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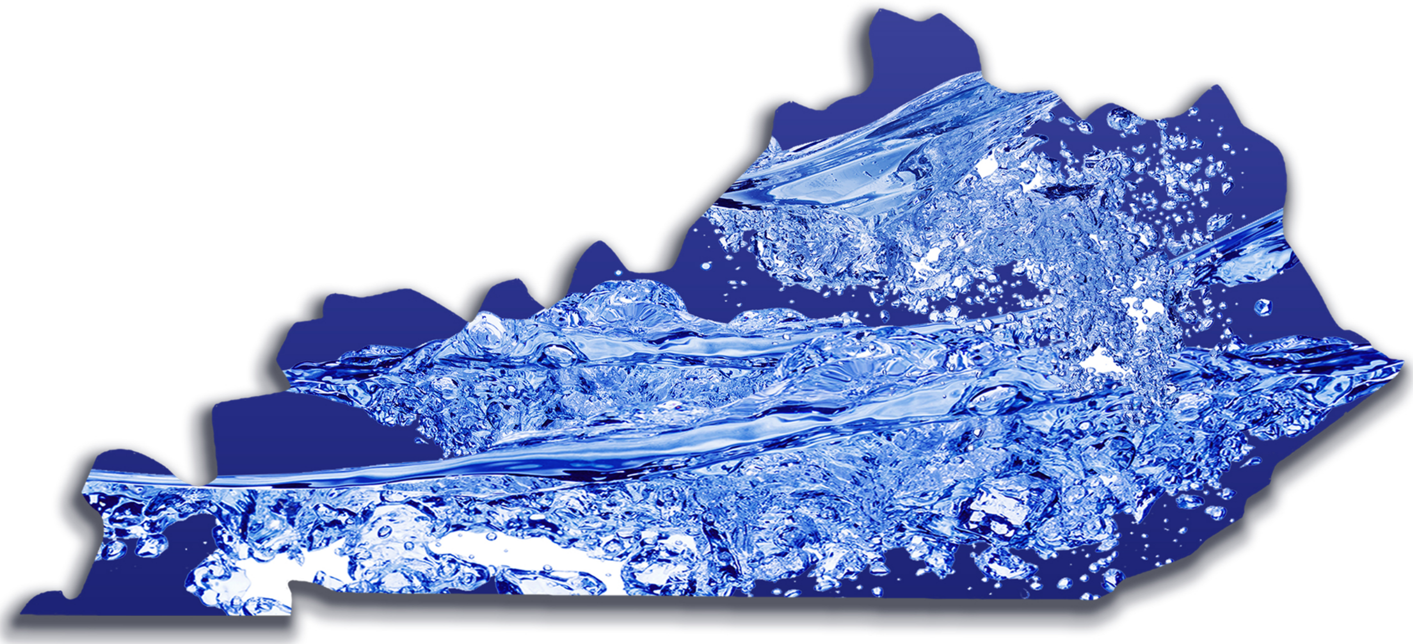
2019 Kentucky Water Resources Annual Symposium



March 25, 2019

Marriott Griffin Gate Resort | Lexington, KY

Kentucky Water Resources Research Institute

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Kentucky Water Resources Research Institute
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AGENDA

2019 Kentucky Water Resources Annual Symposium

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Marriott Griffin Gate Resort, Lexington, Kentucky

Registration and Continental Breakfast (8:00 a.m. - 8:30 a.m.)

PLENARY SESSION (8:30 a.m. - 10:00 a.m.)

Location: Salons E and F

8:30 *Welcome & Introduction,* Kelly Pennell, Acting Director, Kentucky Water Resources Research Institute, University of Kentucky.

8:45 *Water and Wastewater Industry Challenges*, Spencer Bruce, President and CEO, Louisville Water Company.

9:05 *What is the Right Project?* Donna McNeil, Executive Director, Kentucky Infrastructure Authority.

9:25 *Policy and Management Perspectives*, Secretary Charles G. Snavely, Kentucky Energy and Environment Cabinet.

9:45 Panel Discussion and Q & A

POSTER SESSION 1 (10:00 a.m. - 11:00 a.m.)

Location: Dixiana & Lands End and Calumet & Darby Dan

SESSION 1 (11:00 a.m. - 12:20 p.m.)

Location: Salons E and F

Track A

1A - Nutrients and Sediment

Moderators: Kelly Pennell & Steven Hoagland

11:00 *Nutrient Concentrations, Loads, and Yields at Ambient Water Quality Monitoring Stations, 2005-2017*, Caroline Chan, Watershed Management Branch, Kentucky Division of Water.

11:20 *Advancement in Watershed and Sediment Transport Modeling Using Dynamic Lateral, Longitudinal, and Vertical Sediment (Dis)connectivity Prediction*, Tyler Mahoney, Dept. of Civil Engineering, University of Kentucky.

11:40 **Canine Nutrient Contributions to the Urban Environment*, Brad Lee, Dept. of Plant & Soil Sciences, University of Kentucky.

12:00 *Continuous Nutrient and Turbidity Sensors Reveal the Response of Watershed Sources Connected During Storm Events*, Evan Clare, Dept. of Civil Engineering, University of Kentucky.

Track B

1B - Ecological Restoration

Moderators: Steve Evans & Malissa McAlister

11:00 *The Restoration of Cane Run Creek through Lexington's Coldstream Park and UK's Coldstream Research Campus*, Jennifer Carey, Division of Water Quality, LFUCG.

11:20 *Using Multiple Methods for Better Stream Restoration: Including 2-Dimensional Modeling*, Wanda Lawson, Stantec Consulting Services, Inc.

11:40 *An Ongoing Success Story: How Data, Persistence and Patience is Paying Off in the Hanging Fork Watershed*, John Webb, Watershed Management Branch, Kentucky Division of Water.

12:00 *Reclaiming Mill Creek: A Case Study in Urban Stream Restoration*, Jonathan Scheibly, Stantec Consulting Services, Inc.

AWARDS LUNCHEON (12:25 p.m. - 1:25 p.m.)

Location: Bluegrass Pavilion

SESSION 2 (1:30 p.m. - 3:10 p.m.)

Location: Salons E and F

Track A

2A - Ecology, Biology, and Climate

Moderators: Steve Evans & Malissa McAlister

1:30 *Ecological Monitoring of WRP Easements in Western Kentucky*, Karen Baumann, Dept. of Biological Sciences, Murray State University.

1:50 *Discussion of Factors Influencing Ecosystem Productivity in the Greenup Pool of the Ohio River*, Mindy Armstead, Dept. of Integrated Science and Technology, Marshall University.

2:10 *Biotic Interactions Between a Bloom-Forming Cyanobacteria and a Planktonic Protist: Implications for Toxin Production*, Sarah Princiotta, Hancock Biological Station, Murray State University.

2:30 *The Use of Multiple Large and Detailed Databases to Evaluate the Impacts of Climate Change on Water Resources in the Ohio River Basin*, Lynn Jarrett, US Army Corp of Engineers (Retired).

2:50 **Evaluating and Addressing Climate Awareness and Water in Kentucky*, Lauren Cagle, Dept. of Writing, Rhetoric, and Digital Studies, University of Kentucky.

Track B

2B - Groundwater and Karst

Moderators: Kelly Pennell & Steven Hoagland

1:30 *Incorporating Machine Learning with LiDAR for Delineating Sinkholes*, Junfeng Zhu, Kentucky Geological Survey, University of Kentucky.

1:50 *Advances in Urban Karst Hydrological and Contaminant Monitoring Techniques for Real-Time and High-Resolution Applications*, Jason Polk, CHNGES & HydroAnalytical Lab, Western Kentucky University.

2:10 *Finding the Edge: Assessing How to Apply Edge of Field Monitoring to Karst*, Benjamin Tobin, Kentucky Geological Survey, University of Kentucky.

2:30 **An Urban Karst Groundwater Evaluation and Monitoring Toolbox*, Rachel Kaiser, Dept. of Geography & Geology, Western Kentucky University.

2:50 *Center-Pivot Irrigation in Western Kentucky: Adding Context to the Discussion*, Glynn Beck, Kentucky Geological Survey, University of Kentucky.

POSTER SESSION 2 (3:10 p.m. - 4:10 p.m.)

Location: Dixiana & Lands End and Calumet & Darby Dan

SESSION 3 (4:10 p.m. - 5:10 p.m.)

Location: Salons E and F

3A - Drinking Water

Moderators: Steve Evans & Malissa McAlister

4:10 **Evaluating Potential Health Threats from Untreated Karst Springs as Community Drinking Water Sources, Monroe County, Kentucky*, Cayla Baughn, Crawford Hydrology Lab, Western Kentucky University.

4:30 *Benefits of Energy Savings Performance Contracting for Water and Wastewater Treatment Facilities*, Greg Copley, Center for Applied Energy Research, University of Kentucky.

4:50 *Self-Cleaning Nanocomposite Membranes with Phosphorene-Based Pore Fillers for Water Treatment*, Joyner Eke, Dept. of Chemical and Materials Engineering, University of Kentucky.

3B - Pollutant Removal

Moderators: Kelly Pennell & Steven Hoagland

4:10 *Investigation of PolarClean and Gamma-Valerolactone as Solvents for Polysulfone Membrane Fabrication*, Xiaobo Dong, Dept. of Chemical and Materials Engineering, University of Kentucky.

4:30 *Selenium Removal Using Bacteria Entrapped Alginate Gel Beads in a Packed-Bed Reactor*, Yuxia Ji, Dept. of Civil Engineering, University of Kentucky.

4:50 *Nanotechnology and Membranes: Water Detoxification from Lab Scale to Real Site Applications*, Honygi Wan, Dept. of Chemical and Materials Engineering, University of Kentucky.

5:15 p.m. Announcement of Student Awards and Adjourn

Location: Salon F

* Denotes project supported by 2018-2019 USGS 104b grant funds.

Poster Session 1 (10:00 a.m. - 11:00 a.m.)

1. *Evaluating Soil Characteristics in Rural and Urban Areas*, Gabby Barnes, Huston School of Agriculture, Murray State University.
2. *Use of eDNA in Detection of Multiple Salamander Species in Eastern Kentucky Streams*, Florene Bell, Dept. of Natural Sciences, Asbury University.
3. *Evaluation of Biomass and Filtration Method on eDNA Detection of Fantail Darters (Etheostoma flabellare)*, Ben Brammell, Dept. of Natural Sciences, Asbury University.
4. *The Impact of Agricultural Development on Nutrient Contamination Hotspots Within a Small, Intermittent Watershed at EKU's Meadowbrook Farm, Madison County, Kentucky*, Reid Buskirk, Dept. of Geosciences, Eastern Kentucky University.
5. *How Does Drought Length Impact the Runoff and Nutrient Storm Response in an Agricultural, Intermittent Catchment in Central Kentucky*, Trevor Clemons, Dept. of Geosciences, Eastern Kentucky University.
6. *Analyzing Sanitary Sewer Overflow Sensitivity to Storm Characteristics*, Andrew Day, Dept. of Geography and Geosciences, University of Louisville.
7. *Evaluating Soil Properties in No-Till and Conventional Tillage Systems*, River Dowell, Huston School of Agriculture, Murray State University.
8. *Assessment of the Impact of Forest Degradation Caused by Human Activities on a Lake in Omo – Sasha – Oluwa Forest Reserves, Southwestern Nigeria*, Judith Eke, Environmental and Resource Management, National Open University-Nigeria.
9. *Soil Responses to Tillage Practices and Cover Crops*, Carrie Ann Followell, Huston School of Agriculture, Murray State University.
10. *Chlorophyll a and Primary Productivity Dynamics in Kentucky Lake*, Morgan Franklin, Dept. of Earth and Environmental Sciences, Murray State University.
11. *Kentucky Backyard Streams Program*, Amanda Gumbert, Cooperative Extension, University of Kentucky.
12. *E. coli in Urban Streams*, Emily Huff, Dept. of Natural Sciences & Mathematics, West Liberty University.
13. *Assessment of Microbial Respiration and Carbon Loss Rates in the Upper Ohio River and Selected Tributaries in the Northern Panhandle of West Virginia*, Emma McClelland, Dept. of Natural Sciences & Mathematics, West Liberty University.
14. *Fabrication of a Novel Reactive Membrane for Water Treatment*, Alex Mills, Dept. of Chemical and Materials Engineering, University of Kentucky.
15. *Temperature Responsive Membranes and Perfluorochemical Adsorption*, Rollie Mills, Dept. of Chemical and Materials Engineering, University of Kentucky.
16. *What are the LiDAR-Revealed Depressions in Alluvium Along Major Rivers in Kentucky*, Adam Nolte, Kentucky Geological Survey, University of Kentucky.
17. *Nutrient Export and Remediation at Meadowbrook Farm, Madison County, Kentucky: Steps Toward Improving Local and Regional Water Quality*, Ryan Penn, Dept. of Geosciences, Eastern Kentucky University.
18. *Functionalization of PVDF Membranes with Thiol Groups for Heavy-Metal Capture*, Ronald Vogler, Dept. of Chemical and Materials Engineering, University of Kentucky.

Poster Session 2 (3:10 p.m. - 4:10 p.m.)

1. *Climate Change Impacts on Sediment Transport in a Lowland Watershed System: Controlling Processes and Projection*, Nabil Al Aamery, Dept. of Civil Engineering, University of Kentucky.
2. **Assessment of MRSA Presence in Suburban WWTPs Effluent and Receiving Streams in Lexington, Kentucky*, Atena Amirsoleimani, Dept. of Civil Engineering, University of Kentucky.
3. *Heavy Metal Capture and Detection using Colored Synthetic Dithiol*, Shashika Bandara, Dept. of Chemistry, University of Kentucky.
4. *Quantifying Nutrient Fate and Transport in Karst Agroecosystems of Central Kentucky: Application of High-Resolution Sensors, Numerical Modeling, and Isotope Tracers*, Nolan Bunnell and Cory Radcliff, Dept. of Biosystems & Agricultural Engineering, University of Kentucky.
5. *Magnetic Nanocomposite Materials for the Detection and Removal of Halogenated Organic Pollutants in Contaminated Water Sources*, Molly Frazar, Dept. of Chemical and Materials Engineering, University of

Poster Session 2 (3:10 p.m. - 4:10 p.m.) cont.

6. *Measuring and Modeling Morphologic Processes in Karst to Sustain Water Resources in the Future*, Morgan Gerlitz, Dept. of Civil Engineering, University of Kentucky.
7. *Impedance Spectroscopy Based Evaluation of Phytoplankton Health*, Margaret Jett, Dept. of Mechanical Engineering, University of Louisville.
8. *Assessing the Performance of Brookville Flood Control Reservoir*, Mingda Lu, Dept. of Mechanical & Civil Engineering, Purdue University Northwest.
9. *Monitoring and Modelling of Phosphorus Flux Dynamics in Tile-Drained Landscapes: Quantifying the Role of Sediment-bound Phosphorus Fluxes*, Saeid Nazari, Dept. of Biosystems & Agricultural Engineering, University of Kentucky.
10. *Quantifying the Role of Particulate Nitrogen in Disturbed Forested Watershed Nitrogen Budgets: Influences of a Lowland Confluence Wetland*, Ciara Pickering, Dept. of Biosystems & Agricultural Engineering, University of Kentucky.
11. *Insight to the Mineralization of Fine Sediment Organic Matter in Streams Using Stable Isotopes Experiments,* Brenden Riddle, Dept. of Civil Engineering, University of Kentucky.
12. *The Potential Influence of Barge and Boat Traffic on Phytoplankton in the Greenup Pool of the Ohio River*, Cody Schumacher, Dept. of Environmental Science, Marshall University.
13. *Human Exposure Risk Assessment Model: Combining Subsurface and Aboveground Fate and Transport Processes*, Elham Shirazi, Dept. of Civil Engineering, University of Kentucky.
14. **The Impact of Ryegrass Root Exudates on Element Release in a Fragipan Soil*, Keegan Smith, Dept. of Plant & Soil Sciences, University of Kentucky.
15. *Vegetated Filter Strip Management Planning of Deep River Portage-Burns Waterway Watershed Using SWAT*, Linji Wang, Dept. of Mechanical & Civil Engineering, Purdue University Northwest.

* Denotes project supported by 2018-2019 USGS 104b grant funds.

The 2019 Kentucky Water Resources Annual Symposium was made possible with support from:

Kentucky Water Resources Research Institute

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PLENARY SESSION

Spencer Bruce, P.E.

Spencer Bruce has served as President and CEO of the Louisville Water Company since January 1, 2016. He has been with Louisville Water Company 13 years, where he progressed from managing daily operations of the company's distribution system and directing the daily operations of the company's two water treatment plants to serving as Vice President and Chief Engineer, responsible for managing $1 billion in company assets. Louisville Water Company provides water to approximately 1,000,000 people in Jefferson, Bullitt, Hardin, Oldham, Nelson, Shelby and Spencer Counties in Kentucky.

Spencer has a BS in Mechanical Engineering from the University of Kentucky and is a licensed Engineer in the state. He is a member of the American Water Works Association (AWWA), Association of Metropolitan Water Agencies (AMWA) and the Kentucky Society of Professional Engineers.

Donna McNeil

Donna McNeil was appointed the Executive Director of the Kentucky Infrastructure Authority effective February 16, 2017. The Authority is responsible for providing a mechanism for funding local public works projects.

She received a Bachelor of Science Degree in Civil Engineering from the University of Kentucky. She holds an Engineer-in-Training certification from the Kentucky Board of Licensure for Professional Engineers and Land Surveyors. Upon retirement as manager of the Kentucky drinking water programs from Kentucky government in 2008, she had over 22 years of service in the water field. During that time, she implemented programs such as the Drinking Water State Revolving Fund and Capacity Development. As a compliance specialist with Kentucky Rural Water Association, she assisted water utilities with federal and state requirements. She is a member of both the Drinking Water and Wastewater Advisory Councils for the Kentucky Division of Water, for which she chairs the Joint Infrastructure Sustainability Committee. She is also a member of the Kentucky Water Resources Research Institute Committee on Research and Policy through the University of Kentucky. On the national level, she is the 2019 co-chair and active member of the State/EPA State Revolving Fund Workgroup.

Secretary Charles G. Snavely

Charles G. Snavely was appointed by Governor Matt Bevin as Secretary of the Kentucky Energy and Environment Cabinet in December 2015. Mr. Snavely is a graduate of Virginia Polytechnic Institute and State University with a B.S. in Mining Engineering and has an MBA through a joint program of the University of Kentucky and the University of Louisville.

Mr. Snavely retired from the mining industry after more than 35 years, having served as a mine engineer and later president of several large coal companies in southeast Kentucky. He most recently was Executive Vice President of Operations for International Coal Group and President of Eastern Operations for Arch Coal, Inc. He is past chairman of the Board of Directors of the Kentucky Coal Association and a Distinguished Alumnus of the Virginia Tech Department of Mining Engineering.

SESSION 1A: NUTRIENTS AND SEDIMENT

Nutrient Concentrations, Loads, and Yields at Ambient Water Quality Monitoring Stations

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Nutrient loads from the greater Mississippi River basin have created a hypoxic zone in the Gulf of Mexico, which measured a record 8,776 square miles in 2107. States within the basin determined in *The Gulf Hypoxia Action Plan 2008* (Mississippi River/Gulf of Mexico Watershed Nutrient Task Force, 2008) to develop strategies to reduce nutrient loads and develop reasonable and appropriate watershed-specific plans to further manage nutrients. The Kentucky Division of Water, with its partners, is developing a Nutrient Reduction Strategy to assist in this state and federal initiative to reduce nutrient loading to the basin and the size of the hypoxic zone.

To determine if implemented strategies are effective, baseline measures of loads and yields must be known. The Division has regularly sampled stations in the primary ambient monitoring network for water quality and other parameters for decades. While station changes occasionally occur for safety or other reasons, this network can be used to characterize and track changes to the Commonwealth's water quality over the long term. A USGS report, *Concentrations, and estimated loads and yields of total nitrogen and total phosphorus at selected stations in Kentucky, 1979-2004* (Crain, 2009) used these stations to evaluate nutrients. This study provides a broad baseline of nutrient loads and yields throughout the Commonwealth, but is not based on current data.

Contemporary data are needed to craft a modern nutrient reduction strategy, therefore, the USGS study was replicated using data from 2005 – 2017. An effort was made to use the same monitoring stations and methods so that results can provide current nutrient load and yield information, but also be compared directly to the previous study results. LOADEST (Runkel, 2004) was used to determine loads for total nitrogen and total phosphorus, with yields derived from loads and contributing basin area.

LOADEST produced models with good fit for all stations for total nitrogen and all but three stations for total phosphorus. Basins with greater areas of agricultural land use have higher nutrient yields, and conversely, those with greater amounts of natural land cover have lower nutrient yields. Results from this study are being evaluated to inform decision-making in developing the Kentucky Nutrient Reduction Strategy.

References

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Advancement in Watershed and Sediment Transport Modeling Using Dynamic Lateral, Longitudinal, and Vertical Sediment (Dis)connectivity Prediction

Tyler Mahoney, Nabil Al-Aamery, Jimmy Fox, Evan Clare, Thomas Dunlop, Stephen Day, and John Pike
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Sediment connectivity describes the three-dimensional, stochastic nature of sediment detachment and transport between geomorphic features of a watershed. The strength of connectivity reflects the ability and continuity of transport pathways to move matter from source, through the watershed's stream network, to sink. Geomorphologic literature suggests that sediment connectivity plays an important role in sediment transport modelling, but we find contemporary erosion and sediment transport models lack explicit incorporation of sediment connectivity theory. The ubiquity of high-resolution geospatial and water quality sensing data suggests the time is ripe to couple connectivity theory with sediment transport modelling to advance the three-dimensional simulation of sediment movement at the watershed scale. Our objective was to couple sediment connectivity theory with sediment transport modelling to explicitly map active sediment transport pathways and simulate sediment flux of each pathway at the watershed scale in space and time. During our simulations, we also kept in mind the gently rolling, bedrock-dominated watershed configuration, as found in the Bluegrass Region of Kentucky and throughout the USA. Gently rolling catchments foster fertile soils with life-sustaining geomorphologic infrastructure capable of sustaining important critical-zone functions. As a second objective, this research aims to elucidate connected and disconnected geomorphic features within the watershed uplands, stream network, and hyporheic zone in gently rolling, bedrock-controlled catchments.

