Use of numerical modeling to evaluate the impact of hydrodynamic pressure on hydrologic exchange fluxes and resident time for a large-scale river section over a long-term period

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Abstract

Quantifying hydrologic exchange fluxes (HEF) and subsurface water residence times (RT) are important for managing the water quality and ecosystem health in dynamic river corridor systems. Because of limited field accessibility, numerical models typically have been used to quantify HEFs and RTs. These models, however, usually are limited to local-scale bedforms and are based on the assumption that hydrostatic pressure drives surface and subsurface water exchanges. Previous laboratory-scale experiments and models have shown that hydrodynamic pressure variations on the riverbed induced by dynamic river flows can strongly impact HEFs and RTs. In this study, the impacts of hydrodynamic pressure on HEFs and RT for a 30 km section of the Columbia River in Washington State over a three-year period were quantitatively evaluated using a coupled transient three-dimensional (3D) multi-phase surface and subsurface water flow transport approach. Based on comparisons of the model simulations with a reference case that considered only hydrostatic pressure, we found that hydrodynamic pressure significantly enhances upwelling and downwelling HEFs by 2 and 1.7 times, respectively, in the investigated river section and also leads to a reduction of the most likely RT by one order of magnitude (i.e., from hundreds of days to tens of days).

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