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# Kentucky Water Resources Annual Symposium

March 28, 2016



Marriott's Griffin Gate Resort  
Lexington, Kentucky

**UK**  
UNIVERSITY OF KENTUCKY  
Kentucky Water Resources  
Research Institute

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Kentucky Water Resources Research Institute  
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Kentucky Division of Water

# **Kentucky Water Resources Annual Symposium**

March 28, 2016

Marriott's Griffin Gate Resort  
Lexington, Kentucky

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## **PAST RECIPIENTS OF INSTITUTE AWARDS FOR WATER RESEARCH, WATER PRACTICE, AND WATER QUALITY**

### **• Bill Barfield Award for Water Research**

- Dibakar Bhattacharyya (2015)
- James C. Currens (2014)
- Art Parola (2013)
- Andrew Ernest (2012)
- James Dinger (2011)
- Alice Jones (2010)
- Sylvia Daunert (2009)
- Gail Brion (2008)
- David White (2007)
- Wes Birge (2006)
- Don Wood (2005)

### **• Lyle Sendlein Award for Water Practice**

- Richard Warner (2015)
- Derek R. Guthrie (2014)
- Sandra Gruzesky (2013)
- Michael Griffin (2012)
- Linda Bridwell (2011)
- Greg Heitzman (2010)
- Susan Bush (2009)
- Steve Reeder (2008)
- Bill Grier (2007)
- Jack Wilson (2005)

### **• Bob Lauderdale Award for Water Quality**

- Dale Reynolds (2015)
- Brian C. Reeder (2014)
- H. David Gabbard (2013)
- Henry Francis (2012)
- Amanda Abnee Gumbert (2011)
- Malissa McAlister (2010)
- Bruce Scott (2009)
- Ken Cooke (2008)
- Judith Petersen (2007)
- Eddie Foree (2006)



## WORKING WITH FLINT RESIDENTS: LEAD DISCOVERY AND CITIZEN SCIENCE IN THE FLINT WATER CRISIS

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Dr. Marc Edwards, a Charles P. Lunsford Professor at Virginia Tech, is leading his research team and collaborating with local residents to address lead, pathogen and water infrastructure issues caused by a failure to implement corrosion control treatment in Flint, Michigan. As a senior PhD student in Dr. Edwards research team and on behalf of Flint Water Study Team, I want to address the following questions:

- What caused high water lead levels and pathogen growth in Flint drinking water?
- How did we get involved?
- How did we collect and analyze more than 12 times the number of water samples that city officials collected over a significantly shorter period of time?
- Who is to blame for this Flint water crisis?
- What can we do as engineers and scientists to prevent another Flint water crisis in the future?

*Speaker BIO:* Min Tang is currently a PhD candidate in Civil Engineering at Virginia Polytechnic Institute and State University (Virginia Tech). She received her Bachelor of Science degree in Environmental Engineering in 2011 at Sichuan University, China. She then pursued graduate study in Environmental Engineering at Virginia Tech and received her Master of Science degree in 2013. She is a recipient of the Sussman Internship Scholarship and the Torgersen Research Award at Virginia Tech. Her research interests include in-situ remediation of water pipe leaks, corrosion and corrosion control, aquatic chemistry, drinking water regulation and compliance, and water/wastewater treatment.



Photo: Matt Gentry/AP



A PROPOSED BILL TO LICENSE CLOSED-LOOP GEOTHERMAL SYSTEM  
VERTICAL BOREHOLE WELL DRILLERS

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Geothermal (or ground-source) heat pumps use the constant temperature beneath the surface of the earth to produce a highly efficient, renewable energy source for space heating and cooling. The two types of geothermal systems are closed loop and open loop. Closed-loop systems do not use groundwater at all, but employ piping containing an anti-freeze type liquid which is installed in vertical boreholes, horizontal trenches or surface water bodies to transfer heat. Open-loop systems use groundwater as the heat transfer medium, and are currently regulated under KRS 223.400-460, which covers certification of water well and monitoring well drillers. Closed-loop geothermal systems, however, are not currently regulated.

Most closed-loop systems often involve drilling vertical boreholes which can penetrate aquifers and therefore provide potential contaminant pathways into groundwater. For this reason, the Kentucky Groundwater Association, in conjunction with the Kentucky Water Well Certification Board, have been advocating for a revision to KRS 223 that will require closed-loop vertical borehole drillers to be certified under the same program as monitoring well and water well drillers.

The goals of this proposed amendment are: (1) the protection of groundwater resources; (2) the development of minimum standards for design, construction and proper abandonment of closed-loop vertical borehole systems; (3) better education of drillers involved in geothermal work; and (4) to assist in locating and tracking geothermal installations which use vertical boreholes that penetrate aquifers.

Without oversight of the closed-loop geothermal systems installed in Kentucky, little is known about the location, geologic setting, and impact on groundwater of the thousands of vertical borehole geothermal wells that have been drilled in the state. If the current well driller certification legislation is amended, construction and installation standards

will be promulgated and closed-loop vertical borehole driller training required that will help prevent contamination of groundwater resources.

This proposed legislation has been submitted in three of the last four legislative sessions. The bill has been well received in the House, but has failed to gain approval in the Senate. If the proposed bill is successful in a future legislative session, the Secretary of the Energy and Environment Cabinet and the Legislative Research Commission will be charged with developing administrative regulations to implement the certification program. This presentation will summarize the background, goals, and potential effects of the proposed bill to license closed-loop vertical borehole drillers in Kentucky.



## USING OIL AND GAS DATA TO ASSESS THE DISTRIBUTION OF FRESH AND SALINE WATER IN NORTHEASTERN KENTUCKY

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The unconventional Berea oil and gas play in northeastern Kentucky has been developed through hydraulic fracturing and horizontal drilling at shallow depths, sometimes within 1,500 feet of the surface. Such shallow depths call for exceptional diligence regarding well-casing integrity and depth of casing to protect groundwater quality. The “Fresh-Saline Water Interface Map of Kentucky” by H.T. Hopkins published in 1966 remains an important guidance document for well operators and the Kentucky Division of Oil and Gas when making decisions concerning surface casing depth. Hopkins used domestic water wells to create the map, in which the total depth of the wells equaled the base of fresh groundwater (total dissolved solids equal less than 1,000 ppm) or the fresh-saline water interface. However, it is likely that most of the water wells did not penetrate the base of the deepest fresh water or encounter the shallowest saline water. As a result, the Hopkins map underestimates the depth of the fresh-saline water interface.

Further insight into the depth of the fresh-saline water interface might be provided by oil and gas completion reports, in which depths of fresh and salt water are often recorded. Drilled deeper than domestic water wells, oil and gas wells have the potential to provide a more accurate view of fresh and saline water in the subsurface. The accuracy, and hence utility, of water depths from oil and gas records could be limited, however, because methods used to discriminate fresh versus salt water are variably subjective.

Topography exerts a strong influence on groundwater depth. Higher surface elevations tend to result in fresh water at higher elevation; the converse is true for lower surface elevations. The relationship was used to examine the accuracy of fresh water depths documented in oil and gas records. Correlation coefficients between surface elevation and the deepest documented fresh water in Greenup, Lawrence, Johnson, Elliott, Boyd, Carter, and Martin Counties ranged from 0.38 to 0.62, with an average of 0.49. When the same data were examined using watershed boundaries (i.e., hydrologic unit codes, HUCs), the correlation coefficients equaled 0.30 and 0.33 for the Big Sandy and the Little Sandy HUCs, respectively.

Going forward, regression analysis will be used to determine if surface elevation and location can accurately predict the elevation of deepest observed fresh water. The resulting equations could produce more accurate estimates of the fresh-saline groundwater interface. The correlation coefficients show, however, variation in the depths of fresh water, and estimates will therefore need to quantify the variation, be it from human error, geologically discontinuous aquifers, or both.

# NOTES

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A PILOT STUDY TO ASSESS BASELINE GROUNDWATER CHEMISTRY FOR  
THE BEREA SANDSTONE AND ROGERSVILLE SHALE PLAY AREA,  
EASTERN KENTUCKY

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The rapid implementation of horizontal drilling and hydraulic fracturing technology in producing oil and gas from tight rock formations across the country has increased public concerns about possible impacts on the environment, especially on shallow drinking water aquifers. In eastern Kentucky, horizontal drilling and fracturing activities in the Upper Devonian Berea Sandstone have increased in recent years. While production activities in the Berea Sandstone are at a relatively small scale, public attention has been drawn to the Rogersville Shale, a deeper, thicker, and more extensive organic-rich shale projected to become a major shale play in eastern Kentucky. Information about existing groundwater quality in the Berea Sandstone and the Rogersville Shale areas is critical to help state and federal water resources managers address the public's environmental concerns and maintain health and environmental safeguards.

This presentation provides an overview of a federally funded project being conducted by the Kentucky Geological Survey in collaboration with GSI Environmental Inc. to collect and analyze groundwater samples from existing domestic and public water-supply wells located in Greenup, Carter, Boyd, Lawrence, Johnson, and Martin Counties. Between 30 and 50 water wells will be sampled and analyzed for major cations and ions, metals, dissolved gases including methane, and carbon isotopes. The project objectives are to obtain a preliminary understanding of groundwater chemistry and its spatial variability throughout the study area and to use isotope data to evaluate possible sources of methane detected in the groundwater. Results from this study can be used as a reference to infer potential impacts of future horizontal drilling and hydraulic fracturing on groundwater quality.

## NOTES

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## INVESTIGATION OF LIMESTONE AQUIFER CHARACTERISTICS IN THE ELIZABETHTOWN, KENTUCY AREA

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Karstic limestones are among the most productive aquifers in the world and are important sources of water for many communities and citizens in Kentucky. Public water provided by Hardin County Water District No. 2 is supplied in part by groundwater withdrawn from wells drilled into a karstic limestone aquifer near Valley Creek in Elizabethtown, Kentucky. Although several wells are regularly pumped and contribute to the raw water processed daily by the Elizabethtown water treatment plant, supply well No. 1 (W1) is especially productive. For example, during April 2015 an average of 633,330 gpd was withdrawn from W1, or approximately 57 percent of the average daily total withdrawn from all wells and approximately 26 percent of the average daily total intake of raw water. Drilling logs from W1 and three nearby wells indicate that the karst aquifer is highly stratified, and downhole-camera inspection of the open-borehole observation well located approximately 85 ft. west of W1 revealed the presence of multiple zones of vugs, high-angle fractures, and bedding-plane openings modified by dissolution. A hydraulic conductivity value of 434 ft./day was calculated for the aquifer in the vicinity of W1, using the pumping test data and a leaky-confined aquifer test solution. A hydraulic conductivity value of 423 ft/day was calculated for the fractures and larger dissolutional openings, using a test solution developed for dual porosity fractured-rock aquifers, and a value of  $7 \times 10^{-5}$  ft./day was calculated for the limestone matrix. In addition to extensive fracturing and karstification, other hydrogeologic factors that influence groundwater availability in the limestone aquifer include bedrock structure, proximity of mapped faults, and residual deposits of unconsolidated sand and gravel.

# NOTES

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## CHARACTERISTICS OF COVER-COLLAPSE SINKHOLES IN KENTUCKY

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Cover-collapse is the sudden and unpredictable collapse of the unconsolidated material (e.g. soil, alluvium) over karstic bedrock. Sixty-seven percent of Kentucky residents live on karst (Cecil, 2015, personal communication). The estimated cost of cover-collapse sinkholes to the economy ranges from \$20 to \$60 million a year. Sinkholes resulting from cover-collapse damage buildings, roads, utility lines, and farm equipment. Cover-collapse has killed livestock, including some thoroughbred horses, and has injured people. The development mechanisms of cover-collapse have been understood for years (White and White, 1992, Tharp, 1999), but predicting the precise location and timing of future collapse remains enigmatic (Beck, 1991, Wilson and Shock, 1996). The Kentucky Geological Survey (KGS) began collecting case histories of cover-collapse in 1997 and now receives nearly 50 reports annually. The database now contains over 360 reports from individual sites, yet the data are thought to represent less than one percent of the actual number of annual cover-collapse occurrences. Information collected about the physical and geological characteristics of 220 sites are accurately located and precisely dated sufficient to allow further evaluation.

The largest cover-collapse in the database was the Dishman Lane sinkhole in Bowling Green, at 48 meters long, 32 meters wide and a depth over 9 meters. The recent Corvette Museum cover-collapse, also in Bowling Green is the third largest. It was 12.2 meters long by 11.0 meters by 8.2 meters deep. Large cover-collapse sinkholes may be relatively rare, however, as the average length of the long axis of sinkholes in the database is only 2.8 meters, the short axis is an average of 1.9 meters and the depth averages 2.4 meters. The closer the asymmetry and circularity are to 1.0, the more perfect the circle of the collapse opening. For the database, the average opening diameter is 2.4 meters, the asymmetry is 1.96, and the circularity is 0.85. The depth, diameter, asymmetry, and circularity were also grouped by the stratigraphic age of the underlying karst bedrock (Mississippian, Silurian-Devonian, and Ordovician). The stratigraphic groups were tested for equivalency of the standard deviations (f-test) and the means (student's t-test, 95-percent confidence interval) using log transformed dimensions and Statgraphics software. There was no statistically significant difference between the Silurian-Devonian and the Ordovician cover-collapse for depth, asymmetry, or circularity. There was no difference in the depth between the Mississippian and Ordovician. There was, however, a significant difference in diameter, asymmetry, and circularity between the Mississippian and the Ordovician and between the Mississippian and the Silurian-Devonian. Other groupings include the reports from "urban" versus "rural" counties, and from high population versus lower population counties. No difference was found between these groups for log transformed data.

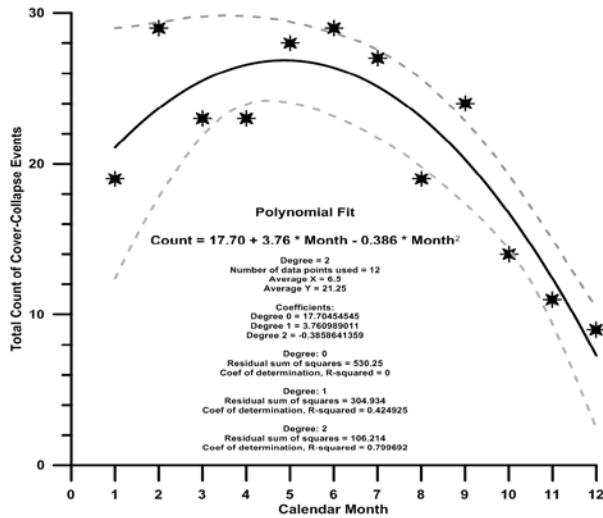


Figure 1 Relationship between the frequency of cover-collapse per month and the calendar month.

