CENTER FOR NUCLEAR WASTE REGULATORY ANALYSES

TRIP REPORT

SUBJECT: Workshop on Alternative Models and Interpretation--UZFM Expert Elicitation Project
(20-5708-861)

DATE/PLACE: December 18-20, 1996
Berkeley, CA

AUTHOR: S. Stothoff

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PERSONS PRESENT:

The meeting was attended by S. Stothoff (CNWRA); Department of Energy (DOE) staff and contractors; an invited panel of experts on unsaturated-zone hydrology; facilitating personnel from Geomatrix; and interested observers. Approximately 50 persons were present in total.

BACKGROUND AND PURPOSE OF TRIP:

A panel of experts on unsaturated-zone hydrology has been established by DOE with the express purpose of providing a basis for determining what approaches to modeling unsaturated zone flow are reasonable. In particular, the panel is to be elicited on issues regarding percolation flux at the repository horizon. The finding of the panel may be presented to regulators to justify the approaches that DOE might take in license-application activities. The elicitation is also intended to be incorporated into total-system performance-assessment (TSPA) modeling efforts for the viability assessment TSPA (TSPA-VA).

The workshop on alternative models and interpretations represents the second of three workshops to be spaced over several months. This second workshop had the stated purpose of familiarizing the seven experts with modeling approaches used to characterize the YM site, and alternative conceptual models that might be used. The final workshop in which the experts will exchange comments and further question investigators, will occur February 3 and 4, 1997. Each expert will then be elicited for opinions in individual sessions in mid-February. Final documentation is scheduled to be completed March 21, 1997.

Three additional expert-elicitation panels will be conducted by DOE over the next year or two. The other panels will investigate thermohydrologic issues, waste-package issues, and saturated-zone issues. The panels are being convened to address the issues that are considered most significant for repository performance by the DOE; thus, each workshop is of great interest to the NRC and CNWRA.

SUMMARY OF PERTINENT POINTS:

1. Agenda and Handouts

The agenda for the meeting is attached. A list of the materials provided to the panel is also attached. Hard copies of the overhead slides are available from the author.

2. Expert Elicitation Panel

The panel comprises G. Campbell (Washington State University), G. Gee (Battelle, Pacific Northwest Laboratories), J. Mercer (GeoTrans), S. Neuman [University of Arizona (UAZ)], K. Pruess [(Lawrence Berkeley National Laboratories (LBNL)], D. Stephens (Dan Stephens, Inc.), and E. Weeks [United States Geological Survey (USGS)].

3. Methodology Development Team (MDT)

The MDT is responsible for selecting the panel, organizing the workshops, conducting the expert elicitation, and collating results. MDT members include R. Andrews (Intera), T. Bjerstedt (DOE), G. Bodvarsson (LBNL), K. Coppersmith (Geomatrix), D. Hoxie (USGS), E. Kwicklis (USGS), P. Morris (Applied Decision Analysis), M. Pendleton (WCKS/M&O), R. Perman (Geomatrix), T. Sullivan (DOE), and R. Youngs (Geomatrix).

4. Presenters

The sessions were run by representatives of Geomatrix. S. Stothoff (CNWRA) made a presentation, as did DOE contractors representing Intera, Los Alamos National Laboratory (LANL), LBNL, Sandia National Laboratories (SNL), Spectra Research, and the USGS. In addition, L. Lehman, formerly representing the State of Nevada, made a presentation.

SUMMARY OF ACTIVITIES:

The author attended all presentations and technical discussions.

CONCLUSIONS:

1. Overall Impressions

The workshop was well run and informative. The presenters were open in their presentations and questions received frank responses. Much of the material presented to the panel has been presented to various oversight panels such as the Advisory Committee on Nuclear Waste and the Nuclear Waste Technical Review Board. The intent for the workshop presentations was somewhat different, as the panel is to provide an opinion that is integratory in nature, estimating uncertainty in issues pertinent to output predictions of the LBNL Unsaturated-Zone Site-Scale Flow Model (UZFM) under ambient conditions, such as percolation fluxes, matrix/fracture interaction, flow into drifts, and flow patterns below the repository.