Materials used to formulate the coupled sediment connectivity and sediment transport model included: (1) probability of sediment connectivity simulations in the watershed uplands (lateral connectivity); (2) estimation of upland sediment flux input to the stream network; (3) instream bathymetry and sediment measurements; and (4) instream and upland connectivity field reconnaissance. The numerical model simultaneously simulates sediment flux and instream (longitudinal and vertical) sediment connectivity. A multi-calibration procedure utilizing total suspended solids (TSS) samples, quasi-continuous turbidity data, connectivity field reconnaissance, and sediment fingerprinting results calibrated and validated the numerical model. We collected TSS samples using a Teledyne ISCO automated sampler and quasi-continuous turbidity data using YSI 6-series turbidity sensors. Sediment traps collected bi-weekly helped formulate sediment fingerprinting results utilized in model calibration and validation. We applied the framework to the Upper South Elkhorn watershed in the Bluegrass Region of Kentucky, USA. We chose to apply our study to this watershed because: (1) it is representative of gently rolling, bedrock-controlled watersheds with mixed land use; (2) of the abundance of data previously collected in the watershed over the past twelve years; and (3) the watershed's proximity to the University of Kentucky.

Modelling results indicate that the geomorphologic watershed configuration controls sediment connectivity for both the watershed uplands and within the stream network. Hydrologic forcings control dynamic changes of sediment connectivity from one hydrologic event to another, but the

input timing of sediment from the uplands to the stream network is generally restricted by the distribution of landforms in the uplands. Results showed that the distribution of lateral, longitudinal, and vertical impedances to sediment transport governed sediment residence time, sediment flux, and sediment connectivity. Bedrock outcrops dominated instream (longitudinal) sediment (dis)connectivity by limiting the instream transport capacity of water and influenced prominent feedback loops relating streambed evolution and streambed erosion/deposition. We found that during high magnitude hydrologic events when significant sediment transport occurred, landforms such as undulating microtopography limited sediment connectivity. The spatially explicit nature of the results highlights the efficacy of the coupled model. Explicit representation of active sediment transport pathways and sediment sources, as simulated herein, is an emergent tool especially useful for watershed managers when applying erosion remediation BMPs at the watershed scale.

Canine Nutrient Contributions to the Urban Environment*

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As dogs become more popular and human populations concentrate in urbanized areas, management of canine excrement will become more important. At present, only about 60% of dog excrement is collected from public spaces and disposed in a landfill. Nutrient contributions to stormwater attributable to dogs are not known to the regulated Municipal Separate Storm Sewer System communities (MS4s), the local regulatory entities that will make dog excrement cleanup a priority in future years. Quantification of nutrients from dogs is particularly important to states like Kentucky, which ranks 3rd in the nation in canines per household (1.9 dogs in 45.9% of households). In order to quantify nitrogen and phosphorus from canine excrement, individually packaged excrement samples were collected from 1005 canines that deposited at 12 apartment complexes and 11 dog parks in 3 of the most urbanized areas of Kentucky. Moisture content averaged 69.2% (s.d. = 5.5%, range: 31.3% - 91.1%, n = 746), nitrogen (N) averaged 3.9% (s.d. = 0.8%, range: 0.9% - 6.5%, n = 1005) and phosphorus (P) content averaged 3.1% (s.d. = 1.0%, range: 0.4% - 8.0%, n = 1005). The Environmental Protection Agency estimates that the average dog produces 125 kg of feces annually. Using this value, the canine population of Kentucky adds 2245 Mg N and 1729 Mg P to the environment each year. At the household lawn scale, the average canine adds 1.2 kg of P and 1.5 kg of N. Using the University of Kentucky recommended annual application rate of 0.9 kg N per 93 m^2 lawn, one average dog would apply enough N to cover a 155 m^2 lawn and 2-fold the amount of P applied at the N-equivalent rate of a 10-10-10 fertilizer. These results suggest that dog excrement is a significant source of nutrients in the urban environment and should be taken into consideration when developing MS4 nutrient management strategies.

*Supported by 2018-2019 USGS 104b grant funds.

Continuous Nutrient and Turbidity Sensors Reveal the Response of Watershed Sources Connected During Storm Events

Evan Clare[1], Tyler Mahoney[1], Jimmy Fox[1], Jason Backus[2], Thomas Dunlop[1], Stephen Day[1], and John Pike[1]
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Recent development of continuous, *in-situ* water quality sensors has allowed for high-resolution, high-quality nutrient and suspended sediment sampling to become increasingly possible. Previously, study of the temporal variations in nutrient concentrations has been limited in terms of the temporal resolution of samples taken, primarily due to the time and manpower constraints that exist when conducting sampling regiments in the field. Low-maintenance, high-resolution sampling methods have been found to be especially advantageous when considering the monitoring of storm event and subsequent nutrient and sediment event-response dynamics, specifically due to the safety concerns that arise during manual sampling in high flows in streams. Storm events have increased capacity for the transport of pollutants, such as sediment and nutrients, from a watershed to a downstream receiving body. This is due to the increased event runoff activating new flowpaths and mobilizing previously disconnected source pools of a given constituent. Studying the nature of the event concentration-discharge dynamics, utilizing novel methods such as hysteresis loop analysis and hydrograph/chemograph separation, can elucidate the transport mechanics of the constituent in question, including source location within the watershed, dominant flowpaths, and timing of load exports.

Nutrient monitoring "platforms", consisting of the SeaBird-Coastal SUNA V2 nitrate sensor, the SeaBird-Coastal HydroCycle-PO4 phosphate sensor, and various Yellow Springs, Inc. 6-Series Water Quality Sondes (measuring temperature, turbidity, conductivity, dissolved-oxygen, and pH) have been deployed in two watersheds in central Kentucky. The South Elkhorn watershed is a 62 km^2 basin near Lexington, KY and has been defined as a surface-flow dominated, immature karst watershed. The Cane Run watershed is a 98 km^2 basin near Georgetown, KY with a 58 km^2 area made up of a coupled surface-subsurface network. Water quality has been monitored at these locations quasi-continuously beginning in June 2017. Storm events with sufficient associated nitrate or turbidity data were subsequently identified for event concentration-discharge response analysis. Between the dates of June 2017 and June 2018 numerous increased discharge events were identified, including 31 independent nitrate-discharge events and 21 independent turbidity-discharge events at the South Elkhorn study site, and 17 independent nitrate-discharge events and 11 independent turbidity-discharge events at the Royal Spring study site in the Cane Run watershed. Hysteresis responses, defined for the purposes of this research as the disparate timing of discharge and nitrate/turbidity fluctuations during an event, were analyzed for each identified event using constructed concentration-discharge loops and used to categorize events. Hydrograph separation techniques modified dependent upon results from the hysteresis loop analysis, as well as developed chemograph separation techniques were used to further analyze each event. The coupled results of these analyses were observed with the goal of identifying end-member contribution concentrations and relative timing during events.

Results of the analysis yield similar responses for nitrate and turbidity in the South Elkhorn watershed, as well as nitrate responses in the Cane Run watershed. This may indicate similar physical and biogeochemical mechanics controlling the event response relationships between the South Elkhorn and Cane Run watersheds, implying karst geology may play a more important role in the South Elkhorn watershed than previously hypothesized. Hysteresis loop analysis yielded several unique results for the two systems, including marked time-lagged nutrient and sediment responses to increased flow in both watersheds, multiple independent identifiable intra-event response patterns (double-loops), and dissimilar responses for events of increasing magnitude. Results from this analysis, coupled with results from hydrograph and chemograph separation indicate that event magnitude and antecedent moisture conditions dominate inter-event response variations; while dynamic end-member source concentrations are largely responsible for variations in intra-event concentration-discharge responses. Methods for the quantification of the end-member concentration fluctuations are necessary for further assessment of nutrient and sediment event response dynamics. However, this study presents a justification for the feasibility of in-situ sensors for improving the quality and the flexibility of water quality monitoring in the future.

SESSION 1B: ECOLOGICAL RESTORATION

The Restoration of Cane Run Creek through Lexington's Coldstream Park and UK's Coldstream Research Campus

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The Coldstream Park Stream Corridor Restoration and Preservation Supplemental Environmental Project (SEP) was developed by the Lexington-Fayette Urban County Government (LFUCG) for inclusion in its Federal Consent Decree to resolve alleged violations of the Clean Water Act. The recently-completed project restored 4,400 linear feet of intermittent stream and its riparian area and created three wetlands to improve water quality and to provide improved habitat for both aquatic and terrestrial organisms. The project location was chosen because Lexington owns a linear park through UK's Coldstream Research Campus. Coldstream Park includes Cane Run Creek, as well as the Legacy Trail along the east side of the creek, which made it an ideal location for a stream restoration project that would improve the experience of trail users and provide educational opportunities for those interested in urban streams.

The project area is located within the Inner Bluegrass karst region, which is one of the four major karst regions in Kentucky. Downstream of the project area (during normal and low-flow conditions), Cane Run sinks into an underground conduit system which feeds the Royal Spring aquifer. Royal Spring is the source of drinking water for the city of Georgetown to the northwest. Following significant rainfall events when surface flow exceeds the intake capacity for the aquifer, the creek flows to North Elkhorn Creek in Scott County.

Over time, the creek had been straightened for farming purposes. Then as development occurred in Cane Run's headwaters in north Lexington, runoff flows increased which led to both severe erosion and degraded water quality. The erosion ultimately resulted in a stream which was disconnected from its floodplain. The design strove to reconnect the stream with its floodplain, slow the flowrate of runoff from the adjacent land, reduce the flowrate through the restoration area, and achieve a better riparian area using native vegetation. Pollutants entering Cane Run from adjacent land were treated with a series of BMPs including stormwater wetlands, a bioswale, and native riparian zone plantings.

The project had its share of design and construction challenges, including stakeholder opposition to removing existing vegetation; resolving whether the stream should be separated from its existing karst features or not; conflicts with existing utilities; construction sequencing with two nearby sanitary sewer Consent Decree projects; and changing permitting requirements. With a focus on the desired outcome for this project, the project team was able to successfully address all of the challenges encountered. The project was completed in September 2018 which met the Consent Decree completion deadline. Lexington also fulfilled the monetary obligation that was stipulated for this project in the Consent Decree.

This project was undertaken in connection with the settlement of an enforcement action under the Clean Water Act, United States et al. v. Lexington-Fayette Urban County Government, brought on behalf of the U.S. Environmental Protection Agency.

Using Multiple Methods for Better Stream Restoration: Including 2-Dimensional Modeling

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Stream restoration is complex with many variables and constraints to consider. Natural Channel Design techniques are very important and helpful; however, we find that it is important to consider or incorporate other methods as well. In many areas where the native stream material is small, there is a need to consider Threshold Design techniques with Natural Channel Design, so the channel can remain stable under larger flows and have some long-term stabilizing features. We have also found that 2-Dimensional (2D) flow analysis on reaches that have a floodplain is very insightful and can be used to make better design decisions with a more informed view of the flood flows on the project.

2D flow analysis can allow the designer to better understand many different components about a stream restoration project, including multi-directional flows, how shear stress values change and shift with rising water elevations and changing slopes, where areas of high and low shear stress occur, how flood flows interact with the bankfull channel, and how flood flows ultimately affect the long-term stability of the bankfull channel. The use of 2D flow analysis has allowed us to better visualize the dynamics of flood flows across our project sites and has benefited our designs in many ways, at different stages of a project.

Stantec has designed and helped implement various stream restoration projects throughout Kentucky and the United States. We have been able to use 2D flow analysis on many different types of projects and at different stages of the projects as well. We have used 2D flow analysis to better understand some existing conditions and inform the proposed design. We have also used it multiple times to analyze proposed designs for refining and optimizing the final design. This includes using it to identify areas that would be under high stress during flood flows that need design adjustments, additional erosion control blanket, or other methods to help reduce erosion during the vulnerable growth stage of the project. 2D flow analysis is very helpful with understanding challenging sites. A restoration project previously designed and constructed by others was having multiple repeat issues during flood events. Stantec used 2D flow analysis to better understand the dynamics of the flood flows across the site as well as inform and guide the new design. We have gained confidence in our 2D models by comparing existing site observations to existing models. Similarly, we have compared field observations on restoration sites after flood events to the 2D models previously prepared for the design. This has given us good validation for the models. Stantec would like to take the time to demonstrate the various benefits of 2D modeling and the ways we have used it to improve designs and the overall success of our stream restoration projects.

About the Speaker: Wanda Lawson P.E. is a Stream Restoration Designer and Project Manager with Stantec. She has been working on stream restoration projects for 15 years in Kentucky and across the United States. Mrs. Lawson obtained a Bachelor of Science in Biosystems and Agricultural Engineering from the University of Kentucky.

An Ongoing Success Story: What Data, Persistence, and Patience has Enabled in the Hanging Fork Watershed

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The Dix River Watershed has been receiving special attention by the USEPA and the Kentucky Division of Water since its selection as a Clean Water Action Plan Priority in 1998. Unfortunately, efforts to address this recognized need for attention did not begin in earnest until 2006, when the Dix River Watershed Council began formally meeting and intensive water quality sampling was conducted.

The Dix River and its impoundment, Herrington Lake, serve as a major drinking water supply source for the Boyle, Garrard and Mercer County region. The lake was created in 1925 by Kentucky Utilities for hydropower, but it is also a recreational attraction for boaters and anglers, and many homes are located along its shores. It includes several tributaries which are impaired for pathogens and nutrients, and the lake itself is documented as impaired for nutrient enrichment.

The unwieldy size of the Dix River Watershed, covering 424 square miles in parts of five different counties, led the Council to focus on two subwatersheds where water quality improvements were most likely to be feasible. KDOW contracted with Third Rock Consultants to conduct and analyze the data from the Hanging Fork and Clarks Run subwatersheds, and ultimately utilize their findings to help develop the watershed planning documents.

The parallel efforts of the local Watershed Council and Third Rock's sampling and analysis ultimately produced two high-value products--USEPA-approved Watershed-Based Plans for both the Hanging Fork and Clarks Run watersheds. Both documents included specific recommendations to address water quality problems, especially those relating to instream high bacteria levels. *E. coli* concentrations in area streams often ranged from ten to 1,000 times greater than the statewide limit for safe wading/swimming. Follow-up microbial source tracking indicated that the bacteria sources were predominantly human rather than livestock, as had been assumed due to the rural, agricultural areas of the watersheds.

One of the highest-priority recommendations for improving water quality in the Hanging Fork watershed was to extend a sanitary sewer line along US127 into Hustonville to capture over 1,250 homes utilizing often-failing septic systems. This line would also enable the decommissioning of an inadequate package sewer treatment plant at the Hustonville Elementary School.

The Lincoln County Sanitation District was formed to pursue this recommendation and became an invaluable partner in the watershed improvement effort. The Sanitation District worked closely with the Bluegrass Area Development District and local officials to acquire a variety of grants and loans for the sewer extension. Phase I of the project has been completed and will capture sewage from approximately 600 homes in the watershed. Planning and funding arrangements for a second phase to capture additional homes and business are currently underway.

As with many sewer extension projects, area residents had mixed reactions to the need to connect to sanitary sewer and face monthly bills for the service. Fortunately, the Sanitation District was able to partner with the Kentucky Division of Water and the Rural Community Assistance

Partnership (RCAP) to develop a USEPA 319-h funded homeowner assistance program, which would defray costs of connecting their homes to the new sewer line. This program is providing cost-share funding at an income-based percentage rate, as well as helping residents understand the rationale for sewer collection through a partnership with the environmental education organization, Bluegrass Greensource. As of February 2019, 344 applicants had been approved for funding assistance, $242,851in reimbursements had been provided to 263 recipients, and 378 total sewer connections had been completed.

The Lincoln County Sanitation District has been recognized for its tremendous efforts to improve the water quality of Hanging Fork creek, as well as strengthen economic opportunities and the quality of life in the watershed. In 2018, they were awarded the Kentucky DEP's Environmental Pacesetter Award, and they received national recognition from the USEPA for performance and innovation in creating environmental success through the agency's PISCES program.

The Division of Water appreciates the local engagement of the Sanitation District and the many other partners in the Dix River Watershed. It is expected that these management efforts and continuing collaboration will produce direct water quality improvements when the streams are re-sampled by the Division.

Reclaiming Mill Creek: A Case Study in Urban Stream Restoration

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Urbanization is second only to agriculture in causing stream impairment in the Unites States and Europe, despite the relatively small area cities occupy relative to farms (Paul and Meyer, 2001). Impacts to streams include significant alteration in flow regime and sediment supply, lateral and vertical confinement, and habitat alteration, with a time scale of decades to centuries depending on date of settlement (Niezgoda and Johnson, 2005). With growing understanding of functions and values of streams, urban stream restoration has become an emerging field in the last 20 years (Gurnell et al., 2007). As the field is still young, there is substantial uncertainty in system assessment and design methodology (Brown, 2000; Niezgoda and Johnson, 2005); even determining a critical design variable like the channel-forming discharge is problematic (Annable et al., 2011). Therefore, a combination of engineering methodologies may be required for effective implementation of a restoration strategy. A recent restoration project in Cincinnati, Ohio utilized a combination of hydraulic modeling, field geomorphic assessment, "green" natural channel design, and traditional "gray" structures for rehabilitation of a highly impacted urban stream.

Mill Creek, located in southwest Ohio, flows approximately 30 miles from its headwaters in Butler County, through the city of Cincinnati, and on to its confluence with the Ohio River. The stream played an important role in the development of Cincinnati, providing drinking water, hydropower, transportation, and sanitation. Mill Creek was subject to intensive urbanization and manipulation, to the point where in 1997, American Rivers designated it as "the most endangered urban river in North America" (MCA, 2019). Stantec partnered with the Mill Creek Alliance to restore approximately 3,500 feet of this stream in 2017. The project reach flows through an industrial area with an active steel recycling facility and electric utility substation, a public golf course, and then a naturalized area with a city nature preserve. Substantial bank erosion was present on the landfill deposits of the steel yard, mass wasting baled plastic, asbestos shingles, and scrap metal into the stream. Invasive species dominated the riparian zone throughout the reach, and improper channel dimension with lack of floodplain connectivity led to bed instability and localized scour.

Design objectives for the project included hazardous material removal, bank reconstruction and stabilization, infrastructure protection, floodplain re-connection, instream habitat improvement, and riparian zone enhancement. Significant site constraints were present, including existing bank armor, two major active sanitary sewer lines, and a private rail line. To meet project objectives within these constraints, the design combined elements of traditional hydraulic civil design and natural channel design while relying heavily on both hydraulic modeling and field studies. Construction incorporated an imbricated stone toe, streambank reconstruction, rock riffle installation, and floodplain grading. The project has resulted in an ecologically and hydraulically diverse stream system with substantially less waste loading into Mill Creek. Since the start of construction, the project reach has experienced storm events near the 5 and 10-year return intervals, as well as several greater-than bankfull events with only minor repairs necessary. Improvement in stream bioassessment scores, bed and bank stability, and riparian zone quality from pre-construction conditions was observed within the first year following the construction. Improvements are expected to continue as the system matures.

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About the Speaker: Jonathan Scheibly, PWS, PE, is a Water Resources Engineer with Stantec. He has been working on stream and wetland restoration projects for over 12 years in Kentucky and across the United States. Mr. Scheibly holds a Bachelor of Science in Biology from the University of Kentucky, a Master of Science in Biology from Morehead State University, and a Bachelor of Science in Civil Engineering from the University of Kentucky.

SESSION 2A: ECOLOGY, BIOLOGY, AND CLIMATE

Ecological Monitoring of WRP Easements in Western Kentucky

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Riparian wetlands improve the quality of our nation's streams, rivers, and lakes, and support diverse assemblages of plant and animal species. Each year, billions of dollars are spent on a variety of projects focused on restoring wetlands, such as the Wetlands Reserve Program (WRP). Our main objective for this study is to monitor water chemistry, hydrology, and community structure of macroinvertebrates and fish on easements enrolled in WRP and in surrounding wetlands in order to assess the effectiveness of restoration strategies. Our study sites include WRP easements of various ages (up to15 years), agricultural fields prone to flooding as control sites, and mature bottomland forests representing relatively undisturbed reference wetlands. Hydrological modification structures, such as levee breaks, ditch plugs, or shallow water areas, have been installed on each easement. We are using stovepipe cores and multi-habitat dip nets to sample macroinvertebrates, a backpack electrofisher to examine fish communities, ISCO automatic water samplers and YSI multi-parameter sondes to monitor water chemistry, and pressure transducers and GIS to determine easement hydrology. Preliminary results reveal higher species richness and diversity in restored and reference wetlands as compared to control sites. Because new easements are permanently enrolled, there is tremendous potential to quantify changes in physical and biological condition over time. Understanding how these easements respond to restoration will provide opportunities for future adaptive management practices.

Discussion of Factors Influencing Ecosystem Productivity in the Greenup Pool of the Ohio River

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Marshall University is participating, with University of Kentucky and Murray State University, in a multistate research partnership to gain insight into the influence of food and energy production on aquatic ecosystems. Specifically, the research is investigating how food and energy production affect harmful algal bloom formation in the partner states with Marshall's research focused in the Ohio River. The NSF-EPSCoR research program, entitled Sensing and Educating the Nexus to Sustain Ecosystems (SENSE), has supported cyber-infrastructure development including the deployment of sensors monitoring real-time water quality parameters at Robert C Byrd and Greenup locks which bracket the Greenup pool of the Ohio River. Additionally, transect sampling in the Greenup pool is being utilized to demonstrate the extent to which real-time monitoring stations represent conditions throughout the pool.

