ENCLOSURE

MINUTES OF THE JULY 21-22, 1997 U.S. DEPARTMENT OF ENERGY/U.S. NUCLEAR REGULATORY COMMISSION TECHNICAL EXCHANGE ON TOTAL SYSTEM PERFORMANCE ASSESSMENTS FOR YUCCA MOUNTAIN

Introduction

On July 21-22, 1997, U.S. Department of Energy (DOE) and U.S. Nuclear Regulatory Commission (NRC) staff conducted a Technical Exchange to discuss the respective staff approaches to performance assessments for Yucca Mountain, Nevada. A secondary goal of the Technical Exchange was for the NRC staff to provide DOE with early feedback regarding the sufficiency of DOE's total system performance assessment (TSPA) to be prepared as part of its forthcoming Viability Assessment (VA). In this Technical Exchange, the following major performance assessment areas were examined: flow and transport in both the saturated zone and unsaturated zone; engineered barrier system abstraction and analyses; and the TSPA-VA geologic repository reference design. There was also some limited discussion of the two staff's approaches to the abstraction of disruptive events and individual dose calculations, and the NRC's approach to sensitivity analysis. The detailed agenda for this two-day meeting can be found in Attachment 1.

The Technical Exchange was held at the Center for Nuclear Waste Regulatory Analyses (CNWRA) in San Antonio, Texas. A three-way video conference connection between San Antonio, Rockville (Maryland) and Las Vegas (Nevada) facilitated the remote participation of additional DOE and NRC staff as well as other interested parties. In addition to staff from DOE, NRC, the CNWRA and DOE's Management and Operating (M & O) contractor, the meeting was attended by representatives from the State of Nevada, the Nevada Nuclear Waste Task Force, Nye County, Nevada, the U.S. Geological Survey, the Nuclear Energy Institute, and the Electric Power Research Institute. Also in attendance were members and staff from the U.S. Nuclear Waste Technical Review Board (NWTRB) and NRC's Advisory Committee on Nuclear Waste (ACNW). Attachment 2 contains the composite list of attendees who were present at one of the three video conference locations.

July 21, 1997 — Background

The meeting commenced with opening remarks by DOE and NRC. The State of Nevada and affected units of local government declined the invitation to provide opening remarks. In the first series of formal presentations (Attachment 3), the NRC identified the goals and objectives of the Technical Exchange. Both DOE and NRC agreed that the overall goal of this Technical Exchange was for DOE to explain, and NRC to comment on, the completeness and technical adequacy of the forthcoming TSPA-VA. Moreover, DOE noted that it sought to provide the staff with some degree of understanding regarding the TSPA-VA itself. However, if more focused discussion was needed to foster understanding on some TSPA-VA issue, the Department recommended that the meeting summary reflect this need and identify the type of interaction(s) that might be needed.

As a point of clarification, the NRC noted that it understood and recognized that the forthcoming VA is **not** a surrogate for a license application for a potential geologic repository at Yucca Mountain. Rather, it is the NRC staff's view that the VA represents a point on a continuum, incrementally leading to the license application, and the NRC VA review will be in that vein. Consistent with its independent licensing function, the NRC is maintaining its own performance assessment capability to be used to review DOE's TSPAs. This capability (referred to as "Iterative Performance Assessment" or IPA) is not expected to be as comprehensive as the DOE TSPA capability because of NRC's role in the licensing process and budget limitations. On balance, because of these limitations, NRC's analyses, models, and supporting IPA computer codes are, in some instances, more conservative than DOE's. Nonetheless, the staff expects to use this capability to evaluate DOE's analyses and assumptions in order to independently judge DOE's conclusions. However, when preparing the VA, the staff noted that DOE should identify not only those areas for which it believes it has an adequate (i.e., strong) licensing case but also those areas for which additional information/data will be necessary to support its positions/designs as identified in the license application. DOE acknowledged the need to provide this transparency.

Before proceeding to the next agenda item, there was discussion among the participants of what was meant by "issue resolution.[1]"

The second agenda item was an overview (Attachment 4)of DOE's *TSPA-VA Plan*[2] . In this series of presentations, DOE talked about TSPA-VA objectives, approach, and schedule. Also discussed was how TSPA-VA process models were correlated to the hypotheses identified in DOE's *Waste Containment and Isolation Strategy* (WCIS) as well as NRC's *Key Technical Issues* (KTIs). During the question period following the presentation, it was noted that the WCIS had been evolving but had not fundamentally changed since July 1996, although certain aspects were undergoing revision — as recently noted during the July 1997 NWTRB meeting. DOE also responded to questions about the recent Peer Review of the TSPA-VA[3] and in doing so, noted that the first step of a four-step peer review had just been completed. DOE also noted that the input data sets to the TSPA-VA would be peer-reviewed.

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[1] The NRC noted that definition of issue resolution was recently re-affirmed in a March 21, 1997, letter to the State of Nevada. Simply stated, issue resolution means that, at the staff level, there are no more comments or questions, at a particular point in time. However, the staff has both the right and the responsibility to reopen any issue, or to request further information on an issue, at any point in the pre-licensing consultation period, or later, during the review of a license application. Although the Technical Exchange meeting format precludes the staff from reaching agreements (e.g., "resolving issues"), it was noted that one of the generic goals of Technical Exchanges was to foster improved understanding of the work the respective staff's were performing and in doing so, help to refine the number and type of issues being raised.

[2] TRW Environmental Safety Systems Inc., 'Total System Performance Assessment Viability Plan," Las Vegas, Nevada, BOOOOOOOO-01717-2200-00179, September 13, 1996.

[3] DOE's TSPA Peer Review Process will consist of four steps: (1) the identification of uncertainties from previous total system performance assessments (DOE's, NRC's); (2) the evaluation of process models to determine sufficiency; (3) the review of abstractions to determine defensibility; and (4) formal peer review of the final TSPA for the license application.

The next series of presentations was designed to provide an overview of DOE's TSPA-VA methodology. The first set of presentations (Attachment 5) addressed the following themes: (1) components affecting DOE's TSPA-VA; (2) information flow in TSPA-VA; (3) definition of the TSPA-VA reference case; and (4) the treatment of variability and uncertainty. During these presentations, DOE highlighted two points. First, the TSPA-VA would rely on the current underground facility design configuration, including the engineered barrier system (EBS), as recently described in the *Repository Design Document.*[4] Second, the TSPA-VA would attempt to do a better job than was done in previously published TSPAs of explaining the basis for the behavior of certain time-varying parameters. In the question and comment period that followed, the following issues were discussed:

- conceptual models and the use of expert judgment;
- DOE's view of the meaning of the 10 CFR Part 60 "substantially complete containment" requirement;
- the meaning of "importance sampling;" and
- the treatment of parameter uncertainty and parameter variability.

The second set of DOE presentations in this series concerned the status of the Department's TSPA-VA abstraction and testing activities (Attachment 6). In summary, DOE noted that it expects to complete TSPA-VA abstraction and testing activities sometime late in calendar year 1997 so that the results can be incorporated into the TSPA-VA base case computer runs — currently scheduled to be completed in January 1998. Moreover, following a review and analysis of the VA base case runs, DOE plans an additional set of abstraction/testing workshops, although the results of these additional workshops would not be reflected in the TSPA-VA. The list of workshop subjects has yet to be identified; they will probably be similar to the first series of topics but in more detail. These workshops are scheduled to be convened sometime in late calendar year 1998. Following questions from the audience, DOE noted that the results of all the abstraction/testing workshops will be documented and publicly available. Moreover, the workshops are expected to be open to observation by interested parties.

Following this presentation, the NRC provided an overview of fiscal year 1998 (FY98) performance assessment efforts. The first NRC presentation discussed how the staff intends to use its IPA capability to review the TSPA-VA (see Attachment 7). In the second presentation (Attachment 8), the CNWRA provided an overview of the current IPA capability (presently focussed on development of the TPA 3.1 computer code), and compared and contrasted this capability with that of IPA Phase 2. Following these presentations, there were a series of questions concerning certain computational features of the TPA 3.1 computer code as well as the staff's plans for documenting modeling assumptions. In response, the staff noted that unlike IPA Phase 2, the results of which were documented

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[4] TRW Environmental Safety Systems Inc., "Reference Design Description of a Geologic Repository," Las Vegas, Nevada, Revision 00, June 5, 1997.

(principally) in a single volume, as NUREG-1464,[5] the staff currently plans to document the TPA 3.1 code (including the FY98 IPA sensitivity analyses) in a series of reports, some as CNWRA products and some as NRC NUREGs; however, the exact details of what documentation will be prepared (and when) has yet to be worked-out.

Following a break, both DOE and NRC presented a summary of items of interest that were identified during the May 1996 performance assessment Technical Exchange. It was also noted that the items of interest (cited in Attachment 9[6]) are not open items *per se,* rather, they represent topical areas for which the two staffs seek improved understanding; this list will be used to track progress in achieving that understanding. Moreover, as was the case in May 1996, both DOE and NRC noted that similar lists of items were expected to be prepared during the course of this Technical Exchange (see Attachments 22 and 33[7]).

Technical Presentations

As noted earlier, the Technical Exchange focused on four major performance assessment subjects. The first subject was discussion of the treatment of flow and transport in the saturated zone (SZ) at Yucca Mountain. DOE opened the discussion by providing a summary of abstraction efforts in this area. The presentation (Attachment 10) identified: (1) DOE's priorities for the abstraction/testing workshop; (2) the models, processes, and parameters to be evaluated; and (3) the expected form of output (results) to be produced from the abstraction. DOE provided some results of its simulations thus far. During the follow-on discussions, it was noted that fracture and matrix flow were treated as a continuum, that the model currently assumes steady state conditions (although this may be treated as a step function at a later date due to changing climate/pluvial conditions), that the alluvium-tuff interface is treated in the hydrogeologic model (provided by the Lawrence Berkeley National Laboratory.

Following the discussion of SZ abstraction activities, there was a presentation (Attachment 11) that described the efforts of the USGS to model the SZ on behalf of DOE. Presently, the USGS is developing two SZ models for DOE: one at the site-scale and one at the regional-scale (e.g., Death Valley ground-water system). It was noted that the regional-scale model was the more advanced (e.g., has more detail) of the two efforts, at this time, and that ultimately DOE hopes to calibrate the two models.

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[5] See R.G. Wescott *et al.* (eds.), "NRC Iterative Performance Assessment Phase 2: Development of Capabilities for [the] Review of a Performance Assessment for a High-Level Waste Repository," U.S. Nuclear Regulatory Commission, NUREG-1464, October 1995.

[6] This attachment is a summary of the items discussed in the May 1996 performance assessment Technical Exchange. These items were identified in Attachment 13 to the meeting summary prepared following that interaction.

[7] At the conclusion of the presentations for each of the four major performance assessment areas, the Technical Exchange participants were asked if there were still some questions that merited additional discussion (and clarification). To the extent that questions were identified, they would be recorded as part of the Technical Exchange Meeting Summary (see Attachments 22 and 33) and discussed during the Working Group Round Table (e.g., the so-called "break-out" sessions) scheduled for later in the day.

The third SZ presentation (Attachment 12) was a description of the status of transport modeling being conducted at the Los Alamos National Laboratory on behalf of DOE. In summary, the goals of this investigation are to evaluate SZ dispersion and matrix diffusion at the C-Well Complex using tracer tests. Through the course of the presentation, the principal investigator noted that results being reported were based on limited data, although more data are expected to be available for the license application. However, based on the experimental data as well as the published literature (both peer-reviewed and project-sponsored), the investigators have concluded that matrix flow and diffusion are the predominant transport mechanisms at the site. During the question and comment period, it was noted that somewhere between 50 to 70 percent of the tracer had been recovered in the experiments thus far.

Following DOE's presentations (Attachments 10 through 12), the NRC staff presented its preliminary views (Attachment 13) regarding the sufficiency and adequacy of DOE's SZ abstraction/testing workshops and expert elicitations. Overall, it was reported that the staff felt that both the workshops and elicitations were asking the right types of questions needed to understand the nature of SZ flow at Yucca Mountain. The staff did note that it was not convinced that the C-Well investigations supported the conclusions that matrix flow and diffusion were predominant. Rather, the staff believes that the results of the C-Well investigations could suggest multiple flow paths. Generally, though, the staff acknowledged that it needed to critically review the work at C-Well Complex in order to better understand the basis for DOE's position.

In the next presentation, the NRC staff introduced its SZ efforts being conducted as part of FY98 IPA sensitivity analyses[8] (Attachment 14, Slides 12 thru 14). During the question and comment period, NRC noted that unlike DOE's 2- or 3-dimensional (2-D or 3-D, respectively) modeling efforts, NRC's modeling efforts were essentially 1-dimensional (1-D). Moreover, following some questioning by the audience, the NRC noted that it intended to address the conservatism of its models in reports documenting the FY98 IPA sensitivity analyses. The final series of questions concerned the SZ production zone used in the staff's dose calculations. The staff noted that the production zone was between 20 to 30 meters in thickness and had been estimated by reviewing existing water well records in the greater Amargosa Desert area.

Following lunch, DOE proceeded to discuss the second major subject of the Technical Exchange, the treatment of flow and transport in the unsaturated zone (UZ) at Yucca Mountain. Sandia National Laboratories (SNL) opened the discussion by providing a summary of abstraction efforts with regard to ground-water flow. The presentation (Attachment 15) identified a number of important issues resulting from the UZ flow abstraction/testing workshop as well as the proposed plans to address the technical issues identified in the workshop. The SNL presentation also contained some preliminary information on how UZ flow would be abstracted and treated in the TSPA-VA. The

[8] Generically, the FY98 subsystem abstractions for IPA consist of the following steps: (1) identification of key features/processes; (2) description of conceptual models; and (3) definition of uncertainties. The subsystem abstractions were developed by the respective NRC KTI teams for inclusion in IPA sensitivity studies in FY98 (as noted in the presentation contained in Attachment 8).

presentation concluded with some preliminary modeling results which evaluated fracture permeability and fracture lambda. The presentation was followed by a question and comment period during which the NRC staff noted that DOE's TSPA confers a lot of credit (i.e., performance) to the matrix diffusion properties of the geosphere. The staff questioned whether DOE should not be examining fracture flow because of the potential for fast pathways, *vis-a-vis* the occurrence of modern chlorine-36 (^{36}Cl) in the exploratory studies facility (ESF). In response, DOE clarified that both fracture and matrix flow would be evaluated. DOE was asked to elaborate on how the proposal to line emplacement drifts with pre-cast concrete was being evaluated. In response, DOE indicated that the possible effects of concrete liners was being evaluated as part of the near-field thermohydrology program.

The next UZ presentation (Attachment 16) was a discussion by DOE and Lawrence Berkeley National Laboratory (LBNL) of efforts to develop a site-scale flow model. In summary, this presentation reviewed the goals of the LBNL modeling efforts, the relationship of this work to other aspects of DOE's performance assessment abstraction and modeling efforts, and the discussion of results, as described in a recent report.[9] During the presentation, a historical perspective was also provided to show how this work evolved as part of DOE's site characterization program. Following detailed summaries of selected portions of this 24 chapter report, the presentation concluded with an overview of how LBNL would be factoring the recommendations of a recently completed expert elicitation[10] into future UZ modeling efforts. During the presentation, it was noted that there are numerous fractures and joint-sets through-out the site; however, only a small percentage of these features where believed to contain water at any time. For example, only one percent of the fractures sampled in the ESF contain ^{36}Cl. Therefore, in the view of the investigators, "matrix" not fracture flow is the transport mode that **may** be the most important at the site. In the question/and comment period that proceeded, the following significant points were identified:

- perched water bodies and ^{36}Cl are important calibration points for the LBNL UZ model;

- the UZ flow model can handle fluxes greater than 15-20 millimeters/year; however, the modeling conducted to date indicates that fluxes in this range are inconsistent with a wide body of site observations of temperature, isotopes, and unsaturated zone groundwater chemistry; and

- the ESF niche studies currently underway are intended to evaluate the potential for water to drip into emplacement drifts.

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[9] Bodvarsson, G.S., T.M. Bandurrago, and Y.S. Wu (eds.), "Unsaturated Zone Model of Yucca Mountain, Nevada, for the Viability Assessment," Berkeley, California, Lawrence Berkeley National Laboratory, LBNL-40376, June 1997.

[10] See Geomatrix, Inc., and TRW Environmental Safety Systems, Inc., "Unsaturated Zone Flow Model Expert Elicitation Project," San Francisco, California, May 1997.

The third UZ presentation by DOE concerned radionuclide transport abstractions (Attachment 17). The discussion included a review of the following: UZ transport issue categories; issue identification; and criteria for issue ranking. Material was also presented regarding how the UZ transport abstractions would be factored in the TSPA-VA as well as the analysis plans to address the issues identified. This presentation concluded with some preliminary results showing the effect of matrix diffusion, sorption, and infiltration on UZ transport.

The last DOE UZ presentation focused on the status of modeling work being conducted by Los Alamos National Laboratory (LANL). In its presentations (Attachment 18), LANL presented some conclusions resulting from its transport work in three areas: transport simulations using neptunium-237, fracture/matrix interactions, and the evaluation of colloids. In the subsequent question and comment period, the following points were noteworthy:

- there is generally good correspondence between modeling efforts and field data;
- there is evidence to suggest that the occurrence of bomb-pulse ^{36}Cl is structurally controlled; and
- colloid-facilitated transport of plutonium may be important if the sorption of plutonium onto colloidal particles is significant.

During the UZ question and comment period, there was also some discussion regarding (hydrogeologic) terminology, as follows. Traditionally, hydrologists and performance assessment modelers have referred to microfracture flow as "matrix" flow because of differences in scale. Although microfracture flow may be adequately approximated in a model calculation as a matrix process, the chemistry of water in a microfracture may be quite different from the chemistry of water in the matrix of the same rock (by virtue of being in contact with a different suite of minerals). Such a difference in chemistry could be significant for radionuclide speciation and transport.

Following the DOE presentations (Attachments 15 thru 18), the NRC staff presented its preliminary views (Attachment 19) regarding the sufficiency and adequacy of DOE's UZ abstraction/testing workshops and expert elicitations. Overall, it was reported again that the staff felt that both the workshops and elicitations were asking the right types of questions necessary to understand the nature of UZ flow at Yucca Mountain. However, it was not clear to the staff how these issues would be addressed by DOE in the TSPA-VA. Moreover, the staff believes that there are multiple lines of evidence to support higher values for infiltration than those being used by DOE. During the question and comment period that followed, the staff repeated its position that it was not convinced that matrix flow and diffusion were predominant at the site.

In the next presentation, the NRC staff introduced its UZ modeling efforts being conducted as part of FY98 IPA sensitivity studies[8] (see Attachment 14; Slides 4 thru 7).

The last formal discussion item on Day 1 of the Technical Exchange concerned disruptive events. The first presentation (Attachment 20) was given by SNL and provided limited discussion regarding which scenarios would be in the TSPA-VA.[11] Four disruptive scenarios are being considered: volcanism, seismicity, nuclear criticality, and human intrusion. For volcanism, results from the *Probabilistic Volcanic Hazard Analysis* (PVHA) expert elicitation will be used. For cases where the needed information was not elicited from the experts, such as probabilities of intrusion types and regional events, additional information may be requested from a selected number of the PVHA experts. The volcanism disruptive scenario will be incorporated as modifications to the base case in TSPA-VA. In addition, couplings between volcanism and seismicity will be considered in TSPA-VA; an example of possible volcanic-seismic scenarios was presented. For seismicity, results from the ongoing *Probabilistic Seismic Hazard Analysis* expert elicitation will be used. The seismicity scenario will be included in the base case (rockfall) and also as modifications to the base case in TSPA-VA. TSPA-VA will be the first time that DOE considers nuclear criticality. The current analysis plan considers criticality analysis for light water reactor spent fuel, which is estimated to comprise about 70 percent of the waste, and three locations: in-package, near-field and far-field. The potential impact of nuclear criticality being modeled in TSPA-VA is an increase in the radionuclide source term. The nuclear criticality scenario will be incorporated as perturbations to the base case in TSPA-VA. For human intrusion, a change in the SZ source term is being considered. This stylized calculation may be presented separately from the TSPA-VA. The main issue during the question and comment period was presentation and incorporation of disruptive scenario results in TSPA-VA. The concern was how probabilities and consequences for those non-mutually exclusive events in DOE's features-events-process approach will be treated. This issue will be further discussed in the next Technical Exchange. Following the presentation, the NRC presented the approach proposed for the FY98 sensitivity analyses for direct release (volcanism).[12] The probability of volcanism is based on CNWRA's model and the consequence analysis is based on analogous volcanic events. To conclude the disruptive events discussion, the NRC presented a proposal of the types of disruptive events issues that might be discussed at the proposed Fall 1997 performance assessment Technical Exchange (Attachment 21).

As noted earlier, following the question and comment period for each presentation, the Technical Exchange participants were asked whether there were still some unanswered questions that merited additional discussion and clarification. To the extent that there were unanswered questions at the end of the presentations on Day 1 of the Technical Exchange, they were recorded at the end of each presentation and summarized in the list found in Attachment 22. Following a break, this list of questions was further discussed during an open, round-table discussion consisting of small groups of DOE and NRC staff and other Technical Exchange participants (so-called Working Groups). Before concluding the first day of the Technical Exchange, both DOE and NRC summarized the results of these discussions (which are listed in Attachment 22).

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[11] The proposed Fall 1997 Technical Exchange is intended to examine this area in more detail.

[12] Seismicity, faulting, and rock-fall were included as part of the EBS presentation on the second day of the Technical Exchange.

July 22, 1997 — Technical Presentations (continued)

The first agenda item on Day 2 was a discussion of the third major subject of the Technical Exchange; the TSPA geologic repository reference design. The first presentation by the M&O provided an overview of the reference design to be used by DOE for the TSPA-VA (Attachment 24). (Portions of this presentation were reported previously at the *Quarterly Technical Meeting* and recently described in the RDD[4].) The M&O identified the specific post-closure design features to be included in the VA reference design (e.g., the "base case" — see Slide 12) and noted that the basic VA design needed to be fixed by September 1997 (although certain post-closure design issues could "float" until February 1998). The alternative design issues (i.e., features) currently "floating"[13] include: the use of backfill; ceramic coating of the waste package overpack container; drip shields; and cladding credit (see Slide 13). Reliance on these four additional design features, in the context of total-system performance, are currently under evaluation; should DOE's analyses conclude that these features contribute significantly to waste isolation, DOE will attempt to include them with its VA reference design. Following the presentation, there was an extensive question and comment period. Most of the questions were related to points of clarification regarding the basic geologic repository design — most of these questions have been raised and addressed at some point in the last two *Quarterly DOE/NRC Technical Meetings* (see the meeting summaries for February and June 1997). Regarding DOE's plan to "apply an overall margin or factor of safety and confirm the expected (post-closure) performance of the selected multi-set design with the selected safety margin," the staff asked in particular what would be used as the measure of the margin of safety and how that measure will be estimated. DOE's response at this time is uncertain.

The second agenda item in Day 2 of the Technical Exchange concerned the fourth and last major subject of the Technical Exchange: abstractions and analyses related to the EBS. DOE had five EBS presentations addressing waste form and waste package degradation, radionuclide mobilization, near-field environment, and thermohydrology.[14] The first presentation was provided by DOE and SNL and concerned near-field thermohydrology in the UZ (see Attachment 24). The discussion included: identification of the criteria used for the prioritization of near-field thermohydrology issues; issue identification; and analysis plans to address the issues identified. DOE's plans include performing 1-, 2-, and 3-D process modeling at both the drift scale and the mountain scale, and during the presentation, provided examples of the types of site- and mountain- scale modeling underway. This presentation was followed by a brief question and comment period.

The second EBS presentation (Attachment 25) was an overview of modeling efforts of the near-field geochemical environment (NFGE). (As a matter of background, it should be noted that the TSPA-VA will be the first time that DOE explicitly incorporates the effects of the NFGE into its TSPA.) This presentation began with a description of the major NFGE issues

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[13] "Floating" design issues are those issues which could have an effect on the post-closure performance of the geologic repository.

[14] DOE's presentations focussed principally on waste package degradation and thermo-hydrology during this Technical Exchange. The other EBS process areas are expected to be addressed in more detail at the second performance assessment Technical Exchange proposed for sometime in the Fall of 1997.

recently identified at an abstraction/testing workshop. This workshop resulted in the identification of NFGE issues in four major areas: solid-phase evolution; gas-phase evolution; aqueous-phase evolution; and colloid-phase evolution. Also presented were DOE's plans and approaches to address the four major issues identified, including plans to address the effects of microbial communities on the NFGE. This particular presentation concluded with a discussion of how the NFGE would be treated (modeled) in the TSPA-VA. Again, the presentation was followed by a brief series of questions and comments.

The third EBS presentation (see Attachment 26) was an overview of plans for modeling waste package degradation. First, DOE summarized the results of the abstraction/testing workshops as well as the analysis plans to address the issues. Overall, the workshop identified 94 issues relevant to waste package degradation; 28 of which were determined to be key and selected for further analysis. The conceptual model that will be used for the TSPA-VA was then described. The presentation concluded with an overview and status report of the DOE-sponsored, on-going waste package degradation expert elicitation. During these presentations, it was noted that absent an NRC interpretation of the 10 CFR 60.113 definition of "substantially complete containment," DOE was relying upon a definition of waste package containment that allowed for some degree of pitting penetration of the waste package container. Moreover, both DOE noted that there was information in the scientific literature that suggested the existence of corrosion products within a waste package would contribute to the sealing of corrosion pits, thereby facilitating containment.

Presentations on the EBS continued with LLNL discussing work in the area of waste form degradation (Attachment 27). This presentation was similar in format to many earlier presentations (e.g., identification and ranking of key issues, description of testing plans, and status of work). In summary, testing plans have been undertaken in six areas:

- cladding and container credit;
- spent fuel dissolution and alteration rates;
- post-dissolution water chemistry;
- defense high-level radioactive waste (HLW) glass dissolution;
- solubility limits on dissolved radionuclides; and
- EBS transport/release.

The following points were raised during the question and comment period: LLNL is still determining how to best model water dripping on waste package canisters; and DOE has not determined how much credit (in terms of performance) will be allotted to cladding.

The last DOE EBS presentation (Attachment 28) addressed waste form mobilization and engineered barrier transport. In order to place the results of the abstraction/testing workshops in context, the presentation began with a description of those EBS components thought to be important to performance. Following the identification of key workshop issues, the proposed analysis plans to address the technical issues identified in the workshop were discussed. This presentation concluded with some detailed discussion of how waste form mobilization and transport in the EBS will be treated in the TSPA-VA.

After the presentations (Attachments 24 thru 28), the NRC staff commented on the adequacy of DOE's EBS programs. The first presentation was the staff's comments and observations with respect to the DOE-sponsored abstraction/testing workshops and expert elicitations (Attachment 29). Next, the NRC staff summarized it's EBS efforts[8] being conducted as part of TPA 3.1 computer code definition (see Attachment 14; Slides 8 thru 11). In the question and comment period that followed, the major discussion topic was the apparent conservatism of NRC's EBS modeling efforts. For example, it was noted that for the TPA 3.1 analyses, the number of repository sub-areas the repository can be divided into could vary, as opposed to being fixed at 7 in IPA Phase 2. When one waste package in a sub-area fails, the NRC's model assumes that all of the waste packages in that particular sub-area have failed (although HLW waste only migrates away from those containers that get wet). The number of waste packages that get wet varies with infiltration and other hydrologic parameters. DOE expressed its reservation that this particular abstraction may be overly conservative whereas the NRC's view was that once waste package canisters start to fail, the mean failure time would be short relative to the time it takes for the initial failure to occur. The NRC staff questioned making the EBS modeling more detailed to calculate more complex waste package failure distributions when these enhanced distributions seem to have little impact on system performance.

NRC staff discussed its approach to sensitivity and uncertainty analyses in a HLW performance assessment. The presentation (Attachment 30) included a description of the current staff methodology (including contrasting it to the IPA Phase 2 methodology), a discussion of how it will be implemented in NRC's KTI/IPA framework, and lastly, how the methodology would be used to comment on DOE's TSPA-VA. The results of FY98 IPA sensitivity analyses will be generally documented in a CNWRA report on the status of issue resolution and the *Annual KTI Status Report*.

The last formal presentation at the Technical Exchange was discussions by DOE and NRC of the respective staff approaches to how individual dose calculations might be conducted at the Yucca Mountain site. The first presentation (Attachment 31) was an overview by DOE of its preliminary plans for defining the hypothetical critical group at Yucca Mountain, evaluating the effects of climate change on biosphere dose pathways, and treatment of the geosphere-biosphere interface. The proposed analysis plans to address the technical issues identified in the abstraction workshop were discussed, including the preparation of a local population survey to better understand the local lifestyles/habits of the population in the NTS/Yucca Mountain area. Based on the modeling efforts to date, some results of sensitivity calculations of doses assuming preliminary biosphere dose conversion factors were shared with the audience. Generally, the NRC staff noted that it was quite interested in learning about the results of the local population survey owing to the 1996 National Academy of Science's (NAS') recommendation to implement a dose-based standard for Yucca Mountain.

Following a brief question and comment period, the NRC staff provided some staff-level comments regarding DOE's June 1997 biosphere abstraction workshop, including the identification of possible items for discussion at the proposed Fall 1997 performance assessment Technical Exchange. This presentation concluded with a brief question and comment period.

As was the case for Day 1 of the Technical Exchange, following the question and comment period for each presentation, the Technical Exchange participants were asked whether there were still some unanswered questions that merited additional discussion (and clarification). To the extent that there were unanswered questions at the end of the presentations on Day 2, they were recorded at the end of each presentation and summarized in the list found in Attachment 33. This list of questions was discussed at greater length during an open, round-table discussion consisting of all Technical Exchange participants in attendance. One of the questions raised by the NRC staff at this point concerned the treatment of issues identified in the abstraction/testing workshops but not considered for inclusion in the TSPA-VA: specifically, how does DOE plan to address these issues? In response, DOE noted that those issues which have been excluded and thought to be potentially important may be examined to a limited extent, e.g., through DOE sensitivity analyses, if it was determined to be necessary. Similarly, DOE was interested in hearing of NRC's plans for prioritizing and analyzing important issues during the abstraction/testing workshops.

Summary/Wrap-Up

The DOE and NRC staff prepared their respective closing comments. Because one of the objectives of the Technical Exchange was to provide DOE with early feed-back regarding the sufficiency of its TSPA to be submitted as part of its forthcoming VA, DOE requested that the staff give specific consideration to that issue.

NRC Staff Comments/Observations

It is the staff's view that there are good lines of communication (with attendant interfaces) between DOE's science, design, and performance assessment programs. These lines of communication should help to advance DOE's position regarding the merits of continuing its repository development activities at Yucca Mountain. It is also the staff's view that although many items of mutual interest were identified and constructively discussed (see tables in Attachments 22 and 33), no open items *per se* were identified.

Lastly, the staff believes that DOE recognizes the need to provide transparency in the documentation supporting the VA. This documentation is expected to include the technical bases for the positions and design alternatives expressed in the VA as well as the identification of areas for which additional confirmation/experimentation/data collection is needed to build its licensing case.

Preliminary NRC Pre-VA Observations

In addition to its wrap-up (or summary comments), the staff identified a number of TSPA areas it expected to evaluate in detail when the VA is produced. These points are not rank-ordered and constitute the issues the staff plans to critically review at the time of VA submittal to Congress:

Multiple Barriers: NRC's safety philosophy contains the multiple barrier, defense-in-depth approach. Although NRC's implementing regulation is likely to undergo change consistent with the recommendations of the NAS, the change is likely to preserve the multiple barrier approach, in some form. DOE's VA plans/designs will need to reflect this philosophy as well.

Matrix Diffusion: Based on the current state of knowledge, DOE and the NRC staffs have different views on the role of matrix diffusion in ground-water transport. The staff expects to evaluate the technical bases and reasonableness of DOE's position in the VA supporting documentation.

Near-Field Environment: Because many of the parameter values for the near-field are likely to be derived or inferred, DOE will need to exercise caution in the treatment of such parameters. Accordingly, DOE will need to support its modeling assumptions with an adequate technical basis.

Variability and Uncertainty: DOE has indicated it intends to treat both variability and sensitivity in the TSPA-VA. The staff would like a fuller explanation of how these aspects will be treated in the analysis, what differences there will be between the treatment of uncertainty and variability, where or how the various probability density functions used in the analysis will be obtained, and how uncertainties that are difficult to parameterize will be treated.

Expert Elicitation: The goals/scope of the expert elicitations need to be clearly articulated and consistent with the information/data needs of DOE's science, design, and performance assessment programs. Inconsistencies between elicitation out-puts and the ultimate user-need may undermine the value of the elicitations.[15]

DOE Staff Comments/Observations
Following the NRC staff comments, DOE agreed with the staff that many performance assessment issues were constructively discussed and that no open items *per se,* with the attendant commitments, were identified during this meeting. Moreover, it was DOE's view that there were several areas in which the two staff's were in accord, as noted:

Matrix Diffusion: DOE recognizes the need to ensure that its position regarding matrix diffusion is technically defensible and supported by adequate documentation. For its part, the NRC staff recognizes the need to evaluate DOE's data and analyses of the C-Well Complex to better understand this phenomenon.

Data Sets for the VA: DOE will provide the VA base case data set to the staff in the early 1998 time frame. NRC staff will provide DOE with its base case data sets to be used in the TPA 3.1 computer code runs. Once these data sets are exchanged, it may be useful to schedule a Spring 1998 Technical Exchange to compare and contrast this information and the respective staff approaches to selecting data for their system-level modeling.

Waste Package Testing: The staff and DOE have different views regarding how much credit can be attributed (e.g., performance allocation) to partially failed waste packages. DOE wants to take credit for the residual protection offered by a partially failed waste package container that has not lost its structural integrity. Based on the discussions, the Department believes that it would be useful for the NRC/CNWRA staff to visit the contractor facilities conducting waste package testing for DOE. The NRC staff agreed with this

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[15] For example, the NRC staff noted a comment previously made during the Winter 1997 PVHA Technical Exchange in which it was remarked that the PVHA had not differentiated between probabilities for intrusive and extrusive volcanic events. As a consequence, it is expected that DOE will need to derive such numbers from the PVHA for the purpose of the TSPA-VA.

recommendation.

Acceptance Criteria: The NRC staff will provide DOE with copies of its VA acceptance criteria to the extent that they are available. However, in its review of the VA, the staff **will not hold** DOE to criteria that were not available to DOE reasonably prior to the preparation of its VA, although a discussion of how well these criteria were generally addressed will be provided.

Future Actions

Through the course of the Technical Exchange, there were a number of mutually agreed-to follow-up actions that the two staffs identified, as listed below:

VA Abstractions: The NRC staff expects to provide the Commission with comments on the adequacy of DOE's TSPA supporting VA. The staff expects to provide early feedback to DOE on the results of its review.

Biosphere Site Survey: Because the NRC staff plans to implement the NAS recommendations regarding critical groups in its revised Yucca Mountain-specific rule, the NRC staff is interested in the results of the forthcoming DOE survey of the demographics/ life styles in the NTS/Yucca Mountain area. The NRC staff has done limited work in this area as well, which will be documented in NUREG-1538. When completed, DOE will provide a copy of this survey to NRC and to the State. This area may be a subject of further discussion at the proposed Fall 1997 TSPA Technical Exchange.

TPA Code Development and Issue Resolution: As with previous IPAs, there are a number of activities supporting development of Version 3.1 of the TPA computer code. The staff is still planning the number and types of documentation describing the translation of process models into the computational algorithms (computer codes) used in the analysis. The schedule and method for release of this information will be provided to DOE as soon as they become available.

Fall 1997 TSPA-VA Technical Exchange: A number of proposed agenda items were suggested for the next performance assessment Technical Exchange:

- Present Reference Design Product
- Summary of TSPA-VA Planning Document
- Treatment of Disruptive Events, Excluding Criticality[16]
- Vertical Mixing in the Saturated Zone[17]
- Biosphere/Critical Group Definition (with DOE/YMSCO/AMESH)[18]

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[16] The proposed Fall 1997 TSPA-VA interaction is to include a more-comprehensive discussion of the treatment of disruptive events. Waste package criticality will be discussed in separate meetings devoted to this subject, as needed.

[17] Includes discussion of the saturated zone model.

[18] The Spring 1998 Technical Exchange is to include discussions of base case results and a final description of the complete TSPA-VA is to contain.

- Matrix Diffusion and Sorption

At the close of these discussions, the staff representing the State of Nevada and Clark County, Nevada, were invited to make some closing comments. Both participants declined to make comments.

Michael P. Lee
Division of Waste Management
Office of Nuclear Material
Safety and Safeguards
U.S. Nuclear Regulatory Commission

Frederick C. Rodgers
Regulatory Coordination Division
Office of Civilian Radioactive
Waste Management
U.S. Department of Energy

AGENDA
DOE/NRC Technical Exchange on Total System Performance Assessments (TSPA) for Yucca Mountain

July 21-22, 1997
8:00 am - 6:00 pm

Location:
Center for Nuclear Waste Regulatory Analyses
SouthWest Research Institute Campus
6220 Culebra Road, Bldg. 189
San Antonio, TX 78238

Agenda Item	*Discussion Lead(s)*
Monday, July 21, 1997	
Opening Remarks	NRC, DOE, State, and Local Governments
NRC Review Philosophy for TSPA-Viability Assessment (VA)	NRC
Overview of DOE's TSPA-VA Plan and TSPA Methodology	DOE
Overview of NRC's TSPA Methodology	NRC
Update of the action items identified in the May 1996 TSPA Technical Exchange	NRC/DOE
Saturated Zone Flow and Transport Abstraction	NRC/DOE
Unsaturated Zone Flow and Transport Abstraction	NRC/DOE
Disruptive Events Abstraction (probability and consequences)	NRC/DOE
Working Group Discussion and Summaries	NRC/DOE
Tuesday, July 22, 1997	
Reference Design for TSPA-VA	DOE
Engineered Barrier System Abstraction and Analyses	NRC/DOE
Individual Dose Calculation	NRC/DOE
Overview of NRC's Sensitivity Analysis Plan	NRC
Working Group Discussion and Summaries	NRC/DOE
Closing Remarks	All

ATTACHMENT 1

LIST OF ATTENDEES
AT THE DOE/NRC TECHNICAL EXCHANGE
ON TOTAL-SYSTEM PERFORMANCE ASSESSMENTS
FOR YUCCA MOUNTAIN, NEVADA

July 21-22, 1997

Advisory Committee on Nuclear Waste

A. Campbell	L. Deeding	J. Garrick	L. Gaskins	R. Jolly	H. Larson
R. Major	W. Hinze	P. Pomeroy			

Center for Nuclear Waste Regulatory Analyses

A. Armstrong	R.Baca	A. Chowdhury	G. Cragnolino	R. Fedors	R. Green
M. Jarzemba	P. Sagar	S. Stothoff	J. Weldy	G. Whittmeyer	J. Winterle

Electric Power Research Institute
J.Kessler

ICF Kaiser
C. Whipple

Los Alamos National Laboratory
B. Robinson

Lawrence Berkeley National Laboratory
B. Bodvarsson

Lawrence Livermore National Laboratory
B. Halsey

Management Solutions
S. Frankiewicz

Nevada Nuclear Waste Task Force
J. Treichel

Nuclear Energy Institute
R. Anderson

Nye County, Nevada
M. Murphy P. Montazer

State of Nevada
S. Frishman L. Lehman

Pacific Light & Gas
J. Lin

Pacific Northwest National Laboratory
W. Nichols

U.S. Department of Energy (DOE)

A. Gil	B. Bush	T. Bjerstedt	C. Newbury	E. Smistad	F. Rodgers
A. Van Luik					

DOE Management and Operating Contractors

B. Andrews	K. Ashe	J. Bailey	J. Blink	S. Echols	M. Eshleman
A. Haghi	R. Howard	J. Lee	M. Lugo	J. McNeish	R. Murray
M. Nutt	J. Rosenthal	D. Sassani	D. Sevougian		

ATTACHMENT 2

LIST OF ATTENDEES
AT THE DOE/NRC TECHNICAL EXCHANGE
(continued)

July 21-22, 1997

Sandia National Laboratories

S. Altman	B. Arnold	R. Barnard	H. Dockery	N. Francis	J. Gauthier
M. Itamura	C. Ito	M. Wilson			

U.S. Geological Survey

P. Tucci R. Wallace

S., C., and A., Inc

S. Colwell

U.S. Nuclear Regulatory Commission

T. Ahn	M. Bell	D. Brooks	E. Brummett	K. Chang	D. Codell
N. Coleman	V. Colten-Bradley		N. Eisenberg	J. Davis	M. Federline
J. Firth	A. Forman	K. Gruss	J. Kotra	L. Hamdan	B. Ibrahim
R.Johnson	P. Justus	M. Lee	B. Leslie	C. Lui	T. McCartin
K.McConnell	C. McKenny	M. Nataraja	J. Pohle	K. Stablein	J. Trapp
S. Wastler					

U.S. Nuclear Waste Technical Review Board

D. Bullen D. Fehringer R. Parizek J. Wong

LIST OF ATTENDEES
AT THE DOE/NRC TECHNICAL EXCHANGE
ON TOTAL-SYSTEM PERFORMANCE ASSESSMENTS
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M. Nutt J. Rosenthal D. Sassani D. Sevougian

ATTACHMENT 2

LIST OF ATTENDEES
AT THE DOE/NRC TECHNICAL EXCHANGE
(continued)

July 21-22, 1997

Sandia National Laboratories

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M. Itamura	C. Ito	M. Wilson			

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K.McConnell	C. McKenny	M. Nataraja	J. Pohle	K. Stablein	J. Trapp
S. Wastler					

U.S. Nuclear Waste Technical Review Board

D. Bullen D. Fehringer R. Parizek J. Wong

ATTACHMENT 3

OBJECTIVES AND LIMITATIONS OF TECHNICAL EXCHANGE

July 21-22, 1997
NRC/DOE Technical Exchange on
Total System Performance Assessments
for Yucca Mountain

Keith I. McConnell
(301)415-7289/kim@nrc.gov
Division of Waste Management
Performance Assessment and HLW Integration Branch

OBJECTIVES OF TECHNICAL EXCHANGE

- Build on the Success of TSPA-95 Audit Review Technical Exchange
- Compare and Contrast Respective NRC TPA and DOE TSPA-VA approaches (assumptions, abstractions, process models, data, etc.) to identify areas of agreement and difference
  - Identify and maintain focus on key performance issues
  - Identify areas of agreement and difference in respective approaches and determine the significance of differences
  - Identify measures necessary to reach closure (action items)
- Continue Progress Towards Issue Resolution (i.e., no more questions at this time at the staff level)

LIMITATIONS OF TECHNICAL EXCHANGE

- NRC Recognizes the Developing Nature of DOE's TSPA-VA
- NRC's Presentations on its TPA Version 3.1 Code and Reference Case are Preliminary and Development is Continuing
- Another TSPA Technical Exchange is Scheduled for 10/97 to Continue These Discussions and Specifically Focusing on:
  - Technical areas which are not covered in depth during this technical exchange (i.e., disruptive events, biosphere, near-field, and waste form)
  - Other Issues identified in this technical exchange

ATTACHMENT 4

YUCCA
MOUNTAIN
PROJECT

Studies

Overview of TSPA-VA Plan

Presented to:
DOE/NRC Technical Exchange on
Total System Performance Assessment
San Antonio, Texas

Presented by:
Eric Smistad
YMSCO Performance Assessment

July 21-22, 1997

U.S. Department of Energy
Office of Civilian Radioactive
Waste Management

Outline

- Viability Assessment Components
- Objectives of TSPA-VA
- TSPA-VA Approach
- Development of Integrated TSPA-VA
- Generalized Schedule of TSPA-VA
- Anticipated Reviewers of TSPA-VA
- Key Process Models in TSPA-VA
- Workshop Goals

Viability Assessment Components

"(1) the preliminary design concept for the critical elements for the repository and waste package;

(2) a total system performance assessment, based upon the design concept and the scientific data and analysis available by September 30, 1998, describing the probable behavior of the repository in the Yucca Mountain geological setting relative to the overall system performance standards;

(3) a plan and cost estimate for the remaining work required to complete a license application; and

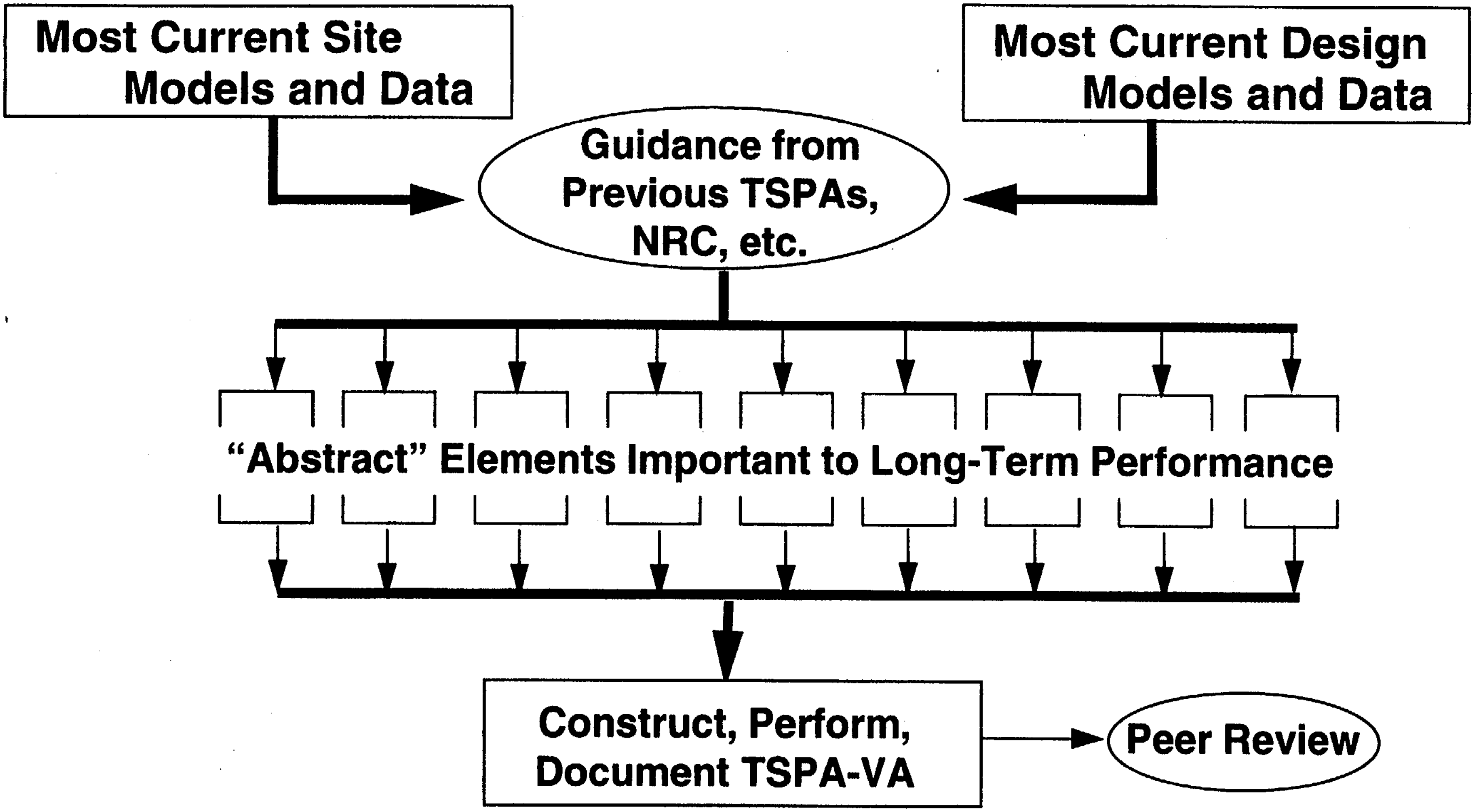
(4) an estimate of the costs to construct and operate the repository in accordance with the design concept."

FY 1997 Energy and Water Appropriations Act

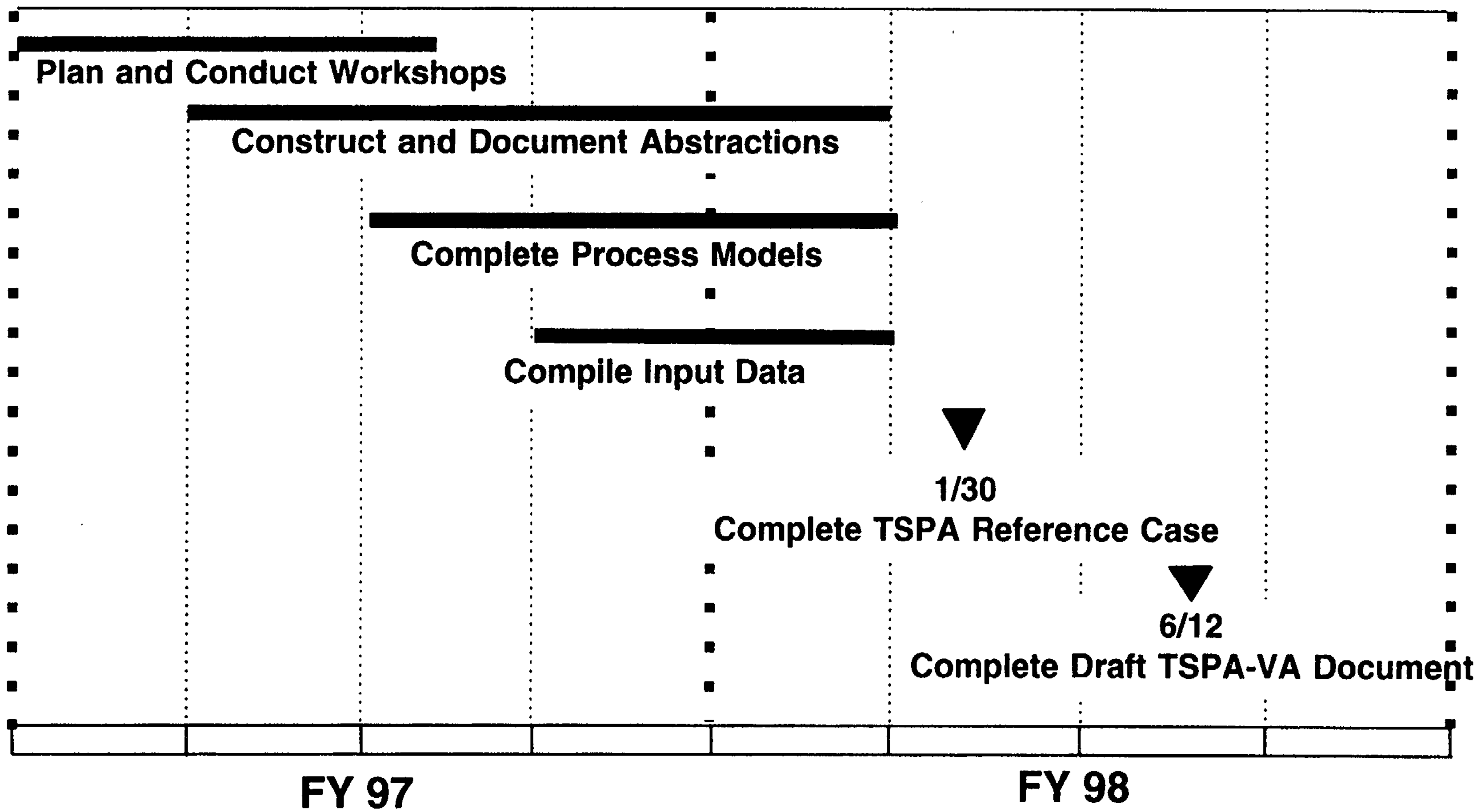
Objectives of TSPA-VA

- Develop a valid and defensible TSPA-VA:
  - Assure completeness/representativeness of models
    - use most complete and current understanding and designs
    - use most appropriate models that capture essential behavior of key processes important to long-term waste containment and isolation
- Assure appropriate issues are identified, quantified and evaluated (to the extent practical)
- Assure bases for assumptions are well-defined, justified, and documented

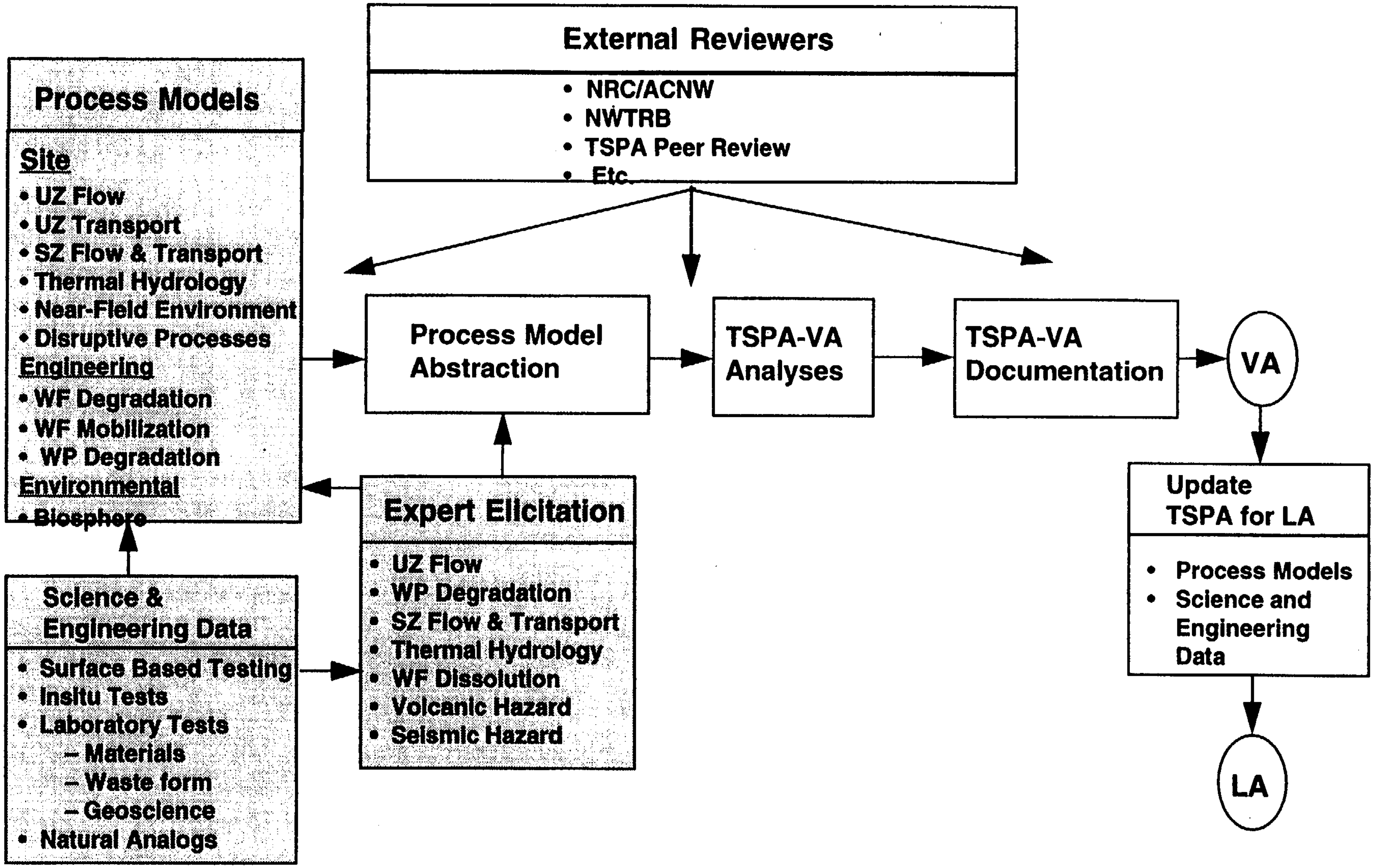
TSPA-VA Approach



Generalized Schedule for TSPA-VA



Development of Integrated TSPA-VA



Anticipated Reviewers of TSPA-VA

- Internal organizations within the M&O and DOE
  - design, scientific programs, licensing
- Nuclear Regulatory Commission (NRC)
  - Center for Nuclear Waste Regulatory Analyses (CNWRA)
  - Advisory Committee on Nuclear Waste (ACNW)
- Nuclear Waste Technical Review Board (NWTRB)
- TSPA-VA Peer Review Panel
- Environmental Impact Statement (EIS) Contractor
- State of Nevada and other affected units of government
- Electric Power Research Institute (EPRI)

Relationship of Key TSPA-VA Process Models to Waste Containment & Isolation Strategy Hypotheses and NRC Key Technical Issues

	WCIS	KTI
Site-Scale UZ Hydrology	1, 2 , 3	4
Repository-Scale Thermalhydrology	4	5
Drift-Scale Thermalhydrology	4, 6	5, 10
Climate Change Indirect Effects	5	4, 9
Site-Scale UZ Geochemistry	n/a	9
Drift-Scale Thermalchemical	n/a	8
Drift-Scale Thermal Mechanical	n/a	10
Drift-Scale Coupled T-H-M-C	n/a	5, 8, 10
Waste Package Degradation	7, 8	6
Cladding Degradation	9	6
Waste Form Dissolution	9	6
Solubility	9	6, 8
Drift-Scale Transport	10	9
Site-Scale UZ Transport	10	9
Site-Scale SZ Flow	11, 12	4
Site-Scale SZ Transport	12	9
Biosphere	n/a	2, 9
Tectonics Direct & Indirect Effects	13, 14	7
Volcanic Direct & Indirect Effects	15	3
Criticality Effects	n/a	n/a

Waste Containment & Isolation Strategy Hypothesis (DOE 1996)

1. Percolation flux at repository depth is significantly less than net infiltration.
2. Fracture flow occurs within a limited volume of the repository host rock at any given time.
3. Seepage into the emplacement drifts will be limited to a small fraction of the incident percolation flux due to capillary forces.
4. Bounds can be placed on thermally-induced changes in seepage rates.
5. Impacts of climate change on seepage rates can be bounded.
6. Heat produced by emplaced waste will reduce relative humidity in the vicinity of waste packages.
7. Corrosion rates are very low at low relative humidity, and corrosion of the inner barrier is slow.
8. Double-walled waste packages will significantly increase containment times due to galvanic protection of the inner barrier by the outer barrier.
9. Radionuclide release from waste forms due to surface area exposed, dissolution, colloid formation, and microbial activity will be low.
10. Transport properties of both engineered and natural barriers will significantly reduce radionuclide concentrations due to depletion, diffusion and dispersion.
11. Flow in the saturated zone is much greater than the flow contacting the waste.
12. Water percolating down through the repository horizon to the water table mixes with the flow in the aquifer.
13. The amount of movement on faults through the repository horizon will be too small to bring waste to the surface, and too small and infrequent to significantly impact containment during the next few thousand years.
14. The severity of ground motion expected in the repository horizon for tens of thousands of years will only increase the amount of rockfall and drift collapse.
15. Volcanic events within the controlled area will be rare and the consequences of volcanism will be acceptable.