The frequency of occurrence data were also evaluated graphically. Figure 1 is the temporal distribution of the cover-collapse events over the calendar year. The seasonality is apparent among the wet months of the year when counts are greater. The number of cover collapse per month when plotted against the average monthly total precipitation (not shown) shows a linear alignment of only eight months. The poor correlation may be in part a result of the overly generalized precipitation data.

Collapse events plotted on a digitized base map of closed topographic contours of sinkholes results in only 7.5 percent of the cover-collapse sites falling inside the mapped sinkhole depression. The small number (11 percent) of the sites that had buried trash exposed by a new collapse also suggests that cover-collapse typically initiates new sinkhole development, as opposed to being a mechanism for the continued erosion and growth of an established sinkhole. Although the collapse outlet may still function as a drain for the larger sinkhole, the reestablishment of cover and a new arch is unlikely.

In conclusion, there is a strong correlation between the frequency of cover-collapse and the wet months of the year. A similar trend is displayed by the count of cover-collapse and average monthly precipitation. Precisely measured and recorded field data have greatly improved the data set and more high quality data are needed. Substantial progress has been made in understanding cover-collapse in the last two decades. The elusive goal that remains is to find a characteristic of the soil arch, before it fails, that can be detected by airborne, orbital, or ground level remote sensing.

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DATA AND MODEL INVESTIGATION OF A FLUVIOKARST SYSTEM IN THE  
BLUEGRASS REGION: WATER, SEDIMENT, AND CARBON INTERACTIONS

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Mature karst topography is well recognized within the hydrology and geology communities to include subterranean fluid pathways that act as turbulent conduits conveying fluid from surface stream sinks called swallets to sources called springs. The extensive karst topographical potential in Kentucky is of particular importance to municipalities and users who draw their drinking water supplies from karst aquifers. Understanding sediment and contaminant transport processes is vital in water resources decision making at the local and state level within Kentucky. Water flow within karst aquifers has been heavily dissected, measured, and modeled. However, we find that little knowledge has been reported with regards to the transport and fate of terrestrially-derived sediment organic carbon (SOC) within karst watersheds. This study investigated the

hypothesis that karst pathways could act as biologically active conveyors of SOC that temporarily store sediment, turn over carbon at higher rates than otherwise considered, and recharge depleted SOC back to the surface stream within the fluvial system.

Mixed research methods were applied within a mature karst network. Methods included high resolution measurements of water and sediment characteristics of surface streams, carbon and stable carbon isotope measurements of transported sediment, and numerical physical and biogeochemical modeling of sediment and carbon. The mixing of sediment during net zero deposition and erosion was investigated in this study using a parameter calibrated to collected SOC data.

Results of this study indicate the ability of phreatic karst conduits to temporarily trap surface-derived sediment during storm events due to downstream flow controls and fluid energy limitations. Exchange of bed and suspended sediment plays an important role in providing carbon-rich sediment to microbial communities in the surface fine grain laminae layer of the conduit bed for later decomposition. Data results show that 29.7% of the sediment organic carbon is depleted when comparing inputs to outputs. This contrasts surface dominated systems in the Bluegrass which show a 50% enrichment in carbon during transport in the fluvial system. Modeling results of this study suggest that heterotrophic bacteria in the subsurface conduit oxidize  $0.05 \text{ tCkm}^{-2}\text{y}^{-1}$  resulting from the temporary storage of terrestrial carbon in the karst conduit. The subsurface conduit transports  $0.15 \text{ tCkm}^{-2}\text{y}^{-1}$  out of the fluviokarst watershed.

# SOURCING AND DYNAMICS OF KARST HYDROLOGIC INPUTS ON HARMFUL ALGAL BLOOM OCCURRENCES IN KENTUCKY LAKES

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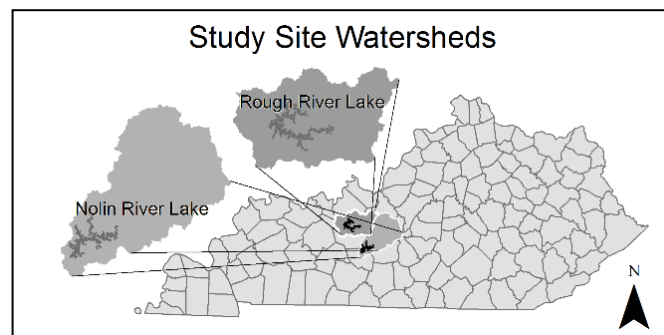
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Almost half of Kentucky is underlain by a well-developed karst aquifer/landscape system in which water resource access and protection challenges are common. Surface water supplies are often limited, groundwater is typically vulnerable to contamination, and even basic delineation of aquifer recharge areas requires specialized methods. The surface water that does exist is often in the form of rivers. Many of these rivers are fed by springs and serve as baselevel for their drainage areas. Often, rivers are dammed for various reasons, typically for flood prevention, recreational use, hydropower, and to aid in navigation. Much of the rainfall in Kentucky is drained internally through the karst system. Due to this, Kentucky has only three naturally occurring lakes. Most importantly, these lakes also provide a drinking water source for several communities. In particular, Nolin River Lake and Rough River Lake, located in south-central Kentucky (Figure 1) and created under the Flood Control Act of 1938, are important and heavily used recreational lakes that also serve several of the aforementioned functions, particularly flood mitigation.

Figure 1: The study sites watersheds. Rough River Lake's watershed is smaller and influenced more by agriculture. Nolin River Lake's watershed is larger and includes the urban center of Elizabethtown.



Recently, freshwater Harmful Algal Blooms (HABs), predominantly made of cyanobacteria (blue-green algae), have been occurring in Rough River Lake and Nolin River Lake and may be caused by nutrient loading introduced through karst hydrologic inputs. Currently, there exists little data regarding the cause of these HAB's with only recent efforts underway to investigate these inputs.

The purpose of this research was to investigate the possible influences of karst hydrologic inputs to Nolin and Rough River Lakes, which are two separate water bodies that share the commonality of having karst inputs and being managed by the USACE. The main goal of the project was to discover the level of influence the karst inputs have on the eutrophication of the reservoirs from water quality impacts, primarily examining nutrient inputs and *E. coli* bacteria contamination, in addition to hydrometeorological influences. To accomplish this task, monitoring of the nutrient loading, *E. coli*, and the stable isotopes of nitrate, <sup>15</sup>N and <sup>18</sup>O, at three sites per lake and the output of each lake's dam has been conducted since summer of 2015.

A look at the preliminary isotope data indicate that the detectable portion of the nitrate loading at Nolin River Lake is a mix of anthropogenic sources, while at Rough River Lake, the nitrate loading is primarily derived from nonpoint agricultural contributions. The hydrological data collected so far indicate that the lakes both are influenced by karst groundwater sources. Some sites see more influence than others, but an influence is detectable. The extent and magnitude of the influence has yet to be established. More data need to be collected before concrete conclusions can be drawn, but this project still has several more months of data collection ahead.

This project continues to be done in partnership with the USACE and other community groups who help manage the lake for the citizens who live around it, such as Friends of Nolin, and the Kentucky Division of Water. These stakeholders originally approached us to help in developing a research strategy to investigate possible causes and enhance their current data and knowledge in order to best manage the lakes' watersheds and surrounding inputs against HABs. The project involves collecting high-resolution scientific data and reducing it in a way that will be communicable to the public to help enhance behavioral changes to minimize possible contaminant inputs that may increase the likelihood and proliferation of freshwater HABs.

INVESTIGATION OF FECAL CONTAMINATION IN THE LITTLE RIVER  
BASIN, KENTUCKY USING MICROBIAL SOURCE TRACKING AND  
FECAL INDICATOR BACTERIA, 2013-2014

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This study evaluated general, human, ruminant (cattle, sheep, deer), canine, and waterfowl genetic markers and found the primary source of fecal contamination in the North Fork Little River (NFLR) was human waste and the main source in the South Fork Little River (SFLR), particularly the headwaters, was ruminant-animal waste. In 2009, the Kentucky Energy and Environment Cabinet—Division of Water developed a pathogen Total Maximum Daily Load for the Little River Basin including the NFLR and the SFLR. From 2013 to 2014, the U.S. Geological Survey (USGS), in cooperation with the Little River Consortium, used *E. coli* concentrations to assess fecal contamination and microbial source tracking (MST) to isolate sources of fecal contamination in the Little River basin near Hopkinsville, Kentucky. Water and fluvial sediment samples were collected at 19 sites and MST samples were collected at 10 of these sites. Thirty-four percent of water samples were above the U.S. Environmental Protection Agency statistical threshold value of 410 col/100 mL for *E. coli*. Lower densities of *E. coli* in fluvial sediments were found more in the headwaters than downstream. The human-associated marker (qHF183) was found above the detection limit in 100 percent of samples from the NFLR basin compared to 15 percent in the SFLR basin. The median ruminant-associated marker (BoBac) was up to three-fold greater in the SFLR headwaters compared to the NFLR. The results of this study will help resource managers prioritize areas where waste management and remediation are the most necessary due to high levels of fecal contamination.

## NOTES

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## KENTUCKY'S SOURCE WATER PROTECTION ASSISTANCE PROGRAM

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The Kentucky Division of Water's (KDOW) Wellhead Protection Program developed the Source Water Protection Assistance Program (SWPAP) to help communities and water systems implement source water protection strategies. As part of the source water and wellhead protection planning processes, water systems must formulate management strategies that will prevent potential contaminant sources from impacting their water supply. This program is one option water systems and local governments can utilize to research and implement source water protection measures specific to their protection area(s). These projects may require Public Water Systems (PWSs) or government entities to work with local landowners, local media, watershed groups, and many others to achieve their source water protection goals.

In a 2008 memo, the US EPA clarified requirements related to using Drinking Water State Revolving Fund (DWSRF) set aside for source water protection projects. This clarification allowed for funds to be contracted to PWSs for source water protection activities. Funding can support various strategies, but do have some limitations with regards to infrastructure and construction projects. KDOW utilized these DWSRF set-asides to implement its SWPAP, which was modeled after existing programs in other states.

Multi-faceted source water protection implementation plans that include both physical management strategies and public involvement are the most successful. Outreach events including meetings, workshops, and public service announcements are an effective way to engage the citizens and local governments in source water protection. With this in mind, project applicants were encouraged to include public education and outreach strategies as part of their applications. Also, it is a common misconception that protecting drinking water is solely the responsibility of the water system. However, in most protection zones the system has little, if any, regulatory control over activities occurring inside these areas. Because of this common lack of regulatory control and the variable nature of protection areas, a wide variety of projects are encouraged. Approved projects have included several protection activities such as plugging unused water wells, best management practice implementation, developing public service announcements about drinking water, and monitoring contamination near a PWS well field.

## NOTES

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SOURCE WATER PROTECTION ASSISTANCE PROGRAM  
TRIMBLE COUNTY WATER DISTRICT #1 CUSTOMER OUTREACH PROGRAM

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The Trimble County Water District takes pride in keeping its water at the highest quality possible. We are working with the Kentuckiana Planning and Development Agency (KIPDA) and the Division of Water (DOW) to bring attention to possible threats to our watershed and wellhead protection area. Together, we are educating the public and the homeowners on how to keep our source water clean and to help protect all of the intake points down stream.

More than half of the employees of the water district are consumers of our product. We all want clean water to drink, shower and use for ourselves, as well as for the rest of the community that we serve. Source water protection is a way to prevent drinking water from becoming polluted by managing possible sources of contamination in the area which supplies water to a public well. Everyone has an important part to play in protecting drinking water wells and springs – today and for the future. Source water protection is a community effort. The water district has a very low budget for education of consumers, less than \$1,000. However in our Wellhead Protection Area we have three customers that are very high potential hazards to our source water (a power plant, a rock quarry, and a farm). We hope that by educating our customers, and taking steps to keep the source water clean, we will save money and time by not having to treat the water to stay in compliance as well as ensuring a clean source of drinking water for many future generations.

We are implementing educational outreach to solve the information gap between the water district and our customers who not only live in the wellhead area but also those who might simply be driving through the area. Many customers do not know where the wellhead protection area is, let alone what it is or what it means to them. The district found that they also were not aware that the system's source is groundwater aquifers, and not the Ohio River. By providing education, we want to teach them about the location of the protection area, the proper storage and handling of threats in the area, and how to report something if they notice a new threat.

The Water district is working to solve the information gap in several ways. Our first step was to hold homeowner outreach sessions in the fall and the spring. These

sessions were basically to let the customers know that we are working to keep our source water clean. We provided them with a list of ways to help us including proper ways to store chemicals and proper fertilizing practices. The second step in outreach will be during our annual customer appreciation day, where we bring in approximately 300 of our customers, feed them, and give out door prizes. We set up a booth and pass out information and get to speak directly with them about the importance of keeping our source water clean.

So far the reception of materials has been greater than expected. During our homeowner outreach sessions the people that have been approached were very happy that we took the time to come out and explain to them about our Wellhead protection area, and what they can do to help us. We are very optimistic that we will see the same result when we open up discussion with the public during our customer appreciation day.

When our 2016 customer appreciation day in September is over, we hope that our customers will be better educated about the watershed and Wellhead Protection Area, their source water, and how we can keep it at a high quality with their help. The Source Water Protection Assistance Program (SWPAP) is a great way for small systems to afford source water protection strategies. There are several other different activities besides education and outreach that you are able to apply to the program for. Trimble County would highly recommend that if you have the opportunity to apply for the next round of SWPAP funding that you take an opportunity. We found that working with the Source Water Protection staff and the SWPAP program was very beneficial to our organization.

## KENTUCKY RURAL WATER ASSOCIATION AND WATER UTILITIES' EFFORTS IN PROTECTING DRINKING WATER SOURCES - CASE STUDIES

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The Kentucky Rural Water Association is in its twenty-sixth year of a program designed to assist communities served by public water systems with highly or moderately susceptible drinking water sources to reduce or eliminate the potential risks to drinking water supplies through the development of Source Water Protection Plans and providing assistance to entities for the implementation of contaminant preventative measures. Kentucky was one of the first states to be funded for this program through National Rural Water Association since our state had already been working on issues related to Source Water Protection. The Commonwealth of Kentucky instituted its source water assessment and protection program in 1990, when the legislature passed a statute requiring long-range county water supply plans. The statute had as its goal the development of long-range water-supply plans for each county and its municipalities and public water systems. In 1999 all counties in the State of Kentucky had received final approval from DOW for their County Water Supply Plans.

