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Scaling Hydrologic and Biogeochemical Processes in a Large River Floodplain and Alluvial Aquifer

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Abstract:
Current methods for characterizing the influence of geomorphic structure on river processes are not well suited for study of large rivers with extensive hydrologic exchanges between the channel, floodplain surface, and alluvial aquifer. We applied a spatially explicit, three-dimensional model to simulate surface and subsurface flow and exchange, temperature, and dissolved oxygen within the 15 sq km Nyack Floodplain of the Middle Fork Flathead River, Montana, USA. We ran the model for four years and simulated nine conservative particle releases across a range of river discharges. Our model results include simulations that: 1) describe the rapid hydrologic response of the alluvial aquifer to flood events, 2) quantify a substantial effect of surface-subsurface water exchange on the hydrologic residence time of the floodplain, and 3) explain >75% of variance in aquifer temperature and >65% of variance in dissolved oxygen concentrations across space and through time (laterally, vertically, and during seasonal discharge variation). We also explore the relationship between simulated residence time and the spatial distribution of electron donors (dissolved organic carbon concentration and quality) and acceptors (nitrate, iron, sulfate) throughout the aquifer. Our results underscore the importance of geomorphic, hydrologic, and temperature dynamics in driving river ecosystem processes, and they demonstrate how a sufficient representation of the physical template of a river ecosystem can be used to explain complex spatiotemporal patterns of biogeochemical dynamics.

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