Goals of Technical Exchange

- Communicate status and plans for TSPA
  - present DOE's approach for TSPA-VA
  - develop common understanding of methodologies and application of performance assessments in DOE's TSPA and NRC's IPA
  - obtain NRC feedback on abstraction workshops and planned activities
- Identify path forward for addressing issues

NRC KEY TECHNICAL ISSUES

1. Support revision of EPA standard/NRC rulemaking.
2. Total System Performance Assessment and technical integration.
3. Igneous activity.
4. Unsaturated and saturated flow under isothermal conditions.
5. Thermal effects on flow.
6. Container life and source term.
7. Structural deformation and seismicity.
8. Evolution of near-field environment.
9. Radionuclide transport.
10. Repository design and thermal-mechanical effects.

ATTACHMENT 5

YUCCA
MOUNTAIN
PROJECT

Studies

Overview of TSPA-VA Methodology

Presented to:
DOE/NRC Technical Exchange on
Total System Performance Assessment
San Antonio, Texas

Presented by:
Robert Andrews
Manager,
CRWMS M&O Performance Assessment

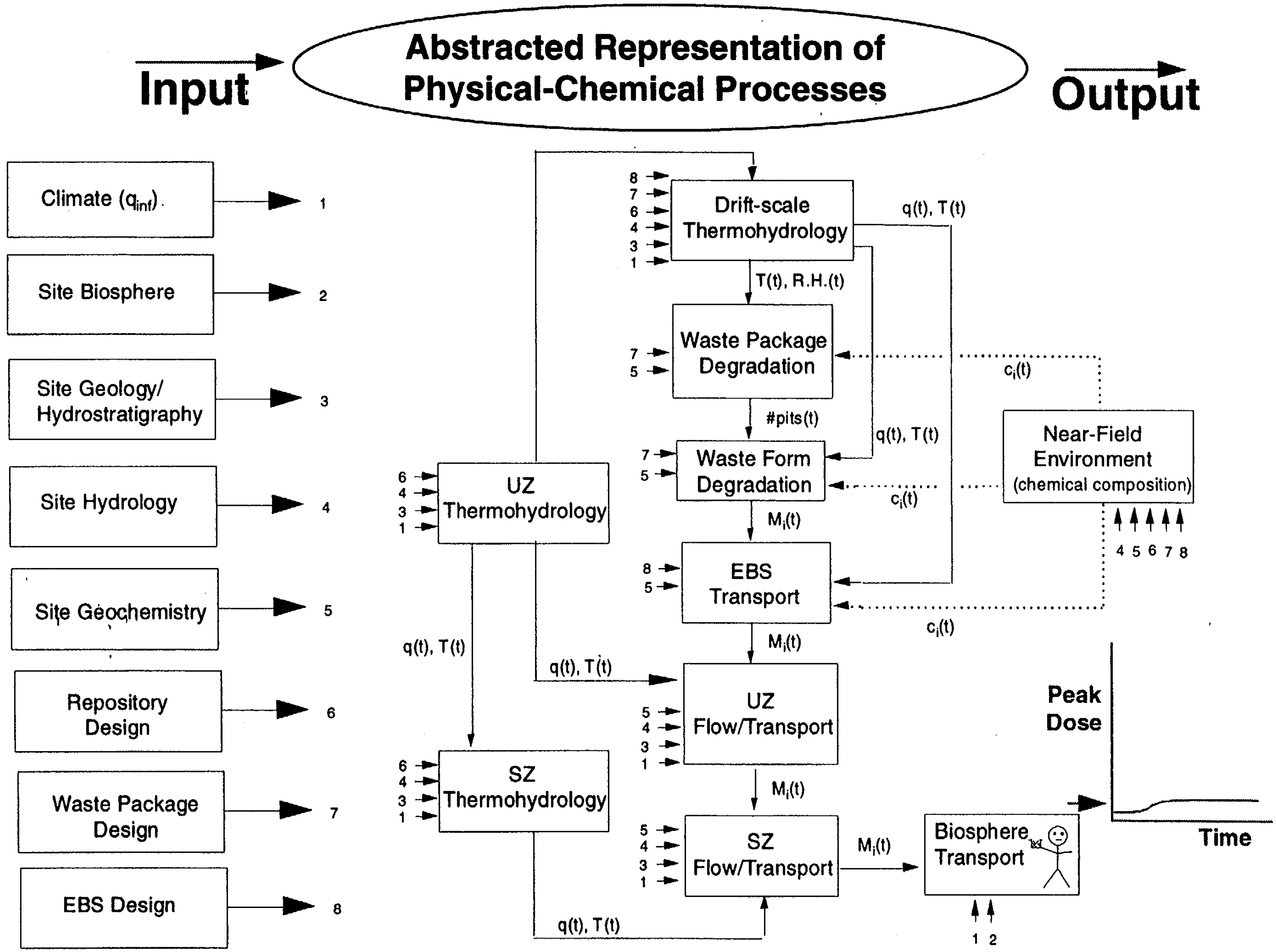
July 21-22, 1997

U.S. Department of Energy
Office of Civilian Radioactive
Waste Management

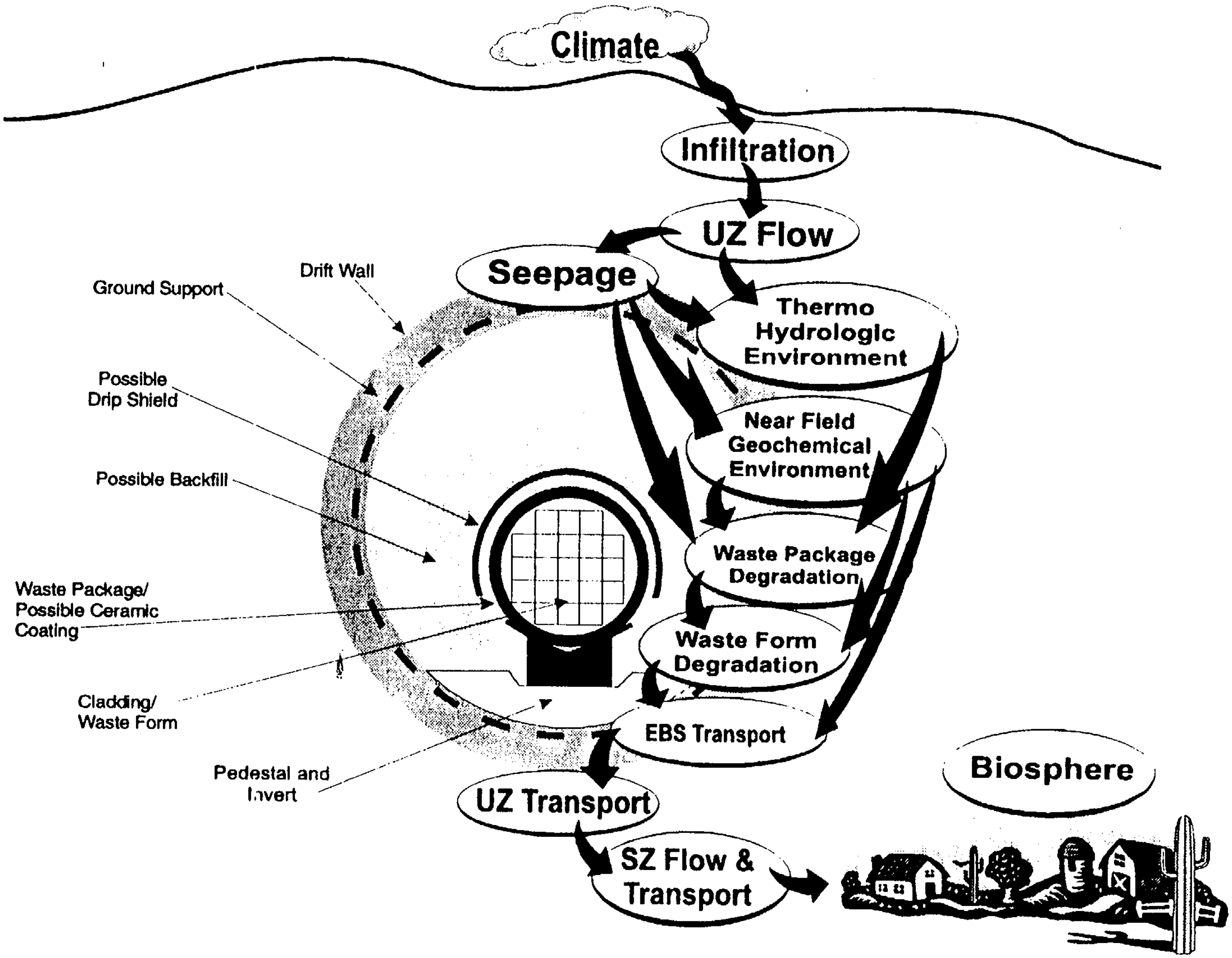
Outline

- Components Affecting Total System Performance
- Information Flow in TSPA-VA
- Definition of TSPA-VA Reference Case
- Uncertainty and Variability in TSPA-VA
- Summary

Abstraction and Modeling



Models for Total System Performance Assessment



NUKWSTP2.CDR.129.6-6-97

Key Process Model Results Used in TSPA-VA

Process Model	Key Results/Surrogates of Performance
Climate	Precipitation (t)
Infiltration	Net infiltration (t)
Percolation	Percolation @ repository (t)
Mt-scale T/H	Avg. Sw @ repository (t); avg. percolation @ repository (t)
Drift-scale T/H	Temperature (t); Invert Sw (t); RH (t)
Seepage	Avg. seepage (t); % area w/seeps (t); % total flux that seeps (t)
Drift T/C	Avg. pH, pCO_2, CO_3 (t)
W P T/C	Avg. pH, pCO_2, CO_3, Cl (t)
WF T/C	Avg. pH, pCO_2, CO_3, F, Si, PO_4, SO_4 (t)
WP Degradation	Pits through CAM (t); Pits through CRM (t), degradation rate CAM (t); degradation rate CRM (t); % WP area w/pits (t)
Cladding Degradation	% cladding w/pinholes (t); % cladding unzipped (t)
Inventory	Ci in place (t)
WF Degradation	Surface area exposed (t); surface area wetted (t); dCi/dt of altered WF

Key Process Model Results Used in TSPA-VA

Process Model	Key Results/Surrogates of Performance
Rn Mobilization	dCi/dt released to mobile phase (t); $\%\sum$Ci in mobile phase (t)
EBS Transport	dCi/dt released to UZ (t); $\%\sum$Ci released to UZ (t)
UZ Transport	dCi/dt released to SZ (t); $\%\sum$Ci released to SZ (t)
SZ Flow & Transport	dCi/dt released to AE(t); $\%\sum$Ci released to AE (t); avg. concentration at AE (t); peak concentration at AE (t)
Biosphere Transport	dose (t); $\%\sum$Ci ingested/inhaled (t)
Disruptive FEP: Volcanism	probability
Disruptive FEP: Tectonism	probability
Disruptive FEP: Criticality	probability

Definition of TSPA-VA Reference Case

- Use reference design
- Identify most probable/reasonable process models based on comparison to observations
  - weight alternative conceptual models
  - conceptual models of features/events/processes with probability < 1% in 10,000 years considered in sensitivity analyses
- Conduct sensitivity analyses using process models and surrogates of system performance to identify significant conceptual models and parameters

Definition of TSPA-VA Reference Case (cont)

- Use simplified models or response surfaces (developed from process model simulations) directly in TSPA software
  - response surfaces retain key correlations
  - simplified models (e.g., reduced dimensionality) compared to process model results
- Explicitly include spatial and temporal variability
- Conduct TSPA analysis using most representative or "expected" conceptual models

Definition of TSPA-VA Reference Case (cont)

- Conduct uncertainty analyses using stratified sampling techniques (LHS or importance) with range of parameters for representative conceptual models
- Conduct TSPA sensitivity analyses using range of alternative conceptual models, including low probability scenarios, and alternative designs
- Combine results of all weighted conceptual models and parameters into a single distribution of results

Approaches to Address Uncertainty and Variability in TSPA-VA

- Variability treated in every realization of system performance
- Uncertainty in process models and parameters treated in scoping sensitivity analyses to determine which issues need to be addressed in TSPA consequence analyses
- Parameter uncertainty within TSPA considered by sampling from appropriate distributions to generate CCDF's or PDF's
- Alternative models treated discretely
  - generate multiple conditional CCDF's and
  - results may be combined given appropriate weights are applied to each model

Treatment of Variability and Uncertainty in TSPA-VA

Process Model	Parameter Uncertainty Evaluated in Process Model	Parameter Uncertainty Evaluated in TSPA-VA	Model Uncertainty Evaluated in TSPA-VA	Parameter Variability Included in TSPA-VA
Climate		✓		
Infiltration		✓	✓	✓
Percolation	✓	✓	✓	✓
Mt-scale T/H	✓			✓
Drift-scale T/H	✓		✓	✓
Seepage	✓	✓	✓	✓
Drift T/C			✓	+
WP T/C			✓	+
WF T/C			✓	+
WP Degradation		✓	✓	✓ ++
Cladding Degradation	✓	✓	✓	✓ ++

Treatment of Variability and Uncertainty in TSPA-VA

Process Model	Parameter Uncertainty Evaluated In Process Model	Parameter Uncertainty Evaluated in TSPA-VA	Model Uncertainty Evaluated in TSPA-VA	Parameter Variability Included in TSPA-VA
Inventory				
WF Degradation	✓		✓	✓++
Rn Mobilization		✓		++
EBS Transport		✓		++
UZ Transport	✓	✓		✓
SZ Flow & Transport	✓	✓		✓
Biosphere Transport	✓	✓		
Disruptive FEP: Volcanism		✓		
Disruptive FEP: Tectonism		✓		
Disruptive FEP: Criticality		✓		

+ variability correlated to T/H variability

++ variability correlated to T/H and T/C variability

Examples of Planned TSPA-VA Sensitivity Analyses

- Infiltration rate models
- Fracture-matrix interaction models
- Seepage models
- Waste package degradation models
- Cladding degradation models
- EBS transport models
- Disruptive effects models

Presentation of TSPA-VA Sensitivity Analyses

- Time histories of expected evolution of the individual components affecting total system performance
  - evaluate surrogates of subsystem performance
- Multiple conditional CCDF's or PDF's
- Weighted CCDF's
- Scatter plots
- Regression and other statistical analyses

Summary and Status

- TSPA-VA Plan (9/96) is being implemented
- Process model sensitivity analyses in progress
  - includes assessment of issues raised in NRC review of TSPA-1995 plus NRC Annual Progress Report
- Architecture of TSPA-VA model being developed
- Abstraction of process model results for incorporation in TSPA-VA reference case being initiated
- Interim report from TSPA-VA Peer Review Panel provided useful suggestions

ATTACHMENT 6

YUCCA
MOUNTAIN
PROJECT

PROJECT Studies

TSPA-VA Abstraction/Testing Activities

Presented to:
DOE/NRC Technical Exchange on
Total-System Performance Assessment
San Antonio, Texas

Presented by:
Dr. Holly A. Dockery
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Albuquerque, NM

July 21, 1997

U.S. Department of Energy
Office of Civilian Radioactive
Waste Management

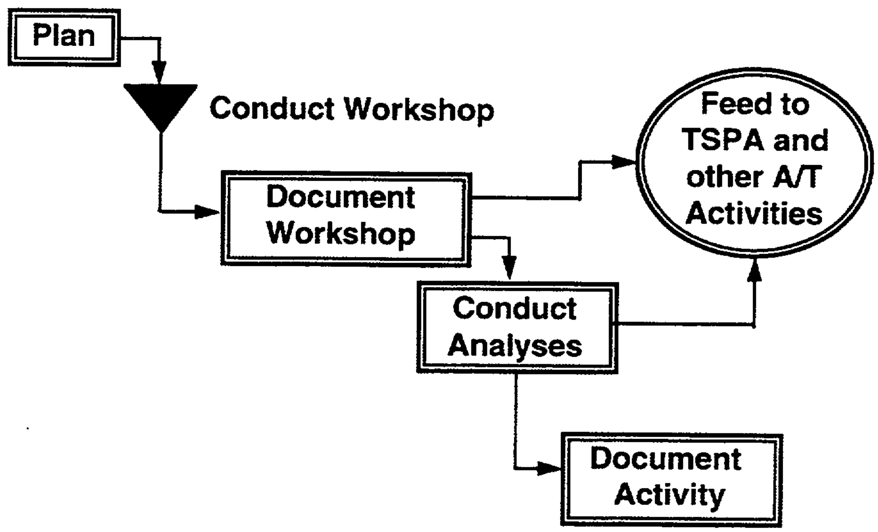
Definition of Abstraction

- A simplified/idealized model that reproduces or bounds the essential elements of a more detailed process model
  - Inputs may be those that form a subset of those required for a process model, or they may be a response function derived from intermediate results.
  - Model must capture uncertainty and variability.
  - Abstracted model must be tested against process models to assure adequacy.

Goal for Abstraction/Testing Activities

- Develop a defensible TSPA-VA
  - Assure completeness and representativeness of models used in TSPA analyses with respect to important aspects of process models.
  - Identify, quantify, and evaluate alternative conceptual models in TSPA.
  - Focus model development and testing on issues most important to performance.
  - Assure bases for assumptions are well defined, justified, and documented.

Generic Abstraction/Testing Activity Schedule



Topics of Abstraction/Testing Activities

Workshop Topic	Workshop Date	Workshop Lead	Documentation Status
Unsaturated Zone Flow	12/10-12/96	S. Altman	Complete
Waste Package Degradation	1/8-10/97	J. Lee	Complete
Thermohydrology	1/21-23/97	N. Francis/ C. Ho	Complete
Unsaturated Zone Transport	2/5-7/97	J. Houseworth	Complete
Waste Form Alteration and Mobilization	2/19-21/97	W. Halsey	DOE Review
Near-Field Environment	3/5-7/97	D. Sassani	DOE Review
Criticality	3/18-20/97	R. Barnard	Complete
Saturated Zone Flow and Transport	4/1-3/97	B. Arnold	DOE Review
Biosphere	6/3-5/97	A. Smith	In Preparation

Goals of Abstraction Workshops

- Develop a comprehensive list of issues (related to parameters, processes, or alternative conceptualizations) that need to be addressed for TSPA-VA.
- Prioritize the list of issues according to a consistent set of performance measures or criteria.
- Develop analysis plans to address top priority issues

Planning for Workshop

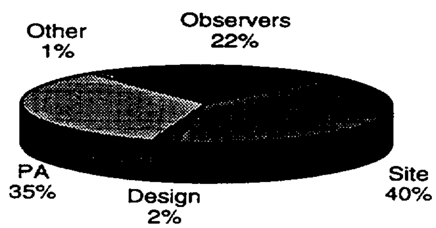
- Identify appropriate staff to represent data collection, process modeling, and PA modeling.
- Develop preliminary list of issues.
- Develop prioritization criteria.

Workshop Activities

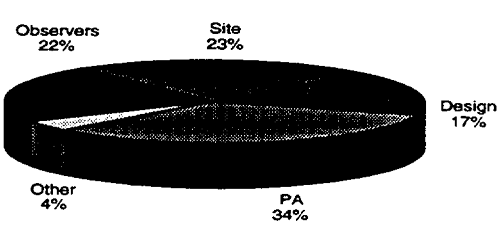
- Brainstorm additional issues for consideration.
- Rank suite of issues according to criteria.
- Determine affinities among issues to form analysis plan groups.
- Write draft plans with approach and expected outputs.
- Solicit feedback from entire group (with emphasis on TSPA input).

Average Attendance at Abstraction Testing Workshops

Geosphere Workshops



EBS Workshops



Post-Workshop Activities

- Finalize analysis plans.
- Develop ties to existing work and define sources of information.
- Finalize metrics for completion.
- Assign roles and responsibilties, and schedule.
- Develop integrated schedule for all analysis plans.

Status of Abstraction/Testing Activities

- All workshops were completed by early June.
- Analysis plans have been finalized and documented in deliverables.
- Coordination and status and meetings have been conducted.
- Analyses are ongoing to support development of abstractions for use in TSPA-VA.

Summary

- Abstraction/testing activities were very successful in facilitating integration of site and design information into PA.
- Activities will be a template for PA abstraction development efforts for the License Application.

ATTACHMENT 7

NRC TSPA PHILOSOPHY AS APPLIED TO THE TSPA-VA REVIEW

July 21-22, 1997
NRC/DOE Technical Exchange on
Total System Performance Assessments
for Yucca Mountain

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Performance Assessment and HLW Integration Branch

OVERVIEW OF NRC'S INTEGRATED HLW PERFORMANCE ASSESSMENT ACTIVITIES

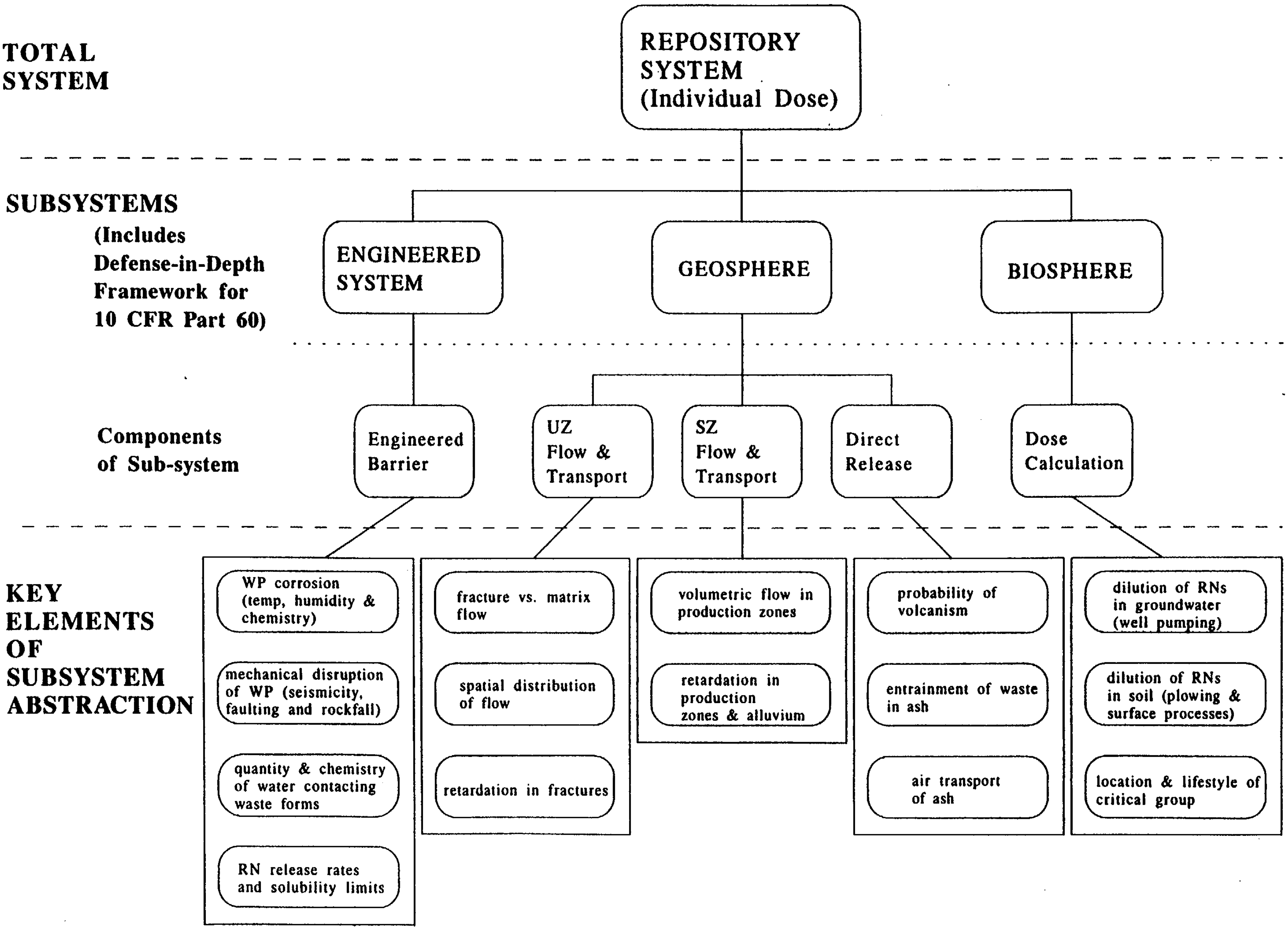
Use TSPA to:

- Support Regulatory framework Development
  - Evaluate implementability of proposed EPA standard
  - Use knowledge gained in TSPA activities, to development risk-informed, performance-based implementing rule for Yucca Mountain
  - Use TSPA to focus development of acceptance criteria and standard review plan

- Integrate and Evaluate Information Across Technical disciplines
  - Evaluate Issues and subissues in terms of total system performance
  - Understand the influence of uncertainties on compliance calculation

- Provide Feedback to DOE on system Performance
  - Independently evaluate DOE's TSPA analyses
  - Determine the sufficiency of data necessary for license application

DRAFT



TOTAL SYSTEM
REPOSITORY SYSTEM (Individual Dose)
SUBSYSTEMS (Includes Defense-in-Depth Framework for 10 CFR Part 60)
ENGINEERED SYSTEM
GEOSPHERE
BIOSPHERE
Components of Sub-system
Engineered Barrier
UZ Flow & Transport
SZ Flow & Transport
Direct Release
Dose Calculation
KEY ELEMENTS OF SUBSYSTEM ABSTRACTION
WP corrosion (temp, humidity & chemistry)
mechanical disruption of WP (seismicity, faulting and rockfall)
quantity & chemistry of water contacting waste forms
RN release rates and solubility limits
fracture vs. matrix flow
spatial distribution of flow
retardation in fractures
volumetric flow in production zones
retardation in production zones & alluvium
probability of volcanism
entrainment of waste in ash
air transport of ash
dilution of RNs in groundwater (well pumping)
dilution of RNs in soil (plowing & surface processes)
location & lifestyle of critical group

DEVELOP RISK-INFORMED, PERFORMANCE-BASED IMPLEMENTING RULE

- Use Total System Performance Assessment Activities to simplify, focus, and explain regulatory criteria;
- Establish a Clear Relationship Between NRC Acceptance Criteria and the Compliance calculation; and
- Ensure that the Implementing Rule and Associated Standard Review Plan are consistent with our knowledge of the Yucca Mountain site and Our Ability to Assess the Performance of the Site and Design

DEVELOP RISK-INFORMED, PERFORMANCE-BASED IMPLEMENTING RULE

- Update NRC's TPA Code to be User Friendly, Workstation-based, Include New Repository Design, and incorporate Mechanistic Models for Elements of Analysis;

- Identify Significant Performance Drivers, Conceptual Models, and Uncertainties Necessary for Abstraction;

- With KTIs, Conduct Sensitivity Studies on Intermediate results to Identify Model Improvements and Data Needs;

- With KTIs, Conduct Studies on Total System Performance to Assess the Importance of Subissues; and

- Report the Results in Issue resolution Status Reports (IRSRs) Including the IRSRs on "Abstraction" and "Relative Importance"

PROVIDE EARLY FEEDBACK TO DOE ON SYSTEM PERFORMANCE VIA REVIEWS OF TSPA-VA PLANS, TSPA-VA, AND PISA

- **Review TSPA-VA plans, WCIS, and Other Information to Evaluate TSPA-VA Abstractions and Input Parameters;**

- **Use Upgraded TPA Code to Review and Independently Evaluate DOEs Results**
  - **Compare TSPA-VA Results with TPA Results with Similar Input Parameters**
  - **Compare TSPA-VA Results with TPA Results Using NRC Input Parameters**

- **Compare the Results of TSPA-VA and NRC Independent Analyses with Past Assessments of System Performance (e.g., Phase 2 and TSPA-95, 93, etc.); and**

- **Report the Results of the Independent Evaluations in IRSRs (e.g., IRSR on Abstraction) and Other Commenting Activities (e.g., Technical Exchanges)**

ATTACHMENT 8

OVERVIEW OF NRC'S TSPA METHODOLOGY

by

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July 21, 1997

Presented at
DOE/NRC Total-System Performance Assessment
Technical Exchange
Southwest Research Institute
San Antonio, TX

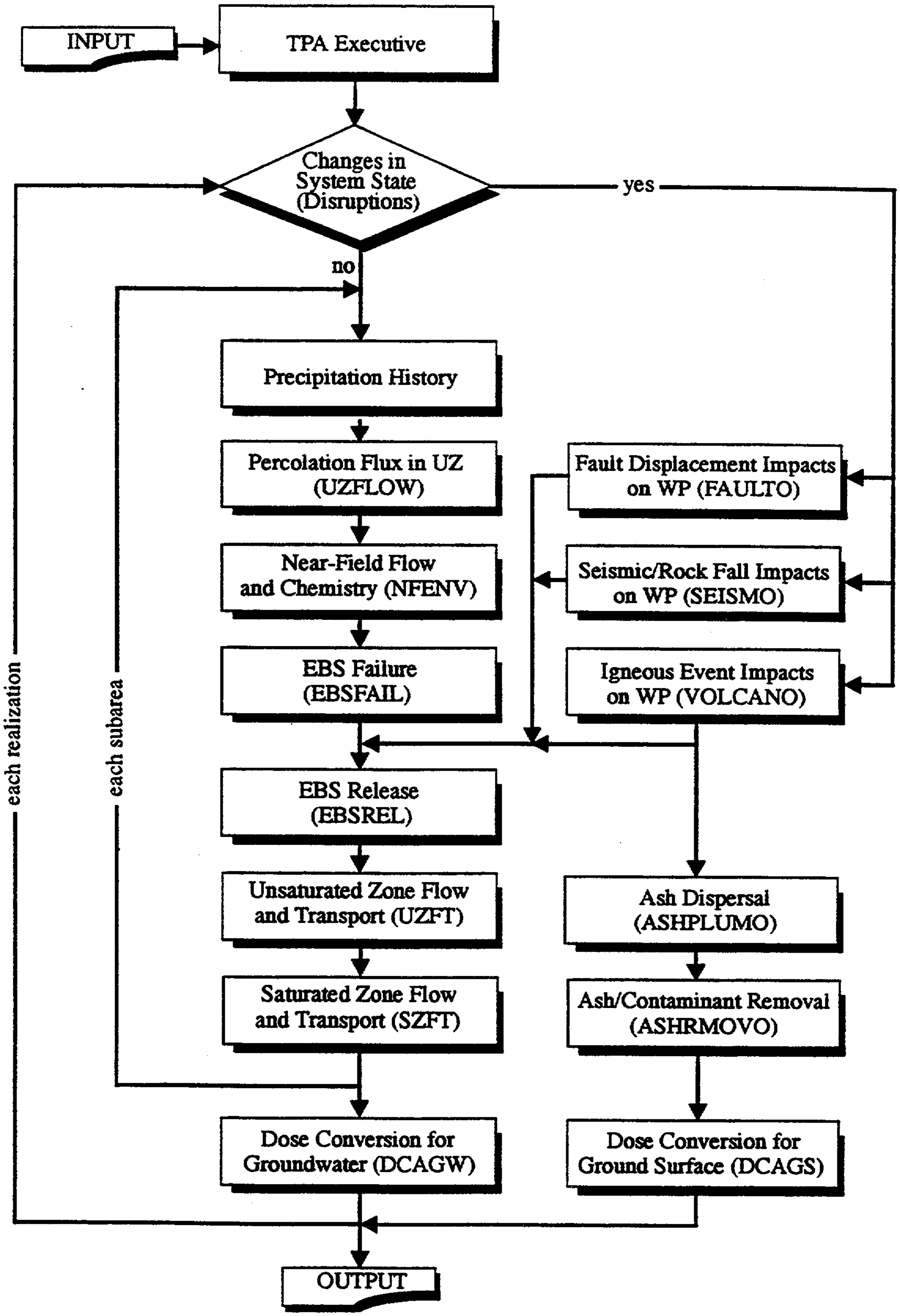
PRESENTATION OUTLINE

- Total-System Performance Assessment (TPA) Code Design
- TPA Code Structure
- Abstraction Implementation
- System Discretization
- TPA Code Outputs
- Code Features, Assumptions, and Limitations
- Auxiliary Support Codes
- Reference Data Set for Iterative Performance Assessment (IPA) Phase 3

TPA CODE DESIGN

- Build Upon the IPA Phase 2 Methodology (NUREG-1464) (i.e., System Description, Scenario Analysis, Consequence Analysis, Probabilistic Performance Measures, etc.)
- Retain IPA Phase 2 Intermediate Outputs and Add Peak Dose (at Designated Compliance Points)
- Accommodate Current DOE Repository Design, Emplacement Mode, and Thermal Loading Options
- Integrate New Knowledge Base, Data, and Models from NRC Key Technical Issues (KTIs)
- Develop Code for Use by a Broad Spectrum of Users (i.e., Subject Matter Experts in KTI Teams)

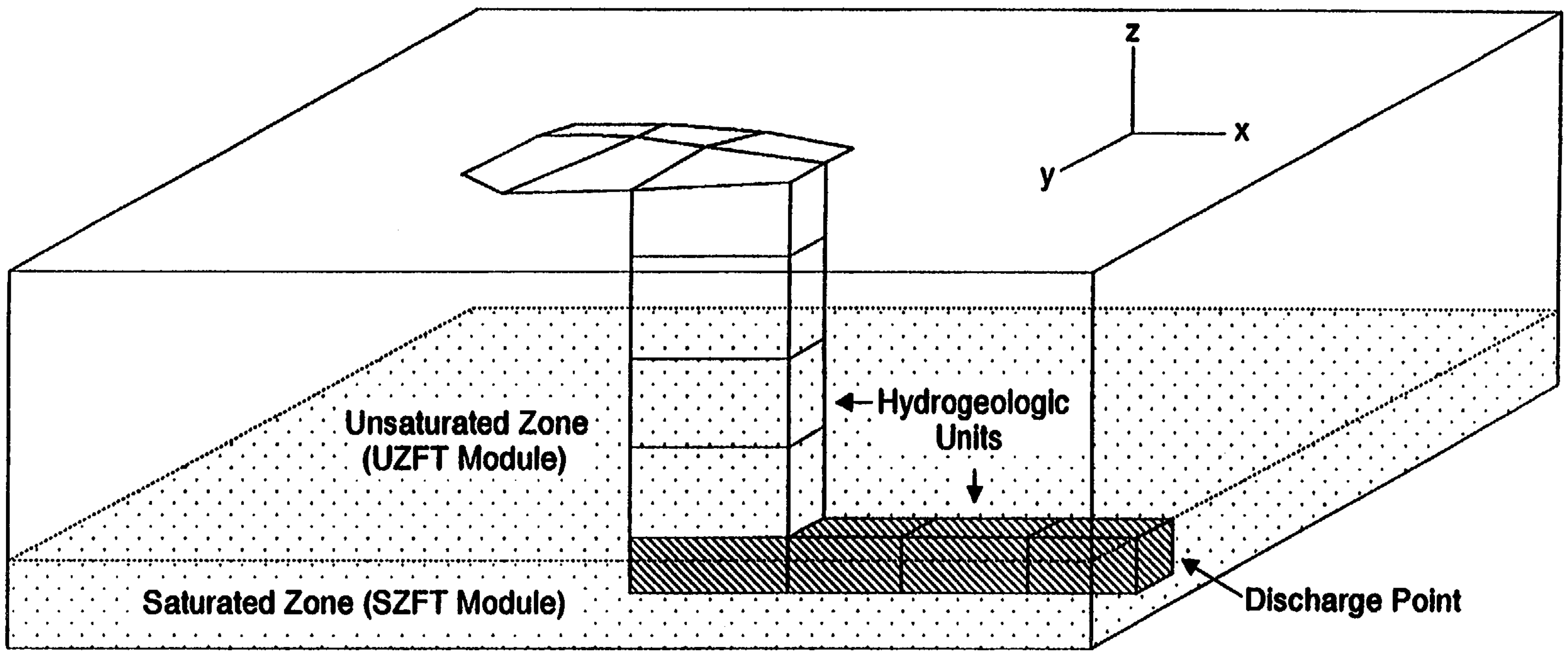
TPA CODE VERSION 3.1 STRUCTURE



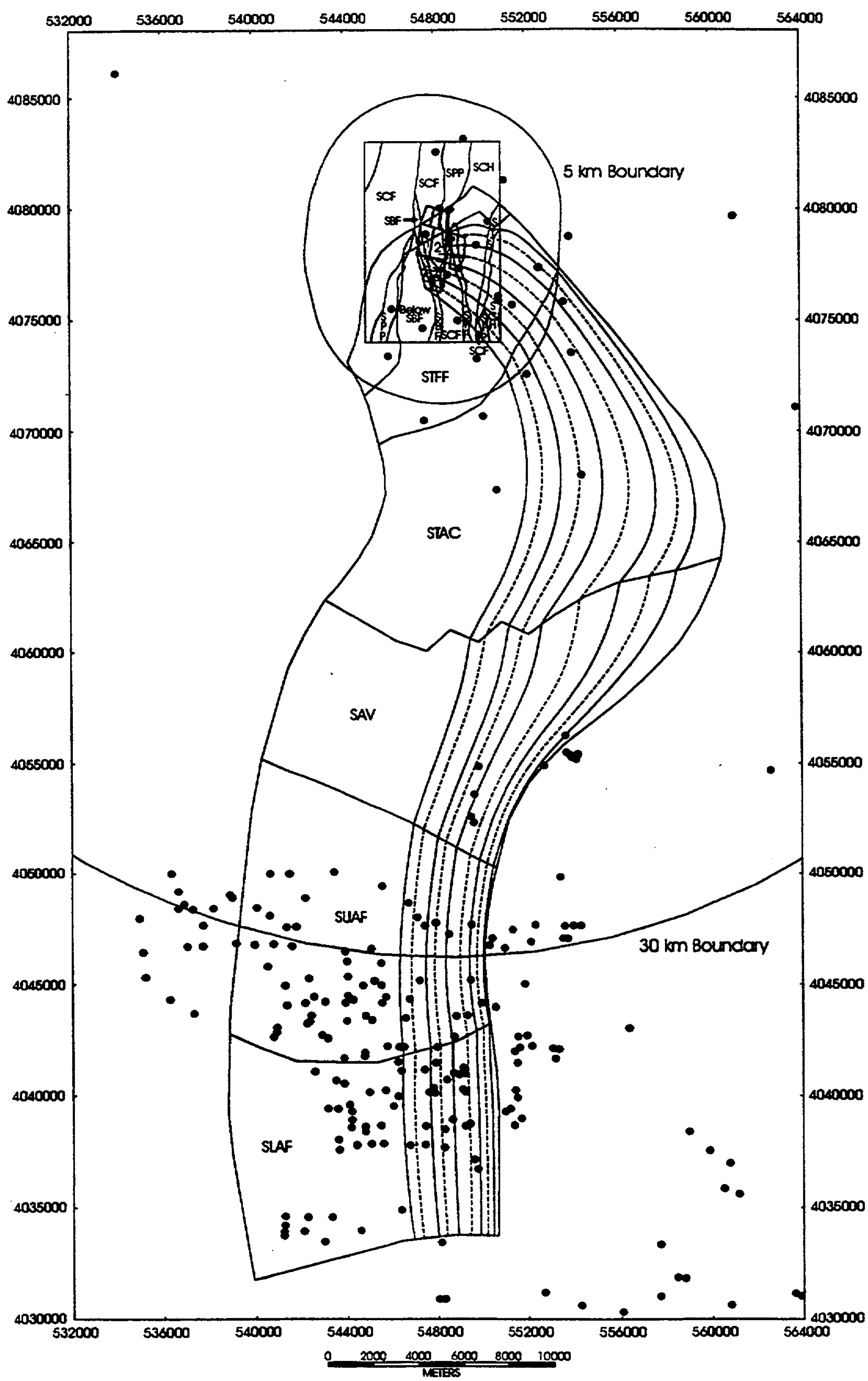
ABSTRACTION IMPLEMENTATION — TPA VERSION 3.1

Consequence Module	Table-Lookup	Subroutine(s)	External Standalone Program
UZFLOW		X	
NFENV		X	
EBSFAIL			X
EBSREL			X
UZFT			X
SZFT			X
DCAGW	X		
FAULTO		X	
SEISMO		X	
VOLCANO		X	
ASHPLUMO			X
ASHRMOVO		X	
DCAGS	X		

SYSTEM DISCRETIZATION



SYSTEM DISCRETIZATION (Cont'd)



TPA CODE OUTPUTS

- Statistical Distributions Constructed for Total System Outputs Peak Dose and Cumulative Release

- Code Flexibility to Generate Intermediate and Total System Outputs on a Disaggregate Basis

  - Scenario Class

  - Repository Component and Subsystem

  - Repository Subareas

  - Performance Drivers

TPA CODE VERSION 3.1 FEATURES

- Executive (i.e. Main Program) Controls Loading of Input, Sampling of Statistical Distributions, Data Flow Between Modules, and Output File Generation
- Centralized Input file (*tpa.inp*) with Internal Documentation
- User Friendly Input File Reader Routine (with Error Checking)
- Library of Modularized Utilities Accessible to All Modules
- Sampling Routine with Monte Carlo and Latin Hypercube Sampling Options
- Selected Modules Possess Options for Alternative Conceptual Models (e.g., Near-field Thermal Environment, Refluxing, and Fuel Dissolution)
- Accommodates 43 Radionuclides (with 4 Major Decay Chains) for Direct Releases and 20 Radionuclides for Groundwater Transport

SELECTED CODE ASSUMPTIONS AND LIMITATIONS

- No Lateral Diversion of Flow in the Unsaturated Zone
- Steady-State Flow in the Saturated Zone and No Flow Perturbations from Well Pumping
- Transverse Dispersion is Neglected in Transport Calculations
- Performance of a Single WP Modeled in Each Repository Subarea (Which Represents all WPs in the Subarea for Corrosion Failure)
- Human Intrusion Scenario Considered as a Separate Stylized Calculation
- Simulation of Volcanism Scenario Considers Direct Release Only
- No Direct Coupling between FAULTO, SEISMO, and EBSFAIL Modules
- Climate Variation Treated as Precipitation History (with Random Perturbations)
- Receptor Individual has "Average" Characteristics of Current Population in the Amargosa Valley (CNWRA 95-018)

AUXILIARY SUPPORT CODES

- MULTIFLO — Simulates Thermohydrologic (e.g., Temperature and Relative Humidity) and Geochemical (e.g., Chloride Concentration) Conditions for the Near-Field
- MAGNUM-2D — Simulates Saturated Groundwater Flow and Computes Groundwater Flow Paths from Repository to Critical Group Location
- BREATH — Simulates Nonisothermal Partially Saturated Flow in the Unsaturated Zone
- GENII-S — Provides Statistical Calculations for Dose Conversion Factors
- UDEC — Discrete Element Code that Simulates Mechanical Behavior of Open Drift as a Function of Seismic and Thermal Loads
- S-PLUS — Statistical Package Used in Evaluation of KTI Sensitivity Analyses

REFERENCE DATA SET FOR IPA PHASE 3

- "Comparison of Reference Input Parameter Values for the Total System Performance Assessment of the Proposed Yucca Mountain Repository", Letter Report
  - Compares NRC Model Parameters with DOE TSPA-95 Parameter Set
  - Identifies Significant Differences in Parameters and Modeling Approaches
  - Builds on IPA Phase 2 Parameter Set
  - Parameter Estimates and Assumptions Grouped by TPA Module
- IPA Phase 3 Reference Parameter Set to be Finalized and Documented in CNWRA Report

ATTACHMENT 9

STATUS OF TOPICS OF INTEREST IDENTIFIED AT THE

MAY 1996 DOE/NRC TECHNICAL EXCHANGE

(*aka* ATTACHMENT 13)

July 21-22, 1997
DOE/NRC Technical Exchange on
Total System Performance Assessments
for Yucca Mountain

Michael P. Lee/NRC 301/415-6677

Abe van Luik/DOE 702/794-1424

STATUS OF MAY 1996 TECHNICAL EXCHANGE TOPICS OF INTEREST
(from Attachment 13, enclosed)

Issue	*Status*
TEMPERATURE AND RELATIVE HUMIDITY	
Conceptual models addressing heat and relative humidity (RH)	Subject of a July 1996 Appendix 7 meeting; proceeded by staff comments (January 1997) and DOE response (July 1997); staff currently evaluating DOE response[1]
Differences between TSPA-95 and CNWRA values for initial temperature and effective conductivity	Staff continuing to monitor DOE efforts in this area
Computational problems associated with high infiltration	DOE: now utilizing dual-continuum models to address issue[1] NRC: utilizing *MULTIFLOW* code to address issue
Waste package characteristics at repository edge (periphery)	No activity at present
CONTAINER LIFE AND SOURCE TERM	
Process for determining importance to performance	DOE: evaluating issue through its on-going expert elicitations (3) and abstraction workshops (2) related to waste package and waste form NRC: generically examining the importance theme as part of IPA Phase 3

1 Also, DOE's on-going abstraction/testing analyses are addressing this issue.

...ste package degradation:[2]	
• extrapolation of data	DOE evaluating through its ongoing expert elicitation related to waste package[1]
• extreme value or normal distribution for pitting	DOE evaluating through its ongoing expert elicitation related to waste package[1 3]
• critical RH vs. temperature	Work in-progress @ LLNL (data) and M&O (importance to performance)[3]
• impermeable vs. porous scale	*Ibid.*
• pit growth vs. environment	*Ibid.*[1 3]
Near-field environment	NRC has proposed a November 1997 Appendix 7 meeting to address this issue[1]
Waste dissolution/near-field/source term	No follow-up action resulting from May 1996 Technical Exchange; however — DOE: conducting experimental work[1] NRC: treatment as part of IPA Phase 3 modeling and sensitivity analyses[4]
(SYSTEM) ABSTRACTION	
Markovian calculations	DOE: revising TSPA-95 approach using *FEHM* transport code in systems code NRC: conducted sensitivity analyses which were documented in NUREG/CR-6515

[2] Sub issues to be addressed in forthcoming FY98 NRC *Issue Resolution Status Report*.

[3] Issue being evaluated by CNWRA through limited independent investigations.

[4] See *Near-field environment,* above.

Model dependency on conclusions/assumptions	DOE: evaluating issue through its on-going expert elicitations and abstraction workshops NRC: providing feedback through the series of Technical Exchanges (July and October 1997)
Limit of response curve	Staff continuing to monitor DOE efforts[1] in this area
Importance of drift-scale calculations	Staff continuing to monitor DOE efforts in this area, in particular, the revised UZ flow model
Correlation between units spatially and vertically. Is there any ? Is the abstraction in TSPA-95 correct in its treatment?	Staff continuing to monitor DOE efforts in this area
FLOW (INFILTRATION)	
Fracture properties	DOE: evaluating issue through (a) C-Hole testing; (b) pneumatic air testing; and (c) mapping in the ESF NRC: limited independent work underway at CNWRA
Areas of focused infiltration	DOE: evaluation of issue underway; including consideration as part of on-going expert elicitations NRC: limited independent work underway at CNWRA
Climate change over 10,000 years	DOE: climate program results are to be reflected in the TSPA-VA[1] NRC: staff preparing an *Issue Resolution Status Report* recommending a path to resolution based on review of available information
Are fracture velocities incorrect ?	DOE: TSPA-95 approach has been modified using the *FEHM* transport code for TSPA-VA[1] NRC: limited independent work underway at CNWRA
Importance of lateral flow	DOE: evaluating issue as part of on-going expert elicitations and revised UZ flow model; results suggest issue may not be as important as originally thought[1] NRC: staff continuing to monitor

...ture-matrix partitioning	DOE: evaluating through (a) on-going expert elicitation and (b) revised UZ flow model incorporating evaluation of ^{14}C and ^{36}Cl data[1] NRC: staff continuing to monitor
DILUTION	
Basis/rationale for mixing depth assumed in TSPA-95	DOE: evaluating through C-Well testing and revised SZ flow model[1] NRC: conducted an auxiliary analysis that was briefly described in NUREG/CR-6513; full documentation of analysis to be provided in NUREG-1538 (in preparation)
Basis/rationale for average flux values used by NRC (0.1 m/yr) vs. others (0.2 m/yr)	No follow-up required; however — DOE: revised SZ flow model is being completed; status to be discussed at July 1997 Technical Exchange[1] NRC: developing improved modeling capability as part of IPA Phase 3
TSPA (SYSTEM) ABSTRACTIONS	
Differences between container failure times and release times	DOE: TSPA-95 approach being modified; results of expert elicitations suggest that episodic flushing need not be considered[1] NRC: staff continuing to monitor
What is meant by NRC's rule-based method for fracture matrix code ?	No follow-up required
CCDF charts: NRC results cover a broader range than do DOE's. What are the differences between the two models (approaches) that could account for the discrepancies ? How are the geometric differences accounted for ?	No follow-up required; differences in CCDF's understood to be attributable to *initial waste package failure times*, *fast pathways*, and *matrix diffusion*

BREAKOUT SESSION SUMMARY: WORKING GROUP 1

Issue	*Discussion*	*Action*
TEMPERATURE AND RELATIVE HUMIDITY		
Conceptual models addressing heat and relative humidity (RH)	Appears at present to be a choice of "equivalent continum model" (ECM) vs. "dual porosity" or discrete fracture models	Possible topic for technical exchange, Appendix 7 visit, or telecon, as arranged.
Differences between TSPA-95 and CNWRA values for initial temperature and effective conductivity	DOE recognizes differences between TSPA-95 and TSPA-93 (Sandia) calculations. For above boiling conditions, the definition of RH used in TSPA-95 was inconsistent with literature.	DOE will re-evaluate. NRC/ CNWRA suggest using the term "vapor pressure ratio" instead of RH.
Computational problems associated with high infiltration	Currently being investigated by DOE's Management & Operating (M&O) contractor and Sandia performance assessment staffs and CNWRA	Possible topic for technical exchange, Appendix 7 visit, or telecon, as arranged: hydrothermal modeling
Waste package characteristics at repository edge (periphery)	Design issues (e.g., waste stream) yet to be resolved.	Later information exchange between NRC and M&O recommended. NRC plans to monitor design development.
CONTAINER LIFE AND SOURCE TERM		
Process for determining importance to performance	Lawrence Livermore National Laboratory (LLNL) has ongoing studies to experimentally or logically defend container failure scenarios. DOE agrees with need for subsystem sensitivity studies.	Possible topics for technical exchange, Appendix 7 visit, or telecon, as arranged — subject: design-specific calculations of temperature and material properties

Waste package degradation: • extrapolation of data • extreme value or normal distribution for pitting • critical RH vs. temperature • impermeable vs. porous scale • pit growth vs. environment	For extrapolation of data, it is DOE's position that: • Critical processes can be determined from short term • Behavior verified by long term • LLNL (site scale – 5 years) • Literature (30 years) • Analogs (long time) Extreme value vs. Normal Distribution for pitting: DOE will evaluate paper provided by CNWRA Critical RH vs. temperature and chemistry: DOE acknowledges concern Impermeable vs. porous-scale formation: DOE acknowledges concern Pit growth as a function of environment:	LLNL will synthesize available data for extrapolation. CNWRA provided DOE with paper by Sharland *et al.* (1995) and will provide additional literature. Work in progress. Work in progress. Ongoing experiments.
Near-field environment	Recommended treating in a separate meeting that would include design engineers and site characterization investigators.	Possible topic for technical exchange, Appendix 7 visit, or telecon, as arranged: Fall 1996 time frame
Waste dissolution/near-field/Source term	Answers expected from experiments and subsystem sensitivity studies. Work is in initial phase.	None

BREAKOUT SESSION SUMMARY: WORKING GROUP 2

Issue	*Discussion*	*Action*
(SYSTEM) ABSTRACTION		
Markovian calculations	Clarification requested on where these type of calculations are described.	See RIP Manual, Version 4.0 (Golder Associates, 1995; pp. 4-16 — 4-21). NRC staff will try to relate Markovian calculations to fundamental physical parameters.
Model dependency on conclusions/assumptions	In terms of process modeling, NRC staff interested in understanding what DOE did and why.	More/additional detail would be useful in future TSPA documentation. Possible topic for technical exchange, Appendix 7 visit, or telecon, as arranged — subject: DOE's TSPA abstraction process.
Limit of response curve	TSPA using response curves to represent the performance of subsystems and ranges in parametric values. Do response curve adequately describe the processes being modeled and the coupling of processes ?	More/additional detail on what these curves mean would be useful in future TSPA documentation, including an examination of how well abstractions represent process modeling.
Importance of drift-scale calculations	Questions concerning the importance of these types of calculations (particularly as they relate to episodic phenomena) when scaled-up to the repository level. (Also see "Differences between container failure times and release times," below.)	Possible topic for technical exchange, Appendix 7 visit, or telecon, as arranged — subject: effects of episodic radionculide release phenomena on repository performance.

Correlation between units spatially and vertically. Is there any? Is the abstraction in TSPA-95 correct in its treatment ?	Additional clarification and discussion on what the issues where. Correlation of physical properties within and between units needs to be addressed. It was mutually recognized that this issue is potentially important to repository performance.	DOE will address vertical as well as horizontal correlations of physical properties within stratigraphic units.
	FLOW (INFILTRATION)	
Fracture properties	Questions raised on the source(s) for the parameter values.	No consensus on which parameters are important or their ranges.
Areas of focused infiltration: Importance and derivation	TSPA does not adequately address this issue. It was mutually recognized that this issue is potentially important to repository performance.	Currently being evaluated by the USGS. Possible topic for technical exchange, Appendix 7 visit, or telecon, as arranged (e.g., flow and transport).
Climate change over 10,000 years	Discussion focussed on how the onset of pluvial conditions would be treated in a TSPA. Discussion also focussed on whether the range in parametric values selected are adequate.	Differences in the respective staff approaches needs to be addressed. Possible topic for technical exchange, Appendix 7 visit, or telecon, as arranged (e.g., flow and transport).
Are TSPA-95 fracture velocities incorrect?	What percentage of the flux is fracture flow. At this time issue is not considered to have a significant effect on performance.	It was agreed that the fracture velocities should have been adjusted for saturation but effect on performance may not be significant.
Importance of lateral flow	It may be important if it occurs; however, it is not clear at this time whether it occurs at the site.	More data is needed to resolve this issue. Possible topic for technical exchange, Appendix 7 visit, or telecon, as arranged (e.g., flow and transport).

Fracture-matrix partitioning	Discussion related to "Markovian calculations," above.	-----
	DILUTION	
Basis/rationale for mixing depth assumed in TSPA-95	Depth assumed; no information to form an estimate at this time. NRC not convinced that significant mixing takes place below the repository. This issue is potentially important to repository performance, especially in the context of understanding how much water is transported through the Amargosa Valley area.	DOE will examine basis for assumption.
Basis/rationale for average flux values used by NRC (0.1 m) vs. others (0.2 m)	Sampled parameter. See p. 7-21 and Chapter (dilution) in TSPA-95.	None.
	TSPA (SYSTEM) ABSTRACTIONS	
Differences between container failure times and release times	NRC concerned that DOE's modeling does not recognize that "episodic" flushing of the waste package, by ground water, could occur and lead to subsequent "spikes" in radionculide releases from the EBS.	NRC staff to do further investigations.
What is meant by NRC's "rule-based" method for fracture-matrix code	Clarification provided by NRC staff. See Chapter 4 ("Flow and Transport") in IPA Phase 2 report.	None.
CCDF charts: NRC results cover a broader range than do DOE's. What are the differences between the two models (approaches) that could account for the discrepancies? How are geometric differences in the curve accounted for?	At the "low release end," NRC's CCDF dominated by the fact that there are no waste package failures initially, whereas DOE would have failures and waste transport in each zone. At the "high release end," the CCDF differences could be attributed: (i) how fast pathways were treated in the respective codes; and (ii) DOE assumptions of significant matrix diffusion effects (re: Markovian calculations).	NRC will do more follow-up on in this area. DOE may have matrix diffusion data that NRC could use as it evaluates the Markovian computational algorithm.

ATTACHMENT 10

YUCCA
MOUNTAIN
PROJECT

PROJECT Studies

Saturated-Zone Flow and Transport Abstraction for TSPA-VA

Presented to:
DOE/NRC Technical Exchange on
Total System Performance Assessment
San Antonio, Texas

Presented by:
Bill W. Arnold, Senior Member Technical Staff
George E. Barr, Distinguished Member Technical Staff
Sandia National Laboratories
Albuquerque, New Mexico

July 21, 1997

U.S. Department of Energy
Office of Civilian Radioactive
Waste Management

Sa... National Laboratories

High-Priority Issues from Abstraction/Testing Workshop

Category 1: Conceptual Models of SZ Flow

- Regional discharge.
- Regional recharge.
- Vertical flow.
- Alternative conceptual models (e.g., large hydraulic gradient).

Category 2: Conceptual Models of SZ Geology

- Channelization in vertical features.
- Hydraulic properties of faults.
- Channelization in stratigraphic features.
- Distribution of zeolites.
- Fracture network connectivity.

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High-Priority Issues (cont.)

Category 3: Transport Processes and Parameters

- Dispersivity.
- Matrix diffusion (effective porosity).
- Matrix sorption.
- Fracture sorption.

Category 4: Coupling to Other Components of TSPA

- Climate change.
- UZ and SZ coupling.
- Thermal and chemical plume.
- Well withdrawal scenarios.