After one year of high frequency data collection, and one series of 23 transect samples, trends in water quality and algal community dynamics are evident in the managed river system. High flows during the spring and fall of 2018 resulted in an atypical evaluation period and may have influenced findings. Primary productivity estimates were lower than expected with turbidity and flow potentially influencing algal productivity more than in typical flow years. Lower productivity in the Greenup Pool has implications for nutrient uptake in the eutrophic system. Real-time high frequency monitoring is ongoing and additional evaluations will be used to continue the development of productivity models for the managed river. With more than five million people utilizing the Ohio River as a drinking water source, management of the river to prevent algal blooms is a high priority and understanding the factors influencing algal productivity is an important first step in preventing bloom formation.

Biotic Interactions Between a Bloom-Forming Cyanobacteria and a Planktonic Protist: Implications for Toxin Production

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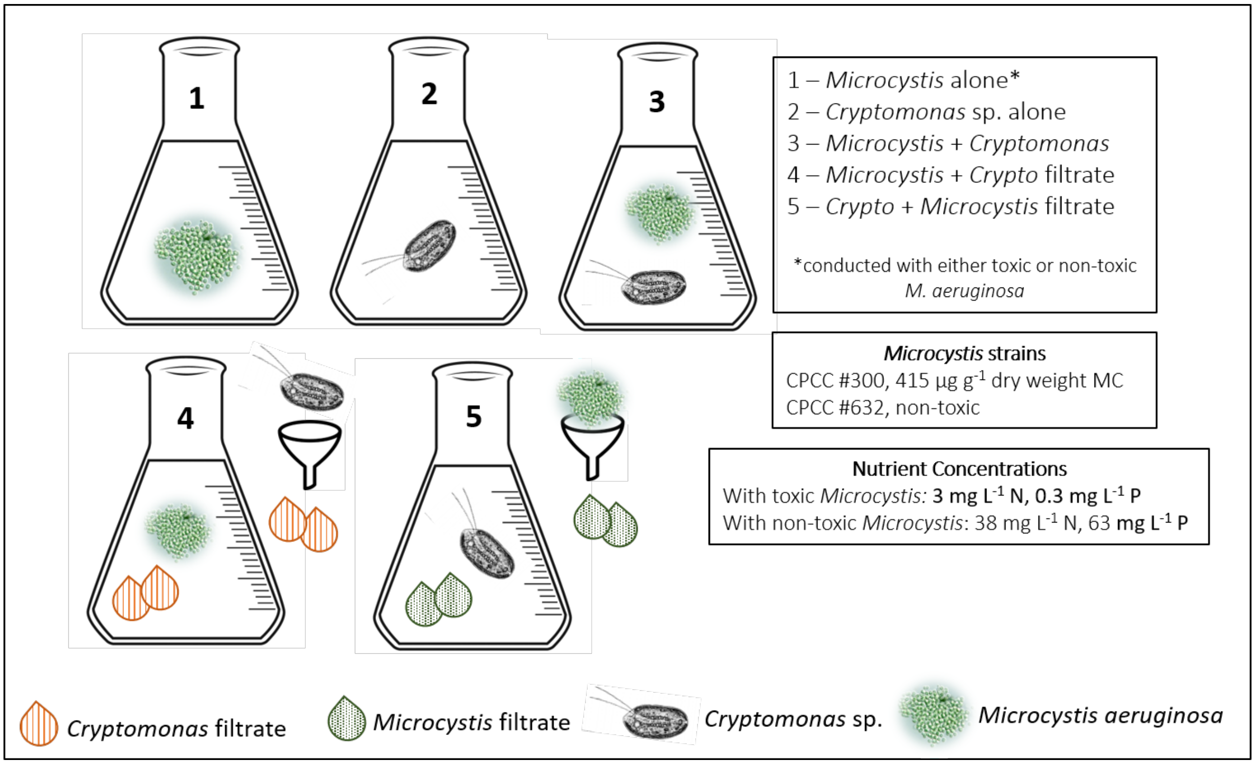
Freshwater ecosystems world-wide face threats of deterioration from toxin-producing cyanobacteria. Non-toxic cyanobacteria blooms also impair aquatic habitats for other organisms by reducing light availability and depleting dissolved oxygen during the decay processes. Multi-trophic interactions govern the formation and degradation of bloom conditions. Much attention on top-down controls of cyanobacteria blooms has focused on zooplankton, yet there is a growing body of literature dedicated to the roles of planktonic protists in "grazing the bloom." It has been suggested that phagotrophic protists can be effective grazers of cyanobacteria despite toxin production and colony formation. Many phagotrophic protists can function at more than one trophic level by combining photosynthesis with ingestion of particulate matter into a nutritional mode called mixotrophy. Here, we describe the biotic relationships between a mixotrophic protist (*Cryptomonas* sp.) and two strains of bloom-forming cyanobacteria (toxic and non-toxic *Microcystis aeruginosa*). Physical and allelopathic interactions were investigated between the protist and cyanobacteria under varying nutrient conditions in a full-factorial experimental design with each grown as a monoculture, grown in co-culture, and with addition of reciprocal filtrates. Cell abundance was determined by microscopic analysis over a period of 8 days, and production of microcystin-LR (MC-LR) was monitored both intra- and extracellularly by liquid chromatography (LC/MS/MS). Population growth rate was determined by slope of the linear regression of log-transformed cell abundance values plotted over time. The ability of *Cryptomonas* to ingest both forms of *M. aeruginosa* was assessed by disappearance of heat-killed, fluorescently labeled cyanobacteria.

Population growth rates of *Cryptomonas* in co-culture or with exudate from both strains of cyanobacteria were not different than when *Crytomonas* was grown alone. The relationship was maintained in both nutrient rich (38 mg l^{-1} N, 63 mg l^{-1} P) and poor (3 mg l^{-1} N, 0.3 mg l^{-1} P) media. However, in nutrient rich conditions, addition of non-toxic cyanobacterial filtrate led to an increase in population growth rate of *Cryptomonas* when compared with the co-culture treatment. Non-toxic *M. aeruginosa* exhibited the highest population growth rate in the presence of *Cryptomonas*. Conversely, population growth of toxic *M. aeruginosa* was significantly reduced in co-culture with the protist or its filtrate (under nutrient poor conditions). Despite evidence of competitive interactions, concentration of intracellular MC-LR was lowest when the *M. aeruginosa* was cultured with *Cryptomonas*. Finally, although abundance of fluorescently-labeled *M. aeruginosa* prepared from both toxic and non-toxic cultures declined in the presence of *Cryptomonas*, the highest protistan ingestion rates occurred during incubation with filtrate from toxic cyanobacteria.

Our work highlights the importance of considering biotic interactions among members of the plankton when studying algal bloom dynamics. The toxic strain of cyanobacteria was negatively affected by the presence of *Cryptomonas* and its derived filtrate, suggesting that the flagellate can either outcompete or ingest *M. aeruginosa* under nutrient poor conditions. Based on the disappearance of heat-killed *M. aeruginosa*, addition of cyanobacterial filtrate provides a nutritional supplement that supports increased feeding by *Cryptomonas* on toxic *Microcystis*. The study also calls into question the role of MC-LR because toxin-production was not likely a response to physical competitive interactions. Although more research is required to disentangle the effects of nutrients and toxicity on competitive interactions between members of the plankton, it should be noted that relationships between *Cryptomonas* and *Microcystis* varied with availability of N and P.



The Use of Multiple Large and Detailed Databases to Evaluate the Impacts of Climate Change on Water Resources in the Ohio River Basin

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Earth's atmosphere as we know it evolved as photochemical dissociation, or the breakup of water molecules by ultraviolet (UV) radiation, produced atmospheric O_2 levels of approximately 1-2% of current levels. At these levels O_3 (Ozone) could form to shield the Earth surface from UV radiation allowing microscopic plants to inadvertently oxygenate the atmosphere through the process of photosynthesis.

The scientific consensus for the last several decades is that the atmosphere of the modern Earth is largely created by and maintained by living organisms on the planet. The composition of the atmosphere is in chemical disequilibrium maintained primarily by the metabolic activities of photosynthesis and respiration and by various geochemical processes.

Beyond generating and maintaining the atmospheric it is widely believed that biological activity has produced catastrophic changes to the atmosphere such as snowball earth scenarios and fostering global fires over the last one billion years.

In the last several decades evidence indicates that another biologically produced event may be occurring. Increases in the atmospheric carbon dioxide (CO_2) concentration has been documented (Figure 1) by the National Oceanic and Atmospheric Administration's (NOAA) Earth System Research Laboratory (ESRL), (Dr. Pieter Tans, NOAA/ESRL (www.esrl.noaa.gov/gmd/ccgg/trends/) and Dr. Ralph Keeling, Scripps Institution of Oceanography (www.scrippsco2.ucsd.edu/).

In 1895 Arrhenius (1896) determined that dissolved CO_2 or carbonic acid trapped infra-red radiation in the atmosphere. He followed with a climate prediction based on greenhouse gases, suggesting that a 40% increase or decrease in the atmospheric abundance of the trace gas CO_2 might trigger the glacial advances and retreats.

In this study, multiple large national and regional water quality databases have been explored to determine if existing data can identify impacts that may potentially result from a changing atmosphere. Although, the signals from these databases are "noisy", numerous lines of evidence suggest that changes may be occurring (Figure 2).

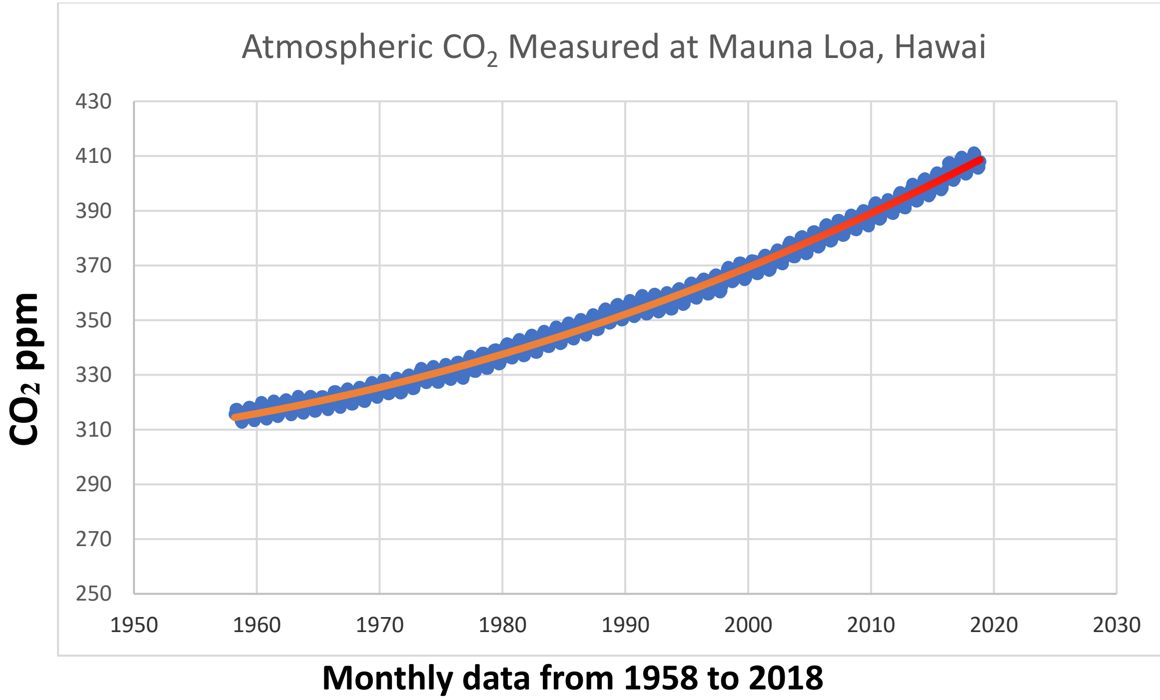

Figure 1. Presentation of monthly atmospheric CO_2 (ppm) at Mauna Loa, Hawaii between 1958 and 2018. A polynomial trend line is superimposed on the monthly cycles to emphasize the nonlinear increase in the measured greenhouse gas.

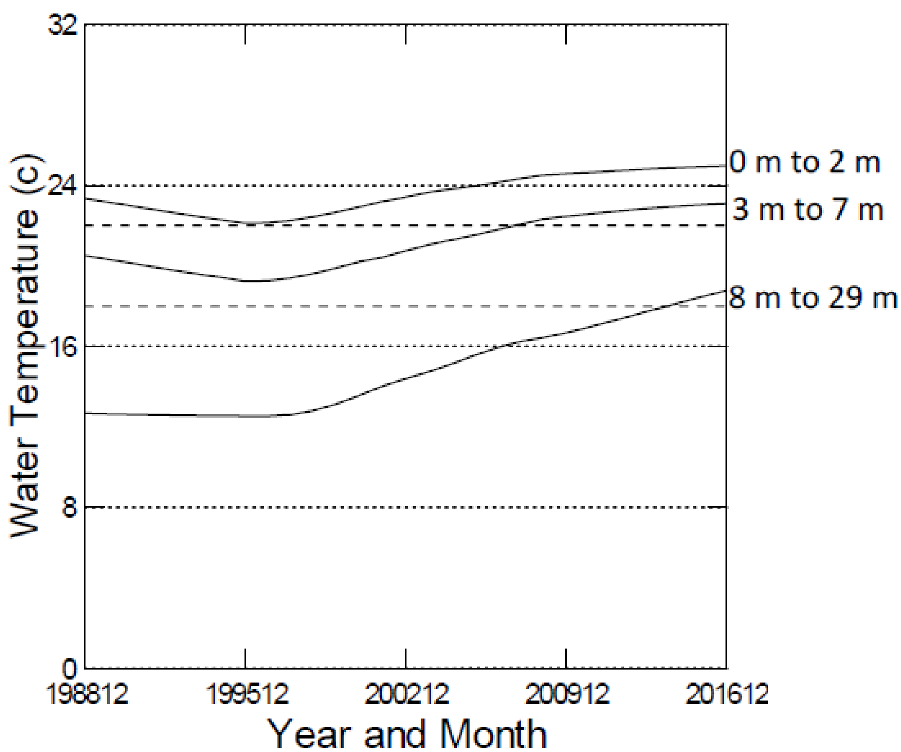

Figure 2. Water temperature trends at three different strata at Nolin Reservoir using forebay profiles and LOWESS smooths.

Evaluating and Addressing Climate Awareness and Water in Kentucky*

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Our changing climate is a global issue with widely varying effects. In Kentucky, our future climate will have distinct effects because of industries, agricultural practices, and communities specific to the state. These effects will include changes to environmental precipitation patterns, which have the potential to negatively impacting freshwater availability, groundwater quality, and storm frequency and intensity, among other outcomes. As water is such an important everyday resource for people, changes to water cycles, availability, and water quality can influence perceptions of the environment and even raise climate awareness. For example, research suggests that individuals' beliefs about climate change can be correlated to their distance from a coastline, perhaps because of visible changes to the coastline functioning to raise climate awareness. Coastal dwellers are not the only ones whose experiences with water can affect their environmental perceptions; similarly, some evidence exists that local flooding risks are related to climate concern and can inform efforts to build community climate awareness. Moreover, Americans broadly consider water, even within the context of urban infrastructure, to be related to climate change; a 2013 survey found that 92% of Americans "want their community water provider to be a leader in preparing their community for climate change." Water issues in Kentucky thus present an opportunity to develop climate awareness about local climate effects in a non-coastal state. Raising public awareness around water and climate in Kentucky can be mutually reinforcing efforts.

The project seeks to increase climate awareness, particularly as it relates to Kentucky's water resources. Specific objectives are to 1) develop a consortium of Kentucky climate researchers and educators to promote collaboration and information sharing on climate awareness issues and the dissemination of said information to the state's population, 2) develop a website linking Kentucky's citizens, students, and teachers to the consortium and Kentucky-focused climate resources, 3) evaluate current levels of climate awareness in Kentucky's population (eastern, central, and western regions) with a focus on water resources, 4) develop a set of training materials, based on current awareness levels, for personnel who regularly interact with the public, such as Cooperative Extension Service agents and Kentucky Watershed Watch basin coordinators, and instructors (K-12 and adult learners), and 5) administer at least one workshop using the developed training materials.

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SESSION 2B: GROUNDWATER AND KARST

Incorporating Machine Learning with LiDAR for Delineating Sinkholes

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Karst sinkholes are a major natural hazard, and information on existing sinkholes is critical in evaluating sinkhole hazards and understanding mechanisms leading to the formation of sinkholes, especially catastrophic cover-collapse sinkholes. LiDAR provides accurate and high-resolution topographic information and has been used to improve delineation of sinkholes in many karst regions. LiDAR data, however, generate a large quantity of topographic depressions and identifying sinkholes from these depressions through manual visual inspection can be slow and laborious. To improve efficiency of identifying sinkholes from topographic depressions, we applied five machine learning methods (logistic regression, naive Bayes, neural network, RusBoost, and support vector machine) to a dataset of morphological characteristics of LiDAR-derived topographic depressions. Sinkhole data from three counties (Bourbon, Woodford, and Jessamine) in the Bluegrass Region of Kentucky were used to derive the dataset for training and testing the machine learning methods. This dataset consisted of 22,884 records with 10 variables for each record. For each method, a random subset of 80 percent of the records was used for training and the remaining 20 percent was used for testing. The test receiver operating characteristic curves (ROCs) showed that all five methods were applicable to the dataset, as demonstrated with all the area under the curves (AUCs) greater than 0.87. Neural network emerged as the best performing method with an AUC of 0.95 and a testing average accuracy of 0.85. This accuracy was not sufficient for sinkhole mapping, however. We subsequently developed a two-step process that combined the trained neural network classifier and the manual visual inspection and applied the process to data from Scott County in the same region. The two-step process located 97 percent of sinkholes with inspecting only 27 percent of the topographic depressions in the county. This study showed that machine learning is promising to help identify sinkholes in karst areas with available high-resolution topographic information.

Advances in Urban Karst Hydrological and Contaminant Monitoring Techniques for Real-Time and High-Resolution Applications

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The City of Bowling Green, Kentucky, is one of the most studied urban karst systems in the world; yet, it still faces issues from stormwater quantity and quality impacting the groundwater and surface water systems. Within the City, multiple sites now have long-term datasets on storm event responses and their associated discharges and hydrogeochemistry to help provide insight to responses of a continuous karst aquifer system with multiple access points for monitoring. Over the past several years, advancement in the monitoring technology and adaptation of it to improved understanding of these systems, including the use of secondary data and additional types of data collection technology now available, has allowed for a deepened investigation of urban karst processes. This includes methods by which to calculate drainage basin area and effective recharge in rapidly responding karst systems during storm events, monitor water quality impacts during first flush and continuous flooding events, and promote education and outreach about stormwater in urban karst settings. Under continuous urban expansion and unpredictable storm events, this is particularly important, due to changes in flood frequency planning, groundwater residence times, water quality impacts, and stormwater infrastructure lagging behind the variability of storm events and their associated impacts.

Since the 1970s, Dr. Nick Crawford carried out extensive research on karst hydrogeology, geophysics, dye tracing, aquifer delineation, water quality mitigation, cave mapping, sinkhole detection and remediation, and developing monitoring techniques for stormwater impacts on groundwater and cave systems in Bowling Green. In building this knowledge, he pioneered several advances in using data sondes data loggers and evaluative techniques for karst areas and raised awareness about pollutant sources, best management practices, and new technologies to improve karst groundwater quality and methods for stormwater control and sinkhole repair. This includes the study and evaluation of injection wells for stormwater runoff, which are still being used in Bowling Green, and elsewhere, today. In partnership with the City of Bowling Green Public Works, WKU CHNGES has established the UnderBG project to integrate advanced scientific and technological approaches, along with new education and outreach activities, to promote the understanding of stormwater impacts on Bowling Green's urban karst aquifer, train new generations of karst scientists, and advance the field through more robust studies in the Bowling Green metropolitan area, which are all applicable to other similar areas. Several theses and new research collaborations have spawned the next generation of high-resolution hydrogeochemical studies, dye tracing techniques, GIS applications for well and karst feature geodatabases, water quality monitoring, and flood prediction in the City, as well as improved education and outreach methods regarding the fragility of karst landscapes from stormwater impacts using geocognition research and a rigorous outreach program. Combined with the scientific work, the use of educational signage, marketing materials, websites, and outreach activities and is being expanded in partnership with the City of Bowling Green to improve karst groundwater awareness and was recently named a 'Model Practice' by the American Public Works Association, which reflects well the pioneering nature of the work what it hopes to achieve in the future through partnership and collaboration.

Finding the Edge: How Can We Apply Edge of Field Monitoring to Karst?

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Edge-of-field monitoring techniques have frequently been applied to understand the impacts of agricultural techniques on water quality immediately adjacent to the fields. This allows for a deeper understanding of the direct impact of these farming practices on water quality adjacent to the fields. Karst terrain often lacks areas where overland runoff occurs; instead water typically flows to sinkholes and drains into the subsurface, ultimately emerging at springs. These subsurface flow paths are often difficult to quantify and it is even difficult to determine direct connections between surface sinkholes and their associated springs. Using a field site in Taylor County, Ky., we were able to quantify basic flow parameters and delineate groundwater basins for Homeplace on the Green River farm. Through this process we developed a set of critical preparatory measures to allow for interpretation of spring water-quality data and the associated edge-of-field impacts of the overlying agriculture. These consist of (1) conducting full karst hydrogeologic inventories, (2) delineating groundwater basins, and (3) quantifying system response. Additional work to understand water quality prior to water entering the subsurface will be critical to understanding how it changes through the groundwater system.

