Longitudinal Study of Water Quality in Jennings Creek, Bowling Green, Kentucky: Urbanization Impacts on Karst Groundwater

Mitchell, L., Polk, J.S., Kaiser, R., Givan, E., and McClanahan, K.
Center for Human GeoEnvironmental Studies
Department of Geography and Geology, Western Kentucky University

Abstract

Karst groundwater systems, which occur in areas where caves, sinkholes, and underground rivers dominate the landscape, are vulnerable to pollution from surface contaminants. In urban areas, like Bowling Green, Kentucky, which is home to extensive caves and groundwater supplies, the immediate transport of heavy metals, organic waste, chemicals, and other pollutants from surface activities into groundwater poses a serious threat. This research project was done to examine the water quality of urban karst sites in Bowling Green, Kentucky at Jennings Creek, which is a local river primarily fed from springs; the water quality of Jennings Creek was never tested before this project, although it is an input to the Barren River, the area's primary drinking water source. Weekly water samples were taken at five sites for six weeks over the summer. Each sample site was selected based on its proximity downstream from a primary spring input with a known drainage area and land use. The samples were tested each week for forty-three different parameters related to water quality, which included alkalinity, total organic carbon (TOC), cations, anions, metal concentrations, dissolved oxygen, total chlorine, and E. coli, among others. The results of the data collected indicate different pollutant concentrations based on land use in the area surrounding the spring inputs, with major detrimental changes occurring at the largest spring inputs. The sites in mixed land use areas (agricultural and residential) had more nitrates and phosphate, while urban areas suffered from more industrial waste and metal contamination. Overall, nearly every site exceeded the EPA drinking water quality standard for several parameters, including nitrates, E. coli bacteria, and several metals, indicating that more research is needed to address the primary causes of these contaminants and better practices to mitigate their input into the groundwater system.

Introduction

Pollutants can contaminate groundwater when introduced, especially in karst landscapes. Karst areas occur where caves, sinkholes, and aquifers develop by the dissolution of soluble bedrock (White 1988; Dreybrodt 1988; Ford and Williams 2007; Ford 2006, 2015). Karst landscapes are especially sensitive, due to the surface and subsurface being closely connected, thereby cutting the time and length required for runoff to be introduced to the groundwater. Groundwater is a non-renewable resource that is found beneath the surface that fills the space between soil and rock particles. A majority of the groundwater extracted is for irrigation uses, but it also provides about half of the world's drinking water. Surprisingly, with such important uses, only weak policies and regulations to protect groundwater resources and karst landscapes are in place. The City of Bowling Green is located in a karst region and is in the process of urbanization. The Barren River is the main waterway in Warren County and is the primary drinking water source. Jennings Creek provides a substantial volume of water into the Barren River; however, no research or studies have been done on Jennings Creek, leaving its quality, flow inputs, and watersheds unknown.

Research Questions:
1. What is the influence of springs on groundwater characteristics in Jennings Creek?
2. What groundwater contaminants, if any, do spring inputs contribute to Jennings Creek quality issues?

Study Area

- Bowling Green has a temperate climate with seasonal variations in temperature and precipitation.
- Bowling Green is a growing urban city with a medium-sized university within its limits.
- Jennings Creek is a spring-fed river that receives a majority of its water from Lost River Rise and has several smaller spring inputs. Jennings Creek averages a normal water flow.
- Jennings Creek flows into the Barren River, which is a main waterway in Bowling Green used for recreation, fishing, wastewater treatment discharge, and drinking water.

Site	Kilometers Downstream	Number of Inputs Before	Coordinates
1		1	36°58'3.96"N 86°29'22.89"W
2	2.1	1	36°58'49.85"N 86°29'22.06"W
3	1.25	1	36°59'23.47"N 86°29'32.70"W
4	2.14	2	36°59'59.25"N 86°29'5.68"W
5	3.11	5	37° 0'34.08"N 86°28'17.80"W

Table 1: Water quality tested sites information (Created by Author)

Sample site one is the headwater of Jennings Creek located in a residential area and has a low flow. Sample site two is also in a residential area, but has a spring input from a nearby park. Site two is downstream of a spring, which comprises most of the flow. Site three is in an urban area with high water volume, due to the spring input upstream of its location. Site four is after the largest spring input with a steady flow and large volume of water that greatly alters Jennings Creek. Site four and five are both in agricultural areas with relatively similar flows and volumes.