The purposes of water supply plans were to evaluate the situation in each of Kentucky's 120 counties so that they could prepare to provide adequate water at all times in the foreseeable future. Through the planning process, each county will know the adequacy and security of current supplies, make recommendations to protect them, create contingency plans, and develop alternatives where additional or alternate supplies will be needed during the next 20 years.

With respect to source water assessment and protection, the regulation specifically requires public participation, delineation of source water watersheds and recharge areas for each public water supply source, a contaminant source inventory with relative susceptibility (risk) assessment, and recommendations for protection.

Drinking water, which may be from ground water, surface water, or both, is vulnerable to being contaminated. If the drinking water source is not protected, contamination can cause a community significant expense as well as put people's health in danger. Cleaning up contamination or finding a new source of drinking water is complicated, costly, and sometimes impossible.

Preventing drinking water contamination at the source makes sense:

- good public health sense
- good economic sense
- good environmental sense

All Counties now have an approved County Water Supply Plan and a Source Water Assessment. It is the intent of the Source Water Protection Assessment Program to help Water Systems implement and comply with the above plans and formulate the next step of development of a Source Water Protection Plan. Systems with impaired sources have immediate concerns, however all water systems need to be striving to protect their source for the long term sustainability of all water systems in Kentucky.

In 2015, Kentucky had about 360 Community Water Systems operating; this is quite different than 30 years ago when we had over 860 operating Community Water Systems. Groundwater currently provides 10% of the total water used by our communities that encompasses 46 active groundwater treatment plants in Kentucky. These groundwater systems are quite aware of the need to protect their critical natural resource. Kentucky is one of only a few states that require Community Groundwater Systems to develop and maintain an active Wellhead Protection Planning Program. Two Community Water Systems (City of Augusta, Western Lewis-Rectorville Water District) will be highlighted to show how their good work over the years has protected their groundwater resource for future generations.

## SOURCE WATER PROTECTION FOR THE RIVERBANK FILTRATION SYSTEM

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Since 1860, the Louisville Water Company has provided high-quality drinking water to the community. Today, LWC provides water to about 850,000 people in the Louisville Metro Area, and parts of Bullitt, Nelson, Oldham, Shelby, and Spencer counties. LWC also operates treatment facilities in Southern Indiana and Fort Knox, Kentucky.

At the B.E. Payne Water Treatment Plant in northeast Jefferson County, LWC relies on a “green” supply of water from Riverbank Filtration (RBF) wells. RBF uses the sands and gravels found deep in the Ohio River Valley as a natural filter. The RBF collector wells move the water to a tunnel, where it is pumped for treatment. Because the water is naturally filtered, it requires less treatment. The process eliminates taste and odor issues, provides an additional barrier for pathogen removal and creates a stable water temperature of around 55-degrees, resulting in fewer main breaks in the distribution system.

The area around the collector wells is the Wellhead Protection Area (WHPA), and was determined by groundwater modeling for travel time for potential contaminants. A Wellhead Protection Plan (WHPP) for the RBF System was created to eliminate, reduce and manage contaminant sources in the WHPA.

The WHPA is located in a well-developed area of Jefferson County. There are over 160 businesses that include retail fuel facilities, marinas on the Ohio River or its tributaries, 20-plus agricultural properties, more than a dozen government properties, including sewer pump stations, and a small bridge project. These are well regulated and well documented. However, there are over 900 residential properties, many of which have domestic wells, septic tanks and/or underground heating oil tanks, which aren’t well documented and are mostly unregulated. Because of the age of some of the residential properties, some owners are unaware that they have domestic wells, septic tanks or heating oil tanks on their property.

The Source Water Protection Assistance Program (SWPAP) from the Kentucky Division of Water (KDOW) has been a valuable tool in the management of the WHPA and protection of the groundwater source. The SWPAP has provided resources to research the undocumented potential contaminant sources and communicate with the property owners. The SWPAP and KDOW personnel have helped LWC develop a plan to address domestic wells, septic tanks and underground heating oil tanks, and implement the plan in the WHPA.



# CONTROLLED DRAINAGE IN WESTERN KENTUCKY: MITIGATING WATER STRESS AND REDUCING NUTRIENT LOSS TO SURFACE WATERS IN GRAIN CROP PRODUCTION

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Water is often a limiting factor for grain crop yield in Kentucky. This study explored controlled drainage (CD) of field tiles as an option for increasing water availability to these crops. In this system, CD structures were installed into fields where subsurface tile drainage already existed. Gates were taken in and out of these structures for management of the water table in the field based on timing of rainfall and time of year. Water conservation through CD was hypothesized to alleviate water stress, increase nutrient availability, decrease winter nutrient loss, and increase yields of Kentucky grain crops. No scientific research had been done to determine the effect of CD on crop yield, soil nutrient levels, nutrient loss through drainage water, or water availability in Kentucky. To determine these effects we chose two fields in Muhlenberg county Kentucky for their similarity in soil type (Belknap silt loam), size, and slope. The cooperators employ the same management practices in each field for a rotation of corn, wheat, double crop soybeans. The CD structures installed at the main tile outlets were closed for one field and left open for the second field. Yield was determined for each field by hand harvesting from six locations across the field and by whole-field yield estimates taken by the producer. Soil samples were taken immediately following hand harvest of double crop soybeans in 2015. To determine the amount of nutrient loss from the agricultural field, grab samples were taken in May of 2014 and August of 2015. We had intended to collect water quality samples once a month; unfortunately there was very little rainfall at the site from July to October 2015. Additionally our cooperator asked that we no longer collect water quality data from this site. The two samples collected were analyzed for nitrate as N, nitrite as N, orthophosphates as P, phosphate calc analyte, total phosphorous, total Kjeldahl nitrogen, and total nitrogen calc analyte by a nationally accredited analytics laboratory (McCoy and McCoy Laboratories; Madisonville, KY). Although, we will be unable to complete the water quality portion of this project, it still has potential to greatly reduce non-point source pollution by encouraging grain crop producers to implement controlled drainage technology for increases in yield and profitability.





COMPARING SIMULATED SOIL PROPERTIES TO FIELD DERIVED VALUES IN  
FORESTED AND GRASSLAND CATENAS OF MLRA 120

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Hydrologic models often incorporate soil properties, including field capacity, total porosity, available water holding capacity, soil thickness, and saturated hydraulic conductivity. Soil carbon content, which is expected to increase under soil-health management practices that include conservation tillage and cover crops, has been linked to hydrologic properties that include soil-water retention and hydraulic conductivity. Obtaining soil hydrologic property data can be costly and cumbersome. This study utilizes equation-derived estimates for hydrologic properties from Rawls et al. (2006) and validates them using field and laboratory data from the Shawnee Hills Loess Catena Studies Project. The Shawnee Hills Loess Catena Studies Project consists of six catenas in MLRA 120. The comparisons between the equation-derived estimates and field obtained values showed no significant differences for field capacity (FC), permanent wilting point (PWP) and saturated hydraulic conductivity (Ksat) in “A” horizons according to the Wilcoxon-signed rank test. In contrast, soil properties for the “B” horizons of the same soils showed statistically significant differences for each property under at least one vegetation type. This suggests that the equation would need to be modified to have a better correlation to simulate plant available water throughout the soil profile. These results will later be used to inform a hydrological model with estimated soil properties that reflect changes in soil carbon as a function of land management.



## SOIL INFILTRATION RATES IN SIX AGRICULTURAL FIELDS OF WESTERN KENTUCKY

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The evaluation of infiltration rates is vital for calculation of surface runoff in order to reduce the risk of pollutants in the environment and to proficiently apply water and fertilizers for a crop's benefit. The objectives of this study were (1) to assess the impacts of six agroecosystems on infiltration rates; (2) to observe the temporal variability of soil infiltration rates under various seasons (fall-spring-summer-fall); and (3) to quantify the relationships between soil infiltration rates with other properties including soil organic carbon (SOC), macroaggregates, and bulk density. The study was held in Calloway County of western Kentucky. The ecosystems consisted of no-till corn, conventional tillage soybeans, conventional tillage tobacco, organically grown vegetables, woodland, and prairie. All of the soils used in this study have a silt loam texture. The infiltration rates were measured using a single ring infiltrometer. Soil organic carbon (SOC) was measured using the loss on ignition (LOI) method. Macroaggregates and bulk density were determined using wet sieving and ring methods, respectively. The data were statistically analyzed using ANOVA followed by the least significant difference (LSD) test at  $\alpha$  5%. The results show that organic farming and the wooded system have the highest infiltration rates (35.2 cm/hr and 37.7 cm/hr) and the lowest bulk densities (1.0 g/cm<sup>3</sup> and 1.1 g/cm<sup>3</sup>), respectively. The relationship between infiltration rate and organic carbon, bulk density, macroporosity, and total porosity was  $r^2=.99$ ,  $r^2=.60$ ,  $r^2=.69$ , and  $r^2=.66$ . The no-till corn field had a higher bulk density than the conventionally tilled systems (1.7 g/cm<sup>3</sup>) and lower total porosity of 37%, but had a higher infiltration rate than the conventionally tilled systems at approximately 12.9 cm/hr. The organic system had a 60% lower bulk density than the no-till corn, which were the highest and lowest bulk densities, respectively. The most dramatic differences amongst infiltration rate occurred in the wooded system which increased from 36.3 cm/hr in the fall of 2013 to 39.3 cm/hr in the summer of 2014. Amongst the averages, however, which range from 4.3 cm/hr to 37.7 cm/hr, the seasonal changes were not significant.

# NOTES

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INVESTIGATION OF THE CLIMATE MODELING FACTORS IMPACTING  
FORECASTED STREAMFLOW FOR CENTRAL KENTUCKY

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The present investigation quantifies the relative importance of climate modeling factors and chosen response variables upon controlling the variance of streamflow forecasted with global circulation model projections. We designed an experiment that varied climate modeling factors (including global circulation model type, project phase, emission scenario, downscaling method, and bias correction) as well as the streamflow response variable (including the forecasted streamflow and the percent difference in forecast and hindcast streamflow predictions). Publically available global circulation model results and the Soil Water Assessment Tool (SWAT) were used to predict streamflow for the South Elkhorn Creek watershed, Kentucky, USA. 113 SWAT model runs were used and analyzed on a monthly basis using analysis of variance. Analysis of variance results indicate that the prediction of the change in streamflow, when considering hindcast simulations, is a function of global circulation model type, climate model project phase, and downscaling approach. The prediction of forecasted streamflow, when not subtracting the hindcast simulation, is a function of global circulation model type, project phase, downscaling method, emission scenario, and bias correction method. Our results suggest that some uncertainty associated with the parameterization in the individual global circulation models is also reduced when

subtracting the hindcast simulations. Overall, the prediction of the change in streamflow is more certain because we have accounted for the uncertainty introduced during coupling of the global circulation models to the hydrologic model by subtracting the hindcast streamflow. Moreover, when predicting the mean and variance of streamflow, use of excessive numbers of realizations appears unneeded for the study system, so long as the ensemble design is well balanced. Results suggest an increase in the average annual temperature, precipitation and streamflow by 3.0°C, 9.65% and 11.2%, respectively, for the future period 2046 to 2065 as compared to the hindcast period 1981 to 2000.

TOWARD RAPID DETECTION OF *Phytophthora cinnamomi*  
IN APPALACHIAN STREAMS

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The Appalachian region is home to some of the most biodiverse temperate forests in the world. These forests have long been threatened by poorly managed anthropogenic pressures. Some of the most destructive forces to have struck Appalachia's forests have been invasive pests and pathogens. For example, the introduction of chestnut blight (*Cryphonectria parasitica*) in the early part of the 20<sup>th</sup> century resulted in the functional extirpation of American chestnut (*Castanea dentata*) from the eastern forests. Another pathogen of particular interest across the US and throughout the world is *Phytophthora cinnamomi*. This oomycete pathogen infects oaks (*Quercus* spp.), chestnuts, and shortleaf pine (*Pinus echinata*), among other host species; thus, efforts to restore species of concern (e.g., shortleaf pine and American chestnut) must carefully consider the distribution of *P. cinnamomi*.

Conventionally, *P. cinnamomi* is detected using a baiting and culturing technique. Susceptible host material (e.g., rhododendron leaves) is placed in a stream or soil sample for several days to permit infection by *P. cinnamomi* zoospores. Lesions are excised from bait material and transferred to be cultured on medium selective for *Phytophthora* species. If successful, *P. cinnamomi* cultures are isolated on growth medium and can be identified by morphological characteristics of chlamydospores and zoospores. Alternatively, DNA can be extracted from isolates, amplified by polymerase chain reaction (PCR), and sequenced to confirm identity. Unfortunately, this method is time-consuming, with both the baiting and culturing steps taking multiple days.

This project was initiated to develop a sensitive and rapid assay to detect *Phytophthora cinnamomi* from streams. Because *Phytophthora* spp. produce motile zoospores which swim toward potential host species, streams have been recognized as an important conduit for the spread and detection of *Phytophthora* spp. As a first step, *Phytophthora cinnamomi* was baited and cultured from soil in Robinson Forest, and a culture collection was established at the University of Kentucky. These cultures will serve as a positive control for ongoing DNA analyses. Additionally, weekly streamwater samples have been collected from four watersheds in Robinson Forest since September 2015. These samples have been filtered through 3  $\mu$ m pore size filters, and filters frozen for further analysis.

This project is still in progress. DNA from cultures isolated from Robinson Forest is being sequenced to confirm *P. cinnamomi* identity. Subsequently, primer and probe sequences from established studies will be validated by PCR of DNA extracted from these isolates. Finally, this PCR method will be applied to DNA extracted from filtered streamwater samples to confirm *P. cinnamomi* presence.

After this method is validated for detection of *P. cinnamomi* from streams, the method will be suitable for characterizing *P. cinnamomi* distribution in the region. Paired with environmental data, detection data can be analyzed to indicate environmental conditions that influence *P. cinnamomi* distribution. While characterizing *P. cinnamomi* distribution, *P. cinnamomi* will be isolated from additional samples, and isolates added to this collection, which will permit analysis of population genetic structure in Appalachian strains. Also, once the method is validated for detection of *P. cinnamomi*, it will likely be applicable with only slight adjustment to detection of *P. ramorum*, the invasive pathogen causing sudden oak death on the West Coast.



