability of demonstrating compliance, cost, and duration. The SPM decision matrix is an array of numbers defining the functional relationship among these discriminators.

6.2.2 Probability of Demonstrating Compliance and the CI

The results of the PA calculations for the assumed activities and their potential outcomes are CCDFs for radionuclide releases and soil concentrations of VOCs. The CI is determined by comparing these results to the applicable quantitative regulatory standard.

The computational approach used for the SPM decision analysis allows for separate analysis of the value of the activity sets with respect to RCRA and 40 CFR 191. This can be particularly useful when considering PB-WAC and engineered design alternatives to implement for purposes of increasing the probability of demonstrating compliance with one or the other regulation.

The probabilities of demonstrating compliance for individual activities and activity sets are calculated. The probabilities for the potential outcomes for activities in the set(s) are combined with the calculated results for the CIs to calculate the probability of demonstrating compliance (see Caveat 6) for each activity set combination. Figure 2 shows Activity Set K,

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[1]Note that decision analysis allows for additional measures of value to be used if desired.

an example of an SPM activity set composed of activities 1 and 3. The potential outcomes for each activity and the estimated probability of occurring are listed.

ACTIVITY SET K

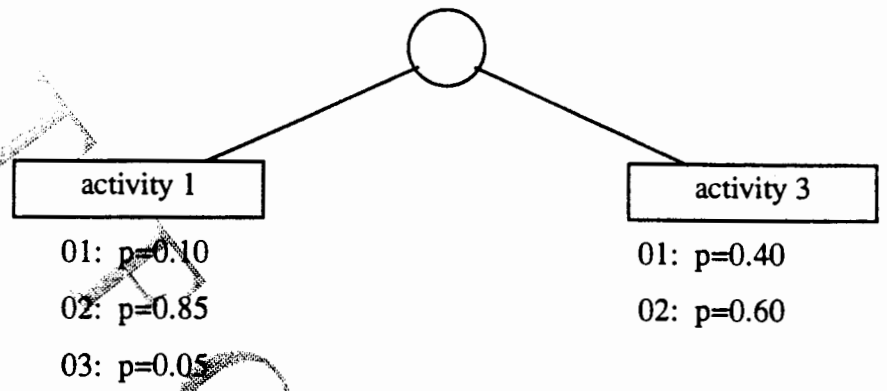

Figure 2. Activity Set K

In this example, assume the PA analyses show that all outcomes, with the exception of Outcome 3 for Activity 1 in combination with Outcome 2 for Activity 3, which results in demonstrating compliance. Then the probability that Activity Set K will demonstrate compliance is the sum of the probabilities of the outcome combinations that demonstrate compliance, or

$$(0.1)[(0.4)+(0.6)]+(0.85)[(0.4)+(0.6)]+(0.05)(0.4)=0.97.$$

The probability that Activity Set K will result in outcomes that, when analyzed by PA, will <u>not</u> demonstrate compliance, is

$$(0.05)(0.60)=0.03.$$

6.2.3 Constructing the Decision Matrix

The SNL SPM team constructed the decision matrix by associating the calculated probability of demonstrating compliance with cost and schedule information for all activity sets considered. The cost and schedule data used in SPM-1 are from the pre-validated, rebaselined SNL five-year plan, and are broken down according to the current WIPP Work Breakdown Structure (WBS) elements. The resulting decision matrix contains, for each activity set

combination, the relationship between the discriminators of cost, schedule, and probability of demonstrating compliance.

6.2.4 Analysis of the Decision Matrix

It is possible to display in a 3-D plot the probability of demonstrating compliance of the activity set that leads to the highest probability of demonstrating compliance (see Caveat 6) within each cost and schedule category (see Section 7.1, Figure 3). In SPM-1, the SNL SPM team also found other analyses useful to understand the results. The SPM-1 results and corresponding database will be used to design corresponding analysis algorithms for SPM-2.

It is important to note that the goal of SPM is to provide DOE-CAO with a decision matrix that shows the activity sets leading to the highest probability of demonstrating compliance with the selected regulatory standards. Correspondingly, the utility function for the SPM decision analysis is the probability of demonstrating compliance with the selected regulatory standards. However, one can also analyze the information produced from the PA analyses of potential outcomes of activities using a different utility function, such as one based on demonstrating the probability of compliance with other portions of 40 CFR 191.

7. SPM-1 RESULTS AND CONCLUSIONS

This section discusses the results and conclusions of the SPM-1 effort. It is divided into three subsections: 1) results of the SPM-1, 2) lessons learned from the implementation of SPM-1, and 3) a discussion of SPM as a decision tool.

7.1 SPM-1 Results

The major purpose of the SPM-1 effort was to conduct a prototype of the SPM in order to determine the feasibility and usefulness of this technology. This effort has demonstrated:

1) The ability to reconfigure the original 1992 PA codes in a timely fashion to contain or approximate altered conceptual models for both a baseline calculation and a suite of activity sets. Examples of reconfigurations include: the addition of a spallings model (see Appendix B.7), the inclusion of actinide colloids (see Appendix B.6), an accounting for preferential (non-axisymetric) flow in the activity sets (see Appendix B.1), the adjustment of the recharge heads

to bound climatic effects (see Appendix A.1.1), and the elimination of effective panel seals (see Appendix C.2).

2) The development of databases and the execution of decision analysis software to handle large files of information regarding budget and schedule, and the CI resulting from the PA models.

3) The ability to handle a large number of: input vectors to the PA models (~37,000 input vectors); computations (500 Cray central processing unit (CPU) hours, 340 Alpha CPU hours, and 600 Paragon node hours); and PA output files (~1,500 mean CCDFs for 40 CFR 191 and 300 RCRA concentration calculations for each of five VOCs).

4) The ability to reduce a very large amount of information, including results from ~1500 separate activity sets, into a decision matrix.

The SPM-1 team implemented steps 1-7 of the SPM. The team specified how the SPM-1 CI would be evaluated (step 1) (see Section 5), identified the models and data believed necessary for evaluating the baseline CI (step 2) (see Appendix A), and then evaluated the CI for the WIPP disposal system using models and data from the baseline (step 3) (see Section 4 and 5). The results of the baseline evaluation for RCRA and 40 CFR 191.13(a) are presented in Tables 3 and 4, respectively. Table 3 shows that the calculated baseline mean soil concentrations are less than the assumed health-based levels. Table 4 shows that the SPM-1 baseline calculated probabilities for the normalized releases exceed the probability criteria in 40 CFR 191.13(a). For the CI to equal 1, both assumptions on radionuclide containment and hazardous constituent concentration (see Section 5 and Caveat 6 in Section 3) must be met. Since both assumptions were not met in SPM-1, the SPM-1 baseline CI equaled 0.

Activities available to the WIPP project that, if implemented, would have the potential to impact the system's CI, were identified (see Appendix B) (step 4). The SPM-1 team prescribed what new information, or changes to existing information, might evolve if specific activities were implemented (step 5). They also identified potential outcomes and appropriate PA parameters and/or models for each of these outcomes (see Appendix B; see also Table 1). The potential outcomes of the identified activities were then modeled using PA codes (step 6), and the probability of demonstrating compliance for combinations of activity outcomes, and the probabilities of those potential outcomes, were calculated. These were compiled into a three dimensional (3-D) plot of the probability of demonstrating compliance of the activity sets that

Table 3. Baseline RCRA Results

Hazardous Constituent	Assumed VOC Headspace Concentration (ppmv)	Calculated SPM-1 Baseline Mean Soil Concentrations (mg/kg)	Assumed Health-Based Level for Soil (mg/kg)
Carbon Tetrachloride	441	0.01	5.38
Methylene Chloride	177	0.001	93.33
1,1,1-Trichloroethane	391	0.01	7,200
Trichloroethylene	14	0.001	63.63
1,1,2-Trichloro-1,2,2-Trifluoroethane	41	0.001	2,400,000

Table 4. Baseline 40 CFR 191.13(a) Results

Normalized Release (40 CFR 191, Appendix A, Table 1)	40 CFR 191.13(a) Probability Criteria	SPM-1 Baseline Calculated Mean Probability of Exceedence
1	<0.1	0.93
10	<0.001	0.85

leads to the highest probability of demonstrating compliance against each associated cost and schedule category (step 7). A representation of the SPM-1 "decision matrix" is shown in Figure 3. **Note that all of these SPM-1 numeric results are subject to the caveats in Section 3 and are not to be used for decision purposes.**

This decision matrix has only one duration category, with all activities being completed between one to two years. This lack of discrimination in the duration variable is a result of the process used to define the SPM-1 budget and schedule input and is discussed in Section 7.2.1.

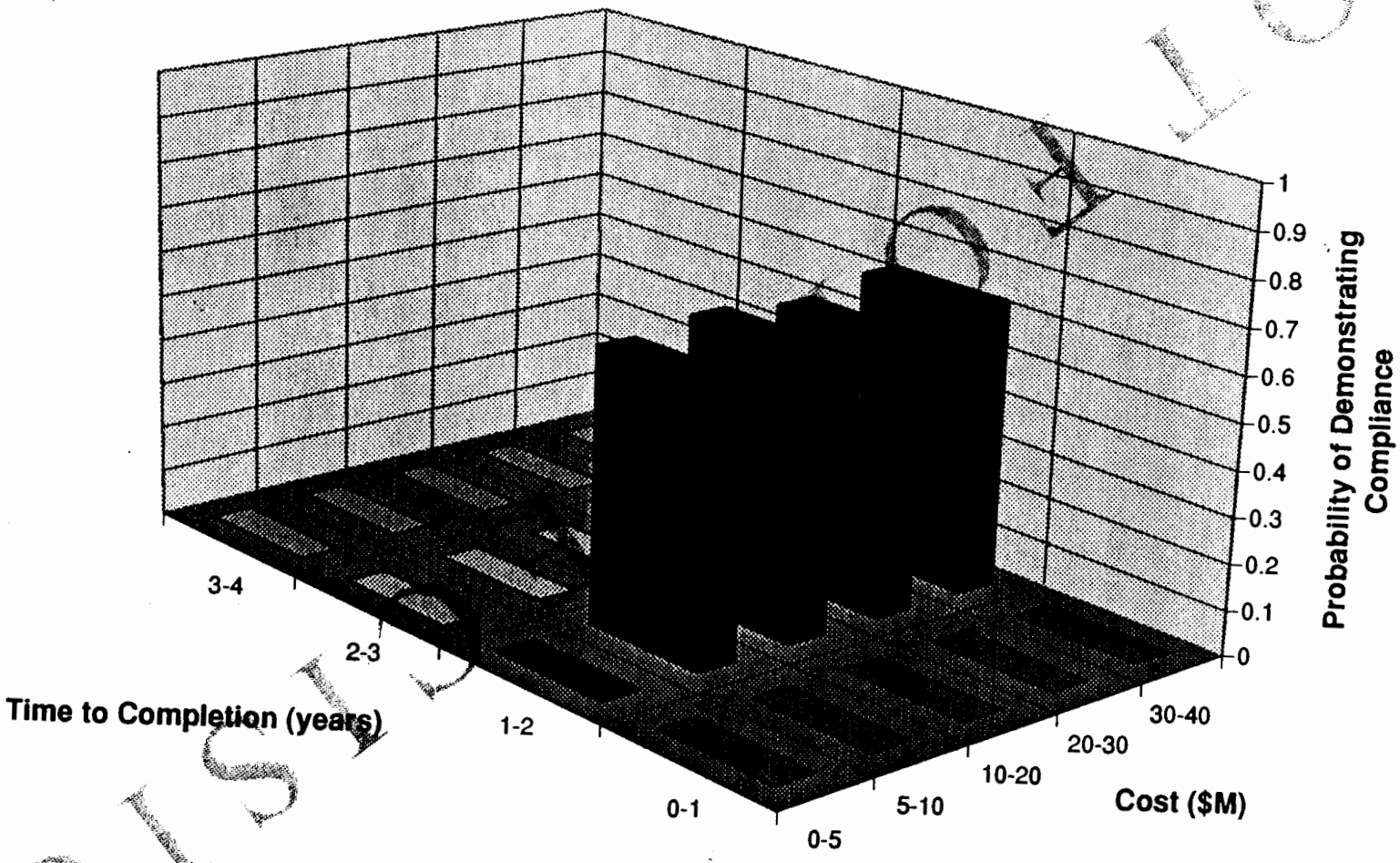

Figure 3. A representation of the SPM-1 decision matrix.

Figure 4 is a representation of a hypothetical fully 3-D form of the decision matrix expected from the SPM-2 budget and schedule process, which will include activity durations that are not constrained by the Disposal Decision Plan (DDP).

A major conclusion of the SPM-1 effort is that SPM analysis is possible given sufficient resources. Future iterations of SPM will need to handle an even larger number of activities and activity sets. This prototype effort has identified methods that are expected to address this need. Furthermore, the results of the SPM prototype will serve both as a benchmark and as a test bed for developing the tools needed for the anticipated requirements of SPM-2.

7.2 Lessons Learned from SPM-1

In addition to the high-level process results discussed in Subsection 7.1, additional information was obtained in the prototype that may impact future iterations of the WIPP SPM process. In this section, we document these "lessons learned."

7.2.1 Budget and Schedule Resolution

The SPM-1 decision matrix resulted in no discrimination in the schedule variable. This is because the SPM team simply imported the SNL portion of the WIPP schedule, which is already in alignment with the DDP, into the analysis. The current plan for SPM-2 includes budget information relating to the Experimental Program Plan (EPA) costs, the total WIPP project, and the National Transuranic (TRU) Program. The plan also includes defining activities with various durations and corresponding outcomes that are not constrained by the DDP. To take full advantage of the SPM as a decision-making tool, solid cost and schedule information of the right scope is needed, just as solid conceptual and computer models are needed to calculate the CI.

7.2.2 Embedded Assumptions

A lesson learned during implementation of the SPM-1 is that the SPM cannot measure the "regulatory compliance worth" of information in the baseline. The process is designed to measure the regulatory compliance worth of activity sets that will change the baseline. The worth is calculated from the potential change to the baseline resulting from implementing the activity sets. The regulatory compliance worth of activity sets with potential outcomes that are the same

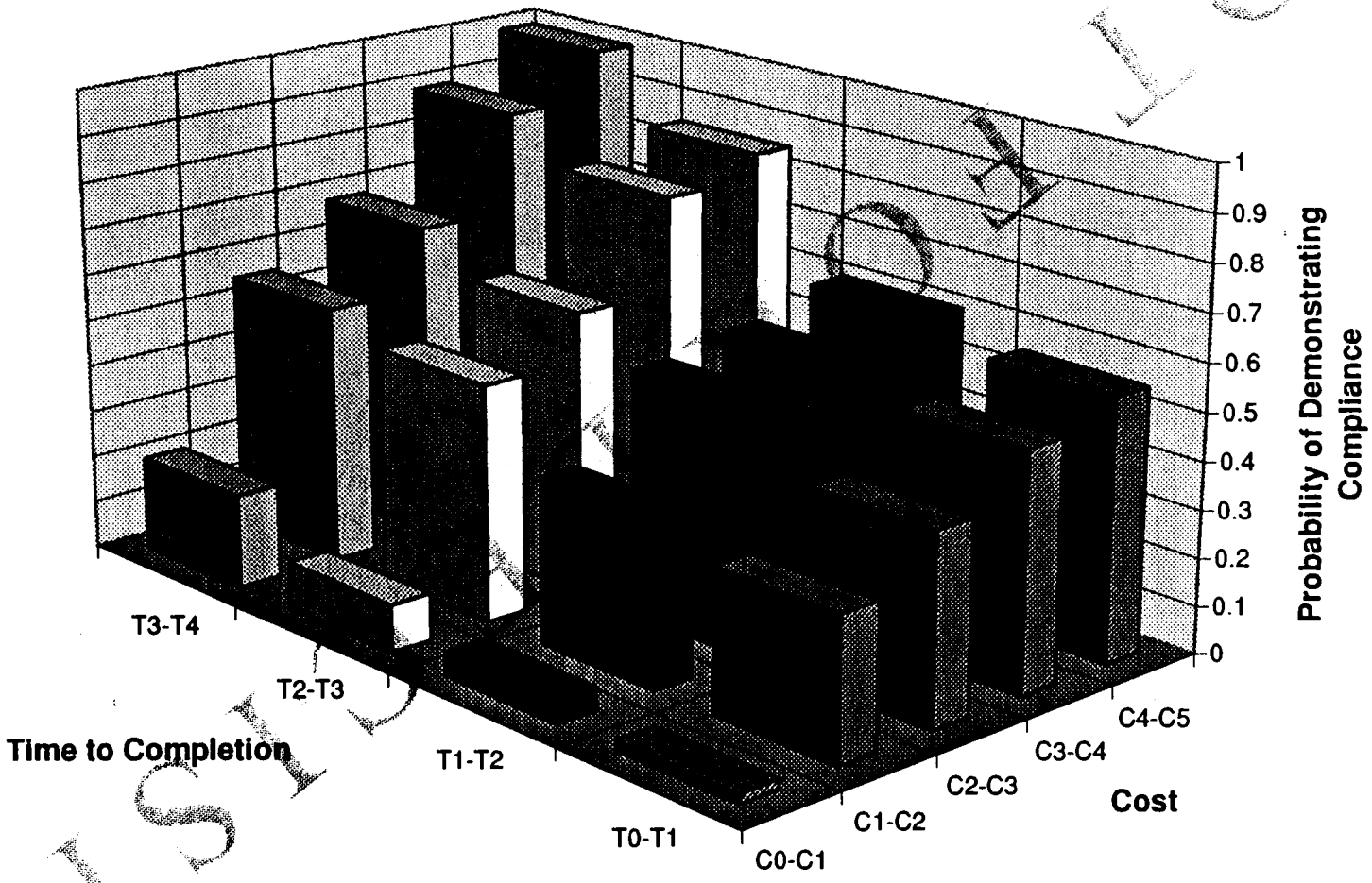

Figure 4. A representation of a hypothetical fully 3-D form of the decision matrix expected from the SPM-2 budget and schedule process.

as the baseline will be calculated to be zero. In some cases, the SPM-1 baseline contains modeling parameters that are unknown. If all possible combinations of these parameters can be used and the set that corresponds to the most significant regulatory impact is identified, that set may be used in the baseline, and the regulatory compliance worth of an activity set designed to measure the actual value of one or more of these parameters can be calculated using the SPM.