An Urban Karst Groundwater Evaluation and Monitoring Toolbox*

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In urban karst areas, such as the City of Bowling Green, Kentucky and the Tampa Bay Metropolitan Area, groundwater quality faces a variety of threats. The development of residential, commercial, and industrial landuse types allows for a wide variety of groundwater pollutants to enter the karst groundwater systems. Various different models and indices, including, but not limited to, the Karst Disturbance Index (KDI), Karst Aquifer Vulnerability Index (KAVI), EPA DRASTIC method, and the Karst Sustainability Index (KSI), have attempted evaluative approaches to identify issues in urban karst areas, but the methods vary by location and lack a focus on urban karst groundwater quality, as well as a lack of a data-driven approach that is able to capture short- and long-term changes in threats to groundwater quality as a result of urbanization. The overall purpose of this study was to develop a holistic, data-driven threat, vulnerability, and monitoring assessment tools for urban karst groundwater systems to better determine the possible threats, data collection needs, monitoring parameters, and analytical approaches needed to ensure groundwater quality is maintained in urban karst regions. This study focused on: 1) determining what indicators, parameters, and data quality need to be prioritized to create an effective, holistic monitoring framework for urban karst groundwater, and 2) developing an effective threat assessment and evaluative tools for urban karst groundwater quality sites using historic and modern data in an urban karst setting. The outcomes include an index and evaluation tool review, historical data evaluation and review, a threat, vulnerability, and monitoring evaluation system for the urban karst landscapes using GIS and a Karst Feature Inventory (KFI), and primary data collection in the City of Bowling Green and the Tampa Bay Metropolitan Area of water quality parameters. The final results of this study will be used to create a data-driven Urban Karst Aquifer Resource Evaluation toolbox that can be used universally.

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Center-Pivot Irrigation in Western Kentucky: Adding Context to the Discussion

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During the summer of 2012, drought conditions in western Kentucky ranged from severe to exceptional. Also, during the years leading up to the drought of 2012, corn and soybean prices were at historical highs. These factors created a favorable scenario for some farmers to install center-pivot irrigation systems. A survey of 85 counties identified 603 center-pivot systems and that the majority of pivots are located in three different geographical areas of western Kentucky. The survey also found that 69,630 acres in the 85 counties were irrigated by center-pivot systems.

Prior to the drought there was one continuous, long-term groundwater-elevation observation well in Kentucky. The observation well, located near Viola in north-central Graves County, is administered by the U.S. Geological Survey and is part of the National Climate Network. Since 2012, as part of the Kentucky Groundwater Observation Network, the Kentucky Geological Survey has installed and instrumented four observation wells and instrumented two existing wells to collect continuous groundwater-elevation data associated with various aquifers in the Jackson Purchase Region. Hydrographs from the U.S. Geological Survey Viola well and Kentucky Groundwater Observation Network wells in the Jackson Purchase indicate that groundwater elevations do not appear to be decreasing over time.

SESSION 3A: DRINKING WATER

Evaluating Potential Health Threats from Untreated Karst Springs as Community Drinking Water Sources, Monroe County, Kentucky*

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The geology of Southcentral Kentucky and Kentucky's Pennyroyal Plateau is characterized primarily by Mississippian-aged limestones that form prominent karst features such as caves and underground rivers. However, these prominent karst features offer markedly reduced filtration of contaminants that enter the groundwater system through the infiltration of surface water. Widespread agriculture in the region, including both livestock and row crop operations, can introduce dangerous contaminants to groundwater including fecal bacteria, pesticides, and fertilizers (White 1988; Currens 2002; Palmer 2007; Croskrey and Groves 2008). *E. coli,* a type of fecal coliform bacteria, is associated with gastro-enteric bloody diarrhea and sometimes fatal complications and has been the cause of large-scale acute GI infection outbreaks (Levine 1987; Nataro and Kaper 1988; Valcour et al. 2002; Tarr et al. 2005; Amraotkar et al. 2015). For this reason, the use of untreated karst groundwater as a drinking water source has been virtually eliminated in locations with highly-developed water supply and treatment infrastructure such as Southcentral Kentucky.

Despite the inherent risks in utilizing untreated karst groundwater as drinking water, two families in "simple living" Mennonite and Quaker communities in Southcentral Kentucky choose to utilize untreated karst groundwater as their primary drinking water source instead of implementing reliable disinfection methods or connecting to local municipal water supplies. These families choose to consume untreated karst groundwater based upon the ideology that "natural" water is safer since it is void of the chlorine and fluoride that are conventionally added to treated water and because it is cost prohibitive to connect to local municipal water supply infrastructure.

In 2015, a study (Amraotkar et al. 2015) was published that examined the relationship between Mennonite lifestyle and fecal bacteria contamination in drinking water in Allen County, Kentucky. Even so, the true extent of this local public health issue in simple-living communities of Southcentral Kentucky is unknown. The study also did not consider hydrogeologic variables, including karst. This project is the first to examine the relationship between Mennonite and Quaker communities and highly vulnerable *karst* groundwater sources in Southcentral Kentucky. It also represents the first phase of a new research program for Western Kentucky University's Crawford Hydrology Laboratory. The *long-term* goals of this program are to use these communities as demonstration sites to 1) evaluate the nature and extent of contaminated, untreated karst drinking water sources; 2) develop a participatory educational/technical approach to raise awareness of drinking water safety; and 3) evaluate a range of potential water resource protection strategies.

Through this project, three springs and one post-filtration home faucet are sampled monthly in a synoptic, non-conditional program with timing based on the US Geological Survey (USGS) National Water Quality Assessment (NAWQA) (USGS 2017). Sampling is synoptic in that it provides a synopsis of the conditions at the selected sites and non-conditional in that the samples are collected on pre-selected days. Sampling began in March with a completion target of May 2019. The four sites consist of Springhouse Spring 001 (secondary water source for Family #1, no filtration), Springbox Spring 002 (primary water source for Family #1, filtered before use), Home Faucet 003 (primary water source for Family #1 supplied from Springbox Spring and filtered), and Cave Spring 004 (primary water source for Family #2). Regular sampling includes collection of water samples for the measurement of anions (to measure nitrate NO_3^-), cations (to measure ammonia NH_4^+), turbidity (by colorimeter), total coliform, and *E. coli* at all locations and the measurement of pH, specific conductivity, and temperature at each site except for Home Faucet 003. In addition, temperature, depth, pH, and conductivity are continuously recorded with a YSI data sonde every fifteen minutes at Springhouse Spring 001.

Preliminary results of the analytical component of the project indicate that while Cave Spring 004 is a highly contaminated drinking water source utilized by Family #2, the filtration system utilized by Family #1 is generally effective at disinfecting faucet water (Home Faucet 003) derived from Springbox Spring 001. Total coliform and *E. coli* measurements have indicated concentrations consistently above EPA primary drinking water standard maximum contaminant levels (MCLs) at all sites except at Home Faucet 003, which demonstrated <1 most probable units per 100 mL (MPN) of total coliform except in the months of May (5.2 MPN total coliform) and August (133.3 MPN total coliform). Family #1 was notified at each of these findings. All Home Faucet 003 samples collected to date show a concentration of <1 MPN of *E. coli*. At all sites, pH and total dissolved solids (measured in terms of conductivity) have been below EPA secondary drinking water standard MCLs and turbidity measurements have varied from <5 FAU to a maximum of 12 FAU. EPA primary drinking water standards dictate that drinking water should be characterized by a turbidity of no higher than 5 NTU (where one NTU is roughly equivalent to one FAU when measuring formazin). Ion data processing is ongoing.

Preliminary results of the community outreach portion of the project have resulted in benefits to both families. After discussing the contaminated nature of Cave Stream 004 with Family #2, the family discontinued the use of Cave Spring 004 as their primary drinking water source and is drinking bottled water until they complete the installation of a reverse osmosis filtration system. Preliminary results have also been shared with Family #1 whose confidence is restored in their home water purification system. Efforts are ongoing to raise awareness of drinking water safety in the neighboring Mennonite and Quaker communities and it is hoped that through the continuation of this project other community members may be reached or will reach out to the principal investigators with water quality inquiries.

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Benefits of Energy Savings Performance Contracting for Water and Wastewater Treatment Facilities

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Communities across the Commonwealth are taking advantage of the state statute **KRS 45A.352 Guaranteed energy savings contracts involving local public agencies.** This statute allows for the upgrading and updating of publicly owned buildings and facilities with new energy efficient materials and equipment. Municipal water and wastewater plants are benefitting economic benefits through reduced energy and maintenance costs and increased income.

The Kentucky Energy and Environment Cabinet, the Kentucky Department for Local Government and the University of KY's Center for Applied Energy Research (CAER) have developed the Local Government Energy Retrofit Program (LGERP) to assist local agencies to work with Energy Services Companies (ESCo) in negotiating, developing and contracting an Energy Savings Performance Contract (ESPC). Under an ESPC, savings achieved in energy or operational costs and capital avoidance costs not to exceed 50% of total project costs, are guaranteed to pay for the project including debt service. Failure to achieve agreed upon savings requires the ESCo to make up the financial difference between actual costs versus the guaranteed savings.

It is generally acknowledged that water and wastewater facilities consume up to 35% of a municipality's energy budget. It is also acknowledged ESPCs achieve 15%- 25% savings. Savings are achieved through replacing existing equipment that is at or beyond its useful life with new energy efficient products. This can include plant equipment, pump and lift stations as well as meters.

Under LGERP, CAER staff works with communities to develop a Request for Proposal, accumulate 2 years of recent energy bills, and participate in mandatory pre-bid meetings and walkthroughs. Assistance in evaluating proposal submissions, ESCo selection and contract negotiation is also provided. This is provided at no cost to the local agency.

Successful projects to date include: Williamsburg, Greensburg, Greenville (underway), and Louisa. CAER is currently working with three municipalities in anticipation of RFP issuance and potential ESPC. A review of current projects and status updates of the anticipated projects as well as detailed explanations of the process will be provided.

Self-Cleaning Nanocomposite Membranes with Phosphorene-Based Pore Fillers for Water Treatment

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Phosphorene is a two-dimensional material exfoliated from bulk phosphorus and it possesses a band gap. Specifically, relevant to the field of membrane science, the band gap of phosphorene provides it with potential photocatalytic properties, which could be explored in making reactive membranes that can self-clean. The goal of this study was to develop an innovative and robust membrane that is able to control and reverse fouling with minimal changes in membrane performance. To this end, for the first time, membranes have been embedded with phosphorene. Membrane modification was verified by the presence of phosphorus on membranes, along with changes in surface charge, average pore size, and hydrophobicity. After modification, phosphorene-modified membranes were used to filter methylene blue (MB) under intermittent ultraviolet light irradiation. Phosphorene-modified and unmodified membranes displayed similar rejection of MB; however, after reverse-flow filtration was performed to mimic pure water cleaning, the average recovered flux of phosphorene-modified membranes was four times higher than that of unmodified membranes. Furthermore, coverage of MB on phosphorene membranes after reverse-flow filtration was four times lower than that of unmodified membranes, which supports the hypothesis that phosphorene membranes operated under intermittent ultraviolet irradiation can become self-cleaning.

SESSION 3B: POLLUTANT REMOVAL

Investigation of PlarClean and Gamma-Valerolactone as Solvents for Polysulfone Membrane Fabrication

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Petroleum-derived solvents used for membrane fabrication through the nonsolvent induced phase separation (NIPS) process are known for their toxicity. Therefore, bio-derived and low-toxicity solvents are starting to be investigated. Examples of bio-derived, low-toxicity solvents include methyl-5- (dimethylamino)-2-methyl-5-oxopentanoate (PolarClean) and gamma-valerolactone (GVL). PolarClean has been previously used to fabricate polysulfone (PSf) membranes with mixed results, such as having similar flux and rejection as traditional membranes, but having membrane pores collapse during membrane cleaning. To address this issue, GVL was investigated as a sole solvent and a co-solvent with PolarClean to fabricate PSf membranes. Membranes prepared using GVL as a sole solvent were observed to be gelatinous, hence not ideal for filtration. On the other hand, when GVL and PolarClean were used as co-solvents, viable membranes were cast with surface charge and hydrophicility not being significantly different from membranes made using PolarClean alone. Furthermore, the average pore size of membranes decreased as the weight percent of GVL in dope solutions increased. Therefore, the use of PolarClean/GVL as co-solvents shows promise for the fabrication of PSf membranes.

Selenium Removal Using Bacteria Entrapped Alginate Gel Beads in a Packed-Bed Reactor

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Selenium has become one of the concerning pollutant in recent years. Its concentration was regulated as 3.1 μg/L in lotic fresh water and 2 μg/L for lentic fresh water by EPA. Selenium has four different oxidation states including Se(VI), Se(IV), Se(0) and Se(-II) with two dominant soluble species in water including Se(VI) and selenite. Anthropogenic activities including glass and pigments manufacturing, fossil fuel combustion, irrigation, mining and metal refining are responsible for most of selenium release into environment. Although selenium is an essential micronutrient, its toxicity may occur at supra-nutritional dosage with symptoms of nausea, vomiting, nail discoloration, brittleness, hair loss, fatigue and irritability. Selenium toxicity on aquatic lives was also reported and can cause reproductive failure, mortality as well as deformities. Traditional treatment technologies of selenium include ion exchange, reverse osmosis, zero-valent ion, adsorption and microbial reduction with few effective in both Se(VI) and Se(IV) removal. Biological selenium reduction provides an alternative in selenium removal. However, as an anaerobic process, active cell loss is significant without immobilization.

In this study, cells of a Se(VI)-reducing strain *Shigella fergusonii* were immobilized in alginate gel beads and packed in continuous-flow reactor. Se(VI) was fed at 10, 50, 200 and 400 mg/L, respectively, with a total duration of 96 days. An HRT of 5.5 days was performed. The results show that the steady states were achieved at all feeding concentrations. 95% Se(VI) was removal with Se(VI) fed at 400 mg/L from the reactor with little Se(IV) detected, indicating the process was both effective in Se(VI) and Se(IV) removal. The results also show that more than 70% of Se(VI) was removed in the reactor under a height of 5.2 cm.

Nanotechnology and Membranes: Water detoxification from Lab Scale to Real Site Applications

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The detoxification of toxic chlorinated organics (trichloroethylene, polychlorinated biphenyls) in groundwater has been widely studied using zero-valent iron (ZVI) and ZVI based bimetallic nanoparticles. To apply the nano-scale particles in field treatment, the functionalized poly(methacrylic acid) membrane platform was used to immobilize nanoparticles and prevent aggregation and leaching of metal particles. The membrane system showed great performance on the treatment of lab synergic polychlorinated biphenyls and field water samples (from a Superfund site, which includes trichloroethylene, tetrachloroethylene, chloroform and carbon tetrachloride). At 2.2 seconds of residence time, nearly 80% of target chlorinated organic species (in ppm level) in the field samples were dechlorinated.

Advanced characterization methods, such as FIB, TEM and XPS, were applied to study the correlation between nanoparticle properties and depth inside membrane pores, leading to the optimization of membrane design and treatment performance. Particles size (17.1 ± 4.9 nm) and density were observed as a uniform distribution inside the membrane matrix.

In addition, fundamental studies on water conditions, such as pH, temperature and hardness, as well as bimetallic particle aspects were made to optimize the dechlorination performance and cost of materials. Even though Pd served as a catalyst in the dechlorination, excess Pd could decrease the available Fe surface for water corrosion, which leads to the deficiency of H_2 production and eventually decreases the dechlorination rate. The 0.5 wt% Pd (as Fe) showed both high reactivity and low cost.

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POSTER SESSION 1

1.1 Evaluating Soil Characteristics in Rural and Urban Areas

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The purpose of this study was to evaluate soil characteristics under different management practices in rural and urban soils. Soil samples from rural areas in Kentucky were collected from a woods plot, a no-till plot, and a till plot. Urban samples were taken from an animal shelter, a middle school, and a high school in Memphis, TN. The soil samples from the rural areas were taken from a depth interval of 0-7cm and 7-15cm. Urban samples were taken from the A Horizon. The samples were analyzed for organic carbon, particulate organic matter, macroaggregates, soil pH, macroporosity and soil water holding capacity (SWHC) and soil water content at field capacity (SWFC). The results show that soil management practices affect soil properties, however the magnitude of the affect differs. Urban soils had more variability in macroaggregates, soil organic C, particulate organic C and acidity levels compared to agricultural fields but showed similar variability with rural soil in soil water holding capacity and soil water content at field capacity. The soil pH in both depths for the rural areas were from 4.5 to 5.8. The pH in urban soil ranged from 5.3 to 7.8. Less variability of soil pH values was observed in rural fields. The SOC in the woodlands ranged from 4 to 6%, the till plot varied from 4.5 to 4.6%, the no till ranged from 3 to 3.5%, and the urban areas ranged from 1.9 to 4.7%. The lowest POM-C was in the urban soils (0.9%) and the highest was in the woodlands (5.1%). The SWHC ranged from 55 to 75%, the SWFC varied from 30 to 50%, and the macroporosity (noncapillary pores) ranged from 48 to 69% across rural and urban areas. On average, the macroaggregates in the rural soils was 38% higher than in urban soils. This indicates that agricultural fields had higher aeration compared to urban soils. This study also showed that urban soil surfaces were more sensitive to erosion as indicated by lower percentages of macroaggregates (about 39%).

1.2 Use of eDNA in Detection of Multiple Salamander Species in Eastern Kentucky Streams

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Environmental DNA (eDNA) utilizes DNA released from aquatic organisms into the environment to detect their presence and provides an effective, non-invasive method to determine organism presence or absence in an efficient manner. We developed species specific eDNA primers for southern two-lined (*Eurycea cirrigera*) and northern dusky (*Desmognathus fuscus*) salamanders to detect these species in eastern Kentucky streams. Primers were designed based on cytochrome b sequences amplified from specimens collected from Robinson Forest using published primers. The developed eDNA primers proved specific to the appropriate target species in tissue tests with all sympatric salamander species. Interestingly, species specific primers developed for four toed salamanders (*Hemidactylium scutatum*) collected from central New York State failed to recognize four-toed salamander DNA from eastern KY. DNA has been extracted from field collected water samples from multiple eastern Kentucky streams and analysis of salamander DNA from these samples is ongoing. The data obtained should add to the growing pool of knowledge concerning eDNA monitoring of salamander species as well as providing useful reference data and molecular tools for future monitoring or range delineation studies in the region.

1.3 Evaluation of biomass and filtration method on eDNA detection of fantail darters (*Etheostoma flabellare*)

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Estimating fish abundance/biomass holds great importance for freshwater ecology and fisheries management, but current techniques can be expensive, time-consuming, and potentially harmful to target organisms. Environmental DNA (eDNA) has proven an effective and efficient technique for presence/absence detection of freshwater vertebrates. Additionally, recent studies report correlations between total fish biomass and eDNA levels although widespread application of this technique is limited by the lack of studies examining this relationship in various species and settings. Additionally, filter clogging is a commonly encountered issue in eDNA studies in environments with significant sediment and/or planktonic algae. Frequently a sample must be split into multiple aliquots and filtered separately in order to process the entire sample. The present study examines both the relationship between biomass and eDNA and the effects of single versus multiple filter sampling on eDNA concentrations of fantail darters (*Etheostoma flabellare*) in a laboratory setting. Tank tests were performed in quadruplicate at four environmentally relevant fantail biomass levels. eDNA samples were collected and processed in duplicate (once as a whole through a single filter, once in parts through multiple filters). Species-specific primers and a probe were developed for *E. flabellare* from cytochrome b sequences obtained from locally collected specimens and real-time quantitative PCR was used to analyze eDNA levels at each biomass. These data should be useful in refining the accuracy of eDNA based biomass estimates.

1.4 The Impact of Agricultural Development on Nutrient Contamination Hotspots Within a Small, Intermittent Watershed at EKU's Meadowbrook Farm, Madison County, Kentucky

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Agricultural activities often contaminate watersheds with excess nutrients, leading to poor water quality and eutrophication. Eastern Kentucky University's (EKU) Meadowbrook Farm raises crops and livestock, and both contribute dissolved nutrients within the Muddy Creek watershed. This farm and many others in the watershed are located within small, intermittent subwatersheds with thin, impermeable soils and little riparian cover. As a result, most of these locations tend to have flashy hydrographs and quickly funnel water into larger order streams without many opportunities for nutrient attenuation. These combined factors make intermittent watersheds potential nutrient contamination hotspots that may disproportionately affect larger water bodies. However, the impacts of surface-groundwater interactions on baseflow nutrient behavior in these small intermittent watersheds and potential ramifications for large-scale watershed contamination is not well understood. Hence, we sampled waters during baseflow conditions and measured dissolved major-ion and nutrient concentrations in an agricultural intermittent watershed in Madison County Kentucky to characterize spatial and temporal sources and controls on nutrients and their transport behaviors.

Seventeen sampling sites were established within a representative watershed on Meadowbrook Farm at groundwater-soil-surface water sources and along the main channel to characterize the compositional end-members and resultant mixtures. Electrical conductivity (EC), temperature, and pH were measured with a YSI Pro-DSS probe. Dissolved major ions (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, Cl^{-}, and SO_4^{2-}) were measured with ion chromatography. Nutrients (NO_3^{-}, NH_4^{+}, PO_4^{3-}) were measured with ion chromatography and UV-Vis spectrometry. Principal component analysis was subsequently used to explore the greatest sources of variation between compositional end members and resultant mixtures in the channel, which should reflect natural processes.

Groundwater is Ca^{2+}-Mg^{2+}-NO_3^{-} rich and is sourced from local Devonian Boyle Dolomite bedrock. Surface water composition mirrors groundwater composition except for higher SO_4^{2-} levels. Baseflow NH_4^{+} and PO_4^{3-} in the channel is primarily sourced from agricultural and management infrastructure in the farm's center, along with higher Cl^{-}, SO_4^{2-}, K^{+}, Na^{+}, Ca^{2+}, and Mg^{2+} concentrations than typically observed in local groundwater.