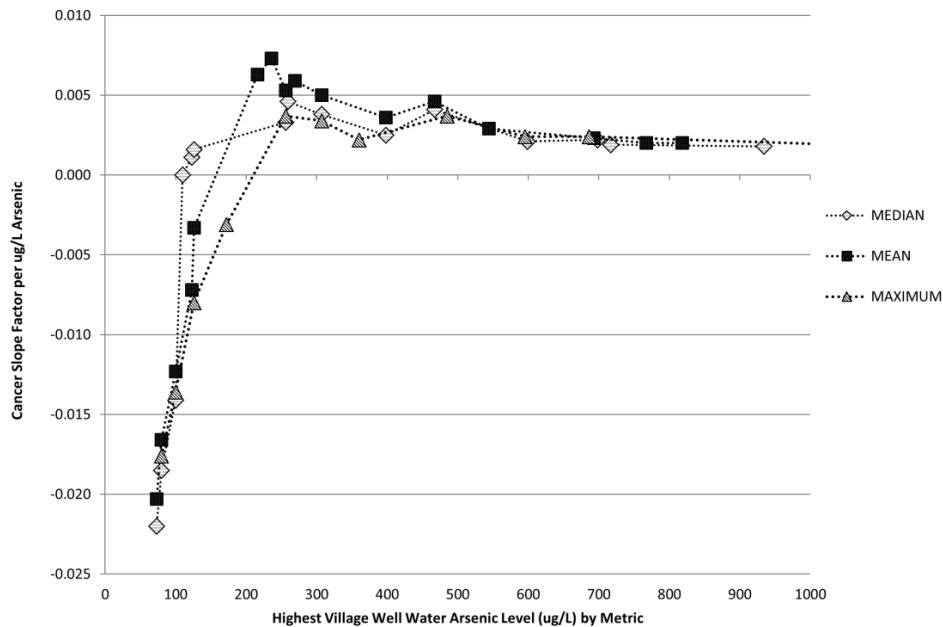
## ARSENIC IN WATER AND RISK OF CANCER IN HUMANS

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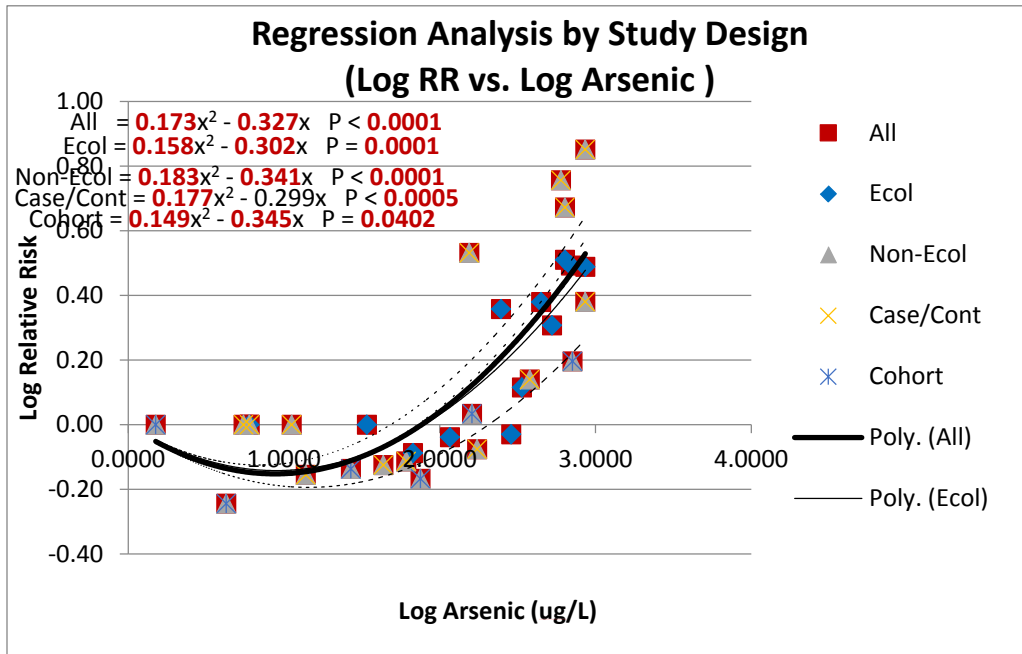
**Background:** High levels of arsenic (200-1,000 ug/L) in drinking water are well known to cause human bladder and lung cancers. Previous analyses have presented linear extrapolations of risk at high exposure levels and assumed that they represent the risks at low levels of arsenic exposure (3-100 ug/L).

**Method:** We have reviewed the world's literature on epidemiologic studies of cancers associated with the ingestion of drinking waters containing levels of arsenic that range from low levels toward high levels.

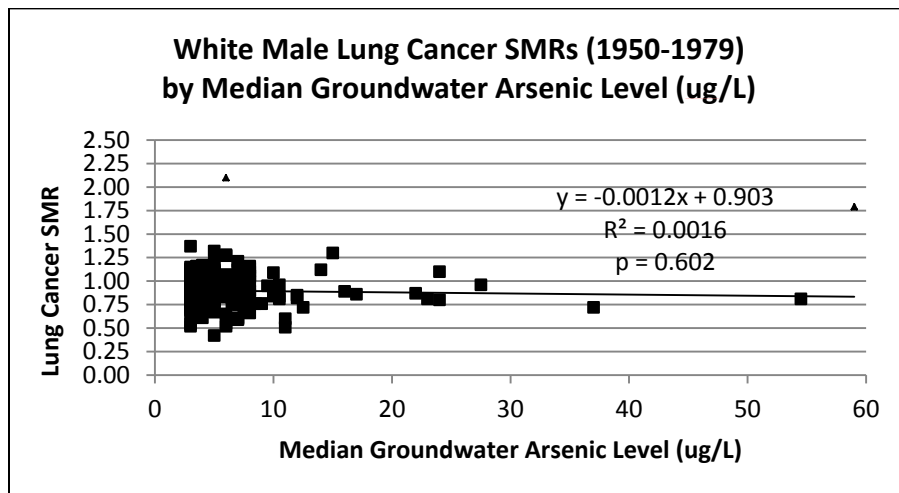
**Findings:** Analyses confirm the risks at high levels but not the prediction of increased risks at low levels. The primary study underlying regulatory assessments has been the study of bladder and lung cancers in the Blackfoot-disease endemic area of Southwest Taiwan. Re- analysis of those data, separating out the villages with mixed high and low exposure, shows no increased risk for exposures below 150 ug/L for both bladder cancer and lung cancer.



Meta-regression of the world's literature on lung cancer found no increased risk below 135 ug/L.



Looking only at areas with no high median arsenic levels (i.e., 3-59 ug/L), no increased risks of either lung cancer or male bladder cancer were seen.



The strength of the evidence was sufficient to reject the magnitude of risk predicted by regulatory analyses.

Conclusion: Drinking water containing low levels of arsenic (< 100 ug/L) are not a causal factor in the development of human bladder or lung cancers, even though arsenic at high levels does cause these cancers.

EXAMINING THE IMPACTS OF VALLEY FILLS IN STREAM ECOSYSTEMS  
ON AMPHIBIAN AND AQUATIC INSECT COMMUNITIES IN  
SOUTHEASTERN KENTUCKY

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Valley fills due to mountaintop-removal mining bury headwater streams and affect downstream water quality and ecological function. Past studies have focused on generally one taxonomic group or purely habitat and water quality effects. The effects of valley fills on streams was approached from an ecosystem perspective by evaluating water quality and habitat, sensitive taxa, and the accumulation of contaminants in the environment and sampled taxa. Because of their relatively high abundance and complex life cycles, stream salamanders and aquatic insects are important trophic links and serve a critical role in transferring energy. Despite this importance, little research has examined their community structure simultaneously in aquatic ecosystems. In this study we evaluated stream salamander and aquatic insect communities, metal concentrations in water and tissue, and stream quality and habitat in 10 streams affected by valley fills (VFS) and 5 reference streams (RS) located in natural areas within 15 km of VFS.

Within each stream, a 100-m reach was sampled for the above stated parameters. Salamander sampling consisted of three sampling periods on a monthly basis, April–June 2015. Aquatic insect sampling consisted of a single sampling event in March 2015, with water and habitat sampling occurring during each aquatic insect and salamander sampling event. The accumulation of selenium was measured in stream water samples June 2015 and via a non-lethal tail clipping procedure in sampled adult salamanders. This study captured 529 individual salamanders of eight species, with captures in RS (n=335) higher than in sampled VFS (n=194). A total of 1,034 aquatic insects representing 8 orders and 37 families were collected, and captures were higher for RS (n=597) than VFS (n=447). Abundance, richness, detection probability, and other community metrics of sampled salamander and aquatic insects were significantly higher in RS than VFS. The reduced abundance and diversity of salamander and aquatic insects may be due to a host of interacting habitat and environmental variables observed at VFS. Several habitat and environmental factors significantly differed between treatments including an increased presence of silt, specific conductance 21 times higher in VFS than RS sites, and an increased selenium concentration in water and tissue in VFS likely leading to the reduced communities of salamanders and aquatic insects observed. By approaching the issue of stream health through multiple abiotic factors and taxa, this study provides critical information of the effects of valley fills on stream quality and function.

# NOTES

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## THE WETLANDS PRIORITIZATION TOOL

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The Kentucky Division of Water has an approved Wetlands Program Plan. The plan calls for the development of assessment tools to bring wetlands into the process of monitoring and assessing the condition of the state's waters. The ultimate purpose of monitoring and assessing is to inform decision-making to better protect, maintain, and restore water quality in the state. To date, the primary achievement of the Wetlands Program Plan is the development of the Kentucky Wetlands Rapid Assessment Method (KY-WRAM). KY-WRAM has value as a rapid wetland assessment method in itself, but it was originally created to assist CWA § 401 and 404 regulatory decisions. Currently, wetland impacts in Kentucky are mitigated at a 2:1 ratio, which does not take into account the quality or type of wetland impacted, only the wetland acreage. Because of severe historic wetland loss, it is prudent that we protect wetlands from further degradation and loss, especially ones of higher quality. When impacts cannot be avoided, the ability to scale mitigation ratios based on quality is essential but requires an assessment of condition and function.

While KY-WRAM has been successful in assessing condition, it has yet to be incorporated into the decision making process. This project takes that step and will create a tool that will use data gathered by KY-WRAM and incorporate it into the decision making process, not only for § 401 and 404 regulatory decisions, but also for organizations addressing nonpoint source pollution in waterways with watershed-based plans funded through the Kentucky Nonpoint Source Pollution Control Program as authorized by Section 319(h) of the Clean Water Act.

KDOW has been implementing the Recovery Potential Screening Tool (RPT) for prioritization of watersheds for management strategies. This tool objectively scores each watershed based on user-selected social, ecological, and stressor metrics and then ranks each watershed (EPA, 2012). This project proposes to modify the RPT to be specific to prioritization of wetlands for protection or restoration. The modified tool will be called the Wetlands Prioritization Tool (WPT).

Some essential differences exist between the RPT and the proposed WPT. The RPT was designed to compare smaller watersheds within state or basin-wide areas with metrics primarily based on characteristics that are determined by land cover and use. Metrics for the RPT are calculated based primarily on large-scale, existing datasets such as the National Land Cover Database (NLCD), digital elevation model data, and the National Hydrography Datasets (NHD), etc. (EPA, 2012). The WPT will calculate scores for individual wetlands with inputs determined from KY-WRAM.

The RPT assigns metrics into one of three classes: ecological, stressor, and social metrics. While these three classes are likely appropriate for ranking wetlands for protection, potential mitigation sites need additional consideration. According to the Wetlands Evaluation Technique (Adamus et al, 1987), wetlands are evaluated by three characteristics: social significance, effectiveness, and opportunity. Social significance is the value that humans place on the wetland. Here, economic valuation is an objective measure of these metrics. Effectiveness reflects the services that the wetland currently provides. An example might be that a wetland removes (or retains) a ton of sediment a year from reaching a particular waterway. In contrast, opportunity is the potential the wetland has at full capacity. That same wetland, if between a construction development and stream might have the opportunity to remove 5 tons of sediment a year. Effectiveness and opportunity will be incorporated into the WPT. How this will be incorporated into the WPT and whether the type of wetlands scenario (protection or restoration) should change the implementation of this concept will be part of the WPT development process.

With the RPT, weighting of metrics is a user input. An important part of ranking wetlands is the quality of the wetlands under consideration. For both § 319 and 401 programs, oftentimes a particular ecosystem service may be a primary consideration. For instance, a § 319 grant recipient may be trying to address a sediment or nutrient impairment. Metrics chosen to be input into the WPT would reflect this focus, but how to weight the chosen metrics may not be obvious. For this project, we propose to do a literature review of the economic valuation of wetland ecosystem services and to use that information to inform the weighting of metrics. Using an economic valuation to weight the input metrics will assure the most value for money invested in preservation or mitigation. Also, by weighting metrics according to an economic valuation, a general knowledge of the magnitude of difference between the wetlands under consideration can be obtained for the ecosystem services they provide.

The completed WPT will move the WPP forward from assessment and monitoring to using the gathered information to inform decisions. Upon a successful pilot of the tool, KDOW will share the WPT with § 319 and 401 partners to inform their decision-making in implementing protection and mitigation projects. By considering economic valuation of ecosystem services in the weighting of input metrics, the tool will assist our partners in determining which wetlands projects will give the biggest return on investment in the quality of the state's wetlands.

#### References:

Adamus, P.R., Clairain, E.J., Jr., Smith, R.D., and Young, R.E., 1987. Wetland Evaluation Technique (WET), v. 2 of Methodology: Vicksburg, Miss., U.S. Army Corps of Engineers, Waterways Experiment Station, Operational Draft Technical Report, 206 p. + appendices.