Workshop Analysis Plans

- Sensitivity Study on Uncertainties in Site-Scale Saturated-Zone Transport Parameters and Models.
- Coupling of UZ and SZ Transport Models.
- The Effects of Large-Scale Channelization on Effective Transport Parameters.
- Determination of Effective Field-Scale Transport Parameters Using C-Wells Testing Results.
- Past, Present, and Future Saturated Zone Fluxes.
- Geologic Structure and Processes Affecting Flow Channelization.

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Expected Form of the Abstraction

- Numerical Convolution Used to Approximate Transport in the SZ.
  Assumptions: 1) Transport processes are linear in the SZ,
  2) Steady-state flow in the SZ.

- Input Function is the Radionuclide Mass Flux History at the Water Table (as Simulated with the UZ Flow and Transport Models).

- Uncertainty in SZ Flow and Transport is Captured Using Monte Carlo Realizations of the Model.

- Output Function is the Radionuclide Concentration History at the Point of Maximum Concentration (i.e., Center of the plume) at Approximately 20 km.

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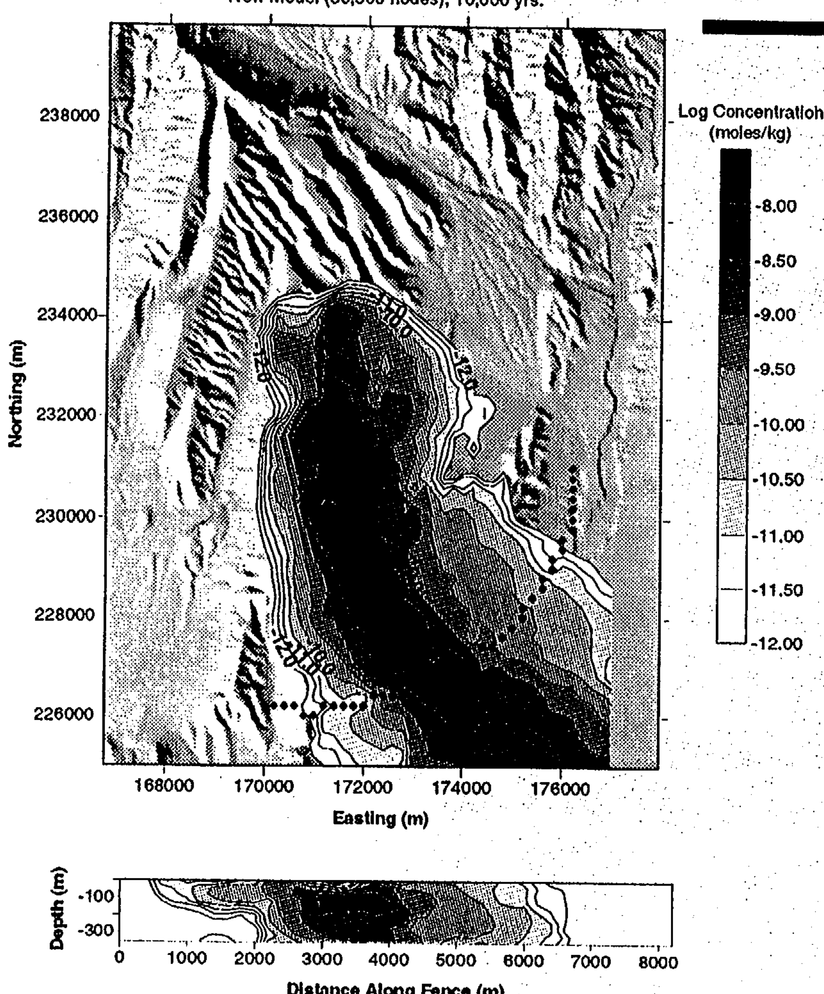
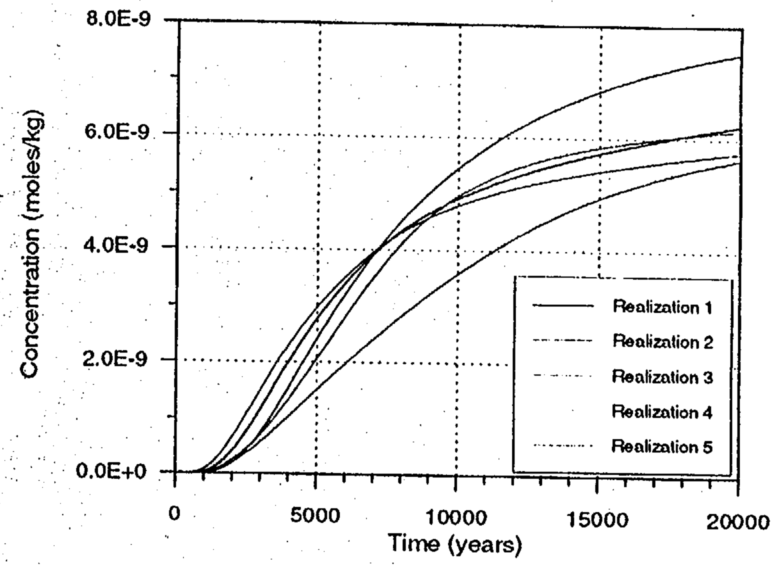
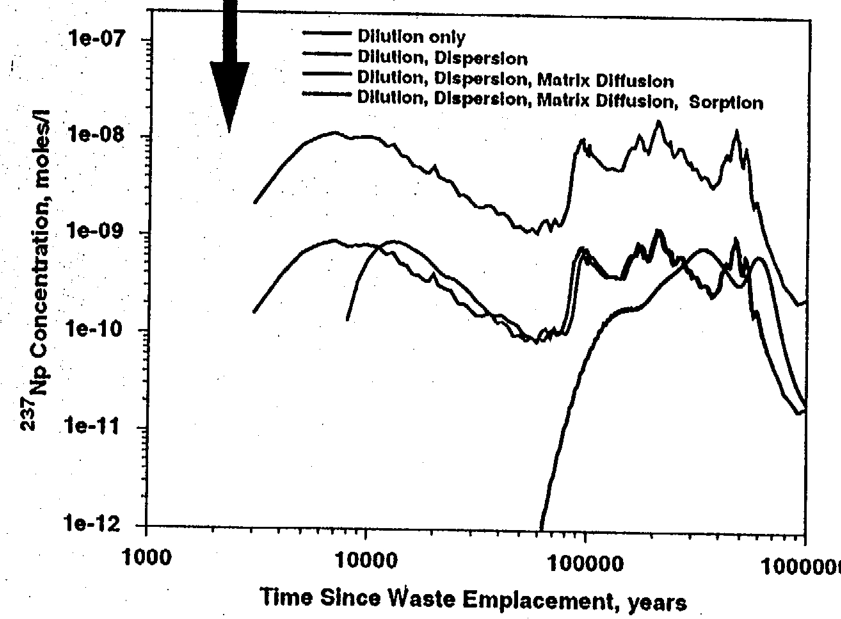
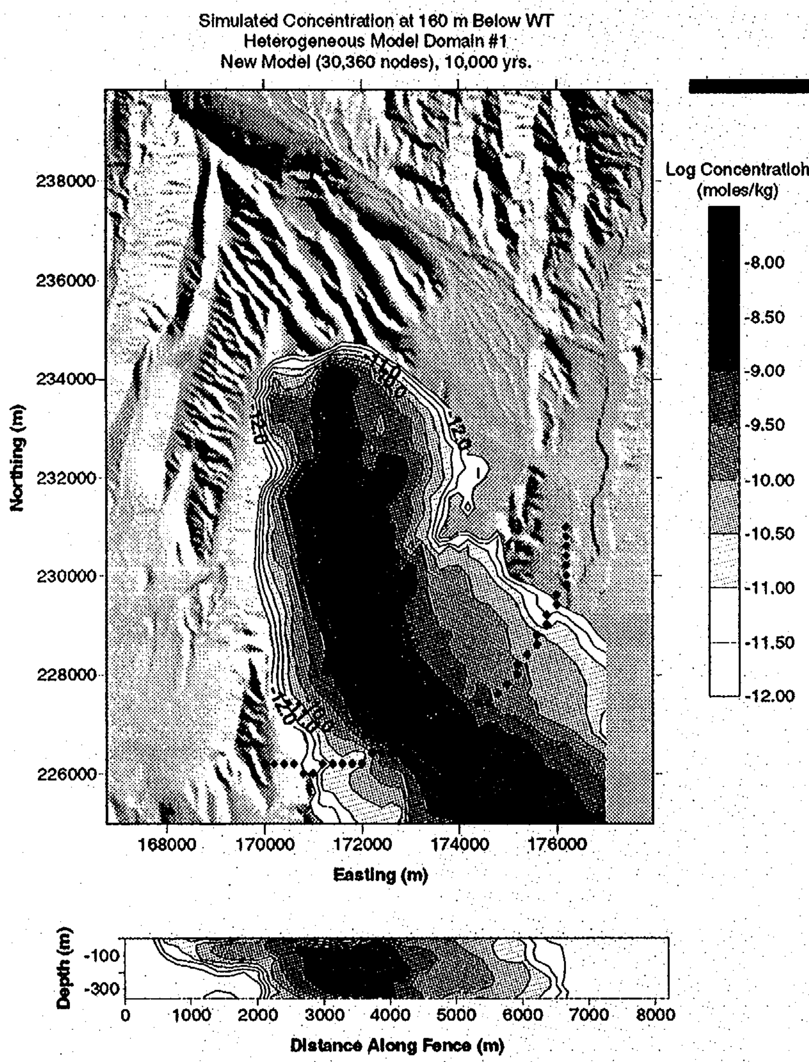
Simulated Concentration at 160 m Below WT
Heterogeneous Model Domain #1
New Model (30,360 nodes), 10,000 yrs.

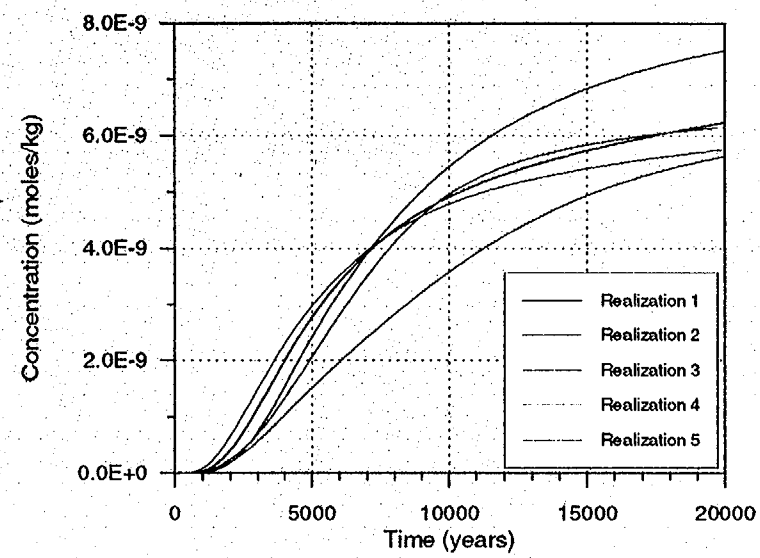




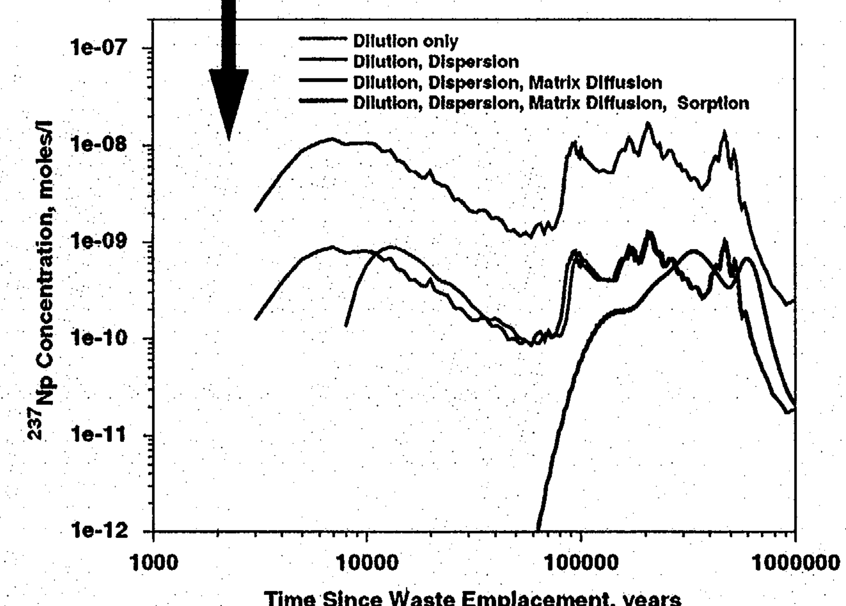
+ UZ Transport Simulation and Convolution







+ UZ Transport Simulation and Convolution



ATTACHMENT 11

YUCCA
MOUNTAIN
PROJECT

Studies

Overview/Status of USGS Saturated-Zone Modeling

Presented to:
DOE/NRC Technical Exchange on
Total System Performance Assessment
San Antonio, Texas

Presented by:
Patrick Tucci
U.S. Geological Survey
Denver, Colorado

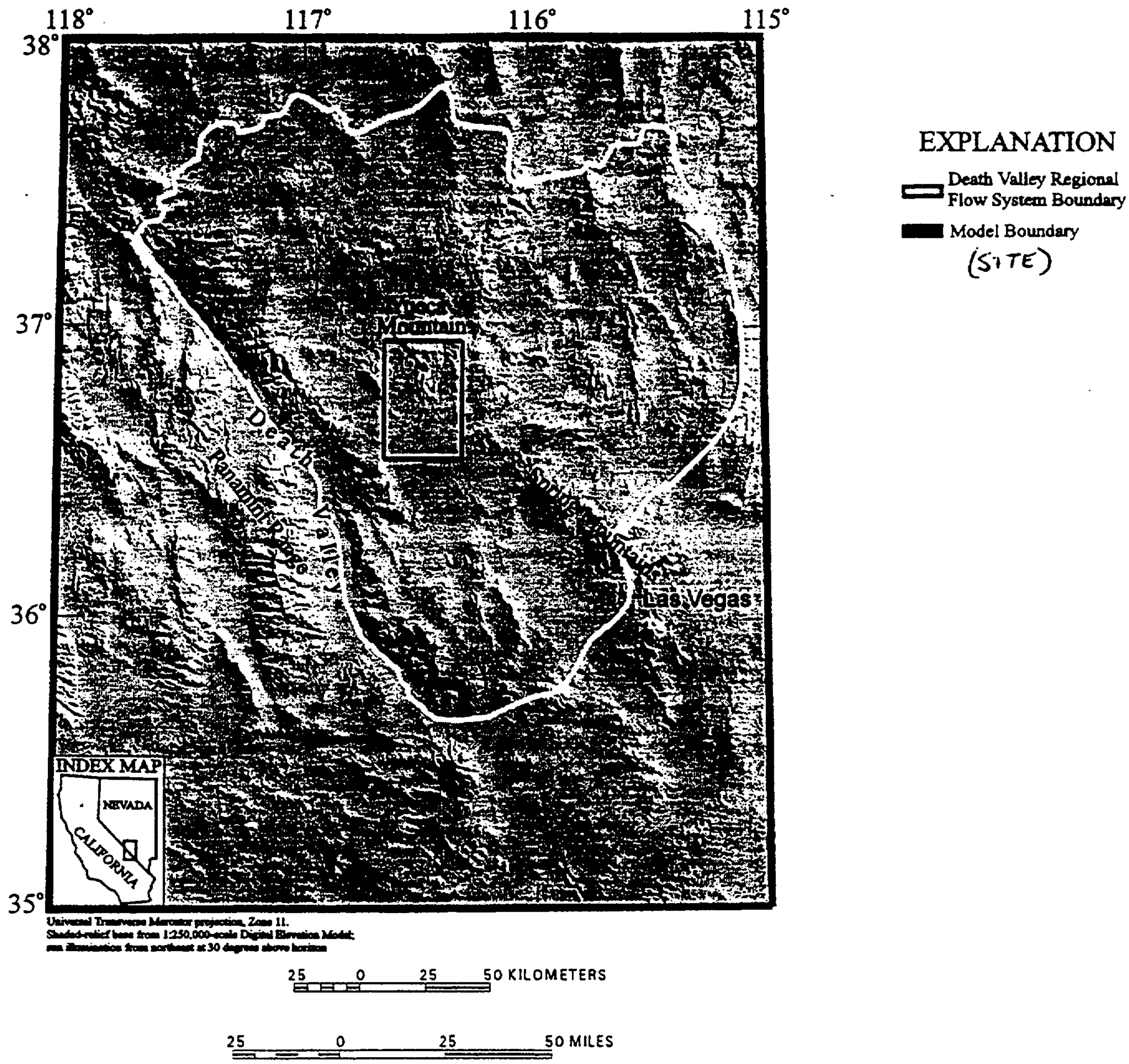
July 21-22, 1997

U.S. Department of Energy
Office of Civilian Radioactive
Waste Management

MODELING AT 2 SCALES

- **REGIONAL: Death Valley GW Flow System**
- **"SITE": 30x40 km, centered on Yucca Mtn.**

Hydrogeologic Framework Models constructed for both scales. Used as basis for flow models.


118°
117°
116°
115°
38°
37°
36°
35°
Death Valley
Panamint Range
Las Vegas
INDEX MAP
NEVADA
CALIFORNIA
EXPLANATION
Death Valley Regional Flow System Boundary
Model Boundary
(SITE)
Universal Transverse Mercator projection, Zone 11.
Shaded-relief base from 1:250,000-scale Digital Elevation Model;
sun illumination from northeast at 30 degrees above horizon
25 0 25 50 KILOMETERS
25 0 25 50 MILES

USGS REGIONAL MODELING

- F. D'Agnese, C. Faunt, M. Hill, G.O'Brien

- Purpose:

  1. Assess regional hydrogeology,
  2. Provide boundary conditions for site model,
  3. Assess climate-change effects on site-model boundaries

- Using MODFLOWP (3d, steady state)

- Status:

  - Steady-state model "completed" (some updates being done this FY)
    - report in press
  - Climate-change effects done this FY report in review

REGIONAL HYDROGEOLOGIC UNITS

Hydrogeologic Unit	Description
Quaternary playa deposits (Qp)	lake bed deposits of silt and clay
Quaternary-Tertiary valley fill (QTvf)	alluvial (stream channel and fan gravels), colluvial, ash fall, and lake deposits
Quaternary-Tertiary volcanic rocks (QTv)	rhyolitic, andesitic, and basaltic lava flows
Tertiary volcanic rocks (Tv)	dominantly rhyolitic ash flow tuffs
Tertiary volcanic and volcaniclastic rocks (Tvs)	tuffs and tuffaceous clastic rocks
Tertiary-Late Jurassic granitic rocks (TJg)	crystalline granitic rocks
Mesozoic sedimentary and metavolcanic rocks (Mvs)	dominantly sandstones
Paleozoic carbonate rocks (P2)	limestones, dolomites, and calcareous shales
Paleozoic-Precambrian clastic rocks (P1)	conglomerates, argillites and quartzites
Precambrian igneous and metamorphic rocks (pCgm)	crystalline rocks (gneisses, schists, and migmatites)

REGIONAL MODEL
Estimated Parameters

- 6 Hydraulic-Conductivity Zones
- 2 Recharge Zones
- Vertical Anisotropy

Model most sensitive to zones of low K and zones of high recharge.

CURRENT FLOW PATHS FROM YUCCA MOUNTAIN

- Based on regional flow model analysis
- East to Fortymile Wash area, then south to discharge points in Amargosa Desert
- Most flow in upper part of flow system (Tertiary volcanics, alluvium, and carbonates)
- Some flow possibly continues south to Franklin Lake playa or deeper into regional carbonate aquifer to Death Valley (or both)

PAST & FUTURE FLOW PATHS

- Based on ***PRELIMINARY*** regional model analysis
  - Past = conditions 21,000 yrs ago
    Recharge = 5x present
  - Future = conditions assume 2x CO_2
    Recharge = 1.5 x present

- ***PRELIMINARY*** Estimated Water Level Rises at Yucca Mtn:
  - Past = 60-150 m
  - Future = 50 m

- Flowpaths not greatly different than present paths

- Discharge in Amargosa Desert; increased discharge to springs and evapotranspiration

USGS SITE SZ MODELING

- J. Czarnecki, C. Faunt, C. Gable, G. Zyvoloski

- Purpose:
  1. Examine complex 3D behavior of flow through aquifers at Yucca Mtn,
  2. Estimate flow direction and magnitude to accessible environment
  3. Identify role of faults on gw flow,
  4. Provide basis for transport modeling.

- Using FEHMN & PEST (3D, transient)

- Status:
  - model being calibrated this FY
  - preliminary model to DOE 6/16
  - report being written

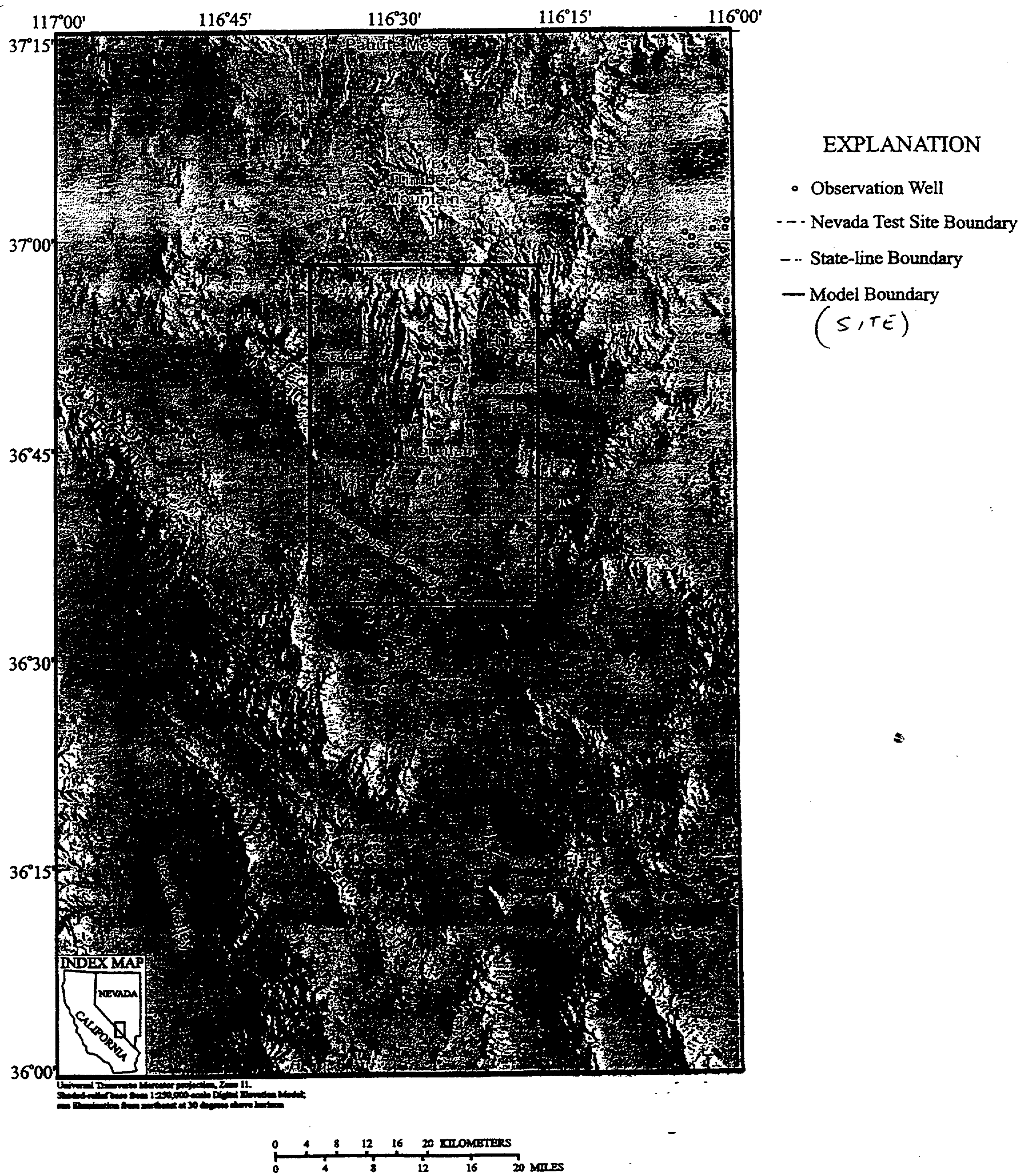
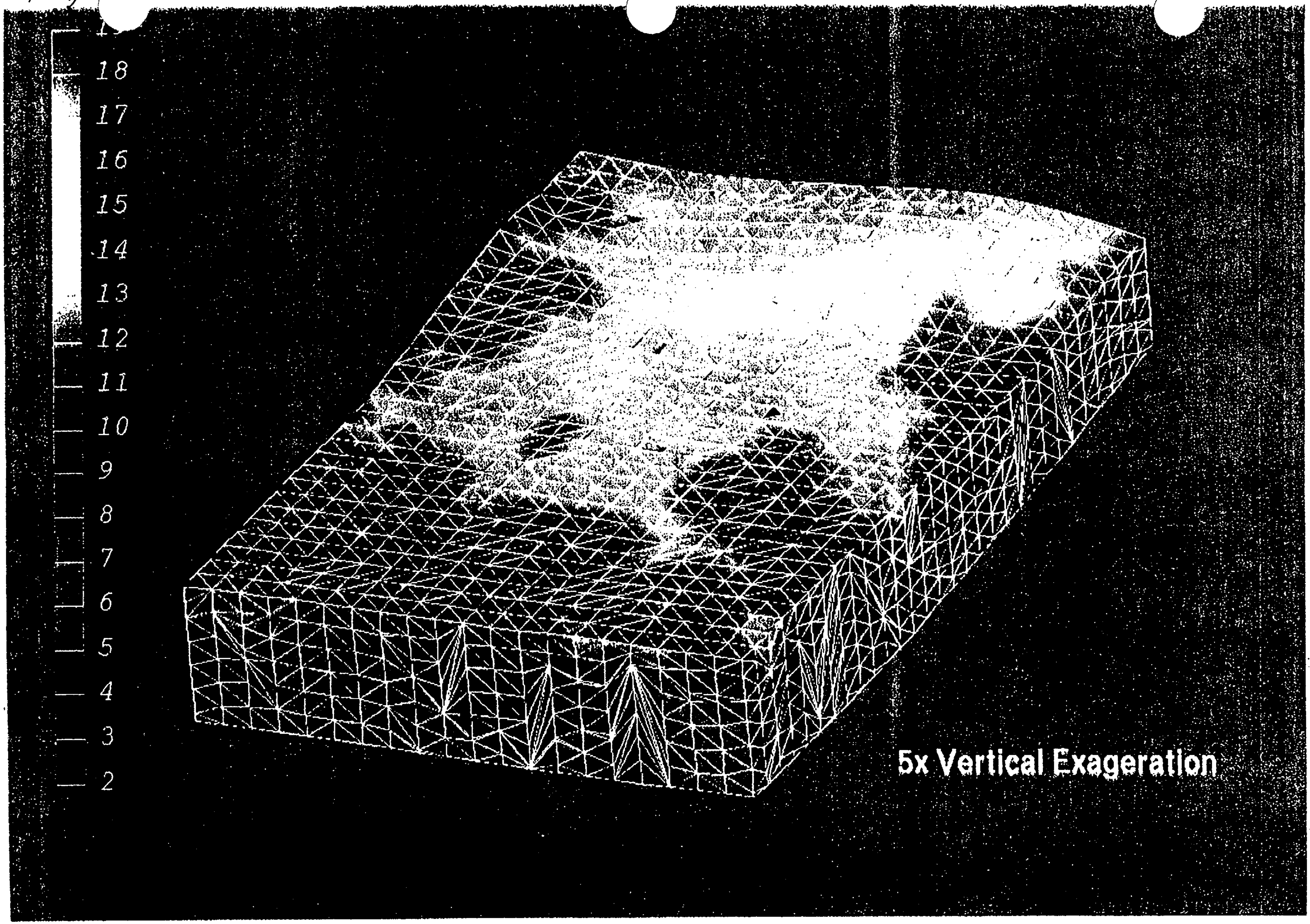


Figure 1. Location map of the study area and associated geographic features.

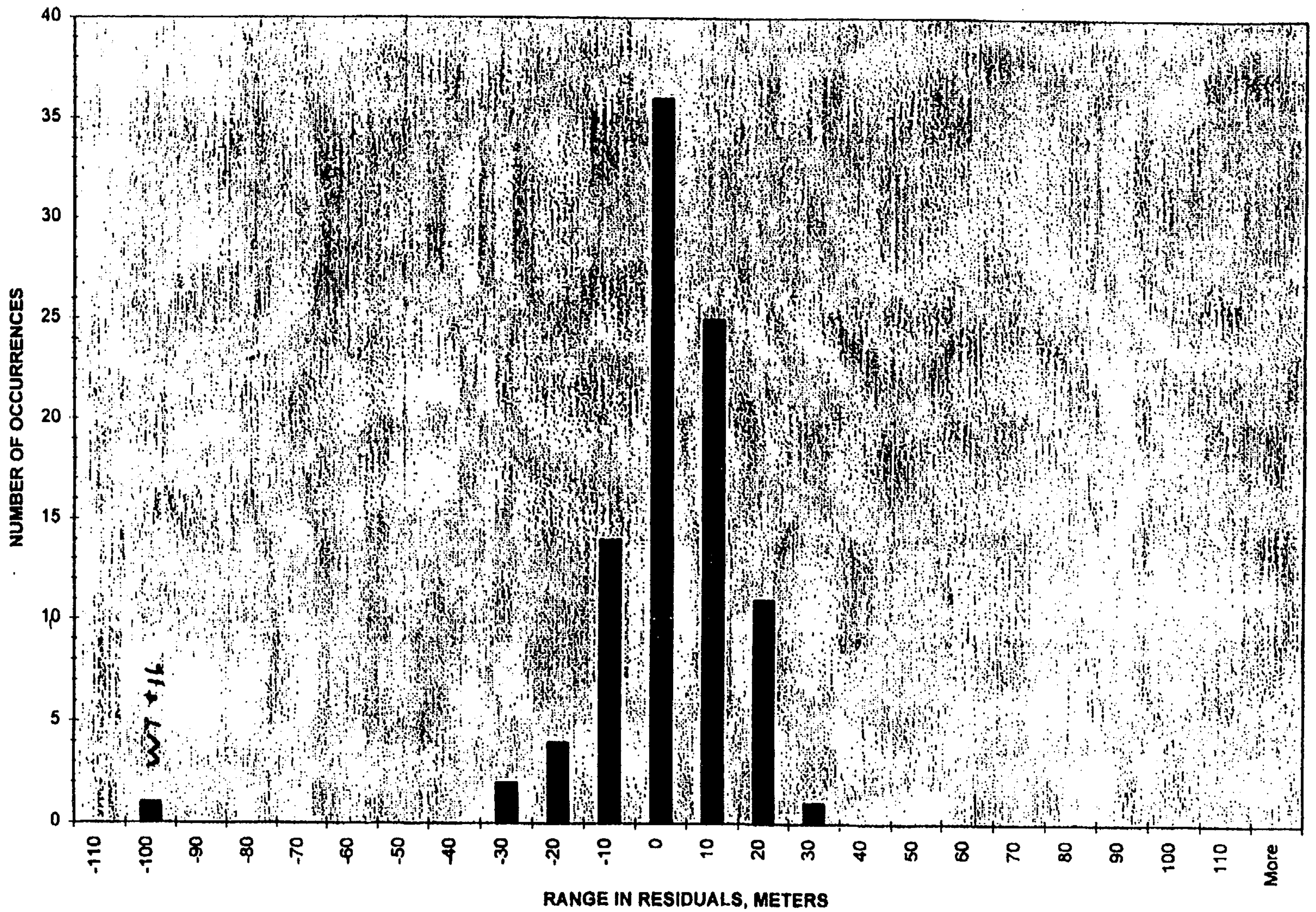
SITE HYDROGEOLOGIC UNITS

Hydrogeologic Unit (#)	Description
Valley-Fill Aquifer (19)	Alluvial fan, fluvial, fanglomerate, lakebed, eolian, and mudflow deposits
Valley Fill Confing Unit (18)	Playa deposits
Tertiary Limestone Aquifer (17)	Lacustrine limestones, spring deposits
Lava-Flow Aquifer (16)	Basalt flows, dikes & cinder cones, latite dikes
Upper Volcanic Aquifer (15)	Variably welded ash-flow tuffs and rhyolite lavas (non-welded tuffs)
Upper Volcanic Confining Unit (14)	Rhyolite lavas, volcanic breccias, non-welded to welded tuffs (argillaceous or zeolitic)
Middle Volcanic Aquifer (13)	Variably welded ash-flow tuffs and rhyolite lavas
Middle Volcanic Confining Unit (12)	Non-welded tuff, commonly zeolitized
Lower Volcanic Aquifer (11)	Variably welded ash-flow tuffs and rhyolite lavas
Lower Volcanic Confining Unit (10)	Non-welded tuff, commonly zeolitized
Lower Valley-Fill Confining Unit (9)	Tuffaceous sandstone, tuff breccia, silt stone, claystone, conglomerate, lacustrine limestone.
Upper Carbonate Aquifer (8)	Limestone
Upper Clastic Confining Unit (6)	Siliceous siltstone, sandstone, quartzite, conglomerate, limestone
Lower Carbonate Aquifer (3, 5, 7)	Dolomite and limestone
Proterozoic Confining Unit (4)	Quartzite, siltstone, shale, dolomite
Granitic Confining Unit (2)	Granodiorite, quartz monzonite

Hydrogeol Unit #



SITE MODEL GRID



SITE SZ MODEL RESULTS

r11/c.

ATTACHMENT 12

YUCCA
MOUNTAIN
PROJECT

Status of Saturated Zone Transport Model

Presented to:
DOE/NRC Technical Exchange on
Total System Performance Assessment
(TSPA)

Presented by:
Bruce A. Robinson
Los Alamos National Laboratory

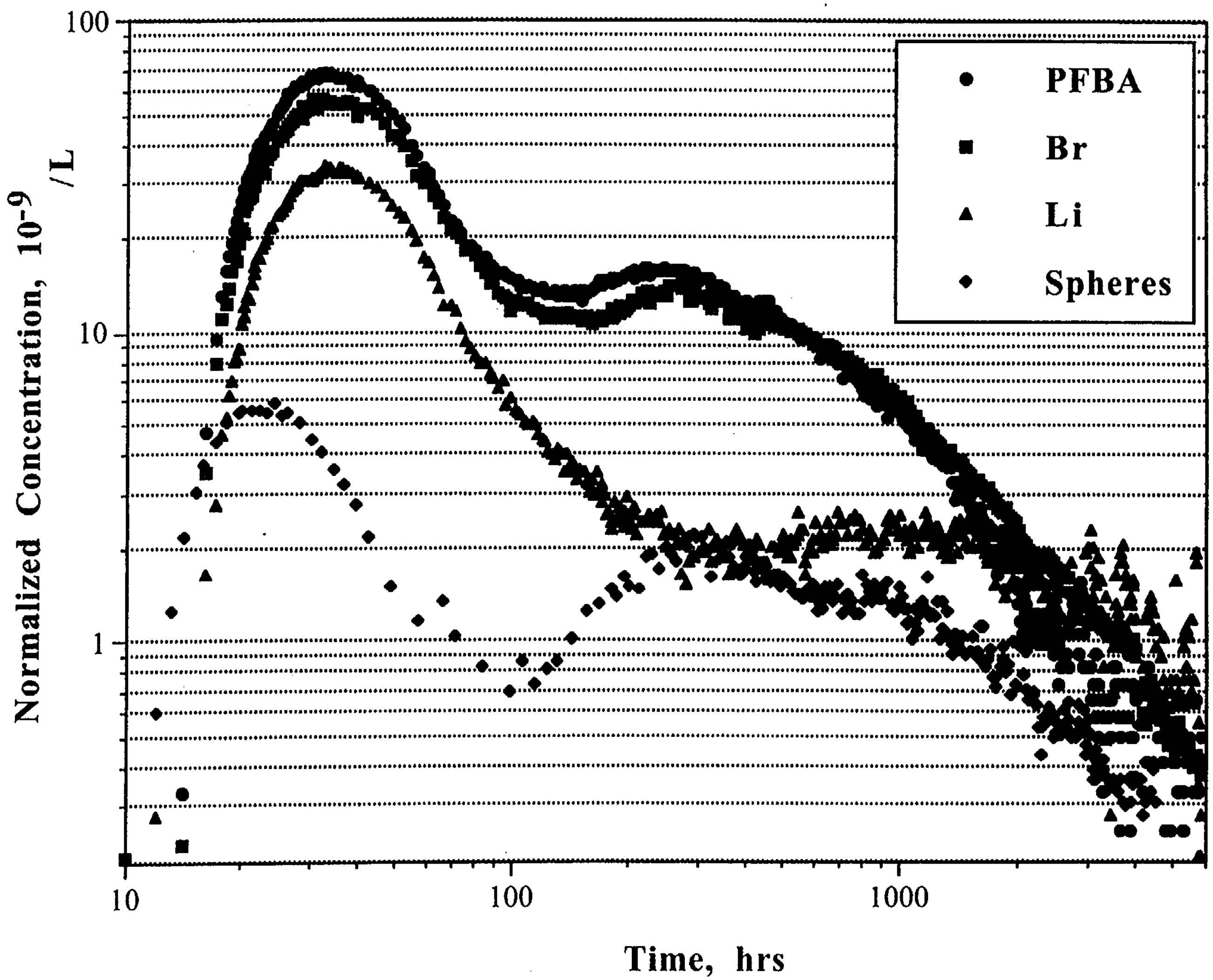
U.S. Department of
Energy
Office of Civilian
Radioactive
Waste Management

July 21-22, 1997

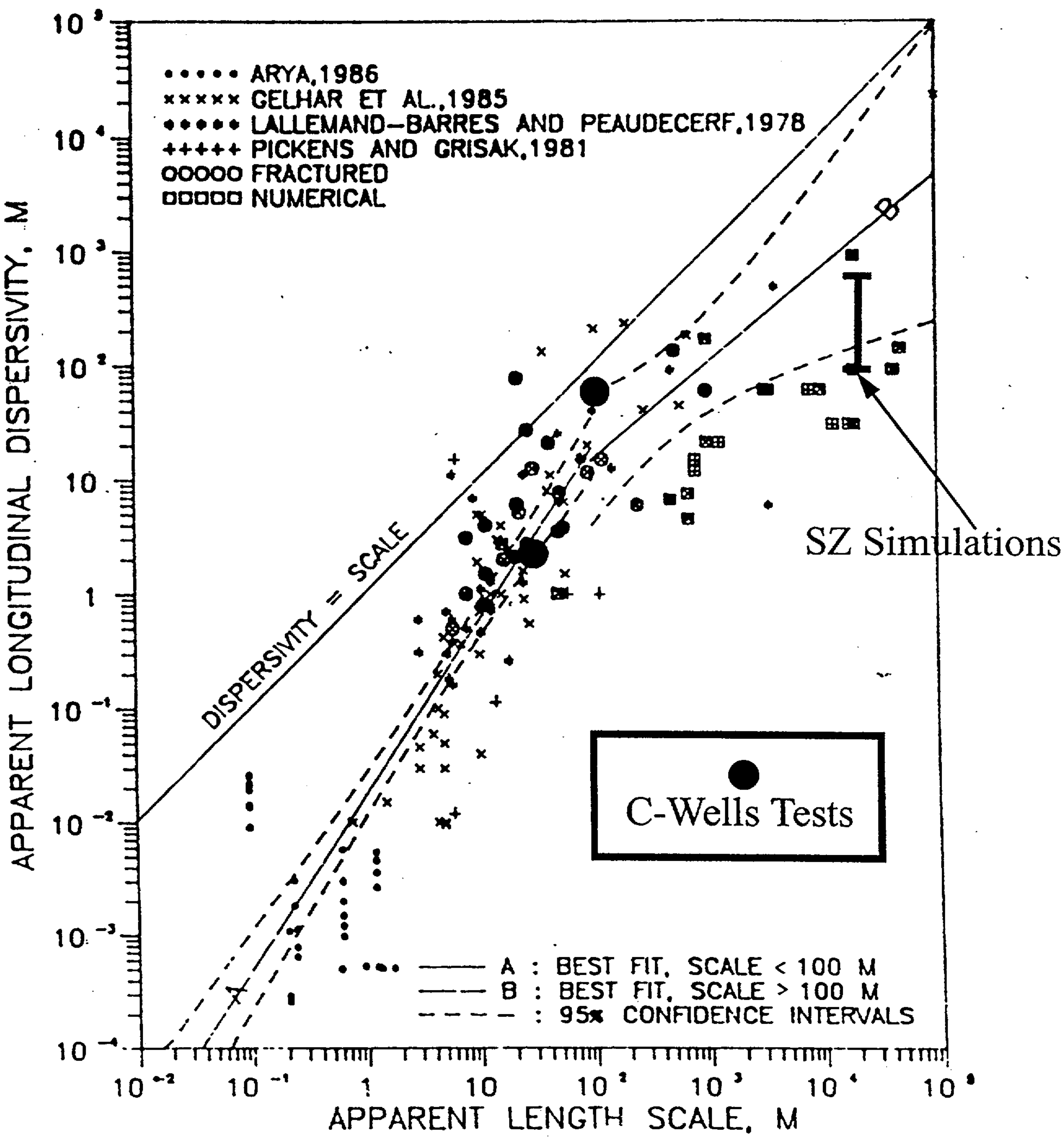
Topics of Discussion

- SZ dispersion and matrix diffusion
- Development of transport grids
- Combined UZ-SZ transport response

C-Wells Reactive Tracer Test

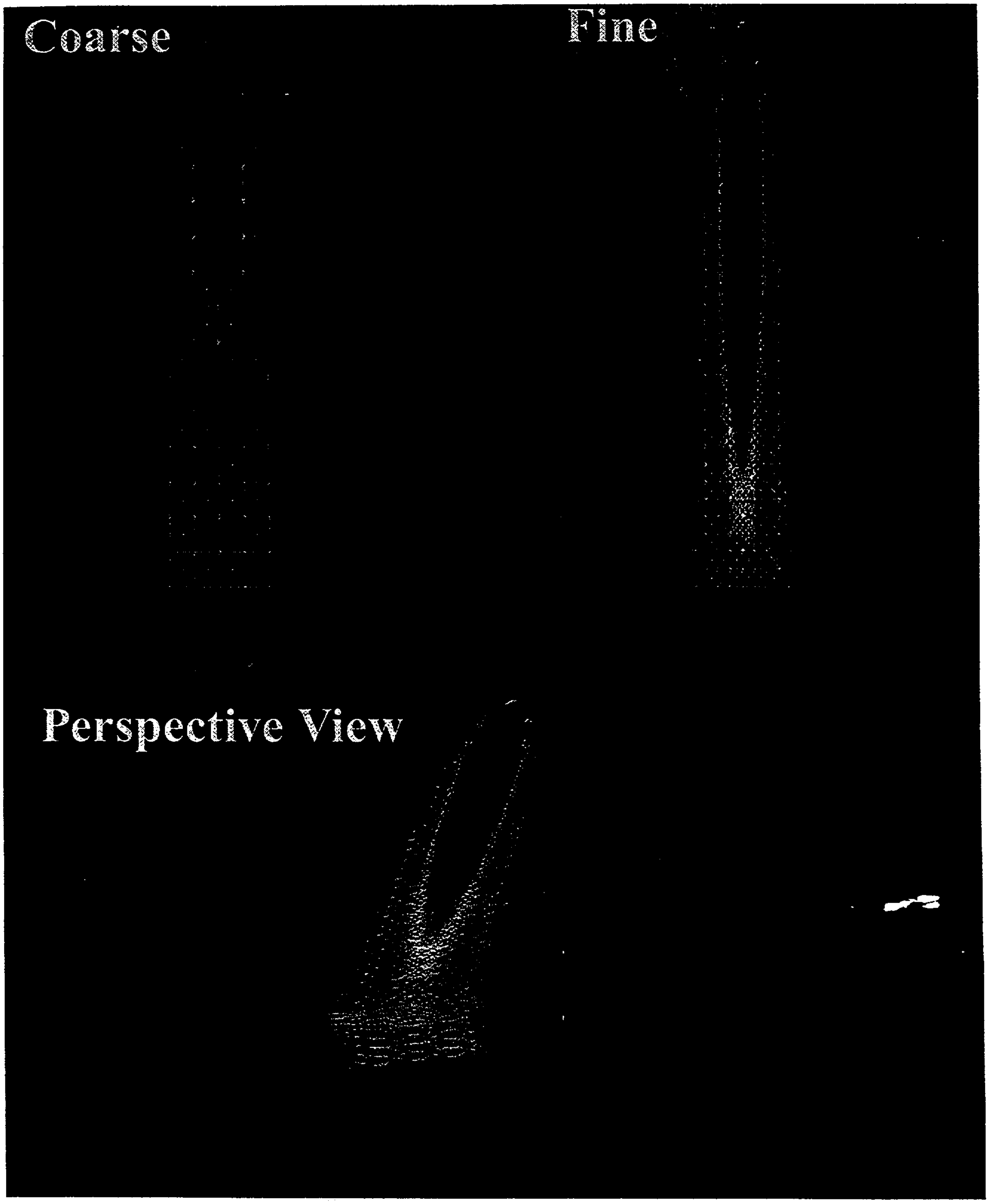


Scale Dependence of Dispersivity

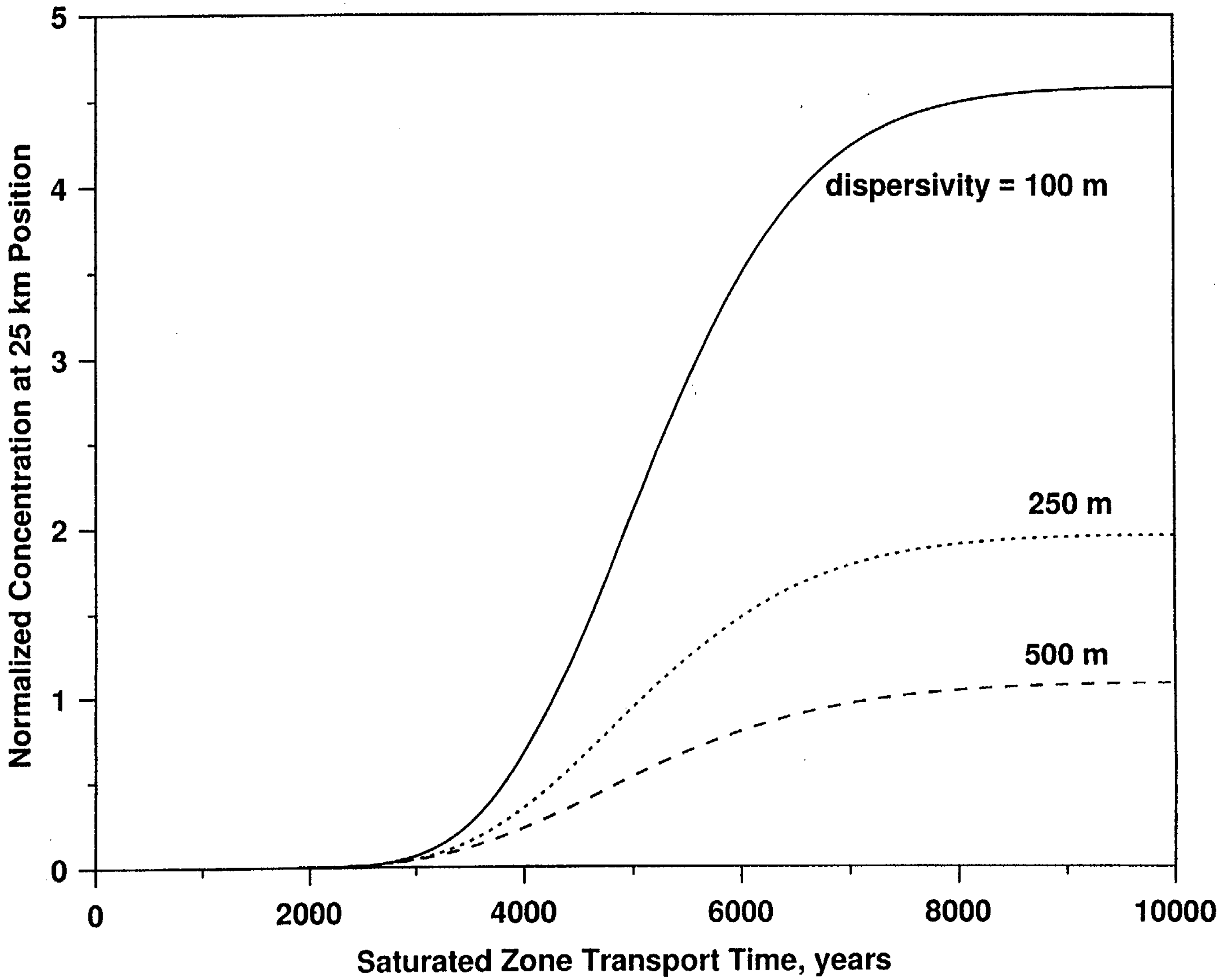


from Neuman, 1990, *Water Resour. Res.*, 26, 8, 1749-1758.

Development of Transport Grid



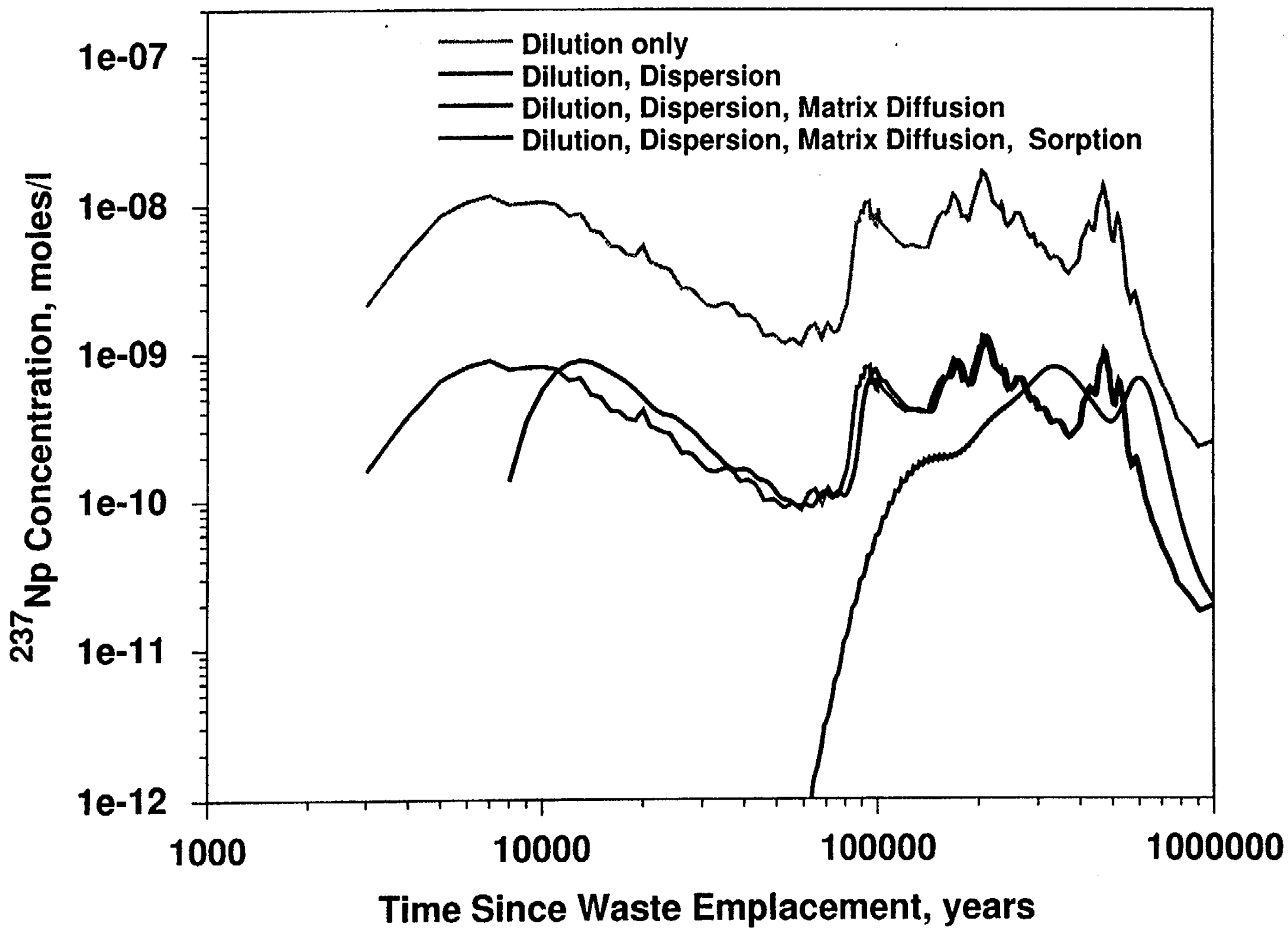
Radionuclide Breakthrough Curves at 25 km



Geoanalysis Group, Los Alamos

Results of Convolution Procedure

$$C_{SZ}(t) = \int_0^t C_{UZ}(t-t')f_{SZ}(t')dt'$$



Current Status - SZ Transport Model

- USGS flow model has been received and initial transport runs have been carried out
- Grid refinement techniques are being performed on the flow model grid
- Numerical techniques have been developed for coupling the UZ and SZ transport models

Conclusions

- SZ has the ability to provide significant dilution of radionuclides from UZ
- SZ provides the greatest dilution to the portion of the inventory that travels rapidly through the UZ
- Sorption and matrix diffusion are quantifiable processes that can be incorporated into SZ transport models

ATTACHMENT 13

NRC STAFF'S OBSERVATIONS OF SATURATED ZONE ABSTRACTION AND EXPERT ELICITATION WORKSHOPS

July 21-22, 1997
NRC/DOE Technical Exchange on
Total System Performance Assessments
for Yucca Mountain

Neil M. Coleman
(301)415-6615/nmc@nrc.gov
Division of Waste Management
Performance Assessment and HLW Integration Branch

NRC STAFF'S OBSERVATIONS OF SATURATED ZONE ABSTRACTION AND EXPERT ELICITATION WORKSHOPS

- The Spectrum of Subissues Identified and Discussed at the Abstraction Workshop encompassed the NRC USFIC KTI Subissues

- To the Extent Credit is taken for Sorption of Typically Mobile Radionuclides (e.g., Neptunium sorption in Alluvium), the Technical Basis Should be Provided in the TSPA-VA

- C-Well Tracer Test Data Suggests Matrix Diffusion Effects. However, Alternative Conceptual Models of Fracture Flow Could Potentially Explain the Observed Effects

- It was Unclear if the Plans for Saturated Zone Analyses would Examine the Effects on Flow associated with Fault Zones, Recharge Along Forty Mile Wash, and Well Pumping

- It was Unclear (i) What Specific Abstractions Would be used to Calculate Dilution below the Repository, Along the Flow Path, and by Well Pumping and (ii) How these Abstractions would be Incorporated into the RIP code

ATTACHMENT 14

ABSTRACTIONS IN TPA VERSION 3.1 CODE

July 21-22, 1997
NRC/DOE Technical Exchange on
Total System Performance Assessments
for Yucca Mountain

Tim J. McCartin
(301)415-6681/tjm3@nrc.gov
Division of Waste Management
Performance Assessment and HLW Integration Branch

ABSTRACTIONS IN TPA 3.1 CODE

- **Site information (including laboratory experiments and information from analogous environments) and results from detailed process models support PA abstractions**

- **TPA Version 3.1 Code developed to provide insights in areas generally considered important to performance and/or very uncertain**

  - **Key elements of subsystem abstractions**
  - **Conceptual model approaches**
  - **Uncertainties**

Presentation will emphasize approaches in the TPA Version 3.1 Code and touch on the information and modeling that supports the abstractions (caution: parameter and model development is continuing —insights and assertions are preliminary)

TPA VERSION 3.1 CODE ABSTRACTIONS

1) Unsaturated Zone Flow and Transport

2) Engineered Barrier System

3) Saturated Zone Flow and Transport

4) Direct Release

5) Dose Calculation

UNSATURATED ZONE FLOW & TRANSPORT

Key Elements of Subsystem Abstractions

- Fracture versus matrix flow
  - matrix conductivity

- Spatial distribution of flow (variation of deep percolation at the repository horizon)

  - Long term climate change
  - Near surface influences on infiltration (evapotranspiration, runoff)
  - Structural controls on the spatial distribution of deep percolation (flow diversion via faults)
  - Thermal reflux due to repository heat load

- Retardation in fractures (radionuclide retardation along transport paths from the repository to the water table)
  - Matrix diffusion (not considered significant at YM)
  - Sorption on fracture surfaces (limited effect)
  - Calico Hills units (K_d for matrix)

UNSATURATED ZONE FLOW & TRANSPORT

CONCEPTUAL MODEL APPROACHES

- Fracture versus matrix flow
  - Transport will be vertical from the repository to the water table
  - Unit hydrologic properties and deep percolation used to determine fracture versus matrix flow (properties of faults considered separately)

- Spatial distribution of flow
  - Long term variation of net infiltration based on paleoclimatic variation (initial infiltration a key input)
  - Spatial variation of deep percolation affects the number of containers that get wet
    1) Spatially "uniform" infiltration conceptual model (infiltration rate and conductivity)
    2) structurally controlled infiltration conceptual model (areal extent of fault zones and cluster fracture zones)

UNSATURATED ZONE FLOW & TRANSPORT

CONCEPTUAL MODEL APPROACHES (Cont'd)

- Thermal reflux will affect flow at the repository level

  1) Rise/fall conceptual model (initially large increase which decreases with time; commencement time and magnitude of increase can be variable)
  2) Bucket conceptual model (intermittent increases which vary with storage considerations)

- Retardation in fractures

  - Matrix diffusion not used
  - Sorption in fractures assumed negligible

UNSATURATED ZONE FLOW & TRANSPORT

UNCERTAINTIES

- Fracture versus matrix flow
  - Matrix conductivity controls transition to fracture flow (for uniform flow model only)
- Spatial distribution of flow
  - Two different conceptual models used for deep percolation
  - Two different conceptual models used for time evolution of thermal reflux
- Retardation in fractures
  - Conservative approach used (limits concern over colloids)

ENGINEERED BARRIER SYSTEM

KEY ELEMENTS OF SUBSYSTEM ABSTRACTIONS

- Waste package corrosion

- Mechanical disruption of waste package
  - Fabrication stresses
  - Seismically induced
  - Fault induced
  - Intrusive volcanism

- Quantity and chemistry of water contacting waste forms
  - Dripping into drifts
  - Water entering waste containers

- Radionuclide release rates and solubility limits
  - Dissolution rate (increases with temperature)
  - Solubility limits (decrease with temperature for some radionuclides)

ENGINEERED BARRIER SYSTEM

CONCEPTUAL MODEL APPROACHES

- Waste package corrosion (temperature, humidity and water chemistry at surface of waste package)
  - Temperature based on a conduction model or table look-up (humidity determined from temperature)
  - Representative container in a subarea used in determining corrosion of container
  - Regimes of different corrosion rates predicted by critical and corrosion potentials
  - Galvanic protection controlled by an efficiency factor

- Mechanical disruption of waste package
  - Mechanical failure determined using fracture mechanics approach

ENGINEERED BARRIER SYSTEM)

CONCEPTUAL MODEL APPROACHES (Cont'd)

- Quantity and chemistry of water contacting waste package and waste form

  - Extrapolation of unsaturated zone flow to water contacting waste should account for the influences of the engineered system
    1) Water flow into drifts (may be sensitive to flow conceptual model)
    2) Failure characteristics of the container (e.g., corrosion pits)
  - Chloride concentration and pH of groundwater are input as single values or table look-up approach to account for evolution of chemistry

- Radionuclide release rates and solubility limits

  - Congruent dissolution of spent fuel
  - Natural analog release model (specified release rate)
  - Dissolution rate versus solubility control
  - Different release models (bath tub, drip)

ENGINEERED BARRIER SYSTEM

UNCERTAINTIES

- Waste package corrosion
  - Effectiveness of galvanic protection
  - Critical relative humidity
- Mechanical disruption of waste package
  - Magnitude of mechanical stress/deformation and material stability
- Quantity and chemistry of water contacting waste forms
  - Parameters used to understand better the sensitivity (at this time process modeling limited)
  - Conservative values used for chloride concentration
  - Evolution of chemistry of water inside container not considered
- Radionuclide release rates and solubility limits
  - Rate controlling process (dissolution or solubility)
  - Role of secondary minerals, cladding, and particle size

SATURATED ZONE FLOW & TRANSPORT

KEY ELEMENTS OF SUBSYSTEM ABSTRACTIONS

- Volumetric flow in production zones

  —Dilution at pumping well

- Retardation in production zones and alluvium (transport processes affecting radionuclide concentrations in the saturated zone at the critical group location)

  — Hydrodynamic dispersion
  — Flow channelization
  — Retardation in production zones in tuff
  — Retardation in alluvium

SATURATED ZONE FLOW & TRANSPORT

CONCEPTUAL MODEL APPROACHES

- Volumetric flow in production zones
  - Radionuclide migration in tuff assumed to occur only in SZ production zones (dilution volume determined for "typical" production zones)
- Retardation in production zones and alluvium
  - Transport velocities will vary with hydrologic unit properties and gradient
  - Retardation considered to be low in tuff production zones (fracture flow)
  - Significant retardation for many radionuclides in alluvium (porous flow)

SATURATED ZONE FLOW & TRANSPORT

UNCERTAINTIES

- Volumetric flow in production zones
  - Conservative assumption that releases go into single production zone in tuff
- Retardation in production zones and alluvium
  - Limited reliance, if any, on retardation in production zone (fracture flow in tuff)

DIRECT RELEASE

KEY ELEMENTS OF SUBSYSTEM ABSTRACTIONS

- Probability of volcanism (probability of direct release of radionuclides by extrusive volcanism)
  - Number of containers affected (extrusive)
- Entrainment of waste in ash
  - Incorporation ratio
  - Waste particle size
- Air transport of ash
  - Deposition and particle size at critical group location
  - Wind speed and direction
  - Eruption energetics

DIRECT RELEASE

CONCEPTUAL MODEL APPROACHES

- Probability of volcanism
  - Based on CNWRA model
- Entrainment of waste in ash
  - Incorporation ratio
  - Grain size of spent fuel
  - Waste package does not affect entrainment
  - Diameter of subsurface area disrupted (amount of waste) estimated using data collected at analogous volcanoes
- Air transport of ash
  - Eruption magnitude is related to ash distribution

DIRECT RELEASE

UNCERTAINTIES

- Probability of volcanism
  - Recurrence rates
  - Structural controls
- Entrainment of waste in ash
  - Magma/waste-package interactions
  - Entrainment of waste in ascending magma
- Air transport of ash
  - Analogous volcanic events

DOSE CALCULATION

KEY ELEMENTS OF SUBSYSTEM ABSTRACTIONS

- Dilution of radionuclides in groundwater
  - Pumping well characteristics and water use of critical group
- Dilution of radionuclides in soil (direct release to surface from volcanism)
  - Plowing and surface processes
  - Resuspension factor
- Location and lifestyle of critical group
  - Diet of locally grown food

DOSE CALCULATION

CONCEPTUAL MODEL APPROACHES

- Dilution of radionuclides in groundwater
  - Concentration of radionuclides in ground water determined based on consideration of flow in repository footprint; tuff production zone flow; and pumping rates necessary to support activities of the critical group
- Dilution of radionuclides in soil
  - Consideration of current farming practices to determine parameters
- Location and lifestyle of critical group
  - Representative person used to calculate dose to average member of critical group
  - Habits and characteristics based on current behavior using cautious and reasonable assumptions

DOSE CALCULATION

CONCEPTUAL MODEL APPROACHES (Cont'd)

- Two locations and lifestyles will be evaluated

  1) Non-farming (less than 20 kilometers down gradient from site)
  2) Farming (more than 20 kilometers down-gradient from site)

- volcanic activity does not affect location and lifestyle of critical group

DOSE CALCULATION

UNCERTAINTIES

- Dilution of radionuclides in groundwater
  - Use of minimum yields
- Dilution of radionuclides in soil
  - Examination of conservative ranges of key parameters
- Location and lifestyle of critical group
  - Conservative approach for interception of plume
  - Use of reference biosphere and cautious and reasonable assumptions

ATTACHMENT 15

YUCCA MOUNTAIN PROJECT

Unsaturated-Zone Flow

Presented to:
DOE/NRC Technical Exchange on
Total System Performance Assessment
San Antonio, Texas

Presented by:
Michael L. Wilson and Susan J. Altman
Senior Members of Technical Staff
Sandia National Laboratories

July 21, 1997

U.S. Department of Energy
Office of Civilian Radioactive
Waste Management

Results of UZ-Flow Workshop — Important Issues

- No numerical ranking of issues, unlike at other workshops
- Criteria for prioritization:
  - Does the issue have a strong effect on percolation flux at the repository?
  - Does the issue have a strong effect on seepage into drifts?
  - Is the issue important to flow/transport below the repository?
  - Does the issue have a strong effect on the partitioning of flow between fractures and matrix?
- The most important issues fall into four categories:
  - Infiltration and future climate
  - Lateral flow and perched water below the repository
  - Flow channelization and seepage into drifts
  - Model calibration

Results of UZ-Flow Workshop — Analysis Plans

- Sensitivity studies on UZ site-scale model
  - Objective: determine UZ-flow abstraction to use for TSPA-VA
  - 14 sensitivity studies were defined and prioritized
  - The highest-priority studies have been done; work on others is continuing
  - LBNL's "base case" has been defined
- Seepage into drifts (pre-waste-emplacement)
  - Objective: Develop seepage model for TSPA-VA
  - Determine hydrogeological conditions under which water will drip into drifts
  - Drift-scale geostatistical simulations have been done, but we do not have flow results yet

Results of UZ-Flow Workshop — Analysis Plans (cont.)

