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Hyporheic flow and residence time distributions in heterogeneous cross-bedded sediment

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We numerically simulated hyporheic exchange and conservative solute transport through immobile bedforms composed of heterogeneous sediment and equivalent homogeneous sediment. The permeability fields are from the cross-bedded Massillon Sandstone and modern climbing ripple deposits of the Brazos River (Texas). In both cases, permeability heterogeneity leads to nested scales of hyporheic exchange and slightly increases the depth of exchange relative to equivalent homogeneous sediment. However, solute concentration distributions within the hyporheic zone are similar in heterogeneous and equivalent homogeneous sediment. Permeability heterogeneity can increase or decrease solute residence times and impact early- through late-time transport behavior. In the Massillon case, heterogeneity delays solute transport at early to intermediate times, relative to equivalent homogeneous sediment. In the Brazos case, heterogeneity increases the rate of solute transport at early times but delays transport at intermediate to late times. In both heterogeneous and homogeneous sediment, hyporheic residence times follow a power-law relationship over the lifetime of immobile bedforms. Current-bedform interactions are primarily responsible for the power-law relationship, as opposed to permeability heterogeneity.