EPA 2012. Recovery Potential Screening: Tools for comparing impaired waters restorability. USEPA. Accessed 14 April 2015. Available:

<http://water.epa.gov/lawsregs/lawsguidance/cwa/tmdl/recovery/index.cfm>

## BANKFULL OPEN CHANNEL FLOW MODEL: DEVELOPMENT AND APPLICATIONS FOR STREAM RESTORATION DESIGN

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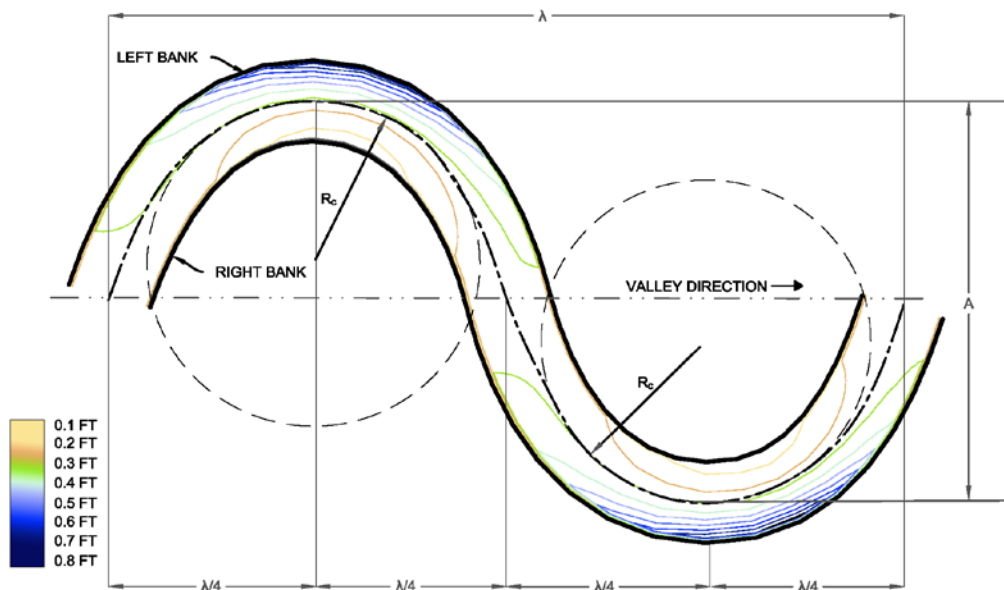
Channel straightening, a widespread practice in Kentucky and throughout the United States associated with urban development, agriculture, mining and silviculture, typically results in channel degradation, negatively impacting water quality for humans and native plant and animal species. This degradation necessitates stream restoration practices including design and construction of meander curves to provide natural form and function to the watercourse. Unfortunately, few models exist which predict accurate three-dimensional channel morphology needed for developing grading plans used for construction of meandering channels. While much research has been conducted in the fields of fluid dynamics, sediment transport, aquatic habitats and geomorphology, relatively few physically-based mathematical approaches to predict channel morphology have been developed. There is a need for efficient methods to develop continually changing channel alignments to represent many different outcomes related to construction constraints and boundary conditions.

This practical need in the industry was the motivation for the development of BANKFULL, a new computer model for optimizing design river pattern geometry based on the governing flow equations. Turbulent coherent macrostructures act as the driving force for the evolution of alluvial channel curves and associated bed topographic features including pools and riffles, and the BANKFULL model accounts for these structures in design. Parametric space curves which capture the large scale geometry of fluid motions controlled by the coherent structures are used to model the time-averaged channel bathymetry of equilibrium flows. A previously developed derivation of meander flow equations, which is quite accurate in predicting depth (i.e., bathymetry) and velocity in sand-bedded alluvial channel curves, is solved herein. This paper extends the derivation of the meander flow equations to channels with heterogeneous gravel-beds. This paper further extends the theoretical basis by accurately modeling meander planform alignment

in response to dominant scales of turbulent structure generated in the roughness layer and in meander bends. An initial solution is created from primary flow characteristics for a single meander wavelength. Then, natural variation is applied to subsequent meander wavelengths using the Mersenne Twister random number generator coupled with the clock randomizer and then Box Meuller transformation to obtain a normally distributed set of pools/meanders to cover the entire valley fall line, with first-order continuity at each splice.

The model predicts three-dimensional river geometry and two-dimensional velocity patterns accurately and is useful for design of stream restoration projects. Figure 1 below shows model results for one meander wavelength of a real-world model application.  $R_c$ , or radius of curvature, changes continuously along the channel centerline, a parametric space curve defined with a series of connected Bezier curves. Typical meander wavelength ( $\lambda$ ) and amplitude ( $A$ ) are defined based on sine-generated curve relationships observed and described for meander curves in alluvial channels, then varied from one meander wavelength to the next using a range of natural variability. Channel morphology, described using depth contours in Figure 1, varies based on the solution of the meander flow equations with curvature defined precisely at every point along the curve.

Two model applications are presented in this study, one for an existing reach as model validation and one for a design reach. Useful model output includes 3-dimensional channel geometry as shown in Figure 1 for use in other design software (e.g., AutoCAD) and hydraulic results.



**Figure 1. Three-dimensional Morphology Output from the BANKFULL Model Shown with Depth Contours**



## USING STREAM RESTORATION FOR POLLUTION REDUCTION

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Sediment is the number one pollutant or cause of impairment in Kentucky streams. Excess sediment impairs habitat and water quality, and also carries nutrients into the stream. Nutrients such as phosphorus and nitrogen are the third leading cause of impairment in Kentucky streams. Often, excess sediment loads are caused by the erosion of unstable banks and channels. The proper restoration of eroding stream reaches can dramatically reduce sedimentation of a system as well as reduce the concentration of phosphorus and nitrogen in the streams.

Working with the Kentucky Department of Fish and Wildlife Resources, Stantec has designed and helped implement various stream restoration projects throughout the state of Kentucky. The Elm Fork and Minors Creek Restoration Project was designed to improve the aquatic habitat in the streams while also minimizing the sediment production from the banks by reducing the stress and erosional forces on the system. Prior to restoration, the stream reaches were overwhelmed with high shear stresses and high banks, resulting in heavy sedimentation of the habitat and stream system. Steep flow gradients and reduced floodplain access contributed to the high shear stress and erosion of sediment.

The project, located on the Kleber WMA property in Owen County Kentucky, incorporates Priority I and II design techniques and includes various riffle forms, various native substrates, deep pool habitat, groundwater dams, and oxbow wetlands/depression areas. The restored stream reaches were designed and constructed to be self-sustaining with minimal erosion as well as provide an array of ecological opportunities including varying flow velocities and depths, various substrates and vegetation, and strong groundwater interaction. Root wads and other woody debris generated from accessing the streams were put back into the site through in-stream structures to hold grade, reduce erosion, provide natural habitat features and varied substrates in the channel. The rock used in the constructed riffles consisted of native material harvested on site or mined on an adjacent property. The result is a fully functioning system of diverse riffle and pool features that support and enhance the stream both ecologically and hydraulically. Significant improvement in sediment impairment compared to the pre-construction conditions was observed within the first year following the restoration. Progress will continue to be monitored as vegetation on the banks and riparian area matures.

*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 over 10 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.

KDFWR HATCHERY CREEK STREAM AND WETLANDS RESTORATION  
PROJECT – A UNIQUE OPPORTUNITY TO MAXIMIZE TROUT HABITAT,  
CREATE RECREATIONAL OPPORTUNITIES  
AND PROVIDE MITIGATION CREDITS: PLANNING, DESIGN

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The KDFWR Hatchery Creek Stream and Wetlands Restoration Project was completed in December 2015. It was a unique opportunity to utilize the latest stream restoration techniques to maximize trout habitat, create recreational fishing opportunities for the citizens of Kentucky, and provide mitigation credits for the KDFWR Wetland and Stream Mitigation Program.

The project is located immediately downstream of the U.S. Fish & Wildlife Wolf Creek National Fish Hatchery at Lake Cumberland's Wolf Creek Dam in Jamestown, Kentucky. The project extended an existing 400 foot long channel, which is the outflow from the hatchery, to create approximately 6,000 feet of trout stream that flows into the Cumberland River.

In an effort to maximize habitat and create a sustainable trout population, the project was designed to provide a variety of habitat for all life stages of trout, especially spawning/egg laying habitat. It included a variety of stream types including A, B, C & DA channels. This project has several unique aspects not typical to natural channel design projects in Kentucky: a constant flow of approximately 35 cubic feet per second (which is approximately 70% of the upstream bankfull flow), a fish migration barrier, and the need to maintain imported spawning gravels from being washed away during flood events. In order to maximize the habitat and recreational features the design team included aquatic biologists, engineers, researchers, and avid fishermen.

This talk will focus on the planning, design and construction of this project under a design/build format. In particular the habitat features will be discussed in detail including the stream type and habitat type selection process and how they relate to the various trout life stages.

*About the Speaker:* Oakes Routt, P.E. is a Stream Restoration Construction Manager with Stantec who has been working on stream restoration projects the last eight years across the United States. He has a broad range of experience in Ecological Restoration including the use of natural channel design, stream assessment and restoration, and watershed assessment. Oakes holds Bachelors and Masters of Engineering degrees from the University of Kentucky.

*About the Speaker:* Eric Dawalt, P.E. serves as the Project Manager for the EcoGro/Ridgewater Team, which designs and builds projects to solve stream and stormwater problems. He is a Professional Engineer with over 16 years of experience in the design, construction, monitoring, and research of stream and wetlands restoration projects. Eric holds Bachelors and Masters of Engineering degrees from the University of Kentucky.

*About the Co-Author:* A graduate of Centre College (2001, Danville, KY) and the University of Kentucky (2003), Rob Lewis, P.E. has worked for Kentucky Department of Fish and Wildlife Resources Wetland and Stream Mitigation Program since 2009. The program oversees an in-lieu-fee program for wetland and stream impacts requiring CWA 404 and 401 permits throughout Kentucky. As the program's engineer, Rob works with consultants and contractors to review and oversee design and construction.

*About the Co-author:* George Athanasakes, P.E. serves as the Ecosystem Restoration Services Leader for Stantec. He has a broad range of experience in Ecological Restoration including the use of natural channel design, stream and wetland restoration, watershed master planning and dam removal. George also led the development of the RIVERMorph Stream Restoration Software and is responsible for software content, new releases and training. George holds Bachelors of Science and Masters of Engineering degrees from the University of Louisville.

KDFWR HATCHERY CREEK STREAM AND WETLANDS RESTORATION  
PROJECT – A UNIQUE OPPORTUNITY TO MAXIMIZE TROUT HABITAT,  
CREATE RECREATIONAL OPPORTUNITIES AND  
PROVIDE MITIGATION CREDITS: CONSTRUCTION & LESSONS LEARNED

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This talk will focus on the planning, design and construction of this project under a design/build format. Project implementation will be discussed including the coordination with numerous stakeholders, construction methods utilized, and lessons learned.

*About the Speaker:* Oakes Routt, P.E. is a Stream Restoration Construction Manager with Stantec who has been working on stream restoration projects the last eight years across the United States. He has a broad range of experience in Ecological Restoration including the use of natural channel design, stream assessment and restoration, and watershed assessment. Oakes holds Bachelors and Masters of Engineering degrees from the University of Kentucky.

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FECAL COLIFORMS AND *E. coli* LEVELS IN SURFACE WATERS  
FROM McCONNELL SPRINGS, 2011-2015

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Since the completion in 2009 of the McConnell Springs Stormwater Quality Wetland Pond by the Lexington-Fayette Urban County Government (LFUCG), the system has been monitored by the LFUCG Division of Water Quality to determine the effectiveness of pollutant reduction. While on site, additional surface water quality monitoring was performed on McConnell Springs itself. McConnell Springs is located in northwest Lexington, KY. The spring system consists of the Blue Hole, where water emerges from an underground channel and flows for approximately 38 m (125 ft.) then disappears underground; the Cave, an open fracture containing water; the Boils, where water emerges again as an artesian spring and flows for approximately 152 m (500 ft.); and the Final Sink, the point where water disappears underground again. The water reappears at Preston's Cave and flows into Wolf Run Creek, which empties into the Town Branch of Elkhorn Creek. Water quality monitoring included the Blue Hole, Cave, Boils, and Final Sink. A total of 28 sampling events were conducted by the LFUCG Division of Water Quality at McConnell Springs in 2011-2015. On-site measurements included: temperature, pH, dissolved oxygen (DO), conductivity, and total dissolved solids (TDS). Additional analysis included: alkalinity, hardness, carbonaceous biological oxygen demand (CBOD<sub>5</sub>), total suspended solids (TSS), total ammonia, nitrate, nitrite, total phosphorus, and orthophosphates. Bacterial enumeration of fecal coliforms, *E. coli*, and total coliforms were conducted using the IDEXX Colilert-18 and Quanti-Tray/2000 method.

Overall pH values at McConnell Springs remained consistent from 2011 to 2015. DO concentrations remained low, with the Blue Hole having the lowest DO and the Final Sink with the highest DO. Average DO concentrations were 4.49, 4.62, 3.90, 4.81, and 4.39 mg/L for 2011-2015, respectively. Conductivity was fairly constant, although an increase was observed in 2013. TDS, total alkalinity, total hardness, and total phosphorous remained constant during the monitoring period. TSS levels were fairly low throughout McConnell Springs. Average TSS concentrations in 2011-2015 for the Blue Hole, Cave, Boils, and Final Sink were 7, 17, 8, 12 mg/L, respectively. Overall ammonia levels were low in 2011-2013, but increases were observed during the February and June 2014 collections. Average nitrate concentrations were highest in 2011 (6.45 mg/L), but decreased in 2012-2015 (2.63, 2.51, 2.58, 2.27 mg/L). Average detectable nitrite concentrations ranged from 0.019 mg/L (2013 and 2015) to 0.030 mg/L (2011), but it was less detected in 2015. Orthophosphate concentrations slightly decreased over time.

Fecal coliforms and *E. coli* were detected in McConnell Springs during the monitoring period. In 2011, Dr. Gail Brion (UK-ERTL) reported contamination by fecal material in McConnell Springs. Dr. Brion proposed that the cold underground flow may

retard fecal aging and the cold, dark conditions repressed indigenous bacterial growth while enhancing introduced coliforms, thus indicating that the source is not local and may be some distance from the collection site. Overall, microbial counts were most elevated in 2013. At the Blue Hole, fecal coliform geometric means for 2011 to 2015 were 719, 249, 742, 169, and 425 MPN/100 mL, respectively. Whereas, geometric means for *E. coli* at the Blue Hole were 290, 435, 620, 560, and 428 MPN/100 mL. Throughout the study period, bacterial enumerations tended to be elevated in June and October. Similar trends were observed in Dr. Brion's 2010 data. The highest bacterial counts were obtained October 18, 2013 at the Blue Hole, Boils, and Final Sink. Fecal coliform counts for all three locations were: 5371, 6086, and 6766 MPN/100 mL, respectively. While *E. coli* counts were 7328, 8361, and 6127 MPN/100 mL, respectively.

