WASTE ISOLATION PILOT PLANT

SALADO FLOW CONCEPTUAL MODELS FINAL PEER REVIEW REPORT

A Peer Review
Conducted By

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Executive Summary

The Waste Isolation Pilot Plant (WIPP) site has been developed near Carlsbad, New Mexico, by the Department of Energy (DOE) as the United States' first underground repository licensed to safely and permanently dispose of transuranic radioactive waste resulting from the research and production of nuclear weapons programs. The first shipment of transuranic waste arrived at WIPP on April 6, 1999.

Peer review of conceptual models developed by the DOE for the WIPP is required by 40 CFR Part 194.27, which was promulgated by the Environmental Protection Agency (EPA) in 1996. In accordance with this requirement, the Carlsbad Field Office (CBFO) of the DOE has conducted a peer review of three conceptual models that are being revised due to changes invoked by the regulator or due to knowledge gained since the original conceptual models were developed. This peer review addressed revisions to selected salado flow conceptual models that were developed for the Compliance Certification Application (CCA).

This report presents the final results of an independent technical peer review of the adequacy of three of the twenty-four conceptual models representing features, processes, and events involved in assessing the long-term performance of the WIPP. These models were identified by the DOE through its scientific advisor, Sandia National Laboratories (SNL).

This independent peer review was conducted by a four-member interdisciplinary team having the requisite broad experience and expertise to address the range of issues associated with the ability of WIPP to successfully isolate waste for the 10,000-year regulatory time frame. The peer review was conducted primarily in Carlsbad, New Mexico, at the SNL Carlsbad offices. The peer review panel was given access to conceptual model descriptions, scientific reports, briefings, SNL staff, and to the SNL Nuclear Waste Management Program Library. The Panel also had access to reports of prior peer reviews and was given the full cooperation of the DOE and SNL throughout the review. Representatives of the EPA, DOE, and the New Mexico Environmental Evaluation Group (EEG) observed the SNL technical presentations and the Panel's questions and deliberations.

A conceptual model is a statement of how important features, events, and processes such as fluid flow, chemical processes, or intrusion scenarios are to be represented in performance assessment (PA). To be used in PA, a conceptual model must be successfully translated into analytical statements and mathematical analogs. The Panel reviewed the three conceptual models of interest in detail, including the assumptions and scientific information used to develop the model, alternative models considered, uncertainties, adequacy, accuracy, and validity of conclusions. The Panel also made an assessment of the information used and whether the conceptual model is adequate for implementation in an overall WIPP PA. The review process and review criteria are discussed in Section 2.

The changed models were reviewed in the context of the WIPP PA. The review did include an assessment of the reasonableness of changes in performance estimates resulting from changes in parameter ranges and in changes to, or resulting from, single values. The review evaluated changes in the conceptual structure of the models and changes in component process models and compared the performance results of the changed models with the results of the earlier models to confirm that the changes in performance estimates are reasonable in sense and magnitude. Changes in computations or in fundamental model aspects, such as gridding were also considered. The review considered the impacts of the changed models on the other WIPP conceptual models and related issues such as the Option "D" panel closures.

The Panel has applied the stringent assessment criteria provided in NUREG-1297, *Peer Review of High-Level Nuclear Waste Repositories*, and has concluded:

- The changes to the three conceptual models appear generally sound in their structure, reasonableness, and relationship to the original models.

- The proposed implementation of the three changed models appears reasonable. Impacts of the changes have been reviewed and the data from selected gas pressure and brine saturation scenarios in performance assessment indicates an acceptable comparison of new results to the prior CCA results.

- Implementation of the three changed models and their interactions with the other models appears reasonable.

1.0 Introduction

Peer review of conceptual models developed by the Department of Energy (DOE) for the Waste Isolation Pilot Plant (WIPP) is required by 40 CFR Part 194.27, which was promulgated by the Environmental Protection Agency (EPA) in 1996. In accordance with this criterion, the Carlsbad Field Office (CBFO) of the DOE has conducted a peer review of three conceptual models that are being revised due to changes invoked by the regulator or due to knowledge gained since the original conceptual models were developed. This peer review has addressed whether revisions to selected salado flow conceptual models that were developed for the Compliance Certification Application (CCA) continue to reasonably represent the WIPP waste disposal system.

Sandia National Laboratories (SNL) is responsible for the development, maintenance, and conduct of WIPP performance assessment (PA). As part of the PA methodology included in the CCA, the DOE identified processes important to the WIPP waste isolation system and developed conceptual models that describe the features, events, and processes relevant to the disposal system and subsystems. These conceptual models were peer reviewed and the results were approved by the EPA during the original WIPP certification (EPA, 1998). Any proposed significant changes to the previously approved conceptual models are being peer reviewed to ensure that the disposal system, subsystems, and future state assumptions continue to be adequately represented.

Twenty-four conceptual models are used in the WIPP PA. The proposed changes associated with Salado flow processes are expected to affect the following models:

- Disposal System Geometry,
- Repository Fluid Flow, and
- Disturbed Rock Zone (DRZ).

The peer review process is a documented, critical review performed by peers who possess qualifications at least equal to those of the individuals who conducted the original work. The peer reviewers are independent of the work being reviewed, i.e., the peer reviewers: a) have not been involved as participants, supervisors, technical reviewers, or advisors involved with the work being reviewed, and b) to the extent practical, have sufficient freedom from funding considerations to ensure the work is impartially reviewed. Therefore, the peer-reviewed subject matter provides additional assurance to the regulator and the public that the subject matter is reasonable, accurate, and valid for its intended use.

This peer review meets the regulatory requirements of 40 CFR Part 191 and the implementation of those requirements by 40 CFR Part 194. This peer review was conducted in accordance with the Nuclear Regulatory Commission's NUREG-1297, *Peer Review of High-Level Nuclear Waste Repositories*. The adequacy criteria set forth in NUREG-1297 were those used by the peer review panel for reviewing the three conceptual models. The Peer Review Panel followed the DOE CBFO Management Procedure MP-10.5, *Peer Review,* to perform the peer review.

This report documents the results of the subject peer review. Section 2 of this report details background information relating to the WIPP facility and the review methodology which includes a description of the repository, its geologic and hydrogeologic settings, the review methodology, and the evaluation criteria. Section 3 presents an evaluation of each of the three models. Each model was assessed against the predetermined evaluation criteria. Section 4 discusses the integration of the peer reviewed models with the other models used in the overall WIPP waste disposal system PA. Section 5 provides a summary of the evaluations. These sections are followed by appendices that include administrative information and professional biographies for each of the peer review panel members.

2.0 Background

The DOE was authorized in 1979 (Public Law 96-164) and funded by the Congress to develop a facility for demonstrating the safe disposal of transuranic (TRU) radioactive wastes resulting from national defense activities. The Land Withdrawal Act of 1992 (Public Law 102-579) provided additional authorization to continue the project under a stipulated statutory process. With more than 20 years of scientific investigation, public input, and regulatory oversight, the WIPP facility became the first underground repository licensed to safely and permanently dispose of transuranic radioactive waste from the research and production of nuclear weapons. The first shipment of transuranic waste arrived at WIPP on April 6, 1999.

2.1 WIPP Overview

The WIPP facility has been constructed in southeastern New Mexico 26 miles east of Carlsbad, on land owned by the Federal Government. Prior to October 1992, this land was administered by the U.S. Department of the Interior, Bureau of Land Management. In October 1992, Congress transferred jurisdiction of the land through the Land Withdrawal Act to the Secretary of Energy. The site encompasses 10,240 acres in a sparsely populated area, with fewer than 30 people living within 10 miles of the WIPP site. The immediate surrounding land is used for livestock grazing, potash mining, and oil and gas production.

Surface structures and the underground repository make up the WIPP facility. The purpose of the surface structures is to provide security and safeguards and to accommodate routine operations, administrative activities, and support further scientific studies.

The underground excavation is 655 meters (2150 feet) below the surface in the bedded salt of the Salado Formation. The underground excavation includes a 12-acre area used for conducting scientific investigations and experiments in which no waste will be placed, an operations area with equipment and maintenance facilities; an area in which the waste is emplaced for permanent disposal; and four major interconnecting tunnels that are used for ventilation and traffic. The subsurface waste-disposal area is planned to cover approximately 100 acres and will contain eight separately excavated panels, each containing seven disposal rooms, and two equivalent panels.

2.2 Peer Review Management

This Salado Flow Conceptual Models Peer Review is an independent review sponsored by the DOE CBFO and delegated to its technical assistance contractor, known as the Carlsbad Technical Assistance Contractor (CTAC). The CTAC appointed Mr. John Thies as the peer review manager.

Early in the peer review process Mr. Thies appointed a technical panel chairperson, John Gibbons, Ph.D., from among the peer review panel members to serve as the technical leader for the peer review and to lead technical development of the peer review report.

The selection and training of the peer review panel members and operation of the review process were governed by DOE CBFO's Management Procedure MP-10.5, *Peer Review*, and the salado flow conceptual models peer review plan. Detailed information regarding the review process is further delineated in this document and in the peer review records.

Twenty-four conceptual models are used in the WIPP PA. This peer review addressed only the proposed changes associated with salado flow processes expected to affect the following three models:

- Disposal System Geometry,
- Repository Fluid Flow, and
- Disturbed Rock Zone (DRZ).

2.3 System Overview

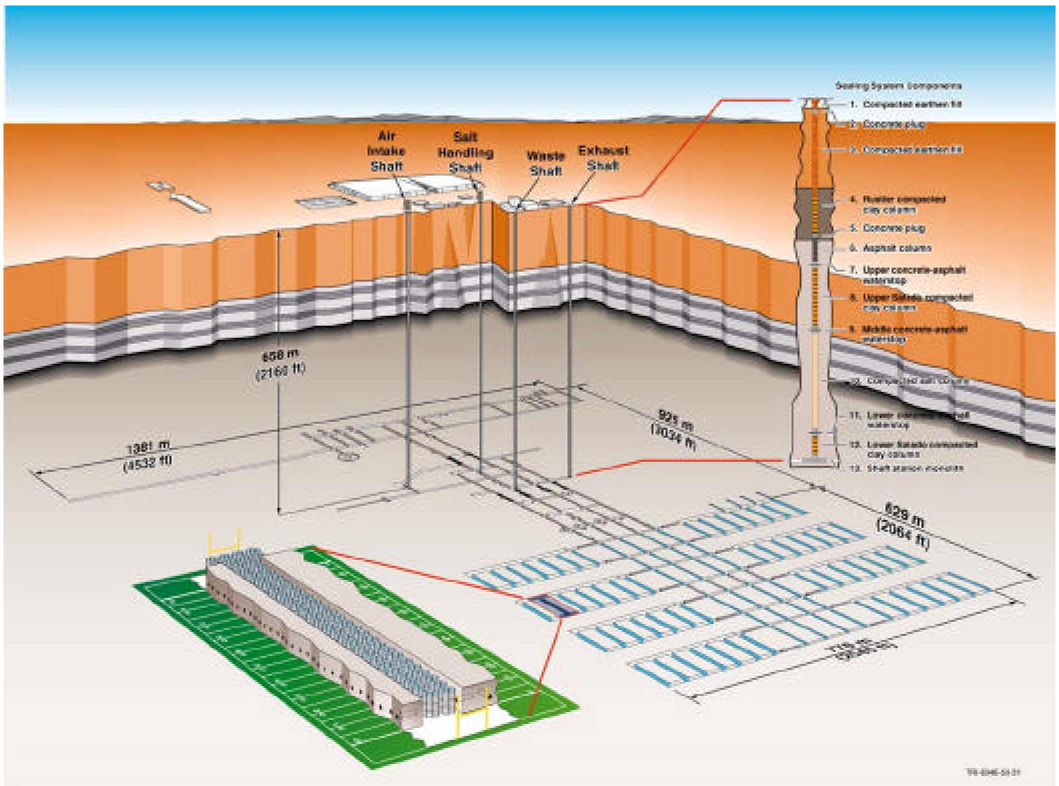
The WIPP disposal system includes the underground repository and shaft system, the geologic host rock, and the local and regional hydrologic system. Figure 2-1 shows the WIPP controlled area, the accessible environment, and the disposal unit boundary.

Figure 2-1 - WIPP Controlled Area

2.3.1 Repository Setting

The WIPP surface facilities, shafts, and underground workings are shown in Figure 2-2. The WIPP repository includes four shafts (exhaust shaft, waste shaft, salt handling shaft, and air intake shaft), an experimental area, an operations area, and a waste disposal area.

Figure 2-2 - WIPP Facilities



Present plans call for mining eight panels of seven rooms each and two equivalent panels in the central drifts. As each panel is filled with waste, the next panel will be mined. Before the repository is closed permanently, each panel will be closed. Waste will be placed in the drifts between the panels creating two additional panel volumes and access ways will be sealed off from the shafts. The shafts will then be sealed to isolate the repository from the ground surface. Final closure of the facility will be facilitated by creep closure of the salt.

