Seasonal Hydrology and Biogeochemical Hot Spots: Carbon, Nitrogen and Mineralogic Controls on Suboxic Conditions in the Rifle Floodplain Aquifer

Steve Yabusaki (yabusaki@pnnl.gov) – PNNL (PI), B. Arora, LBNL; N.F. Spycher, LBNL; S. Molins, LBNL; R.M. Maxwell, Colorado School of Mines; J. Beisman, Colorado School of Mines; A. Navarre-Sitchler, Colorado School of Mines; Y. Fang, PNNL; E.L. Brodie, LBNL; C.I. Steefel, LBNL; S.S. Hubbard, LBNL Project Leader; Sustainable Systems SFA 2.0 Science Team (Co-PIs).

For most of the year, the Rifle floodplain aquifer is generally suboxic (~0.1 mg/L DO) despite communication with the atmosphere through a ~3 m thick vadose zone. Oxygen can be consumed via heterotrophic microbial reduction as well as the abiotic and microbially-mediated oxidation of reduced species and minerals. While each of these processes are thought to be active, microbial contributions from chemo(litho)autotrophic processes (e.g., ammonia, sulfur and iron oxidation) appear to be prominent.

The snowmelt-driven hydrology of the local catchment and Colorado River results in the seasonal rise and fall of the Rifle floodplain water table. After peaking in June, the initial decline of the water table is associated with elevated DO levels across the floodplain. A notable exception is in the central part of the site near the river, where no significant DO enhancements have been observed. This area is part of a probable naturally reduced zone (NRZ) that has been delineated through spectral induced polarization geophysics, groundwater analyses, chemical and mineralogical characterization of sediment, and biological sampling. The sediments in these NRZs are associated with elevated organic carbon, Fe(II), sulfide, and U(IV).

Coupled variably saturated flow and biogeochemical reactive transport modeling is being used to better understand the interplay of the 1) biotic and abiotic processes maintaining suboxic conditions, 2) the seasonal water table fluctuation and oxygenation, and 3) locally enhanced reactivity in the NRZ. The NRZ is relatively small compared to the floodplain; however, it has a potentially outsized impact on the flow of carbon and nitrogen through the subsurface. Our current GEWaSC focus is on hydrologic and seasonal impacts to the floodplain biogeochemistry in the context of surface and variably saturated flow processes in physically and biogeochemically heterogeneous 3-D sediments. Highly detailed 2-D vertical transect modeling is used to develop and integrate modeling capabilities that fundamentally address the reaction network, stable isotopes, and gas analyses. Highly resolved 3-D modeling extends the conceptual model to the entire floodplain to capture the distribution of lithofacies and NRZs across the site. Large scale 3-D local and regional catchment modeling provides transient recharge to the floodplain due to precipitation, runoff, and evapotranspiration; and inflow and water chemistry from the upland watershed. The omics-informed trait-based reactive transport modeling approach provides a foundation for understanding the impact of hydrologic hot moments and biogeochemical hot spots on the rates of carbon and nitrogen flow through the Rifle floodplain, across spatial and temporal scales.