Most of the water quality results observed were consistent with levels found in artesian springs. Fecal contamination has been a historic problem at McConnell Springs. Of interest are the increases in fecal coliforms and *E. coli* counts in June and October and will be followed closely. Additional source tracking is required to reduce bacterial counts and pinpoint the cause of the seasonal fluctuations. LFUCG will continue to monitor water quality regularly. In particular, close monitoring of ammonia, nitrates, total phosphorous and bacterial counts which can have detrimental impacts to McConnell Springs and the receiving waters of Wolf Run Creek and Elkhorn Creek.



BURIED SOILS AS AN IMPORTANT CONTROL ON C STORAGE ALONG  
HUMAN-IMPACTED FLOODPLAINS IN KENTUCKY, USA

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One aim of floodplain restoration is to improve human-impacted wetlands, which affects carbon storage and water quality. However, few studies have assessed the long-term (>10 y) benefits of such restoration work. This study examines soil organic carbon (SOC) with depth in alluvial profiles that vary by restoration age and hillslope and upland profiles in western KY, USA. Five sites were examined. Three of the sites are floodplain soil profiles located in a (1) recently-restored (<1 year), (2) post-restored (>10 years), and (3) unrestored (0 years) setting. Two additional soil profiles along a foot slope and upland summit were examined that experienced reforestation following late nineteenth and early twentieth century deforestation and farming. The SOC was estimated from soil organic matter (SOM) measurements using loss-on-ignition (LOI) on oven-dried soil samples. Bulk density was also measured to calculate SOC stocks, reported here in  $\text{kg C m}^{-2}$ . The recently-restored site contains the highest SOC stock ( $22.39 \text{ kg C m}^{-2}$ ) and is situated on a clay-rich wetland adjacent to a former backchannel slough. The post-restored and unrestored sites have low SOC stock in the surface soil ( $3.35$  and  $5.58 \text{ kg C m}^{-2}$ , respectively), yet higher SOC stocks at depth in buried soils ( $11.97$  and  $8.12 \text{ kg C m}^{-2}$ , respectively). A similar pattern was noted at the footslope site, where the SOC stock in the surface soil ( $9.07 \text{ kg C m}^{-2}$ ) was lower than that of the buried soil ( $12.82 \text{ kg C m}^{-2}$ ). An average SOC stock was calculated for each buried and surface soil and a grand mean was then calculated for each group (buried soils,  $n=3$ ; surface soils,  $n=5$ ). The average SOC stock for buried soils ( $10.64 \pm 3.94 \text{ kg C m}^{-2}$ ) is similar to that of surface soils ( $10.97 \pm 2.35 \text{ kg C m}^{-2}$ ). The similarity between SOC stocks suggest that the presence of buried soils is an important control on carbon storage along human-impacted and restored floodplains and footslopes in western KY. The occurrence and extent of buried soils should be considered in restoration and carbon storage studies. Future research will include taking more samples at different locations to verify the similarity between SOC stocks of buried and surface alluvial soils and comparing different C analysis methods to account for structural water using the LOI method.



# BURIED SOILS ARE AN IMPORTANT CHEMICAL INTERFACE CONTROLLING MINERAL WEATHERING AND SOLUTE GRADIENTS ALONG RIVER CORRIDORS

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Soils along river corridors are important water filters that regulate nutrient flux as water travels downstream. Buried soils are common features along these corridors; yet, very few studies have addressed soil water dynamics in these buried alluvial soils and their role in influencing nutrient cycling in bottomland ecosystems. This project explores the bottomland soil nutrient dynamics for one alluvial terrace soil that hosts a *Quercus stellata* (post-oak) flatwood community using both solid-state and pore-water chemistry and physical characterization.

The Clarks River terrace soil profile is mapped as a poorly drained Alfisol with shrink-swell features and a buried soil at 1 m below the surface. Simulated  $K_{\text{sat}}$  values for the buried soil in the profile are much lower than the surface soil and are similar to those found in unweathered clays or shale. Mass balance geochemistry of the leachable soil fraction shows loss of K, Mg, and Na and enrichment of total Fe in both the surface and buried soils. These elemental trends are more common in well-drained soils. Pore-water Chloride, a proxy for water movement in soil, is in excess of  $0.01 \text{ mol L}^{-1}$  in the buried soil suggesting that this is a potential zone of slow moving pore water with longer residence times. Mean pore-water silica concentrations increase with depth from  $20 \text{ mol L}^{-1}$  in the modern surface to almost  $70 \text{ mol L}^{-1}$  in the buried soil; whereas, mean silica flux is higher in the surface soil ( $6,485 \text{ mol ha}^{-1} \text{ y}^{-1}$ ) and very low in the buried soil ( $13 \text{ mol ha}^{-1} \text{ y}^{-1}$ ).

The soil and pore-water chemistry trends for this one Clarks River alluvial terrace soil are reminiscent of upland soils weathering residuum. Although we have no model that explains how the buried soil chemistry influences the surface water dynamics, we hypothesize that this clay-rich buried soil may affect flatwood development by acting as an important chemical interface, like indurated parent material, and influencing the near-surface chemistry through nutrient uptake in the rooting zone.

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## GEOSPATIAL EVALUATION OF SEWER GAS TO INDOOR AIR PATHWAYS RELEVANT FOR VAPOR INTRUSION

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Aging sewer lines are a major challenge for modern cities. Cracked, broken, or otherwise deteriorated sewer lines can be penetrated by water from outside the sewer. The unintentional entering of groundwater or runoff (e.g. inflow and infiltration (I&I)) into sewer systems is well-known to be a management challenge due to both the increased volume of water being transported by the sewer, as well as the larger volume of water that requires treatment. A less known, but important, challenge associated with aging sewer lines is when contaminated water and vapors enter the deteriorated sewer lines near hazardous waste sites. In this situation, the sewer system can serve as a preferential pathway transporting contaminated water and vapors long distances.

Deteriorated sewer lines are not only a concern outside of homes, but also within homes because plumbing fixtures are often poorly maintained. In most buildings, plumbing traps prevent sewer vapors from directly venting to the indoor air. Therefore, in buildings where plumbing is appropriately installed and maintained, sewer gas infiltration is less likely. However, if traps and/or drains become dry, or if joints and fittings are not properly working, sewer gas vapors have been shown to enter indoor spaces at concentrations that pose health risks.

This research project investigates the sewer gas to indoor air pathway relevant for vapor intrusion scenarios by evaluating available GIS maps of sewer lines and geospatial information about hazardous waste sites within Kentucky, particularly Fayette County. Maps delineating areas where contaminated groundwater (and vapors) from hazardous waste sites may be entering aging sewer lines have been generated. These maps inform about which areas are most susceptible for sewer systems to act as a preferential pathway transporting hazardous waste contaminants long distances from the original hazardous waste site. This sewer gas to indoor air pathway may produce increased exposure risks due to the transport of hazardous waste chemical vapors into indoor air environments.



# INVESTIGATION OF THE UPPER MISSISSIPPI EMBAYMENT AQUIFER SYSTEM HYDROSTRATIGRAPHY USING INTEGRATED GEOPHYSICAL METHODS: JACKSON PURCHASE, KENTUCKY

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Increased groundwater withdrawals associated with agricultural irrigation in the Jackson Purchase has prompted questions related to groundwater availability and sustainability. A key factor in evaluating these questions is knowing the extent and thickness of the local hydrostratigraphic system, or more specifically the upper part of the Mississippi embayment aquifer system.

The upper Mississippi embayment aquifer system is Eocene and includes the upper Claiborne aquifer, middle Claiborne confining unit, and the middle Claiborne aquifer. The upper Claiborne aquifer consists of sand, silt, and clay while the middle Claiborne confining unit is predominantly clay and silt. The middle Claiborne aquifer is primarily composed of sand, minor amounts of clay, and some lignite.

Fifty natural gamma-ray and resistivity well logs have been used to construct cross-sections of the upper Claiborne aquifer and middle Claiborne confining unit in the southwestern part of the Jackson Purchase. The cross-sections have enabled us to improve the resolution of the extent and thickness of the upper Claiborne aquifer and middle Claiborne confining unit. The thicknesses of the upper Claiborne aquifer and middle Claiborne confining unit range between 11-58, and 5-33 meters, respectively. The logs are not deep enough to determine the full extent of the middle Claiborne aquifer, however.

In an effort to more cost-effectively map these units, surface electrical resistivity was acquired and compared with a downhole geophysical log at a well-constrained site to test its limit for resolving these hydrostratigraphic units. The Wenner, Dipole-dipole, and Schlumberger electrical resistivity arrays were considered. The Schlumberger array gave the optimal electrical resolution, and had good correlation with the hydrostratigraphic picks of a gamma-ray log collected from an irrigation well (Thorpe well) located approximately 305 meters north of the electrical resistivity line (Fig. 1). The Schlumberger profile suggests that the top of the upper Claiborne aquifer is located about 14 meters below ground surface. The middle Claiborne confining unit is located about 73 meters below ground surface. The electrical resistivity survey is not deep enough to estimate the top of the middle Claiborne aquifer (increased electrode spacing or additional electrodes would be required). The Thorpe well gamma log indicates that the top of the upper Claiborne aquifer is 7 meters below ground surface and that the top of the middle Claiborne confining unit is 70 meters below ground surface. The correlation is very reasonable for first-order hydrostratigraphic mapping.

Reinterpretation of a P-wave seismic reflection profile collected by Woolery and Almayahi (2014) at the well-constrained Central United States Seismic Observatory borehole site located in the study area indicates the stratigraphic interfaces comprising the hydrostratigraphic system fall within the one-quarter wavelength vertical resolution limits of the data. A relatively modest elastic impedance contrast yields moderate-to-good image quality. Improving vertical seismic resolution and image quality for the hydrostratigraphic system will be tested with additional seismic reflection soundings using an S-wave energy source.

Aquifer and confining unit surfaces and thicknesses within the Mississippi embayment aquifer system, in Kentucky, need to be better defined in order to more accurately evaluate groundwater availability and aquifer interaction. This will require integrated invasive and non-invasive techniques to provide the needed resolution in a cost-effective manner.

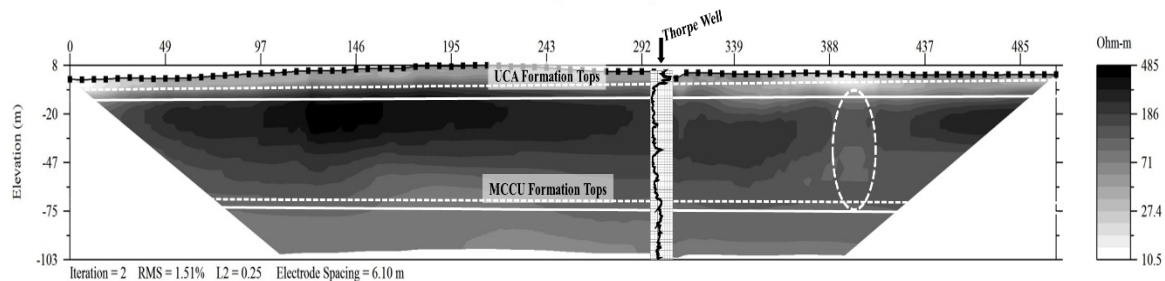


Figure 1. Schlumberger resistivity profile correlated to the Thorpe well gamma log (located 298 meters north of the electrical resistivity line). The darker colors suggest more resistive material (sand) while lighter colors suggest lower resistivity material (clay). The Thorpe well gamma log indicates the top of the upper Claiborne aquifer (UCA) is at 7 meters below ground surface (top white dashed line). The electrical resistivity suggests an average formation top at approximately 14 meters below ground surface (top white line). The Thorpe well gamma log shows the top of the middle Claiborne confining unit (MCCU) at 70 meters below ground surface (bottom white dashed line) while the average electrical resistivity top is at approximately 73 meters below ground surface (bottom white line). The gamma log and electrical resistivity correlation is reasonable for first-order mapping. The smoothing effects of the resistivity inversion curtail the resolution of more exact picks. The anomalous low resistivity zone (ellipse) below electrode 64 can be interpreted geologically as a highly fractured zone or an inversion artifact associated with the highly conductive material at the ground surface.

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EVALUATING PEDESTRIAN COMPACTION VARIATION  
UNDER DIFFERENT GROUND USE SYSTEMS IN CALLOWAY COUNTY,  
KENTUCKY

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Over time, playing fields are monitored by general overall appearance. However, pedestrian compaction is not evenly distributed throughout the entire surface. The objectives of this investigation were to determine the spatial variation of soil compaction in a 50 m square area with 425 measurements using a penetrometer (1<sup>st</sup> study) and to compare soil compaction, soil water content and soil organic matter of 5 different grassed areas in Calloway county (2<sup>nd</sup> study).

The first study was conducted in The University Quad of Murray State University at the soil depth of 15 cm. The highest soil compaction observed was 300 psi and the lowest was 50 psi with an average of 202 psi. The coefficient of variation for the measured values was 36%.

The second study investigated 5 different land use systems including the Soccer Field, Intramural Field, University Quad, Prairie, and the Pullen Farm Recreation Area at a depth of 15 cm. The highest soil compaction and soil water content were found in the University Quad and the Pullen Farm Recreation Area, with the lowest values found in the Soccer Field and Intramural Fields. In addition, there were correlations between soil compaction and other soil properties including soil bulk density, soil water content and soil organic matter.

## NOTES

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# LAND COVER PIXEL SHIFT IN THE KENTUCKY RIVER BASIN AND ITS EFFECTS ON SPATIAL STATISTICS

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Watershed health indicators can benefit from basic land cover data such as those provided by the 2011 National Land Cover Database (MRLC, 2016). Such spatio-temporal variables are: land cover class, percent imperviousness and percent tree canopy closure and their change rates and trends. The 2011 National Land Cover Database contains the most recent and official land cover data layer for Kentucky (MRLC, 2016). The coordinate reference system utilized is the USGS's own -- Contiguous USA -- Albers Equal Area Conic – NAD 1983 (*USGS-Albers*) with specified parameters (USGS, 2013). On the other hand, the official coordinate reference system for the Commonwealth is State Plane Coordinate System Single Zone -- Lambert Conformal Conic – NAD 1983 (*SPCS-KY-1Zone*) with specified parameters (Bunch, 2004; DGI-a, 2016; KRS-a, 1992; KRS-b, 2012; KAR, 2016; Georepository, 2016).