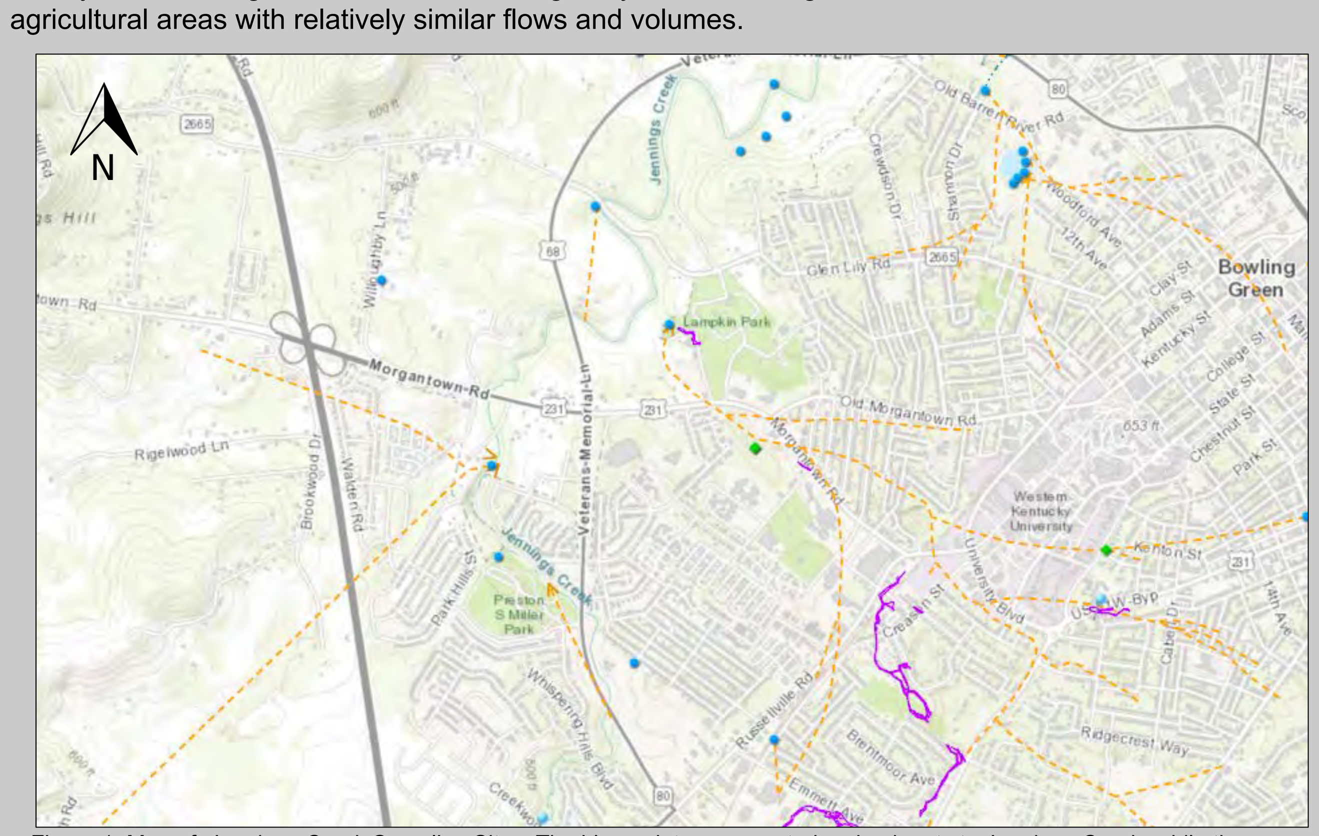


Figure 1. Map of Jennings Creek Sampling Sites. The blue points represented spring inputs to Jennings Creek, while the orange dotted lines are underground flowpaths (Modified from Shelley 2018).

Methodology

- Water samples were collected from 5 sites along Jennings Creek downstream of spring inputs from May 21 to July 9, 2018.
- Data for pH, specific conductivity (SpC), total chlorine, temperature, turbidity, total suspended solids, dissolved oxygen were collected in the field.
- Analyses completed at HydroAnalytical Lab followed specific Standard Methods specified by the EPA and included metals, cations, anions, biochemical oxygen demand (BOD), total organic carbon (TOC), alkalinity, and *E. coli* bacteria.
- Data were Quality Control (QC) checked through duplicates, standards, and blanks and processed using SigmaPlot 11 to graph the most significant and/or harmful water quality data against precipitation and sample date.

