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Poster Session

Kentucky Water Resources Research Institute, University of Kentucky

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Karst aquifers are an important source of drinking water for people around the world. Unlike clastic aquifers, karst aquifers have little filtration capability and thus are prone to contamination. Sinkholes, sinking streams, and other inlets allow water to travel directly to the aquifer without filtration. This presents a problem as unwanted dissolved and suspended matter (including pathogens) can enter the aquifer and be spread quickly. Waterborne pathogens cause a variety of health problems, including diarrhea, dysentery, hemolytic-uremic syndrome, urinary tract infections, eye infections, and abscesses in the brain and lungs. In Scott and Fayette counties, Kentucky, pathogenic bacteria are likely to be derived from a variety of human or animal sources and transported via runoff to Cane Run. These waters can then be transported to the Royal Spring aquifer with little or no filtration via sinkholes or sinking streams, resulting in contamination of the aquifer and ultimately the source of drinking water for Georgetown residents.

Previous work has evaluated the use of a new tracer method utilizing $^{15}$N-labeled Escherichia coli in karst systems. Ultimately this type of tracer will help understand bacterial transport within karst systems and aid in remediation/prevention strategies. A field trace of 500 m done by James Ward (2008, dissertation, University of Kentucky) in the Blue Hole Spring basin in Woodford County, Kentucky, resulted in a significant signal. However, it is unknown how well this method will do under longer traces in more complex systems, such as the Cane Run/Royal Spring basin. It is anticipated that there will be a loss of the signal with a longer trace. A portion of this loss may be attributed to predation of the bacteria, especially by protozoa.

A lab study is being conducted to assess the loss of signal attributed to predation. Two protozoa species, Tetrahymena pyriformis and Colpoda steinii, have been selected as predators. Tetrahymena are considered representative of the phylum Protozoa in general, beyond having characteristics that would make them likely E. coli predators in karst systems. C. steinii are also known E. coli predators likely to be present, especially when associated with organic pollution such as fecal loading.
A wild strain of non-pathogenic *E. coli* used by John Warden (2010, Master’s thesis, University of Kentucky) will be placed in microcosms of sterile Royal Spring water inoculated with the selected protozoa. These samples will be kept in the dark at 14°C to simulate karst conditions. Samples are being taken and analyzed for isotope composition. *E. coli* enriched in $^{15}$N will then be distributed to the microcosms. After one week, samples will be analyzed for their isotope compositions. Pending results should allow us to assess potential loss of the $^{15}$N signal when used in a trace of a natural system.
The University of Kentucky has been coordinating a phased watershed assessment and restoration project in the Cane Run watershed. This watershed includes the recharge zone for the Royal Spring aquifer, a major source of drinking water for Georgetown, Kentucky (pop. 40,000). Phase one of the Cane Run Watershed Project will be completed in February 2011, and includes development of a watershed-based plan (WBP) and initial best management practice (BMP) implementation. The WBP utilizes water quality monitoring to characterize current watershed conditions and identify areas for restoration. Five miles of streamside “No Mow Zones” have been implemented in the watershed to improve water quality, protect stream banks, and support aquatic life. These areas have been developed into graduate student research plots for riparian management strategies. The University of Kentucky’s Agricultural Experiment Station is located in the watershed, and is a major partner in the watershed project. BMPs installed on the University’s farm include a 4,000 tree Conservation Reserve Program (CRP) reforestation project and improved stream crossings. The crossings will reduce stream bank erosion caused by livestock and farm equipment and were utilized by the World Equestrian Games endurance horse race. A 2009 pesticide amnesty in the watershed resulted in proper disposal of 6,700 pounds of outdated and unused pesticides. Local government officials developed an 8.5-mile multi-use recreational trail in the Cane Run watershed. A 26-acre easement for the trail includes streamside “No Mow Zones” and
native plantings. Educational signage and kiosks have been placed along the trail to educate trail users about the watershed, its impairments, and restoration efforts. The city and University are also working together in urban sub-watersheds to identify sanitary sewer and stormwater problems. A watershed festival held in August 2010 promoted water quality awareness to over 300 watershed residents.
Nitrogen polluted surface water runoff is a known cause of hypoxic dead zones that kill important plant and animal species. Riparian areas along waterways reduce nitrate concentrations before reaching coastal waters through denitrification, an anaerobic microbial process. Four paired sites were sampled along the Licking River from Pendleton County (Butler, KY) and ending in Campbell County (Newport, KY) near the confluence with the Ohio River. Monthly sampling of paired sites consisted of 3 sediment cores (5 cm diameter, 10-15 cm depth) from the riparian area adjacent to the river and 3 cores from the bottom of the river. Two water samples were also collected from each site. To determine differences in nitrogen removal capabilities between the riparian soil and river sediment, we measured potential denitrification rate using denitrification enzyme assays (DEA), soil organic matter and inorganic nitrogen concentrations. After analyzing the first eight months of data from our one-year study, we did not find inorganic nitrogen concentration to differ between the riparian and river cores at any of the sites. However, we did find greater soil organic matter in riparian soil than in channel sediment in July. Also, soil moisture was greater in channel sediment and we found ammonium-N concentration to increase with soil moisture. We did not find a trend in soil inorganic nitrogen concentrations along the urban to rural gradient; however water nitrate-N and ammonium-N for June was greatest in the rural areas, likely due to fertilizer runoff from farming. Our study will be used to develop more effective and efficient ways to increase denitrification rates and clean-up our water.
Population dynamics of filamentous bacteria, protozoa and higher-life forms in the activated sludge can provide useful information in monitoring and optimizing operations, and for toxicity assessments of wastewater treatment facilities. Monitoring of protozoan abundance in mixed liquor (ML) from the Town Branch Wastewater Treatment Plant (TBWWTP), Lexington, KY was initiated by the Town Branch Lab in March 2010. The TBWWTP is classified as a single-stage conventional activated sludge system with an average design flow of 30 MGD, which can hydraulically treat a maximum flow of 64 MGD. To differentiate filament characteristics, the filamentous bacteria were Gram and/or Neisser stained. Filament abundance was rated on a subjective scoring scale which ranged from 0 to 6, with 0 being no filaments observed and 6 being excessive filaments or filaments observed in all flocculations. At TBWWTP foaming in the ML basins is linked to a 4 to 6 rating of the filamentous bacteria, occurrence of Nocardia, and also corresponds with high settleable solids. Protozoan counts were grouped into four categories: amoebae/flagellates; free-swimming/crawling ciliates; stalked ciliates; and rotifers/nematodes. Trends in protozoan numbers (No./mg MLVSS) were compared with several parameters, including ML temperature, pH, alkalinity and total suspended solids; F/M ratios; and sludge age. Protozoan dominance was observed to be cyclical over time. As expected, dominance by amoebae/flagellates corresponded with decreases in abundance of both free-swimming/crawling ciliates and stalked ciliates, with converse results observed over time. Even though rotifers/nematodes tended to be less abundant, trends of their numbers over time were similar to those of the amoebae/flagellates. Protozoan’s growth phases correlated with nutrient availability (F/M ratios), settleable solids, and sludge density indices (SDI). Along with protozoan enumerations, data generated from the filamentous bacteria identification will be compared to the above metrics providing a comprehensive view of the activated sludge treatment processes.
SOUTHERN REGION DOWN-WELL CAMERA PROJECT