When considering future intrusion scenarios, the DOE used the following EPA assumptions regarding future penetration of the repository:

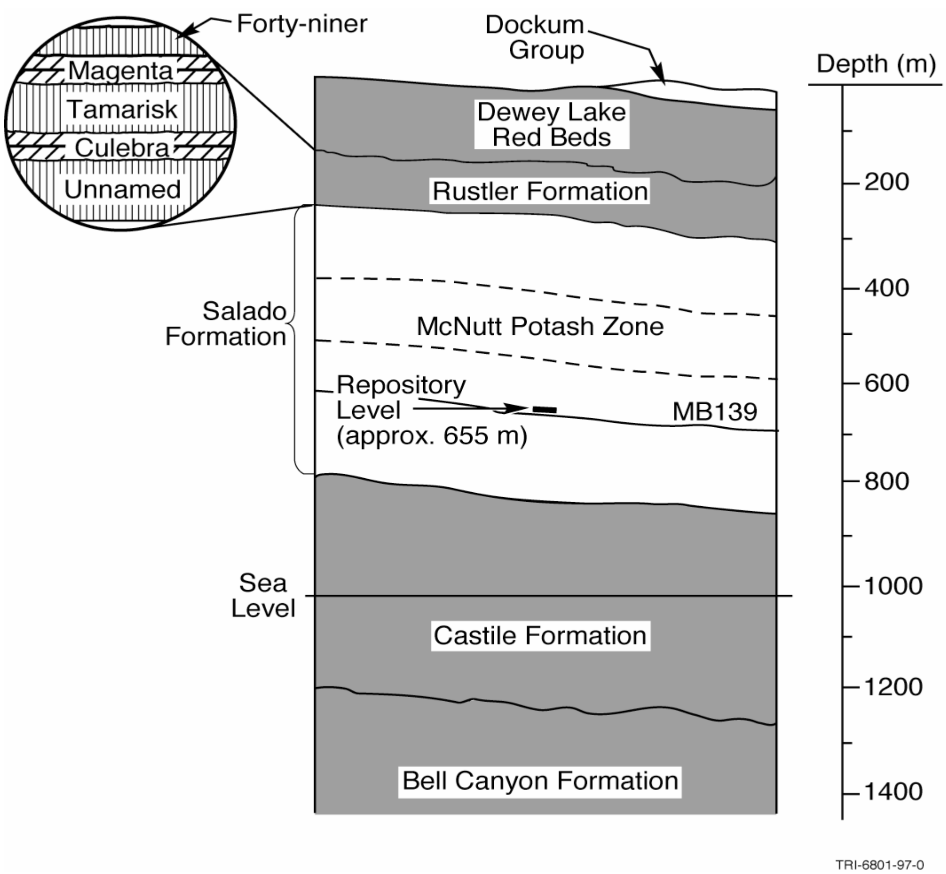
- The regulatory time frame begins at the beginning of disposal and ends 10,000 years after disposal;
- Exploratory drilling may potentially affect the repository;
- Exploratory drilling is inadvertent and intermittent;
- Drilling events occur at random intervals; and
- Future drilling rates will be the same as the rates of deep drilling in the area over the past 100 years.

2.3.2 Geologic Setting

The geologic history of southeastern New Mexico and the data collected regarding the subsurface stratigraphy at the WIPP site are important and are discussed extensively in Section 2 of the CCA and documents referenced in the CCA. The general stratigraphy at the WIPP site is presented in Figure 2-3.

The sandstones, siltstones, limestones, and shales of the Bell Canyon Formation define the first extensive, continuous, transmissive unit below the WIPP repository and provide a source of groundwater that could migrate vertically into the repository. The halite and anhydrite beds of the Castile Formation separate the Bell Canyon from the Salado and contain pressurized brine reservoirs. The brine reservoirs are a repository performance concern expressed through human intrusion scenarios. The halite-dominated Salado Formation contains the proposed repository and provides the primary natural barrier for containing radionuclides. The laterally extensive Culebra Dolomite Member of the Rustler Formation is the closest stratigraphic unit above the Salado with the potential to transport a radionuclide release to the accessible environment. Studies conclude that transmissivities in the Culebra vary by six orders of magnitude across the WIPP site area. Fracturing and vuggy zones account for much of the variability in the physical hydraulic properties of the Culebra.

Figure 2-3 - *General Stratigraphy at the WIPP Site*



While other stratigraphic members of the Rustler Formation, beds of anhydrite and polyhalite, clays, and other inclusions may be important as each of the conceptual models is reviewed, the four formations and units described above define the most important components of the geologic setting for the WIPP conceptual models review.

2.3.3 Hydrologic Setting

2.3.3.1 Surface Water

The WIPP site is located within the Pecos River Basin. At its nearest point, the Pecos River flows approximately 12 miles southwest of the WIPP site boundary. There are no perennial streams at the WIPP site and in this semi-arid region, approximately 75 percent of annual precipitation results from intense, short-duration events between April and

September. More than 90 percent of the mean annual precipitation is lost through evapotranspiration and on a mean annual basis, evapotranspiration potential exceeds expected rainfall. The EPA concluded in 1989 that there were “no surface water features near the WIPP that could potentially affect repository performance in such a way as to influence the no-migration demonstration.”

2.3.3.2 Groundwater

Extensive coring, logging and testing of boreholes in the vicinity of the WIPP site has provided data for the characterization of the hydrostratigraphy important to the WIPP site region. While the deep Capitan Limestone, the Rustler-Salado contact zone near Nash Draw, and the shallower Dewey Lakes and Santa Rosa Formations are important in characterizing the WIPP region; the Bell Canyon, Castile, Salado, and Rustler Formations are the units critical to the evaluation of WIPP groundwater issues.

As presented in the geologic setting, the Bell Canyon Formation is the first continuous, transmissive water-bearing unit beneath the WIPP. This formation provides a source of non-potable ground water below the WIPP repository that could migrate into the repository if a pathway were available. The Bell Canyon Formation exhibits hydraulic conductivities in the range of 10^{-7} to 10^{-12} meters per second and pressures were measured in the range of 12.6 to 13.3 megapascals.

The Castile Formation is of interest to site characterization as a hydrologic barrier between the Salado and Bell Canyon Formations because it contains isolated pressurized brine reservoirs. The Castile is predominantly low-permeability halite and anhydrite with greater permeabilities in zones of fracture and structural deformation. In the areas of higher permeability brine pressures may exist that are sufficiently above nominal hydrostatic pressure for brine to flow upward through a borehole potentially reaching the surface.

The halite and anhydrite rocks of the Salado Formation are relatively impermeable and tests have shown that flows are extremely low to no flow when appreciable pressure gradients are applied. The Salado contains the repository and provides the primary natural barrier for containing radionuclides.

The Magenta and Culebra Dolomite Members of the Rustler Formation are laterally extensive, transmissive, and display hydraulic characteristics sufficient for the lateral transport of radionuclides. Hydraulic conductivities in both members range over five to six orders of magnitude in the WIPP area but the Magenta is generally less transmissive than the Culebra. The Culebra is the most extensive and most transmissive unit above the Salado at the WIPP site. As such, the Culebra provides the most direct groundwater pathway from the WIPP repository to the accessible environment and is the most important component of the hydrogeologic setting for the conceptual models peer review.

2.3.4 Implementation of the "Option D" Panel Closure

The option "D" panel closure is a semispherical concrete closure to be emplaced in drifts and panel exits at several positions throughout the repository. The closure will be emplaced in an enlargement of the drift that will remove some material above the drift and all of the halite and the Interbed #139 below the drift floor. It is presumed that the closure will extend into the ribs of the drift a distance sufficient to remove most of the DRZ in that direction. Back-stress resulting from creep flow in the Salado halite into the repository will immediately begin to heal damage around the closure that may result from construction excavation. It is not expected that the closure will entirely block gas flow in Interbed #139 or the overlaying interbeds, since flow around the closure is not prevented at high gas pressures. Upward gas flow from Interbed #139 into the drift beyond the closure is a possible scenario for bypassing the closure. Rapid gas pressure fluctuations, as in the case of an intrusion into a single panel at a time of high overall repository gas pressures, would be significantly damped in adjacent unintruded repository spaces, but not entirely eliminated by the closure over long time periods. The integrated impacts of the changed DRZ conceptual model and the role of the closure in modeling gas pressure in the waste panels before and during equilibration after intrusion are important interactions with the Repository Fluid Flow conceptual model.

Reduction in the volume of gas available during blowout (a single panel isolated by closures) resulting from intrusion may impact the spalling model. Closures between panels imply that a first intrusion may not lower pressure throughout the repository, which may result in several intrusions in several panels having increased potential for spall events. A drop in gas pressure after intrusion into a panel may accelerate brine flow toward the intruded panel. If a panel closure is left unsupported in an open drift, shear and extension stresses related to the creep closure of the spaces on either side of the panel closure may impact the mechanical stability of the panel closure.

2.4 Peer Review Panel Methodology

Review of the conceptual models commenced after panel member orientation and training in accordance with MP 10.5, the Peer Review Plan, and other relevant information presented in the orientation and training package.

The peer review panel employed the following approaches in their overall method of conducting and accumulating information for the reviews:

- Extensive review of referenced literature relevant to the review;
- Attendance at briefings on conceptual models and relevant aspects of the PA process;
- Issue focused presentations with question-and-answer sessions with SNL scientists and engineers;
- Review of literature and documents referenced during the question-and-answer sessions; and
- Formal and informal discussions among the Panel members.

The Panel was provided several presentations addressing the three conceptual models being reviewed with respect to whether or not they represent a reasonable view of future states of the proposed disposal system for the WIPP repository. For this review, conceptual models are defined as a set of qualitative assumptions used to describe a system or subsystem for a specific purpose. The Panel evaluated the models in accordance with the NUREG-1297 criteria. In addition, the Panel recognized that individual models may warrant varying levels of reviews of their mathematical representations, computerized representations, and results. Due to the volume and diversity of information to be reviewed, individual Panel members were assigned lead responsibility for specific conceptual model reviews. Dr. Gibbons made the following assignments. Dr. Oswald was assigned responsibility for review of the Disposal Room Geometry conceptual model; Dr. Caporuscio was assigned responsibility for review of the Repository Fluid Flow conceptual model; Dr. Chunhong Li was assigned responsibility for review of overall mathematical representations and modeling; and Dr. Gibbons took responsibility for review of the Disturbed Rock Zone conceptual model. The information gathered by individual members during their reviews was freely disseminated among all of the Panel members.

In organizing its work, the Panel established limitations on its review and the content of this report. The Panel members did not review or offer comments on regulations. The Panel confined its review to the three conceptual models identified in the Peer Review Plan. To maintain independence, the Panel did not offer recommendations for specific methods and/or approaches to be employed in future work.

2.5 Criteria for Conceptual Model Review

The nine criteria used by the peer review members are based on the criteria in EPA regulation 40 CFR Part 194.27, NUREG-1297, the EPA Compliance Application Guidance, and Peer Panel discussions.

Information Used to Review Changes in Conceptual Model. This is an evaluation of data and information used to review the changes in the conceptual models and sub-models. It includes attributes of the disposal system learned by SNL during site characterization activities, exercising the models, and a review of the science and concepts that the models are based upon. It also includes information gained during the operation of the repository.

Validity of Assumptions. The validity of key assumptions in the model and its application are assessed in terms of how they could affect the usefulness of the conceptual model. The review addresses the comprehensive inclusion of important features, events, processes, and other key assumptions. Examples are the assumption of Darcy flow in the various media, use of the ideal gas law at high pressures, and the mathematical method chosen to develop the model grid.

Alternative Interpretations. This section briefly identifies and assesses plausible alternative conceptual models or sub-models considered by SNL but not used, and the rationale why such alternative models were not used. The panel assessed alternative interpretations in some instances by evaluating elements of the CCA and the PAVT as alternatives.

Uncertainty of Results and Consequences if Wrong. This includes an evaluation of the key uncertainties in the selected conceptual models and the discussion of the consequences if aspects of the conceptual model chosen were inappropriate or incompletely constrained for the site or process. This is not an exhaustive evaluation, but it does raise the question, “What if the model is wrong?”

Appropriateness and Limitations of Method and Procedures. Based primarily on the previous four criteria, this is a simple statement of whether the individual conceptual models, process models, and sub-models represent a reasonable approximation of the actual disposal system elements.

Adequacy of Application. This is an assessment of whether it appears that the individual conceptual model is being adequately applied into an acceptable overall performance assessment system. This particular assessment does not cover the relationships among conceptual models, but rather whether the significant components of the individual conceptual models are appropriately implemented in support of performance assessment. For example, are the various geometrical systems and representations of the conceptual models adequately applied within the performance modeling system, or do there appear to be discontinuities between the conceptual model and its application? Also, are there alterations of important key assumptions between the conceptual model and its implementation in performance modeling?

Accuracy of Calculations. This is a statement of whether the results of performance modeling using the conceptual model within the performance system are reliable and accurate to adequately simulate the physical and chemical processes represented. Internal consistency among the several iterations of the PA was carefully considered.

Validity of Conclusions. This is a judgment of the validity of any key conclusions that have been drawn based on results of the implementation of the conceptual models in the modeling framework. The key question is whether or not conclusions from model implementations appropriately relate to the expected goal of assessing the long-term performance of the disposal system. This judgment requires an evaluation of output information from the total system PA.

Adequacy for Implementation. This is an overall assessment of whether the conceptual models as implemented in the PA represent a reasonable approximation of the actual disposal system.

2.6 Adequacy

The three conceptual models reviewed were deemed adequate because the changes to the models are sound in their structure, reasonableness, and relationship to the original models. The proposed implementation of the models appears reasonable based on review of selected gas pressure and brine saturation scenarios in performance assessment. Review of the CCDFs for direct brine release and spallings releases which are sensitive to repository pressure and brine volume indicates an acceptable comparison of new results to the prior CCA results. Based on their review, the Panel has judged that the three conceptual models represent a reasonable approximation of the actual WIPP disposal system performance.

