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Influences of Hydromorphic and Hydrogeologic Structure and Variable River Discharge on Hydrologic Exchange Flows and Biogeochemical Transformations in the River Corridor

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This element of the PNNL SFA seeks to understand the influences of hydromorphology and hydrogeology as they interact with variable river flows to control hydrologic exchange flows and associated biogeochemical processes. Hydromorphic structure of the river channel, and hydrogeologic heterogeneity of the underlying riverbed and aquifer sediments, interact with variable river discharge to control the exchange of river water and groundwater (hydrologic exchange flows or HEFs) in ways that are not yet well understood. HEFs stimulate biogeochemical activity which influences water quality (temperature and contaminant removal) and nutrient balances. Recent SFA research has developed and validated an approach that quantifies large-scale HEFs using local temperature measurements to inform and constrain simulations of HEFs using 3D computational fluid dynamics (CFD) modeling, with river flow and the inland water table as boundary conditions. To assign physical properties for the CFD models, we used high-resolution bathymetry from Light Detection and Ranging (LiDAR) surveys and riverbed grain size from underwater camera image analyses and sediment samples. These studies revealed that HEF direction and magnitude are controlled by the river discharge and are highly sensitive to the thickness and properties of the biologically active alluvial layer that forms the first few meters of the riverbed. Proposed research will expand these results to a number of characteristic hydromorphic settings, using our facies-based characterization approach and linked to field observations of HEF, geophysical surveys, and reactive tracer tests. New research will elucidate the impacts of poorly-understood and critical factors (temporally variable discharge, subsurface heterogeneity, and regional groundwater flow) on HEF and associated biogeochemistry through a series of numerical experiments. These will be based on high-resolution CFD simulations linking transient river flow to HEF and predicting subsurface residence time distributions. New reaction models that account for microbial regulation processes and community dynamics will be incorporated into reactive transport simulations to account for impacts of carbon sources and speciation as well as inundation history. Results of these simulations will guide formulation of reach-scale reduced-order models and parameterizations that will build new predictive understanding and simulation capability applicable at river network and watershed scales.