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Streamflow, turbulent eddies and interfacial exchange with the hyporheic zone

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Permeable sediments often underlie channels, streams and rivers. Fluid exchange between the water column and the sediments is forced by spatially varying head gradients along the sediment-water interface (SWI), due to current-bedform interaction, and by ambient groundwater discharge (AGD), due to regional head gradients. We investigate the competing effects of current-bedform induced flow and AGD on the interfacial exchange of fluid, and the flow pattern and residence-time distribution of exchanged fluids within the sediments, for sediments with dune topography. Coupled models simulate turbulent flow in the water column and Darcy flow within sandy sediments. Current-bedform-induced fluid flow in the sediments results in a complicated but predictable interfacial exchange zone (IEZ) flux and flow pattern. The IEZ flux rates and residence times are sensitive to the flow rate in the water column, but the IEZ pattern is not. Because of the presence of stagnation zones within the sediments the residence-time distribution of exchanged fluids follows a power law. When AGD is present, the influence of current-bedform induced advection becomes subdued until, at higher rates of AGD, fluid flow becomes essentially vertically one-dimensional. Current-bedform induced fluid flow and AGD substantially affect the hyporheic zone configuration and interfacial exchange with permeable sediments and should be considered in studies of hyporheic ecological and biogeochemical processes.