2. Noteworthy Highlights

The issue of infiltration was perhaps the most contentious issue, in part due to the importance to performance and in part due to the several orders of magnitude change in predictions over the past five years. The expert panel generally agrees that additional confirmatory analysis, particularly of the infiltration models, is rather desirable, including: (i) comparison of the model(s) with data from a well-instrumented site, (ii) consideration of 2D and 3D effects from lateral flow, and (iii) consideration of watershed modeling.

Experimental film-flow studies on rough-walled tuff blocks (analogous to fractures) also provoked a good deal of interest. It was demonstrated that flow preferentially occurs along rough-walled fractures, and it was suggested that film flow provides a fast-flow mechanism in larger aperture fractures for cases for which parallel-plate theory would predict relatively slow flow.

3. Formal Presentations

K. Coppersmith (Geomatrix) and R. Patterson (DOE) briefly reviewed the purpose and format for the workshops. The format was unchanged from the first workshop, except that training in expert elicitation was included on the last day.

G. Bodvarsson (LBNL) reviewed the key components and uncertainties in the UZFM. The uncertainties fall into two categories, parameter uncertainty and conceptual model uncertainty. As a result of these uncertainties, output uncertainties exist that the panel is directly tasked to quantify: (i) percolation flux at the repository level, (ii) flow into drifts, (iii) fracture/matrix components, and (iv) flow patterns below the repository. In the first workshop, it was stated that below-repository flow was not to be considered by the experts; however, if the experts are up to the task they will be elicited.

M. Badurraga (LBNL) and S. Finsterle (LBNL) discussed issues with model boundaries and software. The presentations primarily summarized background material. Future editions of the UZFM are to use an expanded domain incorporating many more faults. In addition, the mesh has been restructured to allow highly refined meshes within the vicinity of the repository footprint.

E. Sonnenthal (LBNL) further discussed a submodel extracted from the UZFM immediately south of the northern Ghost Dance Fault alcove and east of the ESF. Horizontal grid blocks are on the scale of 10 m rather than 100 m for the overall UZFM. Studies to date have included uniform and heterogeneous property fields. The model predicts quite large lateral fluxes immediately above the zeolitic zone but generally vertical fluxes otherwise. Even in the highly heterogeneous cases, horizon-level percolation fluxes showed relatively little spatial variability (orders of magnitude smaller flux variability than permeability variability).

A. Flint (USGS) provided a presentation on modeling net infiltration that elicited lively questioning from the expert panel. Flint has implemented conceptual models for infiltration that are variants of the bucket model presented in the first workshop that are intended to capture flow dynamics somewhat more like a Richards-equation simulator. The newer models provide larger infiltration estimates than the bucket model, although the work is reported as far from final. Flint also mentioned work translating General Circulation Model (GCM) predictions for future climate into estimates of infiltration at YM.

S. Stothoff (CNWRA) presented results aimed at examining some of the sensitivity of infiltration estimates to hydraulic and climatic properties. Detailed 1D simulations were abstracted into simple regression relationships. The model suggests that infiltration is more sensitive to climate change if the infiltration is small. Under plausible estimates of full glacial conditions, increases of infiltration of 5 to 10 times current conditions are obtained, although this is expected to be buffered by vegetation changes.

C. Doughty (LBNL) discussed conceptualizations of fracture-matrix interactions using one column from the UZFM and breaking the column into a discrete fracture and 1, 5, or 9 matrix columns. Doughty demonstrated that the classical dual-permeability conceptualization may bias predictions in the opposite direction from the equivalent continuum model (ECM) for some cases.

S. McKenna (SNL) presented methods used to generate fields of rock properties for numerical models at the mountain scale. The GLINTMOD software creates realizations in stratigraphic coordinates (the original deposition patterns deformed into a rectilinear grid). The realizations are then returned to the original deposition state, which undergoes tilting and faulting. An attempt is made to maintain observed patterns of correlation and cross-correlation using a process called co-regionalization.

S. Altman (SNL) discussed simulations presented in the GWTT95 exercises using four 2D cross-sections with dual-permeability simulations. It was found that particle travel times to the water table appear to be dependent on the PTn thickness and infiltration rate, and particle travel times varied by 1 to 3 orders of magnitude from one realization to the next at the same location. The implication is that, although simulated matrix saturations are suggestive of measured core samples, uncertainty in hydrologic data has a significant effect on the flow system (at least for the infiltration rates of approximately 0.1 mm/yr considered).