Baseflow chemistry varies both spatially and temporally (Fig. 1). Spatially, channels draining areas with low to medium intensity development introduce high dissolved ion concentrations to the main channel, which are partially diluted downstream before leaving the watershed. Furthermore, concentrations emanating from this complex vary temporally. During activation, this channel and downstream stations exhibit heightened nutrient concentrations, which subsequently decline over the proceeding months until normal conditions are reestablished.

Principal component analysis resulted in twelve principal components (PCs). The first three PCs captured more than 75.4% of the variation present in the dataset. The results from PC1 and PC2 show mixing of the local groundwater-soil-surface waters with contaminated farm complex water.

Surface water, soil water, and groundwater showed similar PC1 results, suggesting that channel water was mainly sourced from the subsurface. Furthermore, contamination from the farm complex exhibits progressively similar PC1 value to groundwater down-channel, reflecting dilution. As contamination abates during the winter, PC's for the farm complex downstream begin to reflect those of local groundwater until renewal of agricultural activity in the spring.

However, water discharging at the watershed outlet still chemically resembles water from the farm complex. This behavior suggests channel water groundwater input does not strongly dilute contamination from developed areas in these small intermittent watersheds. GIS analysis shows that similar intermittent watersheds comprise ~10% of the Muddy Creek watershed. Despite being a minor water flow contributor to higher order streams, the presence of intensive agriculture in these specific regions could have a disproportionate impact on nutrient loading due to the lack of substrate and storage for nutrient attenuation.

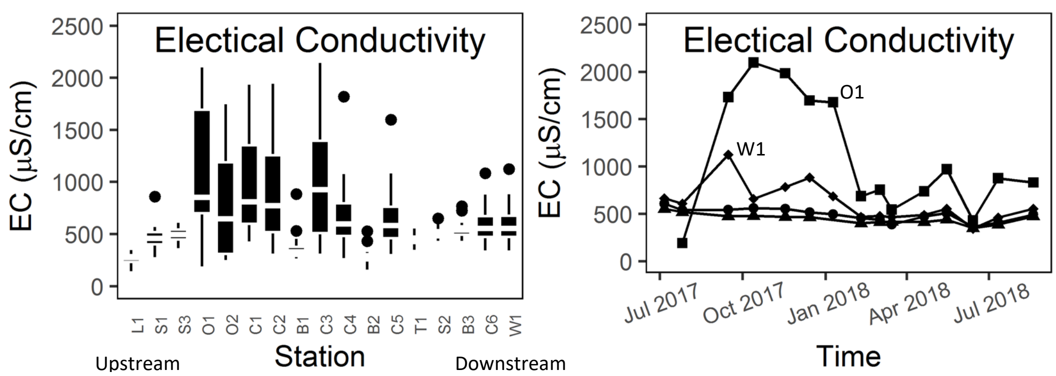

Figure 1. Box and whisker plots of electrical conductivity (left) for the sampling stations in the study area, where sampling stations are ordered downstream from left to right, S1-3 correspond to groundwater springs, and T1 corresponds to a subsurface tile drain. Median values are white. A timeplot from June 2017 to September 2018 of electrical conductivity (right) is presented for stations O1 (circles), W1 (diamonds), S3 (triangles), and T1 (squares).

1.5 How Does Drought Length Impact the Runoff and Nutrient Storm Response in an Agricultural, Intermittent Catchment in Central Kentucky?

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Waterways in Kentucky commonly exhibit high nutrient loads as a result of agricultural practices. Resulting algal blooms and degradation of water quality threatens recreational activities, wildlife, and overall water quality. One way to reduce nutrient loading in large watersheds would be to identify sources that act as hotspots in order to focus remediation efforts. Small, intermittent agricultural catchments in central Kentucky may be one such hotspot due to their geology, hydrograph responses, and proximity to larger order streams. Many such catchments in the region have thin clay soils, which create larger amounts of runoff due to their impermeability.

Due to soil conditions, small size, and a lack of riparian zones, hydrograph responses in intermittent catchments are extremely flashy. As much as 10% of the total watershed area of the Muddy Creek watershed in Madison County, KY, which has high concentrations of nutrients and fecal coliform, is made up of agricultural intermittent catchments that flow directly into the larger order stream with little buffering or intervening stream length. As a result these smaller catchments may disproportionally load higher order streams with contaminants considering there is little chance for attenuation.

In this research it was our goal to characterize the runoff response of an agricultural intermittent catchment given variables such as rainfall intensity, drought length, and evapotranspiration in order to better understand how this type of catchment contributes water and contaminants to larger order streams. The study site was a 0.5 km^2 intermittent watershed that feeds into Muddy Creek near Waco, KY. Flow measurements were taken at 10-minute intervals from a V-notch weir constructed at the catchment outlet. Runoff volumes were calculated from hydrographs generated at the weir in 2017-2018. Daily and 5-minute resolution precipitation data as well as drought length were collected from a Kentucky Mesonet weather station in the study watershed. Potential evapotranspiration calculated with the Penman-Monteith method was collected for the area from the Global Daily Potential Evapotranspiration (GDPE) dataset made available by the United States Geological Survey. A water budget was calculated for 42 individual storm events for the summer and fall months of 2017 and 2018. The relationship between drought length, runoff volume, evapotranspiration, and rainfall intensity was explored by plotting rating curves for each parameter. We also compared storm hydrographs with peak orthophosphate concentration for seven storm events. Results indicated that runoff volume, rainfall intensity, and peak phosphorus were positively related, but drought length greatly changed the watershed hydrograph and nutrient response. Storm responses to most precipitation events lasted less than 48 hours and peak orthophosphate concentrations ranged between 1 mg/L and 6 mg/L. The comparison of runoff volumes for individual storms showed that droughts lasting longer than four days had significantly reduced runoff responses (Figure 1). While total runoff volumes are small compared to the flow of Muddy Creek (a fourth order stream), rainstorms totaling more than 2 cm of rain (~50% of the 42 storms measured in this study) with less than four days of drought produced the highest phosphorous concentrations. On the other hand, droughts lasting greater than four days with similar amounts of precipitation showed a 75% reduction in runoff volume and the lowest phosphorous levels. Droughts lasting up to 20 days reduced runoff to below 1% of the water budget. We conclude that agricultural intermittent catchments could be considered hotspots for phosphorus due to the high concentrations observed during common storm intensities and the short time frame in which storm responses took place. Considering that ~10% of the Muddy Creek watershed is covered by similar catchments, the cumulative impact of agricultural intermittent streams could be larger than expected.

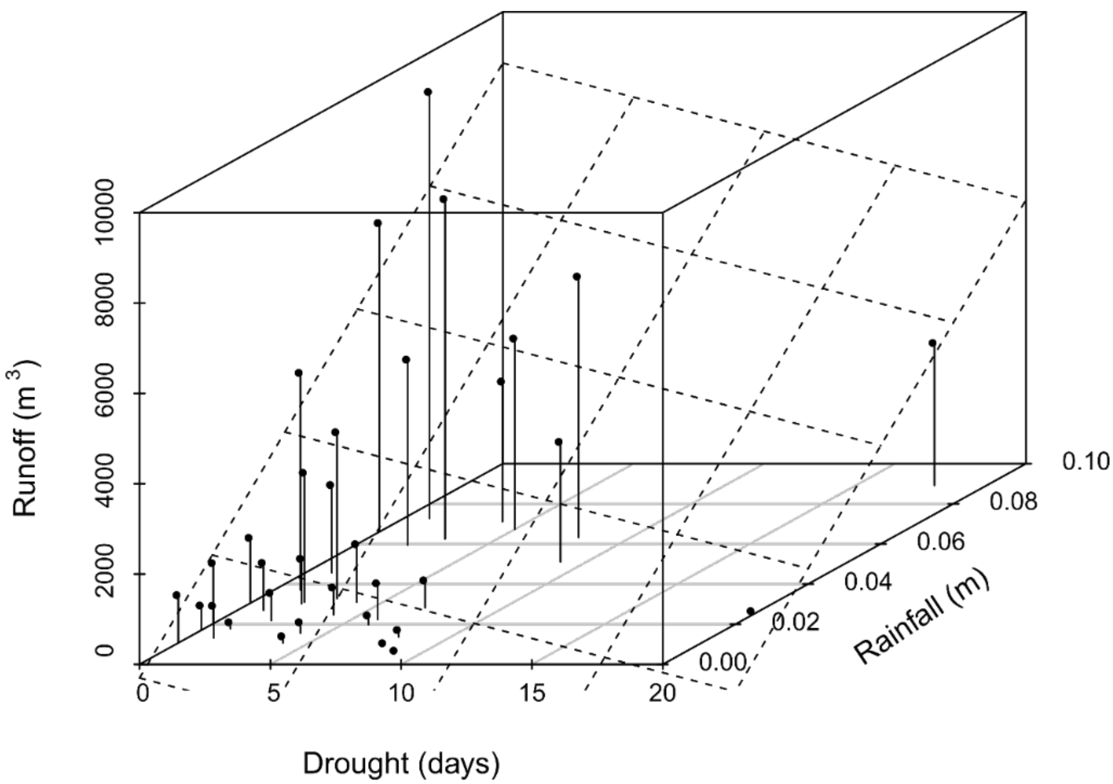

Figure 1: Three-dimensional plot comparing the runoff volumes for individual storm events that occurred after varying periods of drought. Vertical lines connected to data points help to show depth and value of each observation. A plane of best fit is plotted through the points.

1.6 Analyzing Sanitary Sewer Overflow Sensitivity to Storm Characteristics

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Uncontrolled releases of untreated stormwater as sanitary sewer overflows (SSOs) are a serious issue facing many communities across Kentucky. Such events typically occur during and after high-intensity storm activity, classified as wet-weather overflow events. Rainfall dependent inflow into sanitary sewer systems can exceed the hydraulic capacity of the wastewater collection system in one or more locations. These wet-weather flow events temporarily increase the normal dry-weather baseflow of the sanitary sewer system, which accounts for the sewer capacity under normal dry-weather conditions. Despite the frequent occurrence of SSOs across the Louisville Metro area, there is limited existing documented research into quantifying these events. This research analyzed the hydraulic behavior of a single known multiple SSO sewershed in response to a series of recorded storm events between 2015-2017. Relationships were explored between maximum and mean rainfall intensity, total depth and duration and storm frequency to determine minimum storm thresholds for SSO events to occur. The specific timing of SSO initiation events were also examined to assess the SSO sensitivity to expected diurnal dry-weather capacity changes within the sewershed. Initial results identified that a total storm depth of 1.48" at a maximum intensity of 1.2"/hour would trigger an overflow, although the timing of the storms could modify this based on the dry-weather capacity of the system to reduce the total depth necessary to 0.83". Research that documents the causes of, and quantifies, SSO releases would help establish a possible framework for assessing and mitigating the impacts of SSOs and further raise public awareness of this source of pollution in the future.

1.7 Evaluating Soil Properties in No-Till and Conventional Tillage Systems

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Monitoring the changes of soil properties following tillage systems is a key to sustainable agriculture. This study was conducted to observe the changes of soil properties regarding to common tillage systems in Kentucky. Undisturbed and disturbed soil samples were collected from Butler County, western KY at the depth of 0-7.5 cm and 7.5-15 cm from areas which have been tilled through traditional methods (plowed, disked, and rotary tilled). In addition, the same soil samples were taken from a no till hay field, woodland and pasture land for comparison. Soil compaction level as indicated by penetration resistances was determined *in situ*. The samples were analyzed for soil water retention, soil organic matter, the level of acidity, bulk density, and porosity. The data shows that soil porosity is higher in conventional tillage soils (63%) than other non-intensively tilled soils (50%). Bulk density is lower in soils under traditional tillage systems (0.98 g/cm^3) than soils under other practices (1.35g/cm^3). Soil carbon content was higher in traditional tillage systems (6.7%) than in no-till soils (3.4%). Undisturbed soils (no-tilled soil, woodlands, pasture) had consistently higher water holding capacities (77%) than conventional tillage soils (64%). Soil water content at field capacity under conventional tillage management systems were 34%, while soils under other management systems were 57%. Soil pH in woodland and agricultural fields was 6.9 and 7.3, respectively. No acidity was found in all fields. Soil compaction was shown more in no-till soils than conventional tillage systems.

1.8 Assessment of the Impact of Forest Degradation Caused by Human Activities in Lake Omo

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Harmful algal blooms in drinking water sources is a major environmental problem in many developing countries within the tropics and the entire world in general. It has been hypothesized that human activities largely contribute to the rapid growth of algae. The Omo- Shasha- Oluwa forests is one of the most densely populated areas in Africa, and already shows high levels of human activity which includes intensified land-use, sewage discharge, and highly mechanized agricultural farming. It has a lake which serves as a drinking water source to over three million people. Recently the water from the lake tested positive for microcystin leucine argine, a common algal toxin. The study intends to investigate changes in forest integrity due to anthropogenic activities by assessing flora biodiversity in study area and determining the trend of degradation using time series mapping. Stratified random sampling technique will be used to select sampling plots. 0.5 km by 0.5 km grid will be overlaid on the land use land cover map and 5 representative plots each for the vegetated land use classes will be selected. Garmin 78 hand held GPS with an accuracy of 3 meters will be used to locate the center of the selected plots. The concentric plot assessment system will be used to select sub plots. Each modified plot is a cluster of four circular 17.95 m radius annular plots with one central 0.1 ha annular plot, three satellite 0.1 ha annular plots, four 7.32m subplots, and one 2.77 m radius micro plot. Each modified plot also contains three 17.95m long transects from the cluster center, with the first transect positioned at a random azimuth and the others at 60° and 120° from the first transect. Complete vegetation assessment will be carried within the sampled plots during field survey. Maximum likelihood algorithm will be used for the supervised classification after which validation and accuracy assessment will be conducted. Land change detection will be carried out using suitable GIS software. The data collected in situ from the field will be subjected to appropriate statistical analysis to determine the impact of degradation of the tropical forest on the lake. The result will provide invaluable information on the current land use dynamics in the forest reserves of Southwestern Nigeria.

1.9 Soil Responses to Tillage Practices and Cover Crops

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Management practices in cultivated cropland generally affect soil quality, thus eventually influences the crop yield. For sustainability, it is important to improve soils and reduce erosion by using cover crops in the off season with normal crop rotational practices. The objective of this study was to evaluate the changes in soil properties due to tillage systems and the use of cover crops in western Kentucky. Soil samples from no tillage (NT) and conventional tillage (CT) plots were collected from the depth of 10 cm and 20 cm in Calloway County in September 2018. The cover crops being assessed include wheat, cereal rye, oats and radish and a control with no cover crop. The samples were analyzed for soil organic C (SOC), soil water content, particular organic matter-C (POM-C), soil pH and macroaggregates. Soil organic C in the NT systems ranged from 2.4-2.9% while the CT systems ranged from 1.8-2.8%. The macroaggregates varied largely with the CT system with no cover crop containing the most in both depths. The ratio of macro-to-microaggregates in both tillage systems was fairly equal with exceptions to NT cereal rye and CT with no cover crop. CT with no cover crop appears to have the highest ratio of Ma/Mi. The ratio of POM C to SOC remained mostly equal and steady across all samples, averaging 35% for all. The highest POM C was found in CT systems at average of 0.96% and the lowest was observed in cereal rye NT systems at both depth intervals with 0.64%. The soil pH ranged from 5.8-7.4 for the NT systems and 6.8-7.4 for the CT systems. NT systems with cereal rye had the lowest soil pH of 5.8 at depth 10-20 cm. There is no significant impact of tillage systems and cover crops on soil water content at air dry soils. The results of this study would be beneficial to predict the combination effects of tillage and cover crops on soil quality.

1.10 Chlorophyll a and Primary Productivity Dynamics in Kentucky Lake

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Chlorophyll *a* (chl *a*) can be used as proxy for phytoplankton biomass, while primary production (PP), the rate at which carbon is fixed into phytoplankton cells, is an indicator of how quickly carbon is turned over within the phytoplankton community. The two metrics often are highly correlated in lake ecosystems. The purpose of this research was two-fold. We wanted 1) to examine the spatial distribution of chl *a* annually and seasonally in Kentucky Lake, and 2) to examine the relationship between chl *a* and PP in two embayments of contrasting land use. Chl *a* data were available from the Kentucky Lake Long-term Monitoring Program. Fourteen sites on Kentucky Lake have been monitored every 16 days annually for the past 30 years. We used data from 2009-2018. Both PP and chl *a* data were available for two embayment sites over the same time period. The Panther Creek watershed (Land-Between-the-Lakes Recreation Area) is forested, while the Ledbetter Creek watershed is rural/agricultural. Stream chemistry and discharge data from the two watersheds also were examined to characterize the stream sources discharging into each embayment.

For the spatial chl *a* study, strong seasonal hotspots appeared mostly during the summer on both sides of the lake, but also high concentrations occurred during spring and fall on the west side (Fig. 1). This information led to the development of the second part of the project and focused on examination of chl *a* and PP seasonal relationships in two embayments of roughly the same area in but contrasting land-use. Based on historical data, nitrogen inputs are higher from Ledbetter Creek than Panther Creek, while phosphorus inputs are higher from Panther Creek than Ledbetter Creek. N:P ratios average 12/1 and 7/1 in Ledbetter and Panther embayments, respectively, with even higher ratios in the streams discharging into each embayment (e.g. N:P = 39/1 and 7/1, for Ledbetter and Panther Creeks, respectively).

Overall, the 10-year annual chl *a* and PP were often highly correlated; $r = 0.45$ in Ledbetter and $r = 0.55$ in Panther. Seasonally, highest correlations occurred during winter ($r = 0.55$-0.85) and spring ($r = 0.55$-0.85) and lowest ($r = 0.10$-0.25) during summer at both embayments. We conclude that the highest chl *a*-PP correlations occur during times of the year when standing stock of chl *a* is lowest (winter and spring). We also conclude that during times of high chl *a* standing stock (summer and fall), the chl *a*-PP relationship is disrupted or decoupled by lower nutrient inputs later in the growing season. Therefore, the hypothesis that chl *a* and PP are positively correlated in general, 1) is confounded by strong seasonal environmental effects such as nutrient inputs, light, and temperature that may disrupt the relationship and, 2) predicting PP from chl *a* concentrations might not be possible year-round nor should the relationship be used to predict areas of vulnerability for future algal blooms, hypoxia, and habitat degradation without considering seasonal changes in nutrient inputs, light, and temperature.

Our study was developed by M. Franklin while attending an REU workshop at U-K, Lexington, KY, and HBS in 2018 and funded by NSF-EPSCoR Track 2 #OIA-1632888.

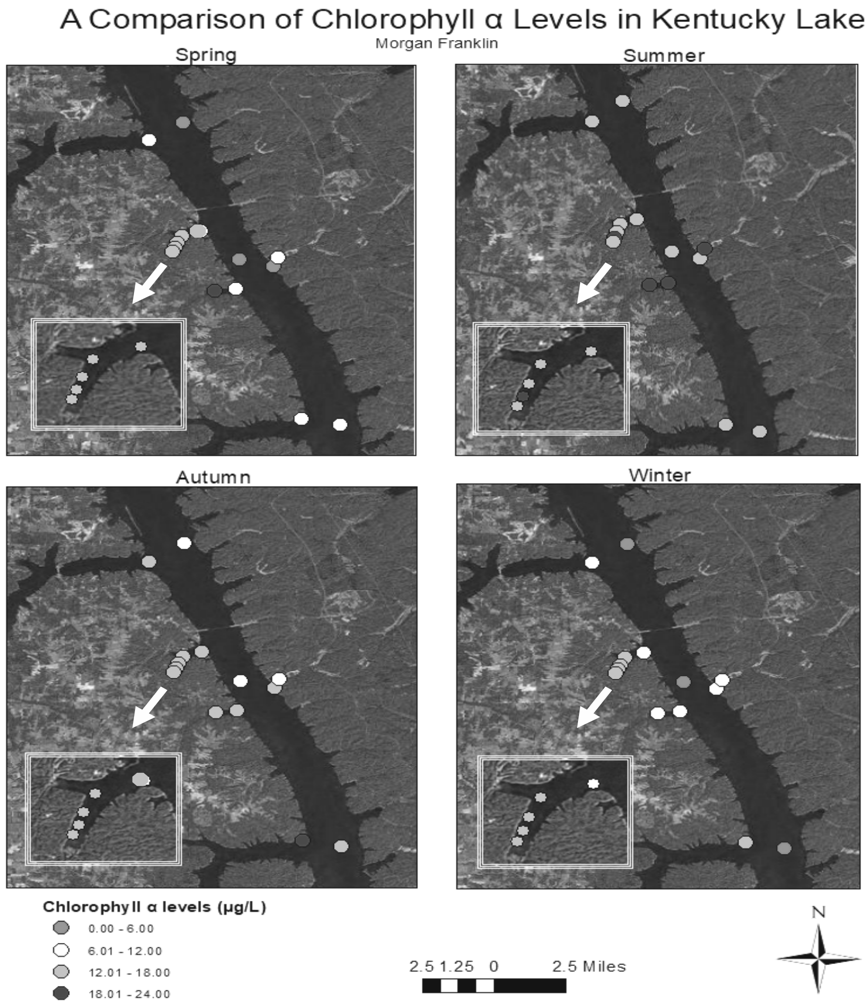

Figure 1. Location of monitoring stations on Kentucky Lake. Inset is blowup of Ledbetter embayments sites. Panther embayment is not shown.