This phenomenon of embedded assumptions represents a limit to the applicability of SPM. The primary impact of it in SPM-1 appears to be in the area of the Salado modeling. Whether it will have an impact on SPM-2 depends on the nature of the SPM-2 baseline currently being defined in the PTB process. The principle risk associated with the embedded assumption phenomenon will arise when the decision to implement the activity sets is made. It appears that the risk will be at a maximum if the embedded assumption has not been identified. The decision risk can be minimized by the identification of these embedded assumptions.

7.2.3 Elicitation Process

There were three important lessons learned about the elicitation process.

The first lesson learned is that the credibility of the SPM depends largely on the credibility of the elicitation process. For SPM-1, the elicitation process involved informal interviews with PIs, when available, performed by SPM team members. For consistency, credibility, and improved quality of information, SPM-2 elicitation needs to be performed by consultants who are familiar with the WIPP project and who specialize in expert elicitations. The questions and documentation of the SPM-2 elicitations need to follow a standardized process.

The second lesson learned is that the elicitation process should allow for more time and for interactions among PIs and between PIs and PA analysts. The information provided by PIs about individual activities, when aggregated into information about potential outcomes of activity sets, can have dependent relationships between activity outcomes that must be verified. Additionally, there must be agreement between the PIs and PA modelers on the representation of the potential experimental outcomes in the PA computational approach for SPM-2. In some cases, potential outcomes for SPM-1 did not have adequate PA representation in the current models. An example is the full effect of colloid retardation, which was not phenomenologically modeled by the SPM-1 PA codes.

The third lesson learned is that more time needs to be allotted for the elicitation process than originally provided for SPM-1. The goal of SPM-2 will be to maximize the information in the position papers and information acquired from stakeholder interactions in order to obtain the necessary input to SPM-2 baseline for PA parameter input and models. We can only do this, however, if the position papers prepared for input to the PTB contain the baseline information required for SPM-2.

7.2.4 SPM-2 Computational Needs

The computational needs of SPM-2 are expected to be significantly larger than those required for SPM-1. Section 6.1 described the computational approaches considered for SPM-1. The results of SPM-1 will be used to develop and evaluate these approaches for use in SPM-2.

7.2.5 Automated Code Operations and Alternate Computational Platforms

One observation made while implementing the SPM-1 was that significant effort by individual analysts was needed to initiate the computer runs of various preprocessor codes, analysis codes, and post-processor codes. The SPM analysis would be faster if the execution of the PA codes were automated, and more analyst time would be available to review calculations, design analyses, or modify codes. The analytical codes that dominate the computer time required for an analysis have been modified for execution on a variety of computer platforms. Calculations in support of the prototype SPM were performed on Alphas using the Open-VMS operating system and Crays, HP work stations, and the Paragon massively paralleled processor using various UNIX-based operating systems. An additional observation was that a UNIX-based computational platform is more readily available than Open-VMS platforms to support the large scale intense computational efforts of SPM.

7.2.6 Post-Closure Design

An observation made during the definition of the prototype SPM analysis is that a formal definition of the post-closure facility conditions is needed to define the initial conditions of the post-closure analysis.

7.2.7 Configuration Control and Information Flow Requirements

The amount of information generated by SPM-1 was large, and the amount of information generated by SPM-2 will be at least an order of magnitude greater. This will lead to significant information management requirements and complicate a meaningful analysis of the results. The results contained in the decision matrix should be traceable back to the original proposed potential outcomes and their probabilities, through the conceptual model used to represent the outcome, the computer platform used to analyze the outcome, and the post-processing of results. This requires an automated process for information flow and a controlled configuration to process the information.

7.2.8 Decision Analysis Post-Processing

The decision matrix distills a large amount of information about the behavior of the WIPP disposal system. Once activity sets that maximize the probability of demonstrating compliance for a given cost and duration had been identified, the SPM team recognized the need to answer auxiliary questions in order to understand the results:

1) How sensitive is the result to the outcome probability?
2) Which activities have the greatest influence on compliance probability?
3) What is the effect of removing activities from, or adding activities to, selected sets?

Additional post-processing of the decision analysis results is needed to help answer these and related questions. Software should be developed to support SPM-2.

7.3 SPM as a Decision Tool

SPM-1 has demonstrated the ability to supply a decision maker with important information to aid in directing a program as complex as the WIPP program. The tool, however, is only as useful as the quality of the input data, including cost and schedule information. Although the SNL SPM team has just started to fully analyze the results from the SPM-1 prototype, it is clear (given activity cost, schedule, and potential outcomes) that SPM is a viable tool for identifying:

1) activity sets necessary for a given probability of demonstrating compliance (Section 3, Caveat 6),

2) activity sets that give the maximum probability of demonstrating compliance (Section 3, Caveat 6),

3) activities that have minimal impact on probability of demonstrating compliance (Section 3, Caveat 6), and

4) the potential worth, with respect to demonstrating compliance (Section 3, Caveat 6), of new activities.

FOR DECISION

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APPENDIX A: SPM-1 BASELINE

APPENDIX A: SPM-1 BASELINE

The SPM-1 baseline estimates the current state of knowledge with which the proposed activities and project design can be evaluated in terms of the regulatory requirements. The SPM-1 baseline is an estimate of the PTB made by the SPM team for the purposes of SPM-1 calculations only.

The following caveats apply specifically to the SPM-1 baseline:

Caveat A-1. The baseline does not include sufficient SNL staff, Westinghouse Waste Isolation Division (WID), DOE-CAO, regulator, or stakeholder involvement to represent a full range of concerns and therefore is not useful for drawing final programmatic conclusions.

Caveat A-2. Baseline model assumptions and parameters used in SPM-1 could not be defended in a compliance application because of Caveat A-1. The SPM-1 results cannot be used to draw conclusions about compliance.

Caveat A-3. The baseline contains embedded assumptions that presuppose the completion of certain activities; e.g., the assumption that fluid flow in the Salado Formation behaves according to Darcy's Law may require the completion of some subset of Salado experiments in order to be defensible.

These embedded assumptions are discussed further in Subsection 7.2.2.

A.1 SPM-1 Models and Data

Conceptual models, computational models, and data not described specifically in this section are the same as those used in the 1992 PA for the WIPP.

A.1.1 SPM-1 Baseline Assumptions about Flow and Transport in the Culebra Dolomite Member of the Rustler Formation

Regional groundwater flow is modeled using the 70 calibrated transmissivity fields used in the 1992 PA from which 20 sample fields were randomly drawn. Other assumptions, models, and data used in the 1992 PA remain unchanged. Specifically, the Culebra is modeled as a two-dimensional (2D) confined aquifer (no leakage) because the SPM team believes that confining transport through the Culebra is conservative with respect to subsurface releases at the site boundary, since the Culebra is the most permeable unit of the Rustler Formation. The regional

three-dimensional (3D) modeling activity is intended to confirm or refute this assumption as one of its objectives. In response to stakeholder concerns that the treatment of climate change is not defensible, SPM-1 uses the approach used in the 1992 PA of varying boundary heads in a northern "recharge strip," except that heads remain at their elevated position for the entire 10,000 years. This results in the maximum possible head gradient across the site, and provides an upper bound on the effect of climate change within the context of the 2D flow model.

The baseline model for radionuclide transport in the Culebra is one of the conceptual models analyzed in the 1992 PA with no chemical sorption and no physical retardation transport (i.e., single-porosity, fracture-only transport). Specifically, there is no porosity in the dolomite matrix and no clay fracture linings. These assumptions are made in keeping with the interpretation offered by the Environmental Evaluation Group (EEG) of the terms of the Agreement for Cooperation and Consultation between DOE and the State of New Mexico. Colloids are assumed to be transported at the same rate as dissolved mobilized actinides (i.e., they simply travel with the flow field). Uncertainty about the rate at which colloids are transported is believed to be insignificant compared to the uncertainty in the flow field already incorporated in the analysis. Furthermore, the source term model for the baseline, described below, does not distinguish between colloidal and dissolved forms of actinides.

A.1.2 SPM-1 Baseline Assumptions about Flow and Transport in the Salado Formation

Several changes have been made since the 1992 PA in the modeling of gas and brine flow and contaminant transport in the Salado Formation. These conceptual changes are included in the SPM-1 baseline and activity set evaluations. The BRAGFLO model now approximates pressure-dependent fracturing of anhydrite interbeds by varying porosity and permeability as a function of pressure when gas generation creates pressures that approach or exceed lithostatic. Additional stratigraphic layers have been added above the Salado Formation to model possible flow into units in addition to the Culebra and to the ground surface. The regions above the Culebra consist of the Santa Rosa, just below the ground surface, and Dewey Lake, 15.76 meters and 149.3 meters thick, respectively, with the water table 24.6 meters above the lower boundary of Dewey Lake.

Above the water table, the brine saturation was taken to be 0.20 and pressure was 1 atm. Below the water table, initial pressures were calculated assuming hydrostatic gradient with fluid (brine) density of 1230 Kg/m^3 and $g = 9.79\ m/sec^2$. Initial excavated regions had pressure equal to 1 atm. Additional properties are shown in Table A-1.

Table A-1

Stratigraphic Layers	Porosity	Permeability (m^2)	Residual Brine Saturation	Residual Gas Saturation
Santa Rosa	0.175	10^{-10}	0.20	0.20
Dewey Lake	0.20	10^{-15}	0.20	0.20

An unsaturated zone was added in the uppermost layer. Transport codes were incorporated for both VOCs and radionuclides, allowing the tracking of contaminants within the repository and the surrounding strata.

Uncertainty remains high about the model used to approximate the effects of fracturing and the validity of the assumption of radial homogeneous property flow used in BRAGFLO (i.e., possible preferential flow effects of channeling, fingering, and non-uniform fracturing were not simulated). The SPM-1 baseline thus contains the following assumption: if at any time pressure within the repository approaches or exceeds 12.5 MPa in the simulation, the gas phase in the repository is assumed to be directly connected to the regulatory boundary through the anhydrite interbeds. Gas concentrations and species filling the void space in the anhydrite just outside the regulatory boundary are the same as those calculated in the repository. No estimate is made of possible VOC degradation or sorption during transport. These assumptions bound the consequences of gas migration with respect to 40 CFR 268.6.

A comparable bounding assumption is not made for liquid-phase flow and transport in the Salado. Brine migration distances are much less than those for gas, and effects of preferential flow in the anhydrite are greatly diminished because capillary effects are assumed to allow brine into brine-saturated halite porosity while gas remains within the anhydrite pores. The system CI related to liquid-phase transport of contaminants in the Salado is estimated using the current BRAGFLO and NUTS models.

The dissolution of gas in brine is not addressed in the SPM-1 baseline. Gas transport is faster than brine transport; not allowing gas to dissolve in brine is therefore conservative.

Vertical fracturing was not considered in SPM-1 because vertical fractures are not expected in the Salado. The modeling of gas-phase transport in the Salado leaves no distinction between gas at the side boundary and at the top boundary of the regulated unit. Once 12.5 MPa pressure is reached in the disposal room, we assume that all disposal room gas is instantaneously transported outside of the regulated unit. For evaluating compliance with 40 CFR 268.6, we

therefore considered vertical fracturing to be no worse than horizontal fracturing. Note that vertical flow up the shaft is a separate issue, and calculated independently of the fracture issue.

In the shaft, initial brine saturation was taken to be 0.25 except in the zones above the water table, where the value 0.20 was used. Residual brine and gas saturations were 0.20 in all shaft regions, panel seals, backfill, and experimental rooms. Initial saturation in panel seals, experimental, and backfill was 0.25. Capillary pressures were assumed to be 0 in shaft regions above the top of the Culebra, the Dewey Lake, and Santa Rosa as well as in the MB139, MB138, and Anhydrite A and B.

A.1.3 SPM-1 Baseline Assumptions About the Inventory

Physical properties of waste and backfill were treated in the same manner as in the 1992 PA; for repository and Salado modeling, waste and backfill is a homogeneous material characterized by the same parameters used in 1992. Parameter values in some cases have been updated to reflect new information.

The radionuclide inventory was based on the 1994 Baseline Inventory Report (BIR) with the exception that values for remote handled (RH) U^{235} were reduced to transportation limits.

The VOC inventory was based on the best information available to DOE-CAO at this time.

Alternative inventories were not included in the SPM-1 baseline. However, DOE-CAO is currently initiating an effort to define a bounding waste envelope based on the performance of the waste in the disposal system. This envelope will be the basis for the PB-WAC that may be considered in future iterations of the SPM.

A.1.4 SPM-1 Baseline Assumptions About the Repository and Near Field

Room closure occurs, according to the 1992 porosity surface, until gas pressure reaches lithostatic. Thereafter, the room porosity and permeability remain constant. We note that the assumption of constant room porosity and permeability after lithostatic pressure is achieved is consistent with the assumption that anhydrite fracturing occurs at lithostatic pressure.

The gas-generation model used in SPM-1 was that used in the 1992 PA, updated with rate information documented in the June 18, 1993, memorandum of record from L.H. Brush to M.S. Tierney titled, "Likely Gas-Generation Reactions and Current Estimates of Gas-Generation Rates for the Long-Term Performance Assessment." In response to stakeholder concerns about

the treatment of the plastic and rubber inventory in past analyses, all plastic and rubber material are available for degradation reactions.

For SPM-1, the repository and surrounding strata are assumed to be horizontal.

The human intrusion model estimated cuttings and cavings in the same manner as in the 1992 PA. A simplified spalling model was included as defined by Berglund and Butcher. For two-phase flow calculations, waste permeability remained constant at 10^{-12} m^2. However, for the cavings, cuttings, and spalling calculations, waste permeability values were sampled from a loguniform probability distribution of 10^{-12} to 10^{-17} m^2.

The Disturbed Rock Zone (DRZ) was modeled with the halite regions having far-field halite properties for porosity, but enhanced permeability (i.e., $k=10^{-15}$ m^2), under the assumption that they do not act as a significant barrier to fluid flow.

In response to concerns from stakeholders that previous PA modeling of seals has taken unwarranted credit for the ability of concrete seals to prevent groundwater from the Culebra from reaching the repository, the concrete elements for all repository and panel seals were assumed to have a permeability range from 10^{-12} to 10^{-14} m^2 for the full 10,000 years. This range is comparable to that of silty sand, and is the best that can be defended until it can be demonstrated that large WIPP concrete sealing elements can be manufactured without fracturing the concrete. The repository seals contain 120 feet of concrete modeled either as a continuous column or as three discrete elements according to the seal design. If fractures occur in these concrete sections, they are not expected to heal. The crushed salt portions of the seals were modeled as having permeability two orders of magnitude less than the concrete elements for the first 200 years. From then on, the lowest 100 m of crushed salt was assigned a permeability value from the range 10^{-13} to 10^{-15} m^2. As modeled in SPM-1, the panel seals do not have halite elements, and have the properties of concrete for the full 10,000 years. Possible consolidation of backfill in the drifts was not modeled.

For the actinide source term, it was assumed that the total actinide inventory was available for liquid-phase transport as either dissolved or colloid-mobilized forms. This assumption was based on: 1) the lack of information concerning the solubility of actinide-bearing materials in the WIPP waste; 2) the anticipated local variability of Eh and pH conditions within the waste/backfill; and 3) the lack of agreement concerning whether the data pertaining to actinide solubilities in fresh water are applicable and/or bounding.

The initial water content of the waste has been estimated as ranging from 0.04% to 5.2%, with a median value of 0.44%. This parameter describes all water initially present in the

waste, including that remaining as residual moisture in the pore volume of well-drained material. The parameter value is expressed as a percent of the total porosity that is filled with water.