- Testing of perched-water concepts and their implications
  - Objective: Test hypotheses of physical controls on perched-water formation
  - This has been done as part of LBNL's UZ-flow-model development
- Sub-grid-scale fractures and model calibration
  - Objective: Determine importance of sub-grid-scale fractures
  - Alternative formulations of matrix and fracture properties will be investigated
  - This work is just getting started
- Impact of long-term variability in infiltration
  - This study was combined with one in the UZ-transport task

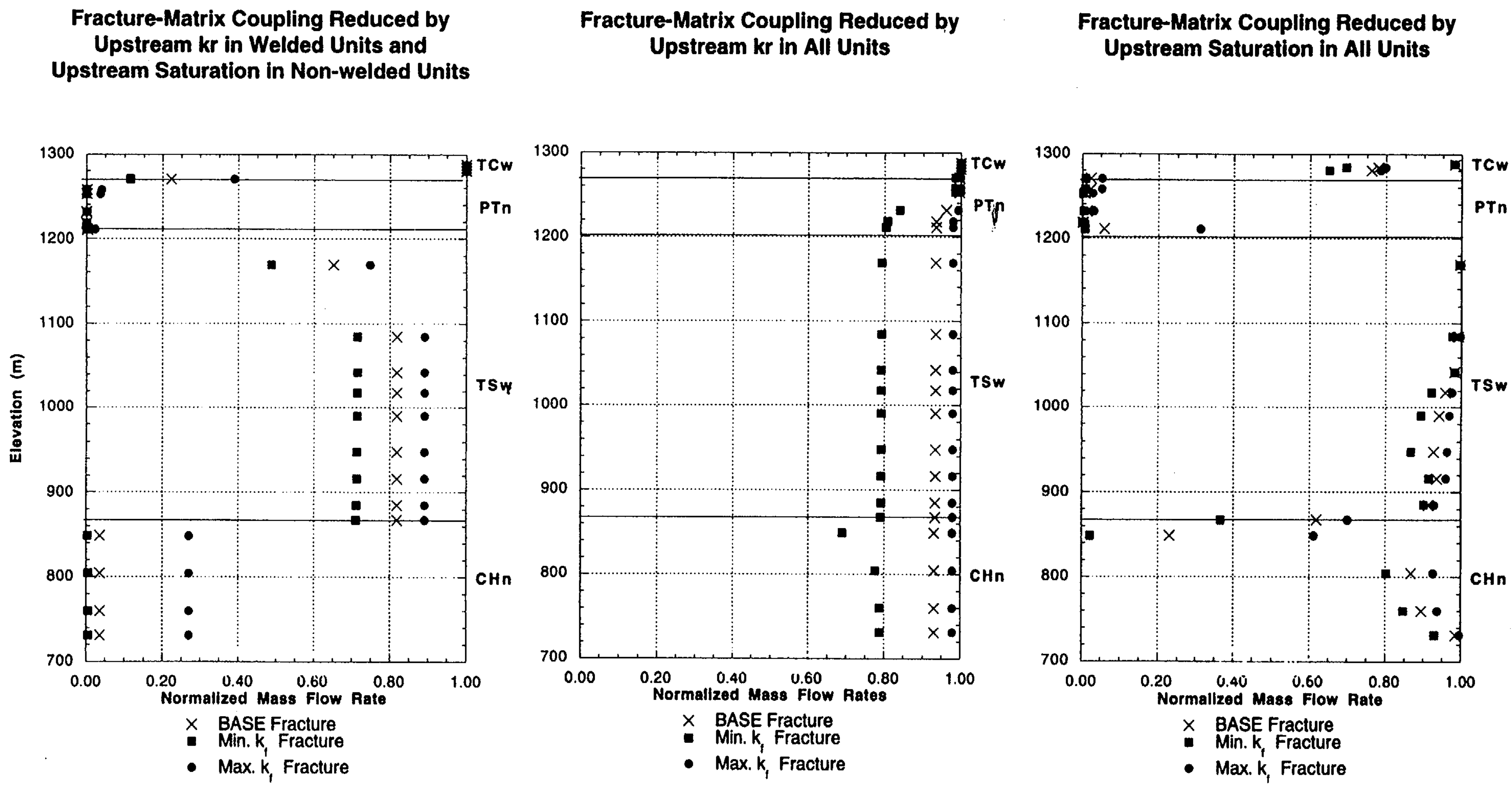
Form of Abstraction for TSPA-VA (Preliminary)

- "Base case" is defined by LBNL milestone of June 1997
  - Dual permeability
  - Fracture-matrix connection area reduced for each layer
  - TOUGH2 or FEHM to be used for flow calculations, in 3-D if practical
- At least one alternative model will be defined
  - Alternative fracture properties and fracture-matrix coupling are being considered
- Uncertainty in infiltration rate will be included discretely
  - Calibration must be redone for each infiltration assumption
  - Weightings will be based on the UZFM expert elicitation
- A few key hydrologic parameters will be sampled within ranges that do not disrupt the model calibration

Form of Abstraction for TSPA-VA (Continued)

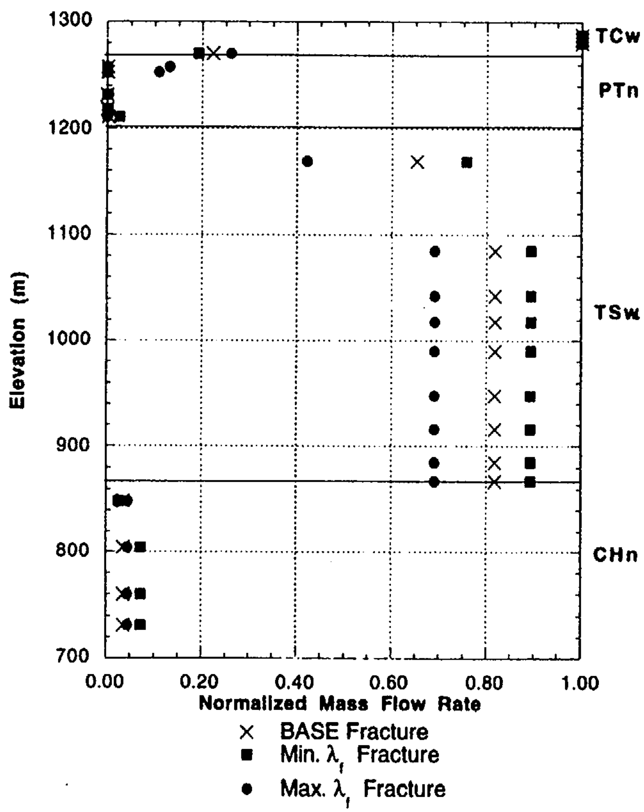
- Climate changes will be modeled by means of a series of steady states
  - Currently considering the following climate states: present conditions, global warming (increased CO_2), “little ice age”, glacial maximum, long-term average
- Separate seepage model will provide input to NFE, WPD, etc.
  - Probably response surfaces for fraction of containers contacted and flow rate(s) as functions of local fracture flux, fracture hydrologic properties, and possibly other factors
- Modification of far-field flow and seepage due to thermal effects is being considered in the UZ-thermohydrology task

Varying Fracture Permeability

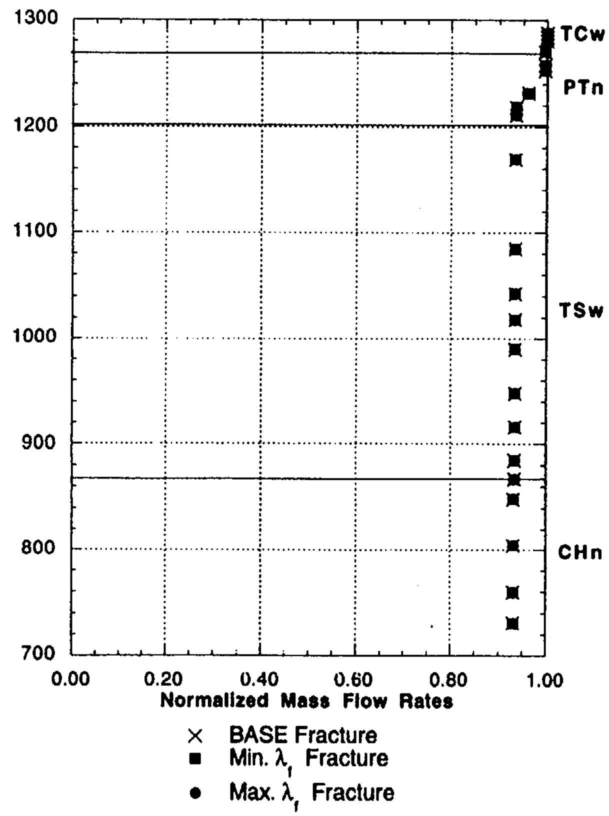


Varying Fracture Lambda

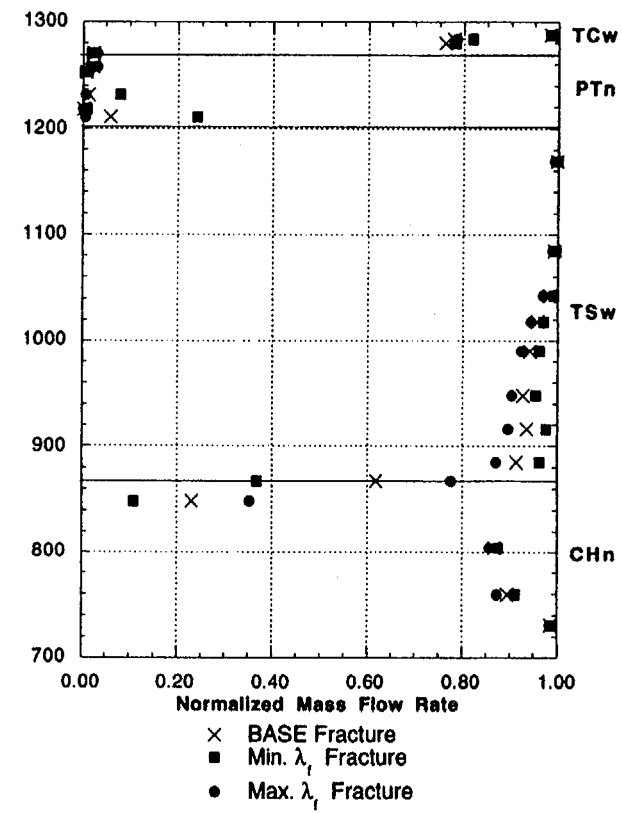
Fracture-Matrix Coupling Reduced by Upstream kr in Welded Units and Upstream Saturation in Non-welded Units



Fracture-Matrix Coupling Reduced by Upstream kr in All Units



Fracture-Matrix Coupling Reduced by Upstream Saturation in All Units



ATTACHMENT 16

YUCCA
MOUNTAIN
PROJECT

Studies

The Unsaturated Zone Site-Scale Flow Model

Presented to:
DOE/NRC Technical Exchange on
Total System Performance Assessment (TSPA)

Presented by:
G.S. Bodvarsson
Lawrence Berkely National Laboratory

July 21-22, 1997

U.S. Department of Energy
Office of Civilian Radioactive
Waste Management

NRC/DOE
TSPA Technical Exchange

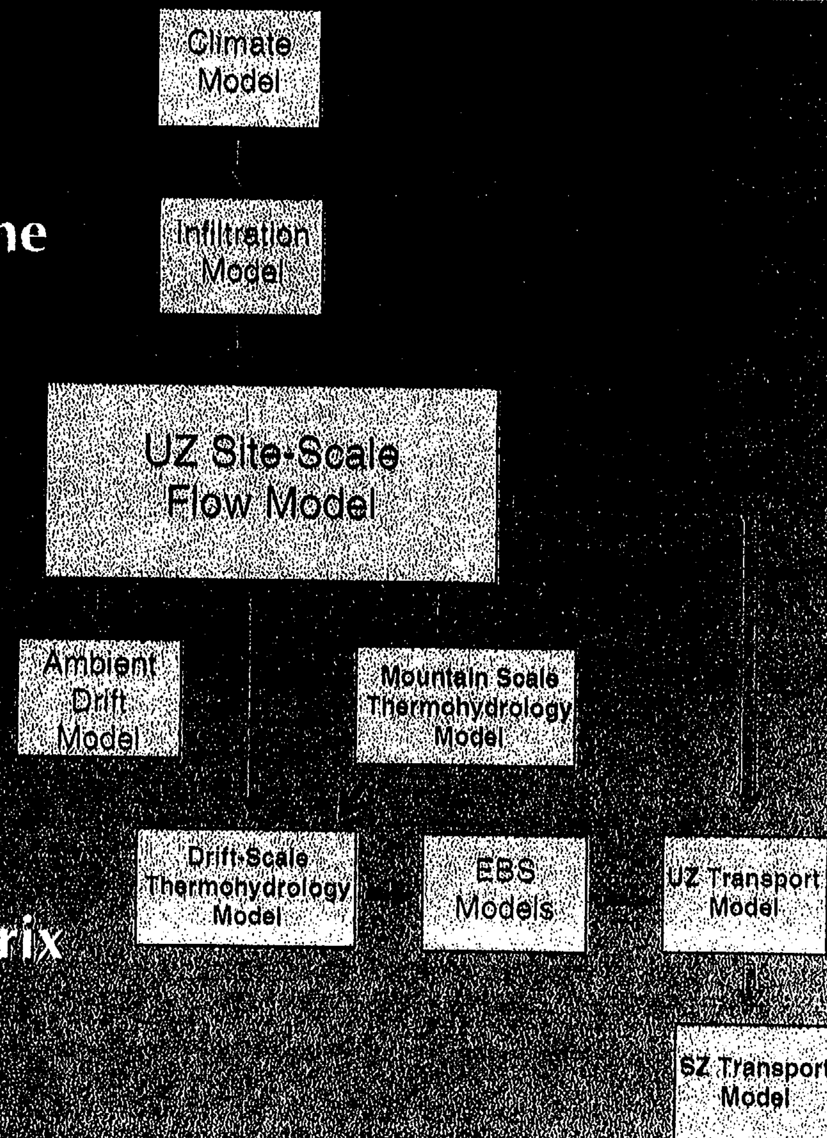
The Unsaturated Zone
Site-Scale Flow Model

G.S. Bodvarsson

July 9, 1997

The UZ Site-Scale Flow Model

- A numerical model that integrates all of the available data from the unsaturated zone into a single model
- A model that is calibrated against various data sets including hydrological, geochemical, pneumatic and thermal data sets
- The primary purpose of the model is to determine percolation flux, fracture/matrix components of flow and flow patterns below the repository



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Large amount of geological, hydrological, geochemical and thermal data are incorporated into the UZ Model

Current ESF testing and planned E-W drift testing will significantly reduce the uncertainties of the Model

1995

Boreholes
Surface Geology
Matrix Properties
Pneumatics
Perched Water
Envir. Isotopes

(Wittwer et al.)

Analytical Results

1-D, 2-D
models
faults
flow

3-D model
infiltration

1996

Surface Geology
Matrix Properties
Boreholes
-gas pressure
-temperature
Envir. Isotopes
Perched Water

(Bodvarsson & Bandurraga, eds.)

Analytical Results

3-D Site-Scale Model
Mass/Energy Balance
Coupled Processes
ECM, Duel-K
Gas Pressure Module
Radionuclide Transp.
Fracture/Matrix Flow
Inverse Modeling
Model Calibration
Enhanced GFM
Gas Pressure Analysis
Saturation Analysis

1997

Surface Geology
Matrix Properties
Boreholes
-gas pressure
-temperature
Envir. Isotopes
Perched Water
Fracture
Properties
Fault Properties
Prelim. ESF Data
Hydrochemistry

(This Report)

Analytical Results

Conceptual Model Update
Refined Grids
Addl. Coupled Processes
Pneumatic Analyses
Thermal Analyses
Hydrochemistry
Cl Geochemistry
SR Analysis
C-14 Analysis
Envir. Isotope Analysis
Integrated Modeling
Percolation Flux
Perched Water
Fracture/Matrix Flow
Flow Under Repository
Prelim. GWTT
Climate Changes
Fracture Flow

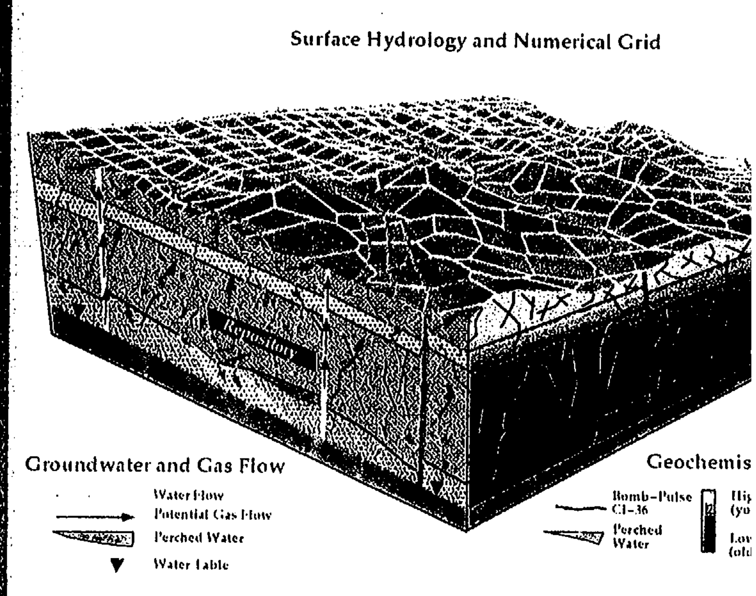
New Data

ESF Data
Niche Studies
New Boreholes
Cross Drift
Drift to Drift
Alcoves:
• N. Ghost DanceFault
• S. Ghost Dance Fault
Pit Studies
Solitario Canyon Fault Testing

Next Iteration of UZ Model

Major Results of UZ Site-Scale Flow Model for

- Current average percolation flux is estimated to be 1-10 mm/yr in t repository area
- Current average percolation flux cannot exceed 20 mm/yr
- Geochemical evidence including total CL, C-14 and Sr helps bound percolation flux, as does the temperature data
- Bomb-pulse CL-36 represents only a very small fraction of total flow, and may be over-emphasized
- Over 80% of flow in TSw occurs through fractures
- Flow occurs through thousands or millions of flow channels, each carrying small amounts of water



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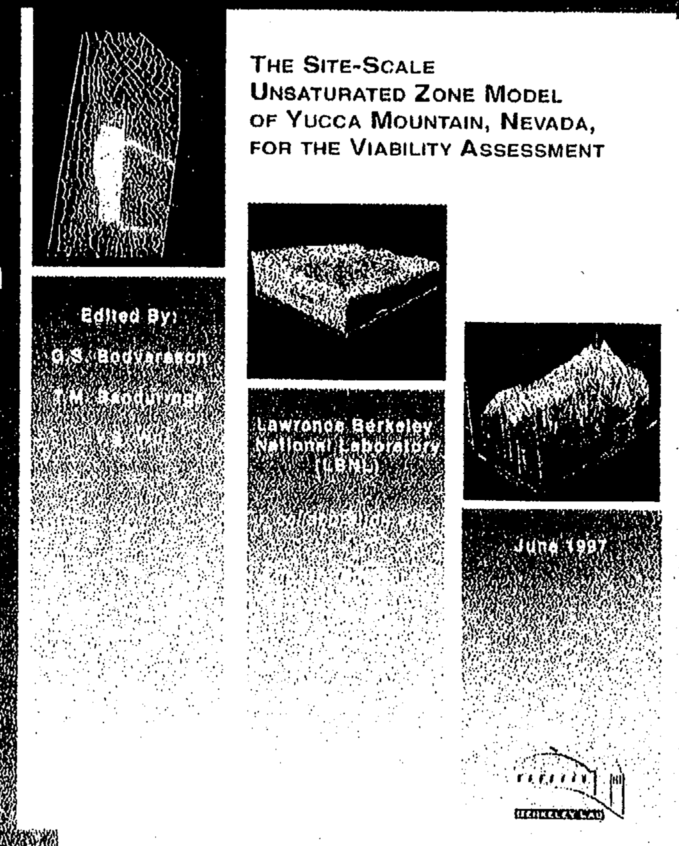
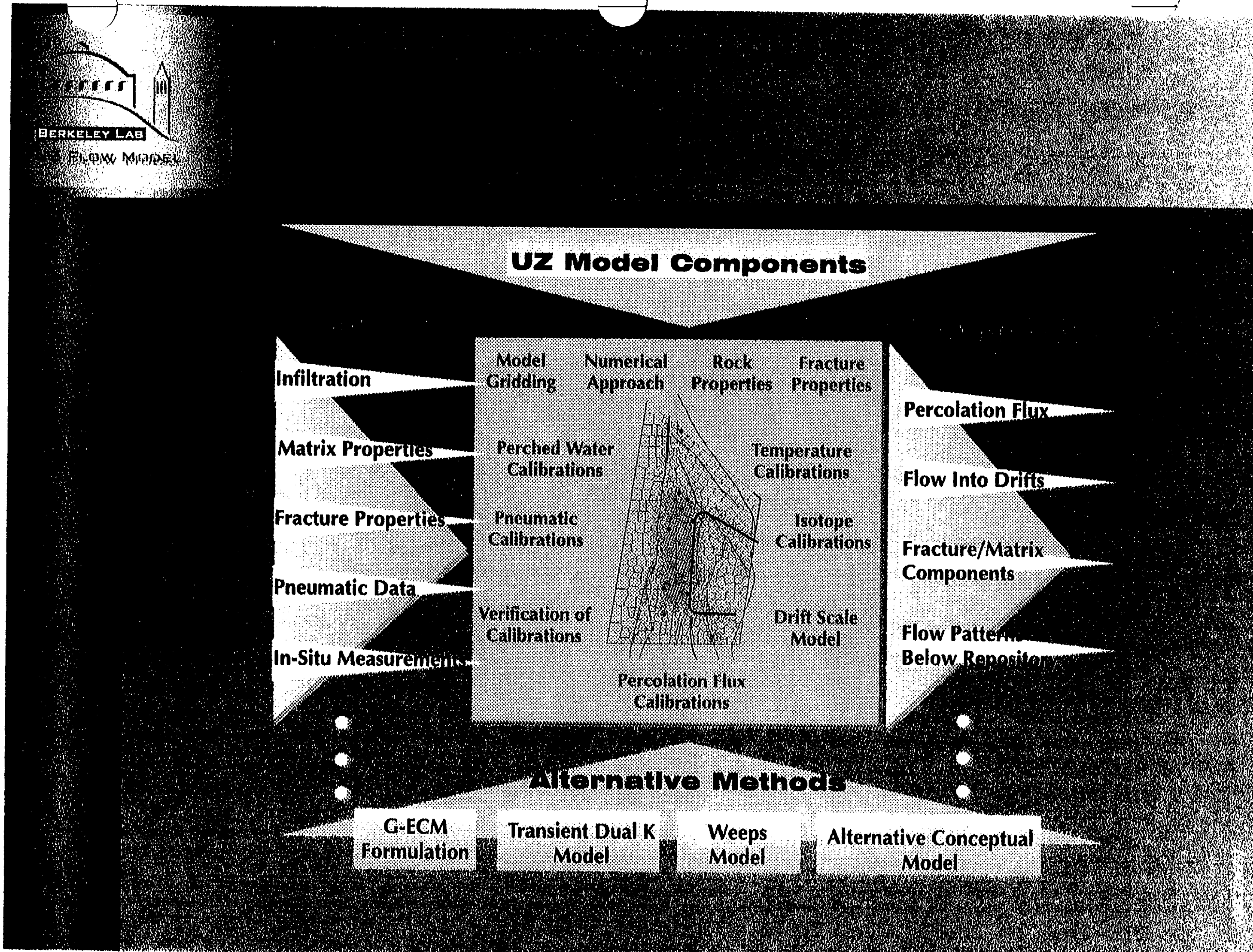
Major Results of UZ Site-Scale Flow Model for VA (cont.)

- Little, if any, water will seep into drifts
- Different fracture/matrix interaction conceptual models lead to different calibrated hydrological properties
- Flow patterns below the repository horizon are uncertain; it is estimated that about 25% of the total flow passes through sorptive zeolitic rock
- Future climate change analysis is estimated to incrase percolation flux multi-fold, and will elevate perched water levels by less than 10 meters

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FLOW MODEL
UZ Model Components
Infiltration
Matrix Properties
Fracture Properties
Pneumatic Data
In-Situ Measuremen
Model Gridding
Numerical Approach
Rock Properties
Fracture Properties
Perched Water Calibrations
Temperature Calibrations
Pneumatic Calibrations
Isotope Calibrations
Verification of Calibrations
Drift Scale Model
Percolation Flux Calibrations
Percolation Flux
Flow Into Drifts
Fracture/Matrix Components
Flow Patte
Below Reposito
Alternative Methods
G-ECM Formulation
Transient Dual K Model
Weeps Model
Alternative Conceptual Model

UZ Site-Scale Flow Model for VA

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Summary of UZ Model for VA: Chapter 1

Conceptual Model of UZ: Ch. 2	Geological Model Ch. 3	Grid Generation Ch. 4	Various Conceptual and Numerical Models Ch. 5

Calibrating F/M Properties Ch. 6	Fracture and Fault Properties Ch. 7	ESF Data and Analysis Ch. 8	TOUGH2 Surface Hydrology Model Ch. 9	Pneumatic Data and UZ Model Ch. 10	Moisture Flow w/Refined Grid Ch. 12	Perched Water Analysis Ch. 13

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UZ Site-Scale Flow Model for VA: (Continued)

Temperature and heat flow data Ch. 11	Hydrochemical Analysis Ch. 14	Chloride Geochemistry Ch. 15	Environmental Isotopes Ch. 16	Strontium Geochemistry Ch. 17	Carbon-14 Analysis Ch. 18

Integrated 3-D Site-Scale UZ Flow Model: Chapter 19

Percolation Flux Ch. 20	Analysis of Fracture and Matrix Flow Components Ch. 21	Flow Patterns Below Repository Ch. 22	Effects of Future Climate Change Ch. 23	Alternative Modeling Approaches In Fractured Rock Ch. 24

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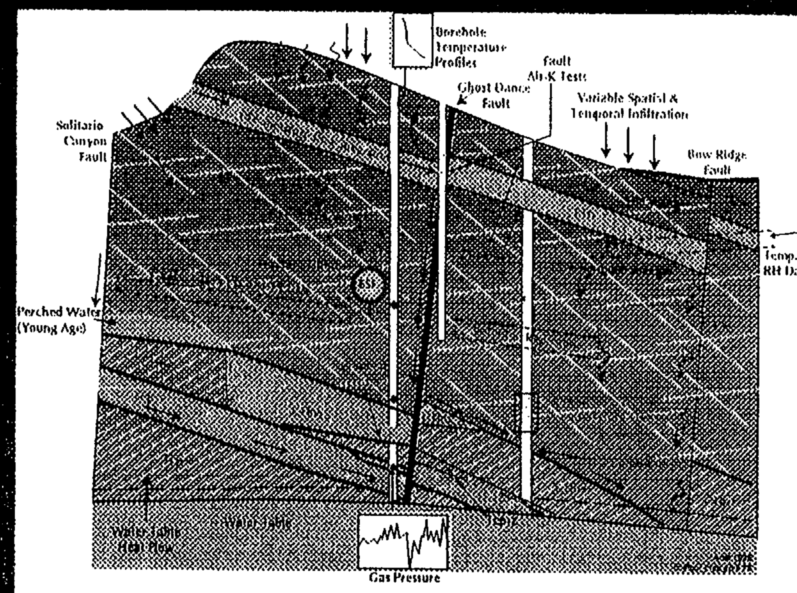
Conceptual Model of Flow and Transport at Yucca Mountain

- Summary of geological framework used to develop numerical grids for the Site-scale UZ model.
- Summary of hydrological framework used in UZ model.
- Issues include:
  - Steady-state and transient phenomena
  - Spatially variable infiltration
  - Matrix and fracture flow partitioning
  - Effects of major faults
  - Perched water sources
  - Effects of zeolites and perching layers on flow pathways
  - Geothermal gradients and their use in constraining infiltration rates
  - Ages of perched water bodies and observations of bomb-pulse isotopes
  - Disequilibrium between Cl concentrations in perched water and matrix pore water



Conceptual Model of Flow and Transport at Yucca Mountain

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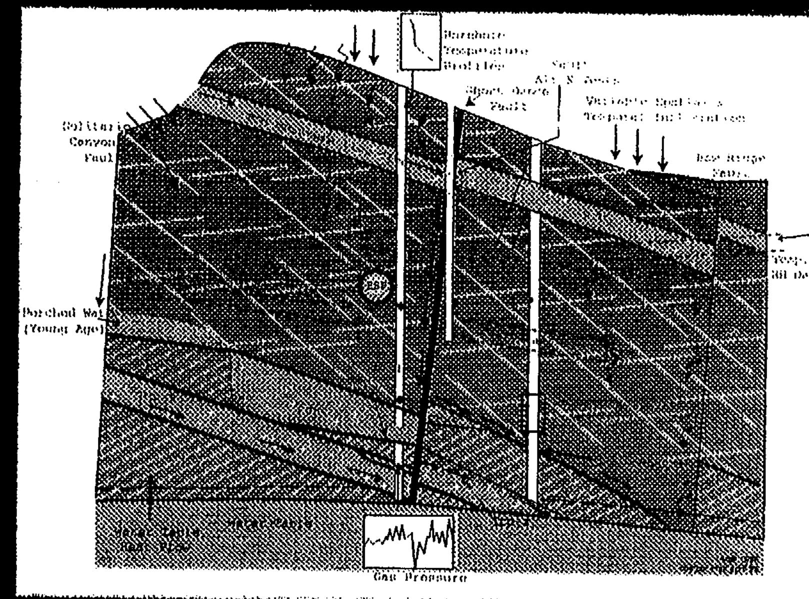
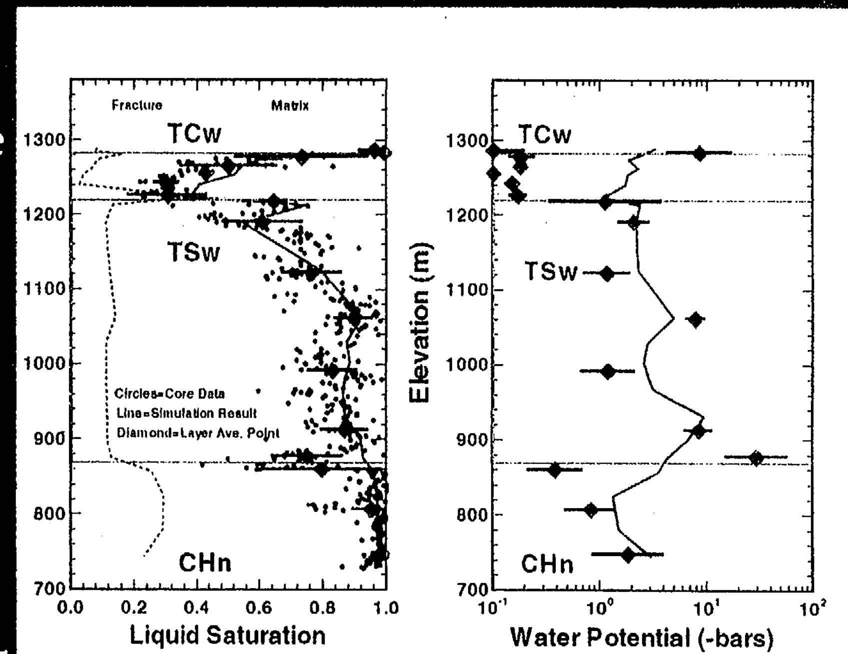
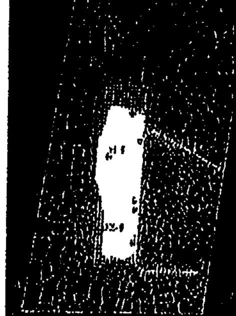


Calibrating Matrix and Fracture Properties Using Inverse Modeling

- Saturation, water potential, geochemical, and pneumatic data from five boreholes were matched simultaneously to generate calibrated layer-averaged property sets for the UZ site-scale model.
- Various conceptual models for fracture/matrix interaction were investigated and a number of calibrated parameter sets were generated.



- Sensitivity analyses evaluated the effect of boundary conditions (infiltration), model formulation (ECM and dual-k), and fracture-matrix interaction models on the parameters sets.
- Individual inversions were performed to evaluate the spatial variability in the properties across the model domain.



Calibrating Matrix and Fracture Properties Using Inverse Modeling (cont.)

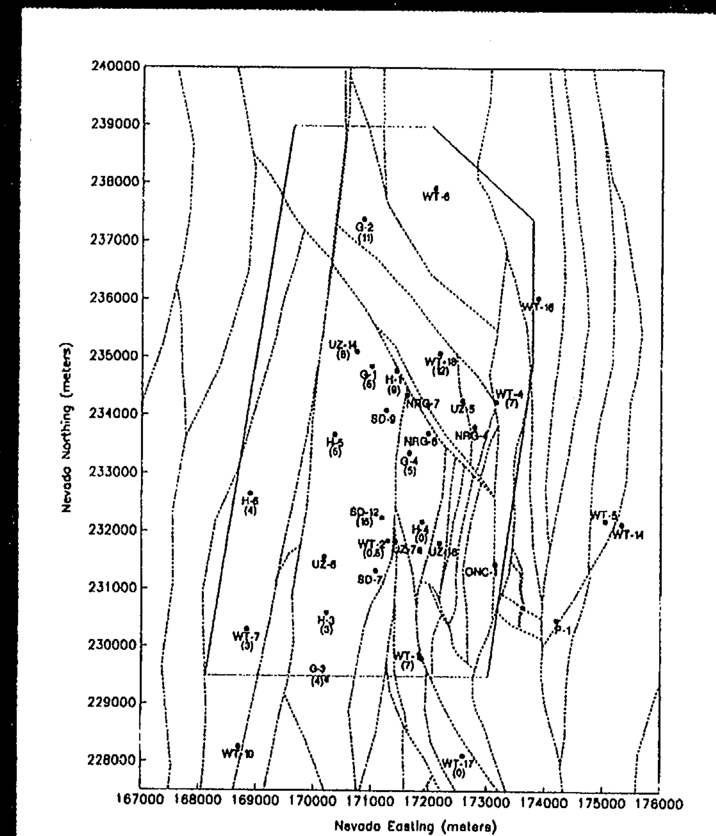
- The resultant parameter sets were made available to YMP process modelers through an anonymous ftp site. The sets are used by the LBNL UZ modeling group, LANL transport modelers, PA staff, LBNL drift-scale modelers, LLNL drift-scale modelers, and others.
- Recommendations
  - 3-D inversions to capture lateral diversion effects.
  - Use temperature and geochemical data to constrain infiltration rates

Table 7.4.1-2. Calibration Results and Standard Deviations (St. Dev.)

Model Layer	Result (log) Fm=0.667	Result (log) Fm=0.492	Initial St. Dev. (log)	JSD (log) Fm=0.492	Result (log) Fm=0.667	Result (log) Fm=0.492	Initial St. Dev. (log)	JSD (log) Fm=0.492
	Matrix Permeability (m**2)				Fracture Permeability (m**2)			
tcwM1	-17.27	-17.27	0.44	0.51	-11.22	-11.22	0.61	0.71
tcwM2	-17.27	-17.27	0.44	0.51	-11.22	-11.22	0.61	0.71
tcwM3	-16.30	-16.31	1.53	1.78	-11.62	-11.62	1.00	1.16
ptnM1	-13.80	-13.51	2.59	1.81	-12.54	-12.52	0.38	0.44
ptnM2	-14.48	-14.52	1.48	1.51	-12.35	-12.36	0.46	0.49
ptnM3	-13.27	-13.08	0.94	0.76	-11.52	-11.54	0.38	0.44
ptnM4	-13.06	-12.94	0.40	0.42	-12.93	-12.93	0.42	0.49

Temperature Data Analysis

- Percolation flux can be estimated from temperature data.
- A new multi-layer analytical model was derived for the analysis of temperature data.
- Results suggest percolation flux for most boreholes in the range of 1 to 10 mm/yr.
- Exceptions are Boreholes G-2, SD-12 and UZ-1.
- Analysis of temperature data from shallow boreholes yields unreliable results because of gas flow.
- Significant vertical gas flow may be occurring in major faults, masking temperatures.



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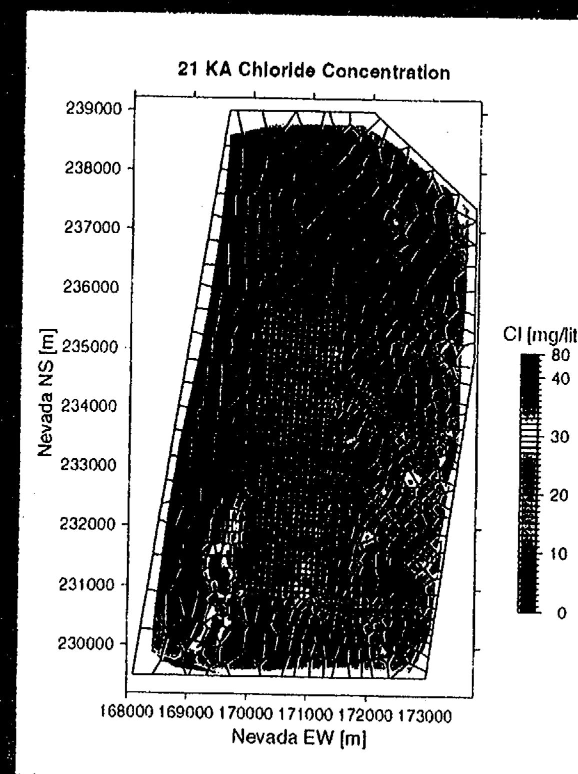
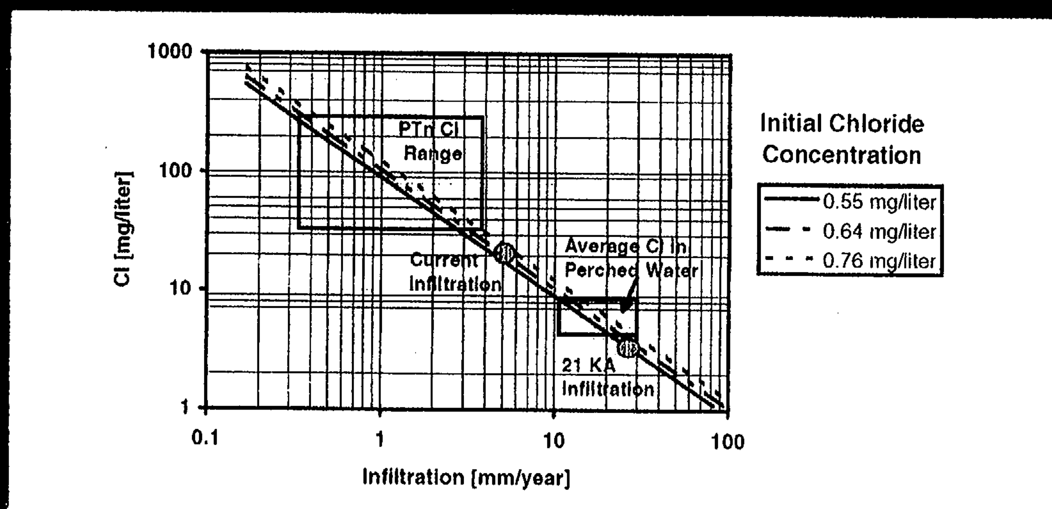
Modeling the Chloride Geochemistry in the Unsaturated Zone

- A 3-D model for spatial and temporal variations in chloride chemistry is presented.
- Surface distributions of chloride concentrations are estimated using precipitation and infiltration maps, and measured concentrations.
- The mean infiltration over the UZ model area may be as low as 1 mm/yr, and certainly lower than 4.9 mm/yr (USGS estimation).
- Waters of the last glacial maximum or prior could be present in the PTn and TSw under low infiltration regions.
- Perched water compositions are closely matched using 21 ka precipitation and infiltration scenario.



Modeling the Chloride Geochemistry in the Unsaturated Zone

- There may be significant mixing of high-chloride water under alluvial channels with low-chloride water flowing laterally in the PTn.
- High chloride concentrations under alluvial deposits are likely to mask bomb-pulse ^{36}Cl, as predicted for the Ghost Dance Fault at the ESF



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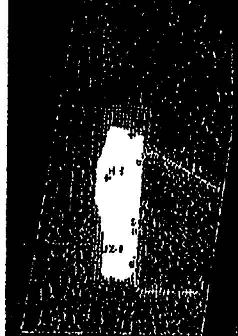
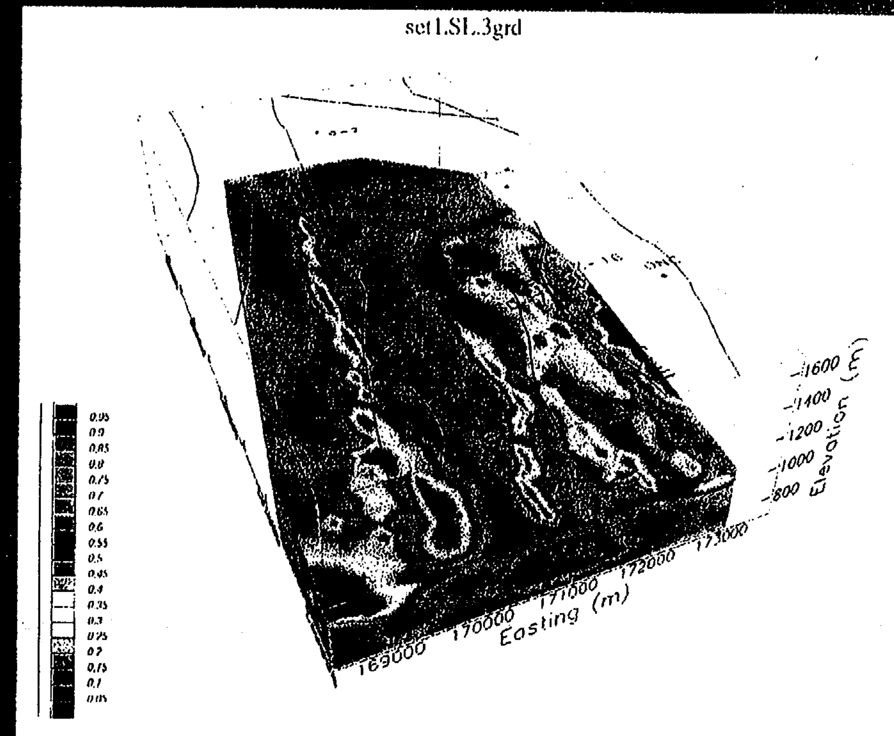


Integrated 3-D Site-Scale UZ Flow Model

- The integrated 3-D site-scale flow model is summarized for FY97.
- The two geological models for LBNL and ISM2.0 are consistent.
- The 3-D site-scale UZ flow model can reproduce the observed moisture and perched water conditions at Yucca Mountain.



- A 3-D, dual-permeability, perched water model was developed
- Local adjustments of rock properties and model grid layer refinement is needed at certain vitric and/or zeolitic layers in CHn.
- A best set of parameters for the TSPA-VA calculations should be determined using a comprehensive approach.

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UZ Model Expert Elicitation

Recommendation	Action
LBNL develop a surface hydrology module for TOUGH2	Preliminary module developed during Elicitation; tested on a 2.0 cross section in Wren Wash; full evaluation in FY98 planning
Dual-K model needed above Ptn, ECM model adequate below that	UZ model has dual-K model throughout entire unsaturated zone
Fast-paths need to be modeled, and more faults added and the sensitivity evaluated	UZ model matches bomb-pulse Cl-36 data; we have added more faults
Transient component of flow needs to be modeled	We have performed sensitivity studies of transient flow
Investigate alternative models to the continuum models, e.g. Weeps model	A new activity of alternative models has been incorporated into FY98 planning
Model mass balance of perched water and water table fluctuation	Perched water mass balance is included in FY97 report
Predictability of which fracture flow should be modeled as random	Currently fracture flow is modeled using dual K continuum with all or some random fractures flowing
Perform uncertainty and error analysis of heat flux and temperature data	We have developed an analytical model for the evaluation of temperature data, that allows for uncertainty and error analysis
Run UZ model to examine effects of higher infiltration; do many "what-if" studies	We have performed some studies and the results suggest that UZ model becomes inconsistent with observed data for average percolation flux rates exceeding 20mm/yr

ATTACHMENT 17

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Studies

Unsaturated-Zone Radionuclide Transport (UZRT) Abstractions

Presented to:
DOE/NRC Technical Exchange on
Total System Performance Assessment
San Antonio, Texas

Presented by:
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Sr. Performance Assessment Analyst
M&O/INTERA

July 21, 1997

U.S. Department of Energy
Office of Civilian Radioactive
Waste Manager

Issue Categories at UZRT TSPA Workshop

- **Physical transport processes:**
  - fracture/matrix interaction
  - transient flow and transport
  - hydrodynamic dispersion
- **Chemical interactions:**
  - adsorption and rock/water interactions
  - colloids
  - repository-perturbed environment: coupled T-H-C-M effects
- **Heterogeneity:**
  - lateral flow
  - stratigraphy
  - areal heterogeneity
- **Model calibration**

Ranking Criteria for Issue Prioritization

- Radionuclide concentration
- Radionuclide velocity
- Liquid flux
- Distribution of travel times to the water table

Issues Ranking from UZRT Workshop

Sub-Issue	Master Sort: Issues 1, 2, and 3 Group 1	2	3	4	Total
1.1 What conceptual model should be used for fracture/matrix interactions?	18	18	18	16	70
1.4 How should long-term transient flow be included in UZRT modeling?	18	18	14	16	66
1.2 What range and dependencies should be used for the fracture/matrix interaction parameter?	16	16	14	16	62
2.3 Is the minimum Kd approach an appropriate modeling approach for UZRT?	16	16	14	16	62
3.1 Do we expect lateral diversion of radionuclide pathways to be important for UZRT?	12	16	18	16	62
3.4 Do we expect that a more detailed stratigraphy (than the TSw, TSv, CHnv, CHnz, PPn) below the repository to be important for UZRT?	16	14	14	18	62
3.5 Do we expect areal variations in abundance and composition of zeolites to be important for UZRT?	16	14	12	18	60
2.1 Do we expect colloids to play an important role in UZRT?	16	14	16	12	58
1.7 What are the key fracture and matrix properties to consider (i.e., fracture porosity)?	12	16	14	14	56
3.9 Spatial distribution of infiltration	10	16	10	18	54
2.5 Do we expect thermal-chemical alteration of existing minerals to be important for UZRT?	12	12	14	14	52
3.6 Are 1,2, or 3-D models needed for modeling the effects of areal heterogeneity on UZRT? (Does the dimensionality of the models for areal heterogeneity affect performance?)	12	16	8	16	52
2.6 Do we expect aqueous geochemical evolution due to the repository to be important for UZRT?	14	10	10	6	40
2.4 Do we expect adsorption in fractures to be important to UZRT?	12	8	8	10	38
1.3 How should short term transients be included in UZRT modeling?	8	6	8	12	34
1.6 Do we expect lateral dispersion to be important to UZRT? Can a smeared source term be used?	12	6	4	10	32
3.3 How should the stratigraphy (and flow field) above the repository be treated for UZRT models?	8	8	8	8	32
1.5 Do we expect longitudinal dispersion within fractures and/or matrix to be important for UZRT if fracture/matrix exchange is explicitly modeled?	8	8	4	8	28
2.7 Do we expect thermohydrologic/mechanical effects on flow to be important for UZRT?	8	6	8	6	28
2.8 Do we expect natural geochemical evolution to be important to UZRT?	4	4	6	4	18

Incorporation of UZRT in TSPA-VA

- **Sensitivity analyses being conducted to support UZRT "abstractions":**
  - Fracture/matrix interactions: models and parameters
  - Transient flow and transport
  - Colloid-facilitated transport
  - Sorption models for UZRT
  - Fine-scale heterogeneity and dispersion
- **Software and Model Architecture:**
  - Dynamically link process code (i.e., FEHM particle tracking) with RIP V5.x, using 3-D YMP flow/transport model and/or one or more 2-D cross-sections from YMP flow/transport model.

Base Case for UZ Transport Analyses

- Consistent with hydrogeologic parameters and boundary conditions developed in UZ flow model:
  - stratigraphy, faults
  - definition of model boundaries
  - conceptual model for flow (including f/m interaction)
- From UZRT sensitivity analyses develop "base case" uncertainty ranges for transport parameters:
  - matrix diffusion
  - sorption for matrix, fractures
  - hydrodynamic dispersion
  - porosity
- From UZRT sensitivity analyses determine if 3-D model domain is necessary or develop representative 2-D cross-section(s) from 3-D model.

Fracture/matrix interaction analysis plan

- Objective: Investigate sensitivity of UZ radionuclide transport to changes in fracture sorption, matrix sorption, molecular diffusion, and porosity, as a function of varying f/m connection area, infiltration, and source-term release rate and duration

- Approach: Compare 3-D and 2-D simulations; run most sensitivities with 2-D model; particle tracker; ^{99}Tc and ^{237}Np; compare mass flux breakthrough at water table

- Output to TSPA: Determine appropriate sampling ranges for transport parameters as a function of infiltration, f/m connection area, and source-term release rate and duration; decide upon the appropriateness of using 2-D cross-sections

Transient flow/transport analysis plan

- Objective: Develop justification for use of a sequence of quasi-steady flows to represent climate change.

- Approach: Use 3D model; base-case values for flow and transport parameters; base-case infiltration varied from 1-10 mm/yr; changes in water table up to 100 m higher; 3 to 5 possible future climates (e.g., global warming, little ice age, pluvial, long-term average). Compare transport response (mass flux at water table) from a sequence of steady state flows with transport response from a transient flow model.

- Output to TSPA: Sequence of steady-state flow fields used directly in particle tracker.

Colloid transport analysis plan

- Objective: Assess importance of colloids in UZRT and develop an abstraction if deemed important.

- Approach: 1-D and 2-D dual-permeability modeling of Pu transport as aqueous solute, sorbed on fracture and matrix, sorbed on natural and introduced colloids (e.g., iron oxides), intrinsic radiocolloid; model Pu sorption on colloids with K_d approach but compare to kinetic model; bound stability and filtration; compare mass flux at water table with and without colloids.