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The Southern Region Down-Well Camera Project is an education and outreach initiative within the Southern Regional Water Program. The Southern Regional Water Program is one of eight regional water programs under the National Institute of Food and Agriculture, which is an agency within the United States Department of Agriculture. The Southern Regional Water Program is comprised of Land Grant Universities within thirteen states (Kentucky, Arkansas, Tennessee, North Carolina, South Carolina, Georgia, Alabama, Mississippi, Florida, Louisiana, Texas, Oklahoma, and New Mexico). These thirteen states are referred to as the Southern Region. For additional information pertaining to the Southern Regional Water Program, go to:
http://www.usawaterquality.org/default.html

High-quality groundwater resources are vital for meeting increasing water needs of the southern United States as its population expands. To protect groundwater quality, it is critical to provide information to well owners regarding the consequences of cross contamination between surface water and groundwater. Private well owners are responsible for monitoring the quality of their wells, and are often at greater risk for exposure to compromised water quality. Down-well cameras enable researchers, Cooperative Extension Service personnel, water-well drillers and well owners to go beyond the traditional above-ground inspection. These cameras enable water wells to be inspected from top to bottom from inside the well casing. The goal of the Southern Region Down-Well Camera Project is to enable Cooperative Extension Service personnel
and well owners to replace conjecture with visual information regarding domestic water well issues.

The down-well camera project has attracted a team of experts from seven Southern Region states (Georgia, Kentucky, Tennessee, Louisiana, Texas, Oklahoma, and Alabama) who use the down-well cameras to address water well issues. Personnel in each state have received training on how to use the cameras and how to diagnose various water well issues. Down-well video footage is presented by Extension and in some cases, state natural resource agency personnel, during local meetings as a tool to inform rural water well owners regarding the condition of their wells and well problems typical for the hydrogeological conditions in the area. In addition, presentations of the video footage have been made at state, regional, national, and international meetings.

More than 100 videos taken from within water wells have been recorded throughout the Southern Region. The videos show cracked casing, rust holes in steel casing, root growth, calcified well screens, and the presence of dead animals or other foreign debris. These water well problems cannot be diagnosed above ground, but can lead to contaminated groundwater and pollution of aquifers.