A number of LBNL researchers (M. Bandurraga, R. Ahlers, Y. Wu, and G. Bodvarsson) presented work aimed at calibrating the UZFM. Each researcher used the ITOUGH parameter estimation module of the TOUGH code to estimate model parameters from the observed data, with each further assuming that model parameters are constant within a hydrologic unit. The non-uniqueness of certain parameter estimates (matrix permeability, fracture van Genuchten alpha) was discussed. Attempts to constrain matrix properties in the TSw unit use a penalty method to include core sample data in the estimation process, so that more recent estimates change fracture properties to compensate for relatively known matrix properties (TSw permeability is only 1 order of magnitude greater than core values, rather than 2 orders of magnitude). Newer (and higher) estimates of infiltration require relatively little adjustment of properties in order to capture perched-body observations, while earlier estimates required artificial lowering of permeabilities and fracture removal in the zeolitic zone. Temperature calibration sparked some discussion from the panel due to the uncertainties in estimating heat fluxes and alternative conceptual models for heat transport.

J. Fairley (LBNL) discussed conceptual models for flow in unsaturated fractured rock in relation to the observed bomb-pulse signature in the TSw unit. Fairley has produced scoping calculations using a 2D discrete-fracture model using properties derived from the UZFM, and transient wetting episodes, that suggest finite pulses can make it to the repository horizon.

A. Wolfsberg (LANL) presented 1D, 2D, and 3D simulations assessing radionuclide transport at YM. Based on the simulations, Wolfsberg hypothesizes that bomb-pulse signatures in the ESF require a break in the PTn unit coupled with infiltration of at least 1 mm/yr. On the other hand, explaining background

levels in the ESF requires that distributed infiltration must be below an upper bound, or ^{36}Cl signatures would be lower than observed.

S. Finsterle (LBNL) has used the UZFM to extract a 2D cross-section and perform simulations with the dual-permeability model and the UZFM parameter set. Finsterle concludes that the dual-permeability model with the UZFM parameters also provides reasonable agreement between observations and predictions.

S. Mishra (M&O/Intera) discussed the flavor of ECM model used for TSPA-95, in which fracture flow is enabled at an arbitrarily imposed level of matrix saturation. The objective of the work is to derive a PDF for infiltration flux based on scaling surface distributions of infiltration to match observed borehole saturations. Mishra observed that calibrating to saturation is not a robust method for determining parameters.

C. Ho (SNL) contrasted behavior of the ECM approach relative to a dual-permeability approach. Ho claims that, although the dual-permeability approach has problems, it is superior to the ECM for capturing the physics of flow in the UZ. The Fran Ridge ponded-infiltration test was offered as support to his position. Ho notes that a significant uncertainty in dual-permeability methods arises from the matrix-fracture interaction term.

C.-F. Tsang (LBNL) discussed recent attempts to model fluxes at the drift scale using detailed 2D and 3D single-continuum models, in which fractures are treated using distinctly different matrix properties within a grid block. Fracture grid blocks are roughly 23 percent of the total volume, and matrix properties are taken from the UZFM (and have higher permeabilities than are observed from core samples). Fracture distributions are created independently of the matrix blocks and superimposed on the matrix distribution. Nominal grid-block dimension is 25 cm on a side. A number of pulse-propagation studies were performed, with and without ventilation. Interestingly, Tsang showed that increasing the size of the pulse may in fact change the location where dripping occurs within the drift.

J. Gauthier (SPECTRA Research) presented the WEEPS model of flow in YM, emphasizing the strengths of conceptual simplicity while not minimizing the difficulty of calibrating the model.

L. Lehman (L. Lehman & Associates) summarized the modeling that she performed roughly 5 yrs ago, starting with the original INTRAVAL exercises in which she suggested that infiltration might be as high as 5 mm/yr. Lehman also discussed water-table fluctuations that might provide information on recharge rates, particularly as the fluctuations appear to be different on the east and west sides of the Solitario Canyon fault. Lehman noted that faults impact the water table, suggesting that 3D modeling is required in the saturated zone. Lehman also noted that variability in heat flux is probably due to volcanic activity in Crater Flat.