A.1.5 SPM-1 Assumptions about Human Intrusion

Consistent with the current EPA guidelines, the intrusion rate for SPM-1 was modeled as 30 boreholes/km^2 for 10,000 years for all realizations. Intrusions were random in time, and the first intrusion was assumed to occur as early as 101 years after closure.

The arbitrary plugs used in the 1992 and previous PAs to divert flow into the Culebra were removed. All SPM-1 borehole plugs were assigned permeability values from the range used in the 1992 PA, approximating that of silty sand.

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APPENDIX B: SPM-1 ACTIVITIES

APPENDIX B. SPM-1 ACTIVITIES

The primary goal of the SPM is to calculate the probability for each activity set identified of demonstrating compliance with portions of 40 CFR 191 Subparts B and 40 CFR 268.6. The activities to be considered in a comprehensive application of the SPM will include activities managed by DOE that have the potential to affect quantitative aspects of regulatory compliance; for example, experimental programs at SNL, engineered alternatives to current repository design or waste form, and possible modifications to the waste acceptance criteria.

For SPM-1, a limited group of activities were selected by the SPM team at SNL based on the following criteria:

- The activities should cover a broad range of program options to provide a useful demonstration of the modeling system and the decision analysis methodology.
- Definition of the activities and their potential outcomes should be based on real WIPP examples. As stated in the following caveats, these outcomes are hypothetical and not for use in programmatic decision-making. However, the usefulness of the demonstration depends on analyzing problems similar to those that will be faced in future iterations.
- The total number of activity sets should be small enough that analyses can be completed within the time available.
- All models and data not explicitly discussed in this appendix remained the same as in the baseline.

Results based on these activities should not be used for programmatic decisions for the following reasons:

Caveat B-1. The choice of activities and the characterization of their potential outcomes do not have project-level input, and reflect only the beliefs of members of the SPM team at SNL.

Caveat B-2. The activities considered in SPM-1 do not cover the full range of options available to DOE-CAO. Some activities have not been considered at all (e.g., various engineered alternatives), and others may have been simplified in inappropriate ways.

Eleven activities were considered in the SPM-1. These activities are: Salado Flow, Shaft Seals, Actinide Solubilities, Culebra Physical Retardation, Culebra Chemical Retardation, Actinide Colloids, VOC Degradation, Cuttings/Spallings, and a combined category, PB-WAC and Engineering Enhancements activities.

B.1 Salado Flow Activities

Many of the ongoing activities related to the Salado Formation are aimed at supporting the assumption that two-phase fluid flow in halite and anhydrite behaves according to Darcy's Law. This effort is aimed at both supporting the two-phase flow conceptual model and defining the appropriate parameter set needed to perform a two-phase flow calculation. Because of the inherent Darcy flow assumption in the present modeling system, SPM-1 cannot completely identify the data worth (i.e., estimate the value of the data relative to compliance), of all Salado activities. Some of the data worth will be essentially hidden from the analysis.

For the purposes of SPM-1 Salado activities, we expect future states of knowledge to change in two areas. We expect to be able to better define the two-phase flow characteristics of Salado halite, and we expect to better define the nature of preferential fluid flow in the Salado.

The Brooks-Corey and Parker-Van Genuchten two-phase flow relationships produce fundamentally different fluid flow behaviors, and they may generally bound the expected fluid flow behaviors in the Salado. They may or may not, however, capture the extremes in flow behaviors. The WIPP project currently has a two-phase flow parameter measurement program underway that should define the range of behaviors in FY95. However, for the purposes of SPM-1, we assume that there is a 50% probability that fluid flow in the Salado will be controlled by the two-phase flow characteristics represented by the Brooks-Corey relationship. Furthermore, we assume that if Salado flow is not controlled by the Brooks-Corey relationship, it will be controlled by two-phase flow characteristics represented by the Parker-Van Genuchten relationship. Thus, for activity-set analysis, we would construct results using only Brooks-Corey relations for one outcome and results using only Parker/Van Genuchten relations for another outcome.

As a result of Salado activities ,we expect to be able to defend calculated gas flow and VOC transport in the Salado instead of using the baseline conceptual model of instantaneous gas transport to the regulatory boundary when the pressure reaches 12.5 MPa. This assumes that we will be able to account for preferential flow behavior either directly in the flow modeling or through the use of simplified modifications to symmetric flow modeling. SPM-1 uses a model for pressure-dependent fracturing of anhydrite where permeability and porosity of the anhydrite are increased as a function of pressure when pressure exceeds the undisturbed pore pressure of the unit. This model is referred to as the "altered anhydrite model." In addition, we multiply the gas transport distance by a factor that is our current best estimate of the effects of preferential flow process (i.e., anhydrite dip, heterogeneity, and fingering). This factor is used to determine the earliest time that gas might cross the regulatory boundary. Once it is

determined that gas has crossed the boundary, VOC concentrations are determined based on the VOC source term and the dilution caused by the net gas generation at that time.

Probabilities assigned to these models, based on the assumption that all Salado activities are implemented, are as follows:

Table B-1. Salado Outcomes.

Gas Flow Conceptual Models	Probability
Baseline Gas Flow Model	0.10
Altered Anhydrite Gas Flow Model	0.90
Preferential Gas Flow Factor	
10	0.2
6	0.3
4	0.3
2	0.1
1 (Axisymmetric radial flow)	0.1

B.2 Shaft Seals

Activities related to sealing address many issues, such as performance of concrete elements, consolidation of salt elements, and DRZ grouting.

Table B-2. Seal Outcomes.

Seal Permeability	Probability
Baseline Values	0.01
10^{-16} - 10^{-18} Loguniform	0.09
10^{-18} - 10^{-19} Loguniform	0.90

Note that the seal program not only improves the permeability of the seal, it gives a better performing seal much earlier in the repository life. Therefore, the above permeability ranges apply, beginning with emplacement, throughout the 10,000-year regulatory period.

For SPM-1, we assume the length of the seal, as a result of seal program activities, will be the same as the baseline length; that is, 100 meters.

B.3 Actinide Solubilities

The following probabilities are assigned for ranges of actinide concentrations, assuming completion of the source-term related activities.

Table B-3. Actinide Solubilities Outcomes.

Outcome	Probability
Inventory Limited (Baseline Values)	0.01
10^{-14} - 10^{1} M (Expert Judgment Values)	0.49
10^{-14} - 10^{-4} M (Possible Reduced Range)	0.50

Note that the distributions for the baseline are defined in Appendix A.1.4 and the other distributions are the same as used for the 1992 PA analysis. In the case of reduced range, these distributions will be truncated at the specified upper endpoint of the range.

B.4 Physical Retardation in the Culebra

Sensitivity analyses conducted as part of the 1992 PA identified fracture spacing within the Culebra as the single parameter in the PA model that had the largest effect on physical retardation when using the dual porosity conceptual model. Fracture spacing in the PA transport model controls the amount of available surface area on fracture walls where contaminants can diffuse into the matrix.

The probabilities assigned for possible value ranges of Culebra fracture spacing, assuming implementation of activities related to physical retardation are shown in Table B-4.

B.5 Chemical Retardation in the Culebra

The chemical retardation activity determines effective values for the partitioning coefficients (K_ds) and chemical retardation models used in PA, based on the type of the groundwater flow, on a laboratory scale, in Culebra core (i.e., whether it occurs in sub-horizontal fractures and/or high-angle fractures, or whether it can be discriminated at all). The type of groundwater flow affects the selection of K_ds and the modeling of retardation, because

Table B-4. Probability of Outcomes for Physical Retardation Experiments.

Culebra Fracture Spacing	Probability
Baseline values	0.05
Based on single well testing 0.1 to 8 m (Uniform)	0.95
Based on single and multiwell testing	
0.1 to 3 m (Uniform)	0.38
0.1 to 1 m (Uniform)	0.57

clay deposits are located along the sub-horizontal fractures and in horizontal clay lenses. The flow in horizontal fractures will have much more contact with clay deposits than will the flow in high-angle fractures, which only intersect the thin clay layers. Probabilities for the five selected potential outcomes of the chemical retardation activity are shown in Table B-5.

For computational expediency in SPM-1, Cases 2 and 3b were both modeled assuming bulk rock K_ds based on a mixture of 95 wt% dolomite and 5 wt% clay. In the SPM-1 analysis, the K_ds were calculated based on 1992 PA distributions for dolomite and clay. For each vector, a matrix K_d and a clay K_d were sampled then weighted. Cases 3a and 3c were both modeled assuming a clay lining and a fracture retardation factor calculated from 1992 clay K_ds. Therefore, the 20 possible permutations of physical and chemical retardation (4 x 5) can be reduced to the five distinct cases shown in Table B-5.

Single Porosity:

1. Fracture flow where clay lining and fracture concentration equilibrium is assumed; fracture retardation is calculated from K_ds based on a 5 wt% clay mixture (Cases 2 and 3b).
2. Fracture flow retardation where clay and fracture concentration equilibrium is assumed; fracture retardation is a function of clay K_ds from the 1992 PA (Cases 3a and 3c).

Dual Porosity:

3. Fracture flow; no clay; matrix K_d = 0.0; use fracture spacing physical retardation outcome 2 (see Table B-5).
4. Fracture flow; no clay; matrix K_d = 0.0; use fracture spacing physical retardation outcome 3 (see Table B-5).
5. Fracture flow; no clay; matrix K_d = 0.0; use fracture spacing physical retardation outcome 4 (see Table B-5).

Table B-5. Probabilities of Potential Outcomes for the Chemical Retardation Activity

Outcome	Probability
Case 1 - No retardation (baseline)	0.01
Case 2 - No distinction between flow in sub-horizontal and high-angle fractures	0.95
Case 3a - Flow in sub-horizontal fractures only	0.0133
Case 3b - Flow in high-angle fractures only	0.0133
Case 3c - Flow in both sub-horizontal and high-angle fractures w/ significant distinguishing differences	0.0133

Note 1: In the case of single porosity and no retardation, all radionuclides released in the Culebra were assumed to instantaneously travel to the regulatory boundary. Release to the accessible environment was assumed equal to release to the Culebra as calculated by the PANEL code. Past PAs have shown that the conceptual model consisting of single porosity fracture flow with no retardation leads to relatively fast travel times, much less than 10,000 years.

Note 2: In the case of dual porosity and chemical retardation (cases 2, 3a, 3b, and 3c), past PAs have demonstrated that integrated release at the regulatory boundary is very small. Therefore, it was not necessary to recalculate these cases.

B.6 Actinide Colloids

Colloids are solid particles small enough to remain suspended in liquids. Radionuclide-bearing colloids may form in the repository environment or during transport within the Culebra. Colloids have the potential to affect radionuclide transport because they will have different physical and chemical properties than dissolved species. Specifically, physical retardation (diffusion) may not occur if colloid diameters are sufficiently large, relative to fracture apertures, that most transport occurs in central portion of the flow path. Furthermore, chemical retardation by sorption may not occur for colloids.

Colloids are assumed to be preferentially mobilized over dissolved species and, once mobilized, they are assumed to be transported with no chemical or physical retardation in the Culebra.

Table B-7 shows the probabilities of the possible outcomes for the colloid investigation activity expressed as total actinide concentrations in mobile colloids (moles/liter).

Table B-7. Probabilities of Outcomes for Colloid Experiments

Outcome Category Total Concentration of Actinides in Moles/Liter	Probability
$<10^{-9}$	0.33
10^{-8}	0.33
10^{-7}	0.18
10^{-6}	0.09
10^{-5}	0.05
10^{-4}	0.01
Inventory Limited	0.01

Interpretation of experimental outcomes from colloid-related activities are likely to be straightforward. However, application of the results will depend on the outcomes of other activities (such as source term), and policy decisions (such as PB-WAC). In particular, the formation of colloids in the repository environment is expected to be sensitive to the presence of humic acids contained in soil-rich waste forms. The two cases below account for a potential effect of humic acids on the concentration of actinides in mobile colloids.

B.6.1 Case 1

If the waste inventory has no significant amounts of high molecular weight organic materials, such as those found in soils, the parameters for the corresponding lognormal probability distribution for the total concentration of actinides to be used in the PA model are those given in Table B-8.

Table B-8. Conditional Probability Distributions for PA Total Actinide Colloid Concentration

Outcome Category (Total Concentration of Actinide Colloids in Moles/Liter)	Lognormal Parameters for PA Model	
	μ	σ
$< 10^{-9}$	-9	1.03
10^{-8}	-8	1.03
10^{-7}	-7	1.03
10^{-6}	-6	1.03
10^{-5}	-5	1.03
10^{-4}	-4	1.03

The lognormal probability density function for colloid concentrations to be used in the SPM-1 activity sets code evaluations is given by:

$$f(x;\mu,\sigma)=(\sigma x)^{-1}(2\pi)^{-1/2}\exp\left[\frac{-(\ln x-\mu)^2}{\sigma^2}\right]$$

where μ is the mean and σ is the standard deviation.

B.6.2 Case 2

For wastes containing significant amounts of high molecular weight organic materials such as those found in soils (for example, wastes related to decommissioning and environmental restoration), the concentrations used in the PA model (see Table B-8) are multiplied by 10. Otherwise the information in Tables B-7 and B-8 remain unchanged.

B.7 Cuttings/Spallings

Spalling occurs when solid waste material is transported into an intruding borehole as the repository depressurizes. The amount of waste released by spalling will depend on the strength and permeability of the waste, and the pressure within the repository, among other factors. The ongoing spalling activities are designed to provide better understanding of the waste's response to rapid depressurization.

Based on the assumption that either a decision will be made to control the waste permeability, or that completion of spalling-related activities will result in a spalling model that includes a waste strength parameter and a non-zero value for waste strength, the following probabilities are assigned to a factor used to scale the baseline spalling release. Calculated baseline spalling releases are multiplied by the scaling factor.

Table B-9. Spalling Outcomes

Spalling Scaling Factor	Probability
1 (baseline release, zero waste strength)	0.05
0.5	0.20
0.1	0.35
0.01	0.40

B.8 PB-WAC and Engineering Enhancements

The idea behind PB-WAC is to control the type, form, or quantity of waste accepted by the WIPP in a fashion that improves the performance of the system with respect to the applicable regulations. For the purposes of SPM-1, only three conditions were investigated. These are PB-WAC Excluding Soils, PB-WAC Excluding RCRA VOCs, and PB-WAC Excluding All Metals.

B.8.1 PB-WAC Excluding Soils

Modifying the waste acceptance criteria to limit or exclude soil from the waste could reduce humic acids in the waste, and thereby limit colloid formation. The treatment of this hypothetical change is discussed in Appendix B.6.

B.8.2 PB-WAC Excluding RCRA VOCs

If the hazardous constituent concentration CI shows non-compliance due to the transport of a single or small number of VOCs, a solution may be found by simply applying a PB-WAC limitation on the inventory of specific VOCs.

Possible benefits of this hypothetical PB-WAC are considered in SPM by assuming that it is possible to exclude VOCs from the inventory.

PRELIMINARY

B.8.3 PB-WAC Excluding All Metals

Numerous engineering enhancements can be thought of as limiting the impacts of gas-generation from waste degradation processes. For the purposes of SPM-1, these are combined into a single category that limits the total gas potential by reducing the amount of corrodible metal in the repository to zero. Note that the cellulosic and plastic content are the same as defined in the June 1994 BIR, and are therefore the same as those used in the SPM-1 baseline.

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APPENDIX C: COMPLETE LIST OF SPM-1 CAVEATS AND ASSUMPTIONS

APPENDIX C: COMPLETE LIST OF SPM-1 CAVEATS AND ASSUMPTIONS

1. The SPM-1 baseline is an estimate of the future PTB used for the purposes of prototyping the SPM and reflects only the beliefs of members of the SPM team at SNL. It does not include sufficient SNL, Westinghouse Waste Isolation Division (WID), DOE-CAO, regulator, or stakeholder involvement to represent a full range of concerns and therefore is not useful for drawing programmatic conclusions.

2. Only conceptual models that could readily be incorporated into the modeling structures used in the 1992 PA analysis were considered for the SPM-1 baseline and the activity set outcomes.

3. Possible outcomes of the SPM-1 activities were defined in part using information obtained in limited and informal elicitation of the PIs and are estimates for the purposes of prototyping the SPM. These activity outcomes are estimates for the purposes of prototyping the SPM. The interpretation of these outcomes and their use in SPM-1 are the sole responsibility of the SPM team at SNL.

4. The tie between activity sets and cost and schedule for SPM-1 is an estimate for the purposes of prototyping the SPM.

5. While in general we believe that the decision matrix information correctly reflects the results of the computer modeling, there may be isolated errors in results because of insufficient time to check the output and behavior of each run of each code in detail, due to the large amount of information handled.

6. The SPM-1 analysis is limited to evaluating the ability of the WIPP disposal system to meet the post-closure regulatory requirements as defined in Section 5. Any other requirements from the regulator are not considered in this analysis.