Team members in Georgia and Kentucky have edited the video footage to produce educational videos tailored to local hydrogeology. The educational videos describe water-well construction regulations, well maintenance, impacts on drinking water and groundwater quality, local hydrogeology and risks to aquifers. These videos are available to Extension personnel and well owners, and may be viewed on the Southern Region Web site:
http://srwqis.tamu.edu/program-information/success-stories/regional-down-well-camera-video

In addition to the well education video, the Kentucky team has created a water-well education Web site, which features video footage collected from the project and additional footage collected by other Kentucky agencies. The Web site contains information on well types and construction, along with simplified descriptions of water-well construction regulations. The Web site provides video and still photo examples of problems that may occur in wells and recommendations for remediation. The Web site is a pilot project that will be used as a model to create Southern Region Water Well and Aquifer Web pages, which will be utilized during Southern Region Well Owner Network training.

The well-camera project has received funding for 2011 and is expected to expand to the remaining Southern Region states (New Mexico, Arkansas, Florida, Mississippi, South Carolina, and North Carolina). Newly collected video footage will be added to the Southern Region Web site.
Sections of the Triplett Creek Watershed have been identified as impaired for their designated use by the Kentucky Division of Water. Excessive levels of *Escherichia coli* bacteria contribute to this impairment. The purpose of this study is to assess the occurrence and density of *E. coli* in 34 sampling sites throughout the watershed over a 12-month period. Monthly sampling of the watershed was initiated in July 2009 and continued through June 2010. Additionally, three seasonal sampling events were conducted in which five samples were collected in 30 days during summer and fall 2009, and spring 2010. EPA Method 1640, which utilizes mTEC medium, was employed to detect and enumerate *E. coli* in the collected water samples. Numerous sites throughout the watershed and the study period exhibited *E. coli* densities that exceeded the KDOW standard of 130 *E. coli* CFU/100 mL (a geometric mean of five samples collected within 30 days) and/or 240 *E. coli* CFU/100 mL (single “grab” sample counts). These data indicate that sections in the watershed continue to exhibit impairment due to pathogen contamination. These data will be used to develop a watershed based plan that will address the impairments through the selection and implementation of appropriate best management practices. This study is supported by the Environmental Protection Agency (under §319(h) of the Clean Water Act) through the Kentucky Division of Water (Grant # C9994861-08), and the MSU Undergraduate Research Fellowship program.
The Paducah Gaseous Diffusion Plant (PGDP) is an active uranium-enrichment facility owned by the U.S. Department of Energy (DOE). It is located in the Jackson Purchase region of western Kentucky, approximately 16.1 km west of Paducah, Kentucky and 6.5 km south of the Ohio River. Historic activities at PGDP have released hazardous, nonhazardous, and radioactive wastes to the environment, including PCBs, trichloroethene (TCE), uranium (multiple isotopes), and technetium-99 (99Tc). PGDP is listed by the U.S. Environmental Protection Agency (EPA) as a National Priority List (NPL) Superfund site. TCE, a chlorinated solvent, is the most widespread groundwater contaminant associated with PGDP. TCE occurs as pure phase, dense nonaqueous phase liquid (DNAPL) in shallow silts and clays and in the Regional Gravel Aquifer (RGA). TCE contamination has resulted in multiple dissolved phase plumes that migrate from PGDP toward the Ohio River. 99Tc, a man-made radioisotope, is also a widespread contaminant in the soils and burial grounds at the site, forming a plume in groundwater that extends from PGDP to the Ohio River.

Groundwater models are valuable tools to help understand the movement of water and transport of contaminants in the subsurface, and are widely used for planning remedial practices. Since 1990, several groundwater models have been developed for PGDP to simulate water flow and transport of TCE and 99Tc. The models are aimed to assist in optimizing remedial actions, assessing potential remedies, evaluating of conceptual hydrogeological models, developing cleanup goals, and others. The most recent version of the PGDP flow and transport model was completed in 2008. The Kentucky Geological Survey (KGS) is conducting an independent review of this recent version of the model and will continue to develop and operate the model to simulate potential groundwater and source-area remedial scenarios at PGDP that are generally outside of the scope of DOE contractor modeling activities. This poster presents an initial overview of the latest groundwater flow and transport model. This version made significant changes from a previous flow model developed in 1997 in model discretization, boundary conditions, property zonation, and calibration method. This version also updated previous transport model efforts conducted between 1998 and 1999 by simulating contamination history and calibrating transport processes.
The figures below compare the measured and simulated TCE plumes in the latest model at year 2005.