T. Tokunaga (LBNL) presented recent experimental and theoretical work in modeling film flow of water along tuff surfaces. In order to perform experiments quickly, Tokunaga worked with permeable tuffs very near saturation; however, less permeable tuffs would be expected to provide a similar response at lower saturations (perhaps to 10 m of suction). Tokunaga applies capillary-bundle theory to vertically oriented capillaries to estimate film flow fluxes. Tokunaga noted that a film 1 micron in depth would be expected to have a velocity of roughly 100 m/yr and average velocity scales with the square of thickness. Not only aperture dimension but roughness information is required to estimate fast film flow. Tokunaga noted that film flow is essentially independent of aperture dimension for wide fractures.

4. Elicitation-Panel Questions and Comments

After all presentations were completed, the elicitation-panel experts discussed elicitation topics and data requests with the facilitator and MDT. The four general topics that elicitation will probe concern percolation flux at the repository horizon, flow into drifts, fracture/matrix interactions, and possibly flow patterns below the repository. Insofar as these topics are outputs from the UZFM, questioning will also examine uncertainties associated with conceptual models and the parameters required for the models.

The experts provided feedback in terms of additional data they would like to be provided.

S. Neuman requested the raw data, details of implementation, and goodness-of-fit estimates, for all of the statistical relationships developed for material-property and fracture distributions, as well as raw data for travel-time calculations in the GWTT-95 exercises. Neuman also indicated that he is quite uncomfortable with the level of verification for the infiltration estimates provided by A. Flint and would like independent models to be used for local confirmatory estimates.

D. Stephens also appeared skeptical regarding estimates of infiltration, and suggested that additional testing of the models against well-documented data sets would be very much in order. Stephens also felt that the information regarding time variation of the water table should be examined. Stephens also voiced the concern, generally shared by other experts, that some sort of table be provided that tracks the various modeling studies of deep percolation fluxes relative to the infiltration assumptions used for the study.

J. Mercer requested that the calibration information for the latest and greatest version of the UZFM calibration be provided.

G. Campbell requested that details of the TOUGH2 model be provided to the panel, such as the user's manual. Campbell will communicate directly with Flint for infiltration issues.

G. Gee felt that it would be appropriate to incorporate the film-flow ideas into TOUGH2 and perform bounding calculations. Gee also felt uncomfortable with the locally 1D approach used for estimating infiltration and asked that some KINEROS runs be performed to assess the impact of runoff. Gee requested that the best-available numbers regarding heat flux be provided.

K. Pruess led a discussion of the applicability of the WEEPS paradigm relative to the continuum modeling that is embodied in the ECM and multiple-permeability approaches, to some extent championing the idea of scaling up local approaches to get a global average rather than estimating local values from a global approach.

PROBLEMS ENCOUNTERED:

None.

PENDING ACTIONS:

None.

RECOMMENDATIONS:

None.

SIGNATURES:

Stuart A. Stothoff
Research Scientist

12/31/96
Date

CONCURRENCE:

English C. Pearcy, Manager
Geohydrology/Geochemistry, Element

12/31/96
Date

Budhi Sagar
Technical Director

1/3/97
Date

ATTACHMENTS:

1. Meeting Agenda
2. List of materials given to experts.
3. List of possible elicitation topics.

See author for copies of presentation overheads.

KEY ISSUES AND UNCERTAINTIES RELATED TO PERCOLATION FLUX AT THE REPOSITORY

(Note: these are the issues for which the experts will be asked to provide their assessments of uncertainties)

Net Infiltration

- Conceptual models
- Parameter definitions, uncertainties, variabilities
- Alternative maps of net infiltration rate
- Temporal distribution of net infiltration: net infiltration vs. time (days, years)

Rock Properties of PTn

- Fracture network
- Continuity of layering
- How PTn handles transient flows/pulses (e.g., lateral flow)
- What flux looks like as leaves the PTn
    + Pulse still or dampened out
    + Components in fractures and matrix

Percolation Flux at Repository Horizon

- Average percolation flux (scales of 100 meter)
- Spatial variability
- Implications of isotopic content of perched water
- Distribution between fractures and matrix

Drift-scale Percolation Flux (tens of meters)

- Distribution in fractures and matrix
- Capillary influence of drift
- Components of flux resulting in seepage vs. flow around drift

