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# A source-responsive approach for modelling rapid groundwater recharge via unsaturated-zone preferential flow

Benjamin Mirus, Kim Perkins, and John Nimmo
United States Geological Survey, Menlo Park, CA USA (bbmirus@usgs.gov)

The high uncertainty associated with the impacts of preferential flow on aquifer recharge and contaminant transport poses considerable challenges to scientists and water-resource managers. Unsaturated flow models that simulate diffuse-flow require extensive site characterization that is rarely available; furthermore, these models typically underestimate fluxes in situations where preferential flow is significant. Here we present a recently developed source-responsive model, which was designed specifically to estimate unsaturated zone preferential fluxes with minimal data. The term source-responsive is used to describe the sensitivity of preferential flow in response to changing conditions at the source of water input. The model incorporates film-flow theory with conservation of mass. We demonstrate the utility of the source-responsive model for simulating rapid water-table fluctuations at two sites with thick unsaturated zones comprised primarily of fractured volcanic rock. Preferential-flow dominated groundwater recharge at both the Idaho National Laboratory (INL) and the Nevada National Security Site (NNSS) (formerly the Nevada Test Site) are of particular interest because the rapid transport of radionuclide contaminants threatens the underlying aquifers. In the case of INL, characterization of temporal variations in water source at the land surface together with the corresponding water-table response, were sufficient to parameterize and evaluate the model. For NNSS, the limited availability of source and response data at temporal resolutions relevant to preferential flow led to greater uncertainty when constraining model parameter values. The model effectively predicts recharge for discrete events at INL, whereas recharge is underestimated during wet years at NNSS. Results for both sites suggest that the parsimonious source-responsive model is a useful alternative or supplement to traditional modeling approaches for recharge estimation and uncertainty assessments in situations where preferential flow contributes significantly to aquifer recharge.