(From Trichloroethene and Technetium-99 Groundwater Contamination in the Regional Gravel Aquifer for Calendar Year 2005 at the Paducah Gaseous Diffusion Plant Paducah, Kentucky)
Biomarkers are effective monitoring tools, allowing researchers to assess physiological responses to pollution thereby contributing to both pollutant detection and an understanding of the biological significance of contamination. We examined the expression of pollutant sensitive genes in zebrafish (*Danio rerio*) caged in either a reference area or in effluent or effluent receiving stream water emerging from the Paducah Gaseous Diffusion Plant (Paducah, KY). The streams surrounding the PGDP that are the focus of this study have a long and well documented history of contamination by both organic and inorganic contaminants. Zebrafish were exposed for seven days in individual cages at either a reference site or one of five effluent or effluent receiving stream sites. Expression of cytochrome P4501A1, metallothionien, and catalase were examined in both hepatic and gill tissue while cytochrome P450 1B1, 1C1, and uridine 5'-diphospho-glucuronosyltransferase were evaluated in hepatic tissue. Expression of hepatic cytochrome P4501A was significantly elevated (five fold) relative to controls in effluent 2, seemingly indicating the presence of an organic inducer. Interestingly both cytochrome 1B1 (six fold) and 1C1 (five fold) were elevated relative to controls in effluent receiving stream water but not in effluent 2. In addition, resident longear sunfish (*Lepomis megalotis*) and green sunfish (*Lepomis cyanellus*) were collected from both reference and effluent receiving sites for evaluation of hepatic gene expression. None of the genes examined in zebrafish have been sequenced for these sunfish species but primer design and sequencing efforts are currently underway. These results provide valuable information linking contaminant levels to biomarker response.
Accumulation of heavy metals in ecosystems is a known environmental problem, and several possible industry sources occur within the watershed of Wilgreen Lake, which is fed by its two major tributaries, Taylor Fork and Old Town Branch. Elevated levels of cadmium, copper, lead, and nickel were found within the waters of Wilgreen Lake during a preliminary survey in 2007. A possible source of these contaminant occurrences is diffusion from lake sediments, which record past and present activities within their drainage basins.

To obtain a history of anthropogenic practices within the drainage basin, we took 1-meter-long cores of lake sediment in each major tributary to see if metal concentrations changed with depth. The cores were taken from prominent levees that are relatively easy to sample and contain thick sediments with a good record of watershed history. We subsampled the core, freeze-dried the samples, and extracted metals from the sediments using hydrogen peroxide and trace-metal-grade nitric acid according to established U.S. Environmental Protection Agency (EPA) protocols. Samples were sent to Activation Laboratories and analyzed for a host of metals using ICP/OES.

Most trace metals (Sb, As, Cd, Co, Se, Ag, Tl, Th) show no pattern with core depth or between the Taylor Fork and Old Town Branch coring sites. Moreover, there was no correlation between core lithology and heavy metal content for any of the measured metals. Antimony, cadmium, and thallium show concentrations at or just above the method blank (≤0.1 mg/L). Arsenic, cobalt, nickel, selenium, silver, thallium, and thorium show background concentrations of 5, 12, 17, 1.5, <0.1, 1.5, and 6 mg/L, respectively. Chromium, copper, and nickel within the Taylor Fork core respectively increase 43%, 25% and 19% in the upper 10 to 30 cm of the core from deeper baseline values, perhaps due to diagenetic precipitation. Lead increases markedly downcore within Taylor Fork sediments peaking at ~53 mg/L, or about 40% above a background concentration of 23 mg/L observed at Old Town Branch. Copper increases slightly downcore with a higher background level at Taylor Fork (18 versus 12 mg/L). Taylor Fork sediments thus display more lead and copper, consistent with industrial sites existing within this tributary’s watershed. These elevated concentrations perhaps reflect industrial releases in the past.
Heavy metal pollution remains a problem in natural waters, particularly for localities near plausible anthropogenic sources. We assayed the level of heavy metals in surface waters and within surface sediments of Wilgreen Lake, whose watershed drains industrial, urban, agricultural, and residential areas near Richmond, Kentucky. We sampled both surface (oxic) and deep waters (anoxic) when the lake was stratified over Summer 2010. Water samples were treated according to U.S. Environmental Protection Agency (EPA) protocols and were digested with trace-metal-grade nitric and hydrochloric acids. Sediment samples were collected with a grab sampler and digested using established EPA procedures with trace-metal-grade nitric acid and hydrogen peroxide. Both water and sediment samples were sent to Activation Laboratories for analysis, and were measured via ICP/MS and ICP/OES, respectively.

All water samples had heavy metal concentrations far below the safety limit for drinking water as determined by the EPA and Kentucky Division of Water (KDW). Lead and nickel were elevated above chronic criteria for aquatic habitat as established by the KDW, or 1.273 and 0.8 μg/L, respectively. Several metals - lead, thorium, and thallium - showed increases in concentration in deeper, anoxic waters compared to oxygenated, surface samples, implying their diffusion out of anoxic sediments. Water-borne lead concentration spiked up to 3 μg/L in anoxic waters of station TF-3; the acute exposure threshold for lead is 1.273 μg/L, with 2 additional samples exceeding this value.