7. Baseline model assumptions and parameters used in SPM-1 could not be defended in a compliance application because of Caveat 1. The SPM-1 results cannot be used to draw conclusions about compliance.

8. The baseline contains embedded assumptions that presuppose the completion of certain activities; e.g., the assumption that fluid flow in the Salado Formation behaves according to Darcy's Law may require the completion of some subset of Salado experiments in order to be defensible.

9. The choice of activities and the characterization of their potential outcomes do not have project-level input, and reflect only the beliefs of members of the SPM team at SNL.

10. The activities considered in SPM-1 do not cover the full range of options available to DOE-CAO. Some activities have not been considered at all (e.g., various engineered alternatives), and others may have been simplified in inappropriate ways.

11. For SPM-1, only those stakeholder concerns received in writing prior to May 1994 and that could be easily implemented as simple code modifications were addressed.

12. For SPM-1, system performance was estimated using the baseline prescribed by the SPM management team (as opposed to the PTB), as described in Appendix A.

13. For SPM-1, potential outcomes of activity sets and the probabilities of these outcomes were prescribed by the SPM management team (as opposed to formal elicitations or a project-wide reference base), as described in Appendix B.

14. For SPM-1, assumptions based on experience from past PAs were used to screen unnecessary calculations.

15. The extent of the information derived from the SPM analysis, coupled with the short time available to study the resulting decision matrix, makes it virtually certain that more conclusions and insights will be obtained in the future.

16. For SPM-1, activities that are to take place during the operational period of the WIPP are not considered.

17. SPM-1 does not address 40 CFR Part 191, Subpart B, 191.15 (individual protection requirements), and 40 CFR Part 191, Subpart C (environmental standards for groundwater protection).

18. For SPM-1, compliance with the radionuclide containment regulatory requirements is assumed when the mean CCDF meets the requirements of 40 CFR Part 191, Subpart B, 191.13(a), i.e., below the values specified in the regulations.

19. For SPM-1, compliance with post-closure hazardous constituent concentration regulatory requirements is assumed when the hazardous constituent concentration calculated at the unit boundary is less than the health-based level for soil for each hazardous constituent.

20. For SPM-1, the anhydrite interbed pathway uses from the top of marker bed 138 to the bottom of marker bed 139, the model shaft diameter, and gas available porosity, for concentration calculations.

21. The hazardous constituent concentrations are calculated from the mean of the multiple deterministic concentration calculations to include the effect of parameter uncertainty.

22. For the baseline, regional groundwater flow is modeled using the 70 calibrated transmissivity fields used in the 1992 PA from which 20 sample fields were randomly drawn.

23. For the baseline, the Culebra is modeled as a two-dimensional (2D) confined aquifer (no leakage).

24. In response to stakeholder concerns that the treatment of climate change is not defensible, SPM-1 uses the same approach used in the 1992 PA of varying boundary heads in a northern "recharge strip," except that heads remain at their elevated position for the entire 10,000 years. This results in the maximum possible head gradient across the site, and provides an upper bound on the affect of climate change within the context of the 2D flow model.

25. The baseline model for radionuclide transport in the Culebra is one of the conceptual models analyzed in the 1992 PA with no chemical sorption and no physical retardation transport, i.e., single-porosity fracture-only transport.

26. For the baseline, colloids are assumed to be transported at the same rate as dissolved mobilized actinides; i.e., they simply travel with the flow field.

27. Uncertainty about the rate at which colloids are transported is believed to be insignificant compared to the uncertainty in the flow field that is already incorporated in the analysis.

28. The BRAGFLO model now approximates pressure-dependent fracturing of anhydrite interbeds by varying porosity and permeability as a function of pressure when gas generation creates pressures that approach or exceed lithostatic.

29. Above the water table, the brine saturation was taken to be 0.20 and pressure was 1 atm. Below the water table, pressures were calculated (initial conditions) assuming hydrostatic gradient with fluid (brine) density of 1230 Kg/m^3 and $g = 9.79\ m/sec^2$.

30. Initial excavated regions had pressure equal to 1 atm.

31. For the baseline, if at any time pressure within the repository approaches or exceeds 12.5 MPa pressure in the simulation, the gas phase in the repository is assumed for the purposes of estimating a CI to be directly connected to the regulatory boundary through the anhydrite interbeds.

32. For the baseline, no estimate is made of possible VOC degradation or sorption during transport.

33. For the baseline, Caveats 31 and 32 bound the consequences of gas migration with respect to 40 CFR 268.6.

34. A comparable bounding assumption (Caveats 31 and 32) is not made for liquid-phase flow and transport in the Salado.

35. The dissolution of gas in brine is not addressed in the SPM-1 baseline. Gas transport is faster than brine transport; not allowing gas to dissolve in brine is therefore a conservative assumption.

36. Vertical fracturing was not considered in SPM-1 because vertical fractures are not expected in the Salado.

37. In the shaft, initial brine saturation was taken to be 0.25 except in the zones above the water table, where the value 0.20 was used.

38. Residual brine and gas saturations were 0.20 in all shaft regions, panel seals, backfill, and experimental rooms.

39. Initial saturation in panel seals, experimental, and backfill was 0.25.

40. Capillary pressures were assumed to be 0 in shaft regions above the top of the Culebra, the Dewey Lake, and Santa Rosa as well as the MB139, MB138, and Anhydrite A and B.

41. Physical properties of waste and backfill were treated in the same manner as in the 1992 PA.

42. The radionuclide inventory was based on the 1994 Baseline Inventory Report (BIR) with the exception that remote handled (RH) U^{235} were reduced to transportation limits.

43. The VOC inventory was based on the best information available to DOE-CAO at this time.

44. Room closure occurs, according to the 1992 porosity surface, until gas pressure reaches lithostatic. Thereafter, the room porosity and permeability remain constant.

45. The gas-generation model used in SPM-1 was that used in the 1992 PA, updated with rate information documented in the June 18, 1993, memorandum of record from L.H. Brush to M.S. Tierney titled, "Likely Gas-Generation Reactions and Current Estimates of Gas-Generation Rates for the Long-Term Performance Assessment."

46. In response to stakeholder concerns about the treatment of the plastic and rubber inventory in past analyses, all plastic and rubber material are available for degradation reactions.

47. For the purpose of SPM-1, the repository and surrounding strata are assumed to be horizontal.

48. The human intrusion model estimated cuttings and cavings in the same manner as in the 1992 PA.

49. For two-phase flow calculations, waste permeability remained constant at 10^{-12} m^2. However, for the cavings, cuttings, and spalling calculations, waste permeability values were sampled from the uniform probability distribution of 10^{-12} to 10^{-17} m^2.

50. The Disturbed Rock Zone (DRZ) was modeled with the halite regions having far-field halite properties for porosity, but an enhanced permeability, i.e., $k=10^{-15}$ m^2, under the assumption that they do not act as a significant barrier to fluid flow.

51. The concrete elements for all repository and panel seals were be assumed to have permeability values from 10^{-12} to 10^{-14} m^2 for the full 10,000 years.

52. For the baseline, the crushed salt portions of the seals were modeled as having permeability two orders of magnitude less than the concrete elements for the first 200 years. From then on, the lowest 100 m of crushed salt was assigned a permeability value from the range 10^{-13} to 10^{-15} m^2.

53. Possible consolidation of backfill in the drifts was not modeled.

54. It was assumed that the total actinide inventory was available for liquid-phase transport as either dissolved or colloid-mobilized forms.

55. The initial water content of the waste has been estimated in a June 4, 1993, memorandum by B.M. Butcher and Lincoln as ranging from 0.04% to 5.2%, with a median value of 0.44%.

56. The SPM-1 baseline did not include the effects of nuclear criticality.

57. The intrusion rate for SPM-1 was modeled as 30 boreholes/km^2 for 10,000 years for all realizations.

58. Intrusions were random in time, and the first intrusion was assumed to occur as early as 101 years after closure.

59. All SPM-1 borehole plugs were assigned permeability values from the range used in the 1992 PA, approximating that of silty sand.

60. Brine releases to the ground surface during drilling was not examined in SPM-1.

61. Because of the inherent Darcy flow assumption in the present modeling system, SPM-1 can not completely identify the data worth, i.e., estimate the value of the data relative to compliance, of all Salado activities.

62. For the purposes of SPM-1 Salado activities, we expect future states of knowledge to change in two areas. We expect to be able to better define the two-phase flow characteristics of Salado halite, and we expect to better define the nature of preferential fluid flow in the Salado.

63. For the purposes of SPM-1, we assume that there is a 50% probability that fluid flow in the Salado will be controlled by the two-phase flow characteristics represented by the Brooks-Corey relationship.

64. We assume for SPM-1 that if Salado flow is not controlled by the Brooks-Corey relationship, it will be controlled by two-phase flow characteristics represented by the Parker-Van Genuchten relationship.

65. For SPM-1, we expect as a result of Salado activities to be able to defend calculated gas flow and VOC transport in the Salado.

66. For SPM-1, we assume that we will be able to account for preferential flow behavior either directly in the flow modeling or through the use of simplified modifications to symmetric flow modeling.

67. For SPM-1, we assumed the information in Table B-1.

68. For SPM-1, we assumed the information in Table B-2.

69. For SPM-1, we assumed the length of the seal, as a result of seal program activities, will be the same as the baseline length; that is, 100 meters.

70. For SPM-1, we assumed the information in Table B-3.

71. Sensitivity analyses conducted as part of the 1992 PA identified fracture spacing within the Culebra as the single parameter in the PA model that had the largest effect on physical retardation when using the dual porosity conceptual model.

72. For SPM-1, we assumed the information in Table B-4.

73. For SPM-1, we assumed the information in Table B-5.

74. For computational expediency in SPM-1, Cases 2 and 3b were both modeled assuming bulk rock K_ds based on a mixture of 95 wt% dolomite and 5 wt% clay.

75. Cases 3a and 3c were both modeled assuming a clay lining and a fracture retardation factor calculated from 1992 clay K_ds.

76. The 20 possible permutations of physical and chemical retardation (4 x 5) can be reduced to the following five distinct cases.

Single Porosity:

1. Fracture flow where clay lining and fracture concentration equilibrium is assumed; fracture retardation is calculated from K_ds based on a 5 wt% clay mixture (Cases 2 and 3b).

2. Fracture flow retardation where clay and fracture concentration equilibrium is assumed; fracture retardation is a function of clay K_ds from the 1992 PA (Cases 3a and 3c).

Dual Porosity:

3. Fracture flow; no clay; matrix K_d = 0.0; use fracture spacing physical retardation outcome 2 (see Table B-5).

4. Fracture flow; no clay; matrix K_d = 0.0; use fracture spacing physical retardation outcome 3 (see Table B-5).

5. Fracture flow; no clay; matrix K_d = 0.0; use fracture spacing physical retardation outcome 4 (see Table B-5).

77. For SPM-1, in the case of single porosity and no retardation, all radionuclides released in the Culebra were assumed to instantaneously travel to the regulatory boundary.

78. In the case of dual porosity and chemical retardation (cases 2, 3a, 3b, and 3c), past PAs have demonstrated that integrated release at the regulatory boundary is very small. Therefore, it was not necessary to recalculate these cases.

79. For SPM-1, colloids are assumed to be preferentially mobilized over dissolved species.

80. For SPM-1, once mobilized, colloids are assumed to be transported with no chemical or physical retardation in the Culebra.

81. For SPM-1, we assumed the information in Table B-7.

82. For SPM-1, we assumed the information in Table B-8.

83. For SPM-1, wastes containing significant amounts of high molecular weight organic materials such as those found in soils (for example, wastes related to decommissioning and environmental restoration), the colloids concentrations used in the PA model (as given in Table B-8) are multiplied by 10.

84. For SPM-1, we assumed the information in Table B-9.

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APPENDIX D: GLOSSARY AND ACRONYMS

APPENDIX D: GLOSSARY AND ACRONYMS

Glossary

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

Activity Set - A collection of activities that constitutes a coherent program option. SPM associates a probability of demonstrating compliance 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 specific post-closure performance requirements in 40 CFR 191.13(a) and 40 CFR 286.6.

Dual Permeability - A conceptualization of flow and transport through a fractured porous media where flow, advective transport and mechanical dispersion take place through both the fractures and pore space simultaneously. 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 the SPM-1 PA.

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 but missing the hypothetical brine reservoir.

E1E2 Intrusion Scenario - A characterization of an alternative future state of the WIPP disposal system that modes 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.

Probability of Demonstrating Compliance - The probability that, if a particular activity set is implemented, a defensible argument for compliance could be made based on the outcome of the activity set.

Acronyms

BIR - Baseline Inventory Report

CCDF - Complementary Cumulative Distribution Function

CI - Compliance Indicator

DDP - Disposal Decision Plan

DOE - Department of Energy

DOE-CAO - Department of Energy Carlsbad Area Office

DRZ - Disturbed Rock Zone

EPA - Environmental Protection Agency

IDB - Integrated Data Base

PA - Performance Assessment

PI - Principal Investigator

PTB - Project Technical Baseline

RCRA - Resource Conservation and Recovery Act

SNL -Sandia National Laboratories

SPM - Systems Prioritization Method

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SPM-1 - The first iteration of SPM

SPM-2 - The second iteration of SPM

PB-WAC - Performance Based Waste Acceptance Criteria

WBS - Work Breakdown Structure

WID - Westinghouse Waste Isolation Division

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Prototype of the System Prioritization Method

OVERVIEW

Mike McFadden
Carlsbad Area Office

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Agenda for Today's SPM Presentations

- SPM-1 Overview
- Caveats
- Decision Analysis Method
- SPM-1 Baseline/Activity Sets
- Results and Conclusions

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SPM First Iteration

- FY92 PA Modified by
  - Written Stakeholder Comments Received Prior to May 1994
  - Estimate of Present State of Knowledge
- Selected Engineered Alternatives from the EATF Report
  - ① Limit gas (metals)
  - ② " VOC
  - ③ " suits
- Plausible Outcomes of Experiments
- Completed September 30, 1994
- Ensure SPM Process Functions Properly

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Purpose of the SPM Prototype

- Evaluate Computational Feasibility
- Evaluate Viability of Decision Analysis Method on WIPP PA/Cost/Schedule Information
- Identify Problem Areas and/or Improvements to Address for Completing SPM-2

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Success of SPM Prototype

SPM-1 HAS DEMONSTRATED VIABILITY OF SPM AS A TOOL FOR IDENTIFYING:

- Activities Necessary for a Given Probability of Demonstrating Compliance
- Activities that Give the Maximum Probability of Demonstrating Compliance
- Activities that Have Minimal Impact on Probability of Demonstrating Compliance
- The Impact of New Activities on the Probability of Demonstrating Compliance

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Success of SPM Prototype

SPM-1 DEMONSTRATED:

- 1992 PA Codes Can Be Reconfigured in Timely Manner for New Data, Scenarios, and Conceptual Models
- Computational Requirements Can Be Met
- Development and Implementation of Activities, Cost, and Schedule Database
- Development and Successful Application of Decision Analysis Software

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SPM Second Iteration

end of March 95

- Regulator Concerns Addressed
- Stakeholder Concerns Addressed

via exchange meetings + followup correspondence (no strict deadline)

- Expanded List of Engineered Alternatives
- Refined Technical Baseline
- Completion Scheduled for March 1995

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Other SPM Iterations

- Will Occur As Necessary Depending on:
  - Results from Experiments
  - New Concerns Raised
  - Program Decisions Required

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Prototype of the System Prioritization Method

CAVEATS FOR SPM-1

Richard Lincoln
Sandia National Laboratories

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Caveat 1: SPM-1 Baseline

- The SPM-1 baseline is an estimate of the future Project Technical Baseline (PTB) used for the purposes of prototyping the SPM and reflects only the beliefs of members of the SPM team at SNL. It does not include sufficient SNL, WID, DOE/CAO, regulator, or stakeholder involvement to represent a full range of concerns and therefore is not useful for drawing programmatic conclusions.

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Caveat 2: SPM-1 Conceptual Models

- Only conceptual models that could readily be incorporated into the modeling structures used in the 1992 PA analysis were considered for the SPM-1 baseline and activity outcomes.
  - Results from a need to rapidly explore the feasibility of SPM technology

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Caveat 3: SPM-1 Possible Outcomes of Activities

- Possible outcomes of the SPM-1 activities were defined in part using information obtained in limited and informal elicitation of the PIs. These activity outcomes are estimates for the purposes of prototyping the SPM. The interpretation of these outcomes and their use in SPM-1 are the sole responsibility of the SNL SPM team.

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Caveat 4: SPM-1 Cost and Schedule

- The tie between activity sets and cost and schedule in SPM-1 is an estimate for the purposes of prototyping the SPM.
  - For SPM-1, cost and schedule were obtained for SNL portion of budget only.
  - Definition of the potential outcomes of activity sets occurred before recent budget validation exercise, which may lead to mismatches between the potential future states of knowledge and the associated budget and schedule.