1.11 Kentucky Backyard Streams Program

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Many homeowners are not sure what to do about the stream in their backyard. Some see it as an asset while others are confused about who owns it and how it should be managed. Uncertainty about stream maintenance plus a partnership between a local watershed organization and the University of Kentucky Cooperative Extension Service led to the development of the Backyard Streams program. Extension specialists facilitated multiple classroom and field workshops centered around urban watershed issues and streamside buffers at the request of Friends of Wolf Run. These workshops, which were audience-focused for stream stewards in Wolf Run Watershed, led to the development of a 12-module online course. The course is hosted through an online learning management system and is now available to anyone interested in learning about watersheds, stream health and stream function, and streamside buffers. Completion of all course modules results in becoming a certified backyard stream steward. Fifty-four individuals have registered for the course and thirteen have become certificated backyard stream stewards since the launching of the course in August 2018. The Backyard Streams program provides a central location (https://www.uky.edu/bae/backyardstreams) for dozens of extension publications and videos highlighting backyard stream steward successes. The program is designed to help homeowners appreciate this resource, protect personal property, and improve water quality and habitat. The partnership between the University of Kentucky and Friends of Wolf Run will continue in the next several years with the offering of additional classroom and field-based workshops and buffer installations. Funding for this project was provided in part by Lexington-Fayette Urban County Government's Stormwater Quality Projects Incentive Grant Program.

1.12 E. coli in Urban Streams

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Escherichia coli (*E. coli)* is a bacterium found in the lower intestines of warm blooded animals. The presence of *E. coli* in streams can indicate that feces from humans or other warm-blooded animals are present and cause water to become cloudy with an unpleasant odor. High concentrations of *E. coli* are a health concern because of the risk of the presence of pathogenic bacteria and viruses. The US Environmental Protection Agency sets a maximum safe limit of 151 colony forming units (cfu) for recreational water usage but concentrations of *E. coli* can change rapidly with environmental conditions facilitating the need for frequent monitoring to protect human health. We sought to investigate trends in *E. coli* concentrations in Wheeling Creek, WV (a tributary to the Ohio River) and the Ohio River because they are being increasingly utilized for recreational activities. However, old wastewater infrastructures frequently discharge untreated sewage into these waterways, raising health concerns about contact with the stream water. We collected water samples weekly at two sites on the Ohio River, five sites on Wheeling Creek, and three sites on tributaries of Wheeling Creek between September 27, 2018 and December 27, 2018. In total, we collected 128 samples that were analyzed for *E coli* using the IDEXX Colilert System. We have found that the concentrations ranged from 25 to 2,400 colonies of *E. coli,* and only 24 readings (18.8%) were below the EPA safe standard for recreational usage with the highest readings occurring at sites along Wheeling Creek. The Ohio River and tributaries of Wheeling Creek tended to have lower concentrations of *E. coli* than Wheeling Creek itself. As the temperature took a decline in the month of December the amount of *E. coli* concentrations had decreased moving into or closer to safe amounts.

1.13 Assessment of Microbial Respiration and Carbon Loss Rates in the Upper Ohio River and Selected Tributaries in the Northern Panhandle of West Virginia

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Stream microorganisms can drive ecosystem processes, such as carbon cycling; however, changes in water chemistry can slow down or speed up the rate that carbon moves through the ecosystem. When microorganisms respire, inorganic carbon is released back into the system. In this study, we investigated the influence of water chemistry on microbial respiration and the breakdown of organic matter using two types of standardized substrates: labile cellulose sponge and recalcitrant red oak wood veneer. The rate of breakdown of these substrates correlated positively with increasing microbial respiration rates. Water chemistry data was used to assess for correlation with the microbial respiration rates. Specific conductance (SPC) was found to be a significant predictor model of microbial respiration rates; as SPC increased, microbial respiration rates increased. These correlations could provide us with new ways to predict the effects of stressors on multiple aspects of aquatic ecosystems, such as carbon cycling.

1.14 Fabrication of a Novel Reactive Membrane for Water Treatment

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Nanomaterials are typically used in the field of membrane technology to impart a desired characteristic on the membrane so as to enhance selectivity of the membrane and increase the life span of the membrane. Fouling, or the accumulation of rejected materials on the surface of membranes, is a menace that plagues separation processes. Photocatalytic membrane processes generate oxygen-reactive radicals under irradiation by light that could degrade pollutants in feed solutions and reduce fouling. Phosphorene is a recently discovered two-dimensional material that shows great promise as a photocatalyst because it can generate reactive oxygen species (singlet oxygen, hydroxyl radicals and superoxide radicals). The goal of this study is to incorporate phosphorene into membranes made from a polymer blend of sulfonated poly ether ether ketone and polysulfone, then test these membranes in different media to examine their stability in various environment and study the method of adhesion of the nanomaterial in the membrane. In this research, phosphorene was first fabricated by the liquid exfoliation of black phosphorus. Experiments were done in an acidic, basic, neutral and in a common solvent media. Various membranes that composed of different wt.% of phosphorene were casted and the rate of leaching of the phosphorene nanoparticle was studied.

1.15 Temperature Responsive Membranes and Perfluorochemical Adsorption

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This research is aimed at evaluating the effect of temperature on the removal of perfluorochemicals in water filtration. Polyvinylidene difluoride (PVDF) microfiltration membranes are functionalized with poly-N-isopropylacrylamide (PNIPAAm), and its temperature responsive behavior is studied as it relates to water flux and adsorption/desorption of perfluorochemicals. PNIPAAm has a relatively low Lower Critical Solution Temperature (LCST) of around 32°C, which makes it appealing for industrial use. PNIPAAm has a sharp transition from hydrophilic behavior below its LCST to hydrophobic behavior above its LCST, thus, when the PNIPAAm is exhibiting hydrophobic behavior, it retracts/collapses upon itself in an aqueous environment. In doing so, the hydrophobic propyl group of PNIPAAm is exposed, which makes the hydrophobic parts of perfluorochemicals more likely to interact with PNIPAAm and is what makes PNIPAAm attractive for perfluorochemical adsorption uses. Reversely, bringing the temperature down past the LCST will allow the perfluorochemicals to desorb out of the membrane. Specifically, this study's goal is to evaluate the feasibility of temperature swing adsorption/desorption of Perfluorooctanoic acid (PFOA) and Perfluorooctanesulfonic acid (PFOS) in water filtration. The time of water flux to normalize through a PNIPAAm functionalized membrane at room (roughly 23°C) and above-LCST temperature was also studied. This research is supported by the NIEHSSRP grant P42ES007380, and by the NSF KY EPSCOR program. Full-scale PVDF membranes were developed through collaborative work with Nanostone-Sepro (Oceanside, CA, USA).

1.16 What are the LiDAR-Revealed Depressions in Alluvium Along Majors Rivers in Kentucky?

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LiDAR (light detection and ranging) is a remote-sensing technology that can be used to map topography at high resolution. The entire state of Kentucky now has LiDAR coverage thanks to the Kentucky Aerial Photography and Elevation Data Program.

Because karst sinkholes are easily identifiable as closed (inward sloping) topographic depressions, they can be detected very clearly in the LiDAR data. The process KGS developed to map sinkholes using LiDAR data improves upon previous sinkhole mapping efforts in Kentucky and is especially beneficial for identifying previously unmapped smaller (down to 500 ft^2) sinkholes and similar karst or pseudokarst features. One such example is small sinkhole-like depressions occurring in the alluvium along some major rivers and streams in Kentucky. Averaging about 5 to 10 ft deep, these depressions tend to form linear bands in alluvial floodplains, near the intersections of adjacent bedrock hillslopes (Fig. 1). We have found these distinctive features along the Green, Salt, Kentucky, and Licking Rivers. Additional data other than LiDAR will be needed to understand how these depressions are formed and what roles they play in the dynamic water cycles involving rivers and karst terrains.

Figure 2. A hillshade of a section of the Kentucky River derived from LiDAR data. The depressions near the river (outlined solid black) are a typical example of the unusual depressions found in the alluvium of some of the major rivers in Kentucky. The depressions on top of the hill (outlined in dashed black lines) are sinkholes.

1.17 Nutrient Export and Remediation at Meadowbrook Farm, Madison County, Kentucky: Steps Toward Improving Local and Regional Water Quality

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Excess nutrient levels in water continues to be one of the leading causes of water degradation in the United States today. In Kentucky, excess nutrients are often sourced from agricultural practices in the form of non-point-source contamination as dissolved and solid forms of nitrogen and phosphorus. Although nutrients are a necessity for healthy and sustainable ecosystems, excess nutrients can lead to eutrophication that results in a decrease in aquatic oxygen levels, occurrence of toxic algae, and significant loss of biodiversity. Limiting entry of nutrients into proximal waterways can improve water quality locally, but should also remedy eutrophication at all scales.

EKU's Meadowbrook Farm, located within the Muddy Creek watershed of Madison County, Kentucky is a typical farm raising crops and stock. A small watershed (~0.46 km^2, 113 ac) draining the Farm contains cropland, pasture, and a portion of a dairy complex and is thus representative of Farm activities as a whole. We have constructed an instrumented weir where the intermittent stream of this small catchment flows into Muddy Creek, a tributary of the Kentucky River, that allows us to measure discharge and estimate nutrient export.

We sampled water during low water flow conditions and during eight rain events during the field seasons of 2016, 2017, and 2018, measuring nutrient concentrations of dissolved ammonium (NH_4), nitrate (NO_3), phosphate (PO_4), and total phosphorus, ($\sum P$). These data, used in concert with flow measurements, enable us to calculate nutrient export for monitored rain events.

We found that the largest storm event exported 4.1 kg of P-PO_4, 11.3 kg of $\sum P$, 3.3 kg of N-NH_4, and 1.7 kg of N-NO_3 [5.0 kg N]. There seems to be a rough, linear relationship between total storm water volume and P-PO_4, $\sum P$, and N-NO_3 export; the relationship between storm water volume and N-NH_4 displays no recognizable pattern (Figure 1). Quantitative relationships between storm flow volume and nutrient export are significant, in that it allows us to estimate total nutrient export coming off the farm for the entire year to certain degree of accuracy.

The next step in our investigation is to measure nutrient export during the next field season as changes in farming practices occur within the research catchment. Some cropland will be shifted to other uses and major pasture areas will be planted with higher-quality forage. Over time we will also fence-out cattle and add riparian cover to the channel area. We hypothesize that these measures will lead to decreases in nutrient export as compared to pre-remediation estimates.

Ultimately, our goal is to deploy multiple measures to reduce the total nutrient export entering the Muddy Creek watershed, and quantify any changes in nutrient export to identify effective mediation strategies. Our efforts will not only serve to improve the quality of water leaving Meadowbrook Farm and entering Muddy Creek, but, if remediation efforts are successful, our methods can be adopted at other agricultural areas that contribute to nutrient overloads within surface and ground waters.

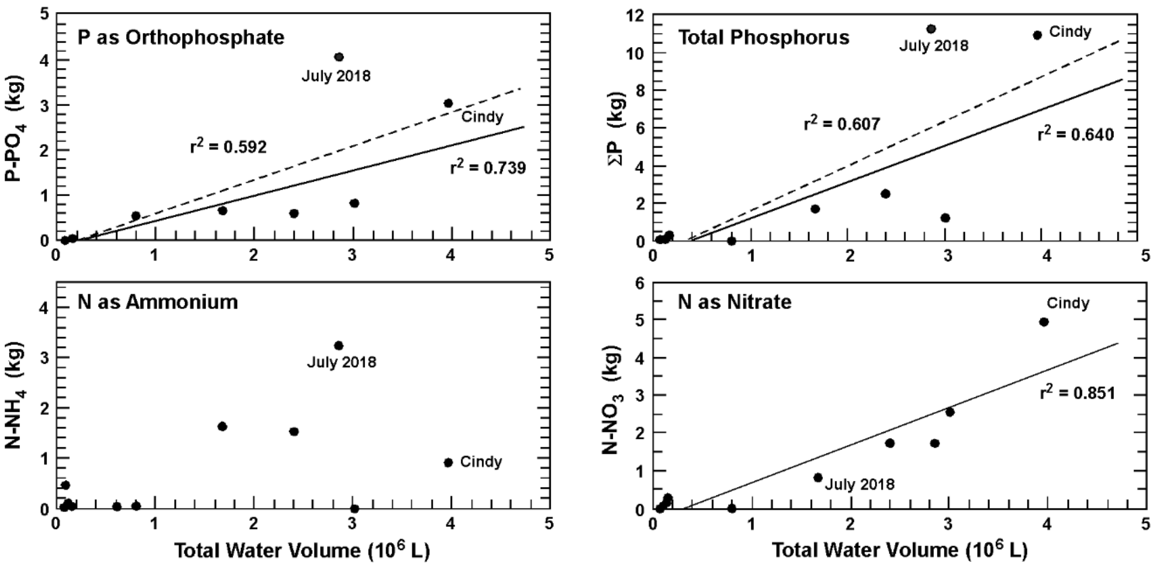

Figure 1**.** Graphs showing relationship between total discharge and total nutrient export for each nutrient species for a given rainfall event occurring in 2017 and 2018. Solid lines within the orthophosphate and total phosphorus panels show best-fit lines that do not include data from the July 2018 rainfall event; dashed lines within the same panels do include those data. Tropical Storm Cindy took place in June 2017. Note that the nitrate panel has the best linear fit for the data, whereas ammonium data display no distinct pattern.

1.18 Functionalization of PVDF Membranes with Thiol Groups for Heavy-Metal Capture

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The presence of heavy-metal ions, such as mercury and silver, in water poses a threat to the wellbeing of humans and nature. Therefore, the development of technology with a high capacity for the capture of heavy-metal ions from water is important. This study involved the incorporation of thiol groups, which are capable of binding to silver and mercury ions, into polyvinylidene-fluoride (PVDF) membranes that had been surface and pore functionalized with polyacrylic acid (PAA) using an in-situ polymerization technique. To incorporate thiol groups, cysteamine was coupled to the carboxylic-acid groups of PAA following the attachment of N-hydroxysuccinimide (NHS) to these groups using EDC/NHS chemistry. The surface hydrophilicity of a commercial, hydrophilized PVDF membrane was lower than that of a PVDF-PAA membrane, but this property remained constant for a PVDF-PAA membrane throughout its functionalization with thiol groups. Additionally, a decrease in the flux and pH-responsive permeability of a PVDF-PAA membrane after the incorporation NHS verified the conversion of carboxylic-acid groups in the pores of this membrane during NHS functionalization. However, with the addition of cysteamine to the PVDF-PAA-NHS membrane, an increase in flux resulted. After thiol functionalization, the resulting membrane captured Ag^+ in a convective-flow mode and an increase in flux occurred during this capture. The capture of Ag^+ by the PVDF-PAA-Cysteamine membrane was indicative of the potential of thiol-functionalized membranes to remove Ag^+ and Hg^{2+} from contaminated water at a high dynamic capacity.

This research was supported by Chevron Corporation, NSF EPSCoR, and NIEHS-SRP.

POSTER SESSION 2

2.1 Climate Change Impacts on Sediment Transport in a Lowland Watershed System: Controlling Processes and Projection

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Climate change proposes pronounced impacts on watershed hydrologic system for most worlds' regions. For some watersheds, depending on their locations under the projected atmospheric circulation change, the impacts are projected to generate noticeable increases in surface runoff and instream flows. Accordingly, sediment redistribution within the watershed and sediment fluxes are more likely to be altered. Yet, there still a lack in the research body on how climate change is modifying and changing the sediment production and redistribution in the watershed. The high number of the available climate scenarios that make building the sediment projection and its associated uncertainty highly expensive complicate the problem. Therefore, the objectives of this study were to develop a unique approach for model selection, examining different bias correction approaches to better correct the mean and the extreme conditions of climate data, and to investigate the upland erosion and in-stream sediment processes under average and extreme conditions to produce changes in sediment redistribution within watersheds.

To do so, the authors include five stages to perform the research methodology. Stage one is the model selection conduction where a subset of climate scenarios from an original set is selected. The subset possesses specific criterions including representativeness, acceptable historical performance, independence, ability to have a sensitive effect on the hydrological variable under consideration, and presence of different climate modeling factors. In stage two we run distribution-mapping method with its two approaches, the parametric and the non-parametric approach, to correct the biases in the subset selected. We selected the best approach that corrects the mean and extreme conditions. Stage three has the Soil and Water Assessment Tool (SWAT) runs to predict hydrologic conditions for the Upper South Elkhorn Watershed in central Kentucky, USA to the year 2050. Both instream flow and surface runoff were extracted from SWAT runs of each climate scenario. In stage four we build an artificial neural network (ANN) to simulate the upland erosion with connectivity processes consideration for each climate scenario. In the final stage, stage five, we used the streamflow, and the surface flow results from SWAT and the sediment fluxes results from the ANN to build and simulate the instream erosion and deposition of sediment processes with the consideration of surface fine grain lamina (SFGL) layer controlling the benthic ecosystem and the equilibrium exchange factor.

Our results show that a subset of 15 climate scenarios can represent the original set of 131 scenarios. The non-parametric approach of distribution mapping was superior in correcting the biases in the climate data. An average change of +8% in precipitation and +2.7 C in temperature will lead to a 17% increase in the mean streamflow and 23% increase in the 100-year return level of streamflow. While our results of sediment redistribution and sediment yield from the watershed still in ongoing processes, the preliminary results suggest the dominance of erosional and depositional redistribution of sediments under different climate scenarios is associated with extreme and mean hydrologic forecasting.

2.2 Assessment of MRSA Presence in Suburban WWTPs Effluent and Receiving Streams in Lexington, Kentucky*

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The key role of engineered systems like wastewater treatment plants (WWTPs) in spreading bacterial contamination and causing water-borne infections highlights the requirement for establishing new standards to check the quality of treated sewage at the discharge point to the environment. Rapid adaptation and evolution of bacteria to environmental pressures introduces new waves of resistant bacteria as environmental not nosocomial sources. *Staphylococcus aureus* (SA) is one of these pathogens with a high potential for adaptation to antimicrobial pressures and evolution to multiple antibiotic resistant species like methicillin resistance SA (MRSA). Thus far, different methods have been developed for rapid identification of hospital acquired MRSA, but limited methods have focused on finding MRSA in environmental samples like water and sediments. In addition, most of the developed genomic methods for environmental samples relied on limited genes to identify MRSA presence (methicillin resistant gene, *mecA*). These studies overestimated the number of MRSA in the environment due to the *mecA* gene being shared with other bacteria.

In our study, a selective enrichment media developed from previous study was applied in an attempt to isolate MRSA from the effluent of West Hickman WWTP, and creek sediment samples downstream after the effluent discharge point of West Hickman WWTP effluent in Lexington, Kentucky. In this modified selective media, acriflavine, nalidixic acid, and polymyxin B were added to mannitol salt broth to suppress different co-growing bacteria like *Staph epidermidis* (SE), gram- negative bacteria and *Proteus mirabilis*, respectively. Potassium tellurite was added to enhance SA respiration. After centrifugation of one liter effluent samples, the pellet was added to this enrichment broth and cultured in an incubator for 48 hours. Then, centrifugation was used again to form a pellet which was spread on acriflavine augmented mannitol salt agar (MSA) to provide isolated colonies of presumptive SA. Adjustment of acriflavine concentrations in the selective enrichment broth was done to enhance recovery of the limited numbers of SA expected to be in the chlorinated effluent, while suppressing the growth of SE, a common co-flora. Thus far, effluent samples have not detected of SA presence in samples from treated effluent, denoting adequate disinfection, even though SA has been regularly detected in the sedimentation plant effluents.

Method development for the extraction of bacteria associated with creek sediments was initiated by reviewing previous research of others, and evaluating different eluents to interfere with the adsorption forces between bacteria, sediment, and biofilms. However, after repeating several tests with various eluents, low recoveries were found utilizing others methods. Therefore, an enrichment broth method was selected to grow SA directly from the sediment particles, with the high salt content reducing the adsorptive forces and encouraging new bacteria to stay in the fluid surrounding the sediment particles.

The same general sample preparation procedure for fluid samples was applied for sediment samples, with equal volumes of sample being mixed with 2X selective broth followed by incubation and recovery of pelleted bacteria from the liquid phase to be spread onto agar plates. Unrestricted growth of non-SA bacteria was observed, thought to be due to the presence of different biofilm-forming bacteria still present in sediment samples after the first selective enrichment. Clearly, the method required more modification to enhance effective suppression of non-SA microbes from the organic laden sediment. In the new method, sediment samples were immersed in enrichment broth, shaken by hand for 5 minutes, allowed one minute settling time, the supernatant removed and centrifuged, with the resulting pellet added to an equal volume of double strength enrichment broth, then incubated for 24 hours. This step was required to reduce the volume of biofilm and other organics that could serve as a carbon source (readily apparent by the growth of fungi and many types of non-SA microbe, requiring cultured organisms to ferment mannitol in the broth as their primary carbon source. After incubation and growth had occurred, centrifugation was used to pellet bacteria and the pellet was spread on augmented MSA to provide isolated colonies.

Preliminary sediment recovery results with the new method showed high concentrations of presumptive SA on acriflavine augmented mannitol salt agar (yellow colonies on yellow plates) which denoted the fermentation of mannitol, decreasing the pH of agar, and changing the color of the agar from pink to yellow. However, these colonies were identified as coagulase-negative staphylococci and not SA in verification by coagulase test. More research needs to be done to modify the method that we had developed for water samples, so that we can assure that SA are not found in the creek sediments, and so we can correctly identify the isolated non-SA colonies that readily grow under the same restrictive conditions as SA. Our results make it even clearer that applying agars and broths developed for clinical samples to environmental samples has great potential for overestimating the true prevalence of SA in our environment.

