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OCT 26 1987

MEMORANDUM FOR: Ronald Ballard, Chief
Technical Review Branch

FROM: Donald Chery, Section Leader
Hydrology Section, HLTR

SUBJECT: REVIEW OF SAND-0112 ON SATURATED ZONE AT YUCCA MOUNTAIN

Richard Codell, John Trapp and Michael Blackford have reviewed the report "Simple Models of the Saturated Zone at Yucca Mountain (SAND-0112)" performed for the NNWSI project by Sandia National Laboratories. The subject report presents the analyses with a two dimensional model of the saturated-zone hydrology at the Yucca Mountain site. The purpose of the study was to identify the probable causes of the apparent mounding of groundwater to the north and west of the proposed repository site, and the possibility that a tectonic event at the site could lead to a sudden rise in the water table under the repository. The authors conclude that fault control is not necessary to explain the mounding. An affirmation of this conclusion would suggest that a disruptive scenario would be less of a threat to the site in terms of a rise in the water table. The reviewers believe however that such a conclusion based on the model would be premature, and that there is still evidence that faults control the mounding of the groundwater. A summary of the report and the review are attached to this memorandum. We would be glad to brief you further on the contents of our review.

/s/

Donald Chery, Section Leader
Hydrology Section, HLTR

Attachment:
Review of SAND-0112

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Review of "Simple models of the saturated zone at Yucca Mountain", SAND-0112, by G.E. Barr and W.B. Miller
Reviewed by Richard Codell, Michael Blackford and John Trapp, HLTR

Brief Summary of Report

A local scale model of the saturated zone of the Yucca Mountain site has been developed by Sandia National Laboratories in order to investigate phenomena such as possible control of flow by faulting and the effects of local recharge. A two dimensional finite element grid was set up with constant head boundary conditions and the hydraulic conductivities of zones within the grid adjusted to obtain the best fit of modeled and observed hydraulic heads. The system was assumed to be under water table conditions. Two main conceptual models were developed. In the reference or "smooth" model, no attention was paid to discontinuities between fault zones. The hydraulic conductivities were adjusted manually to reduce the difference between the modeled and observed heads ("residuals"). In the second or "fault controlled" model, major fault zones were considered to be regions of lower hydraulic conductivity. This model was constructed to investigate the premise that high water table gradients to the north and west of the repository location could be controlled by fault zones of low permeability, with the possibility that shifts in the faults could allow the built-up water table to release, thereby raising the water level underneath the repository. The movement of a tracer dispersing from the site of the repository was calculated for all the cases. The model for tracer movement considered the advective dispersive equation, for which concentration of dissolved tracer was calculated directly. The plume is represented by a concentration contour. Movement of the plume appeared to demonstrate a groundwater travel time to the accessible environment on the order of hundreds of years, once release to the water table has occurred. Some scenarios for the fault-controlled model however had much shorter travel times.

A number of sub-cases were run with the smooth model to study the effects of vertical infiltration from Drill-hole Wash, Solitario Canyon and well G-2 on the position of the water table. No attempt was made to adjust the hydraulic conductivities to reduce variance. Relatively small increases in water table elevation were noted below the recharge blocks. It is not clear that the amount of recharge used in the model is realistic. Sudden vertical leakage along Drill-Hole Wash was simulated. This caused a relatively large increase in the water table under the site of up to 110 feet over a 40 year period and a distortion of the plume. This scenario was non-mechanistic, but presumably could be construed to represent a continuous flooding of Drill-Hole Wash. Another catastrophic scenario was sudden vertical leakage along the Solitario Canyon Fault, again non-mechanistic, but could be construed to be caused by local flooding. In this case, relatively smaller rises of about 10 feet in the water table under the repository were noted.

The fault controlled model assumed that some of the large fault zones were areas of low permeability and were therefore capable of retarding the groundwater flow causing steep gradients. The base case for the fault controlled model is developed by assuming that Solitario Canyon fault bounds on the west, and the Drill-Hole Wash fault bounds on the North, with an extension of the Ghost Dance fault to the north of the repository block. Adjustment of the hydraulic conductivities within the model with the faults in place was then performed. The residuals are much larger than for the smooth model with no fault control. Sub-case of the fault controlled model where various faults were give high or low permeabilities were also developed to determine the importance of those faults to the control of the system. Model experiments do not clearly support the interpretations of the Drill-Hole Wash fault and Ghost Dance fault extension are hydrogeologic barriers.

Sudden changes to the transmissivity of the fault zones demonstrated the response of the water table to catastrophic changes caused by sudden movement of the faults. A sudden increase in the hydraulic conductivity across the Solitario Canyon fault lead to an increase of 65 feet in 115 years.

The investigators conclude that it is not necessary to propose fault-control on the movement of saturated groundwater at the Yucca Mountain site, and that in fact the smooth model gives smaller residuals than the fault controlled model. They further conclude that the fast movement of the tracer plumes may point out the relative lack of importance of the saturated zone as a barrier to the transport of radionuclides to the accessible environment.