Current GIS data layers provisioning protocols provide access to land cover data via services with coordinate reference system *SPCS-KY-1Zone* (DGI-b, 2016). It is well known that the process of reprojecting the data from their native coordinate system may result in changes in area, shape, orientation, etc. In the case of raster datasets, such as the land cover map, equivalent spatial resolution is maintained by converting pixels from metric units to English units (i.e. 30 meters to 98.425 feet). Spatial resolution controls the scale at which the map should be utilized (Nagi, 2010).

The 6, 8, 10 and 12-digit Hydrologic Unit boundaries corresponding to the Kentucky River Basin were used as the study area (DGI-c, 2016). The process of reprojecting the basin boundary polygon represented changes in surface area tabulations for each land cover class. Increases and decreases in the number of pixels assigned to each land cover class were observed and quantified for all 230 sub-watersheds, adding to a total diminution of pixels. Center of pixel points were also used to sample the land cover classes in HUC HUC051002050404 (Drakes Creek watershed) in both the original, *USGS-Albers* and the *SPCS-KY-1Zone* coordinate systems, and to quantify land cover class migration.

Thus far, a state-wide class accuracy analysis for land cover related data layers from different epochs are not available for Kentucky. As a result of geoprocessing of the original data, distortions in the spatial distribution of specific land cover types in some

watersheds may be a potential additional contribution to the cartographic error budget of land cover maps for the Commonwealth.

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## EFFECTS OF VARIOUS LAND USES IN STEWART COUNTY, TENNESSEE ON SELECTED SOIL PROPERTIES

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Different land uses have various effects on physical and chemical properties of the soil. The goal of this study is to examine the impact of six land uses located in Stewart County, TN on selected soil properties (soil water content, bulk density, soil organic matter, and soil acidity levels). The land uses examined include a tobacco field, hardwood forest, corn/soybean rotation, garden, lawn, and a pasture. The garden and tobacco field were plowed using conventional tillage methods for 15 years. The corn/soybean field has been a no-till system for the past 6 years. The forest, pasture and lawn are not plowed. Disturbed soil samples from topsoil (0-4" deep) were collected from each field to determine pH and organic matter content. Undisturbed soil samples of two depths (0-7" and 7-14") were collected from each field for soil water content, and bulk density. The results show that the tobacco field had the highest bulk density (1.10 g/cm<sup>3</sup>), while the garden had the lowest bulk density (0.66 g/cm<sup>3</sup>). The lawn had the highest soil water content (18.9%), while the corn/soybean field had the lowest soil water content (12.6%). The forest had the highest soil organic matter content (10.7 %) while the tobacco field had the lowest (3.2 %). The garden's soil had the highest pH (5.8), while the tobacco field had the lowest pH (5.0). However, all fields were considered in the acid range. The findings of this study provides implications that can help farmers to make decisions regarding soil management for better growing media.



## DIFFERENCES IN SOIL CHARACTERISTICS AMONG NATURAL AND AGRICULTURAL ECOSYSTEMS IN WESTERN KENTUCKY

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Different ecosystems greatly impact soil properties. Soil physical properties are considered sensitive indicators of perturbation due to soil management practices and land covers. Four ecosystems were investigated including forest and grassland as the natural ecosystems while the agricultural systems were conventional tillage and no-till systems. The forest and grassland ecosystems are located in the Kentucky Dam Village State Resort Park in Gillbertsville, KY. The agricultural systems are located in Calloway County, KY. The forest has been undisturbed for at least the last forty years. Part of the grassland, which surrounds the local airport that has been around since 1990, is mowed twice a year with tractor and a pull behind rotary mower. The no-till ecosystem has been in a corn and soybean rotation with an occasional wheat crop for the last ten to twelve years. The conventional tilled system is in a rotation of one year of tobacco and then corn or soybeans for the next two years and then tobacco is planted again. Soil bulk density, soil organic matter content, soil water holding capacity, macroporosity and soil water at field capacity were determined from the depth of 0 to 6 cm and 6 to 12 cm. The results show that the values of these soil properties varied depending on the ecosystem and the soil depth. On average, the highest to lowest bulk density ranking is 1) Grassland 2) No-till 3) Conventional tillage 4) Forest. Soil water holding capacity ranking from highest to lowest is 1) Forest, 2) Grassland, 3) Conventional Tillage, 4) No-till. Macroporosity ranking from highest to lowest is 1) Grassland, 2) Forest, 3) No-till, and 4) Conventional tillage. Soil water content at field capacity ranking from highest to lowest is 1) Grassland, 2) Forest, 3) Conventional tillage, and 4) No-till. Results from this study increase our understanding of the effects of natural and agricultural soil management on soil properties.





INCORPORATING HUMAN IMPACTS AND NATURAL PROCESSES  
TO ASSESS SINKHOLE RISK

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Current sinkhole hazard maps in Kentucky are based solely on geology, but the USGS estimates that over 80% of sinkhole collapses are anthropogenic in origin. There is a need for a reliable sinkhole risk map for use by land use planners, government agencies, and other stakeholders. We develop a new map of sinkhole hazard probabilities utilizing the random forests method and high precision sinkhole data from the Floyds Fork Watershed in North Central Kentucky. In applying the random forests method, we evaluate land use, geology, hydrogeology, land cover, topography, and soils to predict sinkhole risks. This work will identify the most common risk factors based on anthropogenic and natural impacts on a karst environment. Ultimately, we intend to create more accurate sinkhole risk maps in other karst environments by applying the random forests classifier we generated to other areas.

## NOTES

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# VIRTUAL 3D MODEL FOR CONTAMINANT FLOW WITH GROUNDWATER DUE TO UNDERGROUND PIPE BURST FOR EDUCATION AND OUTREACH

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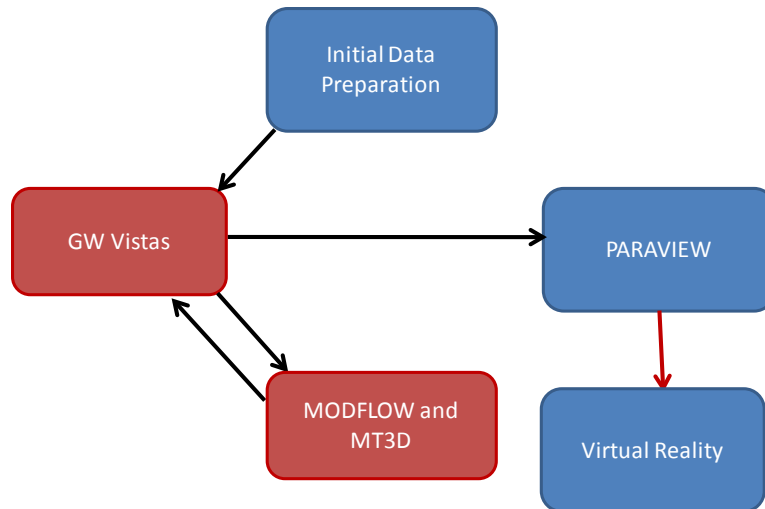
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Several underground pipelines exist in northwest Indiana to transport oil to different destinations. Most of these pipelines are located in the Lake Michigan watershed running in the east – west direction. Several companies such as Enbridge own these pipelines. Due to aging and other factors, pipeline failures were reported. For example, in Michigan, the Kalamazoo River was contaminated due to one such pipe failure (<http://www3.epa.gov/region5/enbridgespill/>). Residents and environmentalists from northwest Indiana were concerned when Enbridge started a new pipeline project a year ago. This research is an attempt to develop education and outreach modules using a virtual 3D platform. This will facilitate visualization and help the public understand potential contamination movement in the ground when an underground pipeline fails in a specific location.

## **Model development**

Developing such models is a data intensive process. From published USGS documents and well log details, soil type and variations with depth were documented. A regional ground water solute transport model was developed to a size of 1600 x 500 x 200 feet. Pipelines in this region are located in the Lake Michigan watershed where, in general, flow is towards the north. The modeling sequence followed is shown in Figure 1.

Based on the soil type, properties such as porosity and hydraulic conductivity were determined from the literature. By implementing boundary conditions (constant head boundaries and recharge boundaries), the initial model grid was structured in the GW Vistas software. Groundwater flow was modeled with MODFLOW. Using MT3D software, a solute transport model was developed. A hypothetical pipe burst and the associated spill were simulated by assuming a 24 hour leakage. The volume of spill and basic properties were estimated to develop the initial concentration at the spill site. Daily simulation was conducted for 2 years and the results were captured for every 15 day time period. Using the GW Vistas platform, cell by cell concentrations were captured and taken to generate virtual 3D models.



**Figure 1. Modeling outline**

These virtual 3D models can be used on a regular PC with 3D glasses or in an online platform using 3D glasses. A 2D version is also available. A user can take a scenario and study the contamination spread with respect to time to help understand the potential risks.

**Acknowledgements:** Authors thank Indiana DNR for supporting this research.

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## NUTRIENT TMDL FOR DEEP RIVER WATERSHED USING KY NUTRIENT TOOL

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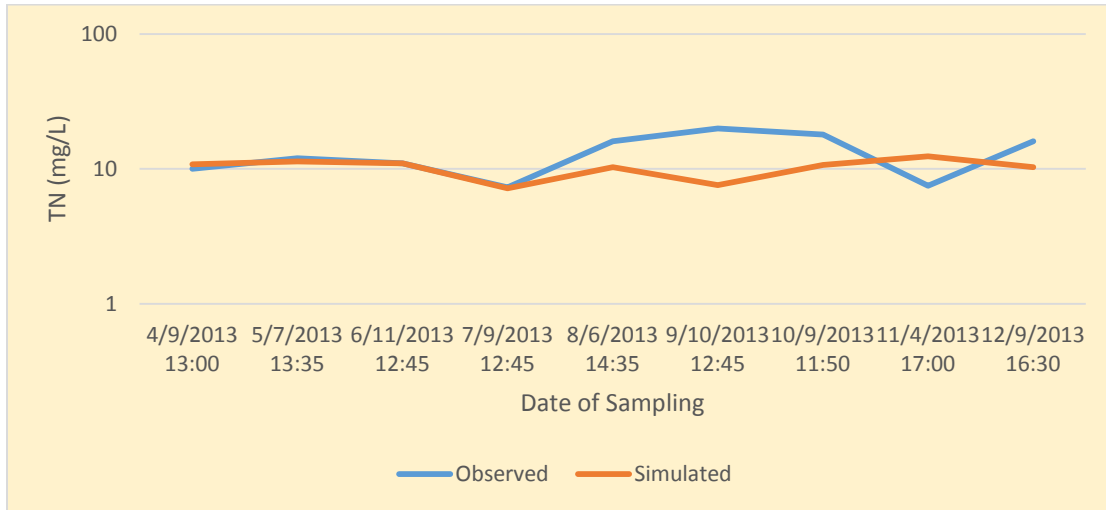
Portage, Indiana

Non-point source nutrients emerging from a watershed produce spikes in concentrations during rainfall events. Best management practices are needed to control non-point source pollution. Point sources also contribute to nutrient loads, but they are better managed. For developing Nutrient TMDLs (Total Maximum Daily Loads), loads from different land uses, failing septic systems and other sources need to be calculated for identifying the required load reductions. An Excel based worksheet program called the KY Nutrient tool, was used to develop a nutrient TMDL for the Deep River system located in northwest Indiana. This tool was developed by a KWRRI research team.

The Deep River system drains towns (including Crown Point, Merrillville, Hobart and Gary) to Lake Michigan. Over half of this 180 square mile watershed is classified as agricultural/pasture/forest/wetland categories. A management plan is being developed and a nutrient TMDL is a part of this plan. Recently, the Kentucky Water Resources Research Institute (KWRRI) created an Excel based worksheet program called the KY Nutrient tool (White *et al.*, 2015). The model uses a daily time step for load calculation. Users can directly use field observed flow data or they can use the tool to simulate and calibrate flow data using rainfall and the SCS curve number runoff calculation (USDA 1973). Water quality is estimated using an event mean coefficient based approach. Hydrologic modeling is done using linear reservoir models and water quality transport is modeled using mass balance approaches. The model provides flexibility to include point source loads and non-point sources. Sanitary sewer overflows and septic systems are modeled as point sources, whereas the non-point source loads for different land use types can be accommodated using coefficients. The model provides flexibility to perform hydrology and water quality calibrations (White *et al.*, 2015).

The Deep River system was subdivided into 9 sub watersheds. Land use data for each sub watershed, observed United States Geological Survey (USGS) flow, rainfall data and soil data were needed. Initially, land use data and soil data were consolidated through geo-processing. Watershed delineation was done using ArcGIS and all of the reaches were derived with proper connectivities. Land use data were obtained from the NOAA (National Oceanographic Atmospheric Agency) Coastal Service Center. The area of different land use types for each sub-watershed was calculated and the area covered by different hydrologic soil groups for each sub-watershed was estimated using the NRCS soil database. The rainfall data were obtained from NOAA. Flow data were downloaded from the USGS website (2006-2013). The USGS observation station is located below Lake George at Griffith, IN. Flows for each sub-watershed were estimated using an area based proportioning method. Water quality observations were made by the Indiana

Department of Environmental Management (IDEM) during 2013 at 15 locations in this system. Nine stations from that study were used for water quality calibration. Model results and observed data were compared and after fine tuning of coefficients, calibrations were finalized (Figure 1).



**Figure 1. Observed and Simulated TN concentration at Sub watershed 1 (40400010501), Station LMG-05-0018**

After satisfactory calibration, TMDL reductions were performed. Load reductions for different sources estimated for each sub-watershed varied from 1% to 90% for the various different land use categories.

