Adapting routine water-quality modeling to reveal watershed function

Phosphorus is commonly the limiting nutrient of algal growth in freshwater systems, and eutrophication in the lower Great Lakes basin has been a familiar water quality issue for decades. Meaningful reductions in phosphorus transfers from land to water were made in the 1970s by addressing low-hanging fruit (i.e., point sources), but the re-emergence of at-risk conditions in the 21st century is mostly from non-point sources that are more complex to address. Modeling nutrient fluxes from large rivers is routine for tracking both the effectiveness of best management practices and progress toward meeting international nutrient reduction targets for the Great Lakes. Rating curve models are typically used to estimate nutrient fluxes, and increasingly these predictions are used for management decisions and as calibration data for process-based water quality and hydrologic models. While statistically powerful, existing tools like LOADEST and WRTDS, are best suited for predicting fluxes with low-frequency (e.g., bi-weekly to seasonally) water quality data and higher-frequency discharge data. The simplicity of these models often leaves information from high-cost *in situ* environmental sensors under-utilized. Moreover, relatively limited attention has been given to developing new model predictors that are process motivated and can facilitate the use of modeled results as diagnostic tools for watershed function and change. This talk will navigate the development of new, easily implemented generalized additive models for predicting nutrient fluxes from eleven relatively small and variable agricultural streams that were intensively monitored by the Ontario Ministry of the Environment, Conservation, and Parks during the Multi-Watershed Nutrient Study. A key advancement of these models is their compatibility with high-frequency data from environmental sensors and their parsimonious handling of subsurface-surface water exchange and hysteretic event-scale nutrient concentration-discharge relationships. These model characteristics are ideal for assessing and comparing nutrient dynamics and losses during high-flow conditions, which are of concern, given the large quantities of sediment and nutrients transported during extreme events that are expected to occur more frequently in the region due to climate change. The results of this work indicate promising model performance and an aptitude for revealing water quality patterns at a range of temporal scales. Specifically, new seasonal trends in phosphorus losses were uncovered and it was shown that as few as three runoff events can be accountable for the majority of annual phosphorus losses. At the event scale, this work also indicated seasonally dominant patterns in phosphorus concentration-discharge relationships that were used diagnostically to assess possible landscape positions of nutrient sources and to assess the timing of elevated concentrations of more bioavailable dissolved phosphorus. Both gross nutrient losses and water-quality dynamics were heavily hydrologically mediated and showed that watershed behavior may be altered significantly above critical discharge thresholds. Besides these findings, this talk will also explore future research avenues and ongoing work to improve the fidelity of model predictors using stable isotopes in water.