- Output to TSPA: Either a bounding analysis that shows insignificance of colloids or include Pu colloidal transport model in particle tracker.

Sorption model analysis plan

- Objective: To assess if the K_d sorption model "bounds" the effects of nonlinear sorption and other reactive transport processes such as speciation reactions, ion exchange, precip/diss, and surface complexation.
- Approach: Steady-flow, 1-D comparison of linear and nonlinear sorption models; 2-D ECM comparison of ^{237}Np linear sorption with precip/diss and ion-exchange, using FEHM.
- Output to TSPA: Justification for using K_d sorption model for all geochemical interactions that affect UZRT. If necessary, modify K_ds to account for complex reactions.

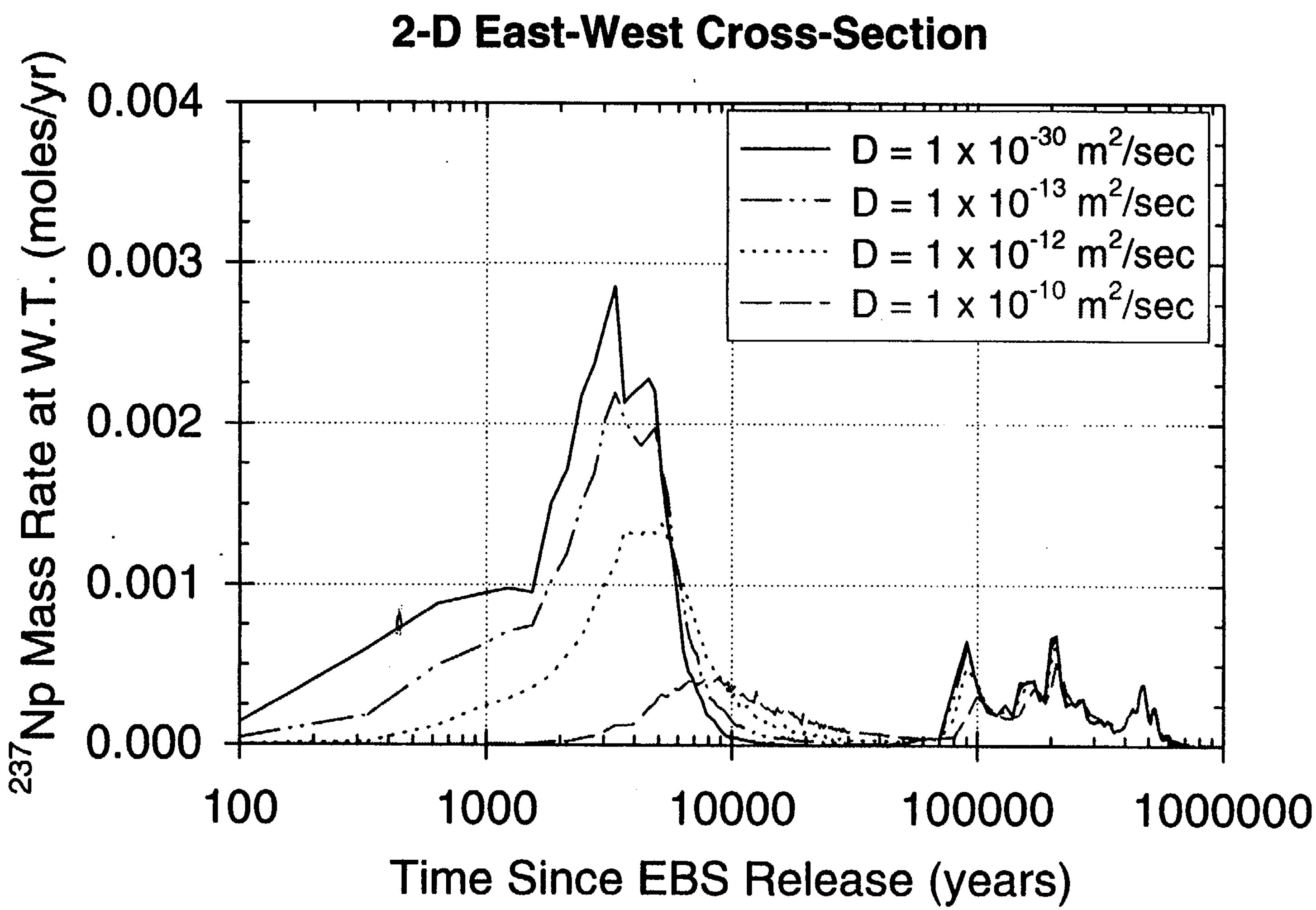
Heterogeneity/dispersion analysis plan

- Objective: Investigate the influence of fine-scale heterogeneity and physical dispersion on radionuclide transport. How do fine-scale heterogeneities affect transport, particularly through the zeolites? Can dispersion be neglected?

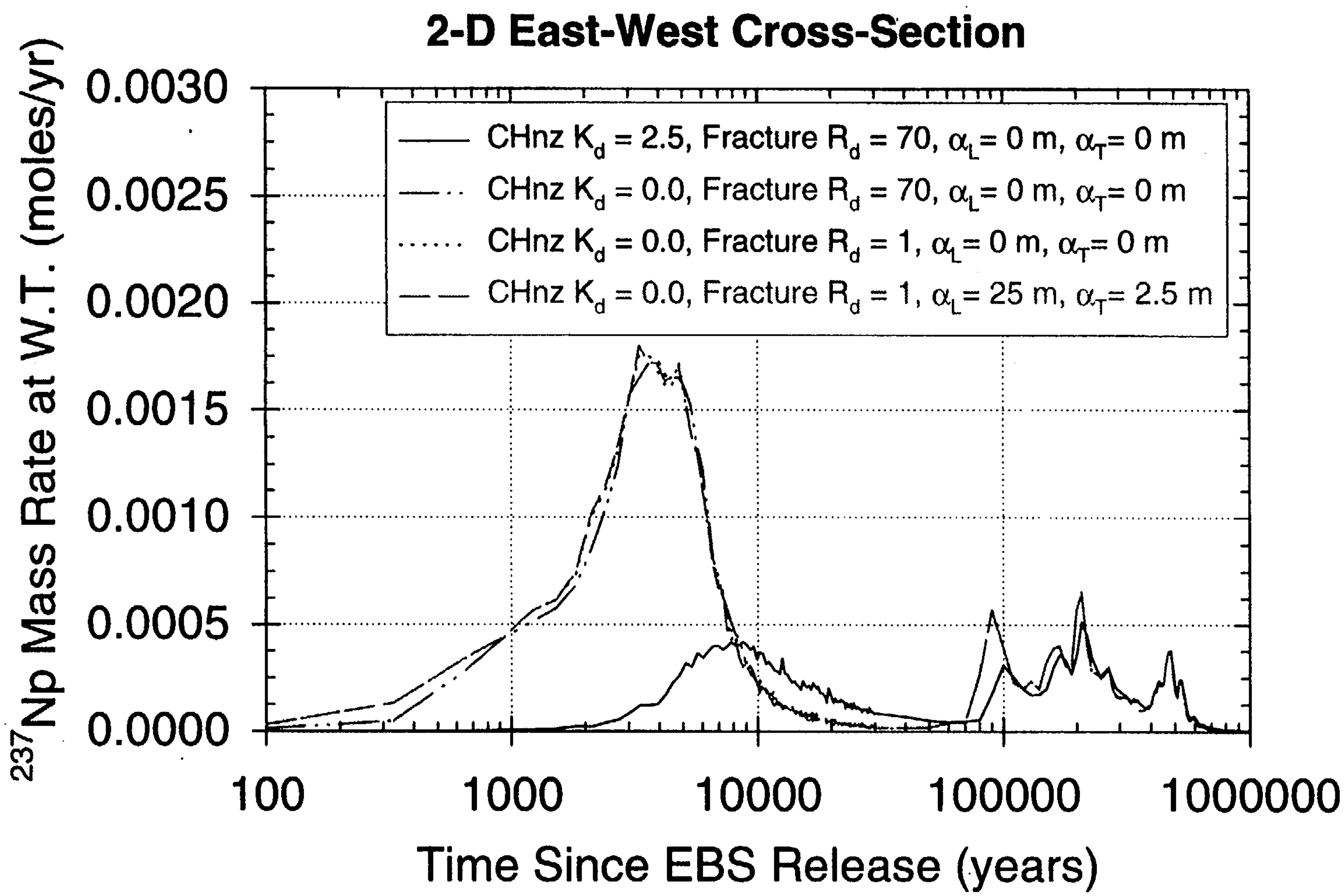
- Approach: Develop fine-scale geostatistical descriptions of UZ cross-sectional mineralogy, and compare resulting transport to a homogeneous stratigraphic model.

- Output to TSPA: Determine if transport through heterogeneous domain is adequately modeled with homogeneous stratigraphic model.

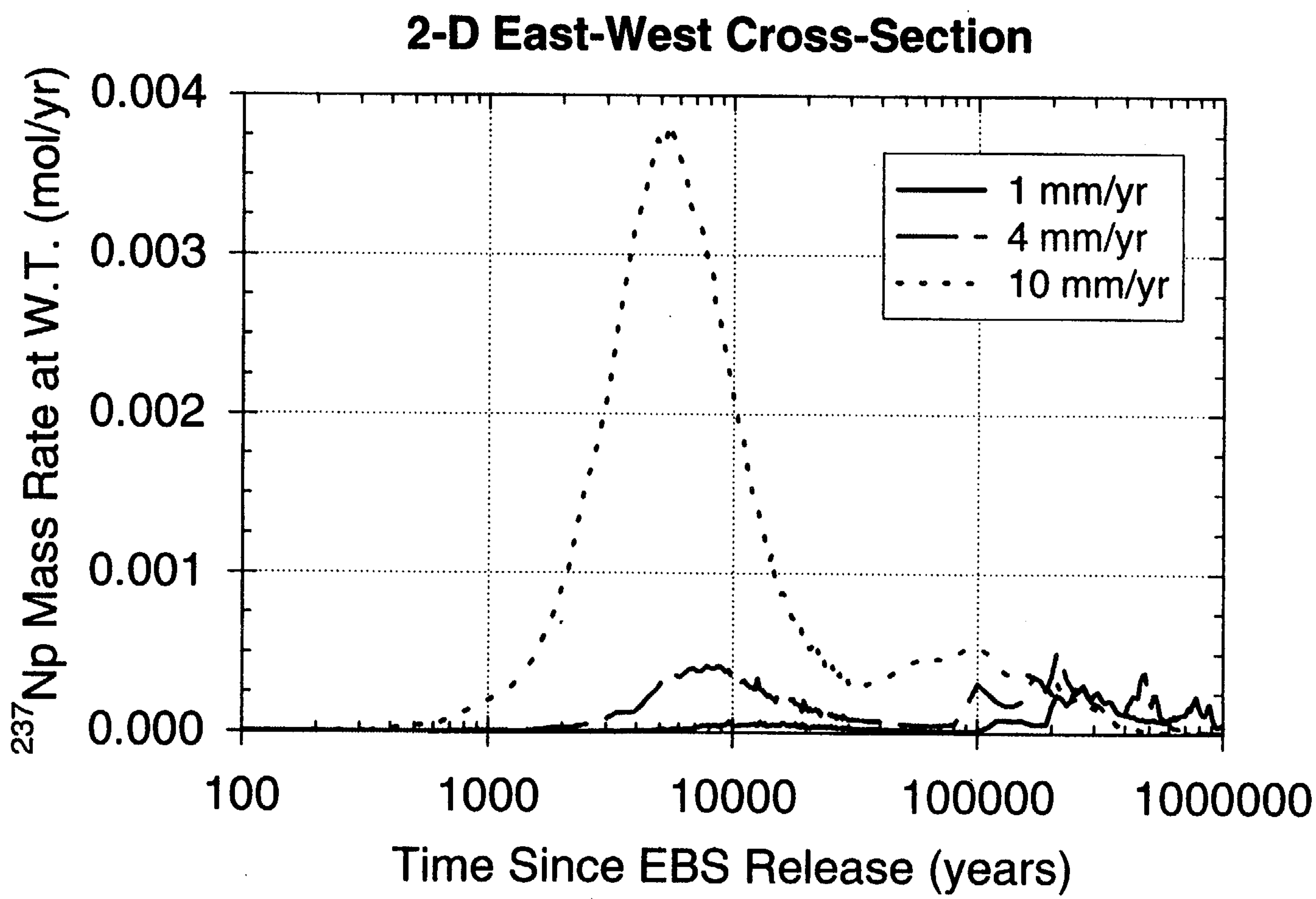
Effect of Matrix Diffusion on UZRT



Effect of Sorption on UZRT



Effect of Infiltration on UZRT



ATTACHMENT 18

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Status of Unsaturated Zone Transport Model

Presented to:
DOE/NRC Technical Exchange on
Total System Performance Assessment
(TSPA)

Presented by:
Bruce A. Robinson
Los Alamos National Laboratory

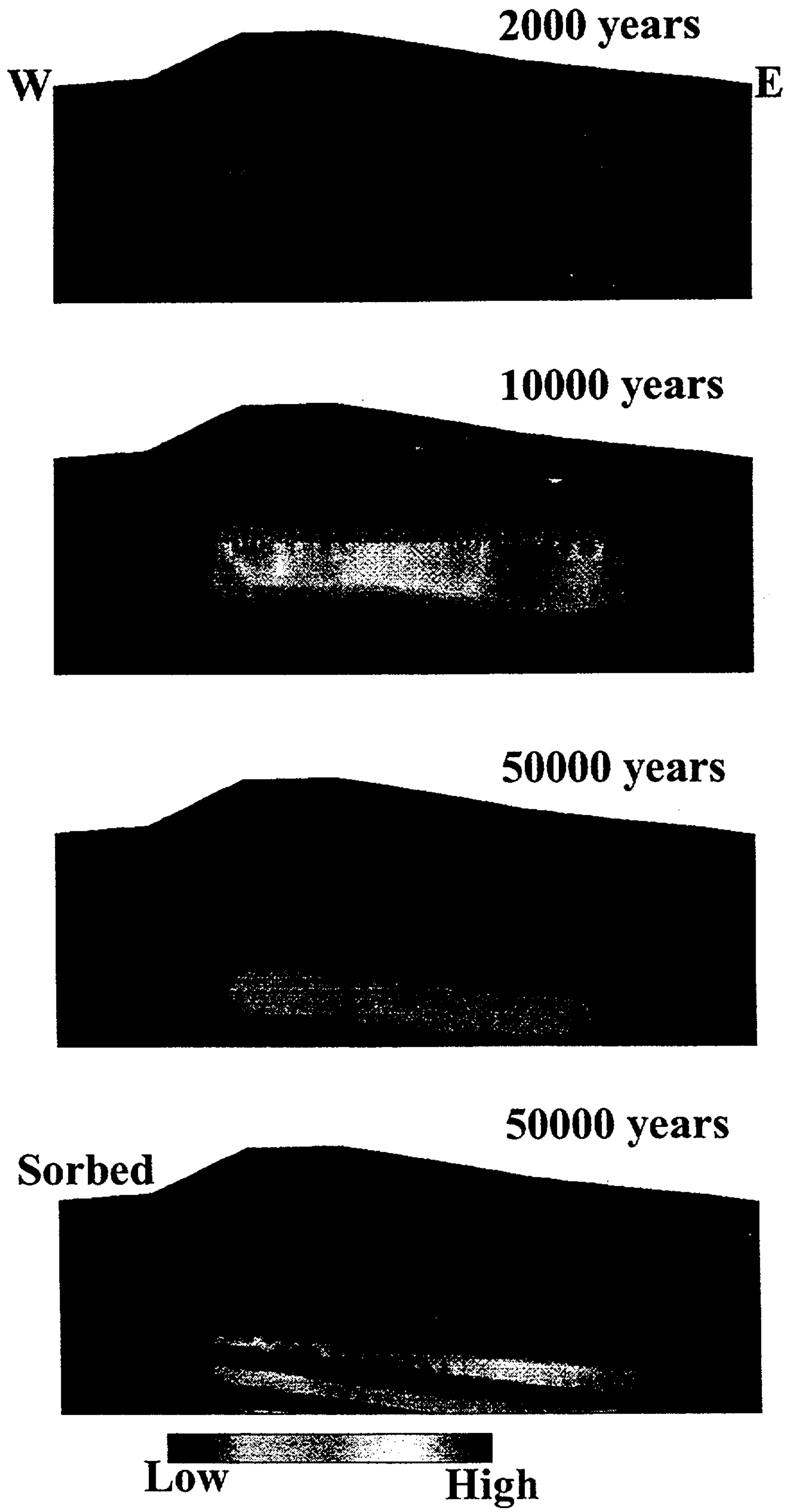
U.S. Department of
Energy
Office of Civilian
Radioactive
Waste Management

July 21-22, 1997

Topics of Discussion

- ^{237}Np Reactive Transport Simulations
  - Chemical interactions (speciation, ion exchange)
  - Repository Heat
- Fracture-Matrix Interactions
- Colloid-Facilitated Transport of Plutonium

Neptunium Transport Predictions
4 mm/y Percolation Flux



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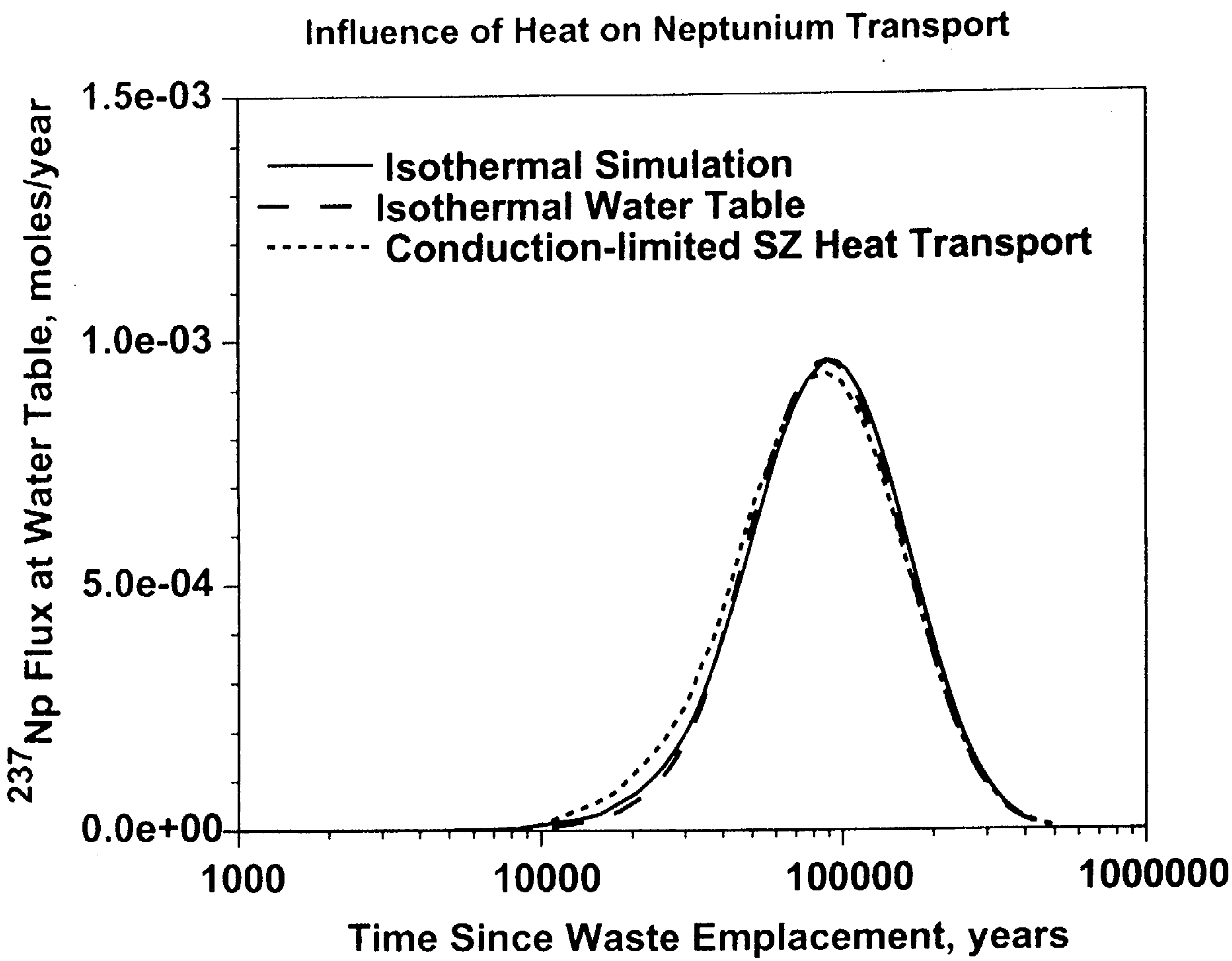
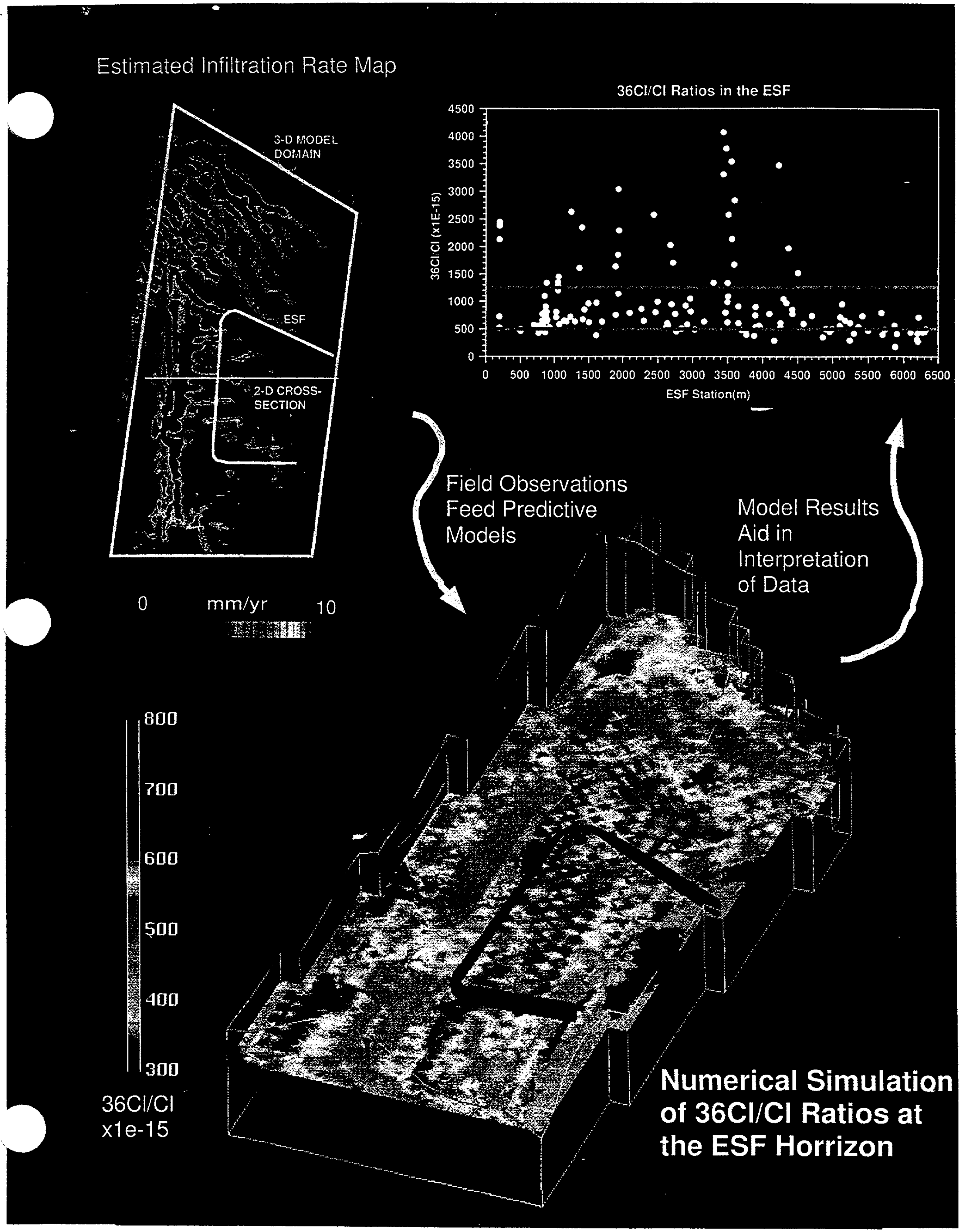
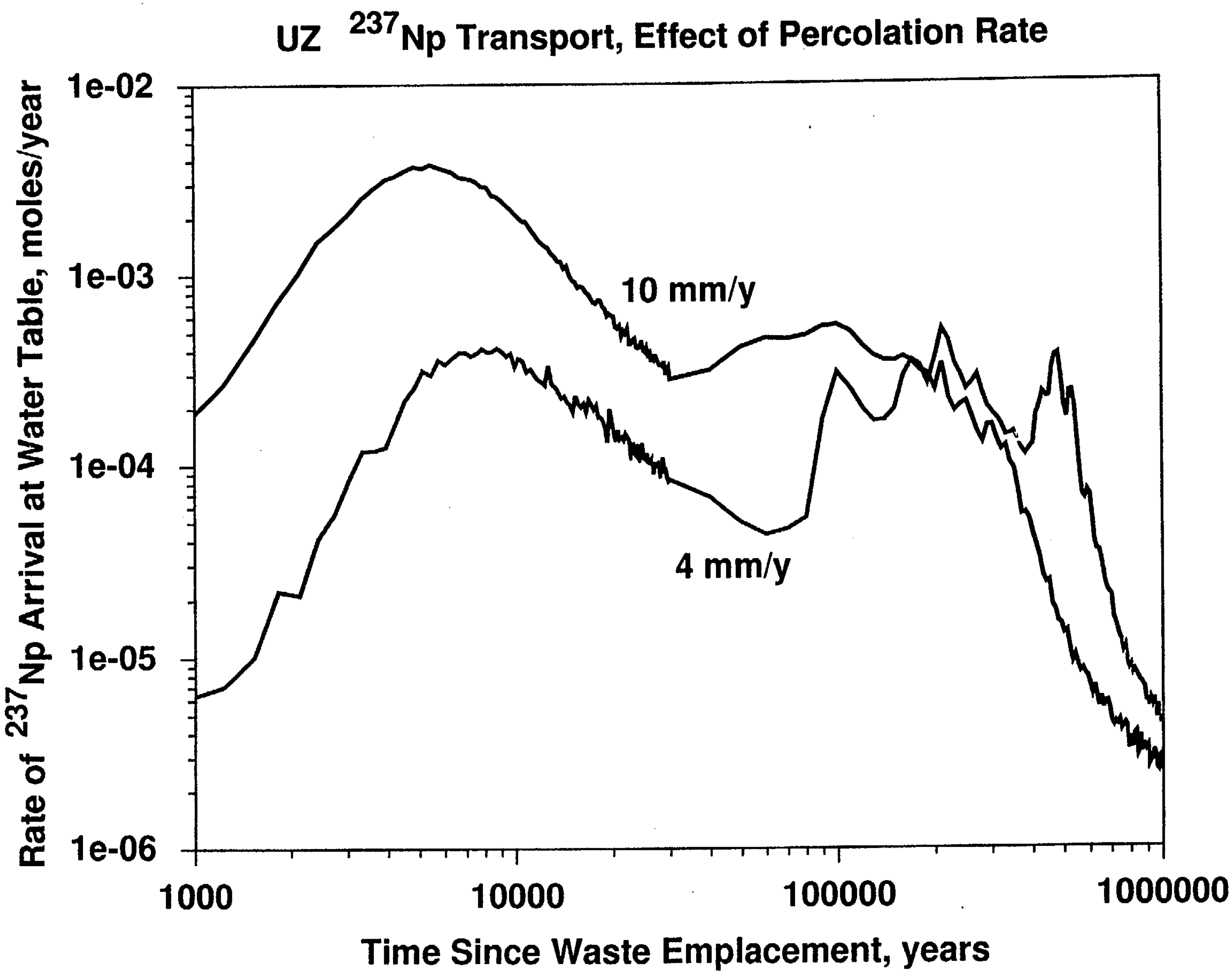
Geoanalysis Group, Los Alamos

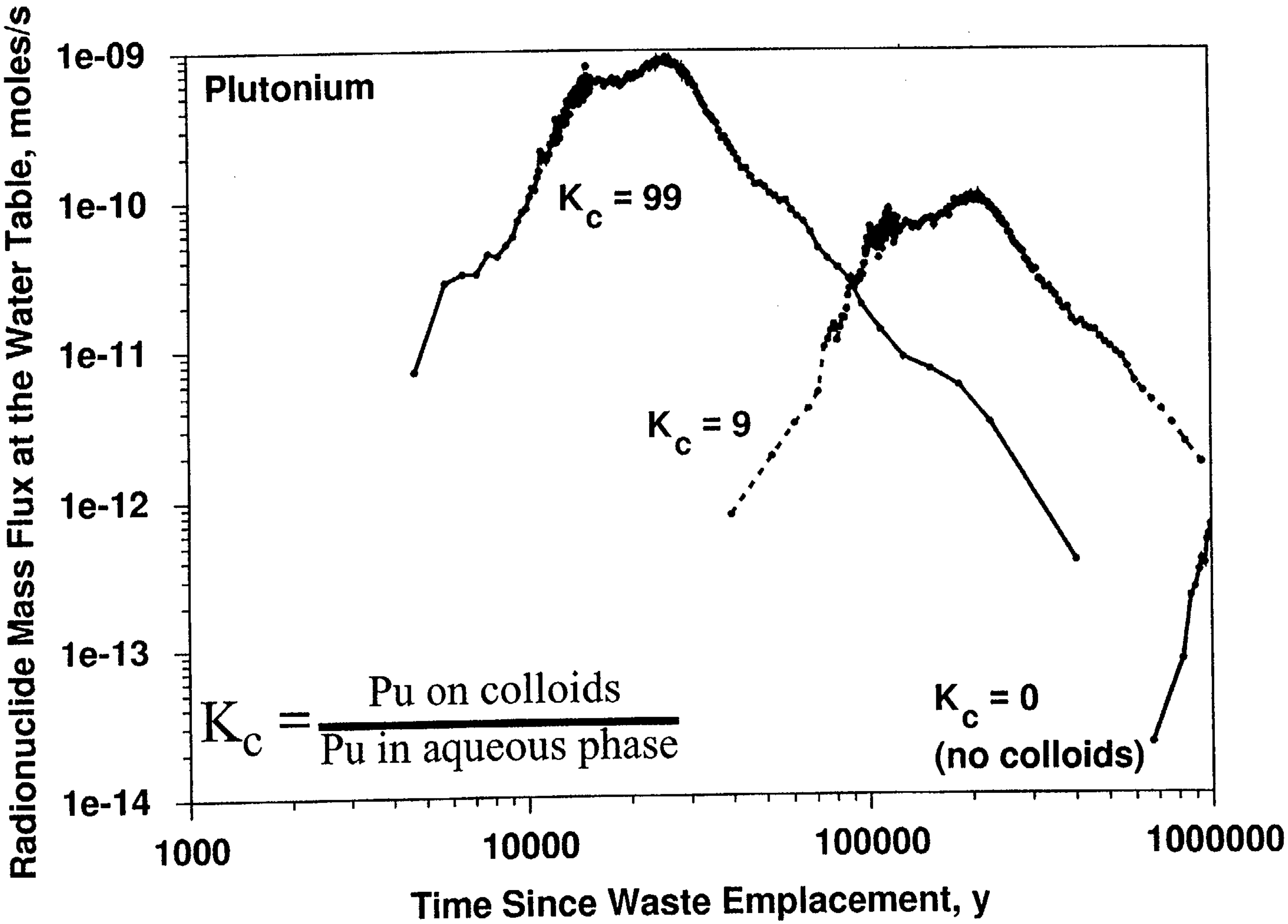


Influence of Heat on Neptunium Transport
Isothermal Simulation
Isothermal Water Table
Conduction-limited SZ Heat Transport
237Np Flux at Water Table, moles/year
1.5e-03
1.0e-03
5.0e-04
0.0e+00
1000
10000
100000
1000000
Time Since Waste Emplacement, years


Estimated Infiltration Rate Map
3-D MODEL DOMAIN
ESF
2-D CROSS-SECTION
0
mm/yr
10
36Cl/Cl Ratios in the ESF
36Cl/Cl (x1E-15)
4500
4000
3500
3000
2500
2000
1500
1000
500
0
0 500 1000 1500 2000 2500 3000 3500 4000 4500 5000 5500 6000 6500
ESF Station(m)
Field Observations Feed Predictive Models
Model Results Aid in Interpretation of Data
800
700
600
500
400
300
36Cl/Cl
x1e-15
Numerical Simulation of 36Cl/Cl Ratios at the ESF Horrizon


UZ ^{237}Np Transport, Effect of Percolation Rate
Rate of ^{237}Np Arrival at Water Table, moles/year
1e-02
1e-03
1e-04
1e-05
1e-06
10 mm/y
4 mm/y
1000
10000
100000
1000000
Time Since Waste Emplacement, years

Effect of Colloids on Plutonium Transport



$$K_c = \frac{\text{Pu on colloids}}{\text{Pu in aqueous phase}}$$

uz_viewgraphs-67

Geoanalysis Group, Los Alamos

Current Status - UZ Transport Model

- LBNL Site-scale flow model parameters are being incorporated into the transport model
- Numerical grids have been developed for use in transport studies
- Initial screening of hydrologic parameter sets has been performed
- Comparisons of TOUGH2 and FEHM computer codes has been carried out
- Coupling of RIP and FEHM is in progress

Conclusions

- Thermohydrologic effects are relatively unimportant for neptunium due to the slow release rates and long travel times
  - Note: Permanent changes to rock properties have not yet been assessed
- Fracture-Matrix interaction is a critical parameter for UZ transport
- Colloid-facilitated transport of plutonium is important if sorption to colloids is significant

ATTACHMENT 19

NRC STAFF'S OBSERVATIONS OF UNSATURATED ZONE ABSTRACTION AND EXPERT ELICITATION WORKSHOPS

July 21-22, 1997
NRC/DOE Technical Exchange on
Total System Performance Assessments
for Yucca Mountain

Tim J. McCartin
(301)415-6681/tjm3@nrc.gov
Division of Waste Management
Performance Assessment and HLW Integration Branch

UZFT CONCERNS AND OBSERVATIONS

- Abstraction Workshops (UZFT) and UZ Expert Elicitation Identified the Significant Issues (How Issues Would be Addressed in TSPA was not Clear in Certain Areas)

- Estimates of Infiltration are Concentrated on a Site Average (Significant Work Using Multiple Lines of Evidence Used to Support Estimates)

  - Spatial Distribution May Have a Significant Affect on Movement of Water into Drifts—Are There Plans to Examine This Importance and/or Investigate the Potential for Focused Flow (e.g., Structural Control)?

  - How Will Estimates of Infiltration for Wetter/Cooler Periods be Derived?

  - How Will Estimates of the Thermal Reflux be Determined for Use in TSPA, Given the Significant Uncertainties Involved?

UZFT CONCERNS AND OBSERVATIONS (Cont'd)

- If Retardation in Fractures in Used as a Significant Contributor to Performance, What Lines of Evidence will be Used to Support Conceptual Models?
- If Quantification of Dripping Into Drifts is a Significant Contributor to Performance, What Lines of Evidence will be Used to Support Conceptual Models?
- Matrix Conductivity can be the Controlling Parameter in Determining the Extent of Fracture Flux—How is the Parameter Considered in the Response Surface Approach?

ATTACHMENT 20

YUCCA
MOUNTAIN
PROJECT

Treatment of Disruptive Events in TSPA-VA

Presented to:
DOE/NRC Technical Exchange on
Total System Performance Assessment
San Antonio, Texas

Presented by:
R.W. Barnard
Senior Member Technical Staff
Sandia National Laboratories
Albuquerque, New Mexico

July 21-22, 1997

U.S. Department of Energy
Office of Civilian Radioactive
Waste Management

Disruptive Scenarios Being Considered

- Volcanism
- Seismicity
- Nuclear Criticality
- Human Intrusion

Volcanism

- Important issues being modeled
  - direct releases to surface
    - lava flows/ apron deposits/ spatter cones
    - pyroclasts/ tephra
  - increased groundwater radionuclide source term inventory
  - altered transport of contaminants in SZ
    - diversion of flow
    - changes in mixing
- Frequency-of-occurrence PDF
  - sensitivity of results to PDF shape
- Analyses will be incorporated as modifications to base-case analyses

Seismicity

- Issues being modeled
  - rockfall onto degraded waste packages
    - degraded due to age
    - affected by volcanic activity
  - PSHA will provide information that may be used for consequence models for earthquakes
    - magnitude-vs.-frequency of occurrence
    - characteristics of vibratory ground motion
- Analyses will be included in base case and as modifications to base case

Nuclear Criticality

- Important issues being modeled
  - in-package criticality
  - near-field criticality
  - far-field criticality
- Analyses will be incorporated as perturbations to base-case analysis

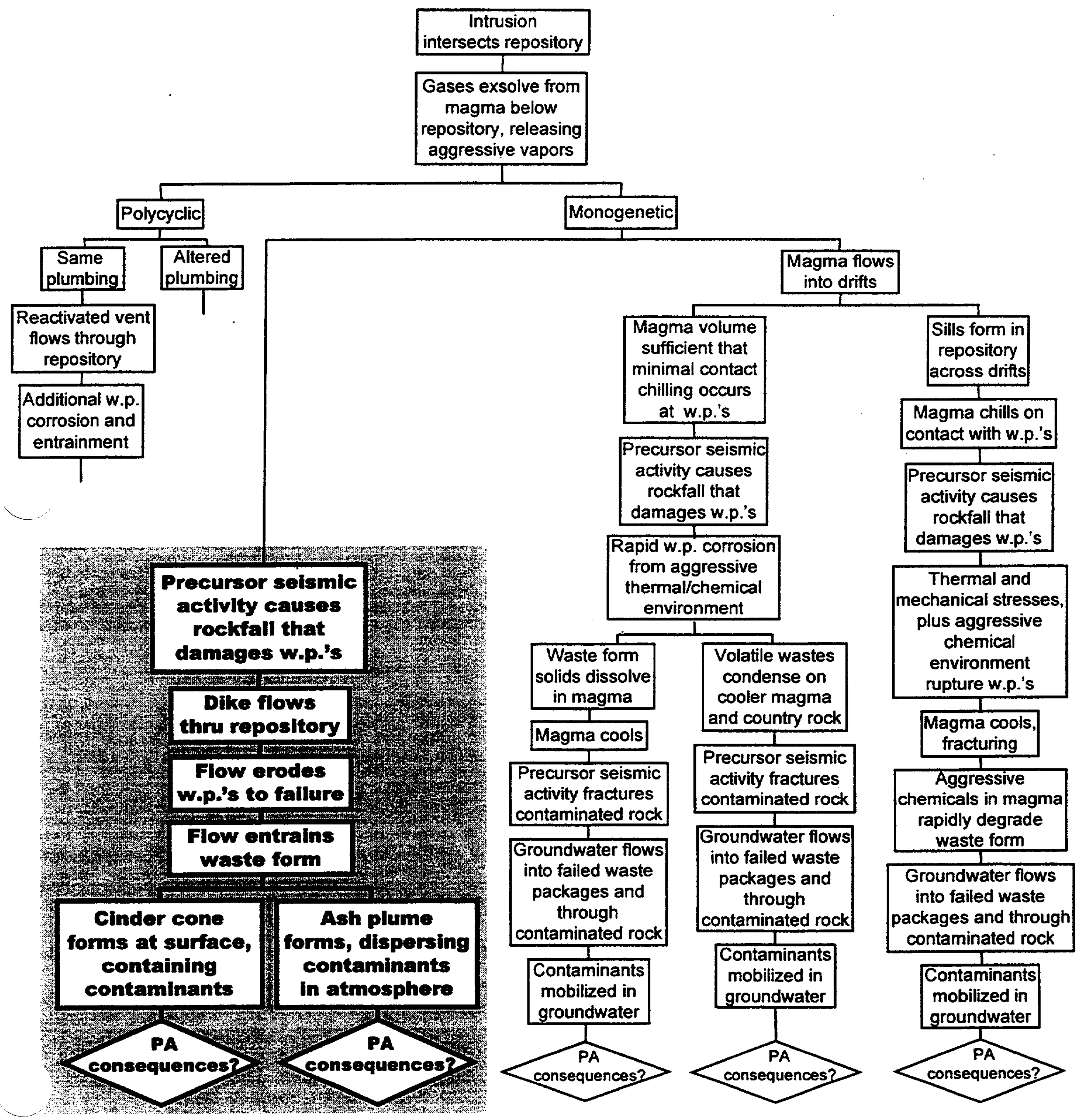
Human Intrusion

- Issues being modeled
  - modification of source term in SZ due to drilling
  - will be incorporated as perturbations to base-case analysis
- Analyses may not be incorporated into final TSPA-VA performance measures, per NAS report

Analysis Plans

- Volcanism
  - Details of processes supplied by experts
    - LANL: intrusion plumbing; entrainment by magma
    - PVHA: probabilities of specific intrusion types; probabilities of regional events
- Seismicity
  - Effects incorporated into volcanic analyses
    - rockfall associated with intrusions
  - Probability PDFs for ground motion from PSHA (as available)
- PA impacts calculated
  - doses from surface releases
  - amounts of contaminants transported by groundwater

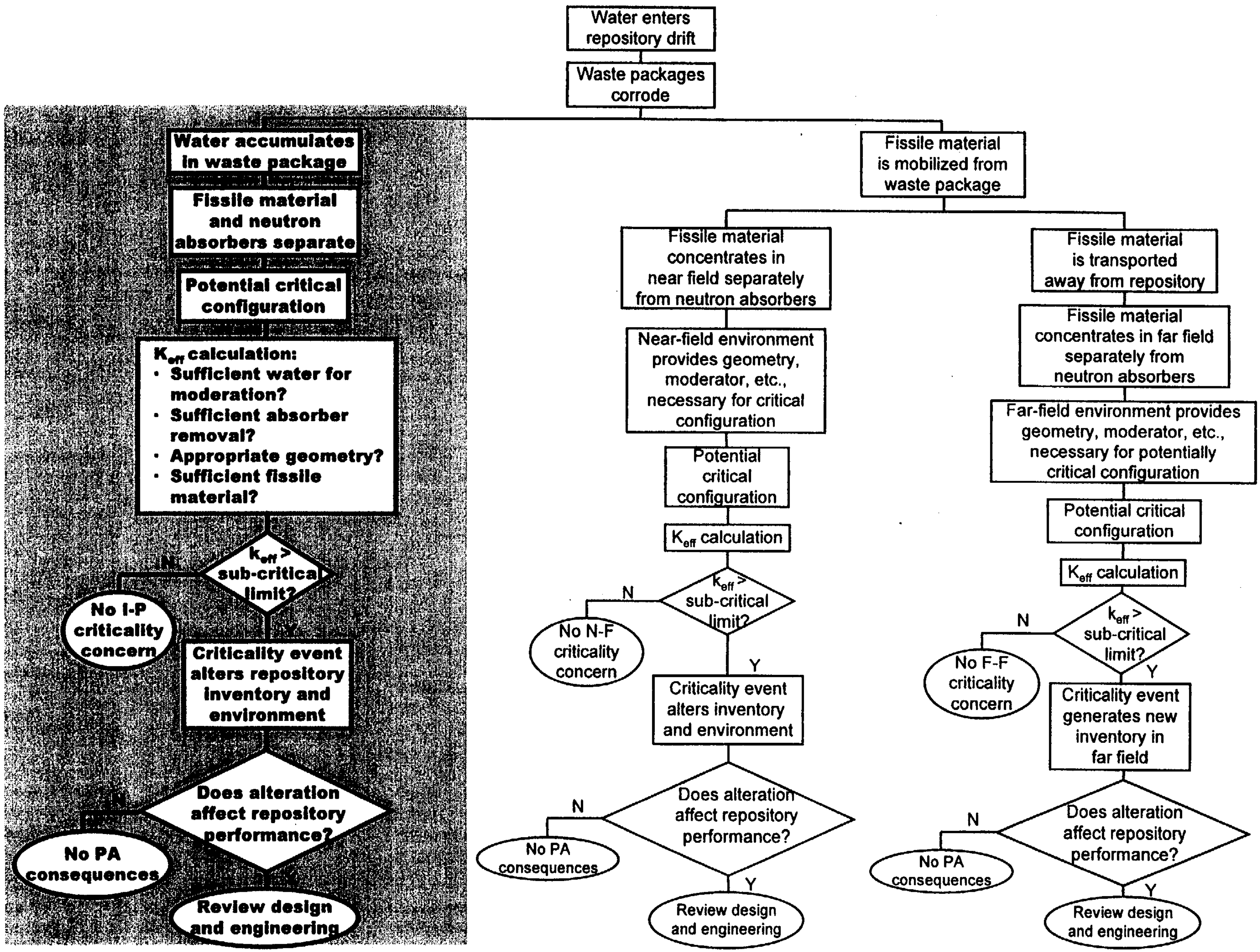
Example Volcanic-Seismic Scenarios



Criticality Analysis Plans

- Abstraction/Testing Workshop identified important issues
  - issues compiled into FEP diagram
  - experts in geo-technology and neutronics select scenarios
- Analyses use geologic processes for generation of critical configurations
- Neutronic activity (k_{eff}) calculated using:
  - amount of moderator
  - amount of fissile fuel
  - geometry
  - presence of neutron absorbers
- PA impacts calculated
  - increase in radionuclide source term (from ORIGEN)

Example - Criticality Scenarios



Summary

- Disruptive events will be treated in a manner consistent with the other parts of TSPA-VA
  - comprehensive catalogs of FEPs potentially leading to radionuclide releases
  - important analyses selected from FEP diagrams
  - abstractions based on process-model analyses
- Most disturbed-condition analyses are sensitivity studies to determine extent of modification to base-case performance
  - rockfall will be included in base case

ATTACHMENT 21

TREATMENT OF DISRUPTIVE EVENTS IN TSPA-VA
PROPOSED ISSUES FOR DISCUSSION AT THE NEXT TECHNICAL EXCHANGE

July 21-22, 1997
NRC/DOE Technical Exchange on
Total System Performance Assessments
for Yucca Mountain

Christiana H. Lui
(301)415-6200/CXL@nrc.gov
Division of Waste Management
Performance Assessment and HLW Integration Branch

Volcanism

Proposed issues for discussion at the next Technical Exchange:

- Consequence Analysis

  - Parameters, their ranges, and the models selected for analyzing consequences for both the extrusive and intrusive volcanic events
  - Waste entrainment by magma
  - Intrusion plumbing system

- Risk Analysis

  - Probability of specific intrusion types
  - How probability will be used with the results of consequence analysis to bound the risk

- Integration

  - Similarities and differences of tectonic models from PVHA and PSHA

Seismicity/Faulting

Proposed issues for discussion at the next Technical Exchange:

- Seismic and fault scenarios incorporated into the TSPA-VA, for example
    - Effects of repeated seismic events
    - Alteration of the flow and transport system characteristics due to seismicity and faulting
- Scenarios proposed by Barr et al. (Sand 96-1132) incorporated into TSPA-VA

ATTACHMENT 22

Issue	*Description of Issue*	*Discussion*	*Response*	*Action/ Status*
		TSPA METHODOLOGY		
Importance Sampling	What is meant by DOE's definition and what approach will be used to determine importance?	Importance sampling can be very difficult if the approach is to sample from the tails (outliers) of the output distribution rather than the input distributions. The DOE approach is to sample the tail of the input distributions; it is a feature built into and described in the RIP Manual.	No further action needed.	Completed.
Parameter Variability vs. Parameter Uncertainty	How are they defined and how are they different from each other? How will they be treated in TSPA-VA?	DOE's intent to separately treat uncertainty and variability is going to be very difficult. NRC staff needs to understand the details of DOE's approach prior to completion of TSPA-VA.	Need an Appendix 7-type meeting to discuss details of approach.	Further discussion as TSPA-VA matures.

Issue	*Description of Issue*	*Discussion*	*Response*	*Action/ Status*
SATURATED ZONE				
Approaches to Mixing	How much conservatism is there in the NRC's Version 3.1 computer code?	NRC's approach is conservative, and this is an important issue because dose is directly proportional to dilution.	NRC will investigate to determine if 2-D or 3-D models are warranted. DOE will provide more information on the vertical mixing depth to be used and its basis in the TSPA-VA in the proposed Fall 1997 Technical Exchange.	Further discussion as IPA Phase 3 and TSPA-VA mature.
Retardation of Radionuclides in Alluvium	What are the respective approaches and where are the numbers coming from?	Not much data is available at this time. Because DOE takes credit for retardation in the matrix and fractures of the volcanic rock, only unretarded and poorly-retarded radionuclides reach the alluvium.	DOE will not take credit for retardation of radionuclides in alluvium unless more data is obtained to provide a basis; no further action needed.	The basis for retardation in the alluvium will be provided in TSPA-VA.
Matrix Diffusion: C-Well Tests	Are there possible alternative interpretations for matrix diffusion ?	Alternative interpretation of C-Well Complex data is possible. "Matrix diffusion" includes micro-fracture imbibition. DOE plans to use the matrix diffusion model in TSPA-VA.	NRC/CNWRA will examine the data and provide independent interpretations; other data will be examined to evaluate the significance of matrix diffusion. DOE (LANL) will re-examine the data for possible alternative interpretations. Either an Appendix 7 meeting with LANL or the proposed Fall 1997 Technical Exchange will be used to complete this discussion.	Further discussion as appropriate.

Issue	*Description of Issue*	*Discussion*	*Response*	*Action/ Status*
Size of Finite Element Grid	How did DOE arrive at the size of the grid (considering numerical dispersion)?	The size of the grid was arrived at by trial-and-error. The issue is the correct way to determine the grid size.	No action required; grid-size sensitivities are to be discussed as part of the TSPA-VA.	N/A
Dilution at the Pumping Well and Pumping Well Rates	How should dilution at the pumping well be treated?	NRC uses 1-D model; DOE uses 3-D model. The relative magnitude of dilution in alternative approaches needs to be evaluated.	More discussion may be needed under the topic of biosphere (should be consistent with the lifestyle of the critical group assumed in the biosphere). DOE needs to provide NRC with results from its Amargosa Valley Site Survey.	NRC to provide dilution assumptions used in IPA Phase 3 and their basis.
	How are/would anthropogenic effects treated (pumping well rates)?	Agree that the treatment should be consistent with the assumptions used in the biosphere and as recommended in the NAS Report.	NRC will use semi-analytical model to assess borehole dilution. NRC will consider this concern in its revisions of 10 CFR Part 60 to implement a new EPA Standard. Also, DOE's survey on well-pumping will provide more information, and needs to be made available to the NRC.	UNLV survey results are expected to be available by August 1997. DOE to provide Site Survey results.

Issue	Description of Issue	Discussion	Response	Action/ Status
Convolution Calculation	How are decay chains treated?	NRC uses a quasi-analytical approach (in NEFTRAN). DOE uses numerical calculations, and the information is passed from UZ to SZ. The issue here is whether or not DOE has correctly modeled the decay chains.	NRC and DOE will compare and contrast the different approaches before VA (in the proposed Fall 1997 or Spring 1998 Technical Exchanges).	Continue discussion as needed.
Saturated Zone Transport	How are steady state and transient states treated?	Neither NRC nor DOE have included transient states in their respective approaches.	The effects of transient states will be examined later, most likely by using sensitivity analyses. It is unlikely that this will be done before the VA.	See License Application
USGS Regional Groundwater Flow Model	What accounts for steep vertical mixing in the particle transport model for the saturated zone?	It was an artifact due the coarseness in the model.	DOE will provide more detail on the model used in the proposed Fall 1997 Technical Exchange (see also Approaches to Mixing item, above)	DOE will provide data to NRC.

Issue	*Description of Issue*	*Discussion*	*Response*	*Action/ Status*
Groundwater Gradient to the Southwest	How is the flow from the saturated zone being represented/treated in the flow and transport model?	This was discussed in an Appendix 7 meeting on the 3-D Geologic Model the week of July 16, 1997. There is apparently a SW component, for a few km, in the predominantly SE-S flow field from the repository site.	DOE will convey this information to the appropriate parties to ensure internal consistency NRC will further discuss the impact of this issue after this Technical Exchange.	Open.
UNSATURATED ZONE				
Matrix Diffusion	How much credit should be taken?	A similar discussion to the SZ concern over this process. NRC believes that some matrix diffusion may occur in the SZ but expects this effect to be very small. NRC anticipates that taking credit for significant matrix diffusion in the SZ will be difficult to defend owing to the absence of supporting data.	DOE is to perform modeling and experimental work to determine how much credit can be taken for this process in the UZ. There will be a discussion of the basis for the modeling of this process in TSPA-VA. A Spring 1998 Technical Exchange, or a separate Appendix 7 meeting, may be required to accommodate further discussion.	Open.

Issue	*Description of Issue*	*Discussion*	*Response*	*Action/ Status*
Colloids	Are they significant to performance?	Colloids are potentially important, and are complex in terms of stability and mobility. Both intrinsic Pu colloids and Fe-oxyhydroxide-radionuclide complex colloids were discussed.	DOE has limited work in progress to evaluate potential effects and their importance. Treatment in TSPA-VA will be limited, and plans for future work will be discussed as part of the License Application Plan to be included in the VA.	DOE to provide plans to address issue in License Application Plan.
Deep Infiltration	What is a reasonably conservative upper bound?	NRC's concern is that the upper bound may be much higher than currently estimated by DOE. During a climate change, vegetation changes could affect net infiltration. Multiple lines of evidence should be used to set an upper bound on net infiltration.	The TSPA-VA bound will be based on the UZ flow model and the results of the expert elicitation on UZ flow. It is recognized that this will be an input parameter that will receive close scrutiny because of its importance to performance, and that some additional work may be needed for TSPA submitted as part of the License Application.	NRC to continue its monitoring.

Issue	Description of Issue	Discussion	Response	Action/ Status
Structural Control of Flow	How much of the UZ flow is controlled/ influenced by structural controls?	The issue is whether or not major focusing mechanisms exist, and are being incorporated in the flow modeling. Could 80 percent of the flow, for example, be in 10 percent of the repository area?	In TSPA-VA, the UZ flow model will be abstracted and implemented. It suggests a small percentage of many fractures carry flow, but doesn't show a clustering of such flowing features. In TSPA-VA, discrete flows will be assigned varying ranges of percolation flux, resulting in heterogeneous flow/ transport. The UZ flow model suggests that the relationship between percolation and seepage into drifts is not straight-forward, and drift-scale modeling is used to provide an estimated range for the number of waste packages likely to see dripping water for TSPA-VA. No action is needed until TSPA-VA is ready for review.	NRC to review in TSPA-VA. DOE to review NRC assumptions in IPA Phase 3.