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Caveat 5: SPM-1 Possible Isolated Errors in Output

- While in general, the SNL SPM team believes that the decision matrix information correctly reflects the results of the computer modeling, there may be isolated errors in results because of insufficient time to check the output and behavior of each run of each code, due to the large amount of information handled.

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Caveat 6: SPM-1 Selected Regulatory Requirements

- SPM-1 analysis is limited to evaluating the ability of the WIPP disposal system to meet specific post-closure regulatory requirements.
  - Only radionuclide containment requirements (40 CFR 191.13(a)) and hazardous constituent concentration requirements (40 CFR 286.6) considered Soil based standards
- Any other requirements from the regulator are not covered in this analysis.
  - Individual protection requirements (40 CFR 191.15)
  - Groundwater protection (40 CFR 191, Subpart C)
  - Others

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Prototype of the System Prioritization Method

DECISION ANALYSIS PROCESS

Nancy Prindle

Sandia National Laboratories

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SPM-1 Decision Analysis Process

CREDITS

The material described in this presentation was developed by an SNL team that included Walt Beyeler, Mel Marietta, Dave Rudeen, Jon Helton, Steve Hora, Fred Mendenhall, and Richard Lincoln

Rip Anderson

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Purpose of Presentation

- Describe General SPM Decision Analysis Process
- Present Details of Decision Analysis Process as Applied in SPM-1
- Answer Questions on Decision Analysis Process and Applications for SPM-2

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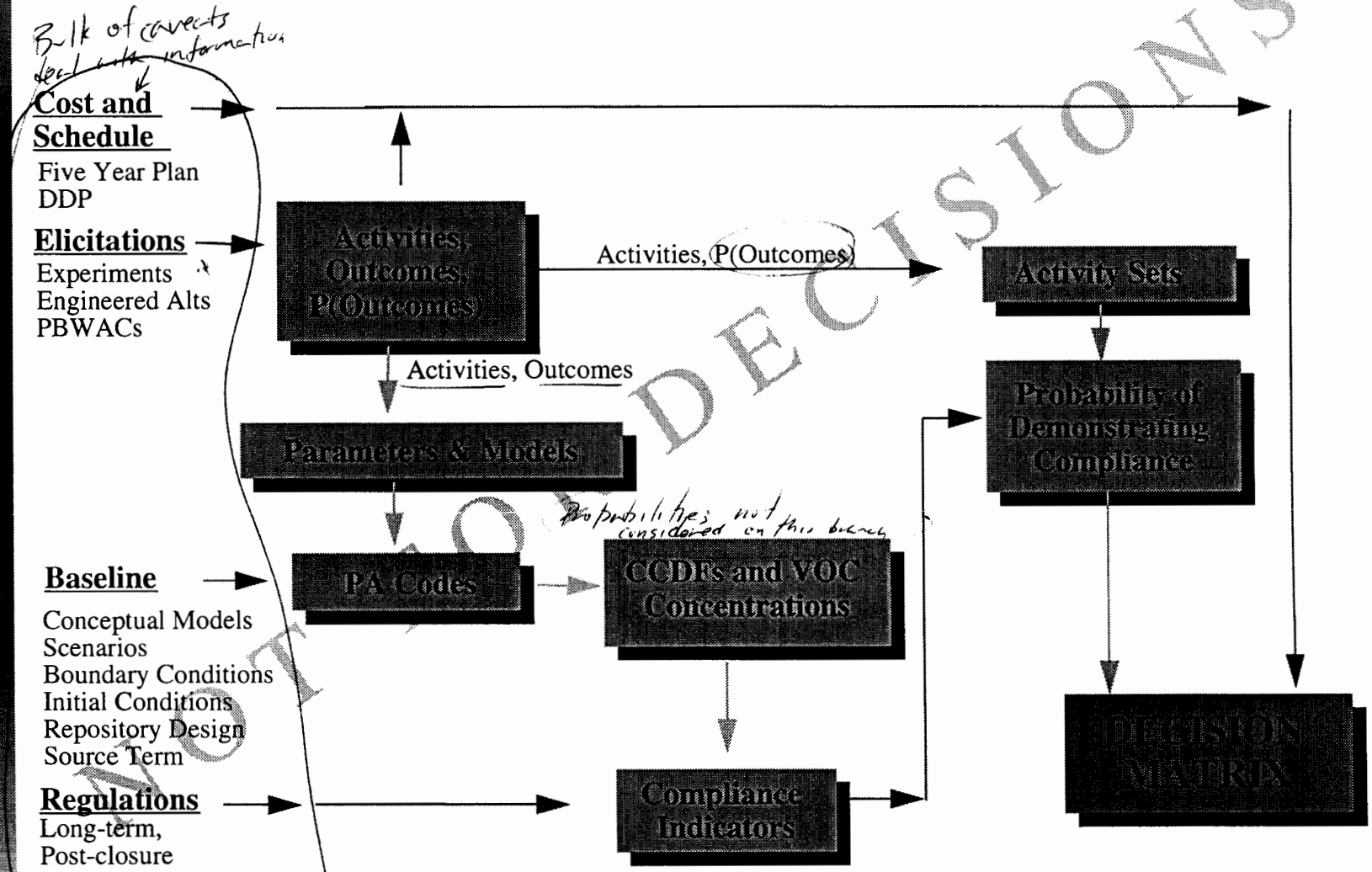
Decision Analysis Process - Information Flow



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Activity Definitions

- Prescribed by SPM-1 Team
- Based on ~~Involved~~ Informal Interviews with PIs
- Guided by 1992 PA Sensitivity Studies
- Tied to WBS (work breakdown Structure) Elements, EPP (Experimental Program Plan)
- Outcomes defined in Terms of PA Parameters and Models

NOT FOR DECISIONS

Examples of Activity Definitions

Activity	Outcomes
Colloid Program	Total Concentration of Actinide Colloids (m/l)
Multi-Well Tracer Test ~~Spacing~~	Culebra Fracture Spacing
Spallings Program	Spalling Scaling Factor

NOT FOR DECISIONS

Activity Set Definition

- Combinations of activities that constitute coherent program options
- Examples:
  - Activities: Colloid Program, Spallings Program, Multi-Well Tracer Test (MWTT)
  - Possible Activity Sets: 2^n

    {Colloid Program}, {Colloid Program, MWTT}, {Spallings Program, MWTT}, {Colloid Program, Spallings Program, MWTT}, ...

NOT FOR DECISIONS

Performance Assessment Calculations - Code Structure

- 1992 Methodology Used for Performance Measure Calculations
  - BRAGFLO, PANEL, VAST, NUTS, SECOFLO, SECOTP, CUTTINGS

new codes, not QA'd

- New Coding Developed for Calculating Complementary Cumulative Distribution Functions (CCDFs) for Radionuclide Releases
  - Will eventually be incorporated as a database routine

NOT FOR DECISIONS

Performance Assessment Calculations - "Selective Brute Force" for Selected Undisturbed Cases

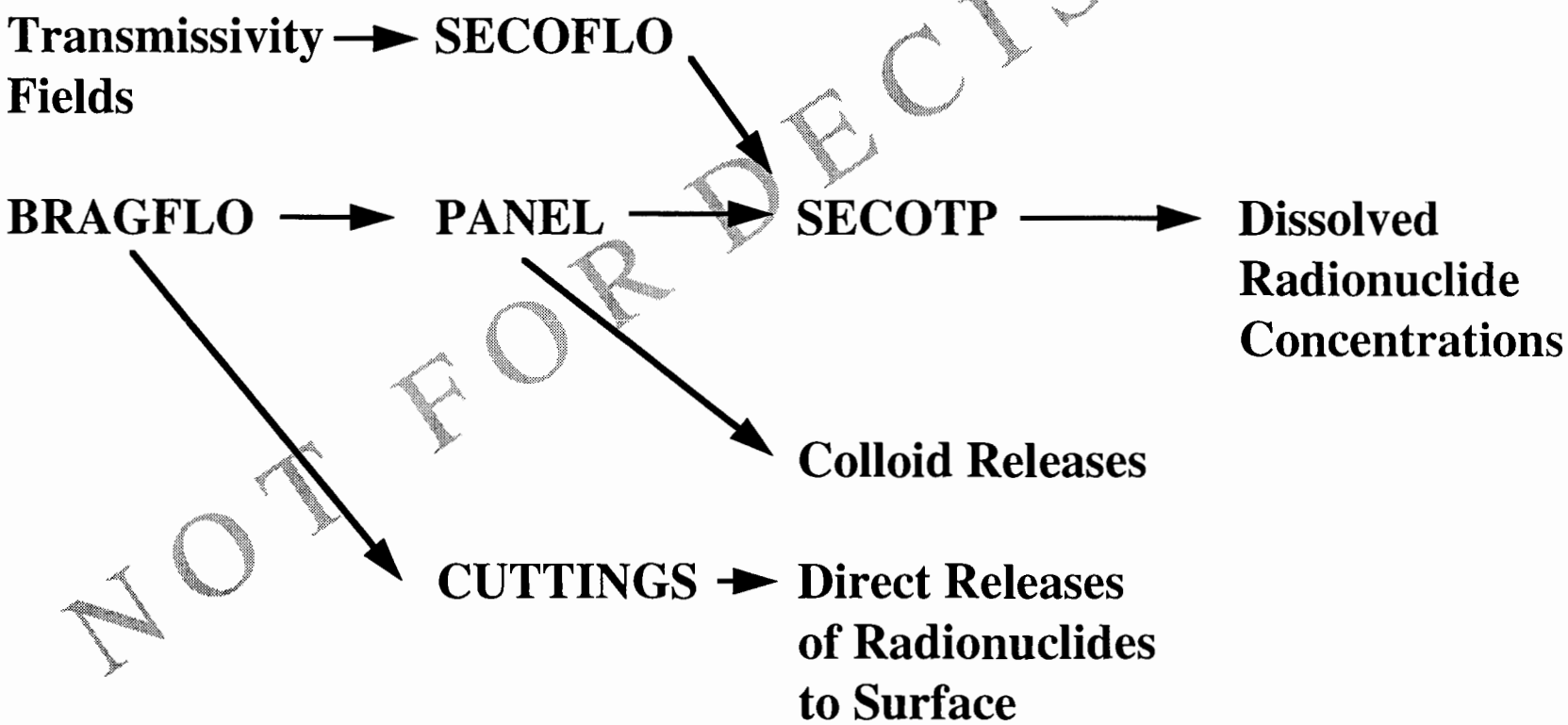
NOT FOR DECISIONS

BRAGFLO → VAST → VOC Concentrations

→ NUTS → Radionuclide Concentrations

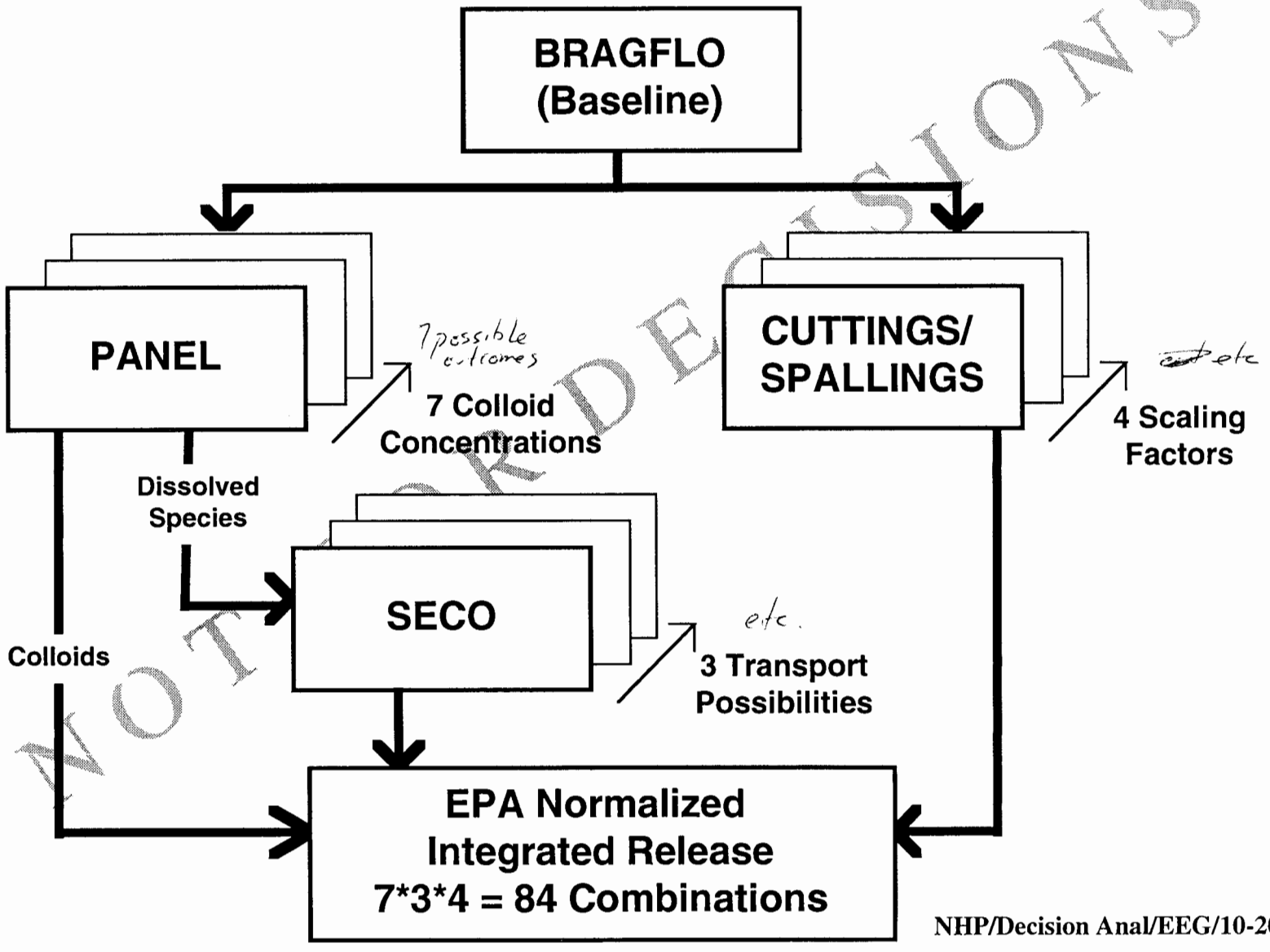
Straight brute force - normal mode of running PA codes

Performance Assessment Calculations - "Selective Brute Force" for Disturbed Cases