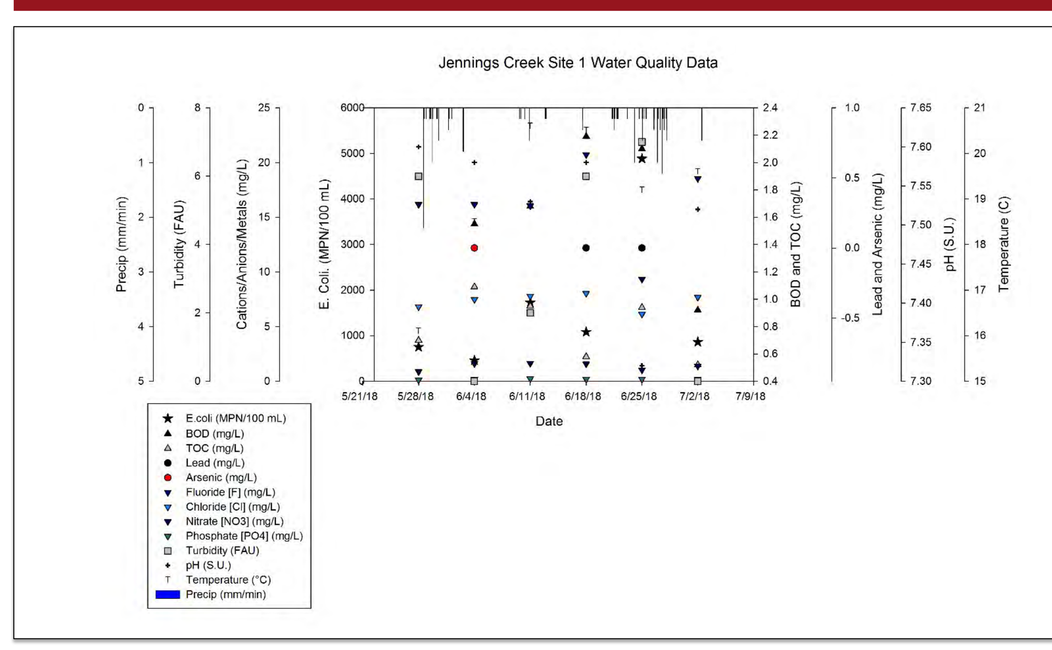

Site 1: Downstream of the headwaters of Jennings Creek, which is formed from a karst spring within Bowling Green.