3.0 Model Evaluations

This section presents the results of the Panel's review of the three individual conceptual models. Each of these models is first described and then evaluated for adequacy in accordance with the criteria summarized in Section 2.5. Following each evaluation, space has been provided for dissenting views. There were no dissenting views by any Panel member resulting from this peer review. An evaluation of the integration of these conceptual models into the WIPP PA is provided in Section 4.

3.1 Disposal System Geometry

3.1.1 Model Description

3.1.1.1 Background

Consistent with the purposes for which the conceptual models were originally developed for the WIPP PA, the Disposal System Geometry conceptual model was developed to represent the dimensionality of the engineered system and the surrounding geologic and hydrogeologic formations. The features that rely on the geometric assumptions and parameters of dimensionality for representation are expressed across the overall performance assessment system through a finite difference model called BRAGFLO. The flow fields generated by BRAGFLO, based on the geometric representations and the finite difference calculations, are communicated with the NUTS code that determines the transport of actinides through the anhydrite interbeds and boreholes. The geometry assumed for any model contains important information about the way in which physical processes are thought to act on the system. For WIPP, the model geometry assumed for the disposal system can only be understood in the context of the important processes considered to take place in a particular region during a specific time interval and for a defined purpose.

3.1.1.2 Description

This peer review focused on the changes in a specific group of conceptual models associated with the Technical Baseline Migration (TBM). Changes were evaluated to determine whether or not the models continue to reasonably represent the relevant features, processes, and future states of the disposal system. Changes to the disposal system geometry conceptual model evaluated were: 1) The removal of the baseline shaft seal system model and replacement with a simplified model, 2) Implementation of Option "D" panel closure design, 3) Dividing the remainder of the repository into two blocks separated by a panel closure, 4) Applying a new method by which flaring is calculated, 5) Refinement of the grid geometry, and 6) Changing part of the repository horizon vertically approximately 2.4 meters to Clay Seam "G".

The final certification decision (40 CFR Part 194) requires the implementation of Option "D" panel closure system. The system, characterized by a concrete monolith and an explosion wall, led to the proposed change in grid geometry since the existing grid block discretization was perceived to be too coarse for the representation of the specifics of Option "D" and the interrelated impacts on the DRZ. In general, where flow has been shown to be important, changes to the grid are proposed to add detail. The proposed grid refinement provides for greater segmentation and allows the detail of Option "D" components to be captured. The changes in the grid increased both vertical and horizontal refinement with the number of grid cells representing the repository increasing from 51 in the CCA to 69 in the TBM. The total number of grid cells increased from 33 to 68 in the x-dimension and 31 to 33 in the y-dimension. The x-dimension changes in the grid required the recalculation of radial flaring. It is understood by previous peer review panels, and this panel as well, that while flow may not be truly radial, the two-dimensional flared grid is reasonable for estimating releases. The CCA grid had several scales of flaring with each calculation including a series of complicated cell wrapping procedures that are difficult to reproduce and use for characterizing changes. The TBM changes include a new flaring algorithm that uses simplified repository geometry, results in flaring representations that closely approximate those in the CCA grid, and allows for changes to be "more easily" made in the x-dimension.

Changes in the BRAGFLO model considered in this peer review, with respect to the Disposal System Geometry conceptual model, include grid spacing changes, removal of the baseline shaft seal system model and replacement with a simplified model. The peer review panel understands that implementation of the Option "D" panel closure was the stimulus for changing the grid and modification of the shaft seal system was a separate decision represented in the BRAGFLO grid.

3.1.2 Review of Criteria

3.1.2.1 Information Used to Review Changes in Conceptual Model

The 1996 peer review of the Disposal System Geometry conceptual model included review of the screening logic, numerous SNL reports, and many technical presentations and discussion sessions. As stated in the report, (July 1996) the information and background references reviewed at that time were for specific inputs and applications, i.e., a comprehensive list of references addressing the "conceptual modeling" of the Disposal System Geometry was not compiled. Information concerning the effects of detailed stratigraphy and stratigraphic dip on brine and gas flow, and uncertainty and parameter sensitivity analyses for gas and brine migration, is presented in Webb and Larson (1996), WIPP (1992a & 1992b), and Christian-Frear (1996). Other reports (WIPP 1993, Rechard 1990, and Marietta 1989) explain the WIPP PA aspects of characterizing the disposal system geometry, and features, events, and processes (FEPs) screening documents present modeling alternatives. Various sections of the CCA (DOE 1996) summarize disposal system, repository, and intrusion event geometries. The Disposal System Geometry conceptual model, as reviewed in 1996 and as addressed in this peer review, is the result of integrating other models that describe the physical and chemical conditions and processes that are expected in the repository to produce a characterization of the repository and the surrounding strata. The references include the various background, technical descriptions, and presentation materials used in conducting the evaluation of the TBM changes in the Disposal System Geometry conceptual model. Previous conceptual model peer review reports, regulatory guidance, and other appropriate documents were provided to the peer review panel early in the process, as required background reading. The key information sources addressing the TBM changes were the technical presentations, technical documents, and background materials provided by SNL supplemented by discussions with SNL scientists.

3.1.2.2 Validity of Assumptions

Along with the assumptions made for the TBM changes, it is important to briefly review the general assumptions made in the original peer review of the Disposal System Geometry conceptual model in 1996. The Disposal System Geometry conceptual model and its assumptions are so closely tied to the processes described by other models that not only is it important that the model have assumptions that are internally consistent, but the assumptions must be consistent with those of the models representing repository processes. Disposal system geometry processes are so closely tied to the processes that govern overall repository performance that it is difficult to conduct a review separate from the other models. Fluid flow and actinide transport are principal processes that rely on the geometric assumptions and these processes in turn have interrelationships with other process models. In 1996 the panel recognized the simplifications and assignment of high permeabilities for the sake of conservatism. Although, this panel's view is that it is always more credible to model the actual system, the assumptions supporting the simplifications remain valid.

Assumptions key to the original Disposal System Geometry conceptual model include: 1) the three-dimensional systems can be represented by two-dimensional simplifications, 2) the associations between and relationships across regions with varying material properties can be represented by the discretized grid blocks and by the finite difference method used in the computational model; 3) the four shafts can be represented by one shaft; 4) the entire repository can be represented by the simplified floor plan used in the computation model; 5) the intrusion borehole(s) represent the range of concerns associated with the intrusion scenarios; and 6) effects of flow in the DRZ and intact rocks outside of the repository are represented by the divergent grid to the north and south, away from the repository.

Assumptions key to the proposed TBM changes in the Disposal System Geometry conceptual model include: 1) The more refined grid spacing provides a more accurate representation of features, events, and processes but does not adversely impact the representation of sources, sinks, and pathways for radionuclide releases; 2) Flow in the shaft is negligible; 3) Removal of the baseline shaft seal system model and replacement with a simplified, two layer system conservatively represents the behavior of seal components in the repository system model and accurately represents shaft seal behavior as modeled in the baseline PA; 4) The new flaring algorithm adequately represents horizontal divergent and convergent flows to the north and south of the repository; 5) The TBM BRAGFLO grid adequately represents the Option "D" panel closure design, the DRZ, anhydrite fracture, repository fluid flow, and other components of the WIPP setting; 6) Moving the repository horizon vertically, approximately 2.4 meters, to Clay Seam "G" enhances operational safety and will not significantly impact the long-term performance of the facility in terms of lateral brine flow, creep closure, release pathways and available pore volume.

During the Salado Flow Peer Review, SNL presented assumptions and justifications for the material property representations proposed for use in the TBM. The panel concludes that the assumptions and justifications are defensible and appear to adequately represent the features and process of concern in the TBM changes. The panel also concludes that as a result of previous PA calculations, illustrating that only negligible flows are released up the shaft, removal of the "baseline shaft seal property details" and replacing them with a simplified, equivalent permeability system with fewer time intervals conservatively represents the behavior of seal components and is valid.

Changes in the Disposal System Geometry conceptual model are proposed to be implemented through the same discretized grid block and finite difference computational approach as was done for the CCA. The Panel judges that if key pathways and simplifications are retained, the overall conceptual model remains valid.

3.1.2.3 Alternative Interpretations

During the Salado Flow Peer Review, information presented and considered by the Panel did not include alternatives or options for changes in the Disposal System Geometry conceptual model. The final certification decision required the implementation of the Option "D" panel closure system and no other panel closure alternatives were considered by the peer review panel.

3.1.2.4 Uncertainty of Results and Consequences if Wrong

The key uncertainties associated with the TBM proposed changes to the Disposal System Geometry conceptual model are related to the material property descriptions and the grid simplifications made for the sake of conservatism, and the representativeness of the computational mesh. Even with the TBM changes the proposed BRAGFLO grid is not sufficiently detailed to describe all flow features and processes and the overall system relies on other conceptual models to reasonably describe such features and processes.

The panel concludes that there is little uncertainty associated with the basic geometric framework and finite difference method used to characterize the changes associated with the proposed TBM. The uncertainty that does exist is related to the grid block densities of the material property representations and the representativeness of the grid block densities and computational mesh. The material property changes appear justified and defensible.

The consequences of the proposed TBM changes in the Disposal System Geometry conceptual model, if they are wrong, can only be addressed in a qualitative way at this time. If the material property representations are wrong and or the computational mesh is not representative, the consequences depend on the relative magnitude of error(s) and the resulting changes in the total system PA.

3.1.2.5 Appropriateness and Limitations of Method and Procedures

The proposed TBM changes in the Disposal System Geometry conceptual model have been made without changing the fundamental geometric framework of discretized grid blocks and the finite difference method implemented through BRAGFLO. The methodology is considered by the panel to be appropriate for the TBM application. The panel concludes that the conceptual model continues to be an appropriate methodology to integrate and express the inputs from other conceptual models.

3.1.2.6 Adequacy of Application

The methodology employed in the Disposal System Geometry conceptual model is appropriate and adequate for application as a performance element. There are no apparent compatibility problems between the geometry and process-related models. Single vector BRAGFLO analyses that focused on saturation and pressure provided comparisons for the Performance Assessment Verification Test (PAVT), Technical Baseline Intermediate (TBI), and TBM. The TBI was intended to isolate Option “D” effects in the BRAGFLO grid. The single vector, time dependent comparisons produced results that were either expected or could be explained. Scatter-plots also provided comparisons that were understandable and where differences could be explained.

The adequacy of the changes in material properties and their representations in the grid can only be measured by how well overall processes are approximated. These approximations and representations, and changes from the baseline model have been evaluated through a PA for the TBM. The results of the PA indicate that total releases are nearly identical to the PAVT and direct releases are nearly identical or less that the PAVT. Based on these results, application of the changes, as modeled in the baseline, is deemed adequate.

3.1.2.7 Accuracy of Calculations

It was not within the scope of the Salado Flow Peer Review to evaluate BRAGFLO code changes. Descriptive write-ups and review of uncertainty and sensitivity analyses that compare the relationship between sampled inputs and dependent variables in the PAVT, TBI, and TBM provide no indications that the accuracy of the "baseline" model has been changed. The PA results for the TBM indicate that total releases are nearly identical to the PAVT and direct releases are nearly identical or less than the PAVT. Since the Disposal System Geometry conceptual model produces results using the material properties, processes, and codes from other models, and the TBM PA illustrates that repository performance continues to be represented as it was in the baseline, the relative accuracy of the Disposal System Geometry conceptual model has been demonstrated.

3.1.2.8 Validity of Conclusions

There are no specific conclusions drawn, with respect to the Disposal System Geometry conceptual model, other than its ability to characterize appropriate properties, processes and features. The conclusion derived from the PA is that the conceptual model continues to reasonably represent repository performance.

3.1.2.9 Adequacy for Implementation

The Disposal System Geometry conceptual model continues to provide an adequate framework for modeling the important processes and their interactions in the disposal system. The concept that the spatial effects of processes and interactions can be represented in two-dimensions is defensible. The simplification in the system representation and computational method to simulate the two dimensions are defensible and adequate for implementation. The basic grid framework for representing the material properties of the disposal system, adjacent DRZ, geologic formations, and intrusion scenarios is adequate. The proposed use of a finite difference method to connect the nodes and generate flow fields is also defensible and adequate for implementation.

The results of the PA for the TBM illustrate that the effects of changes to the baseline conceptual models, described in 3.1.1.2 and associated applications are minimal. The Disposal System Geometry conceptual model continues to be adequate for implementation.

3.1.2.10 Dissenting Views

There were no dissenting views for this model.

3.2 REPOSITORY FLUID FLOW

3.2.1 Model Description

The Repository Fluid Flow conceptual model is a highly complex description of interacting hydrologic, chemical, engineering design, geomechanical and human intrusion conceptual models whose simultaneous effects can be separately described, but require a PA to demonstrate the combined, integrated results. The physical conditions controlling fluid flow in the repository include brine and gas inflow and outflow rates, halite creep rates, and gas generation pressures from waste container corrosion and waste degradation. These physical conditions are contained in separately described conceptual models (Salado Interbeds, Creep Closure, and Gas Generation conceptual models respectively). The Repository Fluid Flow model accepts input from these related models and provides descriptions of pressures, flow rates, and flow directions for gas and brine within the disposal cells and other sections of the repository. A formal description of the coupled processes in the original conceptual model was presented in Freeze, et al. (1995).

