Linking surface topography, subsurface structure, and solute transport in rivers

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Scaling in surface topography and surface water flows is a classic problem in geomorphology and hydrology. Similarly, the effects of complex subsurface structure on solute transport have been recognized for some time, and the resulting anomalous diffusion behavior has been the subject of considerable investigation. The effects of these processes on surface-subsurface hydrologic interactions and solute transport in rivers are not as well understood. Recently, several studies have shown that solute efflux from the subsurface shows fractal scaling behavior in time, and that in-stream breakthrough curves also have power-law tails. Here we discuss the processes responsible for this behavior, as well as the need for modeling frameworks that link surface and subsurface transport. Numerous exchange processes occurring at many spatial scales tend to produce anomalous diffusion behavior in downstream transport. General topographic control of surface-subsurface interactions suggests that the subsurface flow and residence time distributions should be fractal, but the complete range of scaling behavior has not been explored. The linkage between surficial processes, geomorphodynamics, and subsurface structure is clearly important, but has not been explored in sufficient detail to allow general conclusions to be drawn about controls on solute transport behavior. Heterogeneity in the shallow subsurface broadens residence time distributions and increases tailing of in-stream breakthrough curves, but the effects of larger-scale subsurface variability are not known. Improved conceptual and modeling frameworks are needed to understand these linkages, as well as to guide the design of experimental programs that can provide the data needed to evaluate scaling and scale cutoffs in surface-groundwater interactions and solute transport in rivers.