In surface sediments, heavy metal concentrations mostly show no systematic increase or decrease at stations distributed across the lake. However, two stations, M2 and TF-1, located near the inflow of Taylor Fork, showed considerably higher concentrations of lead, chromium, and cobalt than other grab samples. For example, the background lead concentration within surface sediments is about 30 mg/L, but lead levels at stations M2 and TF-1 were 70 and 110 mg/L, respectively. Elevated metal concentrations within sediments in the upper reaches of Taylor Fork can occur from two very different sources. Metals may have originated in the watershed from upstream industrial sources and accumulated within sediments, or they may have entered the lake from septic systems and/or runoff from adjacent residential areas. We continue to investigate these possibilities.
ASSESSING SHORT-TERM CHANGES TO HEADWATER STREAM STRUCTURE AND FUNCTION FOLLOWING ALTERNATIVE FOREST HARVESTING PRACTICES IN A CUMBERLAND PLATEAU WATERSHED

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Forested headwater stream systems are coupled tightly to the adjacent riparian forest and to downstream ecological processes, and provide habitat needs for a diverse suite of macroinvertebrate taxa. Headwater watersheds are typically small and more prone to anthropogenic disturbance than larger systems, yet paradoxically are also inadequately managed. Full-scale logging practices have been demonstrated to have adverse impacts, yet most of these studies were conducted prior to the implementation of Best Management Practices aimed at mitigating the negative influence on headwater systems. Forest harvesting can increase peak streamflows, modify channel morphology and woody debris distribution, reduce inputs of leaves and wood, and alter in-stream biotic communities and ecosystem-level function.

Riparian buffer zones, riparian reserves, or stream-side management zones (SMZs), are terrestrial lands directly adjacent to stream channels where the degree of forest harvesting can be either minimized or eliminated. Proper riparian zone management can alleviate the effects of logging related disturbance. The efficacy of riparian buffer zones, and the protection they provide from logging within headwater systems, is still relatively unknown. For example, there are few published studies detailing the effectiveness of specific SMZ widths. What are needed are assessments of how in-stream macroinvertebrate community structure and ecosystem function responds to alternative forestry practices across both a broad range of landforms and SMZ treatments. The use of benthic macroinvertebrates for assessing both natural environmental gradients and anthropogenic disturbances is well entrenched. The objectives of this project were to assess short-term responses by headwater stream macroinvertebrate communities to three distinct forest harvesting treatments in a Cumberland Plateau watershed. Short-term was herein defined as < 24 months between onset of logging (and completion) and sampling for macroinvertebrates.

This project was performed in Clemons Fork, a 3rd-order Cumberland Plateau watershed located in the Kentucky River Basin of eastern Kentucky and part of a series of Robinson Forest (RF) tracts. A series of eight tributary subwatersheds were established as replicates prior to the onset of forest harvesting in June 2008. Each tributary was divided longitudinally into intermittent and perennial hydrologic permanency stream reaches. Two subwatersheds serve as controls and have been not logged. The remaining six subwatersheds were grouped into three replicate SMZ pairs with different harvesting treatments in perennial and intermittent reaches.
Short-term harvesting responses were based on macroinvertebrate sampling during April 2010 (post-harvesting) and compared to pre-harvesting sampling that occurred in April 2004 and April 2005. Taxa richness (total number of distinct taxa) and density (no./m²) of six variables: total community, EPT (Ephemeroptera + Plecoptera + Trichoptera) fauna, and four functional group measures (shredders, scrapers, filtering-collectors and gathering-collectors, were calculated to assess the influence of the different harvesting practices. To date, however, only the SMZ treatment with the narrowest width (intermittent: 7.6 m; perennial: 16.8 m) and lowest proportion of commercially-valuable trees that remained after harvesting (intermittent: 0%; perennial: 50%) has been analyzed in full. We are currently processing macroinvertebrate samples from the remaining two treatments.

A comparison of macroinvertebrate community structure between pre- and post-harvesting conditions reveal different responses in the intermittent and perennial stream reaches. Most macroinvertebrate richness and density measures were lower in the intermittent reaches after harvesting, while in the perennial reaches macroinvertebrate measures were very similar during pre- and post-harvesting conditions. Although this is still preliminary since we still have samples from each of two remaining treatments to process and identify in full, our initial assessment suggests that these SMZ harvesting practices were more problematic for smaller headwater streams.
CATTLE AND KARST:
SOURCE TRACKING ASSESSMENT & BIOLOGICAL INDICATORS
IN A NUTRIENT-POLLUTED WATERSHED

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Previously, Albright (2006) sought to characterize the cattle-producing Brushy Creek watershed in Rockcastle and Pulaski counties to determine whether the influences of cattle best management practices could be detected at the watershed scale. The results indicated no differences in water quality that could be attributed to the presence or absence of the BMPs. The study suggested that the lack of improvement in water quality could be explained, in part, by the fact that the karstic nature of the watershed was not considered in the development of the BMPs prescriptions and implementation.

The current study, slated for completion in the summer of 2011, seeks to determine whether karstic groundwater-surface water interaction adequately explains why the cattle BMPs have had little effect on water quality. To date, the land and hydrological conditions of the area have been characterized, including land use, groundwater movement, physical habitat assessment of riparian corridors, and censuses of fish and invertebrates.