Changes to the original conceptual model are as follows; 1) Brine inflow and outflow rates and gas pressures have potentially been altered by the introduction of the Option "D" panel closure mandated by the EPA, 2) The Disturbed Rock Zone (DRZ) properties have been altered by the allowance of fracturing both in the anhydrite beds and the salado halite and the "Flow Around" features near plugs at high pressure, 3) The salt creep rate may be affected due to changes in gas pressure, 4) Gas generation is calculated using a different cellulosic molecular weight that provides approximately 10% greater gas production during microbial degradation, and 5) Flows will be simplified since the Disposal System Geometry conceptual model now has a simplified Shaft component.

3.2.2 Review of Criteria

3.2.2.1 Information Used to Develop Conceptual Model

The Repository Fluid Flow conceptual model relies heavily on Darcy flow in porous media, as revised for gas by taking into account the Klinkenberg effect, and for two-phase flow using a modified Brooks-Corey model that includes threshold pressures for gas entry into a brine saturated environment (Wilson, et al., 1996). Gas properties are given by the Redlich-Kwong-Soave equations of state, assuming that the gas behaves as pure hydrogen. The conceptual model addresses (1) fluid distribution in the waste, (2) long-term fluid (gas and liquid) flow to and from the Salado Formation, and (3) long-term fluid flow between the repository and the intrusion boreholes. Interactions with other conceptual models include the Disposal Room Geometry, Disturbed Rock Zone, Creep Closure, Gas Generation, Impure Halite, Salado, the Salado Interbeds, Castile and Brine Reservoirs, Exploration Boreholes, and Multiple Intrusions. In the original CCA, this model also was related to the Shafts and Shaft Seals model. However, the detailed Shafts and Shaft Seals model was replaced by a simplified Shaft Seals model incorporated into the Disposal Room Geometry conceptual model and flow out of the repository via the shafts is considered insignificant. Fluids will now be transported primarily up boreholes during disruptive events (S3 and S5).

The conceptual model for repository fluid flow is implemented for PA using the BRAGFLO code. The repository is represented in BRAGFLO in two dimensional vertical sections as a series of volumes, each with homogeneous isotropic material properties and behaviors, with each representing a major repository feature. The slight one degree ($1^?$) dip of the bedding to the south is represented by the model. The effective depth of each feature (the dimension normal to the plane of the model) is represented by adjusting the cross sectional areas of the cells representing the feature. The effective depths of the model cells were varied to simulate the increasing hydraulic gradients that would occur in the repository and boreholes under radial flow conditions.

The original conceptual model was validated in the CCA and accepted by the Conceptual Models Peer Review in 1996. Since that time, a PAVT sensitivity study was performed. That PA included 60 parameter changes mandated by the EPA. Sensitivity analysis in the PAVT indicates that impact on the complete PA calculations were not substantial.

Since the PAVT, there have been minor changes to the fluid pathways in and around the repository. The model packages presented to the peer review panel were the Technical Baseline Migration (TBM) and the CRA (equivalent to AP-106). These changes are the result of modifications to other conceptual models and corrections of parameter values. The Shaft and Shaft Seal model has been removed from the overall performance assessment model in the TBM and replaced with a simplified Shaft Model incorporated into the Disposal Room Geometry. Modification of the Shaft and Shaft Seal model results in fluids being primarily channeled up the boreholes in the event of human intrusion by drilling in to the repository. Addition of a simplified Shaft Model into the Disposal Room Geometry conceptual model should result in no significant change in the PA.

There have been changes to the DRZ conceptual model in the TBM. Fluids would no longer transport from one panel to another via Marker Bed #138. Instead, fluids will now migrate along Marker Bed #139 below the floor of the panels. The fluids will not be able to circumvent the Option "D" panel closure by taking the path of least resistance in marker Bed #139. Because of permeability fluctuations related to gas pressure variation during the repository history, both gas and liquid phases may be impeded in their flow through the DRZ during certain BRAGFLO simulations. In the latest rendition of this conceptual model (CRA), fracturing of the Salado anhydrite beds is a primary storage and transport medium for outflow from the repository. This allows gases to now flow through Marker Bed #138, and liquids to flow preferentially through Marker Bed #139.

Furthermore, at high pressures, a “flow around” parameter has been implemented which would allow fluids to circumvent the Option “D” plug in the “z” dimension. This modification in the CRA now allows gas and liquid phases to be less impeded during some high pressure BRAGFLO simulations.

The Option “D” panel closure has been incorporated into the final closure plan and has multiple potential effects on fluid flow. Although the upper DRZ still exists it is not allowed to fracture for the TBM analysis except at very high pressures (~12 MPA). The lower DRZ is allowed to fracture for the TBM assisted by tensile stresses associated by floor heave making Marker Bed #139 the preferred pathway. Fluids will more slowly equilibrate throughout the repository after closure, which may result in changes in PA. Gas pressure in the experimental area will most likely be lower than in the PAVT, since there is no gas generation in that region and constrained communication with the waste panels. Brine saturation in the southernmost waste panels may be lower than in PAVT, since there is less brine communication between panels due to the characteristics of the Option “D” panel closure which will prevent down-dip flow of brine between repository openings. Brine saturation in the remainder of the repository will be the same as PAVT calculations because the process models for BRAGFLO have not changed. With the addition of the upper DRZ fracturing in the CRA, most of the Option “D” restrictions are less effective at high pressures. Once lithostatic pressure is realized, the anhydrite fractures can open and fluids migrate through both the upper and lower marker beds (#138 and #139, respectively). This will allow for lower maximum gas pressures and relatively increased brine flow in the waste panel. Pressure and saturation will also be affected by higher transmissivities.

The parameter value changes include the cellulosic molecular structure change and the EPA mandated parameter value changes (Table 3-1). The cellulosic chemical formula ($C_6H_{10}O_5$) provides approximately 10% greater gas production during microbial degradation. The new parameter value changes introduced by the EPA did not introduce significant changes from the CCA to the PAVT CCDFs.

3.2.2.2 Validity of Assumptions

On a larger scale, the original assumptions for the Repository Fluid Flow conceptual model were validated in the original performance assessment (CCA, 1996). The validity of the assumptions in the Repository Fluid Flow model depend in part on the other conceptual models (Disturbed Rock Zone and Disposal System Geometry) in so far as the assumptions in the other models are shown to be valid, those same assumptions will propagate through to the Repository Fluid Flow conceptual model. The BRAGFLO model was not significantly changed in its assumption base (creep closure, gas generation, pressure induced fracturing, use of characteristic curves such as Brooks-Corey and van Genuchten), rather, cell parameters have been improved and cell dimensions have been better adapted to critical features.

The assumptions addressed in the TBM are: 1) modification of the representation of the Shafts and Shaft Seals, 2) change in representation of cellulosic molecular structure, 3) changes in the DRZ conceptual model, 4) implementation of EPA mandated changes to parameters, and 5) implementation of the Option "D" panel closure.

The assumption that the modification of the Shafts and Shaft Seals system would affect the overall performance of the PA in a very minor way is reasonable. Maximum brine flow up the Shaft at the top of the DRZ was calculated to be approximately a total of 30 m^3. During borehole intrusions in the upcoming PA this fluid would be directed up the borehole and would still be insignificant. However, the EPA requested that a shaft be reintroduced. Therefore a simplified Shaft model was included in the Disposal System Geometry model. In lieu of the original 22 materials and six time intervals in the CCA, the simplified Shaft model has fewer materials, time intervals, and permeability values. With this simplified shaft most of the brine flow would still be directed up the intrusion boreholes

The larger molecular weight for cellulose is not an assumption, but rather a refinement of a parameter. The recalculation of the molecular weight and the slight increase in gas generation potential (10%) will produce a slightly more conservative value for overall gas generation amounts in certain PA scenarios.

The two major assumptions for the Disturbed Rock Zone conceptual model (permeability and flow geometry) are reasonable in the TBM model. For the CRA the simplified shaft model is included, fracturing in the upper and lower DRZ is implemented, a high pressure "flow around" concept is extended to permit flow in all anhydrite and Salado beds, and a double concrete panel closure is included at the north end of the repository. These assumptions are reasonable for the CRA and present an acceptable approach to model how fluids would interact with the Option "D" panels.

The 60 parameter changes listed in Table 3-1 (Summary of CCA and PAVT Parameters) and Table 3-2. (Summary of TBM and CRA Values and Distributions) appear appropriate and reasonable. The most notable changes concern actinide solubilities in the fluid. In all cases the solubility values are lower than in the original CCA values. Such values would produce curves with lower values in the CCDF calculations, if all other factors remain unchanged. Most other changes involve taking a single parameter value and replacing it with a range of values that bracket the original. This is an appropriate and reasonable assumption, in that it focuses most new values near the original value, but allows the CCDF calculations a slightly wider variance.

Table 3-1. Summary of CCA and PAVT Parameters

Parameter	CCA Range and Distribution	PAVT Range and Distribution
Log of Borehole Sand Permeability	-14 to -11 log m^2 Uniform	-16.3 to -11 log m^2 Uniform
Log of Borehole Concrete Permeability	-16.3 log m^2 Constant	-19 to -17 log m^2 Uniform
Log of Disturbed Rock Zone Permeability	-15 log m^2 Constant	-19.4 to -12.5 log m^2 Uniform
Log of Waste Permeability	-12.769 log m^2 Constant	-12.6198 log m^2 Constant

PIC Reduction Factor for 100 – 700 years	0.01 Constant	1.0 Constant
Waste Shear Strength	0.05 to 10 Pa Uniform	0.05 to 77 Pa Log uniform
Coefficient, A, in Equation[(a)] for Solubility for Am(III) and Pu(III) in Castile Brine	6.52×10^{-8} mol/l Constant	1.38×10^{-8} mol/l Constant
Coefficient, A, in Equation[(a)] for Solubility for Np+4, Pu(IV), Th (IV) and U (IV) in Castile Brine	6.0×10^{-9} mol/l Constant	4.1×10^{-8} mol/l Constant
Coefficient, A, in Equation[(a)] for Solubility for Np (V) in Castile Brine	2.2×10^{-6} mol/l Constant	4.8×10^{-7} mol/l Constant
Coefficient, A, in Equation[(a)] for Solubility for Am(III) and Pu (III) in Salado Brine	5.82×10^{-7} mol/l Constant	1.2×10^{-7} mol/l Constant
Coefficient, A, in Equation[(a)] for Solubility for Np (IV), Pu (IV), Th (IV) and U (IV) in Salado Brine	4.4×10^{-6} mol/l Constant	1.3×10^{-8} mol/l Constant
Coefficient, A, in Equation[(a)] for Solubility for Np (V) in Salado Brine	2.3×10^{-6} mol/l Constant	2.4×10^{-7} mol/l Constant
Inundated Steel Corrosion Rate	0 to 1.59×10^{-14} m/s Uniform	0 to 3.17×10^{-14} m/s Uniform
K_d in Culebra Dolomite for Am(III) and Pu(III)	0.02 to 0.5 m^3/kg Uniform	0.009 to 0.4 m^3/kg Log uniform
K_d in Culebra Dolomite for Np (IV), Pu (IV), Th (IV), and U (IV)	0.9 to 20 m^3/kg Uniform	0.7 to 10 m^3/kg Log uniform
K_d in Culebra Dolomite for Np (V)	0.001 to 0.2 m^3/kg Uniform	0.001 to 0.2 m^3/kg Log uniform
K_d in Culebra Dolomite for U (VI)	0.00003 to 0.03 m^3/kg Uniform	0.00003 to 0.02 m^3/kg Log uniform
Probability of Hitting a Brine Pocket	0.08 Constant	0.01to 0.60 Uniform
Drill String Angular Velocity	7.7 radians/s Constant	4.2 to 23.0 radians/s cumulative distribution with mean of 7.77 radians/s
Castile Brine Pocket Rock Compressibility	Min: 5×10^{-12} Pa^{-1} Max: 1×10^{-8} Pa^{-1} Mode 1×10^{-10} Pa^{-1} Triangular	Min: 2×10^{-11} Pa^{-1} Max: 1×10^{-10} Pa^{-1}; Mode 4×10^{-11} Pa^{-1} Triangular
Castile Brine Pocket Porosity	Not used in CCA	Min: 0.1848; Max: 0.9240; Mode 0.3696

Brine Pocket Pore Volume	(3.2, 6.4, 9.6, 12.8, 16) x 10^4 m^3 Discrete	Calculated from Brine Pocket Porosity
Inventory Waste Unit Factor	4.07 Constant	3.44 Constant

[(a)]The equation for solubility is $A \cdot 10^b$ where b is a sampled value. Only the coefficient, A, was changed in the PAVT.

