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Influence of Hydrologic Exchange Flow on Nutrient Dynamics in Managed Watersheds

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This element of PNNL SBR SFA seeks to enhance understanding of the role of hydrologic exchange flow in hydrobiogeochemical cycling at the watershed scale. Hydrologic exchange increases surface water's contact time with reactive environments within the hyporheic zone (HZ), facilitating biogeochemical reactions and influencing fate and transport of solutes along the river corridor. Here, we propose and implement a novel watershed modeling framework by coupling the Soil and Water Assessment Tool (SWAT) watershed model and the PFLOTRAN subsurface reactive transport model, via a new Multi-rate Multi Transfer (MRMT) module. Mass transfer between a river reach and multiple subsurface storage zones within a HZ is modeled with a series of first-order mass transfer coefficients and probability density function (PDF) of coefficients in the limit. Within this framework, we also model a two-step denitrification and oxidative respiration reaction as representative biogeochemical processes within the HZ. This integrated modeling framework allows us to examine dynamics of mass transfer between rivers and HZs along the river corridor within a watershed, and to predict constituent transport and transformation at downstream locations.

As a proof-of-concept, we apply the integrated watershed modeling framework in the Upper Columbia-Priest Rapids watershed to investigate influence of the HZ on watershed nutrient cycling. In this modeling effort, mass transfer rates between river reaches and HZs are derived from the mean residence time as predicted by the hyporheic flow model -- Networks with EXchange and Subsurface Storage (NEXSS). Initial modeling results indicate that irrigation can significantly increase groundwater discharge and nitrate loading into river networks. We design different scenarios to yield quantitative understanding of the role of HZ biogeochemical processes and agricultural irrigation return flow on nutrient dynamics and water quality at the watershed scale. In the future, mass transfer rate distributions will be prescribed as a function of hydromorphic features (Hou et al. poster), based on mechanistic hydrobiogeochemical simulations that are currently being conducted in various segments of the Hanford Reach (Bao et al. poster).