Source Tracking
Quantitative real time polymerase chain reaction (qPCR) was conducted at the University of Kentucky’s Environmental Research Training Laboratory (ERTL) on seasonally-spaced samples from the 18 stream sites used in the Albright study, plus 9 groundwater/spring sites to identify fecal sources of pollution using the bovine, human, and “all bacteria” markers (“bobac”, “hubac”, and “allbac”, respectively) developed by Layton (2006). The bobac/allbac ratio was used to classify sites for bovine source tracking on a five-point ordinal range from “very poor” to “excellent.” The hubac/allbac ratio was used to classify the same sites for human sources.

When analyzed geographically, the results suggest that karst may not be a large contributor to bovine contamination, but that it is a large contributor to human fecal sources in the stream.

The analysis suggests further, though, that qPCR as a method of source tracking analysis must be interpreted with a great deal of care because of the multiple opportunities for introducing variability through the multi-step laboratory process. We observed variation in PCR amplification efficiency between triplicates; differences in standard Ct values between runs; issues with the transparent adhesive film used to cover wells; and multiple opportunities for possible operator errors in pipetting, serial dilution of standards, and other laboratory steps.

In addition, to control for the reliability of the marker set, we tested fresh fecal material from three cows collected immediately after deposition. The results indicate that
differences between our cattle population and the population used to develop the marker set.

**Biological Indicators**

Fish samples were collected and analyzed in October of 2009 by Dr. Sherry Harrel and Grayson Patton of the EKU Department of Biological Sciences and each site was ranked on a five-point scale from “very poor” to “excellent” based on the calculated fish IBI scores (KDOW 2003). Then, in May and June of 2010, macroinvertebrates were collected at the sites, and macroinvertebrate IBI (MBI) scores calculated (KDOW 2009).

The results suggest that biological health is not necessarily associated with fecal contamination. Further, the biological indicator rankings varied across species.

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REAL-TIME CONTINUOUS OBSERVATIONS FROM SENSORS AND LONG-TERM MONITORING OF WATER QUALITY ALLOW INCREASED UNDERSTANDING OF BIOLOGICAL AND HYDROLOGICAL PROCESSES IN A RESERVOIR, KENTUCKY LAKE (USA).

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Kentucky Lake (USA), impounded in 1942, is the largest man-made reservoir east of the Mississippi River and one of more than 40 TVA impoundments in the Tennessee River system. The reservoir is 260 km long and 1.6 km wide with a water retention time of 23 days under normal water management conditions. The Hancock Biological Station and Center for Reservoir Research began a long-term monitoring program on Kentucky Lake in 1988. Fourteen to 17 sites are sampled every 16 days (32 in winter) for a variety of physicochemical and biological parameters. Two subwatershed streams, one agricultural and one forested, are sampled every 32 days. Nearly 450 monitoring cruises have been completed to date. The data have been valuable in understanding annual and long-term chemical and biological patterns; however, many short-term events are missed. To address this problem, a real-time (15-min sampling interval) monitoring station was established at a mid-lake navigation pylon in 2005. The combination of long-term and real-time monitoring has already provided a wealth of information on the reservoir resulting in a number of publications. Real-time data are openly available on the Station’s website at www.murraystate.edu/hbs. These and other data are being used in worldwide collaborations through the NSF supported Global Lake Ecological Observatory Network (GLEON). An NSF R2 collaboration (VOEIS) between Kentucky (Kentucky Lake) and Montana (Flathead Lake) is allowing us to expand the number of real-time sites using deployable buoys and optical sensors. Parameters being measured at 15 min intervals include water temperature, pH, dissolved oxygen, chlorophyll α, phycocyanin, specific conductance, oxidation-reduction potential, turbidity, and chromaphoric dissolved organic matter (CDOM). Accompanying meteorological stations on each buoy measure air temperature, barometric pressure, rainfall, wind speed, and photosynthetically active radiation (PAR). One new buoy has been placed in the agricultural watershed embayment and a second will be deployed in the forested watershed embayment in 2011. Additional real-time monitoring sites will be deployed in each stream this year as well. We presently are evaluating calibration needs, issues, and performance in a continuous-measurement environment.

Continuous, high-resolution water quality and meteorological data coupled with the long-term water quality monitoring program (16-day interval over 22 years) will be extremely valuable in helping us understand 1) solute and hydrological fluxes within
Kentucky Lake, 2) the influence of contrasting land-use watersheds in the Tennessee River basin, and 3) spatial and temporal shifts in biological components. For example, the long-term monitoring of sulfate in Kentucky Lake has demonstrated a significant decrease in SO$_4$ concentrations from over 23 mg/L in 1989 to less than 10 mg/L in 2010 (Figure 1) as well as long-term shifts in zooplankton phenology (Figure 4). Continuous high-resolution monitoring from buoy sensors has documented otherwise unobservable hydrologic and precipitation phenomena; for example, seiche activity occurred during Hurricane Ike in 2008 (Figure 2) and a 1.6 inch precipitation event on 01/01/2011 increased turbidity and CDOM entering the lake from the agriculturally impacted Ledbetter subwatershed (Figure 3).

![Figure 1](image1.png)

Figure 1. Decreasing sulfate concentration in Kentucky Lake from 1989 to 2010.