Issue	*Description of Issue*	*Discussion*	*Response*	*Action/ Status*
Steady-State Approximation	Is the steady-state approximation of UZ flow appropriate?	The critical nature of climate changes was cited as a reason for calling the steady-state modeling of UZ flow into question.	It was not clear to DOE that there exists a problem assuming (for TSPA-VA) consecutive steady-state flow fields below the Paintbrush Tuff (nonwelded) unit which buffers flow pulses, except in locales where there are through-going fractures conducting small volumes of water. Development of the UZ flow model is to continue forward beyond the VA.	See License Application

ATTACHMENT 23

YUCCA MOUNTAIN PROJECT

Studies

Repository Design Description

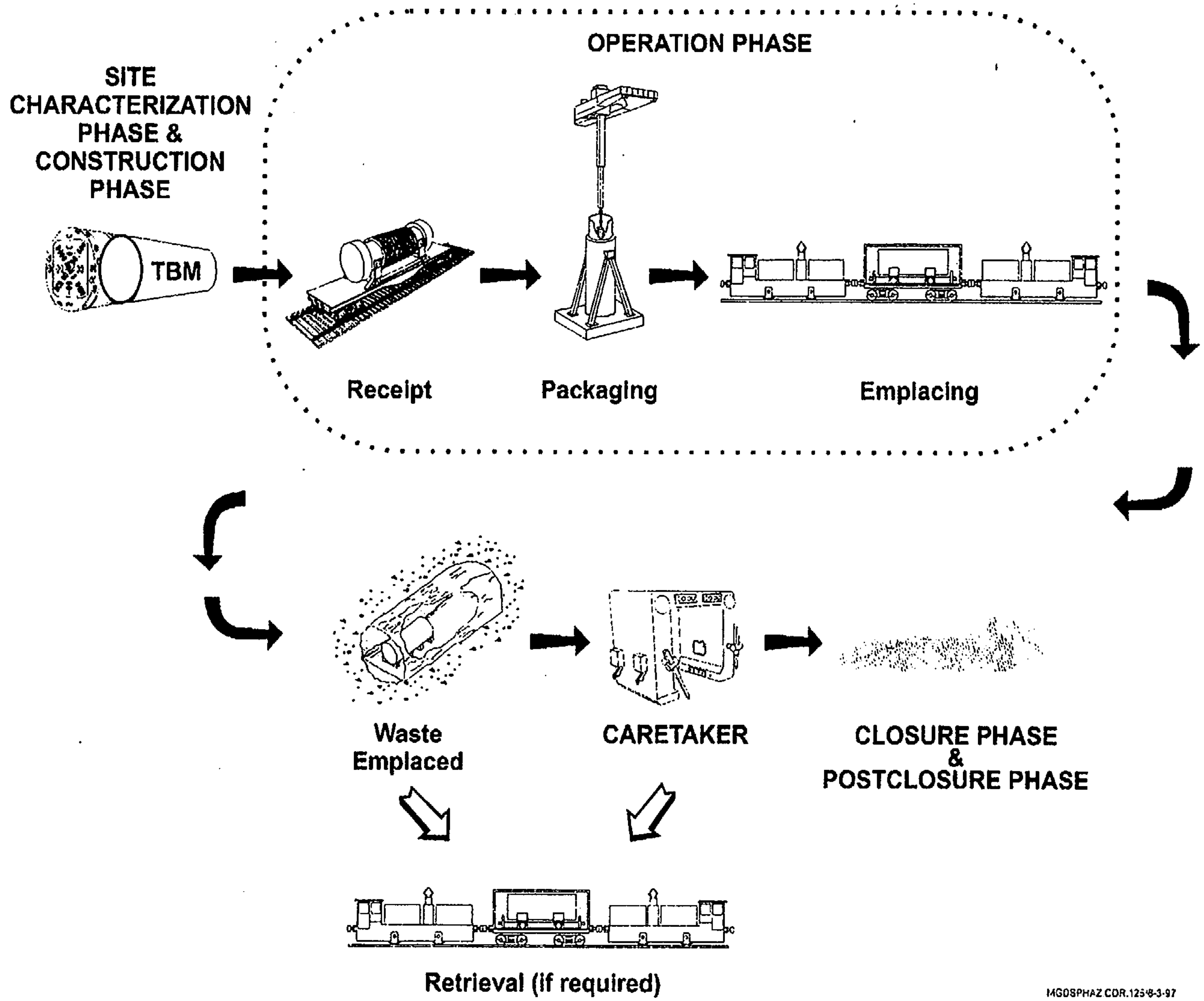
Presented to:
DOE/NRC Technical Exchange on
Total System Performance Assessment (TSPA)

Presented by:
Jack N. Bailey
Deputy Manager, Engineering & Integration
Operations

July 21-22, 1997

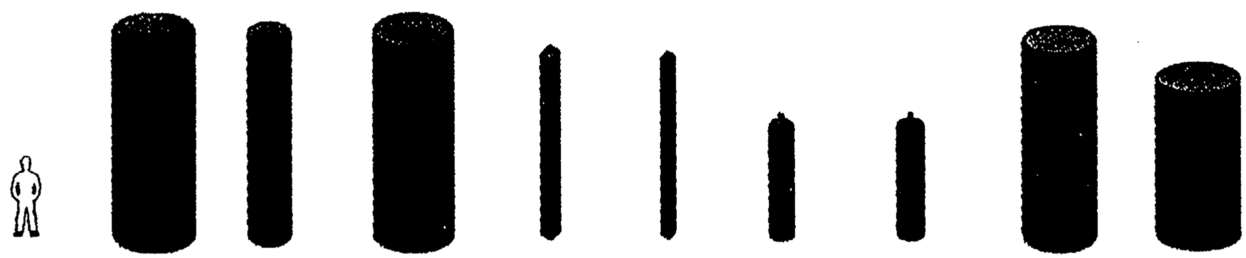
U.S. Department of Energy
Office of Civilian Radioactive
Waste Management

Base Repository Operations



Receipt

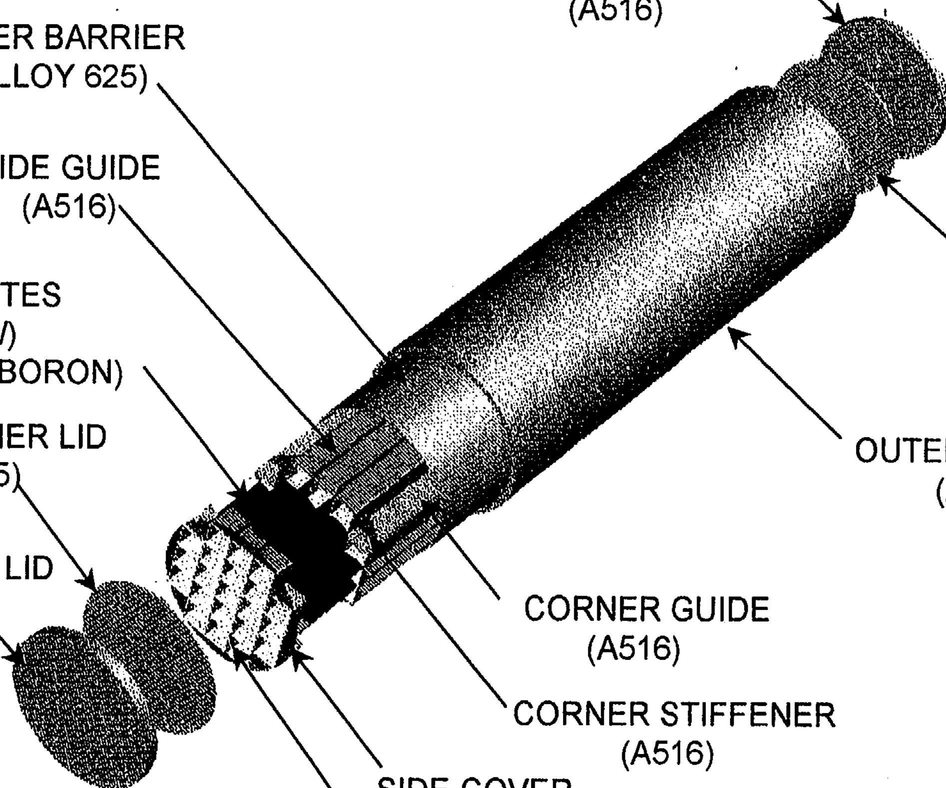
Representative Waste Form Data



	Received		Transferred					Emplaced	
	Rail Cask	Truck Cask	SNF Canister	PWR Assembly	BWR Assembly	DOE SNF	DHLW Canister	SNF DC	DHLW DC 5
Loaded Weight (tons)	105	25	31	0.9	0.4	2.0	1.1	53	39
Peak Units per Year	420	140	460	4,900	8,300	103	800	370	160

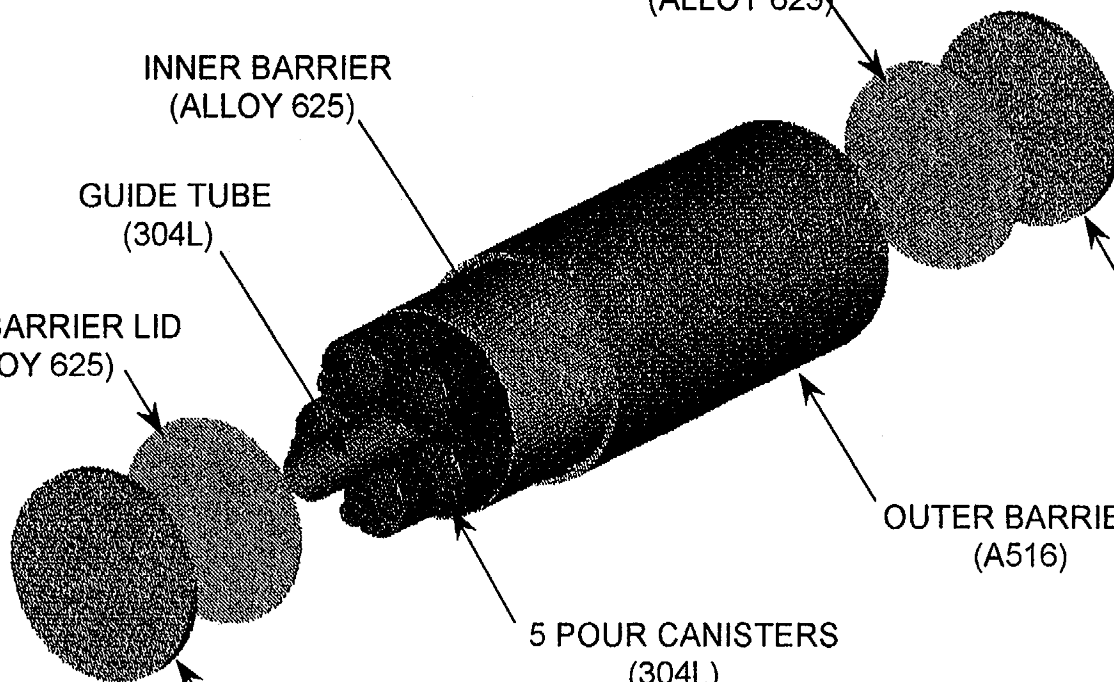
BWR	Boiling Water Reactor	DHLW	Defense High-Level Waste
DC	Disposal Container	PWR	Pressurized Water Reactor
DC 5	5 Pack DOE Center	SNF	Spent Nuclear Fuel

21-PWR UCF Disposal Container



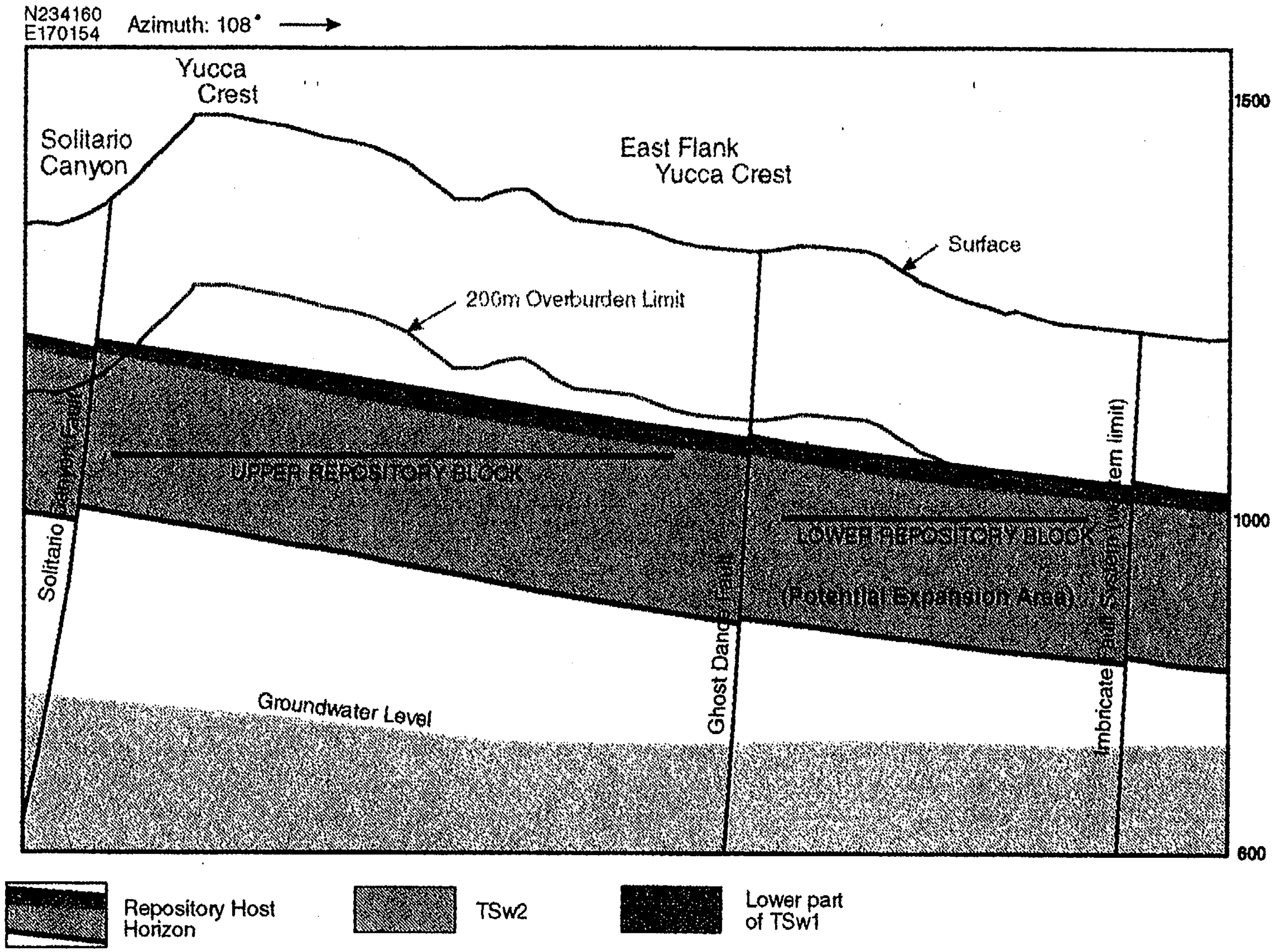
LENGTH = 5335 mm
DIAMETER = 1650 mm
TARE WEIGHT = 34,039 kg
LOADED WEIGHT = 50,423 kg

5-DHLW Disposal Container

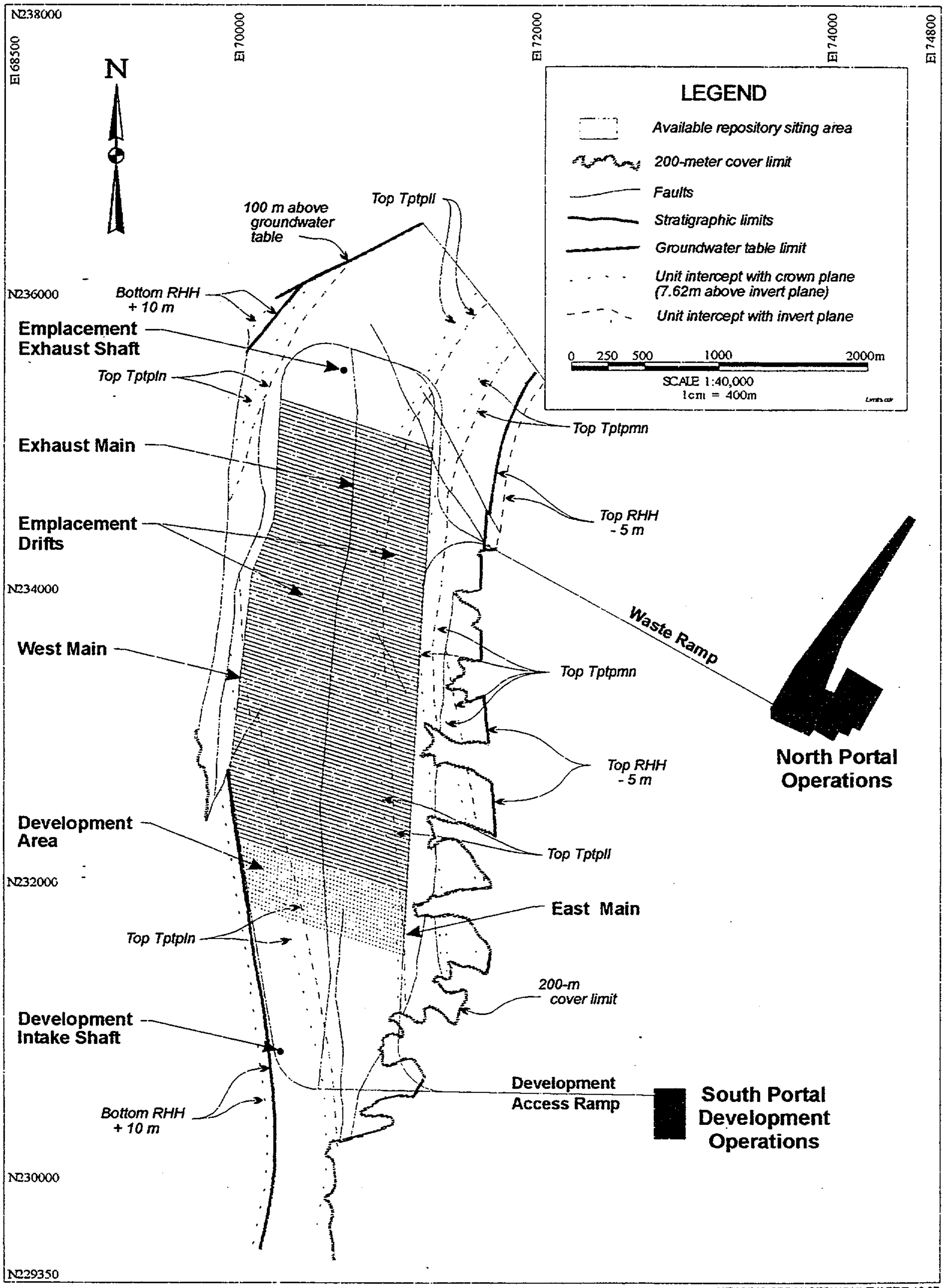


LENGTH = 3790 mm
DIAMETER = 1970 mm
TARE WEIGHT = 24,782 kg
LOADED WEIGHT = 35,692 kg

Repository Cross Section

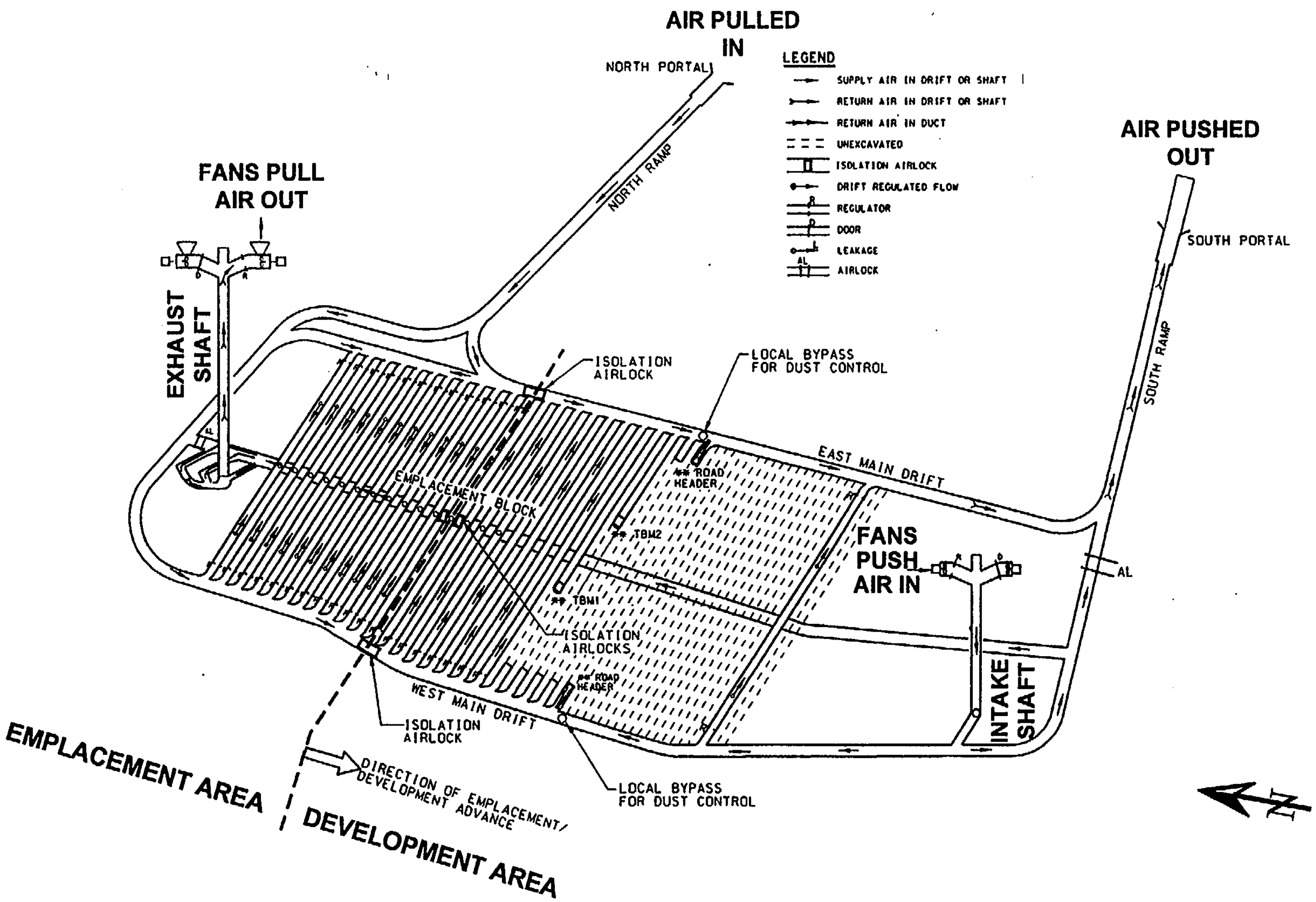


Available Upper Repository Level Siting Area

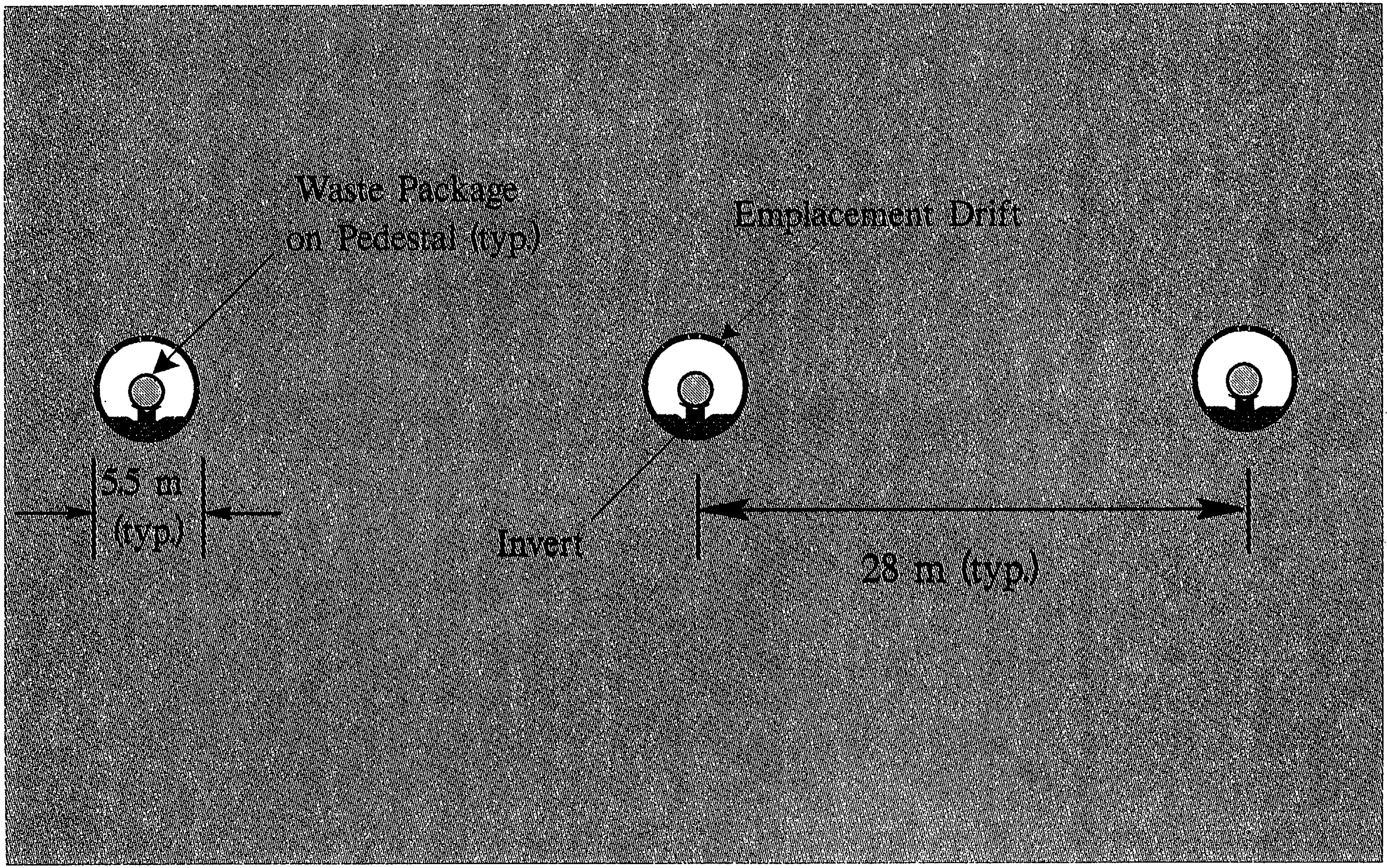


NEWLIMC.CDR.VADTRW.BAILEYART/7-16-97

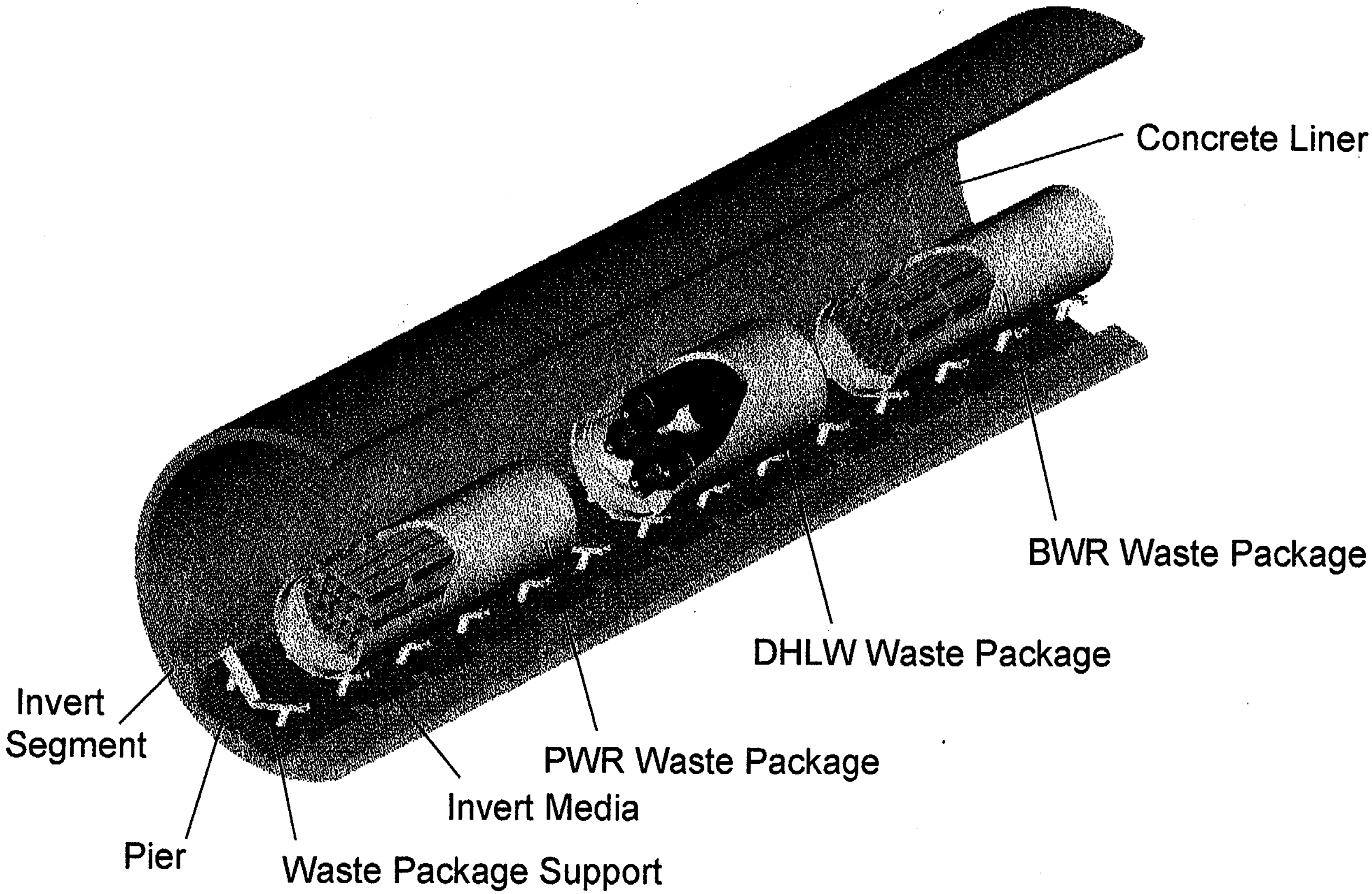
Ventilation



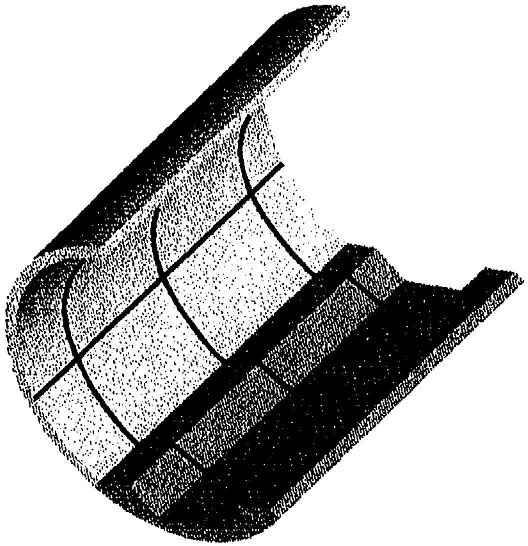
Partial Repository Section
(Looking East)



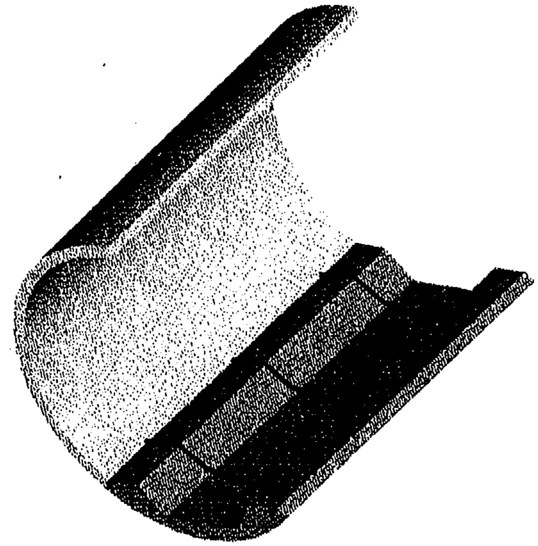
Engineered Barrier System



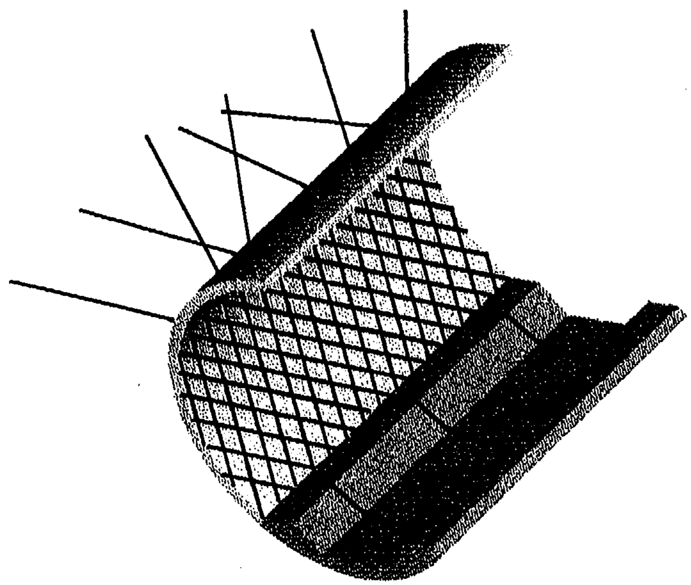
Ground Support System



PRECAST CONCRETE LINING

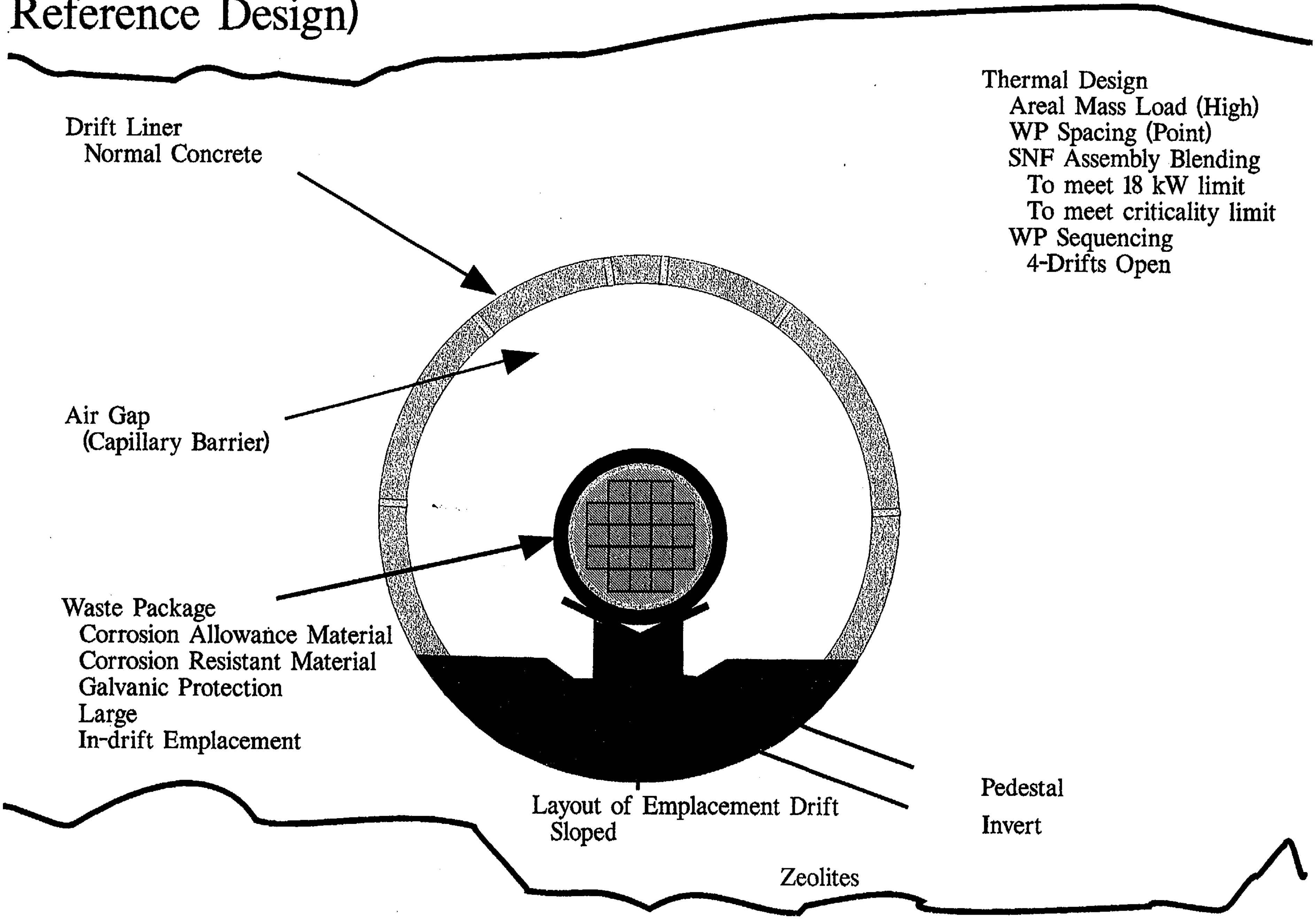


CAST-IN-PLACE CONCRETE LINING

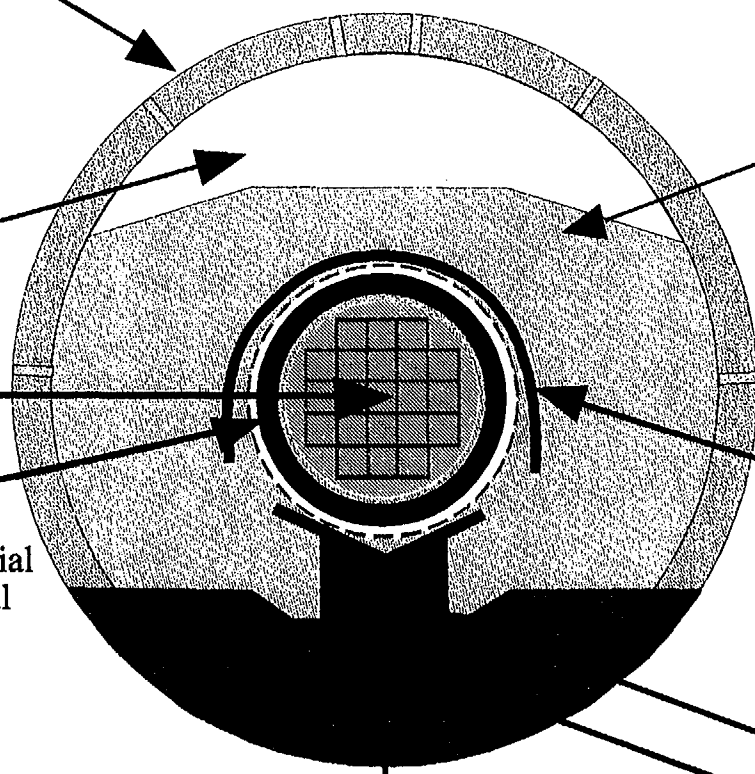


ROCK BOLT & MESH SUPPORT

Design Options for Waste Isolation (Reference Design)



Desig Options for Waste Isolation (Design Features Evaluation)



Engineered Barrier System (EBS)

- **What must a licensable EBS do?**
  - Work in concert with the natural barriers to the repository meets the applicable standard for waste isolation
  - Be configured to provide "defense-in-depth"
  - Be explainable and defendable by analyses and tests for NRC licensing

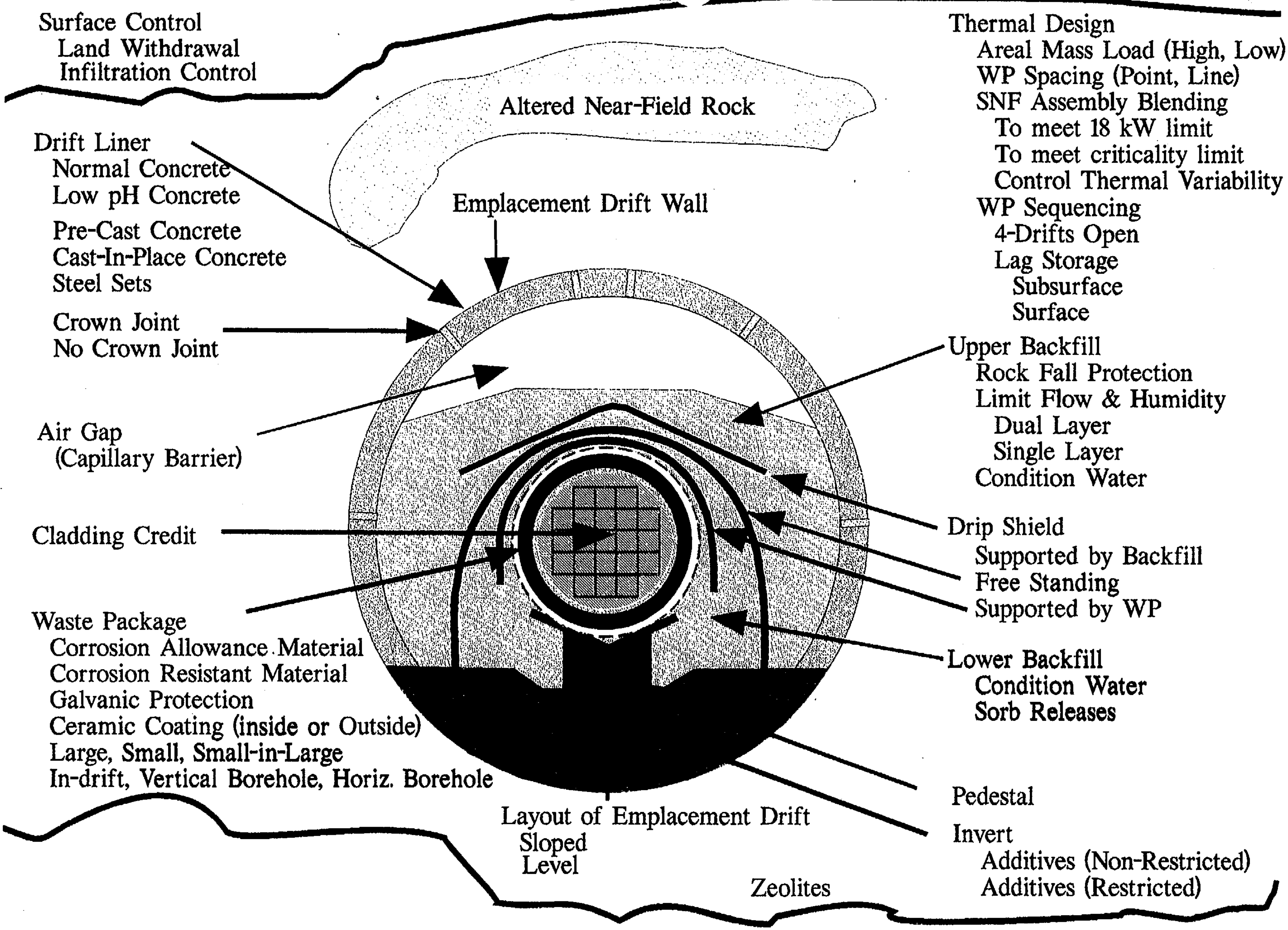
Engineered Barrier System (cont'd)

- What is the strategy for meeting the EBS requirements?
  - Develop a set of conditions that are expected over the life of the repository (e.g., water quantities and flow conditions in the mountain)
  - Identify and characterize a family of EBS design features that could be employed in the repository
  - Use Performance Assessment (PA) sensitivity studies to perform evaluations of the overall performance of the respository (using combinations of the EBS features) against the standard

Engineered Barrier System (cont'd)

- Select EBS features, such that multiple sets of features exceed the performance standard
- Assess the uncertainties associated with natural processes and each EBS feature set and select multiple feature sets for design
- Apply an overall margin or factor of safety and confirm the expected performance of the selected multi-set design with the selected safety margin
- Continue to plan and utilize confirmatory work, including historical data (non-project), analyses, natural analogs, laboratory tests, site tests and prototype tests

Design Options for Waste Isolation



ATTACHMENT 24

YUCCA
MOUNTAIN
PROJECT

PROJECT

UZ- Thermohydrology

Presented to:
DOE/NRC Technical Exchange on
Total System Performance Assessment
San Antonio, Texas

Presented by:
Nicholas D. Francis, Senior Member Technical Staff
Sandia National Laboratories
Albuquerque, New Mexico

U.S. Department of Energy
Office of Civilian Radioactive
Waste Management

July 21, 1997

UZ-Thermohydrology

NRC/DOE Total System Performance Assessment Technical Exchange

Nicholas D. Francis, Clifford K. Ho
Sandia National Laboratories

July 21-22, 1997

San Antonio, TX

The 4 Criteria for Prioritization of the Issues

Does the process/issue affect the magnitude, spatial distribution, or temporal variation of:

A. waste package temperature

B. relative humidity around the waste package

C. liquid water flow rate into the drift environment and onto a waste package

D. aqueous flow field from the repository to the SZ

The Key Issues

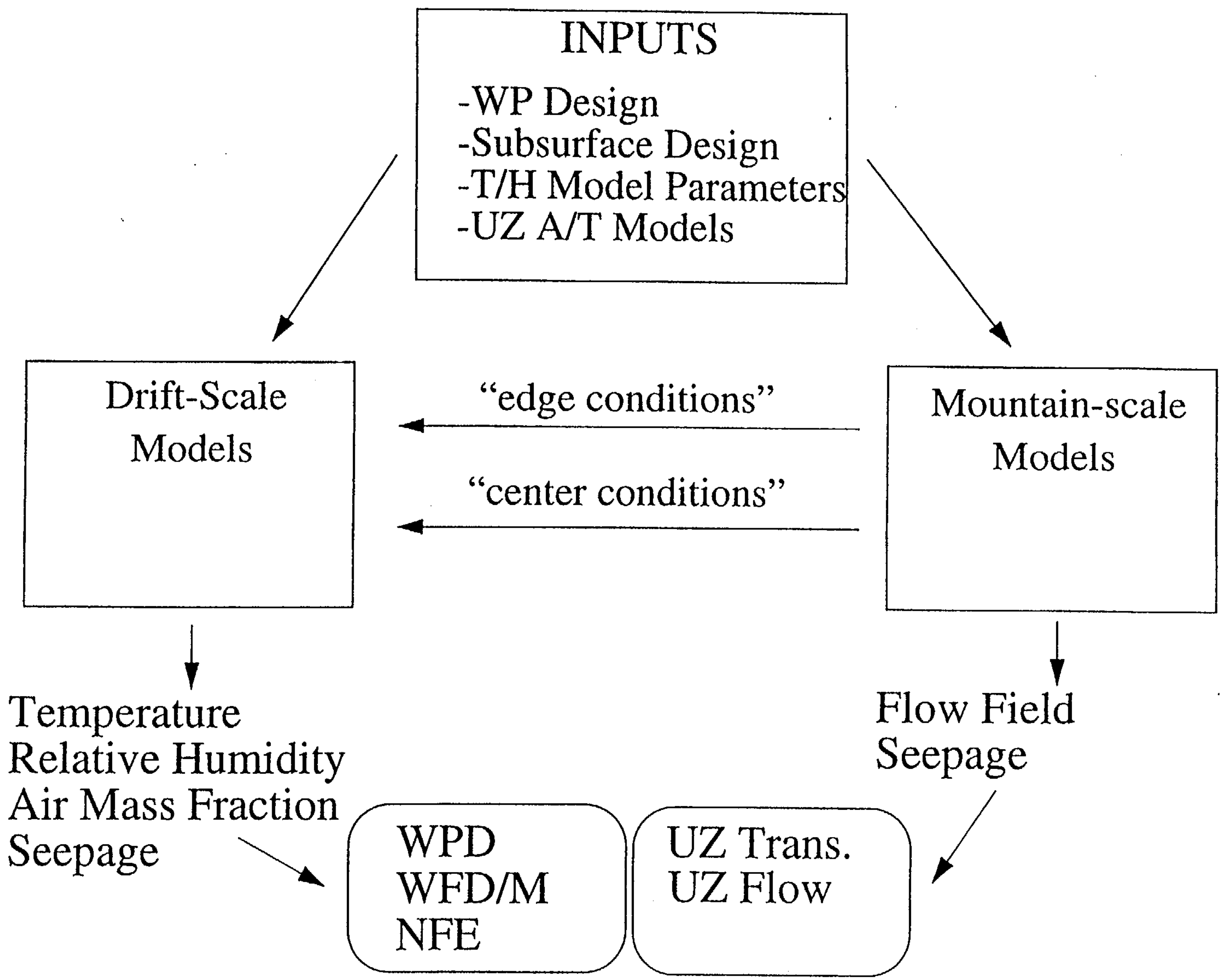
Table 1: Key Issues List for UZ-Thermohydrology

Category	Key Issues
Thermohydro-logic Pro-cesses and Parameters	**Issue 1.4:** What model should be used for fracture-matrix interactions in TSPA? **Issue 1.7:** How to upscale fracture properties and thermo-hydrologic pro-cesses. **Issue 1.3:** Do we need to include lateral (intra-unit) heterogeneity in TSPA?
Mountain-Scale Models	**Issue 2.1:** What alternatives for repository design should be considered in mountain-scale models? **Issue 2.2:** How important is the trade-off between 1-D/2-D modeling and 3-D modeling? **Issue 2.7:** How important is the dual permeability model (DKM) at the scale of the mountain? **Issue 2.5:** (Impact of drift-scale model coupling on the design of mountain-scale calculations.)

Table 1: Key Issues List for UZ-Thermohydrology

Category	Key Issues
Drift-Scale Models	**Issue 3.1:** Will variability of heat output among waste packages allow for condensate shedding onto cooler packages? **Issue 3.6:** How to model seepage into drifts and onto waste packages under non-isothermal conditions. **Issue 3.5:** Is it necessary for TSPA-VA to provide drift-scale models that represent edge as well as repository center conditions? **Issue 3.2:** (Can we use 2-D drift-scale models or will 3-D models be required to accurately predict WP temperature and drift relative humidity?)
Coupled Processes	**Issue 4.1:** Will phase-change processes cause chemical deposition and thus alteration of fracture and matrix properties? **Issue 4.2:** Will thermal stresses cause significant hydrologic-property alterations in regions of compression and tension? **Issue 4.3:** What effects would drift collapse have on temperature of the WP, RH in the drift, and seepage water contacting a WP? **Issue 4.4:** (Will evolution of a non-isothermal geochemical system have a significant impact on dissolved constituents that influence corrosion as well as solubility, speciation, and sorption of RNs?)

UZ-Thermohydrology Abstraction/Testing



Current Analysis Plans/Objectives

- **TSPA-VA may include the following**
  - a determination of repository performance using both mountain-scale models and drift-scale models
  - one thermal load (85 MTU/acre, CSNF only) for potentially four repository designs ("point" loading and "line" loading, with and without backfill)
  - dual permeability (DKM) and modified equivalent continuum (ECM) conceptual flow models to allow for fracture flow
    1) DKM used for a limited number of mountain-scale models
    2) Modified-ECM used as the base case model (mountain, drift)
  - container (also drift and drift wall) temperature, relative humidity, and air mass fraction obtained at repository "center" and "edge" locations for different waste package types (10 year, 26 year, DHLW, etc.)
  - scaled thermal loading for drift-scale edge models based on solution matching using 2-D mountain-scale models
  - approximate water seepage into the drift during the non-isothermal period
  - approximation of coupled mechanical and chemical effects in response to thermal loading

Current Analysis Plans/Objectives

- **TSPA-VA**
  - 1-D, 2-D, and 3-D (possibly a base-case simulation only) mountain-scale models will provide
    - thermally altered flow fields below the repository horizon as a function of time
    - thermally altered temperature and liquid saturation fields as a function of time
    - assessment of the importance of chemical and mechanical alteration of fracture properties during heating (will this influence the results obtained above?)
  - 2-D, 3-D drift-scale models will provide
    - temperature, relative humidity, air mass fraction, liquid saturation at the waste package, in the drift, or at the drift wall as a function of time and repository location
    - water seepage into the drift during the thermal period
    - gas-phase flow rates in the drift during the thermal period

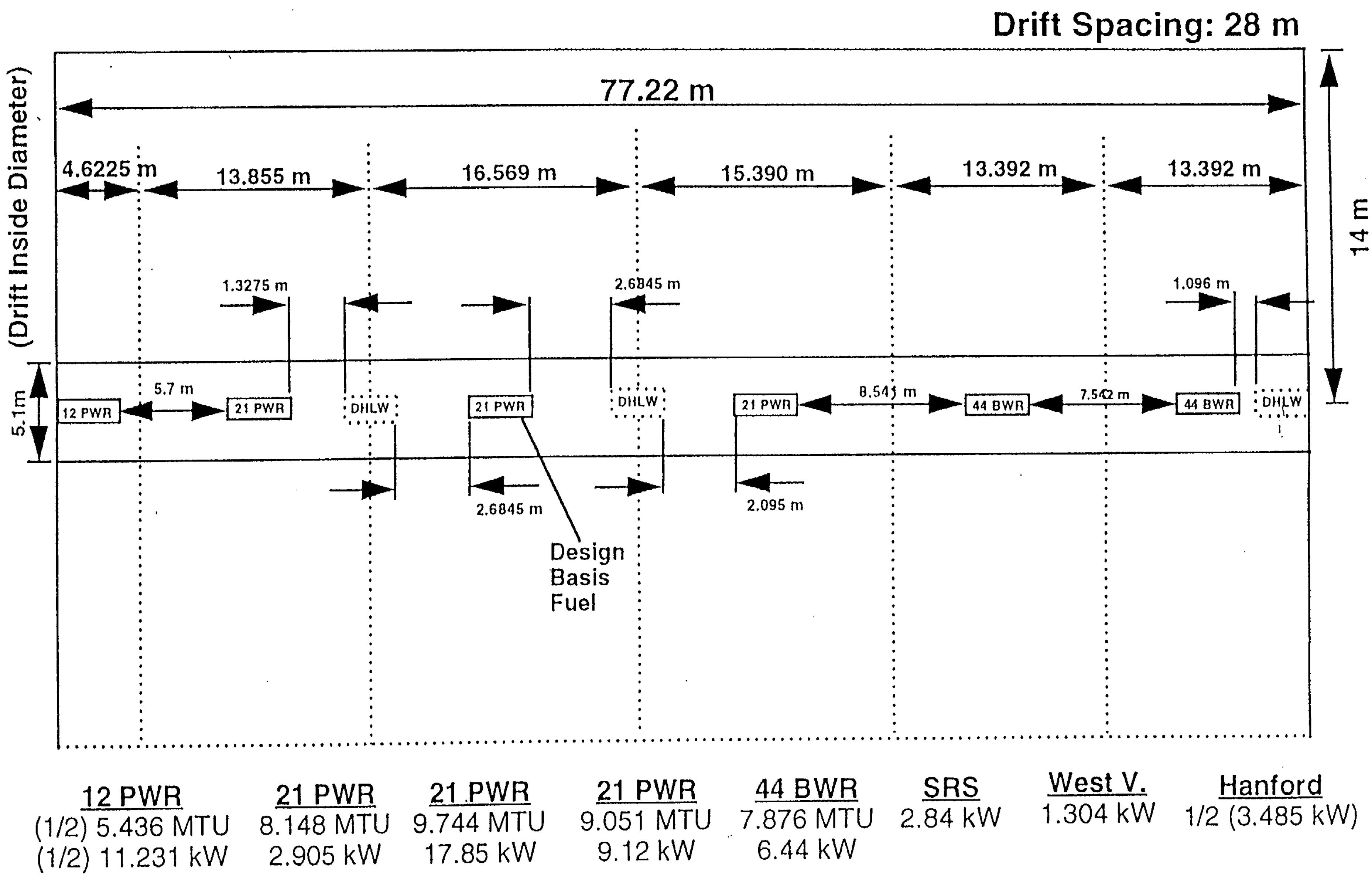
Current Analysis Plans/Objectives

- **TSPA-VA**
  - Design options being considered for TSPA-VA
    - 85 MTU/ac, no backfill, point loading
    - 85 MTU/ac, backfill, point loading
    - 85 MTU/ac, backfill, line loading
    - 85 MTU/ac, no backfill, line loading
    - 85 MTU/ac, no backfill, point loading, with rockfall

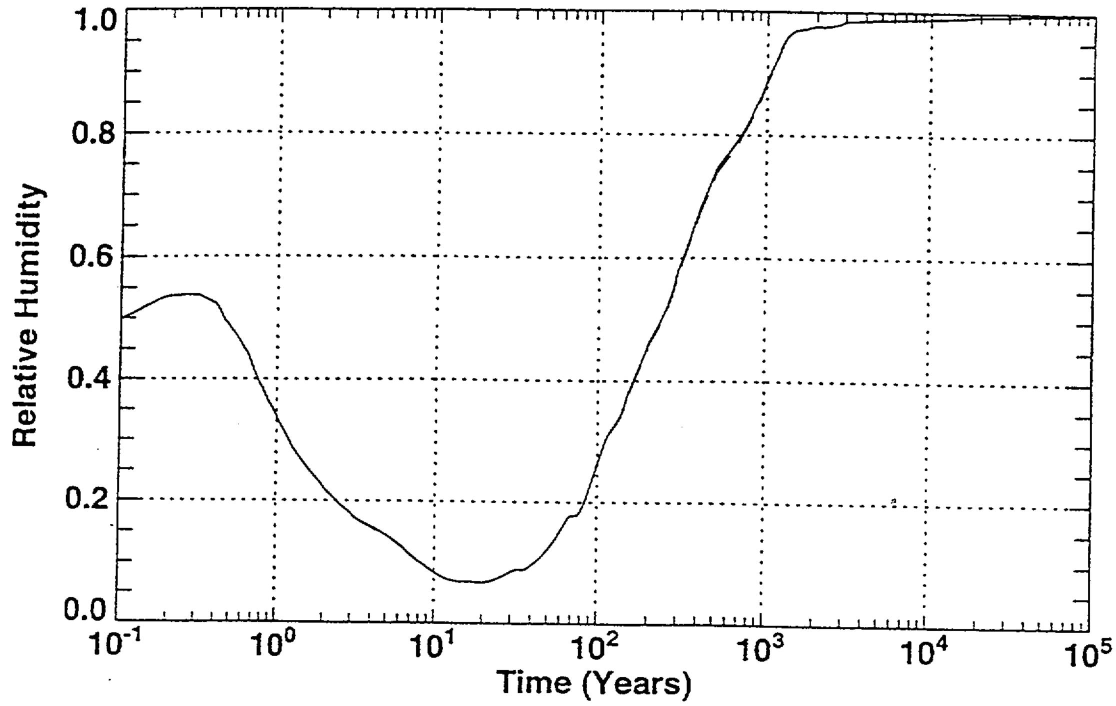
Example of Drift-Scale Process-Level Modeling

A Typical Emplacement Drift Segment

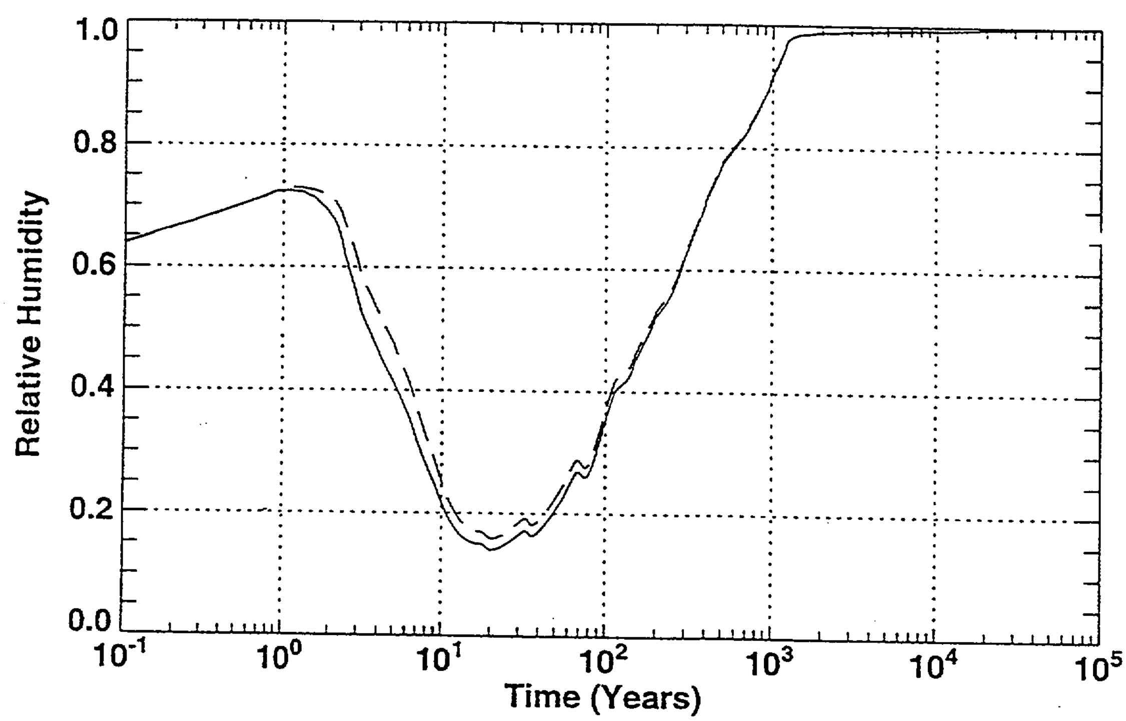
85 MTU/acre (CSNF)



