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On the Effect of Connectivity on Solute Transport in Spatially Heterogeneous Combined Unsaturated-Saturated Flow Systems

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Detailed numerical analyses of flow and transport were used to investigate the effect of spatially connected features on the transport in three-dimensional (3-D), spatially heterogeneous, combined vadose zone-groundwater flow systems. Formations with spatially connected fine- and coarse-textured features (SCFT- and SCCT-formations, respectively), representing the10th and the 90th percentiles of the distributions of the formation's hydraulic parameters, respectively, were considered here. Results of the analyses suggest that in steady-state flow, when the unsaturated zone of the combined flow domains is relatively wet, as compared with a Multivariate-Gaussian (MG) formation, spatially connected features may reduce the solute first arrival time, particularly in the SCCT-formation, and may enhance the spreading of the solute breakthrough, particularly in the SCFT-formation. The effect of the spatially connected features on the hydrological response, however, decreases as the unsaturated zone becomes drier. The latter result stems from the decrease in the fraction of the water-filled, pore-space occupied by the connected structures, with decreasing water content. The latter finding also explains the result that the response of more realistic, combined flow systems, whose unsaturated zone is associated with transient flow and relatively low, intermittent water contents, is essentially independent of the spatially connected features of the formations, regardless of their soil texture.