Table 3-2. Summary of TBM and CRA Values and Distributions

Parameter	Range	Distribution
Log of Borehole Sand Permeability	-16.3 to -11 log m^2	Uniform
Log of Borehole Concrete Permeability	-19 to -17 log m^2	Uniform
Log of Disturbed Rock Zone Permeability	-19.4 to -12.5 log m^2	Uniform
Log of Waste Permeability	-12.6198 log m^2	Constant
PIC Reduction Factor for 100 – 700 years	1.0	Constant
Waste Shear Strength	0.05 to 77 Pa	Log uniform
Coefficient, A, in Equation[(a)] for Solubility for Am(III) and Pu(III) in Castile Brine	1.38 x 10^{-8} mol/l	Constant
Coefficient, A, in Equation[(a)] for Solubility for Np (IV), Pu (IV), Th (IV) and U (IV) in Castile Brine	4.1 x 10^{-8} mol/l	Constant
Coefficient, A, in Equation[(a)] for Solubility for Np (V) in Castile Brine	4.8 x 10^{-7} mol/l	Constant
Coefficient, A, in Equation[(a)] for Solubility for Am(III) and Pu(III) in Salado Brine	1.2 x 10^{-7} mol/l	Constant
Coefficient, A, in Equation[(a)] for Solubility for Np (IV), Pu (IV), Th (IV) and U (IV) in Salado Brine	1.3 x 10^{-8} mol/l	Constant
Coefficient, A, in Equation[(a)] for Solubility for Np (V) in Salado Brine	2.4 x 10^{-7} mol/l	Constant
Inundated Steel Corrosion Rate	0 to 3.17x10^{-14} m/s	Uniform
K_d in Culebra Dolomite for Am (III) and Pu (III)	0.009 to 0.4 m^3/kg	Log uniform
K_d in Culebra Dolomite for Np (IV), Pu (IV), Th (IV), and U (IV)	0.7 to 10 m^3/kg	Loguniform

K_d in Culebra Dolomite for Np (V)	0.001 to 0.2 m^3/kg	Log uniform
K_d in Culebra Dolomite for U (VI)	0.00003 to 0.02 m^3/kg	Log uniform
Probability of Hitting a Brine Pocket	0.01 to 0.60	Uniform
Drill String Angular Velocity	4.2 to 23.0 radians/sec	Cumulative distribution based on range with mean value of 7.77 radians/s
Castile Brine Pocket Rock Compressibility	Min: $2x10^{-11}$ Pa^{-1} Max: $1x10^{-10}$ Pa^{-1} Mode $4x10^{-11}$ Pa^{-1}	Triangular
Castile Brine Pocket Porosity	Min: 0.1848; Max: 0.9240; Mode 0.3696	Triangular
Brine Pocket Pore Volume	Calculated from Brine Pocket Porosity	Not applicable
Inventory Waste Unit Factor	3.59	Constant

[(a)]The equation for solubility is $A \cdot 10^b$ where b is a sampled value. Only the coefficient, A, was changed in the PAVT.

Scatterplots using the CRA values compare well with those using the TBM assumptions for gas generation. At 1,000 years, waste panel pressures are only slightly elevated versus the TBM. For longer periods of time (10,000 years), the CRA pressures in the waste panel coincide with TBM values. This is most probably caused by gas migration once the upper DRZ opens at high pressure. CRA scatter-plots indicate that the rest of the repository brine saturation is equivalent to TBM values (and therefore are the same as PAVT values). A few of the waste panel saturation values are lower than corresponding TBM values and may be related to slight changes in DRZ parameters related to anhydrite fracture and the double panel seal. The review panel concludes that the proposed impacts of the Option "D" closure and DRZ changes are reasonable assumptions.

The Repository Fluid Flow conceptual model is expected to have negligible impact on the other conceptual models and the total system PA. Presentations by SNL indicate that borehole intrusion scenarios will not change from those in the CCA. Increased and decreased values for gas pressure and/or brine saturation impacts on fluid flow have been evaluated and the impact that the changes in fluid flow will have on the spallings and multiple intrusions scenarios and on the PA are acceptable.

3.2.2.3 Alternative Interpretations

The changes incorporated into the Repository Fluid Flow conceptual model are based on three earlier cases of the model. The earlier models represent alternative interpretations. The Repository Fluid Flow conceptual model in the CCA was fully peer reviewed and accepted. The second representation of the model was in the PAVT sensitivity study. The changes incorporated into the third rendition of the model were logical improvements based on modification of the shafts and shaft seals model and the incorporation of the Option "D" panel closure. Adjustments to include a simplified shaft model for the CRA were requested by the EPA. Upper DRZ fracturing and flow around features now mitigate early concerns with the Option "D" closure panels.

3.2.2.4 Uncertainty of Results and Consequences if Wrong

The uncertainty of results related to the changed Repository Fluid Flow model are primarily related the implementation of the Option "D" panel closure. The purpose of the panel closures is to impede flow around the closure between adjoining waste panels. The new Disturbed Rock Zone conceptual model implies that flow will occur in both Interbed #138 and #139 at high gas pressure, and in turn, this should allow gas and liquid in the waste panels to equilibrate over time. However, vector analyses of gas pressure and brine saturation in the TBM and CRA model show that flow occurs for a limited number of vectors when pressures become high enough to cause significant fracturing. When these factors (pressure and saturation) are allowed to interact with the other conceptual models and are evaluated as part of the full system PA, other outcomes may result. Direct release conceptual models (involving cuttings, cavings, spallings, and direct brine release) provide the most significant release pathways. Since there is evidence that the waste panels do not equilibrate quickly with the rest of the repository or with the experimental region, the Repository Fluid Flow conceptual model may impact direct releases when evaluated in the context of a full system PA. If a postulated intrusion intercepts a waste panel with a high gas pressure (at or above lithostatic pressures), and with high brine saturation, it could allow for slightly higher brine transport to the surface. Conversely, if panels with low gas pressure or low brine saturation were intercepted, then the direct release could be much lower. Since the last review of this conceptual model specific waste panels and explicit scenarios for direct brine release have been evaluated and TBM CCDF curves presented. The curves suggest that those scenarios do not adversely impact the performance of the repository.

3.2.2.5 Appropriateness and Limitations of Method and Procedures

The methods and procedures used in the Repository Fluid Flow model are based on refinements of previous models and should provide representative results.

3.2.2.6 Adequacy of Application

The adequacy of application of the model to changes in flow in the repository requires that all new definitions, processes, and applications be clearly identified. Parameters have been identified and qualified by the EPA (Table 3-1) for the PAVT. Intrusion scenarios have been defined by SNL and do not differ from the CCA. BRAGFLO calculations are identical to those used in previous applications (CCA and PAVT) of the PA and comparison of the newly generated CCDFs to the PAVT reveal relatively insignificant changes in total releases. The application of the model using redefined flow paths ("flow around" and anhydrite fracturing) and parameters does not require basic changes in the conceptual model itself. The performance of the repository in the TBM and CRA, as viewed by the presented CCDFs, confirms the adequacy of the application of the Repository Fluid Flow conceptual model.

3.2.2.7 Accuracy of Calculations

Scatterplots and CCDFs presented by SNL illustrate the changes made to calculations since the PAVT in this conceptual model and how they impact the performance assessment. No changes have been made to BRAGFLO or the application of BRAGFLO to the process models. Scatterplots presented by SNL allowed observation of how the most important sub-models (gas pressure, brine saturation and volume) respond in the repository performance assessment and variations were logically explained by SNL personnel. For the CRA, CCDFs were presented for the most pressure sensitive scenario (Spallings) and the most brine sensitive case (DBR). The results of both scenarios were plausible, and did not vary widely from PAVT curves. Importantly, these newly generated curves did not substantially approach the EPA compliance limit. It is concluded that the accuracy of calculations for Repository Fluid Flow conceptual model has been demonstrated.

3.2.2.8 Validity of Conclusions

The conceptual model as reviewed at the time of the CCA was deemed to provide valid conclusions. Present changes to the details of the fluid flow pathway (Anhydrite fracturing, flow around, and repository geometry parameters) are reasonable and appear to be valid. The changes implemented are in the applications of the model and how it relates to other conceptual models in the PA. BRAGFLO has not changed and the conceptual model itself is deemed adequate; the calculations are judged to be accurate; and it is concluded that the changes to the Repository Fluid flow model and how they represent flow in the repository are valid.

3.2.2.9 Adequacy for Implementation

Even though the CCDFs presented were only a partial assessment and not a total system PA, the probability of outliers that would result in non conformance is minimal. The production of Single CCDF curves that represent the most sensitive scenarios (Spallings and direct brine release) in the CRA, along with the full TBM CCDFs, were enough information to judge that the minor modifications made to the Repository Fluid Flow model are reasonable and justifiable. This model is deemed adequate for implementation.

3.2.2.10 Dissenting Views

There were no dissenting views for this model.

3.3 Disturbed Rock Zone

3.3.1 Model Description

The DRZ conceptual model, as originally conceptualized in the CCA, was composed of a layer of halite above and below the drift. This layer provided a flowpath between the drift and the marker beds. The halite that composed this layer was assigned an arbitrary permeability of 10^{-15} m^2, considered a conservative value that would permit gas to escape the repository via the fractured marker bed and allow gravity-driven drainage of brine from the marker bed into the repository ("DRZ rain"). The model was not strongly representative of repository processes; rather it was viewed as a conservative basis for modeling waste degradation and gas generation processes in the repository.

During the PAVT sensitivity study the EPA mandated a range of permeability for the DRZ halite layer which reasonably represents the properties of extensively creep-damaged halite and anhydrite at the high permeability end, and of minimally damaged halite at the low permeability end. This range is unequally distributed around the original single value used for the halite permeability. This range is retained in the changed conceptual model and was not previously peer reviewed. A principal change to the hydrologic processes contained in the model presently under review is the flow path through the repository floor, an average of one or two meters of halite, into Marker Bed #139 which is composed of about one meter of fractured anhydrite. This flow path represents a considerably more transmissive pathway for the exit of gas and brine from the pressurized repository, into the potential storage medium represented by the fractured anhydrite. The gravity inflow of brine through the halite layer above the repository back is still a factor in modeling brine inflow into the repository.

Gas will sometimes, depending on the level of free brine in the repository, flow out through pathways in the repository floor to Marker Bed #139, and , especially at times of high pressure will also flow out through the pathways around the tops of panel seals. This flow will in most cases go to marker beds above and below the repository connected to the repository by fractures opened by floor heave and by stresses associated with room closure about the rigid panel seals into the void spaces on either side of the seals.

A further change in the potential flow paths out of the repository is represented by a design change applied to several waste panels at the southern end of the repository. The purpose of the design change is to enhance repository construction safety by raising the elevation of the drift to place the back of the excavation at a clay seam (G), mitigating what might have become a parting that could increase the risk of roof fall in those waste panels. This will raise the floor of the repository slightly higher (3.8 meters) above Marker Bed #139.Since the stresses and fracture caused by floor heave in repository drifts extend to considerable depth below the drift floor, and since the role of floor fracture is primarily to connect the repository to Marker Bed #139, this design change is not expected to have any significant impact on the repository floor flowpath.

3.3.2 Review of Criteria

3.3.2.1 Information Used to Review Changes in Conceptual Models

The CCA version of the DRZ conceptual model consisted of a 12 meter thick zone above the emplacement panels and drifts that were assigned an assumed permeability of 10^{-15} m^2 for the entire zone. This conceptual model had no basis in actual repository or site performance, but was rather a conservative representation of the damaged rock zone, conceived to permit brine and gas flow between the repository and the overlying Marker Bed #138. The PAVT sensitivity study that followed the CCA used a range of permeability values for the zone between the repository and Marker Bed #138 that were identified by the EPA. The EPA determined the lower bound of the range of permeability from measured gas permeability in anhydrite cores from Marker Bed #139 (Howarth, 1996, Beauheim, 1996, Howarth and Christian-Frear, 1997). The EPA concluded that a value of $10^{-19.4}$ m^2 is an appropriate lower bound for the range of likely values. Based on sensitivity tests, the EPA selected a value of $10^{-12.5}$ m^2 as the upper bound of the range of DRZ permeability. Documents held by the WIPP Project office pertaining to DRZ permeability support this range of the PAVT values (Beauheim, 1996). The more permeable limit represents halite and anhydrite heavily damaged by creep strain. The less permeable end of the range assigned to the assumed disturbed zone above the repository is a value conceived to represent the permeability of halite that has been healed by stresses associated with repository creep closure and is supported by measured permeability values. This value ($10^{-19.4}$ m^2) is comparable to the permeability of halite that has been disturbed only by far field stresses caused by creep toward the repository opening beyond the disturbed rock zone (Beauheim, in press). This range of values is an acceptable bound of the permeability of the disturbed rock zone that includes both the Salado halite and the anhydrite of the marker beds.

The changes proposed to the DRZ conceptual model for the next total system PA modifies the geometry of flow associated with the DRZ but retains the range of permeability assumed for the DRZ under the PAVT sensitivity study. The changed conceptual model routes flow through the floor of the repository to Marker Bed #139 whose upper surface is about 4 meters below the drift floor in the raised repository region (south part) and 1 to 2 meters in the north part of the repository. This flow routing represents the path of least resistance for the flow of gas and brine out of the repository and provides a reasonable basis for estimation of gas pressures in the repository.

The potential for flow around the top and bottom of panel seals is a topic whose consideration is made necessary by the addition of the much more restrictive option “D” panel seals. In the case of the bottom footprint of the seal, the concrete monolith is seated at the bottom of Marker Bed #139. The top of the seal is seated against a freshly excavated inset into the halite of the repository roof. At repository pressures that exceed the hydraulic activation pressures of closed fractures in the areas around the seats of the seals, flow is likely around the seals (Figure 68 SNL presentation, Feb. 19, 2003) The cited figure shows flow around the bottom of a panel seal, however, flow around the top of such a seal would differ only in that the top of the seal would be seated in halite and that gas flow only would be predominant around the top of the seal at some times in the repository history. Brine flow would almost always be the dominant flow mode in the lower seat area. This set of flow paths has some potential to impact the pressure histories of the individual spaces in the repository and the model is applied to these consequences of changes of repository design in a manner similar to that applied to the new scenario of flow through the repository floor.