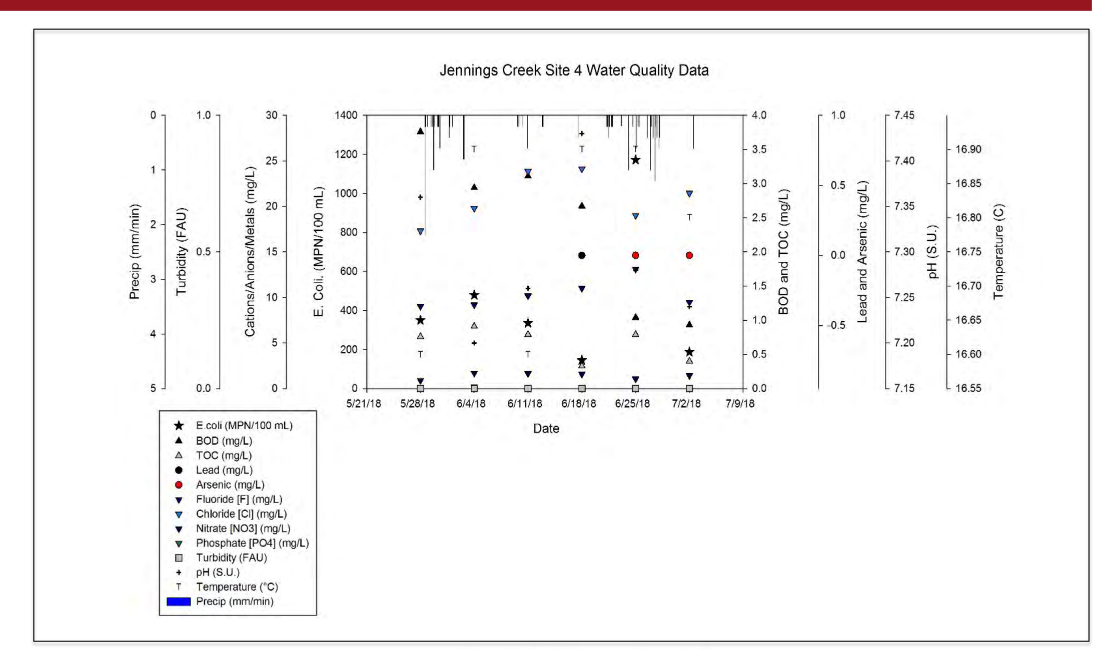

Site 2. The first major spring input into Jennings Creek next to a major park and large residential neighborhood.

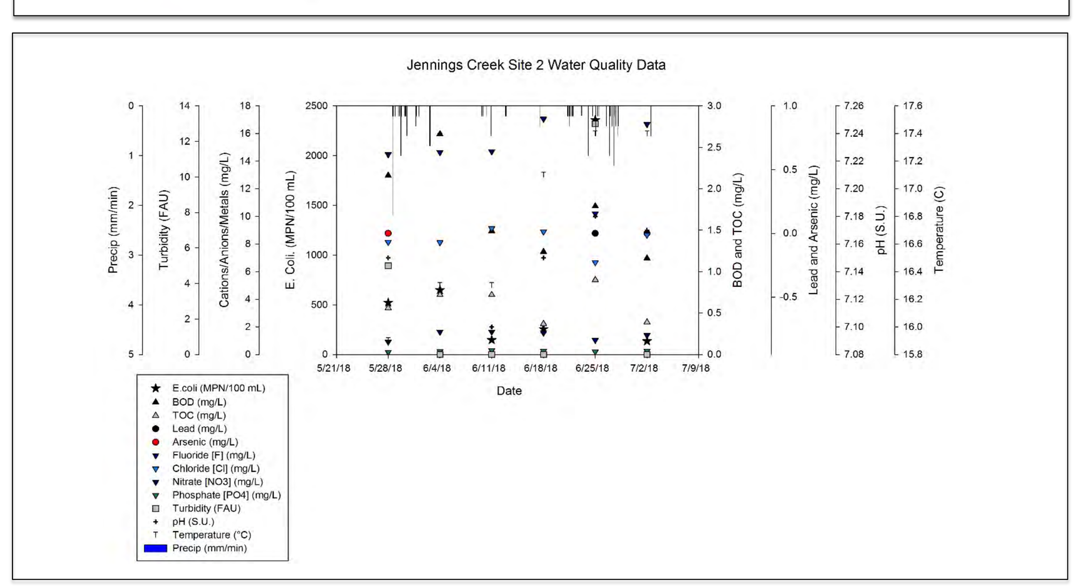

Site 4. Downstream of the Glen Lily Road bridge, where many people fish and kayak.