![Figure 2](image2.png)

Figure 2. Hurricane Ike causes a seiche in Kentucky Lake on 09/14/2008.

![Figure 3](image3.png)

Figure 3. Effects of Jan 1, 2011 precipitation event (1.6") on turbidity and CDOM export from an agriculturally impacted subwatershed of Kentucky Lake.

![Figure 4](image4.png)

Figure 4. Contour plot of totaled zooplankton densities for site CH. Contours indicate interpolated temporal increases in zooplankton densities.
The broad objective of this research initiative is to develop a novel sensor network so that a real time monitoring system for velocity and sediment discharge of a watershed can be implemented in remote locations in a cost effective manner. The sensor network is a combination of new, inexpensive velocity, sediment concentration, and
pressure sensors, which are designed to collect data necessary to represent the vertical velocity and sediment distributions in a channel cross-section. Results of this new technology include relationships developed for the new velocity and sediment concentration sensors. Laboratory testing has shown a strong correlation between measured light intensity at a known depth and sediment concentrations for sediments derived from the same watershed. Sediment concentrations and velocities have been quantified during field application using the laboratory relationships. The sensors predicted values of velocity and sediment concentration that were reasonably close to measured values. Ongoing results are expected to provide accurate data of suspended sediment load derived from watersheds so that this data can be used to calibrate hydrologic and suspended sediment transport models. Further research is needed to quantify the effect of secondary variables on the sediment and velocity sensors.
The Southern Appalachian Forest Region (SAFR) has experienced considerable land use disturbance by surface coal mining over the last several decades. Much is known about the effects of active mining on the environment, but substantially less information relating to the impacts of mining on watersheds after a site has been reclaimed. This research examines the effects mining has on the particulate organic carbon flux in first order watersheds in the SAFR. Samples of sediment were collected by in-situ sediment traps at the outlets of several first-order watersheds in the Southern Appalachian Forest Region in southeastern Kentucky, and analyzed using an isotope ratio mass spectrometer for various parameters including soil organic carbon content. These watersheds have experienced different levels of disturbances from surface coal mining. Two have also
experienced residential development. Four land uses—mined, reclaimed, residential, and grassland—were identified by digitizing areal polygons from orthophotographs from the 2008 National Agricultural Imagery Program 2008. Flow data were also calculated using a simple runoff model with three parameters, including the area of the watershed, amount of rainfall, and a runoff coefficient based on the areas devoted to each land use. Average concentrations for sediment loads throughout rainfall events were calculated using data from ISCO samplers placed at the outlet of each watershed. Sediment flux was then calculated by rainfall event. When correlated with the carbon concentration data from the sediment samples collect at the outlets of the watersheds, particulate organic carbon flux by rainfall event can be calculated. The results support the accepted belief that surface coal mining leads to an increase in sediment flux. Further work is underway to finalize loading with respect to carbon in the watersheds.
Soil health on reclaimed grassland mining sites impacts both carbon and nutrient storage at the site as well as downstream water resources issues. In this modeling research, the soil organic matter model known as CENTURY is being used to simulate soil organic carbon (SOC) development and turnover in reclaimed Southern Appalachian mine soils. While models have been produced for use on reclaimed mine soils in other regions and allow for a simple analysis, the few inputs do not accurately reflect biogeochemical processes occurring in the plant-soil ecosystem. This new approach will allow for the input of various initial elemental properties of the soil, as well incorporating nitrogen, phosphorus and sulfur sub-models. Simulations of soil development of up to 1000 years can be produced, while specifying important climate and land management factors that change with time. In addition to quantifying C, N, S and P dynamics, significant advancements over previous modeling will be the incorporation of stagnated rooting depth as a result of high bulk density, high presence of rock fragments and the contribution of geogenic organic matter in regards to nutrient dynamics. Preliminary results will be presented. Results are calibrated against existing SOC and carbon stable isotope data collected during the past two summers. An analysis of the previously collected data has provided a 14 year chronosequence of SOC uptake and development in the soil column. With this analysis, it has been established that these soils are well below their potential in terms of the ability to store and cycle carbon and other nutrients as well their ability to sustain a fully-functioning forested ecosystem typical for the region. It is expected that these results will further detail the long-term consequences of the current reclamation process and allow alternative methods to be investigated.
INTEGRATED MODELING APPROACH TO PARTICULATE ORGANIC CARBON ESTIMATES ON A REGIONAL SCALE BASIN

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The transport of particulate organic carbon associated with fine sediments has been shown to account for 10 to 80% of total carbon flux in rivers; however variability is high requiring further estimates of POC for different watershed systems. Accurate estimates of POC fate and export in a fluvial system requires an integrated modeling approach. Currently, uniformity in methodology and quantitative estimates are lacking in the literature. This study provides a conceptual framework outlining the processes impacting POC transport in River systems. Thereafter, a model framework was developed to account for processes in the conceptual framework. The model framework incorporates coupling of hydrologic, soil organic carbon (SOC), erosion, hillslope routing, fate (biogeochemical processes), and transport models to generate POC estimates. The model is built such that estimates can be generated for systems of varying size. This study uses a sub-watershed POC flux model to inform a regional scale model. The subwatershed (Upper South Elkhorn) is a 61.8 km² basin located within the Inner Bluegrass Region of Central Kentucky. The South Elkhorn basin is a lowland, mixed land use (hay/pastoral agriculture and urban) system with limestone and dolomite for underlying geologic material. Such characteristics are typical across the Inner Bluegrass Region, hence processes in the sub-watershed are characteristic of processes throughout the region.

