Title: Multi-Watershed Perturbation-Response Traits Derived Through Ecological Theory

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Project Abstract: *This project is focused on transforming our ability to understand and predict how the influences of biogeochemical hot spots and hot moments on surface–subsurface systems are altered by perturbation. New theory and models are being developed across a broad range of watersheds to ultimately inform next-generation Earth system models and help preserve long- term national clean water security.* A major challenge in watershed hydrobiogeochemistry is predicting how perturbation changes the influences of hot spots and hot moments over aggregate biogeochemical function. Studies of hot spot/moments are often done at single sites; these studies are powerful for revealing mechanisms, but do not immediately provide transferable knowledge and models. To enhance transferability, this study is using a multi-watershed approach that leverages existing field sites across agencies. The approach is inspired by the Worldwide Hydrobiogeochemical Observation Network for Dynamic River Systems (WHONDRS) consortium. This study also builds from the recent merging of hot spots/moments into the concept of ecosystem control points, defined as "…areas of the landscape that exert disproportionate influence on the biogeochemical behavior of the ecosystem." This notion of control points is extended here to the new concept of control point influence (CPI): the contribution of elevated biogeochemical rates in space or time to the net aggregated rate within a defined system. There are major gaps in our knowledge of how CPIs vary across systems and what drives that variation, and a need to facilitate inclusion of additional features (e.g., DOM chemistry) in state-of-the-art models. This study is revealing mechanisms underlying cross- watershed variation in CPI through a trait-based framework to predict post-disturbance CPIs across watersheds. While the trait framework can be applied to any watershed component, this project uses variably inundated hyporheic zones as a biogeochemically active, tractable model system to test underlying hypotheses and multi-watershed transferability. The trait framework couples environmental variables (e.g., stream depth variance), porewater dissolved organic matter (DOM) chemistry, and CPIs. A key element of this framework is based on an innovative application of ecological theory to highly resolved DOM chemistry analyzed via collaboration with EMSL. The focus on DOM chemistry is based on field, lab, and modeling work showing that DOM chemistry strongly influences hyporheic zone respiration rates. In addition, simulation modeling and lab experiments show strong causal associations among environmental variance, DOM chemistry, and CPIs. The hypotheses and objectives of this project are addressed by quantifying (1) spatial variation in DOM traits using broadly distributed field sampling, (2) connections among environmental traits, DOM traits, and post-disturbance CPIs using lab incubations, and (3) multi-watershed predictions of post-disturbance CPIs based on environmental and DOM traits. The study's concepts and methods can be extended to any watershed component, and outcomes can help build next-generation reactive transport models linking environmental conditions to DOM chemistry to CPI and, in turn, improved predictions of energy and material fluxes relevant to the Earth system and national water quality.