**Acknowledgement:** Support for this study was provided by IDEM.

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DESIGNING POLYPHENOLIC NANOCOMPOSITE MATERIALS FOR THE CAPTURE  
AND SENSING OF POLYCHLORINATED BIPHENYLS  
IN CONTAMINATED WATER SOURCES

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Polyphenolic based nanocomposite materials have been developed using several distinct methods to capture and sense organic pollutants from water sources. The polyphenolic moieties were incorporated to create high affinity binding sites for organic pollutants within the nanocomposites and serve as a sensing platform. Multiple strategies have been employed to create these polyphenolic based nanocomposite materials. The first method utilized a surface initiated polymerization of poly(ethylene glycol)-based and polyphenolic-based crosslinkers on the surface of iron oxide magnetic nanoparticles to create a core-shell nanocomposite. The second method consisted of a single step direct functionalization process for the synthesis of polyphenol coated iron oxide magnetic nanoparticles. The third method utilized a bulk polymerization method to create macroscale films that were composed of iron oxide nanoparticles incorporated into a polyphenolic-based polymer matrix, and then, these films were processed into microparticles. All three methods produce nanocomposite materials that can specifically bind chlorinated organics, can rapidly separate bound organics from contaminated water sources using magnetic decantation, and can use thermal destabilization of the polymer matrix for contaminant release and material regeneration. The polyphenol functionalities used to bind organic pollutants, such as polychlorinated biphenyls (PCBs), were quercetin, curcumin, quercetin multiacrylate (QMA), and curcumin multiacrylate (CMA), the latter two which are acrylated forms of the nutrient polyphenols. In some systems, N-isopropylacrylamide (NIPAAm) was incorporated to create temperature responsive materials for reversible binding. All particles were characterized using transmission electron microscopy (TEM), dynamic light scattering (DLS), Fourier transform infrared spectroscopy (FTIR), and thermal gravimetric analysis (TGA). Pollutant binding studies were performed using PCB 126 as a model system for chlorinated organic pollutants to determine binding affinity and capacity, and this was quantified using gas chromatography coupled to an electron capture detector (GC-ECD).

## NOTES

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# EMERGING TRENDS IN KENTUCKY LAKE WATER QUALITY: 25 YEARS AND OVER 500 CRUISES

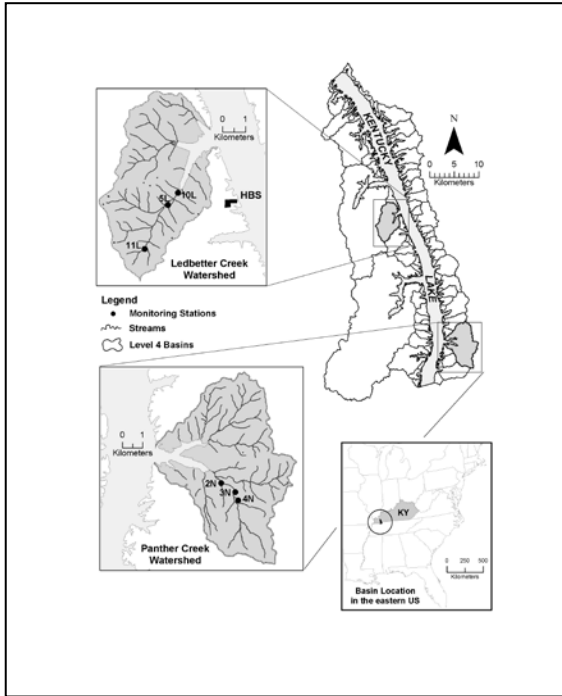
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Kentucky Lake water quality has been monitored at sixteen sites on the lake and six sites on small tributaries by the Hancock Biological Station (HBS, Murray State University) since 1988 (Fig 1). Several long-term trends in some water quality parameters have emerged. For example, as sulfur dioxide emissions from fossil fuel plants have decreased over the past three decades for several reasons, sulfate ( $\text{SO}_4^-$ ) concentrations also have decreased and pH has increased in precipitation falling on the lake and subwatersheds.  $\text{SO}_4^-$  concentrations in Kentucky Lake surface water also have decreased while surface water alkalinity has increased in both main channel and tributaries suggesting that atmospheric inputs are no longer an important source of sulfates to the lake. Nitrate ( $\text{NO}_3^-$ ) nitrogen concentrations have increased over time while phosphate ( $\text{PO}_4^{=}$ ) concentrations have remained the same over the 25-year record.

Most interesting, however, is that mid-channel water temperature has increased by  $1^\circ\text{C}$  since 1988, consistent with increasing temperatures reported for other lakes over the same time period. Additionally, the frequencies of water temperatures above  $30^\circ\text{C}$  during summer months (June, July, and Aug) has increased over the past decade. Water temperatures of two streams (Panther and Ledbetter creeks, Fig. 1) discharging into Kentucky Lake also have increased over the same time period. While Kentucky Lake, a mid-latitude lake, has not experienced temperature increases as dramatic as boreal (e.g., Lake Superior) or arctic lakes, it is not immune to the effects of climate change.

Fig. 1. Location of Kentucky Lake and tributaries, Ledbetter (west side and Panther Creeks





## DOES LIGHT PENETRATION AFFECT THE PELAGIC FISH COMMUNITY IN KENTUCKY LAKE?

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Kentucky Lake provides a valuable recreational and commercial fishery for the Western Kentucky region, and understanding the water quality of Kentucky Lake is essential to properly managing this ecosystem. The availability of light is a crucial water quality parameter, since light is necessary for photosynthetic organisms. Light is also essential for sight-feeding organisms, such as small fish. But, many things can degrade water quality and reduce the availability of light in the water. Reduced light penetration can have cascading, long-lasting effects on the rest of the aquatic ecosystem. Thus, studying the water quality of Kentucky Lake can lead to greater understanding of the fish community.

Although factors such as temperature are most often thought to control year class strength in young fish, few studies have looked at how water quality influences juvenile fish. Little is known how light penetration affects young fish, even though these fish are very reliant upon light for sight feeding. Sampling small, juvenile fish and coordinating those samples with other water quality sampling, such as turbidity and Secchi depth readings, might lead to a greater understanding of the dynamics of the Kentucky Lake ecosystem.

We propose to study the relationship between light penetration and small, pelagic, juvenile fish in Kentucky Lake. The Hancock Biological Station (HBS) of Murray State University collects bi-weekly water samples at several locations in Kentucky Lake. We wish to coordinate fish sampling with the HBS water quality sampling in order to look for effects of light penetration on these small fish. We will compare turbidity and Secchi depth samples to trawl samples of juvenile fish to determine how reduced light penetration affects these fish.

Trawl sampling for small, pelagic fish will be conducted at 2 of the HBS sampling locations. One site will be in a large embayment, and the other site will be in the main channel. The embayment site is more protected from the wind than the channel site, so a large difference in light penetration should exist between the 2 sites. A surface trawl will be used in order to obtain a thorough sample of the small, pelagic fish species. Sites will be sampled bi-weekly from March through August. All fish catch will be identified and measured (length and weight). The numbers, biomass, and species composition of the fish catch will be compared to the turbidity and Secchi depth readings obtained by HBS.

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LONG-TERM EFFECTS OF FORESTRY BEST MANAGEMENT PRACTICES ON  
HYDROLOGY AND WATER CHEMISTRY IN THREE APPALACHIAN  
HEADWATER CATCHMENTS

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Headwater streams are typically small in stature; however, they contribute 60 to 85% of the total stream length in a network, and drain 70 to 90% of the drainage basin area (Benda et al. 2005, MacDonald and Coe, 2007). Due to their small size, headwater streams are quite sensitive to anthropogenic disturbances such as timber harvesting, this can cause larger runoff volumes, higher peak flows, and decreased water quality. Although the significance of headwater stream systems on overall stream and river health has become more apparent in recent years, research on the consequences of timber harvesting in headwater stream systems is quite limited, especially on the long-term.

In 1982, a study was initiated in the Field Branch watershed in the University of Kentucky's Robinson Forest to evaluate forestry best management practice (BMP) effectiveness after intensive harvesting. The study utilized a paired watershed approach on three adjacent headwater catchments. One watershed was left as the control, one watershed had BMPs implemented (including a 50-ft undisturbed buffer along the stream), and one was clear-cut to the stream bank without BMPs (i.e. logger's choice). Most forestry BMPs are designed to decrease sediment transport resulting from soil erosion. Soil erosion and subsequent suspended sediment in surface waters is considered by many as one of the largest environmental concerns in the U.S. today. Erosion of organic and nutrient rich surface soil decreases forest productivity and has many adverse consequences once it reaches the stream. Some of these consequences include loss of stream habitat, altered stream hydrology and geometry, and nutrient/pH imbalances. Monitoring of the three streams has continued since the study began in February of 1982 and preliminary observations indicate that the hydrology of the two harvested watersheds still differ from the control watershed even after a 30-year period.

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PROGRESS TOWARD IMPROVED  
STATEWIDE GROUNDWATER-LEVEL MONITORING

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Groundwater is an important natural resource used by the agricultural, industrial, and energy-extraction sectors throughout much of Kentucky, and by many municipalities and private citizens that rely on wells or springs as a source of potable water. As the state's population and economic activities continue to increase, data needed to evaluate groundwater availability and sustainability become more important. Long-term measurements of water-level fluctuations collected from a suitable network of observation (monitoring) wells provide fundamental information about changing groundwater conditions and help provide answers needed to assess how much groundwater is available at any point in time, whether stresses such as periodic droughts and increasing withdrawals are depleting Kentucky aquifers, and whether enough groundwater will be available to meet the commonwealth's future needs.

From the mid-1950's until the late 1980's, groundwater-level data were collected cooperatively by the USGS and KGS across the state using a loosely defined network of abandoned or unused private water wells. The number of monitored wells in the network varied from more than 64 to fewer than 12, depending on available funding and other agency resources; however, over the years, continuing decreases in federal and State funding steadily eroded the number of observation wells until only one well in Graves County remained actively monitored in the early 1990's as part of the federally funded USGS National Climate Response Network. In 1998, KGS was mandated by KRS 151.625 to oversee the establishment of a long-term groundwater monitoring network for the purpose of "... characterizing the quality, quantity, and distribution of Kentucky's groundwater resources"; however, no funding was ever appropriated to enable carrying out this mission. As a consequence, groundwater-level data are lacking for much of the state, and records of water-level measurements collected from previously monitored wells are often 30 years or more out-of-date.

In 2015, KGS committed funding and resources to begin to address the critical lack of groundwater-level data and rebuild a statewide groundwater-observation network, with a goal of establishing at least 15 observation well sites to monitor naturally occurring changes in groundwater levels that are representative of groundwater conditions in major representative aquifers present throughout Kentucky. To minimize costs, existing wells,

including some that have been previously monitored, are presently being inspected and tested by KGS hydrogeologists for inclusion in the network. All of the wells included in the observation network will be equipped with pressure transducers and data loggers recording groundwater levels at 15- to 30-minute increments. Approximately seven of the wells will also be equipped with a telemetry system that will automatically transmit recorded groundwater-level data to enable tracking and evaluation of daily changes in groundwater conditions. All groundwater data collected from the network's wells will eventually be posted to the KGS website and available for the public's use. To date, long-term observation well sites have been established in Calloway, Hickman, Henderson, Edmonson, and Fayette Counties. Additional wells are undergoing evaluation in Hardin County, and potential observation well sites are being sought in west-central, south-central, and eastern Kentucky.

Continuous monitoring of water-level measurements over a period of at least 5 years is needed to build the database (or period of record) needed to identify monthly, seasonal, and longer-term trends in groundwater-level fluctuations and to enable calculations of statistically valuable parameters such as mean (average), maximum, and minimum groundwater levels. KGS has committed the funds, equipment, and human resources needed to maintain the network through fiscal year 2017; however, longer-term maintenance of the network will require additional sources of funding and collaboration/support from additional partners.



DETECTION OF *Percopsis omiscomaycus* (TROUT-PERCH) USING eDNA in  
EASTERN KENTUCKY STREAMS

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Environmental DNA (eDNA) provides an effective, non-invasive method to detect the presence of rare organisms in aquatic systems, provided sufficient molecular tools are available. *Percopsis omiscomaycus* is a small fish with a limited, disjunct distribution in central and eastern Kentucky. We amplified and sequenced a 769 BP region of *Percopsis omiscomaycus* cytochrome b and used this sequence to design eDNA primers that selectively amplify *P. omiscomaycus* DNA from filtered water samples. One liter water samples were collected from 17 locations in northeastern Kentucky, filtered, and DNA was extracted in a manner consistent with established methods. Additionally, each location was intensively sampled for *P. omiscomaycus* by seining. Initial results indicate eDNA successfully detected *P. omiscomaycus* at sites where specimens were collected using seines in addition to at least one site in which suitable habitat was observed but no specimens were collected. These data add to the body of knowledge concerning *P. omiscomaycus* distribution and provide a useful tool for detecting cryptic populations for this and other species.

## NOTES

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## SEASONAL FLUCTUATIONS IN SALAMANDER eDNA IN CENTRAL KENTUCKY STREAMS

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Environmental DNA (eDNA) provides an effective, non-invasive method to determine organism presence or absence in an efficient manner. The majority of salamanders native to central Kentucky have an aquatic phase to their life cycle. Some *Ambystomid* species persist as aquatic larvae for just a few months while other sympatric species spend more than one year in the juvenile aquatic phase. We developed species specific eDNA primers for streamside (*Ambystoma barbouri*), southern two-lined (*Eurycea cirrigera*), and cave (*Eurycea lucifuga*) salamanders that effectively amplify salamander DNA filtered from stream water. We collected 1 liter water samples biweekly from February to July 2015 in three small streams in Jessamine County to examine seasonal fluctuation in eDNA levels of different salamander species. Initial data reveal a complete absence of *A. barbouri* eDNA in early spring samples but high levels later in the spring corresponding with breeding and larval presence. These data add to the growing pool of knowledge concerning eDNA monitoring of species and should provide useful reference data for future monitoring or range delineation studies.

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## ENGAGING STUDENTS IN COMMUNITY CLIMATE RESILIENCE AND EDUCATION

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The Center for Environmental Education has been integrating student learning with the implementation of the Triplett Creek Watershed-Based Plan. Triplett Creek is impaired by excess sedimentation, and streambank erosion is a significant contributor (Emrich, et. al., 2013). Further research conducted in the Triplett Creek Watershed on the causes of streambank erosion supports the implementation of Best Management Practices that reduce stormwater runoff in areas through the reduction of impervious surfaces within the watershed instead of focusing on habitat improvements along the streambanks (Haight, Phillips, Meade, 2015). Morehead State University has been conducting and promoting environmental protection and restoration activities for over 20 years and has recently engaged MSU preservice students in a service learning project to design the retrofit of an existing stormwater basin on campus. The identified stormwater basin was retrofitted into an outdoor classroom that focuses on watershed and climate change impacts. Through the service learning process the students designed features, activities, and educational signs for the classroom. A pre- and post-assessment of the project showed that students: 1) increased their ability to identify causes of flooding, waterway impairments, and climate change; 2) increased their willingness and confidence to teach climate change and watershed issues; and 3) were able to make more connections between climate change and community best management practices to improve community climate resilience. The number of students that believed climate change was happening also increased. This presentation will share the data and the resulting retrofit of the basin into an outdoor classroom.

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