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LIST OF REFERENCES DISTRIBUTED TO EXPERT PANEL MEMBERS THROUGH DECEMBER 17, 1996

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GEOMATRIX

FINAL AGENDA
WORKSHOP ON ALTERNATIVE MODELS AND INTERPRETATIONS

UNSATURATED ZONE FLOW MODEL (UZFM) EXPERT ELICITATION PROJECT

December 18 to 20, 1996
Lawrence Berkeley National Laboratory
Berkeley, California

PURPOSE OF WORKSHOP:

- To present and discuss the key issues and uncertainties associated with assessing the percolation flux at the repository horizon using the unsaturated zone flow model (UZFM) developed for Yucca Mountain
- To present and discuss alternative models for treating particular components of the unsaturated zone flow system and for explaining Yucca Mountain data
- To discuss and agree upon a set of questions that will be addressed in the elicitations
- To present and discuss methods of eliciting expert interpretations, including methods for quantifying uncertainty

WEDNESDAY, DECEMBER 18, 1996

8:00 - 8:05	Welcome (R. Patterson, DOE)
8:05 - 8:15	Introduction, Purpose of Workshop (K. Coppersmith, Geomatrix)
8:15 - 9:00	Key Components and Uncertainties in the UZFM (G. Bodvarsson, LBNL)
9:00 - 9:40	Model Boundaries/Discretization (M. Bandurraga, LBNL)
9:40 - 10:20	Fracture Properties and Heterogeneities in UZFM (E. Sonnenthal, LBNL)
10:20 - 10:30	**Break**
10:30 - 11:10	Modeling Net Infiltration (A. Flint, USGS)
11:10 - 11:50	Net Infiltration Models (S. Stothoff, CNWRA)
11:50 - 12:50	**Lunch**
12:50 - 1:30	UZFM Software (S. Finsterle, LBNL)
1:30 - 2:10	Conceptualizations/Fracture-Matrix Interactions (C. Doughty, LBNL)
2:10 - 2:50	Rock Properties (M. Bandurraga, LBNL)
2:50 - 3:30	Incorporating Heterogeneities in Rock Properties (S. McKenna, SNL)
3:30 - 3:40	**Break**
3:40 - 4:20	Results of Incorporating Heterogeneities (S. Altman, SNL)
4:20 - 5:00	Calibration Using Pneumatics (R. Ahlers, LBNL)
5:00 - 5:40	Calibration Using Perched Water (Y. Wu, LBNL)
5:40 - 6:00	**Comments from Observers**

GEOMATRIX

THURSDAY, DECEMBER 19, 1996

8:00 - 8:40	Calibration Using Temperature (G. Bodvarsson, LBNL)
8:40 - 9:20	Calibration Using Natural Isotopes (J. Fairley, LBNL)
9:20 - 10:00	Explanations for Observed Distribution of Natural Isotopes (A. Wolfsberg, LANL)
10:00 - 10:10	**Break**
10:10 - 10:50	Verification of Calibrations (S. Finsterle, LBNL)
10:50 - 11:30	Percolation Flux Simulations (Y. Wu, LBNL)
11:30 - 12:10	Uncertainty Propagation Using a Generalized Equivalent Continuum Model (S. Mishra, INTERA)
12:10 - 1:10	**Lunch**
1:10 - 1:50	Transient Dual Permeability Model (C. Ho, SNL)
1:50 - 2:30	Drift-scale Hydrology (C. Tsang, LBNL)
2:30 - 3:10	UZ Modeling Studies by the State of Nevada (L. Lehman, L. Lehman & Assoc.)
3:10 - 3:20	**Break**
3:20 - 4:00	Weeps Model (J. Gauthier, SPECTRA Research)
4:00 - 4:40	Film Flow Models (T. Tokanaga, LBNL)
4:40 - 5:00	Draft Questions for Elicitations (Discussion by Expert Panel)
5:00 - 5:15	Where We Go From Here (K. Coppersmith, Geomatrix)
5:15 - 5:30	**Comments From Observers**

FRIDAY, DECEMBER 20, 1996

8:30 - 9:00	Working Session
9:00- 12:00	Elicitation training (P. Morris, Applied Decision Analysis)
12:00	**Adjourn**