The changes to the DRZ conceptual model include the assumptions supporting the range of permeability values and the change in the geometry of flow from the 12 meter overhead DRZ (CCA) to the 1 to 3.8 meter long flowpath, through the repository floor and into the fractured anhydrite of Marker Bed #139, and flow at high pressures around the tops and bottoms of panel seals into marker beds above and below the repository (AP 106).

3.3.2.2 Validity of Assumptions

Assumptions used in developing the proposed changes to the DRZ conceptual model are of two kinds. The values for the permeability of the DRZ have evolved over two iterations of PA. In the first PA (CCA, 1996) the permeability of the thick, overhead DRZ contained in that conceptual model was a "conservative" value assumed to permit communication between repository openings and the upper Marker Bed #138. The chosen value was assumed to permit free drainage of brine from the marker bed into the repository and to permit gas to escape from the repository to the marker bed. The permeability chosen was an intermediate single value between perceived extremes implied by the material properties of the marker bed and pure halite. For the PAVT sensitivity study a range of permeability was necessary to permit sampling and development of distributions to better represent flow through this complex zone. The end members of the distribution represent the measured permeability of the fractured anhydrite marker beds and the estimated permeability of "tight" halite. Pure halite, disturbed only by very small and slow strain resulting from creep into the repository beyond the DRZ, is probably a reasonable representation of well-healed halite after the disappearance of the DRZ due to back-stress around seals or after the closure of repository open spaces. As such, these end members are reasonable limits to the permeability of the DRZ. The permeability range used in the PAVT calculations ($10^{-12.5}$ m^2 to $10^{-19.4}$ m^2) represents reasonable parameters between the end member conditions.

Changes in the geometry of flow in the DRZ represent the second kind of assumption. The basis of this assumption is that gas flow out of the repository panels will follow the path of least resistance or the path of greatest transmissivity. The short distance (4 meters in the raised repository region (south part) and 1 to 2 meters in the north part of the repository) between the repository floor and Marker Bed #139 represents a much lower resistance to flow than upward flow through 10 meters (south part) to 12 meters (north part of the repository) of halite that is horizontally compressed by arching stresses over the repository openings. Floor heave implies an extensional stress environment in the floor. This extensional stress and gas pressures may also help to keep the fractures in both the halite in the repository floor and in the anhydrite marker bed open. The large storage space represented by the well connected fracture porosity of the marker bed may provide for retention of gas and brine expelled from the repository via this flowpath.

A further assumption is that at relatively high repository pressures (high enough to activate hydraulic flow through fractures around panel seals) that repository gasses (mostly) will flow out through marker beds above the repository. Flow through these pathways will help to regulate repository pressure at certain times during repository history, but the impact on the cycle of waste decomposition, gas generation, gas pressure, and brine inflow is not expected to be important. Flow around panel seals (both top and bottom) was included in modeling of repository pressure and saturation as shown by SNL in scatterplots for the TBM and AP 106.

The assumptions contained in the changes to the DRZ conceptual model are reasonable to represent repository materials, flow geometry, and system properties. The permeability range used to generate the sampled distributions that will be used in PA is based on permeability of materials similar to those in the disturbed rock zone in comparable geomechanical environments. The geometry of flow follows principles of hydraulics that are appropriate to the repository structure, stress environment, and material properties.

3.3.2.3 Alternate Interpretations

The proposed changes to the DRZ conceptual model follow two earlier iterations of the model. These earlier iterations include a full PA (CCA) and a sensitivity study (PAVT) that represent alternative models that have received more detailed consideration than is usual in alternative concept evaluation. The CCA iteration was fully peer reviewed. The changes proposed to the model represent reasonable development of the earlier alternatives. The changes to the model are supported in part by recent calculations, geophysical and hydrologic measurements in the repository floor (Bryan, et al, 2001, Beauheim, 2002, Holcomb, 2001).

3.3.2.4 Uncertainty of Results and Consequences if Wrong

The uncertainties of results in the changed conceptual model lie mostly in the ranges of permeability used to represent the flow properties of the rock along the flow paths proposed. The geometry of the flow paths is not a great source of uncertainty, in that they are the most reasonable paths of least resistance for gas flow and their dimensions and material properties are easily characterized. The range of permeability proposed as bounds of the properties of the rock through which flow will take place is reasonable. The range is supported by measured values and it will be sampled and represented by a CCDF, which is a reasonable analytical approach. Exceeding the upper limit of the permeability range would allow gas to migrate from the repository more easily and reduce gas pressure. Ultimately, gas pressures depend on permeability in the anhydrite marker bed where storage of gas will take place at distances from the repository far enough to be less damaged by creep. The impact of the uncertainty in the conceptual model is that the gas pressure in the repository might be slightly lower than predicted by modeling at some times in repository history.

3.3.2.5 Appropriateness and Limitations of Methodology and Procedures

The methods and procedures used in the changed model are refinements of the previous models and will generate representative results in PA. Constituative models based on measurement of the influence of creep damage on hydrologic properties may be feasible in the future, but such models are not expected to indicate that the changed model has failed to conservatively bound repository performance. The methods and procedures are appropriate to the present state of information and the needs of PA.

Changes in the repository design that impact gas and brine flow through the DRZ are clearly defined and present no new problems in characterizing flow processes and flow paths that are different from those that exist in previous PAs. The assessment of any impact on the performance of the repository can be readily accomplished by applying the existing numerical and conceptual models to changes in flow geometry and changes in the geometry and stress/strain states of the DRZ resulting from design changes. The methodologies and procedures of assessment of the repository are therefore fully appropriate

3.3.2.6 Adequacy of Application

Consideration of the adequacy of application of the model to changes in flow in the DRZ due to changes in the repository design, reinterpretation of flow paths or changed definition of properties, requires that the changed processes that impact flow be clearly identified. In the present case, the necessary scenarios have been identified and the new permeability parameters proposed by the EPA for the DRZ are justified in the PAVT. The necessary BRAGFLOW calculations are identical to those used in other iterations of the PA model except that changed (decreased grid cell size) increases resolution of modeling along new flow paths, and two earlier iterations of that model exist for comparison (CCA and PAVT). Application of the model to redefined sets of parameters or to redefined flow paths resulting from changes in the repository design, as in the case of flow over the panel seals, does not require fundamental changes in the conceptual model. The redefinition of a new principal flowpath out of the repository (through Marker Bed #139, through the heaved floor) requires only the application of the flow model to preexisting process models. Application of BRAGFLOW to cases containing new hydrologic definition of flow in the DRZ is straightforward and requires only the recalculation of the pertinent impacts on principal factors such as repository pressure and brine volume. Those calculations are represented by scatterplots and CCDF plots in the SNL presentations and demonstrate that performance is not significantly impacted. Those representations of the performance of the changed repository are sufficient to demonstrate the adequacy of the application of the model to the changed configuration of flow in the DRZ.

3.3.2.7 Accuracy of Calculations

New calculations since PAVT that impact repository performance assessment are represented in scatterplots and CCDF plots presented by SNL. No changes in BRAGFLOW except the reduction of grid cell size which increases resolution or in the methodology of application of BRAGFLOW to the process models resulting from the changes in DRZ Conceptual Models under review have been made. The plots presented by SNL address the most important sub-models in repository PA (pressure, saturation, and brine volume) and address the variance associated with chosen individual vectors. A CCDF representing the most pressure sensitive release case (spallings) and the most brine volume sensitive case (direct brine release) were presented and the results were seen to be reasonable, lacked large unexplained variance, and did not approach noncompliant releases. It is therefore concluded that the accuracy of calculations which include the calculation of changes in flow due to changes in the DRZ hydrogeological process models is demonstrated.

3.3.2.8 Validity of Conclusions

Validity of conclusions drawn from the application of the changed DRZ conceptual model in PA is the same as for those drawn from the previous iterations of the model so long as the adequacy of application and the accuracy of calculations are concluded to be appropriate. The general structure of the conceptual model was peer reviewed during the CCA and the changes to the details of the flow paths and the definition of permeability appear to be valid. Changes consist entirely of applications of the flow model to process models that either already exist in the PA model (flow through marker beds, inflow through the DRZ,) or are readily defined (flow through fractures connecting the repository to marker beds) or to application of the flow model to changed results of process models operating on redefined parameters (DRZ permeability). Since BRAGFLOW and the general conceptual model are adequate and the calculations appear to be accurate, the conclusion that the changes more accurately represent flow in the DRZ appears to be valid.

3.3.2.9 Adequacy for Implementation

The changed DRZ model modulates the relationship between repository pressure, waste degradation and brine inflow in a more realistic and conservative way than preexisting models, while integrating the influences of two design changes. Flow of brine and gas into and out of the repository through all of the marker beds within reasonable proximity, both above and below the repository, linked to the repository through its pressure history is more realistic than the previous single flowpath model. Assessment of the impact of the "Option D" panel seals is closely tied to the repository history and flowpath assessment. The impact of the second design change, the small elevation of the southern waste panels for reasons of construction safety, is concluded to be insignificant on conceptual grounds.

The partial PA assessment provided adequately supports the reconfiguration of the model and shows that the impact of the changes on the model is minimal. It is concluded that the changes to the DRZ flow model have not invalidated its adequacy for implementation

3.3.2.10 Impact of the Disturbed Rock Zone Model on Closure Performance

Impact of the changes in the DRZ conceptual model are shown to be small by the limited performance assessment calculations presented by SNL during this review. Although limited, these calculations addressed the most important impacts (gas pressure, brine volume, and saturation) resulting from changes at the process model level, and the release mechanisms (DBR, Spallings) most dependent on pressure and brine volume. These results and the acceptance that the aspects of the model changes leading up to the calculations are adequate indicate that the impacts of the changes to the DRZ model do not negate the compliance of the repository. It must be noted that the Spallings model used in the calculation of the Spallings release is not the latest iteration of that model, which has yet to be reviewed.

3.3.2.11 Dissenting Views

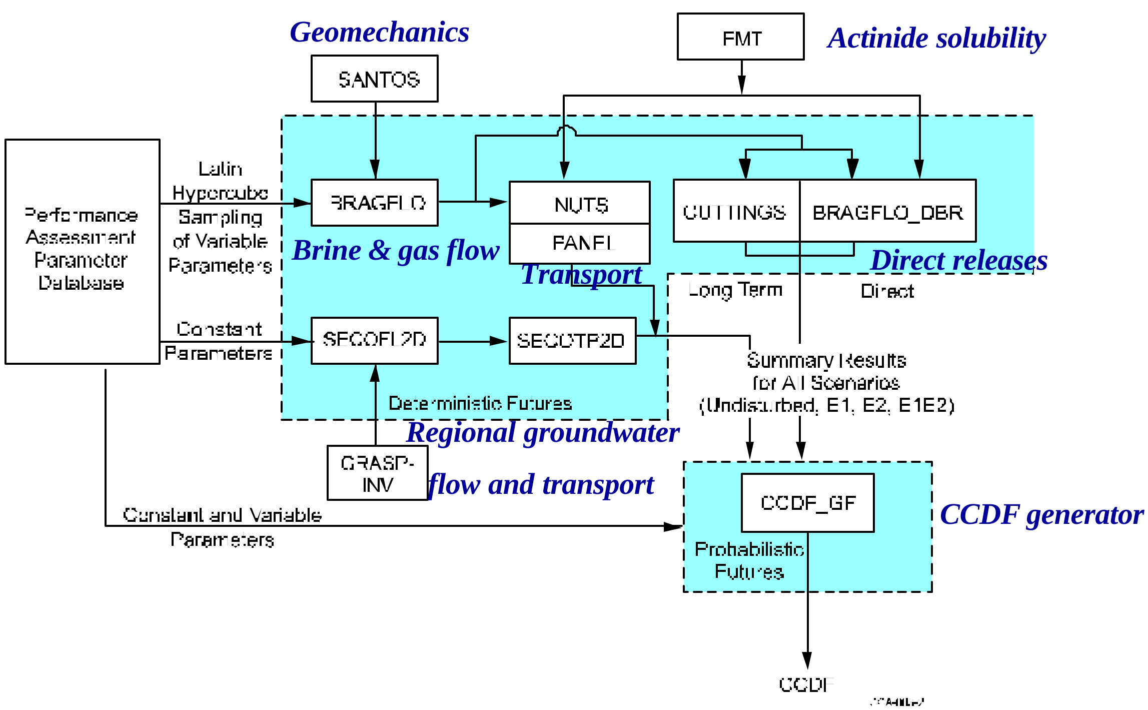
There were no dissenting views for this model.

4.0 Integration of Conceptual Models in Performance Assessment

4.1 Model Integration

Figure 4-1 is a simplified illustration in which selected conceptual models represent a system or subsystem within the CCA, PA code sequence. BRAGFLO DBR, as illustrated, is a special, short-term application of BRAGFLO related to a drilling intrusion and includes the conceptual model system representations listed under BRAGFLO plus the Direct Brine Release model. The direct brine release element illustrates that the calculated brine volume removed from the repository by a drilling intrusion is input directly to the CCDFGF.