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2.3 Heavy Metal Capture and Detection Using Colored Synthetic Dithiol

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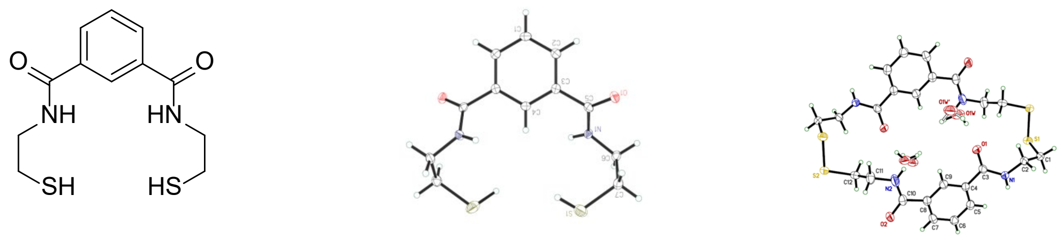
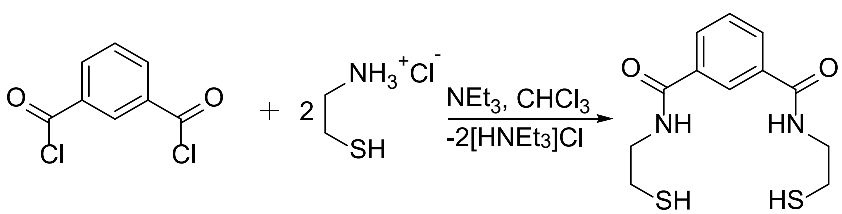
In our group we synthesis a series of synthetic dithiol molecules which can precipitate by forming strong covalent bonds with heavy metals and metalloids as L-M. The parent synthetic dithiol molecule B9= *N,N'*-bis(2-mercaptoethyl)isophthalamide, (figure 1.(a), (b) and (c)) common name "benzenediamidoethanethiol" found to have unique ability, to immobilize heavy metals Cd, Hg, Pb and As from water to below the detection limits of ICP-OES and CVAAS by the formation of strong covalent S-M bonds which are exceedingly stable with metal leaching occurring only at very low and high pH.



a b c

Figure 1. (a) Chemical structure, (b) Crystal structure, (c) Dimeric crystal structure of B9.

The synthesis of B9 is carried out by combining isophthaloyl chloride with two equivalents of cysteamine (to make B9, scheme 1.), cysteine (to make AB9), cysteine methyl ester (to make MB9) and cysteine ethyl ester (to make EB9).



Scheme 1. One-Step Synthesis of $BDTH_2$ from isophthalolyl chloride and cysteamine-HCl

However, the insolubility of the B9-M compounds has precluded structural characterization by single-crystal X-ray crystallography. Thus, a series of new dithiol molecules was synthesized as carboxylic acid derivative of B9; AB9= 2,2'-(isophthaloylbis(azanaediyl))bis-3-mercaptopropanoic acid, the methyl ester MB9= 2,2'-(isophthaloylbis(azanaediyl))bis-methyl 3-mercaptopropanoic acid and EB9= ethyl ester 2,2'-(isophthaloylbis(azanaediyl))bis-ethyl 3-Mercaptopropanoic acid are other synthetic dithiol molecules which are able to form M-L bond.(Figure 2.) expecting similar bonding possibilities as B9, give new functianility through various functional groups, expanding the solubility for X-ray crystallographic analysis. Thus, they maintain the same binding of B9-M as S-M-S with different functional groups attached to the main carbon backbone providing different inductive effects towards the CH_2CH_2SH group.

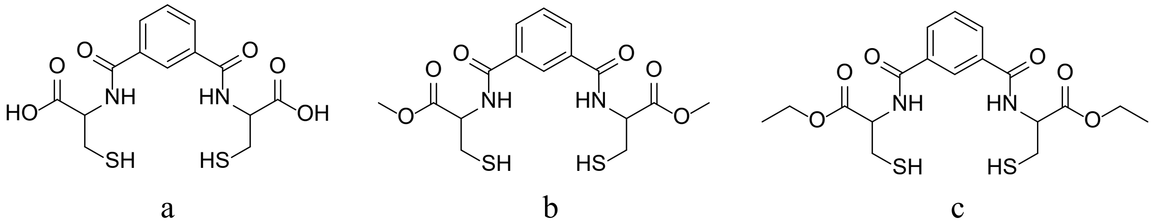


Figure 2. Chemical structures of (a) AB9, (b) MB9, (c) EB9.

These synthesized molecules show several advantages over conventional methods. These include odorless, no toxic byproducts, cost-effective, no excess precipitating agent needed, the heavy metal removal >60 % (under normal/uncontrolled pH and open to air synthesis from a stock solution of each heavy metal). Moreover, the sulfur providing starting material are resistance to get oxidized, which prevents the formation of disulfide bonds, immediate precipitation and resistance to release the bound heavy metal under wide pH range and long time. Thus, these systems are ideal to study the covalent bonding to heavy metals and determine the effects, characteristics, and stability of M-S bonds.

Several modifications to the existing ligands were also made. Thus, a new class of colored compounds using anthraquinone and anthracene achieved by conjugated aromatic system backbone containing pendant thiolate groups. So, colored acid chloride instead of colorless isophthaloyl chloride was used. The interactions between anthracene/anthraquinone units and/or with the metal ions provide quantification via colorimetric methods, efficient identification of wastewaters and natural waters contamination and obtaining a crystal structure for L-M are main objectives.

2.4 Quantifying Nutrient Fate and Transport in Karst Agroecosystems of Central Kentucky: Application of High-Resolution Sensors, Numerical Modeling, and Isotope Tracers

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Pathways and in-stream fate of nutrients in karst agroecosystems remain poorly understood, despite the known impact of karst on water resources at local to global scales. In the Inner-Bluegrass region of central Kentucky, heterogeneity of karst maturity, flow pathways, and nutrient sources adds to the complexity of quantifying nutrient dynamics, thus requiring novel monitoring and modeling approaches. This presentation will focus on our previous and on-going research efforts related to nutrient fate and transport in karst agroecosystems of the Inner-Bluegrass.

Regarding surface stream dynamics, karst streams receive preferential groundwater discharges, such as springs or fissures in bedrock, and are often routed over scoured bedrock channels. The significance of these streams are recognized given spring/surface water confluences have been identified as hotspots for biogeochemical transformations. Current in-stream nutrient models place emphasis on benthic and hyporheic nutrient processing, but often neglect the potential for floating aquatic macrophytes to uptake nutrients and facilitate denitrification. We analyzed a 10-year dataset from an agriculturally impacted, immature karst watershed in Woodford County including biweekly to monthly nitrate (NO_3-), dissolved reactive phosphorus (DRP), total organic carbon (TOC), and total ammoniacal-N (TAN) measurements at nested spring and stream sites, as well as flowrates at the watershed outlet, along the main-stem, and in major tributaries. Preliminary results from multiple linear regression and Empirical Mode Decomposition time-series analysis show significant decreases in NO3- and DRP and increases in TOC and TAN from the spring sites to the watershed outlet. While DRP dynamics were well-described by periphytic algal biomass uptake, NO3 attenuation in the bedrock stream was not well-explained, suggesting a potential sink in the floating aquatic macrophyte pool. We will present a reach-scale modeling framework of nutrient dynamics in bedrock-controlled streams that accounts for coupled interactions between hydrology, hydraulics, and biotic (benthic and floating aquatic macrophytes) dynamics downstream of springs. Further, we will present preliminary results from a high-resolution monitoring effort that was initiated in September 2018 that support inferences of our long-term data and modeling efforts.

Regarding upland nutrient pathway dynamics, our research has focused on dissolved reactive P pathways and loading. Based on our 10-year data analysis, we found the Woodford County watershed contrasted findings from other karst agroecosystems in the literature in that subsurface conduits were not retentive of P and P loadings were an order of magnitude higher than other karst agroecosystems. This result may be attributed to P-saturation of soils and sediments in subsurface pathways that were derived from phosphatic Ordovician Limestone. A new oxygen isotope tracer monitoring study is being conducted in the Cane Run watershed and Royal spring basin (a mature karst watershed in Central Kentucky), in order to test the efficacy of the tracer to differentiate between anthropogenic and ambient P sources during stormflows. Samples will be collected at agricultural and urban tributary sources, as well as the Royal Spring conduit to measure nutrient concentrations, water isotopes, and phosphate oxygen isotope signatures for several events. With isotope signatures characterized, statistical tests will be utilized to determine distinguishability of source signatures. Through improved understanding and modeling of nutrient dynamics in karst agroecosystems, we aim to better inform upland and in-stream management of nutrients with goals of optimizing agricultural production and nutrient retention.

2.5 Magnetic Nanocomposite Materials for the Detection and Removal of Halogenated Organic Pollutants in Contaminated Water Sources

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Decades of use of toxic materials in products that are manufactured and sold commercially have presented a grave concern for worldwide access to clean drinking water. The need for highly efficient water remediation technologies with minimal associated costs are in great demand. In response to this call, our research has focused on developing magnetic nanocomposite platforms that can selectively capture and remove halogenated organic contaminants from aqueous mediums. These sorbents can be modified to possess a variety of moieties that would fine-tune the affinity and selectivity of the nanocomposite towards binding of the desired contaminant. Examples of synthesized nanocomposites include platforms that incorporate polyphenols, offering high affinity for polychlorinated biphenyls (PCBs) and materials that possess cationic and/or fluorinated moieties that are shown to attract perfluoroalkyl substances (PFAS). In one method, a surface initiated polymerization of poly(ethylene glycol)-based and polyphenolic-based crosslinkers on the surface of iron oxide magnetic nanoparticles was utilized to create a core-shell nanocomposite. In another method, a bulk polymerization method was utilized to create macroscale films composed of iron oxide nanoparticles incorporated into polyphenolic-based polymer matrices that were ultimately processed into microparticles. In some platforms, a thermos-responsive monomer, N-isopropylacrylamide (NIPAAm), was employed to develop “smart” materials that can transition from a hydrophilic to hydrophobic state will a small swing in temperature. The produced nanocomposites can specifically bind halogenated organics, rapidly remove bound organics from contaminated water sources via magnetic separation and have interesting options for contaminant release and sorbent regeneration. Extensive characterization of materials was conducted using dynamic light scattering (DLS), Fourier transform infrared spectroscopy (FTIR), transmission electron microscopy (TEM), mechanical testing for strength and compression modulus. Pollutant binding studies were performed using PCB 126, chlorinated organic pollutants, and perfluorooctanoic acid (PFOA) in order to determine binding affinity and capacity. Results were obtained via GC-MS and LC-MSMS and the materials were found to effectively bind PCBs as well as PFOA.

2.6 Measuring and Modeling Morphologic Processes in Karst to Sustain Water Resources in the Future

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Karst is a landscape that is formed by the dissolution of soluble rock producing features such as fissures, sinkholes, and swallets that create a high degree of connectivity between surface water and groundwater. Karst aquifers supply 25% of the freshwater used by humans for drinking worldwide, however the complex underground and aboveground geomorphology of karst terrain creates unique challenges for researchers and water managers seeking to sustain water resources for karst. This is particularly true in Kentucky where 25% of the state's terrain is well-developed karst and 55% has karst potential. Therefore, we seek a greater understanding of water and sediment transport in karst using the Cane Run watershed and Royal Spring basin in the Bluegrass region of Kentucky as a study site.

The Cane Run Watershed drains the upper portion of the North Elkhorn Creek and surface water is lost through a series of swallets that feed into a conduit under a perched aquifer. The conduit runs along a similar path to the North Elkhorn from the Kentucky Horsepark north of Lexington and draining into the Royal Spring in Georgetown. The site was chosen due to its relatively mature fluviokarst nature and extensive historic data records with ongoing data collection and environmental modelling.

First, we ask, how do the complex flow pathways of karst control water, sediment and nutrient fluxes across flow regimes? Building on existing research and using maps, field assessment, electrical resistivity, dye tracing, isotope and nutrient tracers, we have developed a conceptual model of how water, sediment, and nutrients are transported across the flow regimes. A spatially explicit numeric model will couple surface and soil hydrology, streamflow hydraulics, groundwater hydrology, and conduit flow hydraulics, in order to effectively simulate all processes in a coupled surface watershed and karst aquifer. The numerical model of flow pathways and fluxes will be used to build on Husic's existing research on sediment, carbon and nutrient biogeochemistry in the karst system to expand understanding of the role of specific karst morphologic features in this system. Utilizing the continuous sensors already in place at Royal Spring, we will be able to calibrate the model at 15 minute time steps, looking specifically at nitrate, conductivity and turbidity.

Second, we also ask if fluviokarst morphology reflects interactions between surface (fluvial) processes and subterranean (fracture) processes that may be predicted with measurable variables. This question will be investigated using intensive mapping and field investigation of study reaches that can be used to determine if interactions between surface and subsurface processes contribute to karst fluviomorphology. Isotope, nutrient, and SENSE data will be utilized along with numerical modelling to test hypotheses regarding formation of karst features. Furthermore, we are not just interested in understanding karst systems in the present, but will utilize existing work on climate and land use changes to understand the evolution of this system in the future. We will utilize 16 climate model future scenarios optimized for the inner bluegrass region as well as a USGS model of future land use as inputs into the numerical model in order to understand how projected anthropogenic impacts on the CRRS system in particular, and fluviokarst systems in general, will impact fluid, sediment and nutrient fate and transport.

2.7 Impedance Spectroscopy Based Evaluation of Phytoplankton Health

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Phytoplankton are photosynthetic plankton that float near the surface of water and use sunlight as well inorganic nutrients such as nitrates, phosphates, and sulfur, to produce carbohydrates, proteins, and fats [1]. Phytoplankton are sensitive to changes in their environments and stressors, such as pollution or nutrient deficiencies, can deplete phytoplankton populations. Evaluating small samples of larger phytoplankton populations is useful for the evaluation of water quality and the health of the ecosystem.

Impedance is the measure of the opposition that an electrical current faces when passing through a material and is measured by applying a known sinusoidal alternating current (AC) electrical field. The impedance of an organism changes depending on whether the organism is stressed, unstressed, or dead due to decomposition and stress reactions [2]. Using a method called *impedance spectroscopy* these differences in impedances can be identified and used to classify the health of phytoplankton populations.

Our technique involves passing an AC electrical field through a small population of phytoplankton suspended in a medium with a known electrical conductivity. The resulting impedance is measured over a frequency spectrum (Fig. 1). By modelling the suspended phytoplankton as an electrical circuit, the resistance and capacitance of the phytoplankton can be extracted. How the electrical properties of various stressed phytoplankton change can be established.

The phytoplankton were tested using a commercial impedance chip (ECIS Cultureware ™, Model Number 8W20idf PET) that contained wells with sensing electrodes on the bottom. This chip is placed into a custom-built holder (Fig. 2). Phytoplankton were suspended in a well at known fluid conductivity, and impedance measurements were acquired. After each trial the well would be cleaned and checked for degradation.

Several stressed phytoplankton were measured for this experiment; for example, one type was cultured in a medium that lacks nitrogen. However, phytoplankton encounter a wide variety of stressors in the wild and their responses to these stressors may be different depending on each situation. By evaluating these stressors using impedance spectroscopy, trends can be established and used to identify struggling phytoplankton populations.

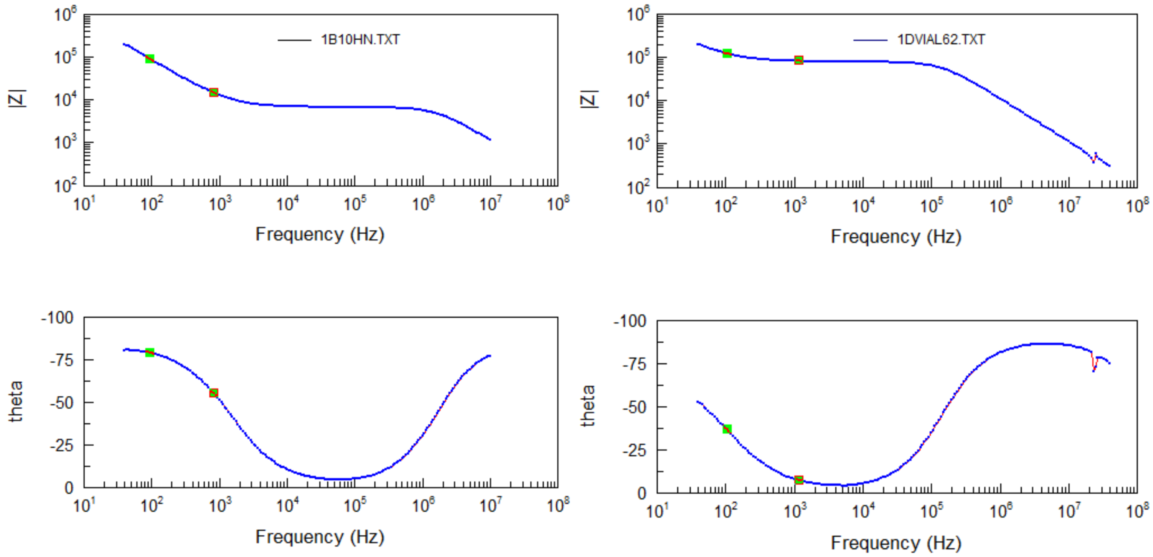

Figure 1. (left) Impedance and phase change over range of frequencies for dead phytoplankton. (right) Impedance and phase change over range of frequencies for unstressed living phytoplankton.

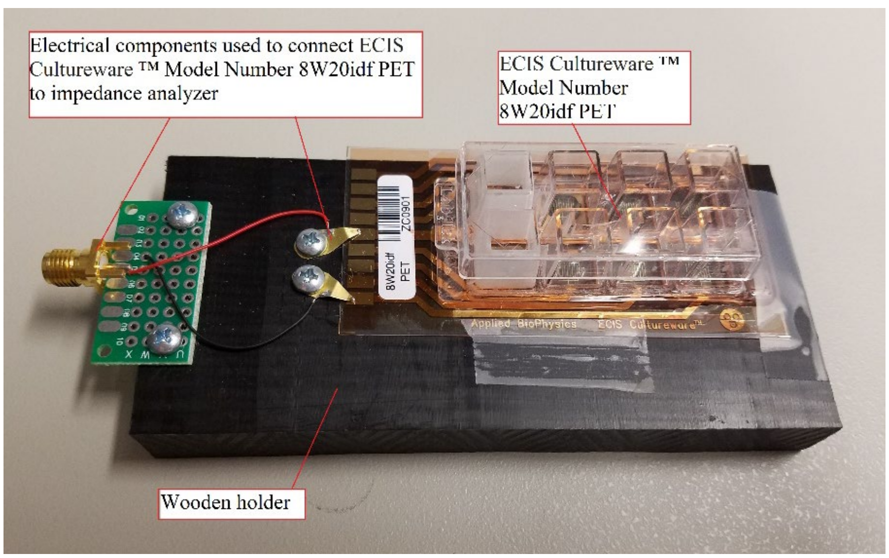

Figure 2: ECIS Cultureware ™ (Model Number 8W20idf PET) in custom-built holder, with electrical components designed to connect it the impedance analyzer.

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2.8 Assessing the Performance of Brookville Flood Control Reservoir

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In this study, the performance of a flood control reservoir called Brookville Reservoir, IN was assessed using historic and futuristic data. This reservoir is located in the East Fork of the Whitewater River Basin, near Cincinnati DNR 1988). With EPA BASINS and HSPF software, a rainfall runoff model was developed for the entire Whitewater River Basin up to Brookville, Indiana. Using uncontrolled flow data, the model was calibrated using 35 years of data and validated using 5 years by evaluating the goodness-of-fit with R^2, RMSE, and NSE.

Using historic data, the historic performance was accessed initially (Chandramouli *et al,* 2018). After satisfactory calibration, this model was used for futuristic scenario. Downscaled CMIP5 (Coupled Model Intercomparison Project 5) are available for different HUCs from PCMDI (Program for Climate Model Diagnosis & Intercomparison). Daily rainfall data for the considered region were downloaded and used for generating daily flows using the calibrated HSPF model for 100 years. A reservoir operation model was built using the present operating policies. By appending the reservoir simulation model with HSPF model results, future reservoir outflow was simulated and performance of the reservoir was assessed for the future conditions.

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2.9 Monitoring and Modelling of Phosphorus Flux Dynamics in Tile-Drained Landscapes: Quantifying the Role of Sediment-bound Phosphorus Fluxes

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In the Midwestern US, farmers have extensively used tile drainage systems to drain excess water from fine-textured, poorly-drained agricultural fields in order to enhance crop productivity, however, excess delivery of phosphorus (P) from tile drains to surface waters has led to proliferation of harmful and nuisance algal blooms in receiving water bodies. While most studies have emphasized the role of dissolved reactive P (DRP) fluxes, sediment-bound particulate P (PP) fluxes are also recognized to be significant in tile drains and contribute to legacy P issues, yet the mechanisms controlling these fluxes and dynamics are not well understood, nor are they represented in prevailing agroecosystem management models. The purpose of this research is threefold: 1) We aim to quantify fluxes of PP to tile drains using long-term data from the USDA-ARS SDRU edge-of-field network, which includes measures of dissolved inorganic nitrogen (DIN), total nitrogen (TN), DRP, and total P (TP) from 2012 to 2017, with supplemental suspended solids and ICP analysis data from 2014 at two paired field sites with contrasting management and soil characteristics. 2) We aim to use continuous high-resolution water quality data (including turbidity, pH, DO, conductivity, and temperature), from a paired site with drainage water management (DWM) in order to test existing perceptions of sediment delivery to tile-drains and to study the impact of DWM on sediment fluxes. 3) We will develop and test a numerical model of sediment P dynamics in tile drain fields that quantifies pathways and fate of sediment.