<u>Importance of Report to NRC Program</u>

This study reaches several preliminary conclusions relevant to the licensing of the Yucca Mountain site. Firstly, the question of the mounding of the water table to the north and west of the repository site was addressed. A question of the control of saturated groundwater at the site by low permeability zones caused by fault displacement raises the specter that a further movement of the fault could cause a precipitous rise in the water table at the repository location. This in turn would decrease the distance from the waste to the water table, or in the worst case, resaturate the site. The authors contend that no such fault control is necessary to predict the high water table to the northeast of the site, and that a model which does have fault control is less plausible because of the higher residuals of the inverse modeling problem in that case. Vertical leakage had a relatively small effects on the water table. In any event, the modeling indicates a relatively small benefit can be gained in performance by considering the saturated zone at all.

<u>Problems or concerns with report</u>

The authors are very candid about the crudeness of the modeling effort and the lack of data. They identify the study as a first attempt to explain some of the phenomena of the saturated zone at the Yucca Mountain site, and caution against too much reliance on the results of this study. Irrespective of this candor, we have the following reservations about the study. First, the way in which the water levels were interpreted could lead to a serious misinterpretation of the possible effect or lack of effect of fault control. Actually, no model is necessary at all to distinguish the fact that there appear to be at least three distinct zones in the modeled area where the water table is essentially flat, but with sharp differences in water level between zones. The wells to the west of Solatario Canyon have a water level of 775.2 $\pm$ 0.5 meters. The area north of Drill Hole Wash has an elevation of 1029.3 $\pm$ 0.2 meters, and the area to the east of Solatario Canyon has a water elevation of 729.8 $\pm$ 2.6 meters. There is another region bounded on the west by Solitario Canyon, on the north by Drill Hole Wash and on the southeast by an unnamed feature that appears to have an intermediate water level. In this example, observation was used to perceive the four regions. The divisions between the different regions appear to be controlled by low permeability features which coincide with the fault traces. The flat water table in the southwest quadrant of the model would suggest a relatively high hydraulic conductivity with small flow controlled by the barriers.

The above conclusion is reinforced further by the observation that the residuals from the inverse procedure are not random. In all cases, calculated residuals were negative at the edge and positive in the middle of the modeled region. This non-random nature of the residuals suggests that the fit of the model to the data is biased; i.e.; hydrogeologic features are present which have not been incorporated adequately into the model. This fact is exemplified in the area of USW H-1, where the residuals are large and uniformly positive. While the report stresses that the area of USW 6-2 has negative residuals, it offers no explanation for the high positive residuals near USW H-1.

The third concern with the modeling approach is that the inverse problem is not unique; that is the same water table elevations would be demonstrated by the model at steady state if all the hydraulic conductivities were multiplied by a constant. There did not seem to be any attempt to reference the hydraulic conductivities to a measured value which would have given a tie point to reality. Consequently, some of the conclusions about the groundwater velocity and the response of the water table to catastrophic changes may be misleading, even if the model had been calibrated perfectly to the observed heads. There are two other concerns of lesser importance. The permeability of the fractured tuff and carbonate making up the saturated zone is known to be controlled by fractures (0.002 to 0.005, Draft EA, December 1984), even though the porosity used in the model was taken uniformly as 0.2, which is more typical of the matrix. The main consequence of this would be that the plume velocities might be underestimated unless matrix diffusion is considered. A dual porosity model might have given different results for flow also, possibly with faster transients. Note however that the report suggests that there should be no credit taken for the saturated zone in the performance assessment.

On the subject of the plume model, artificial dispersion in the advective-dispersive equation brought about by the coarseness of the grid is probably responsible for the large dispersion and broad shape of the plume observed in the modeling study. The movement of tracer particles would probably lead to a different picture of dispersion and transport in the model, avoiding the pitfalls of numerical dispersion.

Recommendations

We make the following recommendations to improve the modeling effort:

1. There should be an attempt to make the inverse modeling problem unique. This could be accomplished for instance by tying the hydraulic conductivities used in the model to actual measured values if available. The work of Hoeksema and Kitinidis (Water Resources Research, Vol 21, no 4, 1985) comes to mind as an applicable procedure for using both head and local measured values of transmissivity together in an inverse modeling procedure. Data would have to be available for this procedure to be worthwhile.

Environmental tracers, age dates or hydrochemical data could also be used to make the problem unique.

2. Particle tracers would probably give a more meaningful picture of tracer movement than the advective dispersive model used, given that the grid size is rather coarse.

3. It would be worthwhile to investigate the ramifications of the dual-porosity nature of the fractured porous rock on the conclusions drawn from these calculations.

4. It would be a useful extension of the modeling effort to consider the change in water table resulting from a catastrophic change to the transmissivity of the fractured porous rock mass resulting from a sudden stress change; e.g. an earthquake.

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