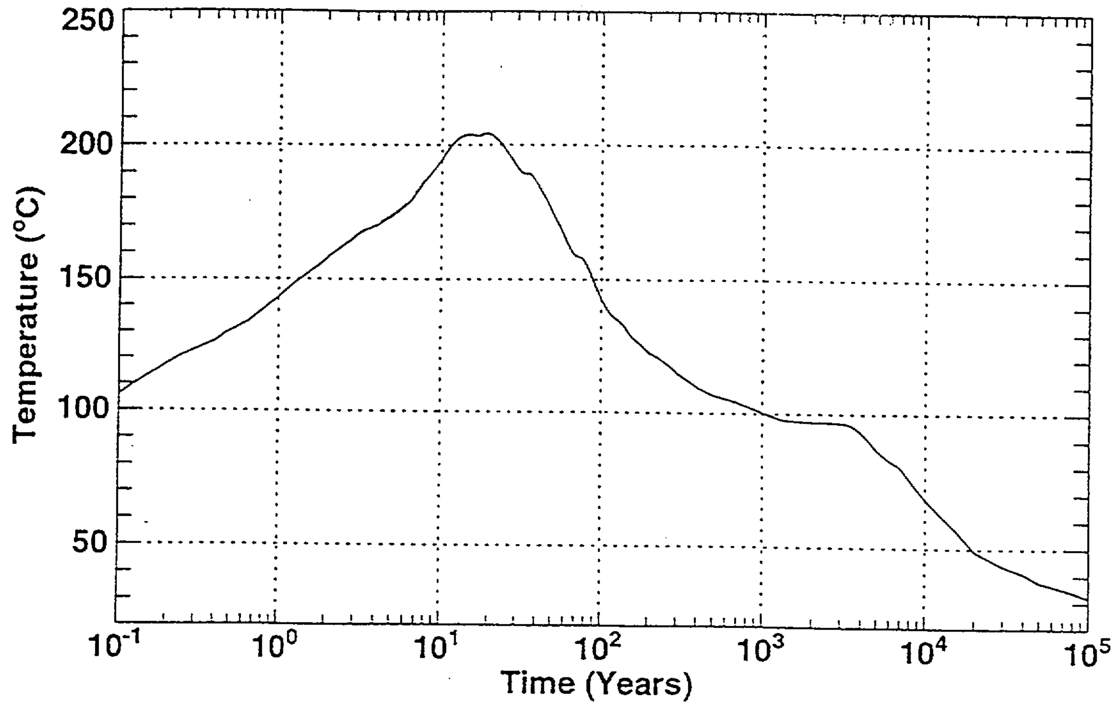
21 PWR (Hot) CSNF



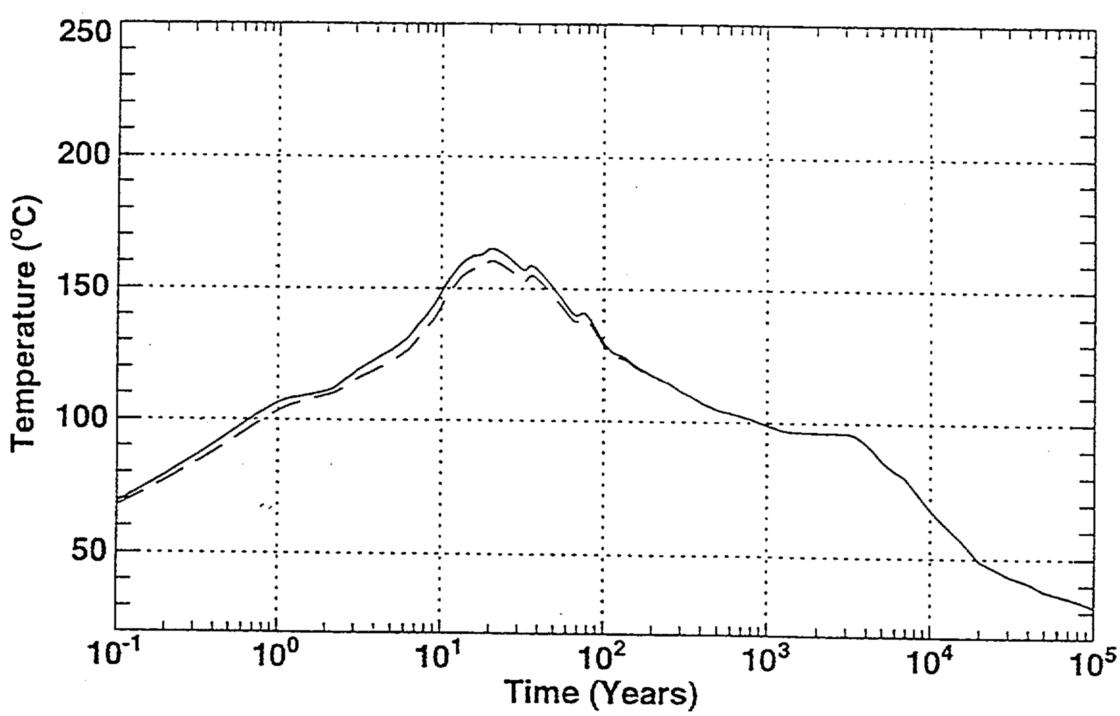
21 PWR (Medium) CSNF

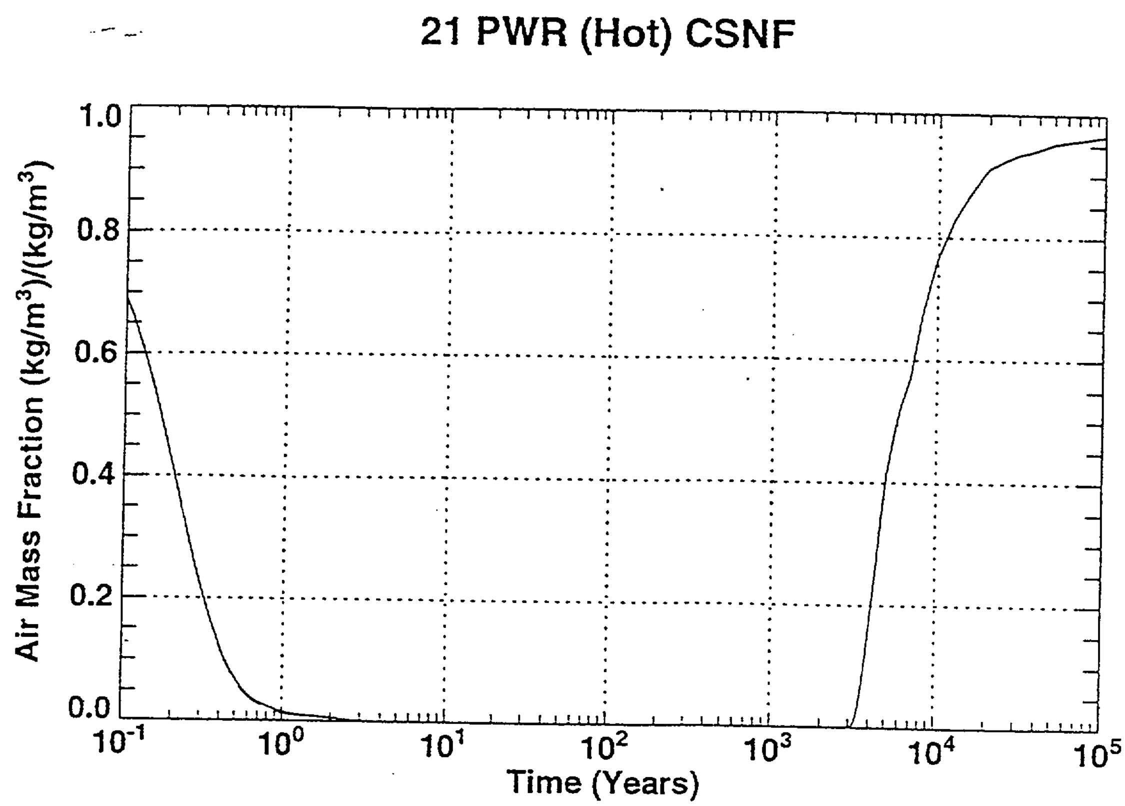


21 PWR (Hot) CSNF: Centerline Temperature

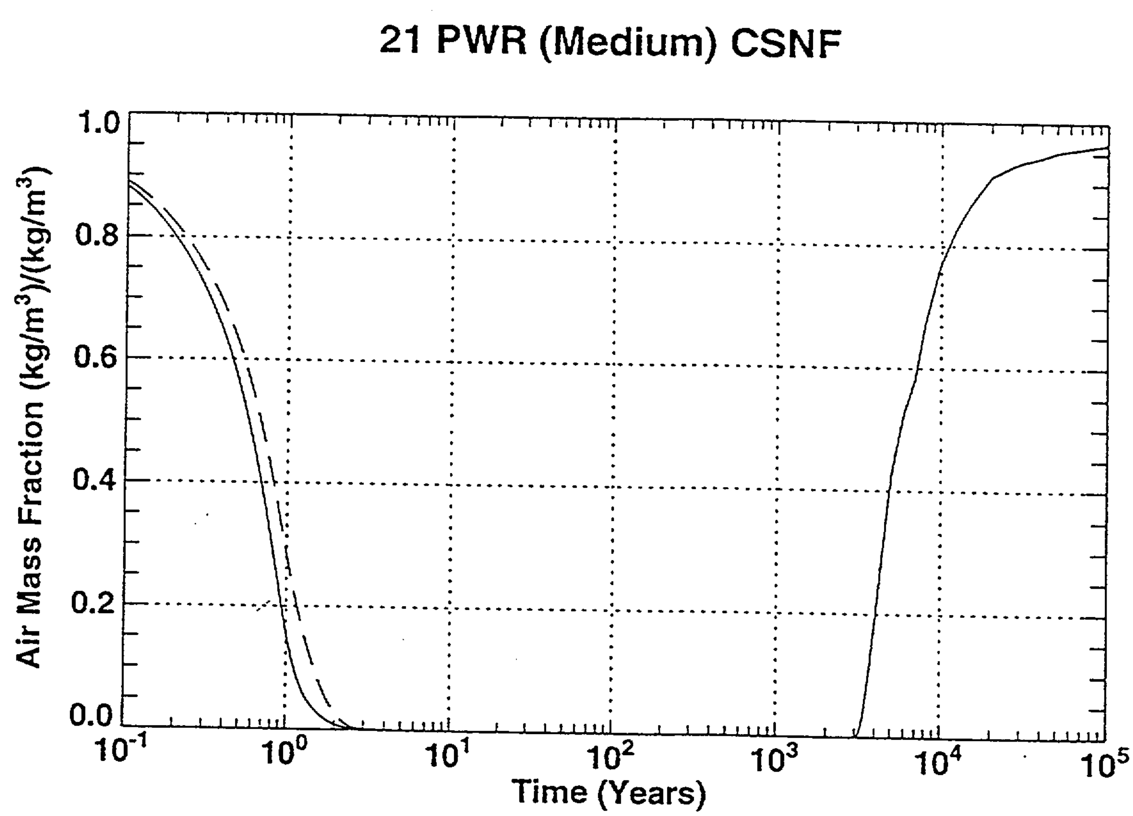


21 PWR (Medium) CSNF





21 PWR (Hot) CSNF
Air Mass Fraction (kg/m3)/(kg/m3)
1.0
0.8
0.6
0.4
0.2
0.0
10-1
100
101
102
103
104
105
Time (Years)



21 PWR (Medium) CSNF
Air Mass Fraction (kg/m3)/(kg/m3)
1.0
0.8
0.6
0.4
0.2
0.0
10-1
100
101
102
103
104
105
Time (Years)

Example of Mountain-Scale Process-Level Modeling (Coupled Processes)

Thermo-Mechanical Simulation of Zones of Compression and Tension at Yucca Mountain (Mack et al., 1989)

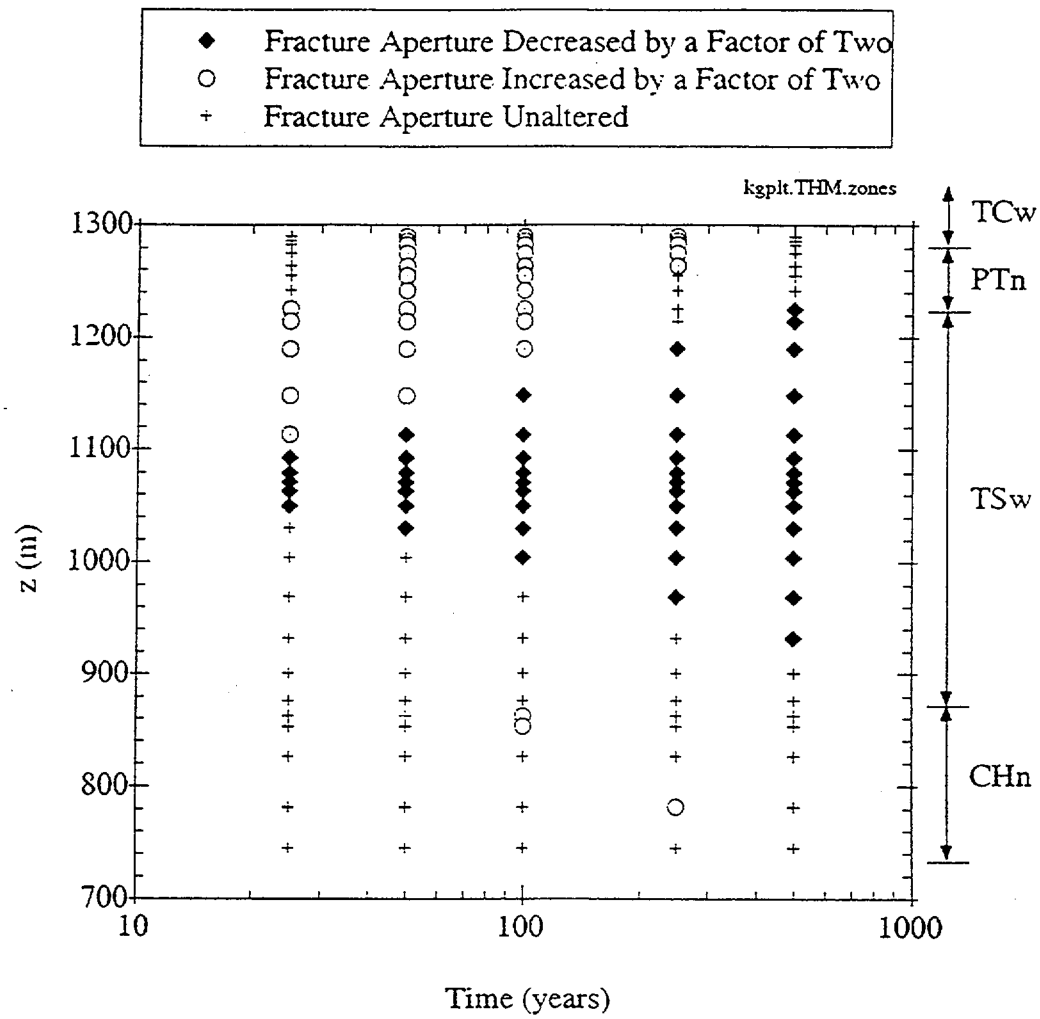


Figure 1. Regions of the one-dimensional thermo-hydrologic model where the fracture aperture has increased or decreased by a factor of two at 25, 50, 100, 250, and 500 years. The spatial and temporal distributions of altered zones were determined from a thermo-mechanical simulation described in Mack et al. (1989). Each symbol represents an element in the thermo-hydrologic model, and the repository is assumed to be located at 1071 m.

Comparison of Fracture Fluxes for Altered and Unaltered Thermo-Hydrologic Simulations

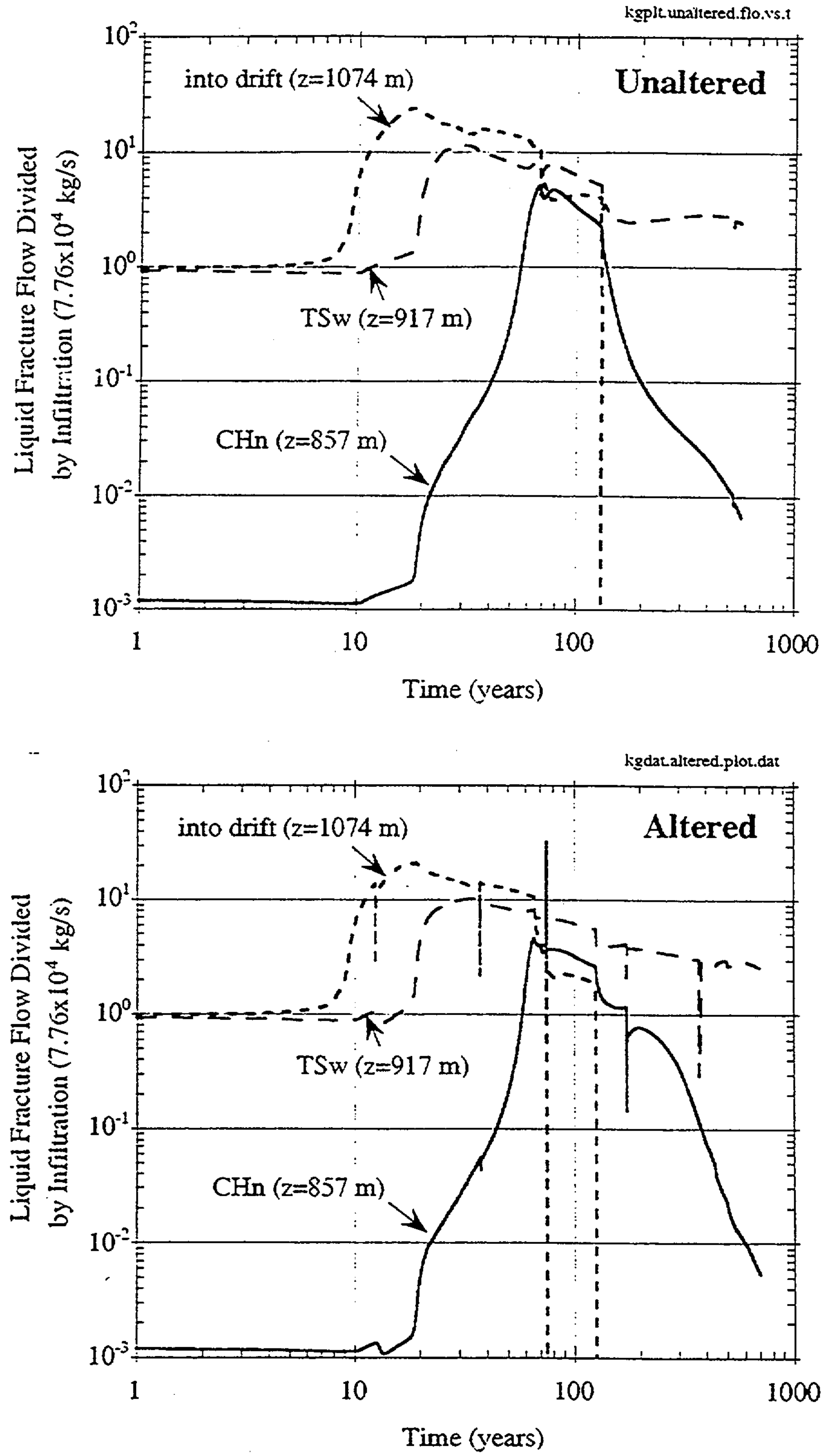


Figure 3. Liquid fracture flow divided by infiltration at three locations as a function of time for unaltered and altered simulations.

Conclusions

- **Thermal-mechanical-hydrologic coupling did not significantly alter flow fields in the mountain for the case considered**
- **Not much waste package variability after about 1000 years for the "point loading" cases considered**
- **Work still remains:**
  - drift-scale calculations for the repository "edge"
  - consideration of other design cases (e.g., backfill)
  - develop mountain-scale flow field multipliers during the thermal period
  - other sensitivities at both scales

ATTACHMENT 25

YUCCA
MOUNTAIN
PROJECT

Studies

Near-Field Geochemical Environment Abstraction/Testing Activities Overview

Presented to:
DOE/NRC Technical Exchange on
Total System Performance Assessment
San Antonio, Texas

Presented by:
David C. Sassani
Senior Geochemical Analyst
CRWMS M&O Performance Assessment

Date: July 21-22, 1997

U.S. Department of Energy
Office of Civilian Radioactive
Waste Management

Presentation Overview

- Introduction to NFGE Abstraction/Testing Workshop Sessions & Major Issues
- Summary of Abstraction/Testing Activity Plans
- Conceptual NFGE Model Abstraction for TSPA-VA

Workshop Sessions and Major Issues

• Session I - Solid Phase(s) Evolution			Score
–	1.11	Volume and flux of water into drift	74
–	1.1	Compositions, abundances, and distribution of introduced materials	70
–	1.5	Reactions with aqueous and gas phases	66
• Session II - Gas Phase Evolution			
–	2.9	Gas flux into drift	66
–	2.3	Reactions with materials & microbes (excluding waste package)	50
–	2.4	Reactions with waste package	50

Workshop Sessions and Major Issues

- **Session III - Aqueous Phase Evolution** — **Score**
  - 3.3 Reactions with major introduced materials (excluding wp) — 68
  - 3.1 Effects of open vs closed system — 62
  - 3.4 Reactions with WP materials — 60
- **Session IV - Colloidal Phase(s) Evolution**
  - 4.9 Reversibility of radionuclide sorption onto colloids — 58
  - 4.5 Effects on colloids of aqueous phase composition — 54
  - 4.3 Generation of colloids from waste form(s) — 52

Summary of Abstraction Plans

- Water-Solid Chemistry Model
- Colloid Sensitivity Studies
- Effects of Microbial Communities Model
- Gas Composition Evolution Model

Water-Solid Chemistry Model

- **Objective**
  - Model the reaction of water with major materials to estimate
    - aqueous compositions contacting waste packages and waste forms
    - aqueous compositions in the EBS through which RN transport
- **Approach**
  - define solids' evolution scenarios from experiments
    - Cementitious materials, steels
  - calculate equilibrated fluid compositions along path
    - ambient gas
  - incorporate perturbations
    - gas composition, microbial effects

Colloid Sensitivity Studies

- Objective
  - To assess the role of colloids in facilitating Pu transport within the drift and into the geosphere
- Approach
  - assess introduced colloid formation/stability
    - Pu intrinsic colloids
    - description of Fe-oxide colloid stability
    - Pu sorption/desorption rates with Fe-oxides
  - evaluate transport
    - 1-D weeps
    - 2-D detailed transport
  - compare to aqueous release at water table
    - integrated breakthrough
    - peak concentrations
    - time of first arrival

Effects of Microbial Communities Model

- **Objective**
  - bound the development of microbial communities and resultant effects of microbial processes on *bulk* fluid pH and gas composition evolution in the drift
- **Approach**
  - define constraints on microbial development/activity
    - macronutrient and energy supply
    - temperature
    - water activity
  - augment McKinley et al. model for YM site specifics
    - unsaturated system
    - CO_2 gas supply
    - aerobic processes

Gas Composition Evolution Model

- **Objective**
  - constrain the evolution of in-drift gas composition for four components (O_2, CO_2, H_2O, and N_2) considering gas flux into the drift and source/sink terms.
- **Approach**
  - base-case gas scenario is TH flux/air mass fraction
  - identify source/sink terms for O_2 and CO_2
    - metals as O_2 sinks
    - CO_2 reactions to consider
      - materials (microbes)
      - single heater test constraints
  - O_2 reduction times via mass balance
  - evaluate controls on CO_2 composition through time

Conceptual NFGE Model for TSPA-VA

- Use Staged Approach to Development
  - incorporate changes to gas, water, and solids based on the thermal perturbation only (least coupled)
    - incoming gas composition
    - incoming water composition
    - solids' scenarios defined by T-regime
  - incorporate changes to gas, water, and solids from reactions with major materials in the drift
    - simple solids evolution scenarios
    - more coupled solids reaction
  - incorporate changes to gas and water from microbial activities
  - incorporate colloids if sensitivity studies indicate

ATTACHMENT 26

YUCCA
MOUNTAIN
PROJECT

Waste Package Degradation Modeling and Abstraction for TSPA-VA

Presented to:
DOE/NRC Technical Exchange on
Total System Performance Assessment
San Antonio, Texas

Presented by:
Joon H. Lee
Sr. Performance Assessment Analyst
CRWMS M&O/INTERA

July 22, 1997

U.S. Department of Energy
Office of Civilian Radioactive
Waste Management

Outline of Presentation

- Introduction
- Summary of waste package degradation abstraction/testing workshop
- Summary of analysis plans for waste package degradation abstraction/testing
- Conceptual model for waste package degradation modeling and abstraction for TSPA-VA
- Key issues addressed in the waste package degradation expert elicitation
- Concluding remarks

Performance Measures of Waste Package

- Waste containment - time of waste package failure
  - waste package failure defined as the first perforation (pit penetration or crack propagation) through the container wall
  - correspond to the initiation of waste form degradation inside the failed waste package
- Controlled/gradual release of radionuclides - waste package failure rate and subsequent perforation rate of failed waste container
  - waste package failure rate provides the rate of waste inventories that become available for release
  - subsequent perforation rate of failed waste container provides the area in the waste container available for radionuclide transport by diffusion and/or advection

WP Degradation Abstraction/Testing Workshop Summary

- **Criteria for issue prioritization**
  - significance of the issue/process on <u>the time of waste package failure</u>
    - generally, the earlier the waste package failure, the higher the EBS release rates will be, and thus the AE release rates will be
  - significance of the issue/process on <u>the rate of waste package failure</u>
    - generally, the greater the waste package failure rates, the higher the EBS release rates will be, and thus the higher the AE release rates will be
  - significance of the issue/process on <u>the rate of waste package perforations</u> and thus <u>the rate of radionuclide release</u> from the failed waste package
    - the EBS release rates from failed waste packages also depend on the waste package perforation rates and the failure modes (cracks, pit penetration, structural failure, etc.)

WP Degradation Abstraction/Testing Workshop Summary (continued)

- Developed a total of 94 issues relevant to waste package degradation
- Selected 28 key issues based on the prioritization criteria
- Combined the key issues into four major topics important to long-term degradation of waste package
  - carbon-steel outer barrier corrosion
  - nickel-based corrosion-resistant inner barrier corrosion
  - microbiologically influenced corrosion
  - representation of the effects of variability and uncertainty in near-field conditions, WP manufacturing, WP materials, and WP materials corrosion

Summary of Analysis Plans for Waste Package Degradation Abstraction/Testing

- **Carbon-steel outer barrier corrosion**
  - improve/update existing model(s) of humid-air and aqueous corrosion of carbon steel by incorporating additional data from the on-going comprehensive corrosion testing program and literature
    - humid-air general corrosion of carbon steel modeled as a function of RH, T, salt deposit, and water dripping
    - aqueous general corrosion modeled as a function of T and water chemistry including pH and chloride concentration
    - localized variations of carbon steel corrosion represented by a "pitting factor" as a multiplier to the (uniform) general corrosion depth

Summary of Analysis Plans for Waste Package Degradation Abstraction/Testing
(continued)

- **Nickel-based corrosion-resistant inner barrier corrosion**
  - localized corrosion of inner barrier modeled using a stochastic approach as a function of temperature and chemistry of the contacting solution
  - incorporate interactions between the inner barrier and the outer barrier materials
    - effects of the outer barrier corrosion products
    - localized corrosion of inner barrier in the crevice and gap between the inner and outer barriers
    - galvanic protection of inner-barrier
- **Microbiologically influenced corrosion (MIC)**
  - MIC modeled as localized corrosion incorporating additional constraints
    - temperature, water availability, nutrient availability, pH

Summary of Analysis Plans for Waste Package Degradation Abstraction/Testing

(continued)

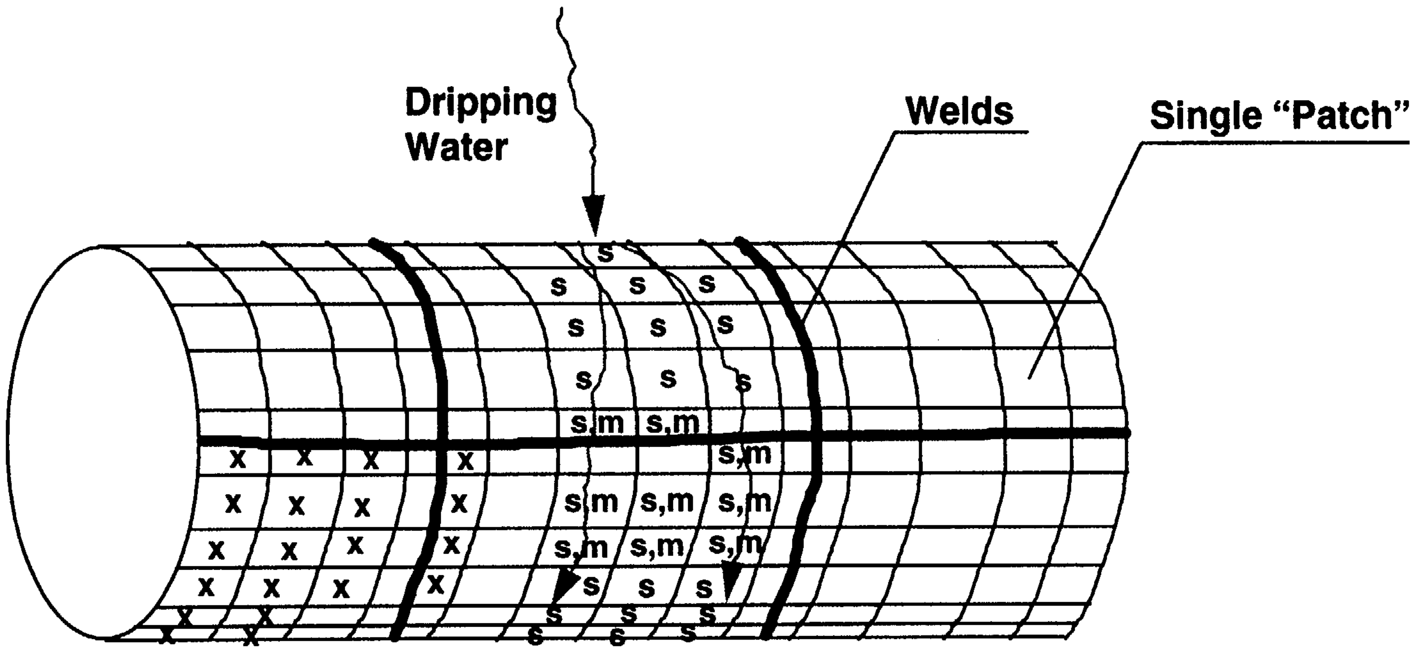
- **Representation of variability and uncertainty in waste package degradation**
  - develop models/abstractions to represent variability and uncertainty in near-field conditions, WP manufacturing and materials
    - temperature, relative humidity, in-drift water chemistry, in-drift water dripping, rockfalls, welds, etc.
  - develop models/abstractions to represent uncertainty in the WP degradation conceptual model and individual corrosion models
  - develop methods to incorporate the models/abstractions into waste package performance assessment
  - exercise the models/abstractions to investigate the sensitivity of waste package degradation

Schematic of the Conceptual Model for WP Degradation Modeling and Abstraction for TSPA-VA

* T, RH, in-drift water dripping across repository from drift-scale T-H model

* pH, [Cl^-] of dripping water, $P(O_2)$, across repository from NFE model

* Number of patches per waste package?



s - Patches w/ drips [0.1-10% of S.A.? distribution type?]

x - Patches w/o Galvanic Protection [1-10% of S.A.? distribution type?]

m - Patches w/ MIC [1-10% of S.A.? distribution type?]

Patches w/ welds [1% of S.A.?]

Key Issues Addressed in the Waste Package Degradation Expert Elicitation

- **Elicitation workshops and interviews**
  - workshops held in March and May in Las Vegas and June in San Francisco
  - elicitation interviews conducted following the 3rd workshop
  - elicitations will be completed in August (the report due by 8/15)
- **Corrosion of carbon steel outer barrier**
  - threshold for initiation of humid-air corrosion of carbon steel outer barrier
  - threshold for initiation of aqueous corrosion of carbon steel outer barrier
  - effects of water drips on the corrosion rate of carbon steel outer barrier
  - representation of "localized variations" of corrosion, emphasizing the long-term corrosion effects

Key Issues Addressed in the Waste Package Degradation Expert Elicitation (continued)

- **Corrosion of nickel-based corrosion-resistant inner barrier**
  - threshold for initiation of localized corrosion
  - probability of pit generation as a function of exposure conditions (T, Cl^- concentration and pH)
  - probability of "stifling" of pits with depth and other factors
  - pitting/crevice corrosion rate, pit density, and pit size as a function of exposure conditions (T, Cl^- concentration and pH) and pit depth
  - pitting/crevice corrosion rate in the presence of galvanic coupling with the carbon steel outer-barrier as a function of exposure conditions (T, Cl^- concentration and pH), pit depth, and degree of the outer barrier degradation
  - elicitations include associated uncertainty (and/or bounding uncertainty) and variability

Key Issues Addressed in the Waste Package Degradation Expert Elicitation (continued)

- **Microbiologically influenced corrosion (MIC)**
  - probability and spatial distribution of microbe (bacteria and/or fungi) colony population on the carbon steel outer barrier and CRM inner barrier
  - corrosion rate of carbon steel and localized (pitting/crevice) corrosion rate of the inner barrier under the microbe colony
  - elicitations expressed as a function of the exposure conditions (T, RH, and the contacting solution chemistry), nutrient availability, "liquid" water availability, and the presence of carbon steel and its corrosion products, including associated uncertainty (and/or bounding uncertainty) and variability

Concluding Remarks

- In TSPA-VA, the waste package degradation model and its abstractions will be refined from the TSPA-1995 results
  - develop corrosion models/abstractions based more on mechanistic processes
  - incorporate additional important corrosion processes
  - corrosion models/abstractions supported by site-specific corrosion data
- Alternative models/abstractions being developed from the expert elicitation project will enhance the confidence of the waste package degradation modeling and abstraction for TSPA-VA

ATTACHMENT 27

YUCCA MOUNTAIN PROJECT

Studies

Waste Form Degradation Modeling/Abstraction

Presented to:
DOE/NRC Technical Exchange on
Total System Performance Assessment
San Antonio, Texas

Presented by:
Bill Halsey
EBS/NFE PA LLNL
CRWMS M&O Performance Assessment

July 22, 1997

U.S. Department of Energy
Office of Civilian Radioactive
Waste Management

Waste Form Degradation/Radionuclide Mobilization

- Workshop held February 19-21, 1997 at LLNL
- Six Abstraction/Testing Plans were developed:

  Cladding and Canister Credit

  Spent Fuel Dissolution

  Post Dissolution Water Chemistry and Precipitated Phase Formation

  DHLW Glass Degradation and Radionuclide Release

  Solubility Limits on Dissolved Radionuclides

  EBS Transport/Release

Waste Form Issues Considered

<u>Session I Issues:</u>
1.1.1 Inventory of SNF
1.1.2 Distribution of radionuclides
1.2.1 Cladding degradation model
1.2.2 SNF Oxidation model
1.2.3 SNF Dissolution model
1.2.4 Time dependent evolution of solution and alteration layer
1.3 Representation of evolution of the near-field environment
1.4 Representation of data uncertainty/variability
1.5 Exposed SNF surface area

<u>Session II Issues:</u>
2.1 Inventory of glass waste
2.2 Distribution of radionuclides
2.3 Canister degradation
2.4 Vapor hydration
2.5 Dissolution rate
2.6 Time dependent evolution of solution and alteration layer
2.7 Evolution of NFE
2.8 Representation of data uncertainty/variability
2.9 Exposed glass waste surface area

<u>Other DOE Fuels Breakout Issues</u>
2B1 Cladding and Canister Credit
2B2 Evolution of NFE
2B3 Dissolution

Issue Ranking and A/T Plan Correlation

#	SESSION I Spent Nuclear Fuel	numerical score	Abstraction/Testing Plan
1.2.3	Dissolution rate (includes issue 2B3)	62	SNF Dissolution
1.2.4	Time dependent evolution of solution and alteration layer	62	Post Dissolution Chemistry/Phases
1.3	Representation of evolution of the near field	56	Post Dissolution Chemistry/Phases
1.5	Exposed SNF surface area	48	SNF Dissolution
1.2.1	Cladding degradation model (includes issue 2B1)	46	Cladding/Canister Credit
	Priority Cut-Off Point		
1.4	Representation of data uncertainty/variability	38	SNF Dissolution
1.1.1	Inventory of SNF	36	
1.2.2	Oxidation model	34	Cladding/Canister Credit
1.1.2	Distribution of RNs	32	
	SESSION II DHLW (Glass) and Other Wastes		
2.6	Time dependent evolution of solution and alteration layer	66	DHLW Glass Degradation/Release
2.4	Vapor hydration	60	DHLW Glass Degradation/Release
2.7	Evolution of NFE (includes issue 2B2)	60	DHLW Glass Degradation/Release
2.5	Dissolution rate	56	DHLW Glass Degradation/Release
	Priority Cut-Off Point		
2.1	Inventory of glass waste	36	
2.8	Representation of data uncertainty/variability	36	DHLW Glass Degradation/Release
2.9	Exposed glass waste surface area	30	DHLW Glass Degradation/Release
2.3	Canister degradation	26	
2.2	Distribution of radionuclides	22	

Cladding and Canister Credit

Objective: To include the effects of cladding on the delay in release of fission products

Product: Time dependent fraction of fuel exposed

Status: Evaluating mechanisms of cladding perforation and unzipping to determine how best to represent cladding performance.

1) Pin perforation from strain failure, delayed hydride cracking, cladding oxidation, surface oxidation and mechanical failure are considered:
   - Cladding failure from stress causes small % of cladding perforation
   - Current DHC analysis shows failure not expected

2) Mechanical failure of cladding from degradation of waste package and drift wall/liner eventually ends cladding credit

3) Clad unzipping based on fuel oxidation model by Einziger determines fuel exposure after initial failure

Spent Fuel Dissolution and Alteration Rates

Objective: To update the bounding intrinsic dissolution rate model for commercial SNF

Product: Spent Fuel dissolution rate model as function of temperature, burnup, and bounding, aggressive water chemistry

Status: Updated bounding intrinsic dissolution model (Steward, LLNL) is currently being evaluated

Compare new model predictions with previous model and other data:

- Compare Model with ANL Unsaturated Test Alteration Rates
- Additional PNNL Flow-through Test data available this summer
- Compare model with Canadian and European data

Post-Dissolution/Release Radionuclide Concentration, Water Chemistry and Precipitated Phase Formation of Alteration Layer on Spent Fuel Surface

Objective: To estimate radionuclide "in solution" and colloidal concentrations at the altered waste form surface (alteration/precipitated phases, alteration layer retention factors, colloidal species, film-flow rate model)

Product: 1) Solid phase formation (identification, radionuclide content, paragenesis, final solubility limiting phase)
2) Solution chemistry (major element composition, radionuclide content, colloid content)
3) Rate model relating aggregated precipitated phase formation to intrinsic dissolution rate

Status:
- Alteration/precipitated phase formation: Update report in review (ANL)
- Solution chemistry: Update report in review (ANL)
- Film-flow rate model: work in progress

DHLW Glass Dissolution and Radionuclide Release

Objective: Model the alteration of DHLW glass waste and the release of radionuclides as a function of temperature, water chemistry, water contact mode and the extent of vapor hydration prior to liquid water contact

Product:
- Humid air alteration: Look-up table of alteration rate
- Aqueous alteration: Analytic expression of dissolution rate
- Aqueous release from unaltered glass: Bounded by availability from aqueous alteration rate but not solubility limited due to colloid formation.
- Aqueous release from altered glass: Bounded by rapid release of a substantial amount of the altered inventory.

Status: Testing in progress:
- YMP drip tests with as-cast actinide doped glass (ANL)
- EM tests on range of glass including as cast radioactive glass and vapor hydrated material

Model updates expected this fall

ATTACHMENT 28

YUCCA
MOUNTAIN
PROJECT

Waste Form Mobilization and Engineered Barrier Transport

Presented to:
DOE/NRC Technical Exchange on
Total System Performance Assessment
San Antonio, Texas

Presented by:
Jerry McNeish
Performance Assessment
CRWMS M&O (INTERA/DESI)

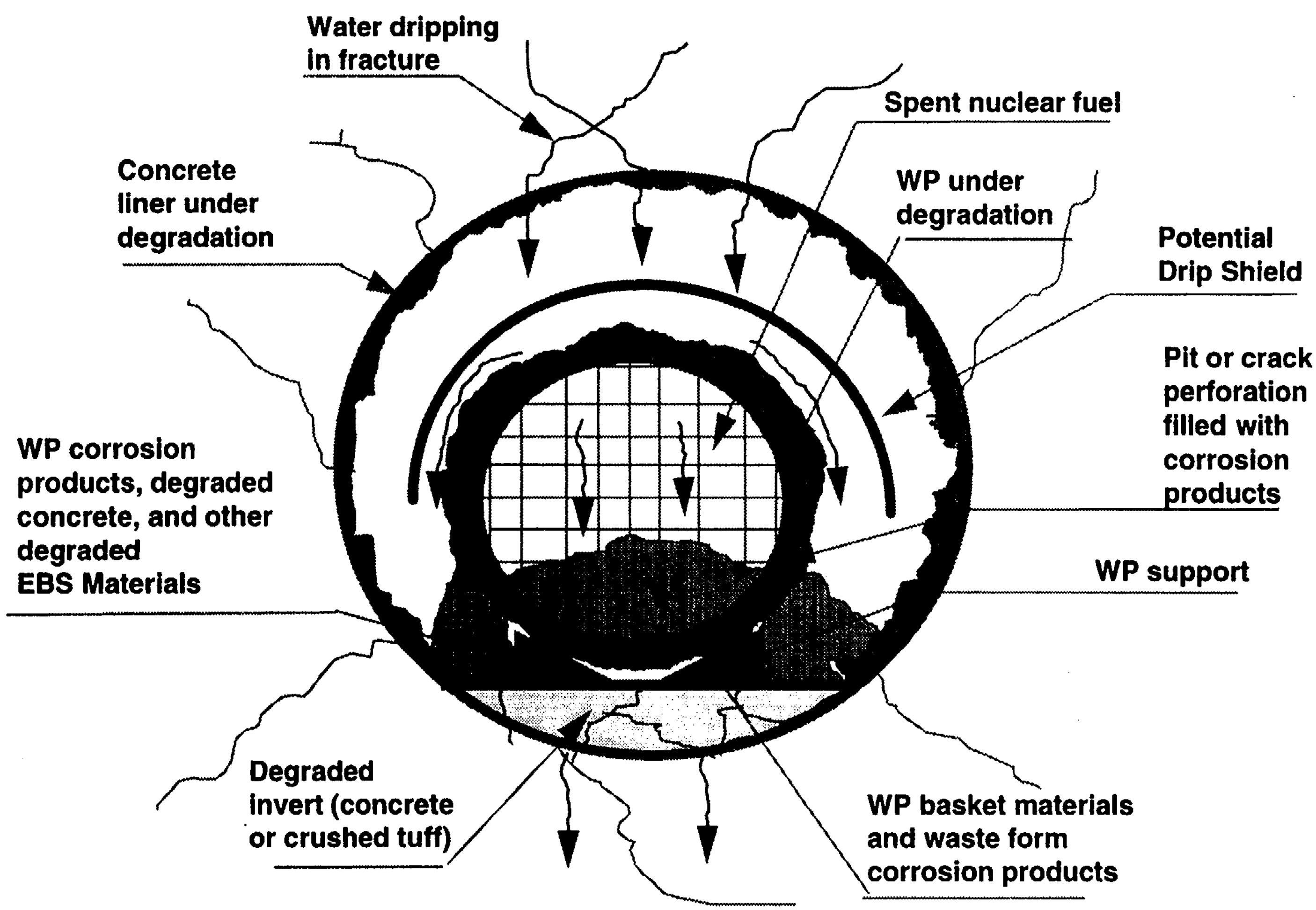
July 22, 1997

U.S. Department of Energy
Office of Civilian Radioactive
Waste Management

Overview

- What Areas will be Discussed
- Key Issues from Workshop
- Status of Analysis Plans from Workshop
- Expected Form of Abstractions for TSPA-VA

Schematic of Important EBS Components



Key Issues from Workshop

- **EBS Transport Model**
  - Important water contact modes
  - Primary transport paths
  - Aqueous transport through WP and other EBS components (including corrosion products)
  - Colloid transport through WP and other EBS components (including corrosion products)
- **Solubility Limits on Dissolved Radionuclides**
  - Update solubilities for key RN's

Status of Analysis Plans from Workshop

- EBS Transport Model:
  - Objective: Develop EBS RN source-term model to provide input to UZ far-field transport model
  - Expected Result: Model(s) which capture water contact mode and RN transport for 3 waste package conditions and 2 EBS flow-path elements. Concentration of soluble and colloidal RNs through EBS.
  - Status: Reference Case is being developed in RIP compartment model.

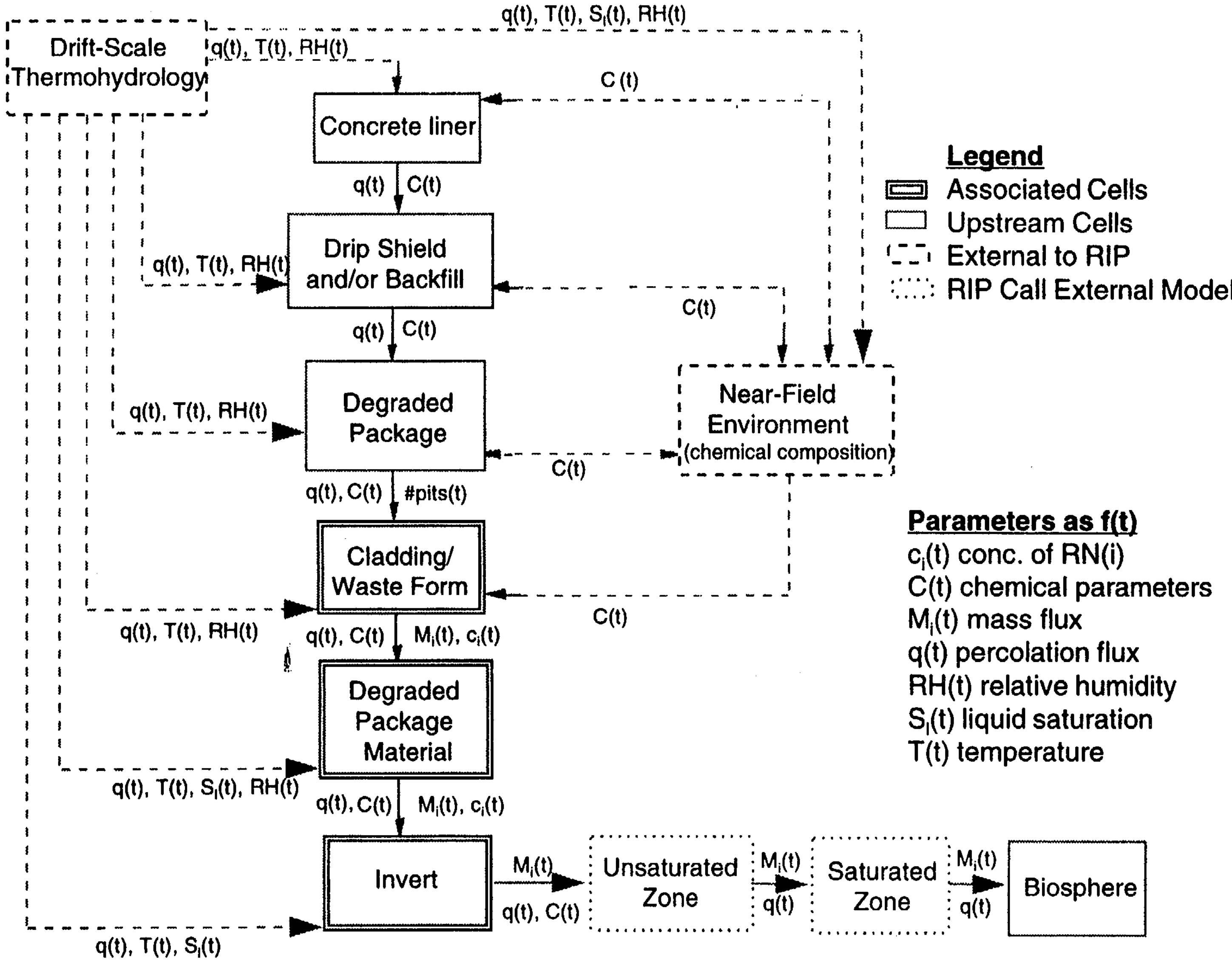
Status of Analysis Plans from Workshop
(continued)

- **Solubility Limits on Dissolved RN's:**
  - Objective: Derive constraints on dissolved radionuclide concentrations based on long-term interactions with the geologic environment.
  - Expected Result: Response surface with uncertainties or a distribution of dissolved RN concentrations for various fluid compositions and T effects and dissolved concentration limits.
  - Status: Expect updated solubility values for selected RNs by mid-August.

Form of Abstractions for TSPA-VA

- **Base Case:**
  - Use RIP compartment model approach to simulate multiple components of the EBS and develop source term from EBS.
  - Implement solubility constraints as response surface or distribution.
- **Sensitivity Analyses:**
  - Compartment discretization (e.g., additional compartments for other EBS components)
  - Alternative pathway scenarios.

Information Flow in EBS for TSPA-VA



Parameters as f(t)

- $c_i(t)$ conc. of RN(i)
- C(t) chemical parameters
- $M_i(t)$ mass flux
- q(t) percolation flux
- RH(t) relative humidity
- $S_l(t)$ liquid saturation
- T(t) temperature

ATTACHMENT 29

COMMENTS ON DOE'S

ENGINEERED BARRIER SYSTEM APPROACH IN TSPA-VA

July 21-22, 1997
DOE/NRC Technical Exchange on
Total System Performance Assessments
for Yucca Mountain

James R. Firth
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Division of Waste Management
Performance Assessment and HLW Integration Branch

INTEGRATION OF THE EBS WITH THE NEAR FIELD ENVIRONMENT

- THE WASTE PACKAGE, WASTE FORM, AND EBS TRANSPORT MODULES RELY ON THE NEAR FIELD GEOCHEMICAL FLUID COMPOSITION:

  - HOW WILL DOE COMPENSATE FOR THE DELAY IN THE NEAR FIELD ABSTRACTION EFFORTS IN DEVELOPING THESE MODULES?

EXTRAPOLATION OF CORROSION DATA

- HOW WILL DOE EXTRAPOLATE THE SHORT TERM LLNL DATA ON WASTE PACKAGE CORROSION THAT WILL BE AVAILABLE FOR TSPA-VA?

CREDIT FOR BENEFICIAL EFFECTS SHOULD BE JUSTIFIED

- IF DOE IS TO TAKE CREDIT FOR GALVANIC PROTECTION IN ASSESSING THE PERFORMANCE OF THE WASTE PACKAGE, THE TECHNICAL JUSTIFICATION FOR THE MODELING APPROACH NEEDS TO BE STRENGTHENED

  - WHAT APPROACH IS DOE TAKING TO IMPROVE ITS MECHANISTIC BASIS FOR ITS GALVANIC PROTECTION MODELS?

  - WHAT CURRENT AND POTENTIAL DISTRIBUTION DATA WILL BE AVAILABLE FOR USE IN TSPA-VA?

  - WILL DOE CONSIDER THE POTENTIAL FOR TEMPERATURE, GEOMETRY AND CORROSION PRODUCTS TO REDUCE COUPLING EFFICIENCY?

- LIMITED DATA WILL BE AVAILABLE ON SOME DESIGN ALTERNATIVES (E.G., CERAMIC DRIP SHIELDS OR COATINGS); HOW WILL DOE SUPPORT ITS CONCEPTUALIZATION OF THESE ASPECTS OF ITS DESIGN?

ABSENCE OF POTENTIALLY SIGNIFICANT ADVERSE EFFECTS FROM EBS DESIGN SHOULD BE ADDRESSED/JUSTIFIED

- THE LARGE QUANTITY OF CONCRETE WILL CAUSE FLUIDS TO REACT WITH THE HOST ROCK, WHICH MAY BE DETRIMENTAL TO REPOSITORY PERFORMANCE

- THE EFFECTS OF THERMAL LOADING ON THE NEAR FIELD AND EBS, FOR EXAMPLE:

  - MECHANICAL RESPONSE OF FRACTURES DURING HEATING AND COOLING COULD SUBSTANTIALLY INFLUENCE NEAR FIELD FLUID FLOW FIELD

ABSENCE OF POTENTIALLY SIGNIFICANT ADVERSE EFFECTS FROM EBS DESIGN SHOULD BE ADDRESSED/JUSTIFIED (CONTINUED)

- THE CHEMICAL CONDITIONS AT THE WASTE PACKAGE SURFACE WILL BE INFLUENCED BY PERIODIC REWETTING AND EVAPORATION, WHICH MAY LEAD TO MORE AGGRESSIVE CONDITIONS FOR CORROSION (E.G., SALT BRINE FORMATION)

- MECHANICAL FAILURE ASSOCIATED WITH:

  - RESIDUAL STRESSES

  - THERMALLY-INDUCED CHANGES IN MECHANICAL PROPERTIES

- GALVANIC PROTECTION OF INNER-BARRIER MAY RESULT IN ACCELERATED CORROSION OF THE OUTER-BARRIER

ATTACHMENT 30

SENSITIVITY AND UNCERTAINTY ANALYSES FOR THE NRC HLW PROGRAM

July 21-22, 1997
DOE/NRC Technical Exchange on
Total System Performance Assessment
for Yucca Mountain

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Performance Assessment and HLW Integration Branch

OUTLINE

- Objectives

- Approach

    IPA Phase 2

    Current Approach

        Subsystem (Module)

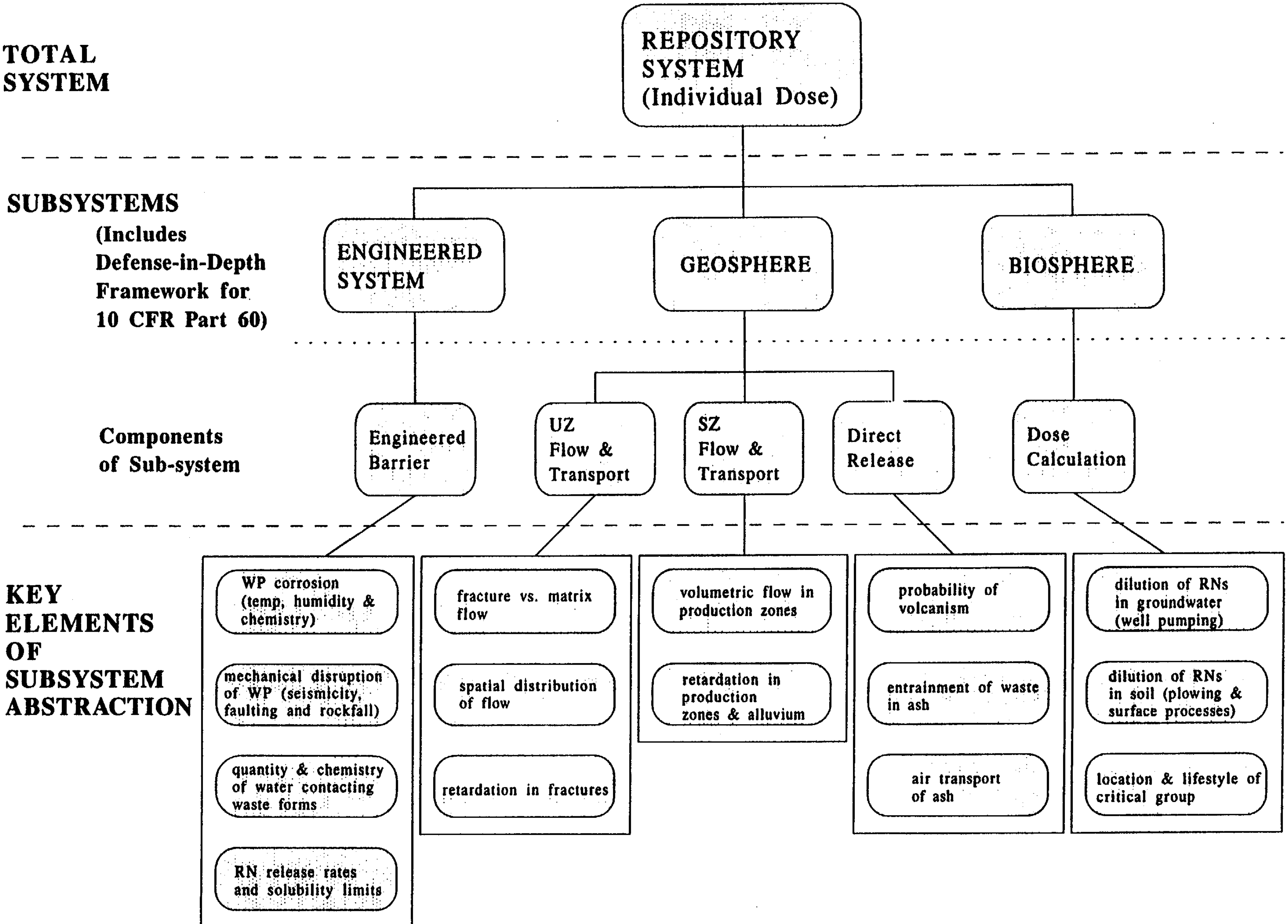
        Total System

- Use of Results

OBJECTIVES

- To determine the parameters to which the output (e.g., dose) is most sensitive.
- To quantify the output sensitivity and uncertainty associated with the important parameters.
- To explore how the TPA 3.1 code reflects the analysts' conceptual model or "biases."
- To determine which characteristics of the system are most significant to overall performance.
- To develop review capabilities.