Preliminary analysis of the previously collected USDA-ARS data shows that the sediment-bound and organic P contributions (TP-DRP) constituted 60% to 70% of TP load at a site with heavy clay and extensive tillage, but only 10% to 20% in a site with a coarser silty-clay-loam soil texture and conservation tillage practices. Further work will include further partitioning of organic and inorganic P pools, and comparison with un-mixing analysis results using Ca, K and conductivity as tracers to quantify flow contributions from different pathways during storm events. We will use improved understanding of dynamics of sediment and PP for development of a numerical model that can represent behavior of tile-drained systems in transporting TSS and PP to the stream channel. Broadly, the work aims to improve our understanding of sediment P delivery in tile-drained landscapes with the ultimate goal of developing a modeling framework that could be interfaced with existing agricultural water quality models in order to improve management of P.

2.10 Quantifying the Role of Particulate Nitrogen in Disturbed Forested Watershed Nitrogen Budgets: Influences of a Lowland Confluence Wetland

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Harmful algal blooms (HABs) are of increasing concern in the Ohio River Basin, partially stemming from an expansive 650-mile cyanobacterial bloom on the Ohio River in fall 2015, impacting the drinking water supply and recreational activities for millions of people in five different states. These HABs occur as a result of various riverine conditions such as thermal stratification, low stream velocity, and eutrophic conditions. All these conditions play a role in the development and intensity of the HABs, however, high nutrient concentrations are thought to have the greatest influence on their proliferation and toxicity. While dissolved inorganic nitrogen fluxes can now be monitored continuously and directly at high temporal resolutions, sediment-bound nitrogen fluxes require coupled monitoring of sediment loads with characterization of sediment nitrogen composition dynamics; and hence are less well-characterized for the disturbed forested watersheds. Further, the fate of sediment at confluences of tributaries and the main river system are important zones for sediment retention and transient storage, which can influence both the wetland and downstream N transformations.

In order to quantify sediment nutrient dynamics in a broader context, sediment N fate and transport will be considered in a reach-scale model that currently considers hydrology, hydraulics, and nitrate fate and transport dynamics. We will present an overview of our approach to couple monitoring of sediment fingerprints in uplands and core samples within the wetland, high-resolution in situ sensors, and numerical modeling with broader aims to quantify sediment nitrogen source, fate, and transport dynamics. A disturbed forested watershed (Fourpole Creek, Huntington, WV) that is impacted by a backwater floodplain wetland at the confluence of the Ohio River will be used as our testbed. The individual budget components include high resolution sensing of sediment fluxes upstream and downstream of the wetland, soil cores from the wetland to quantify depositional patterns and non-conservative sediment fingerprint behavior, and elemental and isotopic analysis of sediment trap samples upstream and downstream of the wetland to determine sediment bound nitrogen fluxes and sources. Modeling will couple hydrologic and hydraulic dynamics with sediment erosion and deposition and will consider non-conservative degradation of sediment organic matter.

While our final presentation will include quantitative budget estimates of sediment nitrogen fate and transport and how it compares with dissolved inorganic N fluxes, preliminary results from our high resolution sensors show turbidity decreases from upstream to downstream of the wetland during storm-flows when the wetland is inundated, suggesting significant deposition. Regarding spatial distribution of deposition, Bayesian mass-balance unmixing results for streambed sediment cores were counterintuitive and showed sediment deposition to be predominantly Ohio River sediments in up-stream portions of the wetland and Fourpole Creek sediments in lower-sections, likely highlighting the importance of decelerating streamflows under backwater conditions to settle much of the Fourpole Creek sediment inputs. Regarding sediment N composition and fate, preliminary analysis of sediment trap data suggests that sediment nitrogen concentrations are significantly higher upstream as compared to downstream, signifying degradation of sediment during transient storage. Together, these findings suggest confluence wetlands may be a major sink for sediment nitrogen in these landscapes and merit further consideration in local and regional N management strategies.

2.11 Insight to the Mineralization of Fine Sediment Organic Matter in Streams Using Stable Isotopes Experiments

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Activity at the sediment-water interface is essential to understanding biogeochemical transformations of stream systems, but is difficult to analyze due to the coupled processes of organic matter oxidation, benthic oxygen uptake, and nutrient cycling. Recent water resources literature suggests that coupling stable isotope tracers with in-stream water quality models can help to reduce uncertainties by constraining model parameterization and nutrient exchange rates *via* biogeochemical processes. However, the microbial transformations of sediment organic matter (SOM) that change the isotopic signature of sediments have not been studied extensively, and requires future work to elucidate their nonconservative nature and advance the applicability of organics in tracer studies. This study was motivated by the need to formulate a sediment fate model that integrates organic matter decay rates consistent with biochemical processes observed in a controlled incubation experiment with on-going research in carbon and nutrient dynamics of stream systems.

Previous laboratory-scale studies on the preservation of organic matter during sedimentary diagenesis have compared elemental decay rates in both oxygenated and anoxic systems, but rarely utilize stable isotopes to quantify SOM decomposition. We have designed a laboratory incubation experiment to characterize the initial bioavailability of fine sediments from South Elkhorn Creek, and to examine organic matter mineralization and isotope fractionation in a controlled setting. Each experimental system is incubated for 3+ months (105 days) in Erlenmeyer flasks on an orbital shaker platform in a dark, temperature-controlled (25°C) environment. South Elkhorn Creek surface water containing a natural microbial community is used as incubation medium for the experimental systems. Transported sediments collected using *in-situ* sediment traps serve as the enzymatic substrate of the study, due to interest in examining SOC turnover, nutrient fate, and hydraulic control on biogeochemical cycling. Sediments representative of upland (allochthonous) derived materials and in-stream sediment reflecting benthic autotrophic (autochthonous) transformations are incubated separately in each system. The alteration of the elemental (TOC, TN, & TS) and isotopic ($\delta^{13}C_{sed}$, $\delta^{15}N_{sed}$, & $\delta^{34}S_{sed}$) signature is observed in a series of batch experiments with varied aerobic and anaerobic (redox) conditions. The dissolved constituents (TOC, NO_3^-, NH_4^+, o-PO_4^{3-}, & SO_4^{2-}) in each experiment are also analyzed to observe solid (sediment) and liquid (water) macronutrient exchanges.

Initial results from a 30-day preliminary study suggest preferential oxidation of organic matter enriched in ^{13}C occurs in all experimental systems. In contrast, ^{15}N-depleted OM observed in anaerobic conditions is dissimilar to the conservativeness of $\delta^{15}N_{sed}$ displayed in the oxygenated system. Early hypotheses attribute different redox pathways to the type and degree of microbial activity, in agreement with previous studies on the degradation of organic matter. Numerical modelling of isotope fractionation under ideal conditions of the laboratory study will provide insight for transformations in a complimentary field study at the reach-scale. The controlled-laboratory component will ensure adequate internal validity and field observations will be interpreted to maintain realistic systems for the incubations. Through this study, we hope to elucidate further the governing biochemical processes that dictate isotope fractionation rates of SOM in stream systems.

2.12 The Potential Influence of Barge and Boat Traffic on Phytoplankton in the Greenup Pool of the Ohio River

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The NSF-EPSCoR research program, entitled Sensing and Educating the Nexus to Sustain Ecosystems (SENSE) is a multistate research partnership aimed at gaining insight into the influence of food and energy production on aquatic ecosystems. Marshall University is participating with University of Kentucky and Murray State University in this endeavor investigating how food and energy production affect harmful algal bloom formation in the partner states. Marshall's research is focused in the Ohio River which host over 25 million people in the basin and serves as a drinking water source for more than five million people. The managed river system has 20 locks and dams for flood control and navigation and 38 power generating facilities. Recent increases in the frequency of harmful algal blooms and an extensive bloom of *Microcystis aeruginosa* during the summer of 2015 have increased attention on algal growth in the Ohio River.

SENSE has supported the deployment real-time water quality monitoring sensors at Robert C Byrd and Greenup locks which bracket the Greenup pool of the Ohio River (OH-KY-WV tri-state). These data are being utilized to evaluate factors influencing algal growth in the river and have revealed a potential relationship between commercial barge traffic and turbidity patterns within the Greenup pool. Because boat traffic can mix stratified layers in the water column and bottom sediments in shallow areas, they may influence phytoplankton growth positively by creating nutrient sources or negatively by creating water column turbidity. Determination of the influence of barge traffic on phytoplankton is necessary as it could influence the onset of harmful algal blooms.

2.13 Human Exposure Risk Assessment Model: Combining Subsurface and Aboveground Fate and Transport Processes

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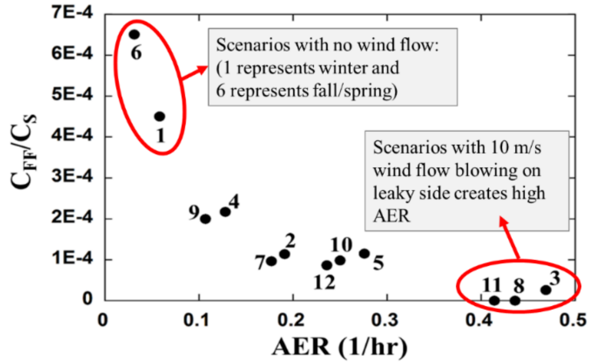
This presentation summarizes the results of a newly published indoor air model that demonstrates the importance of airflow inside and around buildings. Model results for the case of vapor intrusion, a process by which vapors from volatile contaminants in groundwater and soil, migrate through soil and enter indoor spaces, show the importance of weather effects. Vapor intrusion is well-known to be difficult to characterize using field data because indoor air concentrations exhibit considerable temporal and spatial variability throughout impacted communities. Using the newly developed model, we investigate how wind flow above and around a building, as well as, stack effects (i.e. building temperature differentials) influence 1) the distribution of vapor concentrations in the subsurface, and 2) indoor air pressure which consequently affects the indoor air concentration. Our analysis is advantageous over previous attempts because we incorporate information that have been shown to influence indoor air exposure risks, rather than just environmental subsurface fate and transport processes.

Model Outputs	**Previous models**	**NEW model**
Mass entry rate	✓	✓
Indoor air concentration	✓	✓
Soil concentration	✓	✓
Soil pressure	✓	✓
Outdoor air pressure	✕	✓
Indoor pressure	✕	✓
Building AER	✕	✓

Figure 3. Shirazi and Pennell (2017) vs. previous models.

The results of our study indicate that low wind speed in "shoulder seasons" (spring and fall) causes the highest indoor air concentration which is consistent with empirical data in radon studies; however, vapor intrusion regulatory guidance, lacking science-based evidence, recommends winter sampling (Figure 2). Our results show that contaminant mass entry rate and basement pressure are inversely related, whereas wind conditions and building characteristics influence the pressure inside the building (Figure 3). These findings offer insight as decision makers at state and federal levels are grappling with best approaches for assessing exposure risks at vapor intrusion sites. More results and implications are included in a recently published paper in *Environmental Science: Processes & Impacts* (DOI: 10.1039/c7em00423k 19:1594-1607).



Scenario #	Scenario WD-WS-(ΔT)	Scenario #	Scenario WD-WS-(ΔT)
1 (winter)	N/A-0-(-35)	6 (shoulder)	N/A-0-(-15)
2 (winter)	0-5-(-35)	7 (shoulder)	0-5-(-15)
3 (winter)	0-10-(-35)	8 (shoulder)	0-10-(-15)
4 (winter)	90-5-(-35)	9 (shoulder)	90-5-(-15)
5 (winter)	90-10-(-35)	10 (shoulder)	90-10-(-15)
Note: Shoulder seasons can be representative of spring or fall		11 (summer)	0-10-(0)
		12 (summer)	90-10-(0)

Figure 2. Relationship between indoor air concentration and AER for different seasons.

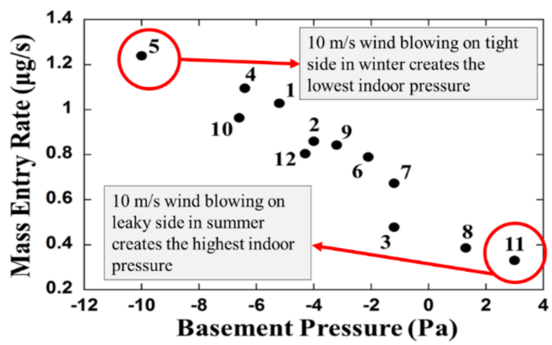


Figure 3: Relationship between basement pressure and contaminant mass entry rate.

The project described was supported by a CAREER Award from the National Science Foundation (Grant Number 1452800) and by Grant Number P42ES007380 (University of Kentucky Superfund Research Program) from the National Institute of Environmental Health Sciences.

2.14 The Impact of Ryegrass Root Exudates on Element Release in a Fragipan Soil*

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Soils containing fragipan horizons occupy a significant land area in western Kentucky (Figure 1). Fragipan horizons are dense layers of soil, often close to the surface, allowing them to alter water and nutrient distribution across a landscape. These shallow, subsurface horizons are typified by higher bulk densities and lower porosities than overlying horizons which can affect crop yields. They are dense due to the cementation of aluminosilicate minerals in combination with iron[1]. There is a need to explore management strategies to remediate shallow, fragipan horizon. Previous experiments showed that planting ryegrass as a cover crop in intact soil cores changed physical and chemical properties of fragipan horizons[2]. A possible explanation is the release of root exudates which solubilize cementing agents of the pan.

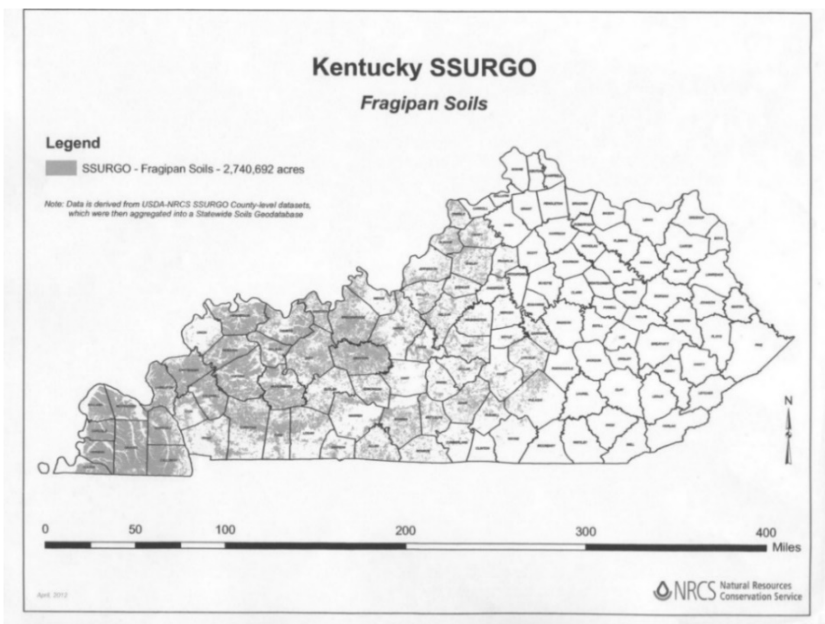

Figure 1. The extent of fragipan soils in Kentucky derived from the web soil survey (http://websoilsurvey.nrcs.usda.gov).

Previous experiments provided mass spectra collected from water extracts planted to ryegrass that indicate the presence of azelaic acid (AZ acid) and 3,4-Dihydroxydihydrocinnamic acid (DHPPA)[2]. Both of these organic compounds vary in their structure. It is unclear whether AZ and DHPPA will react with fragipan soil horizons. The purpose of this study is to investigate the reactivity of AZ and DHPPA with the Btx1 horizon from a Zanesville silt loam using the stirred-batch method. The amount of aluminum released into solution decreased in the order: DHPPA, control, and AZ (Figure 2). The amount of silica in solution steadily increased over time (Figure 3). Dissolved silica was greatest in the presence of DHPPA when compared to AZ or the control at time periods greater than 24 hours (Figure 3). Work on this project will continue to evaluate the interaction between Al and Si in the presence of DHPPA, follow the evolution of dissolved Fe in light of its role in cementing the fragipan[1], and evaluate the role of ryegrass in promoting vertical movement of water in fragipan soils using intact soil cores in greenhouse studies.

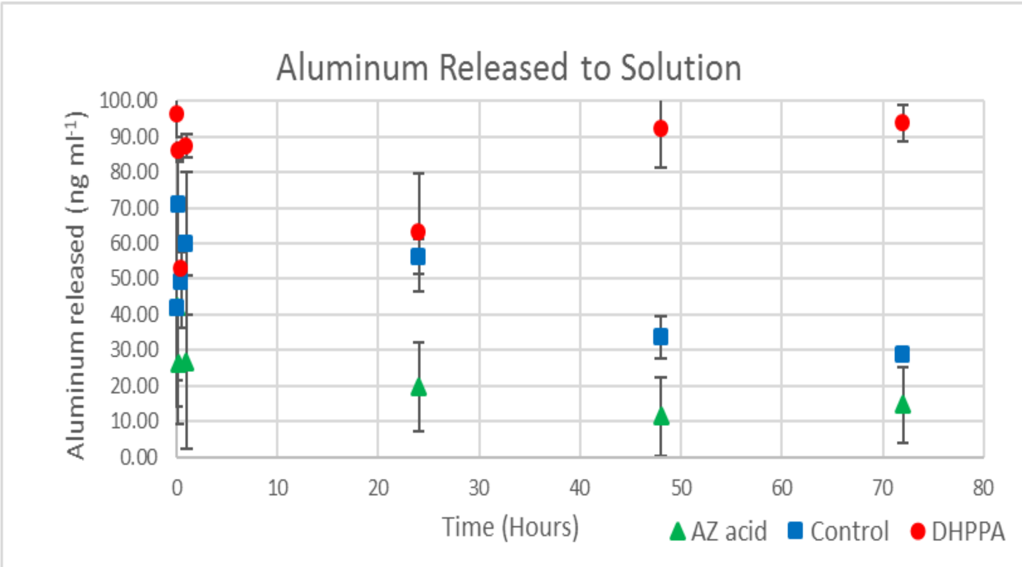

Figure 2. Aluminum Released to Solution

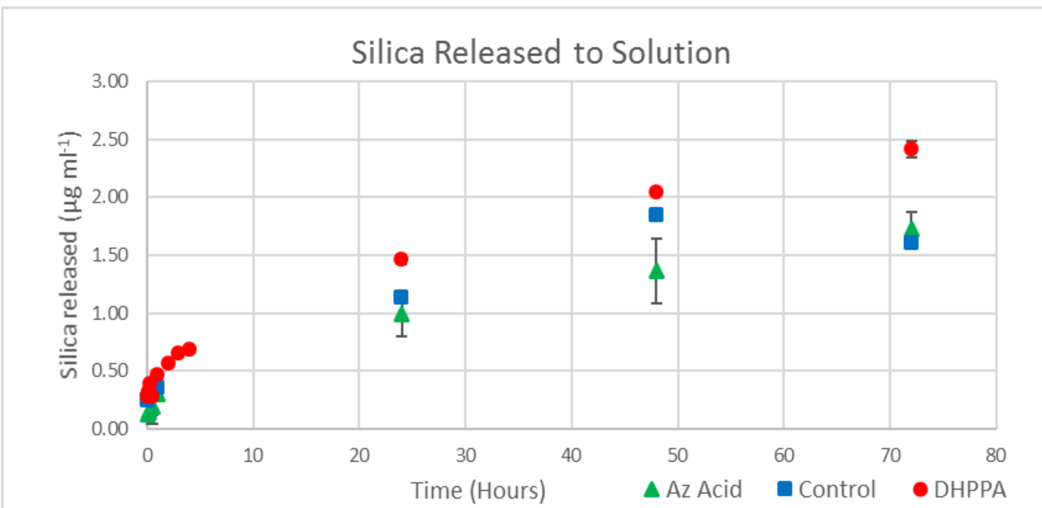

Figure 3. Silica Released to Solution.

References:

1. Marsan, F.A., Torrent, J., 1989. Fragipan bonding by silica and iron oxides in a soil from Northwestern Italy. Soil Science Society of America Journal 53, 1140-1145.
2. Matocha, C.J., Karathanasis, T.D., Murdock, L.W., Grove, J.H., Goodman, J., Call, D., 2018. Influence of ryegrass on physico-chemical properties of fragipan soil. Geoderma 317, 32-38.

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2.15 Vegetated Filter Strip Management Planning of Deep River Portage-Burns Waterway Watershed Using SWAT

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Recently, with the help of 319 grant cost share program, a watershed management plan was prepared for the Deep River Portage-Burns Waterway Watershed located in the Northwest Indiana. Northwest Indiana Regional Planning Commission developed this plan. It was initiated in an effort of maintaining and restoring the health of this watershed. The watershed management plan proposed the implementation of vegetated filter strips (VFS) as a best management practice (BMP) option. In this research, the optimal VFS implementation location within the targeted area of the watershed was examined using a hydrological model scheme.

In this research, a Soil Water Assessment Tool (SWAT) (Arnold et al, 2012, Chaubey et al 2010) model was constructed with required watershed characteristic data and climate data. The initial hydrologic and nutrient parameters of the SWAT model were further calibrated using SWAT Calibration and Uncertainty Programs (SWAT_CUP) with historical flow and nutrient data in a two-stage calibration process. The calibrated parameters were validated to accurately simulate the field condition and preserved in the SWAT model for further analysis of VFS implementations.

To find the optimal VFS implementation location, Four VFS implementation scenarios were created along different sections of the Turkey Creek. The plan recommends multiple BMPs, including VFS in this area using the calibrated SWAT model. The simulated results were captured and evaluated based on the total phosphorus (TP) removal from the outflow, including maximum daily percentage TP removal, average daily percentage TP removal, and annual TP removal.

Among the four VFS implementation scenarios, three scenarios yielded insignificant results with 3.93% to 30.29% maximum daily TP removal, 0.65% to 2.51% average daily TP removal, 1.60% to 8.29% (28.11 kg to 190.11 kg) annual TP removal. The scenario with VFS implementation in the upper most sub-watershed yielded the best result with 90.30% of daily TP removal (23.79% on average) and 78.59% (465.01 kg) annual TP removal.

References:

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