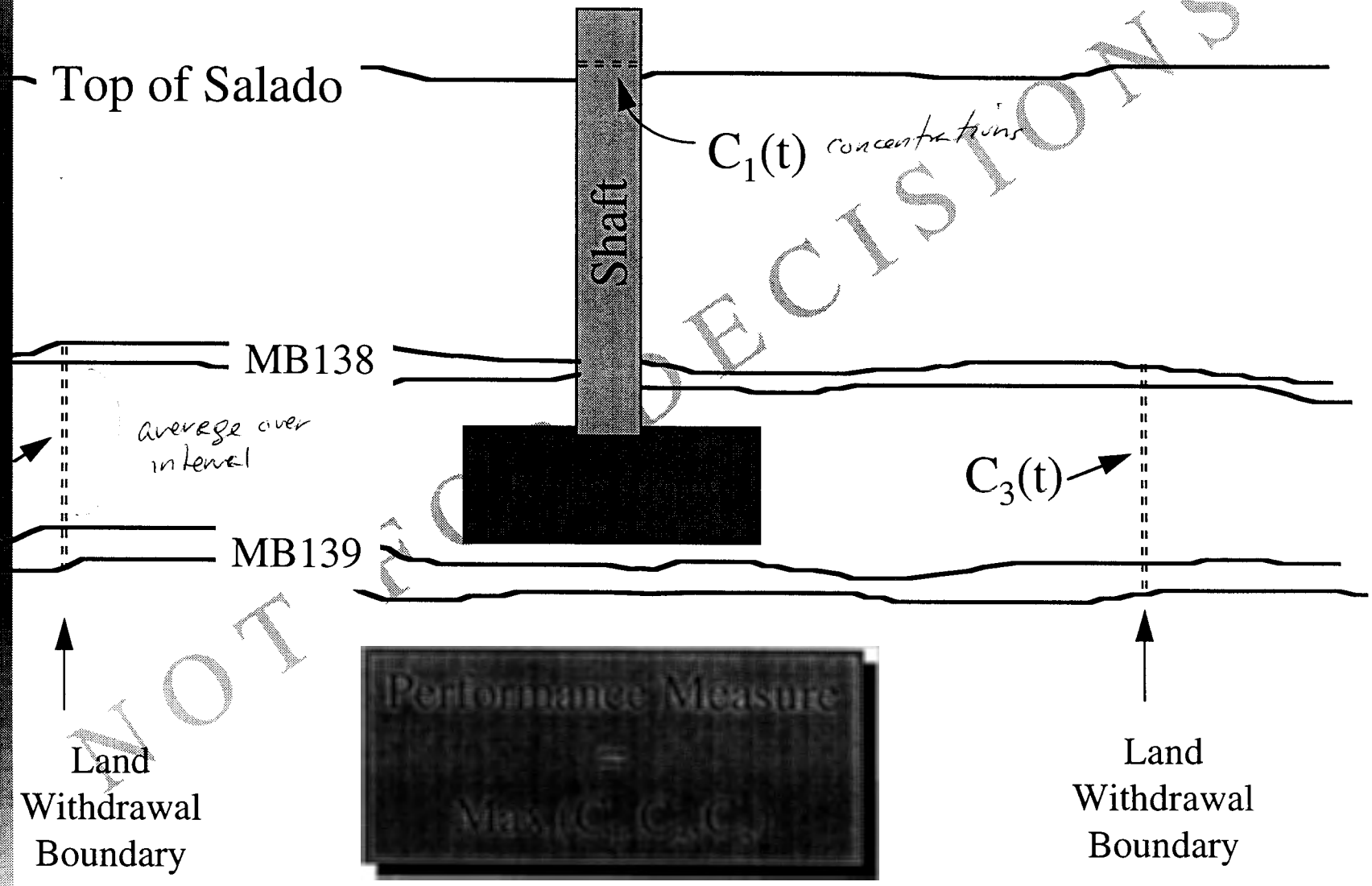
NOT FOR DECISIONS

Models and Parameters for Example Activity



NOT FOR DECISIONS

RCRA Performance Measure Calculations



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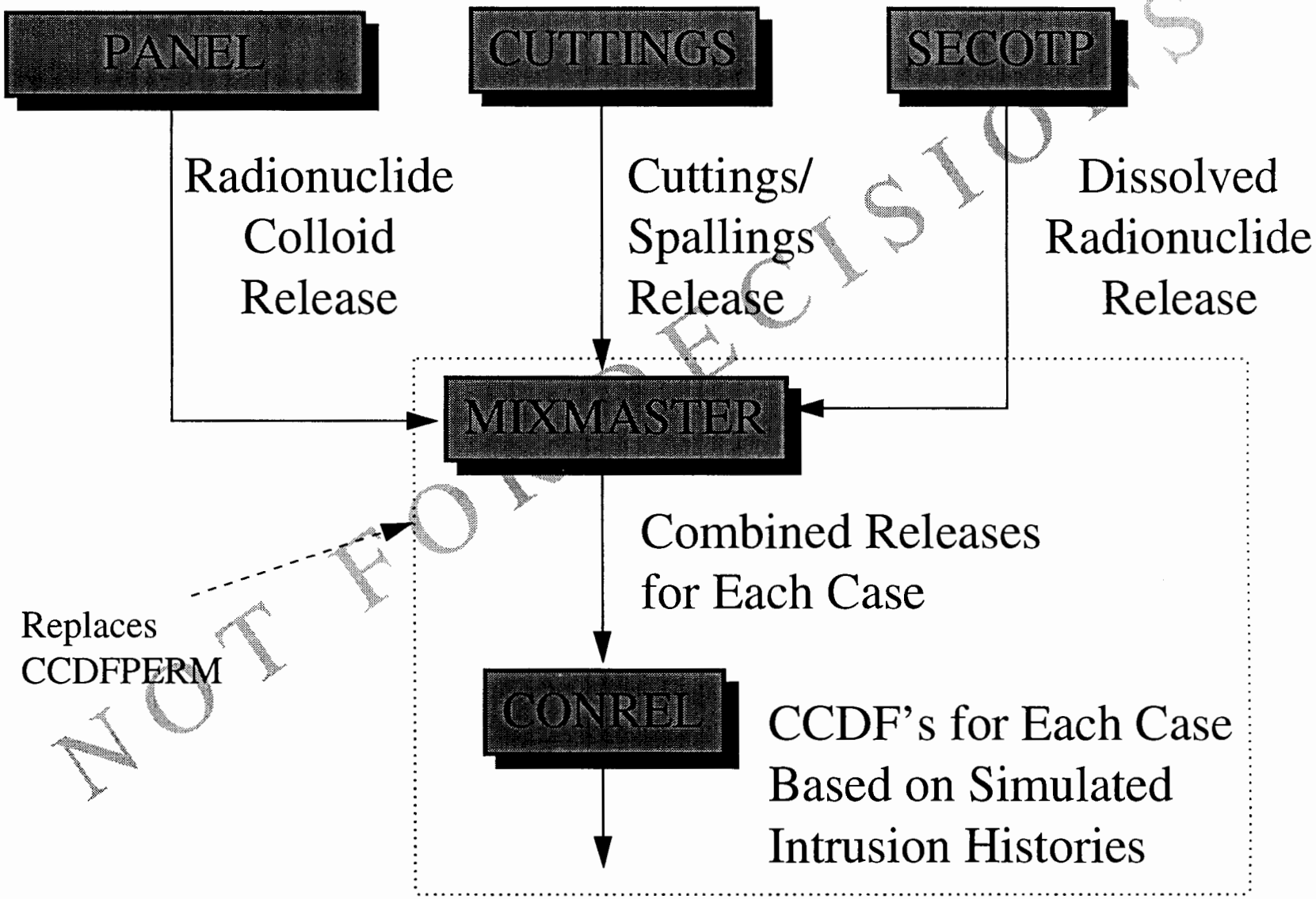
CCDF Calculation



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Compliance Indicator (CI)

- Binary Measure of whether the WIPP Disposal System is predicted to succeed or fail with respect to selected regulatory requirements
- SPM-1 CIs calculated by comparing values for performance measures to quantitative standards in 40 CFR 191.13 and 40 CFR 286.6

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Probability of Demonstrating Compliance

- Associated with Activity Sets
- Input to calculation:
  - probabilities of activity outcomes from elicitation
  - activity set definitions
  - compliance indicators for calculational cases
  - mapping between activity outcomes and calculational cases (big bookkeeping effort)
- Calculated for 1536 distinct activity sets in SPM-1

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SPM-1 Example: Calculation of Probability of Demonstrating Compliance

- For example activity set, CI = 1 when the following three conditions were satisfied: simultaneously
  - (1/1) Total colloid concentrations < 10^{-9} moles/liter
  - (2/3) Either outcome for fracture spacing in the dual porosity model (.1-3m or .1-1m)
  - (3/4) Any of the spalling factors less than one (i.e., 0.5, 0.1, or 0.01)

NOT FOR DECISIONS

SPM-1 Example: Calculation of Probability of Demonstrating Compliance

- Probabilities of these three conditions being satisfied:
  - 0.33 for Total colloid concentrations < 10^{-9} moles/liter
  - 0.38 + 0.57 for dual porosity model = .95
  - 0.20 + 0.35 + 0.40 for spalling factors less than one = .95
- Probability of demonstrating compliance for this example Activity Set is approximately

$$(.33)(.38 + .57)(.2 + .35 + .4) = 0.3$$

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Decision Matrix

- Built from activity set information in ACCESS database
  - probability of demonstrating compliance
  - cost
  - schedule
- Displays highest probability of demonstrating compliance for given cost and schedule categories

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Decision Matrix (cont)

- Multiple activity set solutions possible
- SPM-1 used only currently planned WIPP costs
- Process set up to allow other cost/schedule bases (not included in SPM1)
  - National TRU Program, Total Taxpayer
  - Elicitations as part of Activity Definitions

NOT FOR DECISIONS

Computational Resources Required for SPM-1 Decision Analysis Process

Module	Cray	HP	Alpha	Paragon	PC
BRAGFLO	475/950	35	195		
SECOFL, SECOTP	25/50				
VAST, NUTS			20		
PANEL			5		
CCDFCALC			5		
CCDFPERM			20		
Decision Analysis					50
MPP (Massively Parallel processor)				325 (5950)	
TOTALS	500/1000		245	325(5950)	50

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What will be different in SPM-2?

- Stakeholder Input to Baseline
- Formal Elicitation Process for Activity Definitions
- PA Code Automation & Configuration Management
- Expanded Information Base (i.e., cost and schedule)
- Conceptual Models in PA Codes

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What limitations remain in SPM-2?

- Limited to considering selected post-closure regulatory requirements only
- Worth of activities designed to confirm imbedded assumptions (baseline) difficult to measure by this process

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Conclusions

- SPM-1 Decision Analysis Process is Successful as Prototype for Generating Desired Information
- Design Improvements for SPM-2 Based on Lessons Learned
- SPM-2 Process will remove most but not all of SPM-1 Caveats

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Prototype of the System Prioritization Method

SPM-1 BASELINE & ACTIVITY SETS

Fred Mendenhall

Sandia National Laboratories

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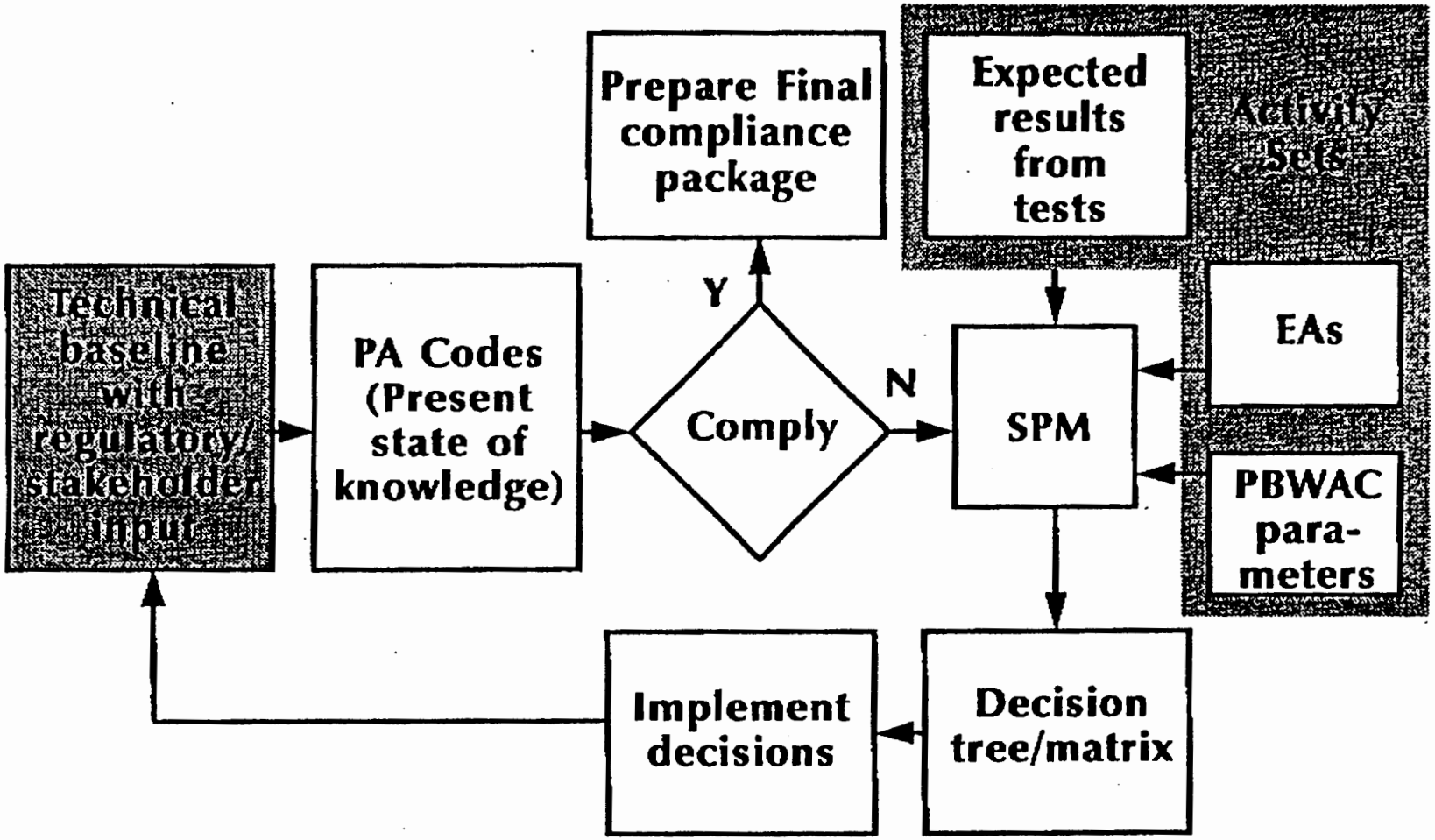
SPM STRATEGY



EA - Engineered Alternatives

PBWAC - Performance-Based Waste Acceptance Criteria

PA - Performance Assessment

784L:6535y

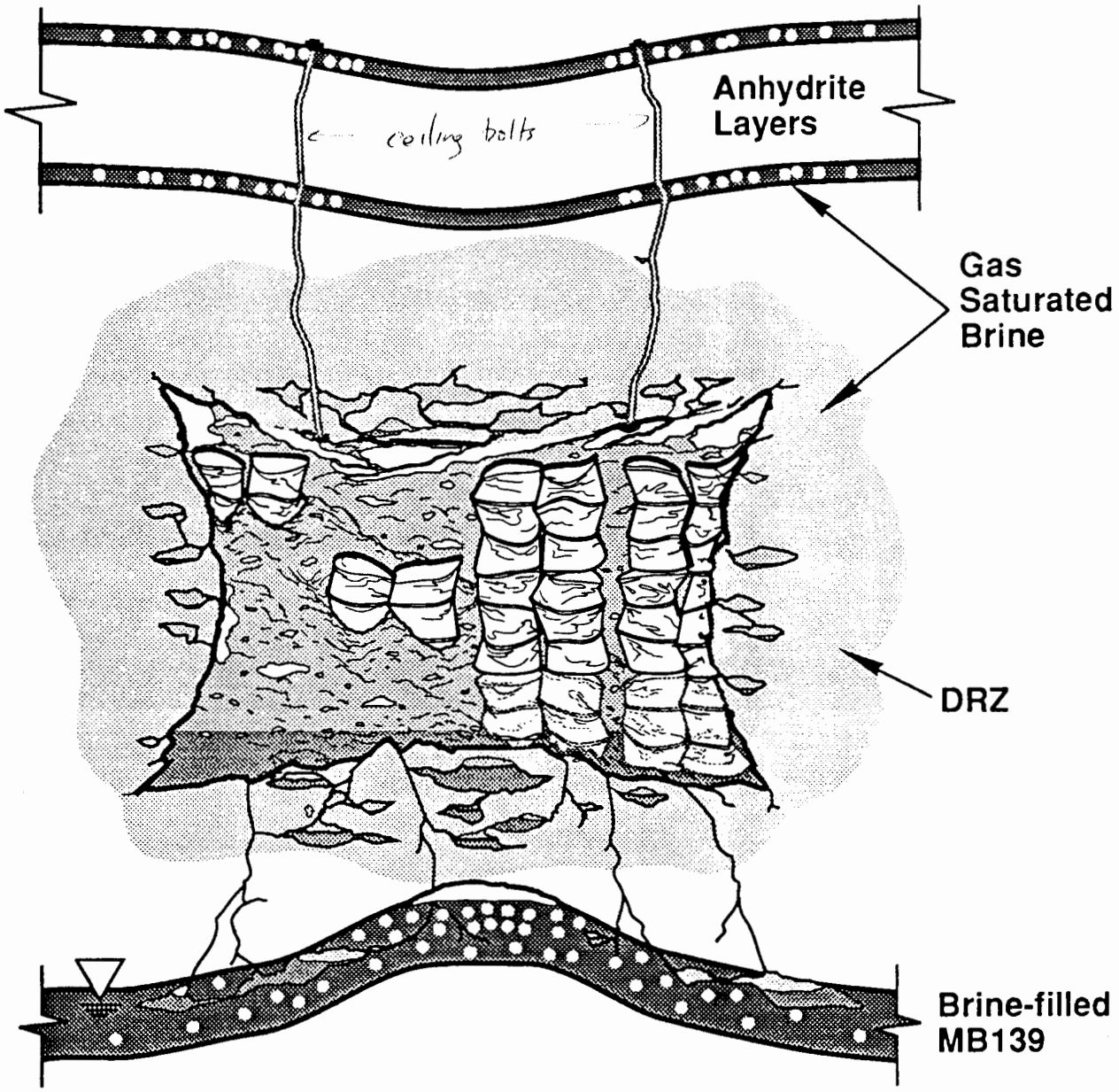
SPM-1 Baseline Assumes 12/92 Modeling.

- The 12/92 PA modeling is the default condition. That is, unless a change is specifically stated, the modeling and input parameters are those identified in the 12/92 PA Calculation.
- PA methodology is used.