Figure 4-1. Illustration of Conceptual Model Integration



As shown in figure 4-1, the conceptual models do not all represent a system or sub-systems in the same place in the code sequence. Figure 4-1 illustrates that the conceptual models, as interpreted through the various codes, are ultimately integrated at the CCDFGF where results are prepared. The figure ignores many preparatory and post-process codes and relationships between codes that are not linear and in a single direction. For example, while SANTOS is related to BRAGFLO and receives system representation from the Creep Closure conceptual model, creep closure results from an iterative relationship between gas pressure, compaction, and brine characterizations from BRAGFLO and the porosity surface in SANTOS. The integration of the conceptual models, therefore, identifies the overall WIPP PA model as a complex structure that represents 24 conceptual models through preparatory, process, flow and transport, presentation, and enabling codes.

4.2 Review of Criteria

Applying evaluation criteria to the integration of conceptual models, as a step in the assessment of model adequacy, results in most of the discussion being summations of the individual conceptual model evaluations. For example, evaluations of information used in the integration, assumptions, uncertainties, adequacies, accuracy, and validity are all based on the individual conceptual models or the implementing mathematical representations or codes. The criteria have been discussed in Section 3.0 for the three conceptual models reviewed.

Because a total and complete system PA was not available for Peer Review Panel to review, the overall adequacy for implementation of the integrated conceptual models can only be judged at this time through the adequacy of the three individual conceptual models as discussed in Section 3. Based on the review of the individual models, implementation of the integrated conceptual models is expected to be adequate.

5.0 Summary of Evaluations

This section presents a summary of the evaluations of the WIPP Conceptual Models Peer Review Panel performed between April 2002 and March 2003. Over twenty years of scientific effort have been expended on WIPP site characterization and there have been approximately three years of successful operational experience. It is beyond the scope of this report to summarize all of the positive factors and scientific evidence compiled concerning the WIPP site. This section is not intended to be a reiteration of comments and discussions on the individual conceptual models but to provide an overview of conclusions from the evaluations.

The list of the twenty-four WIPP conceptual models is provided in the Table 4-1 with the three models reviewed during this peer review bolded so as to put them in the context of the total WIPP waste disposal system modeling effort.

Disposal System Geometry

The changes in the Disposal System Geometry conceptual model retain the necessary features of the original conceptual model and the grid changes appear reasonable and sound. The Disposal System Geometry conceptual model continues to be adequate. The results of a PA for the TBM illustrated that the effects of changes in the conceptual model are minimal. The Disposal System Geometry conceptual model continues to represent repository performance with no significant change from its representation in the baseline.

Repository Fluid Flow

The Repository Fluid Flow conceptual model has been determined to be both reasonable and adequate for its intended purpose. The identified changes (shaft simplification, EPA mandated parameters, cellulosic molecular structure, and fluid flow paths) appear reasonable and are expected to have minimal impact. The interaction of this conceptual model with the Option "D" Panel closure (with revised anhydrite fracturing and "flow around" features at high pressure), and subsequent gas pressure realizations in waste panels have been illustrated by a series of TBM CCDF's that show very little resultant change. The influence of the model when coupled with the other conceptual models appears appropriate and adequate.

Disturbed Rock Zone

Four changes to the DRZ conceptual model have the potential to impact PA. These are the adoption of a range of limiting porosity values to replace the original (CCA) single value for the halite and anhydrite layers in which the disturbed rock zone is developed; the definition of a flow path through the floor of the repository openings into Interbed #139; flow paths around the tops and bottoms of panel seals at high pressure; and a change of elevation of the waste panels in the southern end of the repository. Based upon data and analyses presented by SNL, these changes appear to be reasonable. The change of waste panel elevation aides repository operations and is not considered a significant change in concept. The impact of these changes on PA calculations and CCDF plots appears negligible. The impact on releases sensitive to repository pressures, saturation and brine volume, show that changes in the DRZ model do not significantly impact the predicted compliance of the repository.

Table 5-1

WIPP Conceptual Models

Disposal System Geometry	**Addressed During This Peer Review**
Culebra Hydrogeology	Not Addressed During This Peer Review
Repository Fluid Flow	**Addressed During This Peer Review**
Salado	Not Addressed During This Peer Review
Impure Halite	Not Addressed During This Peer Review
Salado Interbeds	Not Addressed During This Peer Review
Disturbed Rock Zone	**Addressed During This Peer Review**
Actinide Transport in the Salado	Not Addressed During This Peer Review
Units Above the Salado	Not Addressed During This Peer Review
Transport of Dissolved Actinides in the Culebra	Not Addressed During This Peer Review
Transport of Colloidal Actinides in the Culebra	Not Addressed During This Peer Review
Exploration Boreholes	Not Addressed During This Peer Review
Cuttings/Cavings	Not Addressed During This Peer Review
Spallings	Not Addressed During This Peer Review
Direct Brine Release	Not Addressed During This Peer Review
Castile and Brine Reservoir	Not Addressed During This Peer Review
Multiple Intrusions	Not Addressed During This Peer Review
Climate Change	Not Addressed During This Peer Review
Creep Closure	Not Addressed During This Peer Review
Shafts and Shaft Seals	Not Addressed During This Peer Review
Gas Generation	Not Addressed During This Peer Review
Chemical Conditions	Not Addressed During This Peer Review
Dissolved Actinide Source Term	Not Addressed During This Peer Review
Colloidal Actinide Source Term	Not Addressed During This Peer Review

References

Beauheim, R.L. 1996. *DRZ Permeability, Revision 1*. Records Package. ERMS #232038. Albuquerque, NM.: Sandia National Laboratories.

Beauheim, R.L.; Roberts, R.M. 2002. *Hydraulic-test Interpretation in Systems with Complex Flow Geometries.* SAND2000-1588J. Carlsbad, NM: Sandia National Laboratories.

Brian, C.R., Hansen, F.D., Chapman, D.M., and Snider A.C., 2001. *Characteristics of the Disturbed Rock Zone in Salt at the Waste Isolation Pilot Plant*, American Association of Rock Mechanics.

Butcher, B.M., Thompson, T.W., VanBuskirk, R.G., and Patti, N.C. 1991. *Mechanical Compaction of Waste Isolation Pilot Plant Simulated Waste.* SAND90-1206. Albuquerque, NM: Sandia National Laboratories.

Christian-Frear, T.L.; Webb, S.W. 1996. *Effect of explicit representation of detailed stratigraphy on brine and gas flow at the Waste Isolation Pilot Plant*, SAND94-3173, Albuquerque, NM: Sandia National Laboratories..

Dunagan, S. 2003. *Complimentary Cumulative Distribution Functions (CCDF) for the Technical Baseline Migration (TBM), Rev 0* Carlsbad, NM: Sandia National Laboratories. ERMS #525707.

Freeze, G.A., Larson, K.W. Davies, P.B. 1995. *Coupled Multiphase Flow and Closure Analysis of Repository Response to Waste Generated Gas at the Waste Isolation Pilot Plant (WIPP).* SAND93-1986. Albuquerque, NM: Sandia National Laboratories.

Hadug, T. 2002. *Analysis Plan for the Analysis of Direct Releases Part of the Technical Baseline Migration, AP-085*, Carlsbad, NM: Sandia National Laboratories. ERMS #522634.

Hansen, C.W., Leigh, C.L., Lord, D.L., Stein, J.S. 2002. *BRAGFLO Results for the Technical Baseline Migration, Revision 0.* Carlsbad, NM: Sandia National Laboratories. ERMS# 523209

Hansen, C.W., Leigh, C.L. 2002. *A Reconciliation of the CCA and PAVT Parameter Baselines, Revision 1*. Albuquerque, NM: Sandia National Laboratories.

Holcolm, D.J. and Hardy, R., 2001, *Assessing the disturbed rock zone (DRZ) at the Waste Isolation Pilot Plant (WIPP) in salt using ultrasonic waves*. DC Rocks 2001, Proceedings of the 38th US Symposium on Rock Mechanics, Washington, DC.

Howarth, S.M. and Christian-Frear, T.L. 1997. *Porosity, single-phase permeability, and capillary pressure data from preliminary laboratory experiments on selected samples from Marker Bed 139 at the Waste Isolation Pilot Plant underground facility*. SAND94-0472/2, Albuquerque, NM: Sandia National Laboratories.

James, S.J., Stein, J.S. 2002. *Analysis Plan for the Development of a Simplified Shaft Seal Model for the WIPP Performance Assessment, AP-094,* Carlsbad, NM: Sandia National Laboratories. ERMS# 524958

Key, S., et. al. 1994. *Background and Basis for the Fluid Flow Model Incorporated in BRAGFLO for Representing Pore Pressure-Induced Alterations in Permeability and Porosity in the Anhydrite Interbeds Above and Below the WIPP Repository Horizon,* SAND94-0381. Albuquerque, NM: Sandia National Laboratories.

Marietta, M.G., S.G. Bertram-Howery, D.R. (Rip) Anderson, K.R. Brinster, R. V., Guzowski, H. Iuzzolino, R.P. Rechard, 1989. *Performance Assessment Methodology Demonstration: Methodology Development of Evaluating Compliance with US EPA 40 CFR Part 191, Subpart B, for the Waste Isolation Pilot Plant*. SAND89-2027. Albuquerque, NM: Sandia National Laboratories.

Park, B.Y. 2002. *Analysis Plan for Structural Evaluation of WPP Disposal Room Raised to Clay Seam G, Rev 1, AP-093.* Carlsbad, NM: Sandia National Laboratories. ERMS #524805.

Stein, J.S., 2002. *Analysis Plan for Calculations of Salado Flow: Technical Baseline Migration (TBM), AP-086.* Albuquerque, NM: Sandia National Laboratories.

Stein, J.S. 2002. *Minor difference found in TBM grid volumes*. Memorandum to M.K. Knowles, May 20, 2002. Carlsbad, NM: Sandia National Laboratories. EMRS #522357.

Stein, J.S., Zelinski, W. 2003. *Analysis Plan for the Testing of a Proposed BRAGFLO Grid to be used for the Compliance Recertification Application Performance Assessment Calculations, AP-106*, Carlsbad, NM: Sandia National Laboratories. ERMS# 525236

Rechard, R.P., Beyeler, W., McCurley, R.D., Rudeen, D.K., Bean, J.E., and Schreiber, J.D. 1990. *Parameter Sensitivity Studies of Selected Components of the Waste Isolation Pilot Plant Repository/Shaft System*. SAND89-2030. Albuquerque, NM: Sandia National Laboratories.

US EPA, 1998. *40CFR Part 194 Final Rule. Criteria for the Certification and Recertification of the Waste Isolation Pilot Plant's Compliance With the Part 191 Disposal Regulations: Certification Decision*, U.S. Environmental Protection Agency, Office of Radiation and Indoor Air, Washington, D.C.

Webb, S.W., and K.W. Larson. 1996. *The Effect of Stratigraphic Dip on Brine and Gas Migration at the Waste Isolation Pilot Plant.* SAND94-0932. Albuquerque, NM: Sandia National Laboratories.

WIPP Performance Assessment Department. l992a. *Long-Term Gas and Brine Migration at the Waste Isolation Pilot Plant: Preliminary Sensitivity Analyses for Post-Closure 40 CFR Part 268 (RCRA), May 1992.* SAND92-l933. Albuquerque, NM: Sandia National Laboratories.

WIPP Performance Assessment Department. 1992b. *Preliminary Performance Assessment for the Waste Isolation Pilot Plan, December 1992- Volume 5: Uncertainty and Sensitivity Analyses of Gas and Brine Migration for Undisturbed Performance*. SAND92-0700. Albuquerque, NM: Sandia National Laboratories.

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

Appendix A - Panel Member Technical Qualifications

Florie Caporuscio

Los Alamos National Laboratory

- Environmental Restoration - developed criteria for and wrote portions of two-site characterization Work Plans (Los Alamos Pueblo Canyon, Canyon Core Document).
- Project Manager to characterize Omega West Reactor leak.
- Developed radiometric survey technique to investigate radionuclide transport (Pu, Cs, Sr) by geomorphic processes in Los Alamos Canyons.
- Investigated Sr transport in aqueous media in Los Alamos Canyon.
- Peer reviews of Performance Assessment of Material Disposal Area (MDA) G at TA-54, Los Alamos National Laboratory.
- Co-author of MDA Performance Assessment Core Document for Environmental Restoration Projects at LANL.

WIPP

- Final Peer Review for License Application Conceptual Models
- Peer Review Member for salado Fluid Flow
- Peer Review Member – Natural Barriers

Environmental Protection Agency

- Principal Investigator evaluating effects of U, Th, Ra contamination and transport through geologic media at CERCLA and FUSRAP sites.
- Section Chief of US EPA WIPP Technical Review Program. Supervised review of Test and Retrieval Plan.
- EPA Principal Investigator for Gas Generation and Source Team models at WIPP (ORIA).

Pertinent Research/Other

- Oxidation of Fe oxides - characterization of oxidation state of 24,000 feet of ash flow core on Yucca Mountain.

- Determination of Fe oxidation state for paleomagnetic studies at Yucca Mountain.
- Empirical determination of Hematite-Ilmenite solvus with field samples.
- Crystal chemical studies of radioactive elements in crystal structures of mineral phases.
- Technical reviewer for *American Mineralogist* (1988-1989, 2002-2003)

John Gibbons

Over thirty years of experience in the geology and mine mechanics of salt deposits, including New York, New Mexico, Texas, and Kansas bedded salts and domed salts in Louisiana and Texas.

