Numerical Investigation of the Temporal Damping Effect in the Unsaturated Fractured Rock of Yucca Mountain

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RESEARCH OBJECTIVES

Performance assessment of the Yucca Mountain unsaturated zone (UZ) as an underground repository of radioactive waste is based on a key assumption that physical processes in the unsaturated zone can be approximated as a steady-state condition. Justification of such an assumption relies mainly on the temporal damping effects of certain geological units within the unsaturated formations—in particular, the nonwelded tuff of the Paintbrush Group (PTn unit), above the repository horizon at Yucca Mountain. The main objective of this study is to investigate the damping function of the PTn unit via a three-dimensional (3-D) mountain-scale model and one-dimensional (1-D) column flow and transport models.

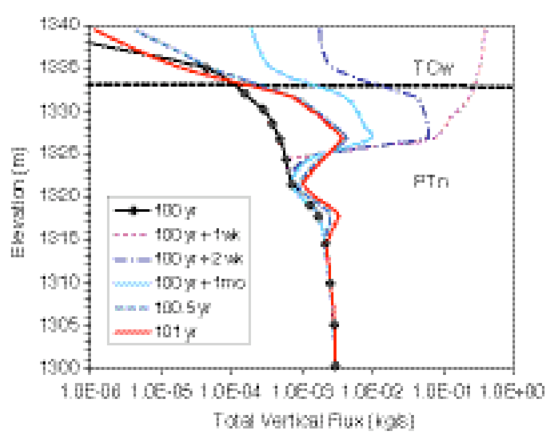

Figure 1. Flux distribution along column f96 at different times: right before an applied infiltration pulse (100 years), and right after an applied infiltration pulse (100 years+1 week), and afterwards

APPROACH

The 3-D mountain-scale model incorporates a wide variety of updated field data for the highly heterogeneous formation at Yucca Mountain. The model is first run to steady state and calibrated using field-measured data under present-day mean infiltration. Then, pulse infiltrations are applied to the model top boundary. The episodic infiltration boundary condition is implemented by concentration of the present-day mean infiltration of 50 years into one week as infiltration pulses. Flux changes at the bottom of the PTn unit and inside the unsaturated layers are examined under episodic infiltration boundary conditions. The 1-D column model consists of a single vertical column extracting directly from the 3-D mountain-scale model. The 1-D model is used to examine the long-term response of the flow system to higher infiltration pulses. The damping effect is also investigated through examining tracer transport in the UZ under episodic infiltration conditions.

ACCOMPLISHMENTS

This study provides insights into unsaturated zone flow behavior under episodic infiltration conditions and the role of the PTn unit in damping of pulse percolation. The large-scale transient 3-D flow model and 1-D models have been run to investigate vertical flux inside and at the bottom of PTn. Damping mechanisms have been analyzed by looking into the flux allocation inside the UZ vertical columns. Flux can be imbibed into dryer rock matrix, diverted to faults or other flow paths, detained along fractures, or continue percolating downward. Figure 1 shows vertical fluxes within a typical column at the repository area at different times.

SIGNIFICANCE OF FINDINGS

Model results show that the total fluxes at the PTn bottom gradually approach the average mean-infiltration-rate value for the entire period, with the probability that the system would eventually reach a dynamic equilibrium condition under the uniform pulses of infiltration. Episodic infiltration, once crossing the PTn, can be approximated as steady state. Results from the 1-D model with higher infiltration scenarios confirm that higher infiltration pulses will not weaken the damping effect. The transport model results further reveal that the damping effect exists specifically in the PTn unit. Flux allocation analyses suggest that the damping effect at nonfault columns is mainly caused by matrix rock water storage, absorbing and releasing water at different periods. Along fault columns, both lateral flow and rock water storage play an important role, with the importance of these two damping components being location-dependent.

RELATED PUBLICATION

Zhang, K., Y.S. Wu, and L. Pan, Temporal damping effect of the Yucca Mountain unsaturated fractured rock on transient infiltration pulses. Journal of Hydrology (submitted), 2005. Berkeley Lab Report LBNL-57534.

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