The SPM-1 Baseline Defined Changes in These Areas:

- Salado
- Waste Inventory
- Culebra
- Near Field (areas near the disposal room) within 10's of meters
- Main Shaft Seals

Salado-Transport



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Salado Changes

- At lithostatic fluid pressure, disposal room gas is transported to the regulatory boundary without storage or degradation.
- VOC do not degrade

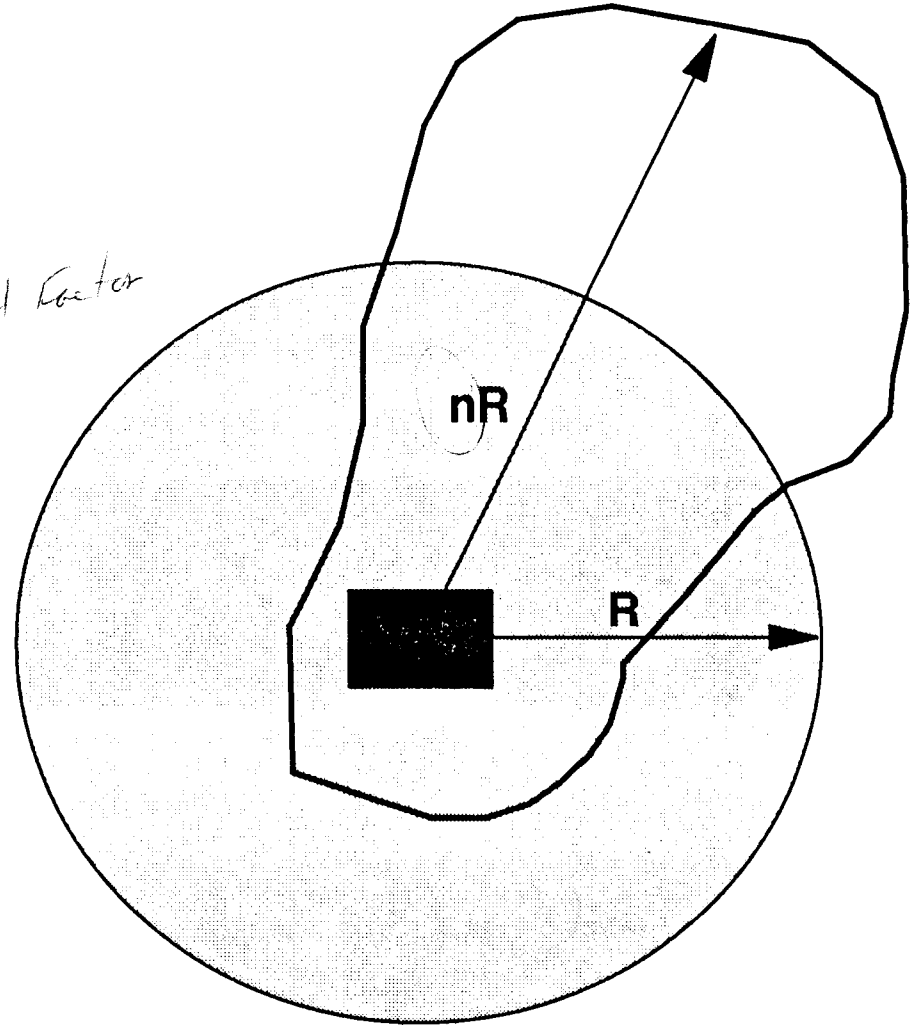
Salado Outcomes

Gas Flow	CDF
Baseline	1.0
Two Phase Flow	0.9

Transport Factor (n) on next viewgraph	CDF
10	1.0
6	0.8
4	0.5
2	0.2
1	0.1

Gas Transport Factor

n = Transport Factor

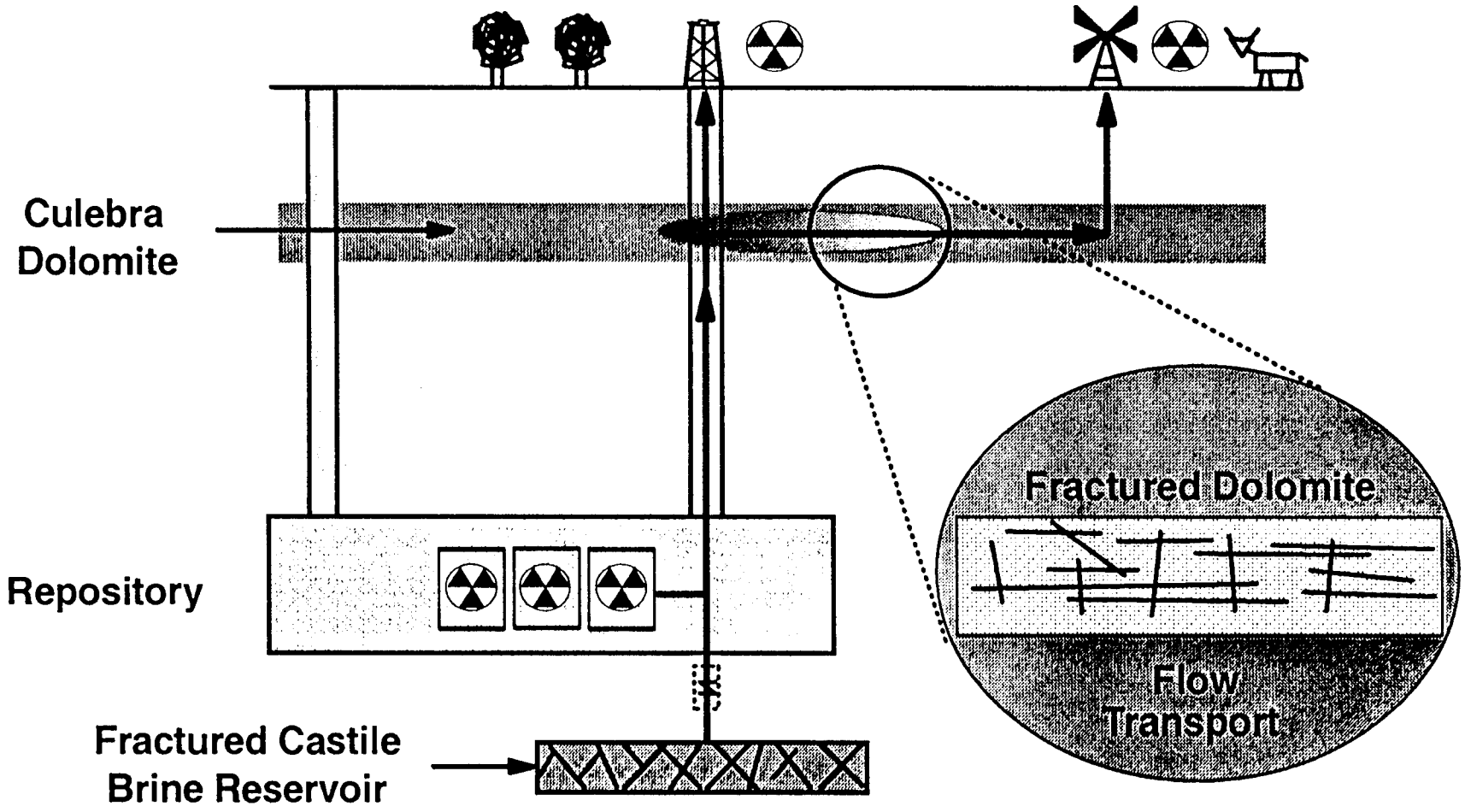


FLW/Fred-M/Culebra.pre

Inventory Changes

- The Waste and Activity Inventory for the SPM-1 Calculation ~~will be~~ was taken from the June 1994, Waste Isolation Pilot Plant Transuranic Waste Baseline Inventory Report, CAO-94-1005 Revision 0.

Culebra



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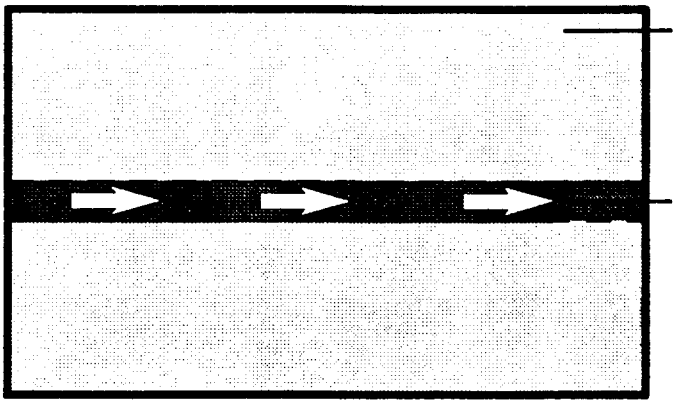
Schematic Illustration of Fracture-Only Versus Double-Porosity Transport

Fracture-Only Transport

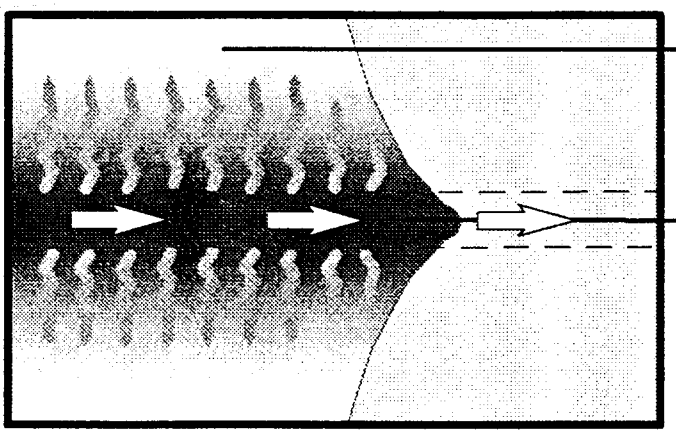


Matrix
no transport

Fracture
rapid transport

no chemical/physical retardation

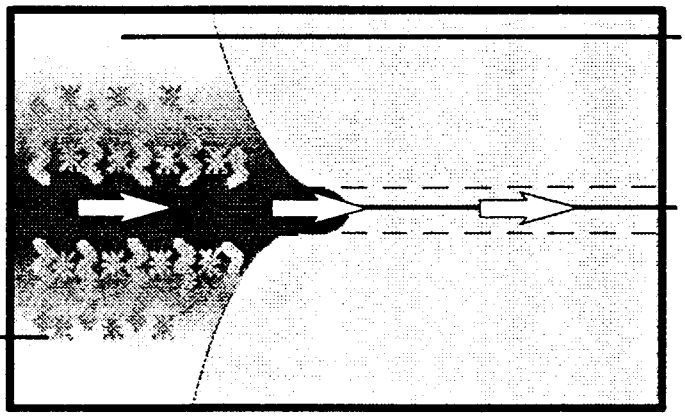
Double-Porosity Nonreactive Transport (Physical Retardation)



Matrix
slow diffusive transport
high solute storage

Fracture
rapid transport
low solute storage

Double-Porosity Reactive Transport (Physical and Chemical Retardation)



Matrix
slow diffusive transport
high solute storage

Fracture
rapid transport
low solute storage

Chemical Reactions
due to clay matrix

Culebra baseline Changes

- No retardation of actinides in the Culebra
- No dual porosity flow
- Colloids travel with the flow
- Ground water level in the areas of recharge set to land surface for 10,000 years to account for future climatic changes

CHEMICAL RETARDATION

SINGLE POROSITY TRANSPORT MODEL

- ADVECTIVE FLOW IN FRACTURES
- NO DIFFUSION INTO DOLOMITE MATRIX
- RETARDATION IN CLAY ADJACENT TO FRACTURES

→ $K_{D,F}$

DOUBLE POROSITY TRANSPORT MODEL

- ADVECTIVE FLOW IN FRACTURES
- DIFFUSION INTO MATRIX
- RETARDATION IN BOTH CLAY AND DOLOMITE

→ $K_{D,F}$ & $K_{D,\,MATRIX}$

CHEMICAL RETARDATION - OUTCOMES

$K_{D,MIXED} \equiv K_{D,5WT\%CLAY+95WT\%\ DOL}$

SINGLE POROSITY [P(SP)=.05]

1. $K_{D,F} = K_{D,MIXED}$ P=0.33
2. $K_{D,F} = K_{D,CLAY}$ P=0.66
3. $K_{D,F} = 0.0$ P=0.01

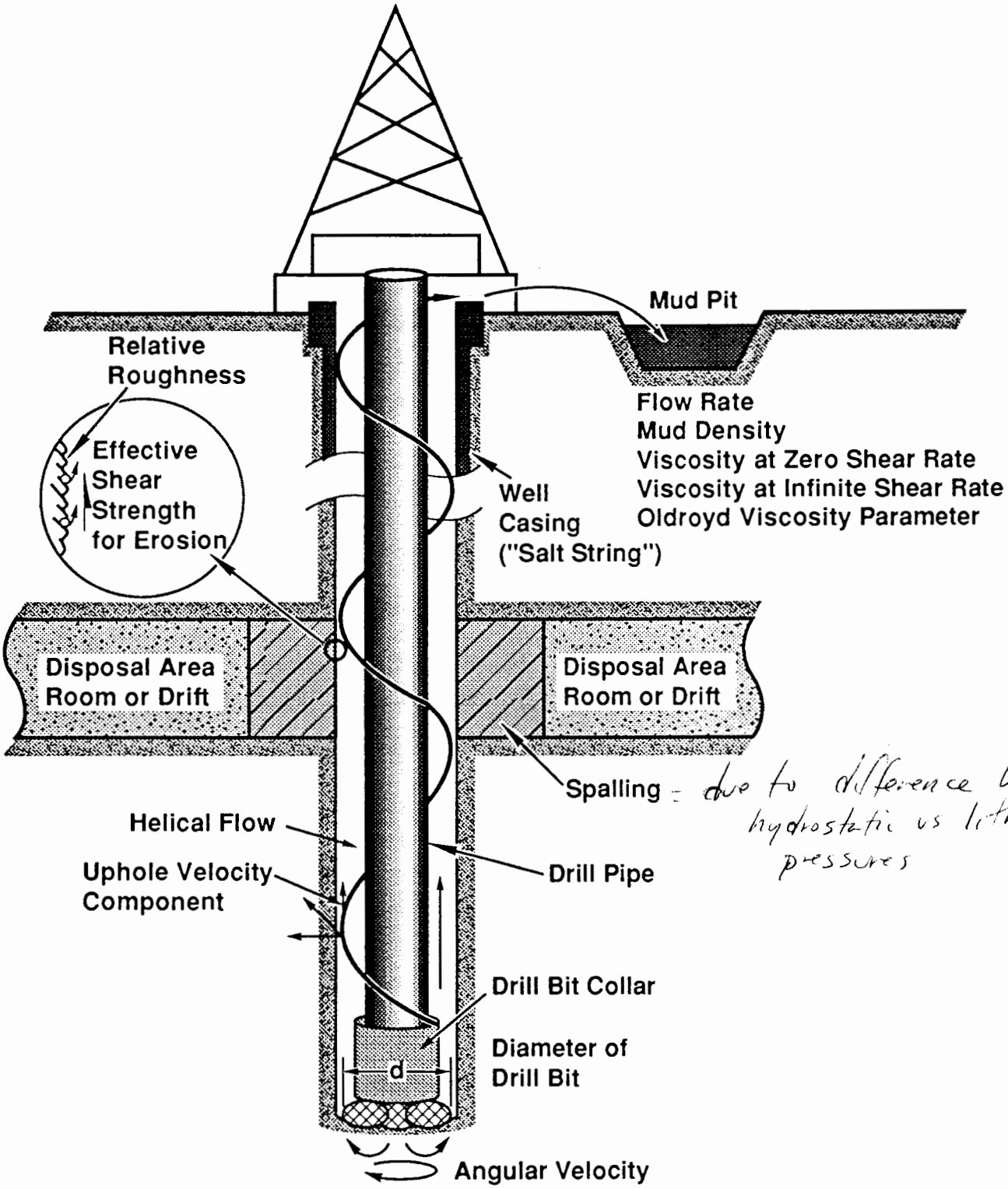
DOUBLE POROSITY [P(DP)=.95]

1. $K_{D,MATRIX} = K_{D,MIXED}$ P=0.964
2. $K_{D,F} = K_{D,CLAY}$ P=0.026
   and
   $K_{D,MATRIX} = K_{D,DOL}$
3. $K_{D,F} = K_{D,MATRIX} = 0.0$ P=0.010

Near Field Changes

- All plastic and rubber are available for gas generation. (worse case)
- Human intrusion spalling added (zero strength waste worse case)
- Intrusion rate set to maximum constant of 30 boreholes per square kilometer for 10,000 years

Direct Release Mechanisms



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Spalling Outcomes

Release Factor	CDF
1 (Baseline - zero strength)	1.0
0.5	0.95
0.1	0.75
0.01	0.4

Near Field Changes - cont.

- Degrade shaft and panel seals (worse case)
- Total Actinide inventory mobilized, either dissolved or in Colloids (worse case) - includes RH-TRU
- Reduced initial room moisture

Main Shaft Seals 100 Meters Effective Length

- From seal emplacement -100 years, Seal Permeability ranges from 10^{-12} to 10^{-14} m^2
- For time > 100 years, Seal Permeability ranges from 10^{-13} to 10^{-15} m^2

increases slightly

Seal Outcomes

Note seal values are from the time of emplacement

Seal Permeability	CDF
Baseline	1.0
10^{-16} to 10^{-18} m^2	0.99
10^{-18} to 10^{-19} m^2	0.90

Colloid

- Actinide associated with a long chain molecule or solid substrate 1 to 4 orders of magnitude larger in size than a single actinide ion dissolved in brine

Colloids

- For SPM-1 activity sets calculations colloids will be preferentially mobilized over solute species and once mobilized they will be transported with no retardation in the Culebra.