Yucca Mountain Project

Preparation of site suitability documents for presidential consideration, data qualification and integration for the federal high-level nuclear waste disposal site at Nevada

WIPP

Review of conceptual models and engineered barriers models for PA in support of license application. Review of data packages for PA in support of license application.

Illinois Department of Nuclear Safety

As a principal consultant:

- Detailed review of conceptual models (hydrogeologic and site character) and integration with the MODFLOW numerical flow model. Included radionuclide transport models and the site performance assessment model for Martinsville Illinois site.
- Developed site search models for hydrogeology and seismic ground motion for a second site.
- Developed conceptual model for vertical hydrologic flow through overconsolidated, fractured glacial till.
- Developed integration plan for site characterization through performance assessment of new site including applications of STRATAMODEL three-dimensional site model and model-based tests of site hydrologic characterization adequacy.

Applied Research Associates

Principal investigator for a DOE research committee funded study to develop a model-driven site characterization technology, which integrated geophysical (down-hole and surface), cone penetrometer and borehole data acquisition systems.

Senior hydrogeologist in support to Sandia National Laboratory in development of hydrostratigraphy conceptual model of Yucca Mountain High Level Nuclear Waste Repository Site.

Dames and Moore

As a principal investigator, did proposal preparation and was project liaison to the Federal High Level Nuclear Waste Program. Site characterization planning and model integration were principal areas of technical responsibility.

Chunhong Li

Numerical Modeling

- Conduct numerical modeling to study groundwater flow and mass transport at the Yucca Mountain site to assist system performance analysis at the proposed high level nuclear waste repository site.
- Carried out numerical simulations to study the influence of matrix diffusion on radionuclide transport in the fractured media at Yucca Mountain site.
- Carried out numerical simulations to investigate the sensitivity of radionuclide transport to variations in transport parameters under different flow conditions in UZ/SZ at Yucca Mountain.
- Worked on scaling related problems in groundwater modeling. Carried out numerical simulations using different scaling schemes for rock permeabilities to reconstruct water imbibition process observed in laboratory experiments in Topopah Spring tuffs at Yucca Mountain site.
- Expanded the Finite Element Heat and Mass transfer code (FEHM) to handle multiple species particle tracking process with spatially distributed transient source terms.
- Developed multiple species radionuclide decay-ingrowth module for FEHM.
- Developed algorithms for use with FEHM particle tracking module to better manage memory for simulating multiple species decay-ingrowth in the unsaturated zone.
- Modified the Finite Element Heat and Mass transfer code (FEHM) for GoldSim-FEHM coupling and supported Total System Performance Assessment (TSPA) work for GoldSim-FEHM simulation runs.
- Developed code SZ_CONVOLUTE V2.2 for calculating saturated zone responsive curves based on unsaturated zone mass flux and generic breakthrough curves for risk assessment at the Yucca Mountain Project.
- Developed a numerical code using the spectral representation theorem and FFT to generate 1-D and 2-D stochastic field with different spatial correlations.
- Developed Lattice Gas Automata (LGA) code to simulate solute transport behavior in fractured porous media.

- Applied harmonic analysis to study the dynamic response of well-aquifer system to earth tides and its application in estimating aquifer parameters, Jilin, China.
- Developed Java, JSP, and Oracle application programs for the Department of Veterans Affairs Data Center at Austin, TX.

Field Investigation

- Involved in designing and setting up a 3-D (multi-level) groundwater flow and transport research site at Sevilleta, New Mexico.
- Conducted field hydrogeological investigations, field pumping tests and tracer tests, and data analysis for a water supply site at Jinan, Shandong, China.

Laboratory Experiment

- Designed and carried out laboratory experiments to investigate solute mixing behavior at fracture junctions. The experimental results were then used to verify the numerical simulation results and good agreement was observed.

Design of Conceptual Models/Structures

- University of Arizona, Department of Hydrology and Water Resources, Dissertation, 1976. Designed a conceptual model with which to assess the socioeconomic impacts of coal-fueled power generating facilities on Native Americans in the Four Corners region of the Southwest. The conceptual model related critical social, economic and cultural parameters of Native American systems to natural resource use, economic and environmental effects and power plant location and operation phenomenon. The conceptual model was implemented through a mathematical simulation technique.
- Designed conceptual models (assumptions, structures and relationships) for evaluating the impacts of FWPCA, Section 208, non-point pollution control practices on land and surface water quality. As part of a policy analysis project under USDA, Economic Research Service, the models were published in internal, peer-reviewed working papers (1977-1984).
- Assisted in the design of the conceptual models and implementation of the mathematical realizations of a linked system of linear programs and a finite difference representation of the Navajo sandstone aquifer. The linked LPs were designed to evaluate the regional impact of power generation grid distribution and the ground water model was built to estimate the impacts of commercial water withdrawals on local wells. The modeling was done under a contract with the Ford Foundation through the University of Arizona, Department of Hydrology and Water Resources (1976-1977).
- Montana DNRC, 1995. Developed the conceptual model for evaluating the effects of high TDS water from coal mine pit discharges to the Tongue River and reservoir system.
- Montana DNRC and U.S. Bureau of Reclamation, 1994. Designed the conceptual model(s) for evaluating the impacts of increased reservoir depth and area on alluvial ground water quality and storage and shoreline erosion.

- Designed the conceptual model for evaluating water use and disposal systems at remote Missile Launch Control Facilities, Malmstrom AFB, and Montana. The model considered the timing of water use, percolation and infiltration capacities, evapotranspiration and climatic influences and resulting short and long term potential for water balance. This 1995 project was in response to recent EPA guidelines governing remote water systems.
- Montana DEQ. Currently involved in conceptualizing a model or framework for evaluating the utility and stability of post-mining reclamation. The model will involve the characterization of future land use scenarios and the assessment of economic, aesthetic, recreational, surface environmental and alluvial ground water impacts of the scenarios.

Model Operation, Application

- Operated a regional linear program-based model designed to optimize the interplay of agricultural/silvicultural production systems with imposed pollution control practices. Published as part of the USDA, Columbia River Basin Project Report, 1980-1983, Portland, Oregon.
- University of Arizona, Department of Hydrology and Water Resources, 1975. Operated a stochastic, dynamic programming model with an application to a multi-year (50 years) multi-stage water supply reservoir operation system.
- Montana, DNRC, U.S. Bureau of Reclamation, 1994. Application of MODFLOW software to an evaluation of alluvial water withdrawals and the impacts of alternative rates on surface stream flow. At issue was the volume of ground water available for consumptive use without diminishing local stream flows.
- Oregon Department of Environmental Quality, published as USDA Working Paper, ERS Working Paper Series. Design and application of a riparian habitat model to estimate the effects of various agricultural, silvicultural and mining practices on riparian zones and the aquatic and terrestrial habitats included.
- Montana DEQ, U.S. Army Corps of Engineers, 1996. Responsible for review of geochemical, limnological and mixing zone models used to predict water quality in a pit lake, the Blackfoot River and the alluvial ground water resulting from

proposed gold mine operations. The results and interpretations of the model reviews will be presented in an EIS.

- USDA, EPA, Corvallis, Oregon, 1983. Conducted review of alternative models for evaluating chemical and erosional impacts to the ground water and surface streams associated with FWPCA, Section 208 and RCWP practices. The CREAMS model developed by USDA, ARS was adopted for use.
- Reviewed and evaluated various modeling approaches to be applied to the Agricultural/Rural environment system characterized by a project area in Austria. The review and model review was conducted at the IIASA, Laxenburg, Austria during a joint effort by Russian, Austrian and U.S. scientists.
- RCRA, RFI, Malmstrom AFB, Montana. HDR Engineering, 1993. Review and evaluation of proposed deep and shallow aquifer models proposed to characterize potential containment migration.
- Final Peer Review for License Application; Conceptual Models, WIPP, 1996-1997.
- WIPP Salado Conceptual Model Peer Review, May 2002

Data and Models

- As project operations manager, principal hydrologist and corporate QA manager, I routinely review the raw data and data presented in environmental sampling reports. Included in the reviews are ‘cursory’ data validation (traceability, achieving QA goals, etc.) as well as how the data can be interpreted, statistically or otherwise.
- Compliance Certification Model Data Review and Certification WIPP, 1995-1996.
- The data reviews and QA reviews routinely lead to conceptual models of contaminant migration route; rate and the conceptual models are used to propose more extensive and/or confirmatory sampling and data collection.
- As applied science manager working on the Rocky Mountain Arsenal and CERCLA projects manager for EPA’s TESIV, project data review (QA and statistical) and interpretation of data for intended uses were routine activities. Krieging and other techniques were applied to interpret data spatially, illustrate

data gaps and needs and make decisions on the appropriateness of RFI and RIFS data for proceeding with remedial action.

Appendix B

Determinations of Peer Review Member Independence

ATTACHMENT III
Page 1 of 1

Determination of Peer Review Panel Member Independence Form

Are you currently employed by DOE ____ or a DOE Contractor X — Yes / No

Were you employed by DOE or a DOE Contractor previously? — Yes / No
(If yes, give dates, location, organization, position, and type of work performed).

1993 - 1996 ASI - ER project at LANL
1996 - 1997 Informatics - WIPP peer Review
1997 - present Eberline Services - Gamma Spectroscopy at LANL, two months writing procedures for TWCP prior to first WIPP shipment.

Do you have or have you had any direct involvement or financial interest in the work under review? — Yes / No
(If yes, describe the involvement)

If there any reason why you cannot perform an impartial peer review? — Yes / No
(If yes, state the reason(s))

Is there any aspect of your past that may lead to a perception of a bias in the results of your peer review? — Yes / No
(If yes, describe)

I pledge that my review of this work will be completely impartial and based solely on the information available during the review.

Signature: Florie A Caporuscio

Print Name: Florie A Caporuscio

Date: 1/24/03

ATTACHMENT III
Page 1 of 1

Determination of Peer Review Panel Member Independence Form

Are you currently employed by DOE or a DOE Contractor — Yes / No

Were you employed by DOE or a DOE Contractor previously? — Yes / No
(If yes, give dates, location, organization, position, and type of work performed).

Yucca Mountain Project
Apr 1999 through Oct 31 2002
Data Review, Site Suitability Document Preparation
Peer Review WIPP 1996-1997-1998

Do you have or have you had any direct involvement or financial interest in the work under review? — Yes / No
(If yes, describe the involvement)

If there any reason why you cannot perform an impartial peer review? — Yes / No
(If yes, state the reason(s))

Is there any aspect of your past that may lead to a perception of a bias in the results of your peer review? — Yes / No
(If yes, describe)

I pledge that my review of this work will be completely impartial and based solely on the information available during the review.

Signature: John F. Gibbons

Print Name: JOHN F. GIBBONS

Date: 1/25/03

ATTACHMENT III
Page 1 of 1

Determination of Peer Review Panel Member Independence Form

Are you currently employed by DOE No or a DOE Contractor No — Yes / No

Were you employed by DOE or a DOE Contractor previously? — Yes / No
(If yes, give dates, location, organization, position, and type of work performed).

Do you have or have you had any direct involvement or financial interest in the work under review? — Yes / No
(If yes, describe the involvement)

If there any reason why you cannot perform an impartial peer review? — Yes / No
(If yes, state the reason(s))

Is there any aspect of your past that may lead to a perception of a bias in the results of your peer review? — Yes / No
(If yes, describe)

I pledge that my review of this work will be completely impartial and based solely on the information available during the review.

Signature: [signature]

Print Name: CHUNHONG LI

Date: 7/5/2003

ATTACHMENT III
Page 1 of 1

Determination of Peer Review Panel Member Independence Form

Are you currently employed by DOE ____ or a DOE Contractor ___ Yes / No

Were you employed by DOE or a DOE Contractor previously? Yes / No
(If yes, give dates, location, organization, position, and type of work performed).

A previous employer may have been a DOE contractor, at one time, or may be a DOE contractor now, but I was not involved in any aspect of DOE work.

Do you have or have you had any direct involvement or financial interest in the work under review? Yes / No
(If yes, describe the involvement)

If there any reason why you cannot perform an impartial peer review? Yes / No
(If yes, state the reason(s))

Is there any aspect of your past that may lead to a perception of a bias in the results of your peer review? Yes / No
(If yes, describe)

I pledge that my review of this work will be completely impartial and based solely on the information available during the review.

Signature: [signature]

Print Name: Eric B Oswald

Date: 23 January 2003

Appendix C

Certifications Regarding Organizational Conflicts of Interest

I have reviewed each of the selected peer review panel member's (Florie Caporuscio, John Gibbons, Chunhong Li, and Eric Oswald) backgrounds and employment histories. I have also interviewed each of them to determine if they have an organizational conflict of interest or a bias for or against the WIPP facility as a nuclear waste repository. Though these background investigations and interviews I have determined that none of the selected peer review panel members has an organizational conflict of interest related to the Salado Flow Conceptual Models Peer Review.

John A. Thies,
Peer Review Manager

Appendix D – Signature Page

I acknowledge by my signature below that I concur with the findings and conclusions documented in the Salado Flow Conceptual Models Peer Review Report.

Florie Caporuscio — Date: 3/04/03

John Gibbons — Date: March 4/3/03

Chunhong Li — Date: 3/4/03

Eric Oswald — Date: 3/3/03