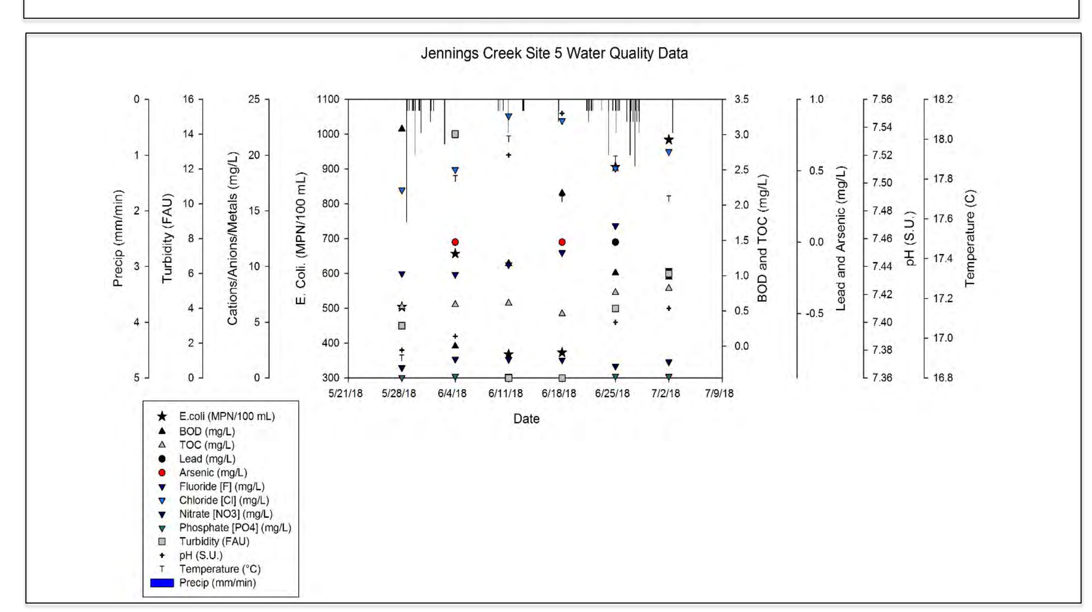

Site 5. Downstream of several major spring sites, including New Spring, which is the major spring outlet for the City of Bowling Green downtown area.