Colloid Outcomes

Concentrations (moles/liter)	Probability
Less than 10^{-9}	1/3
10^{-8}	1/3
10^{-7}	16/87
10^{-6}	8/87
10^{-5}	4/87
10^{-4}	1/87

Colloids

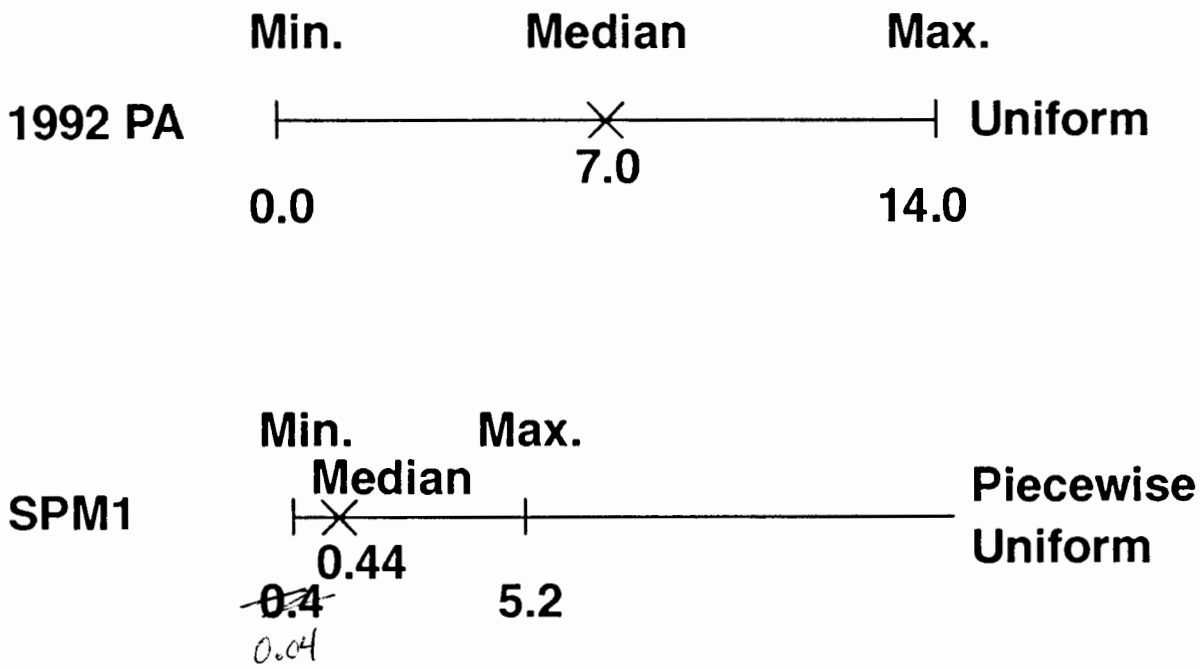
- For waste containing significant amounts of high molecular weight organic materials such as may be found in soils, the outcomes of the colloid concentrations are multiplied by 10.

Actinide Solubilities Outcomes

Concentrations	CDF
Baseline (Inventory Limited)	1.0
10^{-14} to 10^{1}	0.99
10^{-14} to 10^{-4}	0.50

Reduced Initial Room Moisture

Parameter Values [%]



FLW/Fred-M/Culebra.pre

PB-WAC and Hypothetical Engineering Enhancements

- Limit High Organics (See Colloids)
- Limit VOCs
- Limit Gas Potential (said metals didn't produce gas)

Summary - Changes based on the need for more data to support 12/92PA

- Seals - degraded
- Culebra - fracture flow
- Culebra - add colloids
- Culebra - maximum boundary heads
- Salado - instantaneous gas transport at lithostatic pressure
- All plastics and rubber degrade to make gas
- Add spalling
- Max human intrusion rate
- All actinides mobilized

Summary - based on better data than was available for 12/92 PA

- BIR inventory values
- Initial room brine saturation reduced

Summary- SPM-1 Activity Sets

- Salado - preferential gas flow
- Seals - enhanced seal effectiveness
- Culebra - physical and chemical retardation
- Colloids - concentrations and transport
- Actinide Solubilities- Reduced Solubilities
- Spalling - Reduced Releases
- PB-WAC- reduced high organics, VOC's & Gas

Prototype of the System Prioritization Method

SPM-1 RESULTS AND CONCLUSIONS

Richard Lincoln

Sandia National Laboratories

NOT FOR DECISIONS

Results of SPM-1

PURPOSE OF SPM-1:

- Evaluate Computational Feasibility
- Evaluate Viability of Decision Analysis Method on WIPP PA/Cost/Schedule Information
- Identify Problem Areas and/or Improvements to Address for Completing SPM-2

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Lessons Learned

- Budget and Schedule Resolution
- Activities to Confirm Imbedded Assumptions Examples: characteristic curves 2 phase flow in Salado
- Standard Process for Elicitation
- Other Modeling Approaches for SPM-2 Computational Needs

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Lessons Learned

- Automation and Configuration Control
- Conversion to Unix-Based Platforms
- Need a more Formal Definition of Post-Closure Design
- Decision Analysis Post-Processing (looking at the output & making sense of it)

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Lessons Learned

- Budget and Schedule Resolution — SPM1 was locked into Disposal Decision Plan, no flexibility
  - Allow for Alternate Cost and Schedule Scenarios
  - Ensure Consistency Between Elicitations for Outcomes (June/July) and Cost/Schedule Assumptions (September)
- Activities to Confirm Imbedded Assumptions Section 7.2.2
  - Measured by Current Process to Have Zero Value

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Lessons Learned

- Elicitation Process
  - Standard Process to be Defined and Followed by Consultants for SPM-2
  - Significant Time of SPM Team, PA Staff, and PIs Needs to be Planned in Schedule

Not all data elicited could be modeled in PA

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Lessons Learned

- SPM-2 Computational Needs Will Require Other Modeling Approaches
  - SPM-1 Computations: 37,000 Input Vectors → (500 Cray CPUs + 340 Alpha CPUs + 600 Paragon Node) Hours → 1500 Mean CCDFs + 300 RCRA Concentrations for Each of 5 VOCs
  - SPM-1 Method was "Selective Brute Force"
  - Alternate Methods: "Mean-Mean," "Interpolations"
  - SPM-1 Results will be Basis for Benchmarking Alternate Methods

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Lessons Learned

- Automation
  - Code Operations: Initiate Runs, Name and Transfer Files, Convert File Formats, Do Pre- and Post-Processing
  - Graphical Representation of PA Model Results

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Lessons Learned

- Configuration Control and Information Flow
  - Large Amounts of Information Generated and Complexity of PA Models Drive Need for Improvements
  - Traceability Required

    Input Vectors → Conceptual Model → Computer Code → Computer Platform → Results

NOT FOR DECISIONS

Lessons Learned

- Conversion to Unix-Based Platforms
  - Open VMS Platforms Available: 6300 Alphas
  - Unix-Based Platforms Available: Crays, Workstations, Other SNL Alphas
  - SPM-1 Proved Viability of Running on Alternate Platforms and Doing File Transfers
- Formal Definition of Post-Closure Design for modeling purposes
- Decision Analysis Post-Processing

NOT FOR DECISIONS

Baseline RCRA Results for SPM-1

Hazardous Constituent	Assumed VOC Headspace Concentration (ppmv)	Calculated SPM-1 Baseline Mean Soil Concentration (mg/kg)	Assumed Health-Based Level for Soil (mg/kg)
Carbon Tetrachloride	441	0.01	5.38
Methylene Chloride	177	0.001	93.33
1,1,1-Trichloroethane	391	0.01	7,200
Trichloroethylene	14	0.001	63.63
1,1,2-Trichloro-1,2,2-Trifluoroethane	41	0.001	2,4,000,000

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Baseline 40 CFR 191.13(a) Results for SPM-1

Normalized Release (40 CFR 191, Appendix A, Table 1)	SPM-1 Baseline 40 CFR 191.13(a) Probability Criteria	Calculated Mean Probability of Exceedence
1	<0.1	0.93
10	<0.001	0.85

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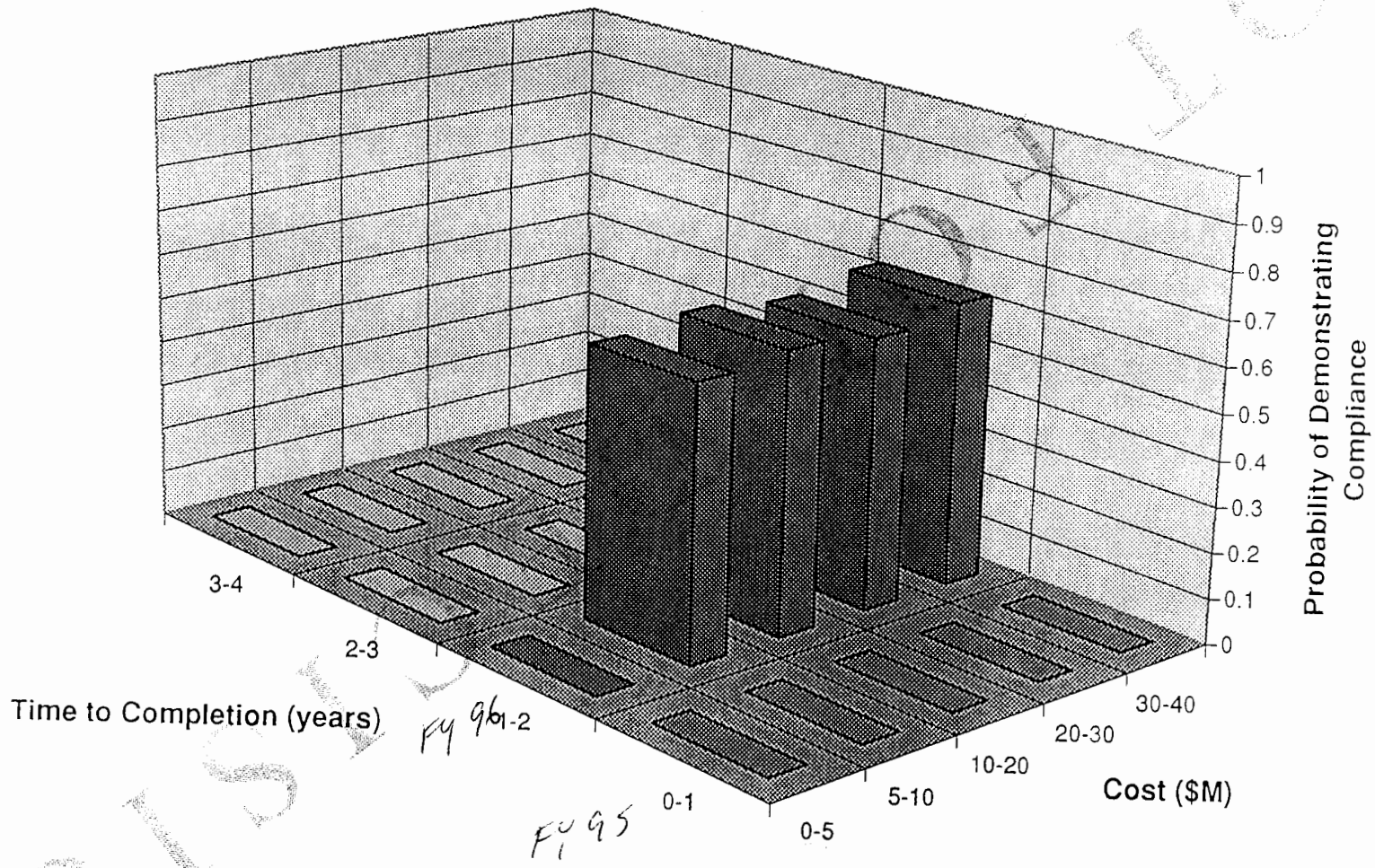

Figure 3. A representation of the SPM-1 decision matrix.

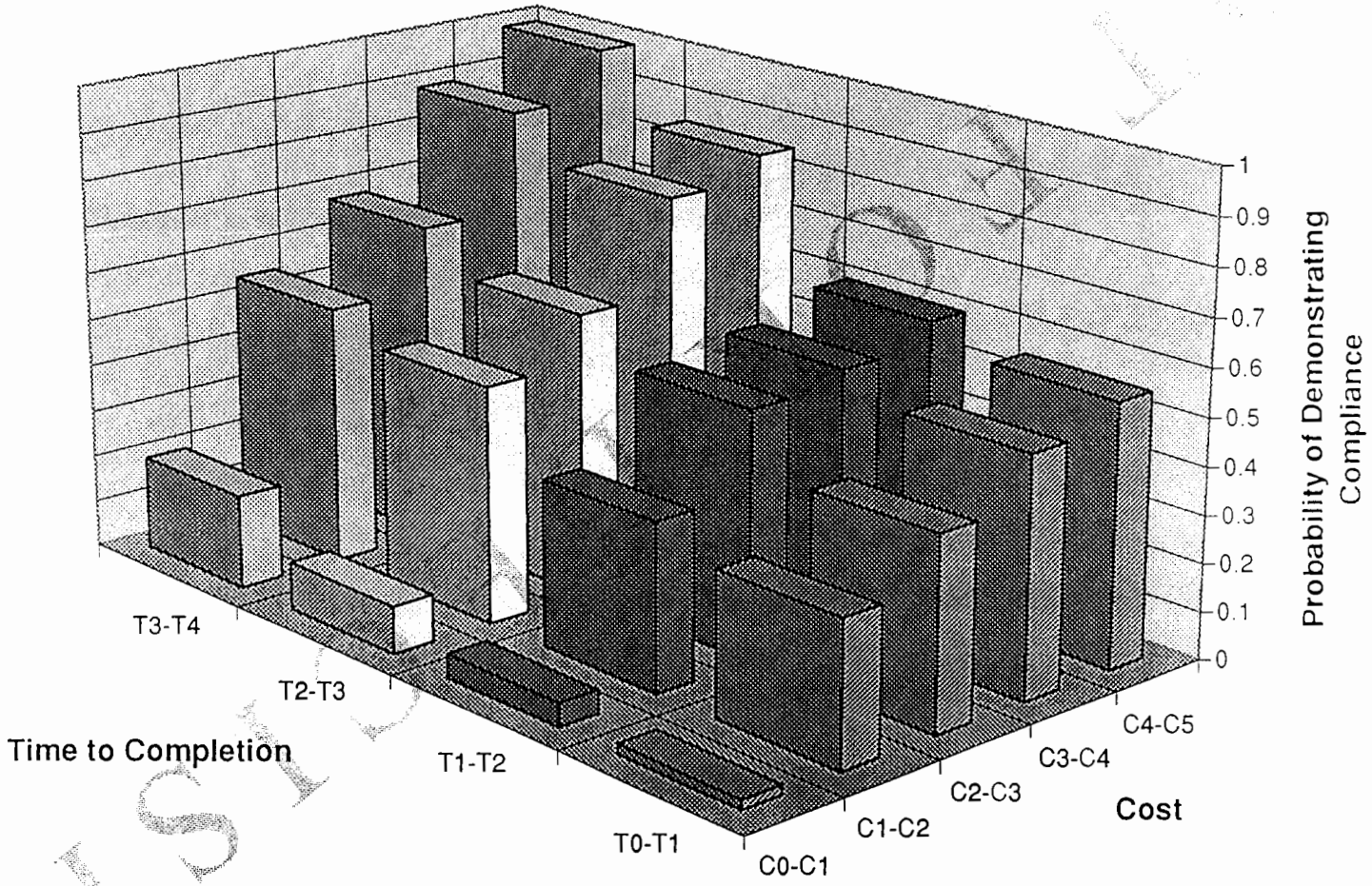

Figure 4. A representation of a hypothetical fully 3-D form of the decision matrix expected from the SPM-2 budget and schedule process.

Conclusions

SPM1 DEMONSTRATED:

- 1992 PA Codes Can Be Reconfigured in Timely Manner for New Data, Scenarios, and Conceptual Models
- Computational Requirements Can Be Met
- Development and Implementation of large Activities, Cost, and Schedule Database
- Development and Successful Application of Decision Analysis Software

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Conclusions

SPM-1 HAS DEMONSTRATED VIABILITY OF SPM AS A TOOL FOR IDENTIFYING:

- Activities Necessary for a Given Probability of Demonstrating Compliance
- Activities that Give the Maximum Probability of Demonstrating Compliance
- Activities that Have Minimal Impact on Probability of Demonstrating Compliance
- The Impact of New Activities on the Probability of Demonstrating Compliance

NOT FOR DECISIONS