DRAFT


TOTAL SYSTEM
REPOSITORY SYSTEM (Individual Dose)
SUBSYSTEMS (Includes Defense-in-Depth Framework for 10 CFR Part 60)
ENGINEERED SYSTEM
GEOSPHERE
BIOSPHERE
Components of Sub-system
Engineered Barrier
UZ Flow & Transport
SZ Flow & Transport
Direct Release
Dose Calculation
KEY ELEMENTS OF SUBSYSTEM ABSTRACTION
WP corrosion (temp, humidity & chemistry)
mechanical disruption of WP (seismicity, faulting and rockfall)
quantity & chemistry of water contacting waste forms
RN release rates and solubility limits
fracture vs. matrix flow
spatial distribution of flow
retardation in fractures
volumetric flow in production zones
retardation in production zones & alluvium
probability of volcanism
entrainment of waste in ash
air transport of ash
dilution of RNs in groundwater (well pumping)
dilution of RNs in soil (plowing & surface processes)
location & lifestyle of critical group

TECHNIQUES USED IN IPA PHASE 2
(NUREG 1464)

- To determine the most significant parameters

  Step-wise regression
  Kolmogorov-Smirnov Test
  Scatter Plots

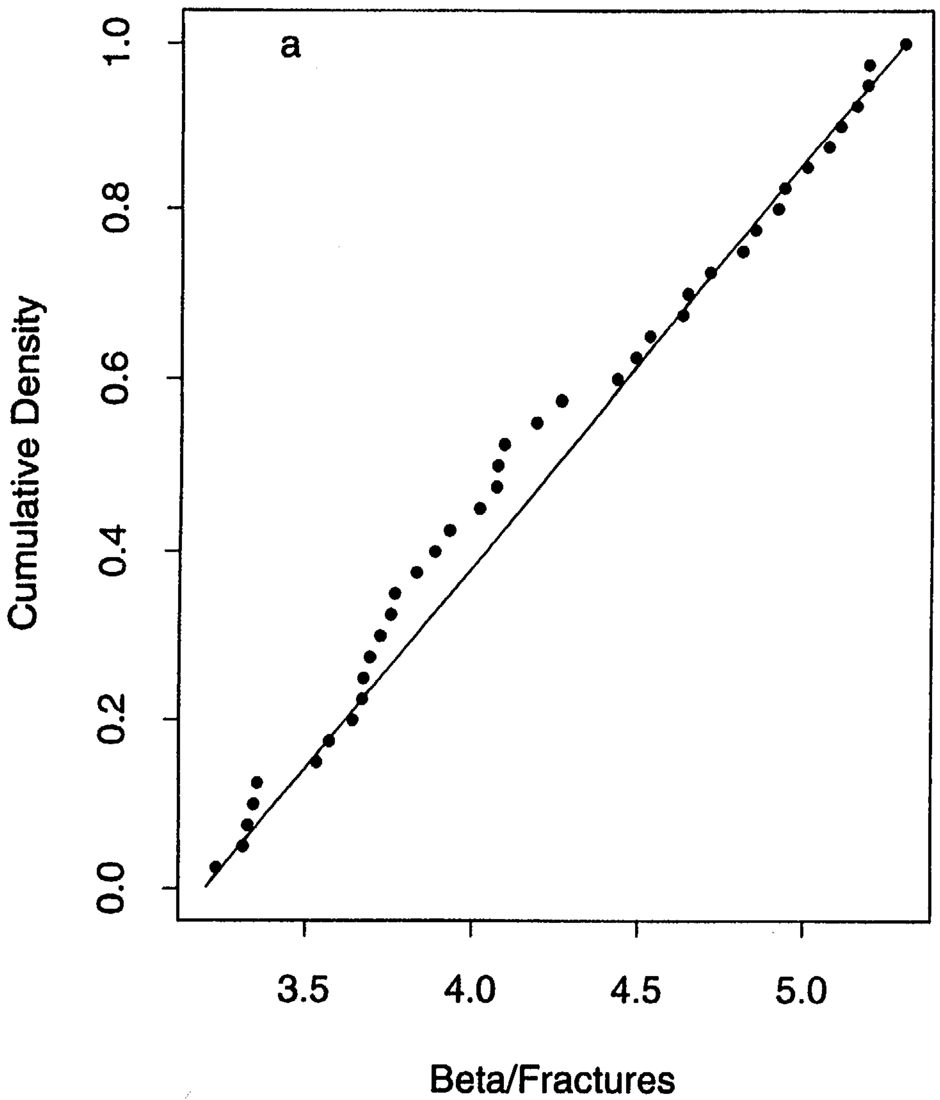
- To determine performance relative to surrogates for subsystem requirements

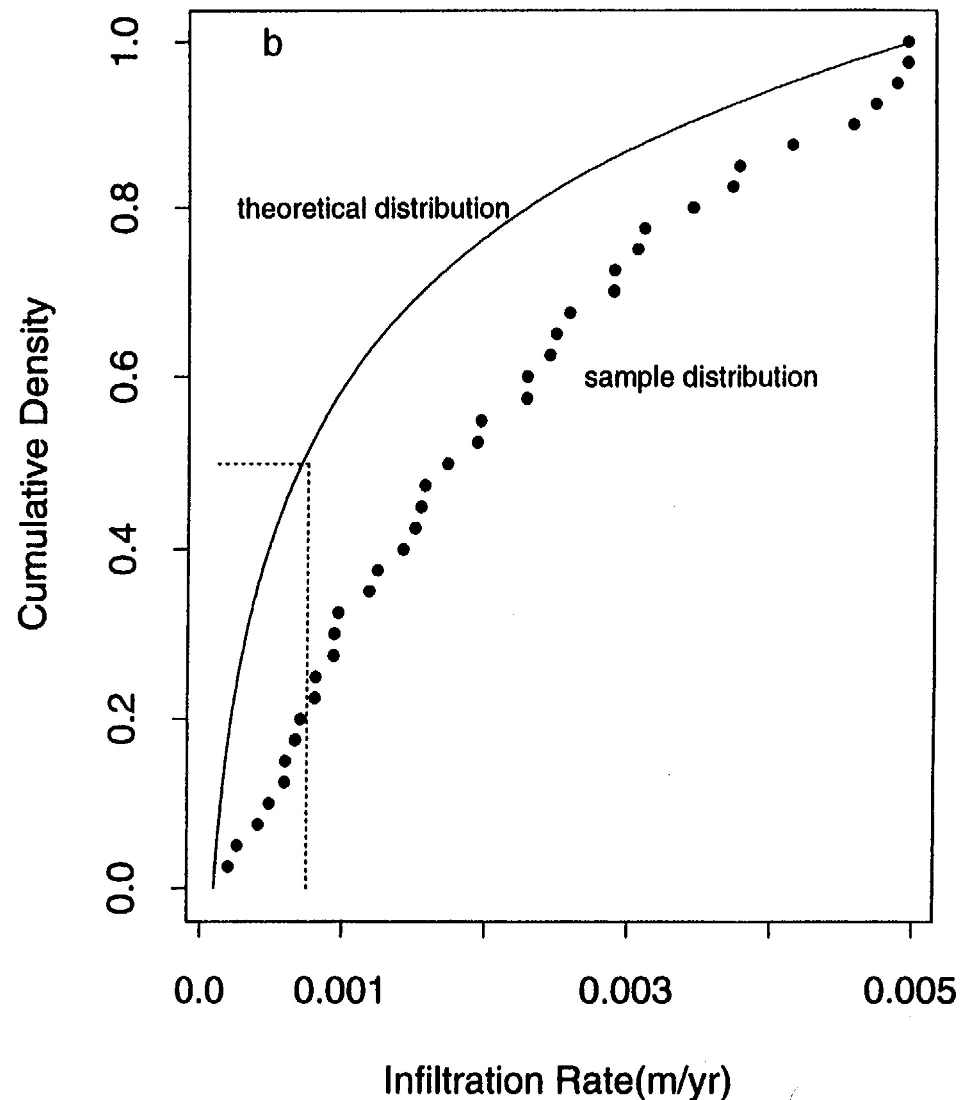
  Scatter plots with subsystem requirement delineated
  Histograms

- To illustrate variability in output

  Histograms
  Box plots

Distribution functions for Kolmogorov-Smirnov test

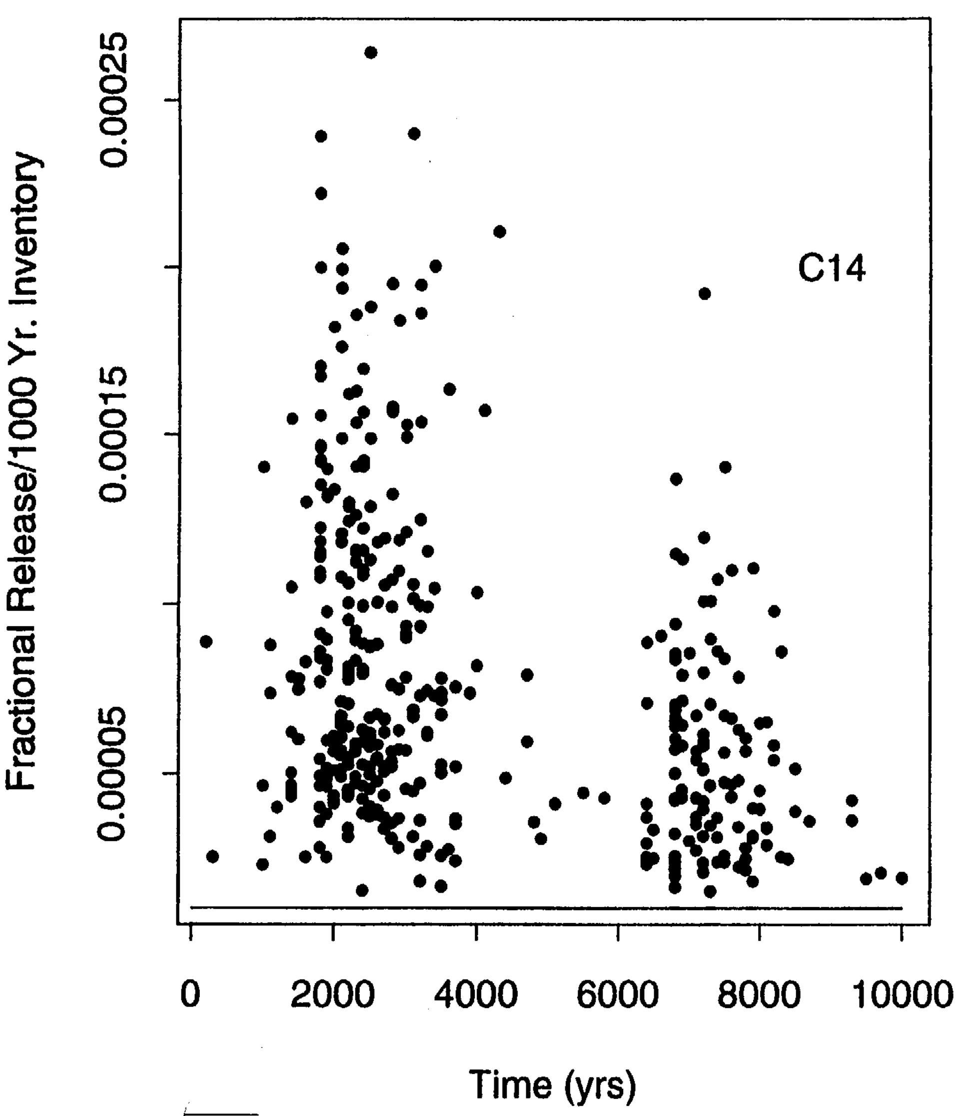


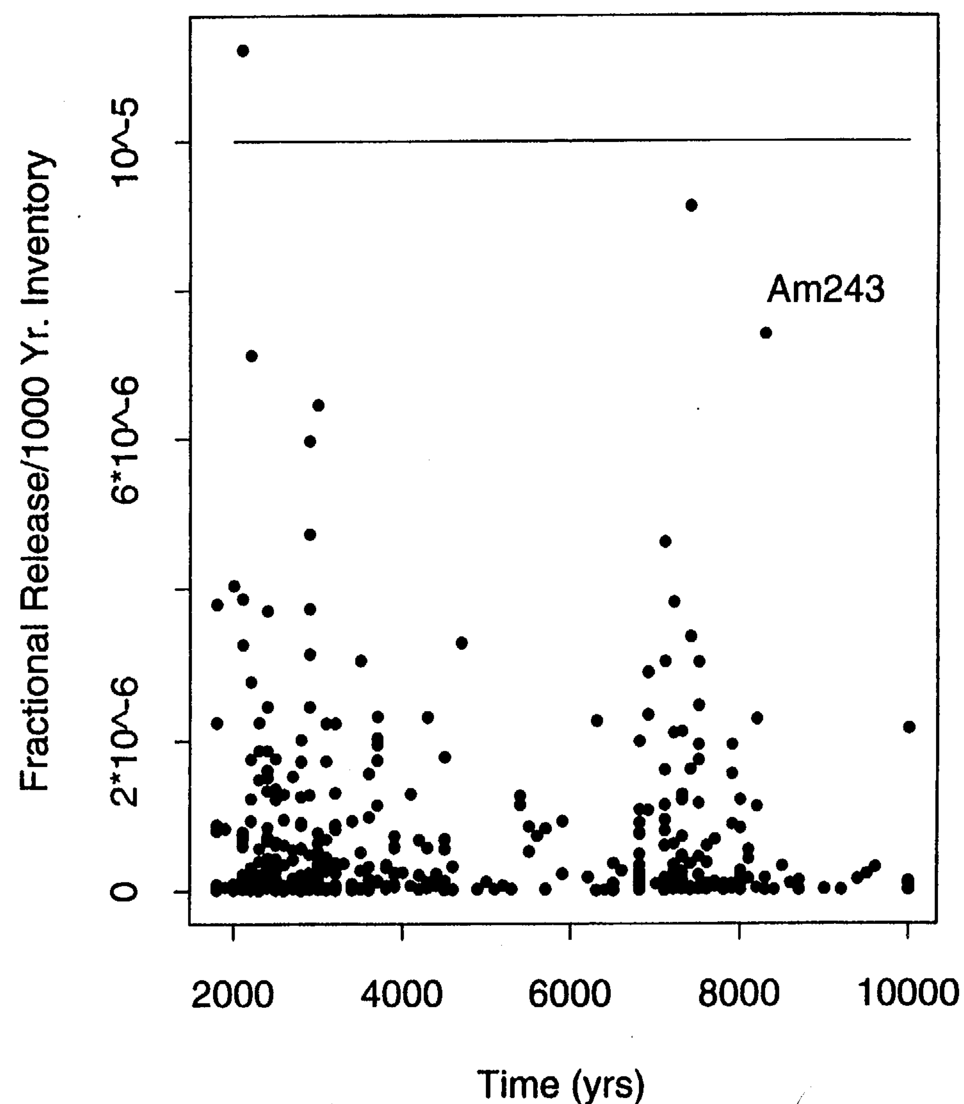


TYPES OF MOST SIGNIFICANT PARAMETERS IN IPA PHASE 2

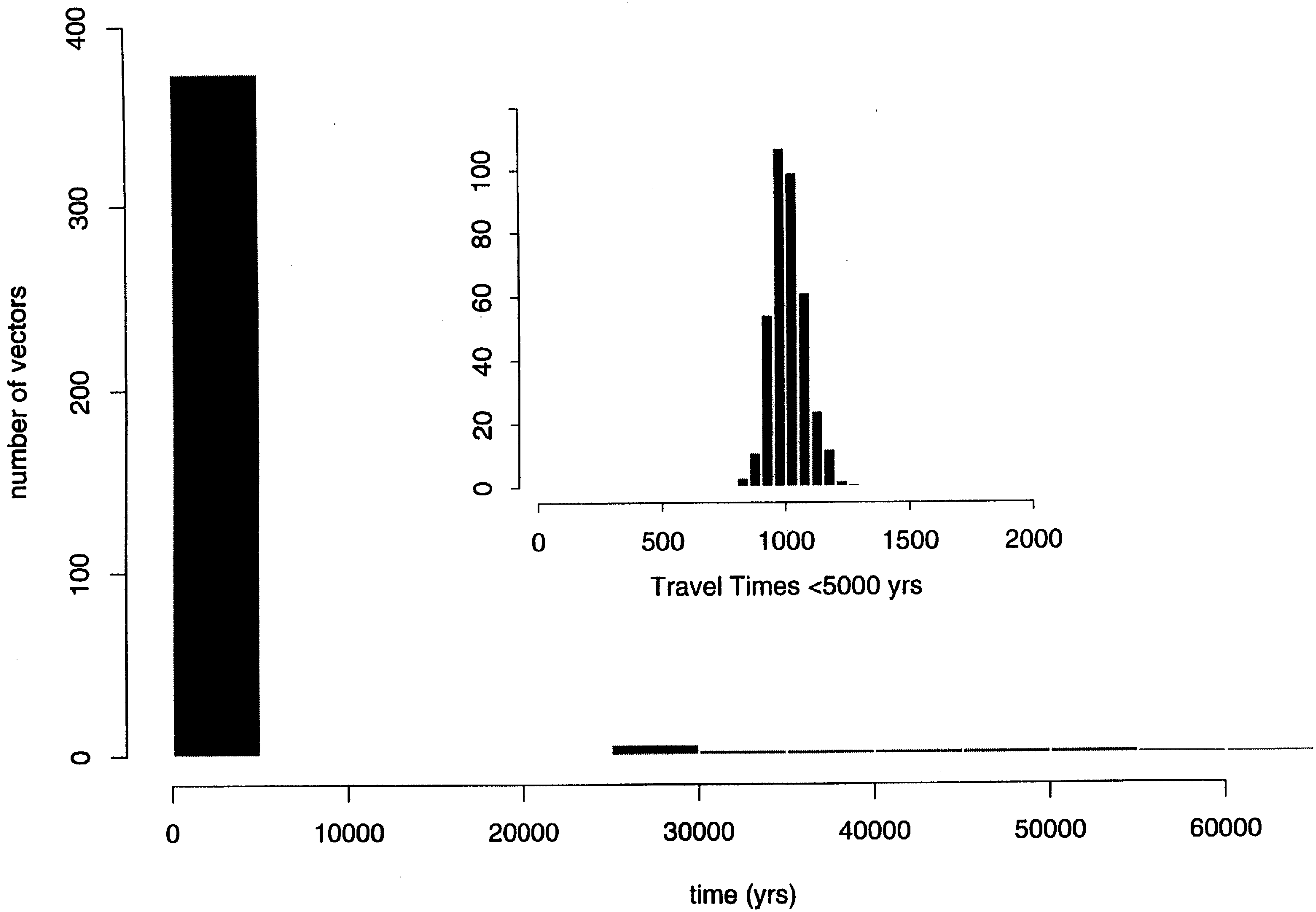
- Undisturbed Scenario
  - Infiltration
  - Corrosion
  - Retardation
  - Dissolution rate
- Fully Disturbed Scenario (includes seismic, volcanic, and drilling activity)
  - Corrosion
  - Retardation
  - Hydrologic parameters
  - Disturbed scenario parameters (e.g., location of drilling activity)

Maximum Release Rates from EBS versus Time

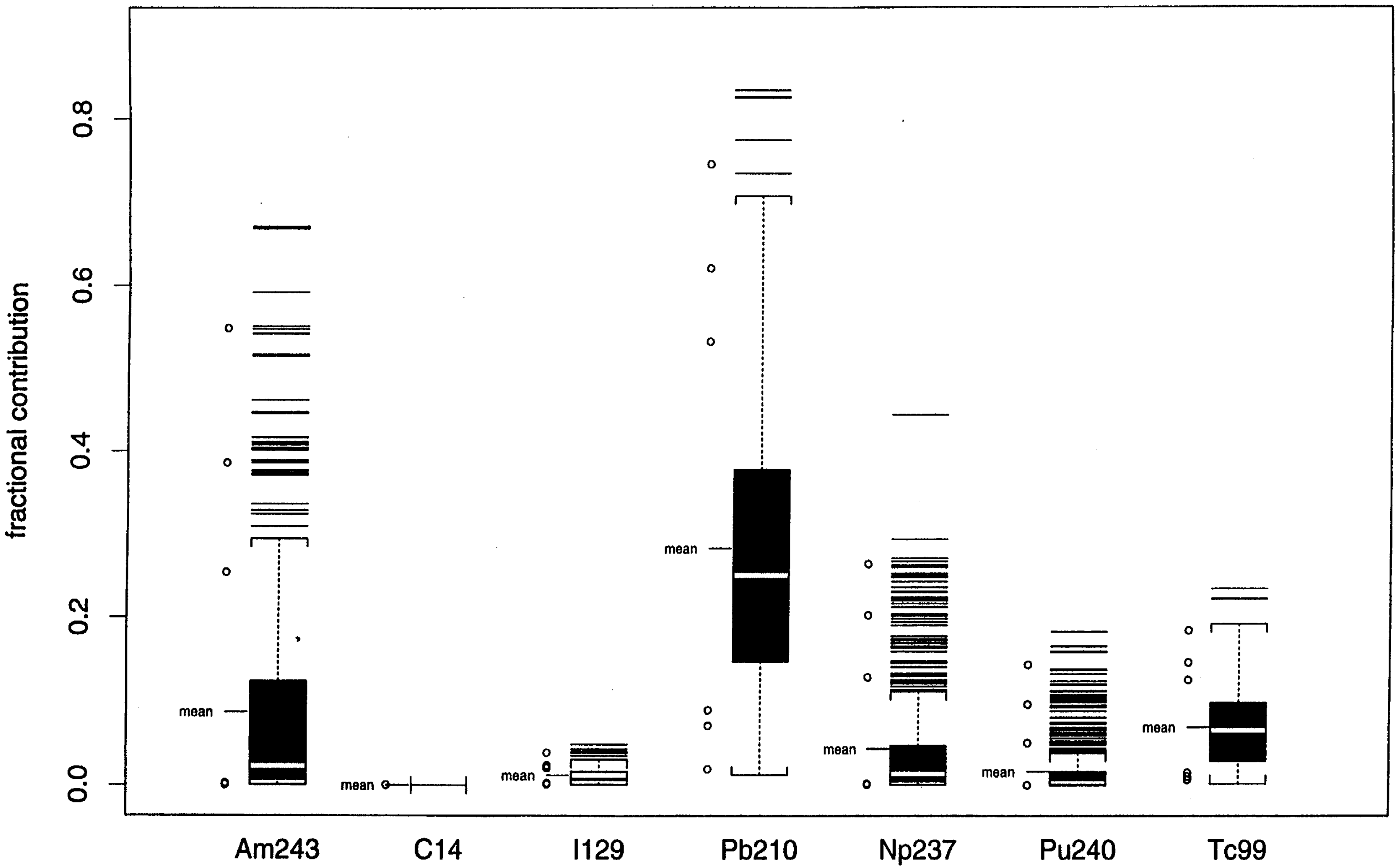




Groundwater trave(ne distributions/oooo

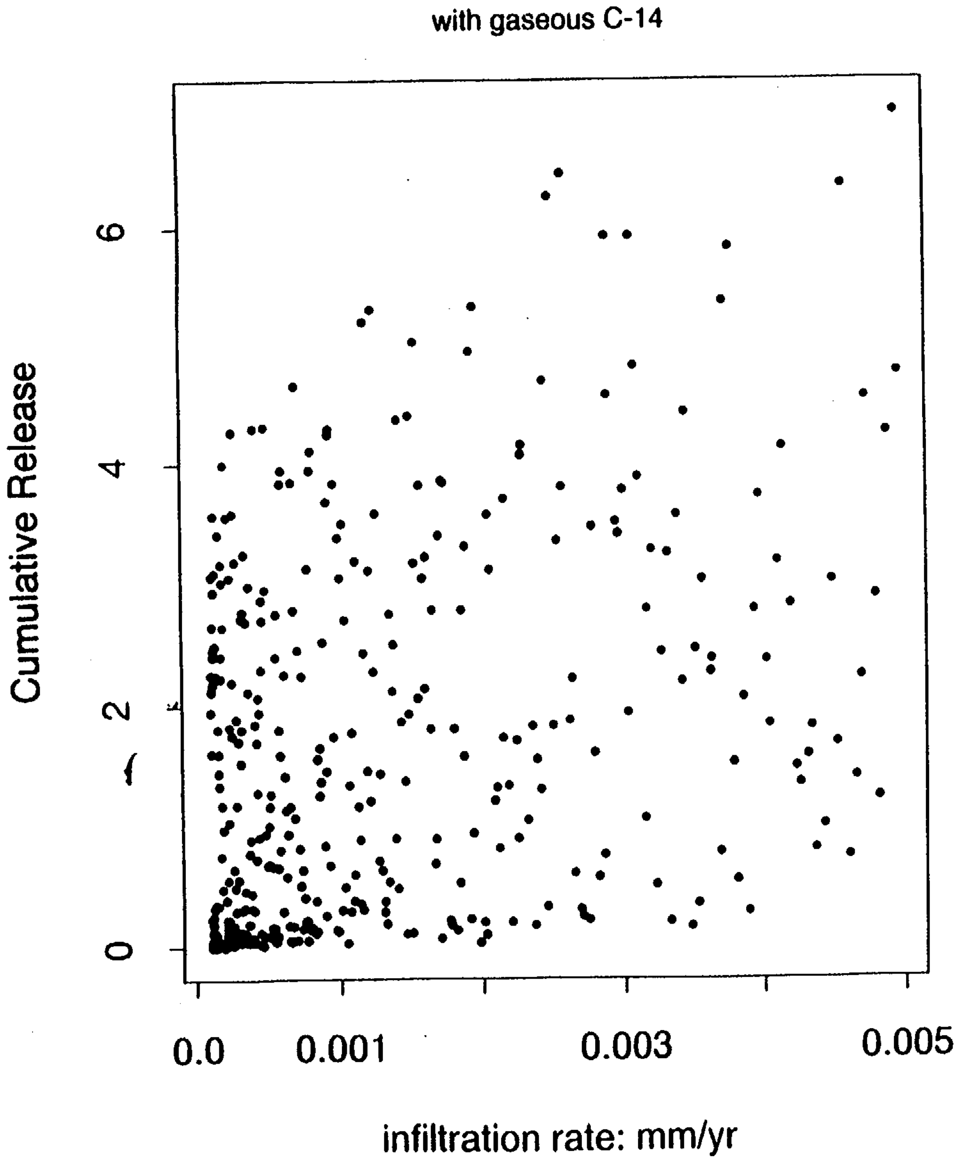


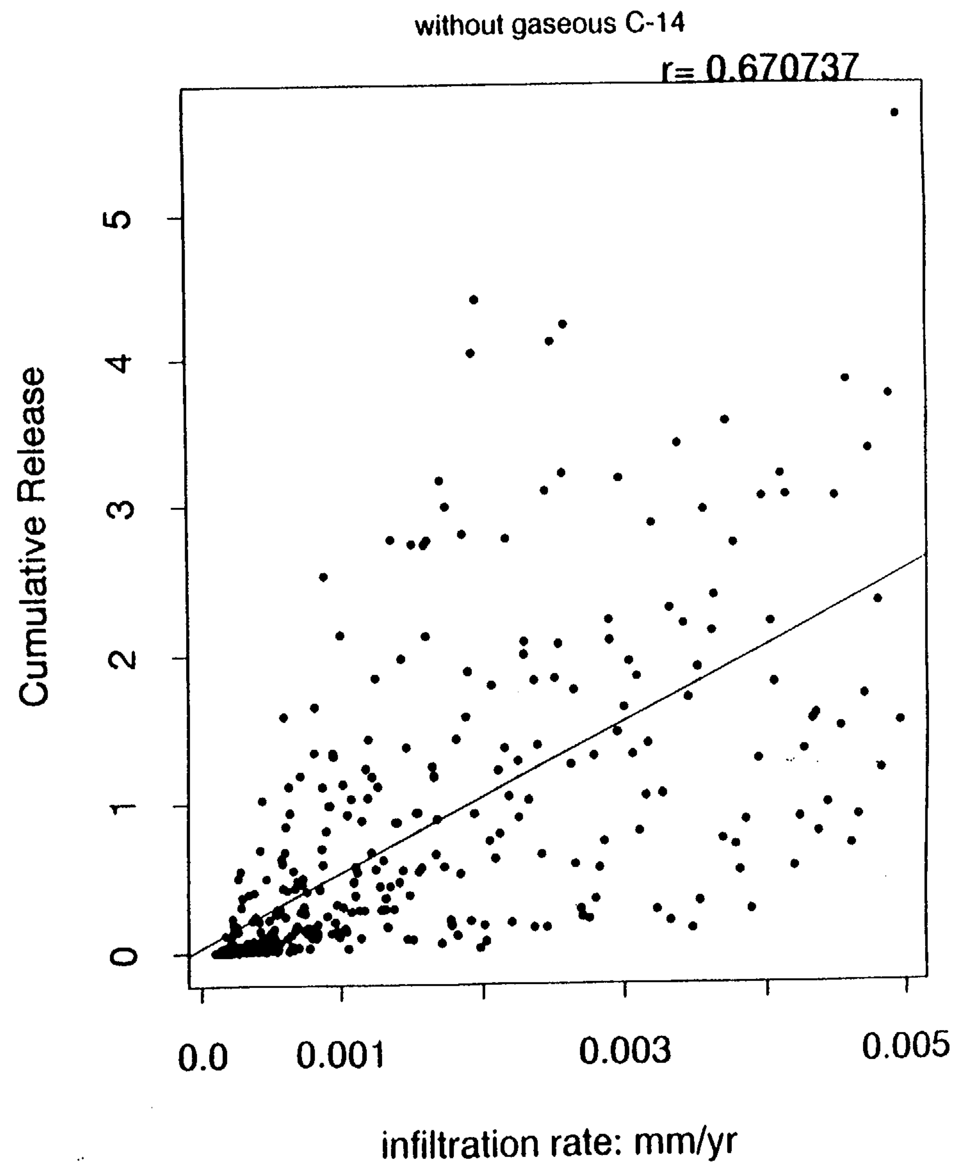
Fractional Contributions to Cumulative Population Dose By Nuclide



based on 40^ vectors

Effect of filtering data for scatter plots





CURRENT APPROACH

- Two Levels of Sensitivity Analyses

  Subsystem (Module)

  Total System

- Team Participation

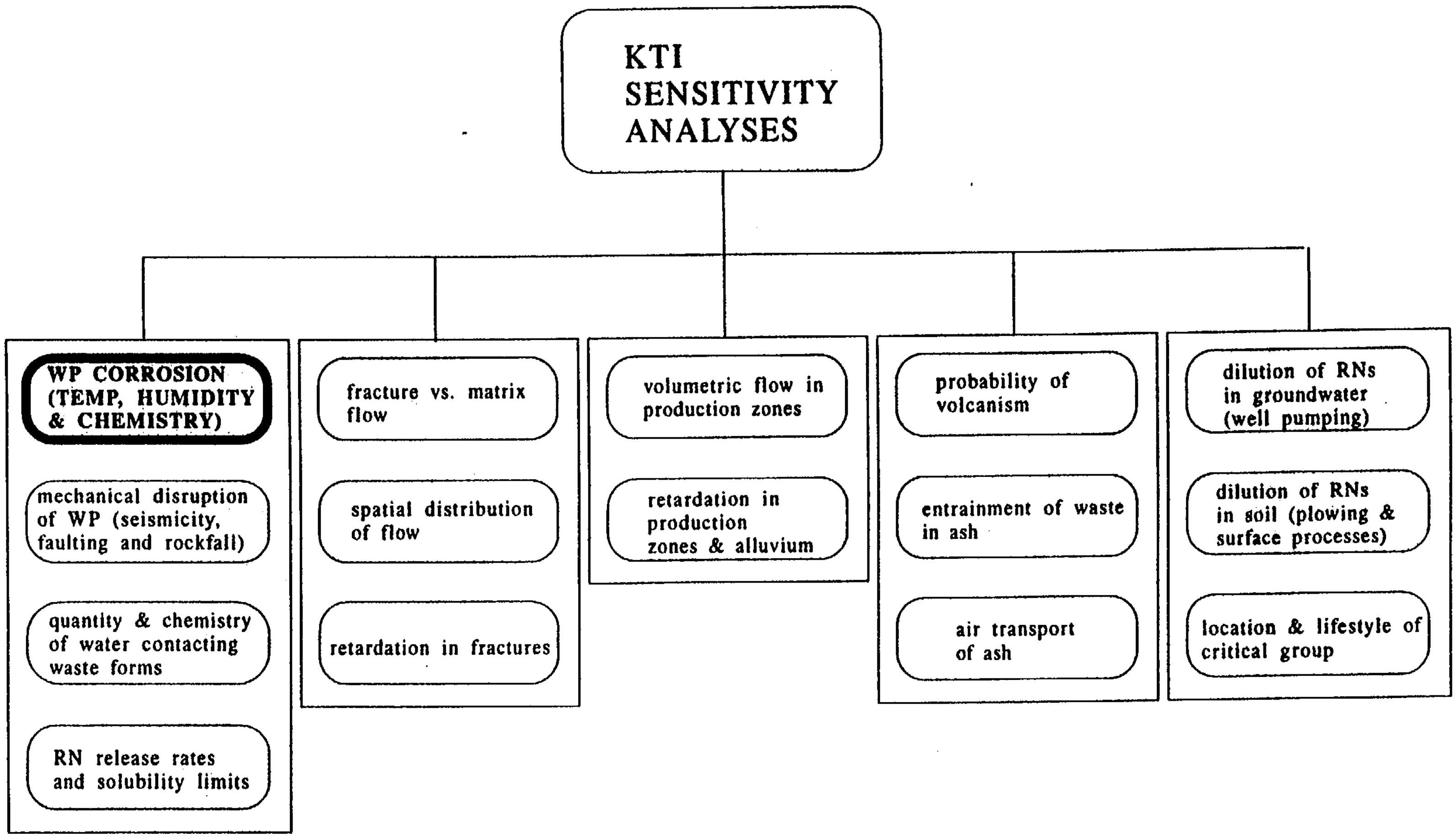
  KTI Teams

SUBSYSTEM SENSITIVITY ANALYSIS

- To determine the most important parameters in a particular module (e.g. VOLCANO) and better define parameter distributions.
- Can be done in a sampling or "what if" mode.
- Generally done by setting parameters for other modules to a nominal value; vary only the parameters within module of interest.
- Will be performed by KTI Teams.
- Results will be used to refine Reference Data Set and refine IRSRs.

THE "BASE CASE"

- Uses nominal values based on Reference Data Set.
- "Flags" will be set (e.g., Uranium dissolution rate in EBSREL).
- Basis for comparison in Subsystem and Total System Sensitivity Analyses.

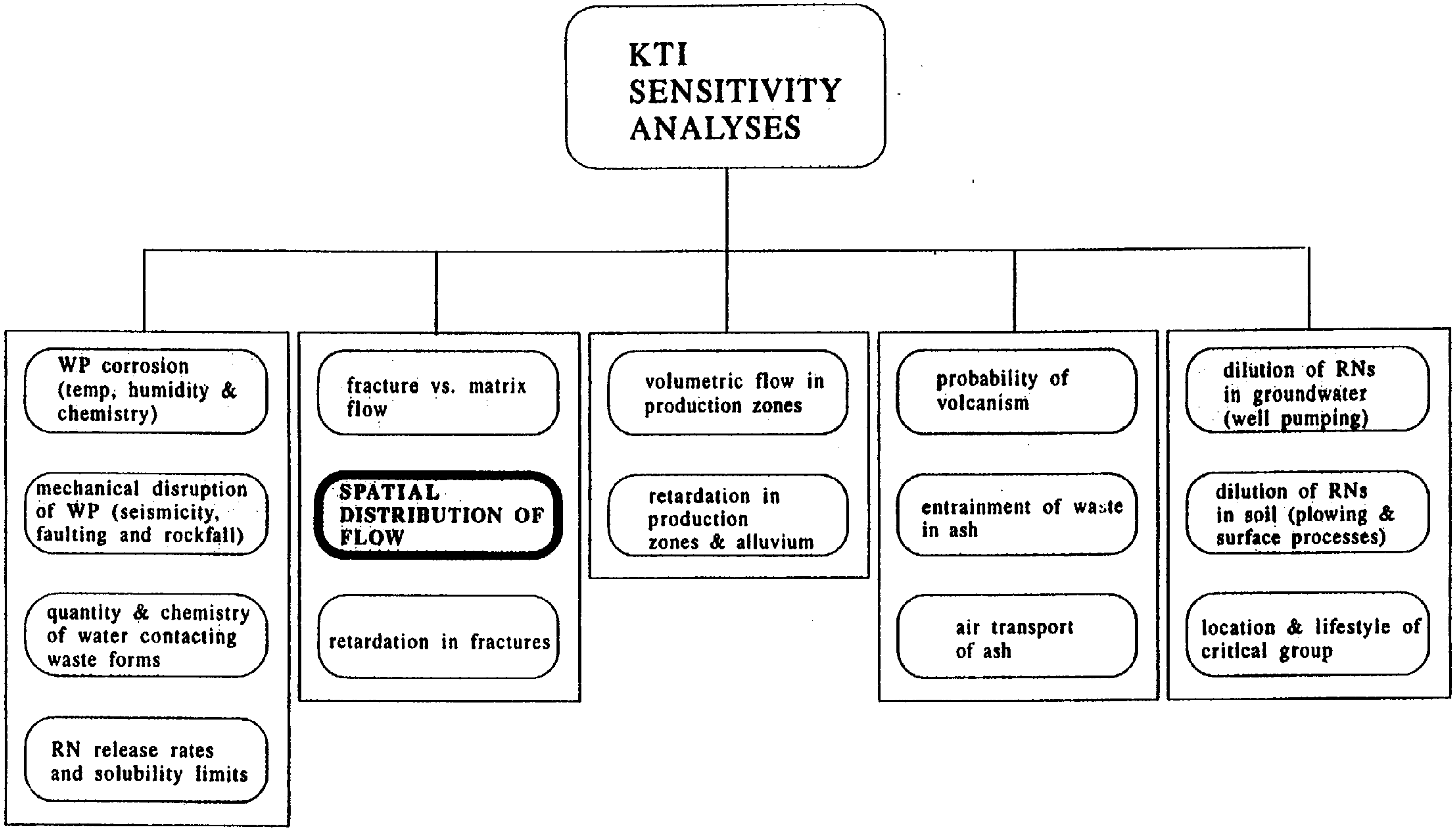


VARIED INPUT: CHLORIDE CONCENTRATION

CRITICAL RELATIVE HUMIDITY

OUTPUT: FAILURE TIME

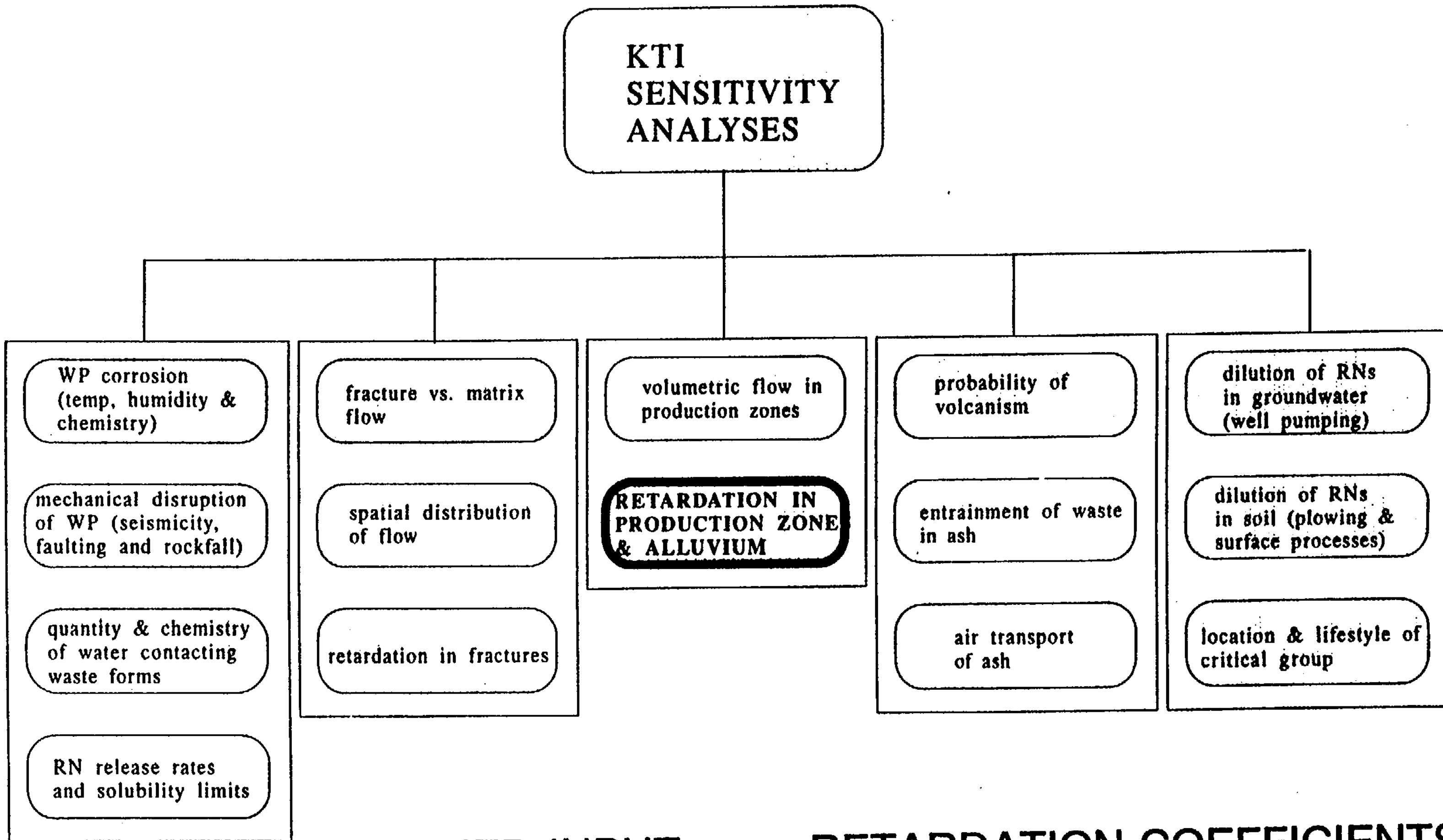
NUMBER OF CONTAINER FAILURES



VARIED INPUT: INFILTRATION AS FUNCTION OF CLIMATE

OUTPUT: NUMBER OF CONTAINERS THAT GET WET

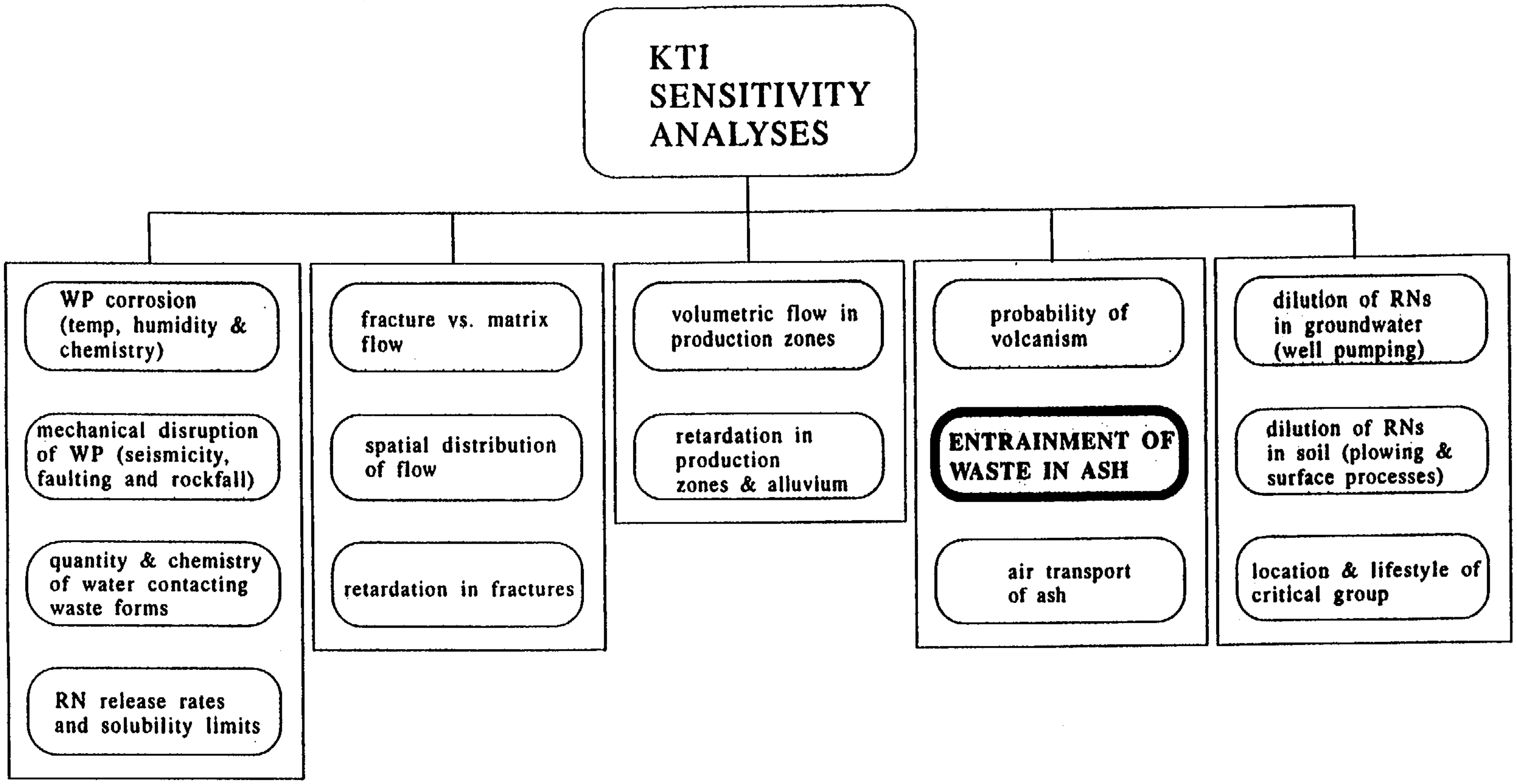
REFLUX



VARIED INPUT: RETARDATION COEFFICIENTS

SATURATED ZONE PROPERTIES

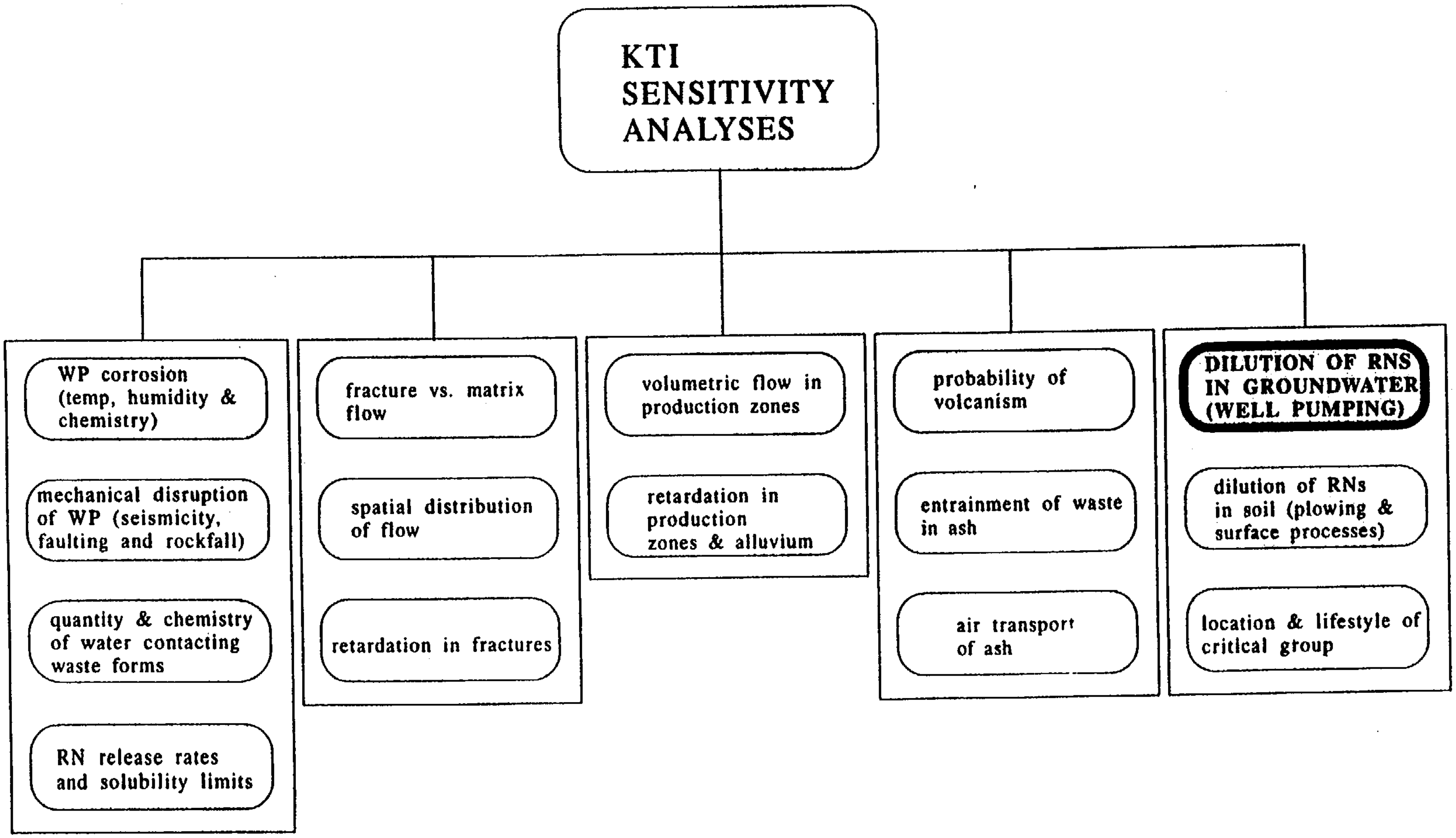
OUTPUT: RELEASE FROM SATURATED ZONE



VARIED INPUT: SIZE, LOCATION OF DIKE

WASTE PARTICLE SIZE

OUTPUT: AMOUNT OF ENTRAINED WASTE



VARIED INPUT: PUMPING RATE

OUTPUT: CALCULATED DILUTION

CONCENTRATION OF RADIONUCLIDES

TOTAL SYSTEM SENSITIVITY

- Will be done with results of sampling mode analysis.
- Will determine most important sampled parameters for the TPA 3.1 code.
- Will be performed using a variety of techniques:

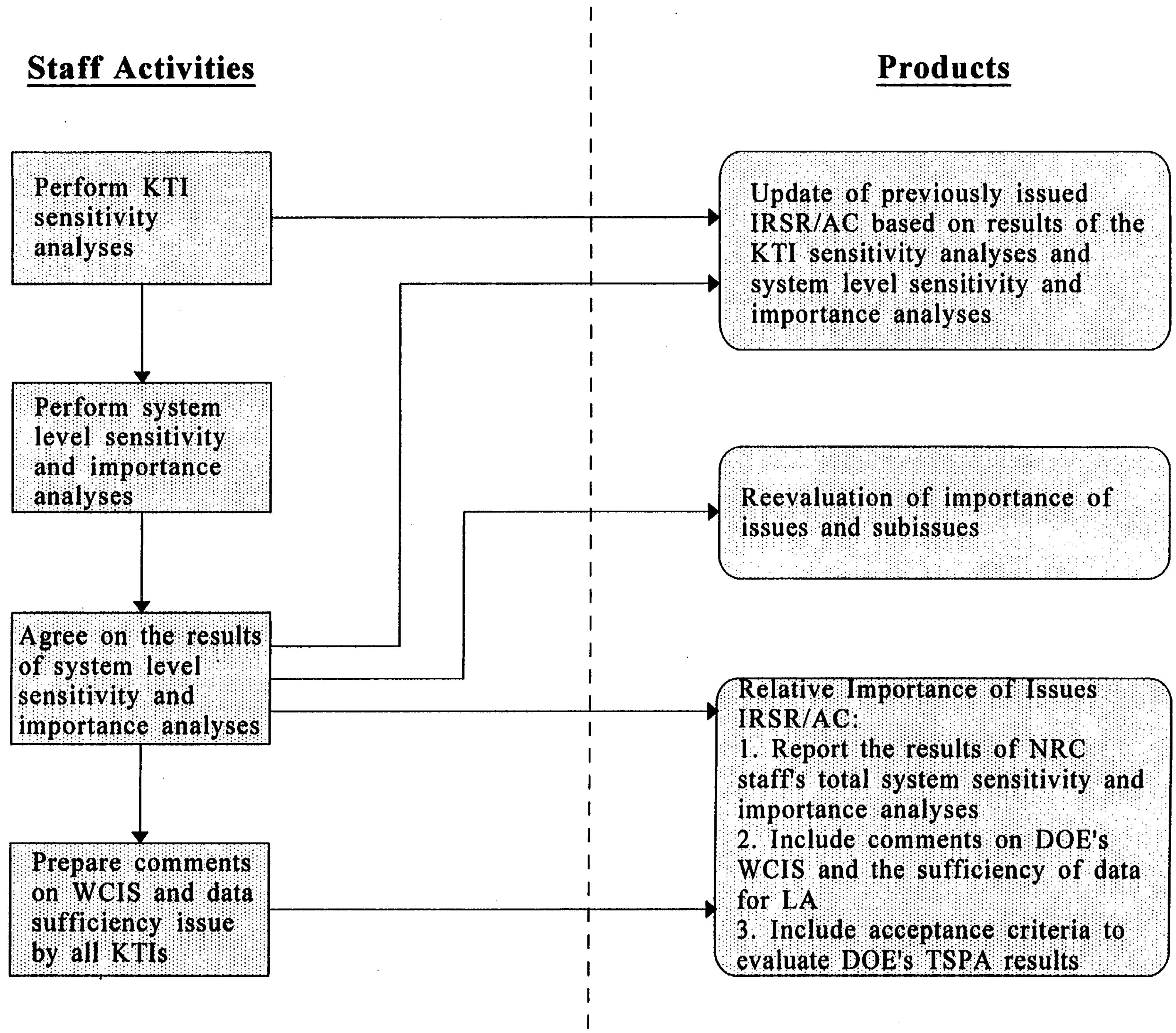
  Step-wise regression analysis

  Non-parametric tests (Kolmogorov-Smirnov test)

  Exploratory Data Analysis
  (surface plotting, scatter plots, distribution plots)

USE OF RESULTS OF THE SENSITIVITY AND UNCERTAINTY ANALYSES

- Compare with IPA Phase 2 Sensitivity and Uncertainty Analysis Results.
- Identify issues concerning data or system components.
- Develop Acceptance Criteria and comment on the DOE WCIS.
- Summarize results in HLW Annual Report.


Staff Activities
Products
Perform KTI sensitivity analyses
Perform system level sensitivity and importance analyses
Agree on the results of system level sensitivity and importance analyses
Prepare comments on WCIS and data sufficiency issue by all KTIs
Update of previously issued IRSR/AC based on results of the KTI sensitivity analyses and system level sensitivity and importance analyses
Reevaluation of importance of issues and subissues
Relative Importance of Issues IRSR/AC:
1. Report the results of NRC staff's total system sensitivity and importance analyses
2. Include comments on DOE's WCIS and the sufficiency of data for LA
3. Include acceptance criteria to evaluate DOE's TSPA results

ATTACHMENT 31

YUCCA
MOUNTAIN
PROJECT

Biosphere

Presented to:
DOE/NRC Technical Exchange on
Total System Performance Assessment
San Antonio, Texas

Presented by:
Jack Gauthier
SNL/Spectra Research Institute
Albuquerque, New Mexico

July 21, 1997

U.S. Department of Energy
Office of Civilian Radioactive
Waste Management

Biosphere Abstraction/Testing Workshop

- Las Vegas, NV
- 2–3 June 1997

Top-Priority Issues

- Critical Group
  - 1.3 Extrapolation of habits to future
  - 1.2 Habits of critical group
  - 1.4 Location of critical group
- Climate
  - 2.10 Effects of climate change on Biosphere pathways
  - 1.5 Effects of climate change on critical group
  - 2.1 Soil build-up
- Pathway Variability
  - 3.7 Location and definition of Bio-Geo interface
  - 1.7 Range of uncertainties and variability in parameters and pathways for critical group
  - 1.9 Variation in dominant pathways with time
  - 2.6 Radionuclides of importance
  - 3.4 Volcanism
  - 3.2 Which radionuclides and how transferred in disruptive scenarios
  - 3.5 Inadvertent intrusion

Analysis Plans

Group 1 Critical Group Definition Issues: Objective "Provide appropriate BDCFs to TSPA." Survey data to be used to generate hypothetical individual; alternative scenarios to be developed, soil quality to be measured between valley and mountain to determine limitations of agriculture (and pathways), BCDF to be derived for each radionuclide and pathway.

Group 2 Biosphere Pathways Issues: Objective "Determine the radionuclides that are significant contributors to dose"

Group 3 Geo-Bio Interface Issues: Objective "Provide consistency between radionuclide concentrations in the saturated zone and biosphere scenarios." Determine well-withdrawal scenarios, climate-change effects.

Expected Form of Abstraction

- Biosphere Dose Conversion Factors (BDCFs)
  - dependent on radionuclide, pathway, climate
  - dose/conc for inhalation and ingestion pathways—air, water, soil, etc.
  - dose/activity for direct exposure (?)
- Uncertainty measure—e.g., error bars, standard deviation

Expected Form of Abstraction

- Reference farmer based on local population survey
  - well water
  - most foodstuffs locally produced
  - dust, bathing, etc.
- ~10 radionuclides
- Climate. . .
- Disruptive events. . .

Preliminary Results