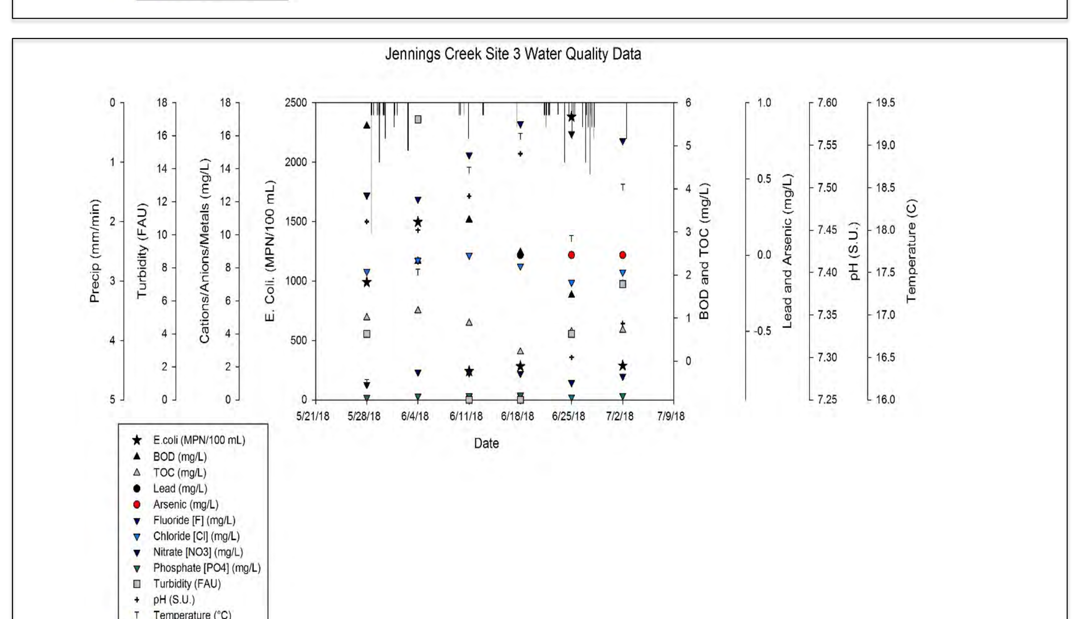
Results

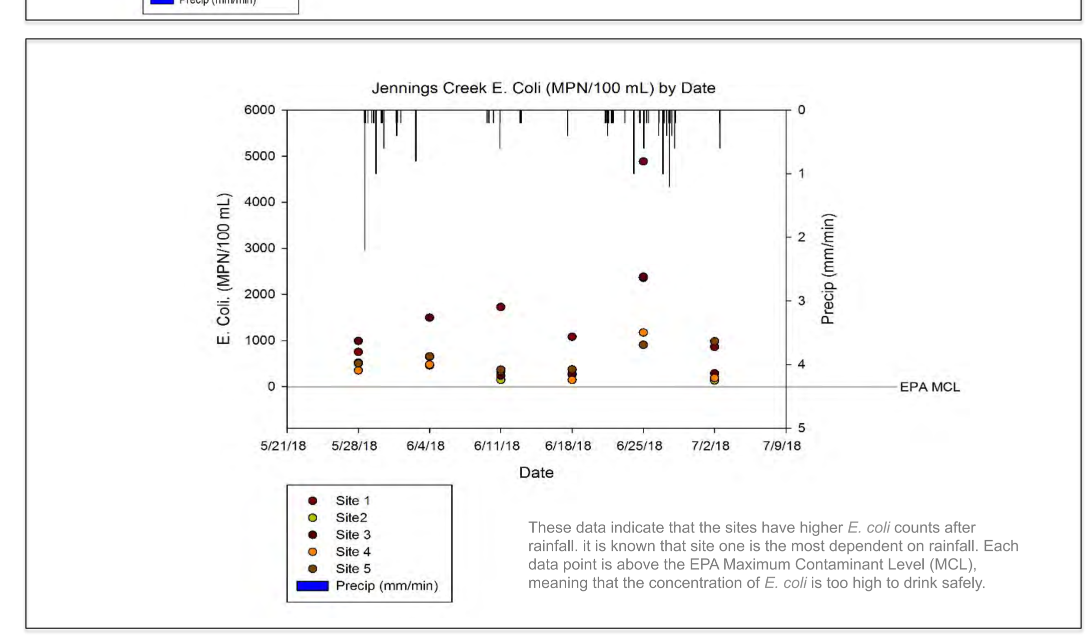












These data indicate that the sites have higher *E. coli* counts after rainfall. it is known that site one is the most dependent on rainfall. Each data point is above the EPA Maximum Contaminant Level (MCL), meaning that the concentration of *E. coli* is too high to drink safely.

Discussion

- Turbidity measures the clarity of water, or how much sediment there is. The first three sites spiked after rainfall likely from an increase sediment input with runoff, while sites four and five do not spike.
- Fluoride is an indicator of sanitary water leaks. The first three sites have a high fluoride concentration, so it is possible to assume there is a leak from sanitary water lines.
- Chloride is often in industrial cleaners, the high concentrations that appear at sites four and five could be explained by the industrial land use in watersheds that feed these springs.
- Lead and arsenic indicate heavy metal contaminants in waterways. The drinking water standard for arsenic is 0.010 mg/L; during data collection, six different samples tested higher than the arsenic maximum. The appearance of large amounts of lead and arsenic in sites one and five indicate there are more heavy metal contaminants in those areas.
- Nitrates and phosphates are found in fertilizers and plant nutrients. The lack of high concentration of these parameters at sites four and five (agricultural areas) are likely due to dilution from high water volume.
- BOD is the amount of available oxygen in the water. High BOD means there is less oxygen due to oxygen depletion from contaminants. Site four would be the area that is least suitable for aquatic life.
- TOC indicates general stream health and water quality based off organic contaminants, such as agricultural chemicals. TOC is consistent between all five sites, but there is probably more industrial water in the first three sites and higher agricultural contaminants in the last two sites.
- Temperature is very important in water quality, because all other parameters depend on it. When temperature rises, other indicators tend to have higher values and be less precise. Temperature itself depends on the area, time, proximity to springs, amount of solar radiation, etc.
- Another basic water quality indicator is pH, which indicates acidity. If there is a pH spike it could mean there is a contamination, leak, or spill. Similar to other contaminants, pH tends to spike after rainfall, due to higher spring discharge.
- Rainfall is another independent parameter of water quality. Rainfall in surrounding areas can dilute a waterway or cause a spike in contaminant concentrations due to runoff, as exhibited at several of the sites over the study period.

Conclusions

- Water pollutants differ by land use, precipitation events, watersheds, etc., with springs being the main input from sources outside the main runoff area of Jennings Creek.
- Agricultural areas tend to have higher heavy metal concentrations and higher BOD. Industrial and residential areas have more sanitary contaminants. Both types of contaminants are present in Jennings Creek, due to a diversity of land use.
- Dilution of waterways can cause some areas to seem less contaminated than reality, so water volume is important.
- Spring inputs can make it difficult to find the original source of a pollutant, since basins are often unknown, but this study indicates the importance of understanding springsheds in urban karst areas.
- One of the major issues with Jennings Creek water quality is *E. coli* contamination, especially from residential septic leaks and unregulated farm practices within the springsheds.
- Higher-resolution data collection is needed to better assess how storms influence the water quality.

Acknowledgements

- City of Bowling Green, Kentucky
- WKU HydroAnalytical Lab
- Adam Shelley, WKU CHNGES
- WKU Gatton Academy Summer Research Grant