Data for the sub-watershed model were collected at the outlet of the watershed. Suspended sediment samples were collected for particulate organic carbon using a sediment trap, and sediment load samples were collected using an automated grab sampler. Hydrologic modeling was conducted using HEC-HMS, a well recognized commercial program developed by the Army Corp of Engineers, and calibrated using gage data from a USGS gauging station. Upland erosion and transport of POC to the
stream channel was conducted using WEPP (Watershed Erosion Prediction Project). Likewise the Regional Scale model was developed using geospatial techniques. Sediment loads, including contributions from the uplands, was conducted using the SPARROW model (Model developed by the USGS). The land to delivery ratio was updated using results from the sub-watershed model. Thereafter, the associated particulate organic carbon content was estimated using a STATSGO SOC model and an enrichment ratio (estimated from the subwatershed model). Biogeochemical processes were estimated based on the sub-watershed model.

Initial results of the sub-watershed model show a POC flux of 1.5 tC*km⁻²yr⁻¹. Carbon content of suspended sediments was found to vary seasonally as a result of biochemical processes in the bed sediments. Initial geospatial estimates show high variability of sediment loads. Ongoing research is being conducted in an effort to increase accuracy of the SPARROW model with increasing scale. Further, though estimates from lowland systems contribute smaller fluxes than mountainous rivers, they constitute larger areas and are heavily influenced by biochemical processes in bed sediments.
Wilgreen Lake in Richmond, Kentucky, has been listed by both the state and the Environmental Protection Agency as an “impaired” lake due to excess nutrients, which may be in part contributed by domestic septic systems. Caffeine can be used as an anthropogenic marker to estimate the contribution of septic tank effluent to the lake. We have modified existing analytical methods to produce a viable method for the determination of caffeine in environmental water samples and applied the method to water samples collected from Wilgreen Lake. The modified method allows determination of caffeine in a concentration range of 75 to 10,000 ng/L in the water samples. Waters Oasis® HLB solid phase extraction cartridges are used to clean up and concentrate the water samples, which are then analyzed by liquid chromatography-tandem mass spectrometry. A Waters X-Terra MS C18 column (3.5 µm film thickness, 2.1 x 100 mm column dimensions) is utilized in the separation. Carbon-13 labeled caffeine is added to all samples prior to extraction and serves as an internal standard. The parameters of the optimized method and results of the application of this method to water samples collected from Wilgreen Lake will be presented.
A STORMWATER COURSE FOR GENERAL EDUCATION

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A course, Protecting Water Resources, was developed to teach undergraduate, non-science majors about water resource limitations, threats, the impact of non-point source pollution, the Clean Water Act, and stormwater regulations and control measures. The course is offered as a lecture with an optional laboratory component. To assess the effectiveness of this course as a stormwater education tool, a 50 multiple choice question exam was developed. Students enrolled in the course fall semester of 2010 were given the exam on the first day of the class and again at the end of the semester as a comprehensive final exam. Thirty-five students took the initial exam with an average of 18.7 questions correct out of 50. At the end of the semester, 34 students took the exam and the average was 43.4 correct answers out of 50. Wilcoxin Signed Rank mean comparison demonstrated that the final scores were significantly higher than the initial scores (p = 0.000). There was no difference in improvement between the students in the lecture only and those in the lecture and lab (p < 0.05). These results suggest that the material, format and course design is a valid method of stormwater education and meets the criteria described by the National Pollutant Discharge Elimination Systems (NPDES). This course is offered as a model for institutions of higher education to earn stormwater credits under the NPDES program through educational activities.
This research work is a part of the ongoing efforts in the flood management activities for Little Calumet River, located in northwest Indiana. The Little Calumet River drains to Lake Michigan through the Cul-De-Sag canal. Hart Ditch is a major tributary to this river. During 2008, due to the hurricane storm IKE, a major flood was caused in this river basin. Huge property damages were reported due to this flood. Subsequently, the US Army Corps of Engineers is enhancing the levees of this river for a 16 mile stretch to avoid future flooding in northwest Indiana. In this research work, hydrologic and hydraulic models were developed for Hart Ditch to examine the system response with varying conditions.

Watershed rainfall runoff model simulation and river channel hydraulic simulation was performed using HEC HMS (Hydrologic Engineering Center – Hydrology Modeling System, 2009) and HEC RAS (Hydrologic Modeling Center – River Analysis System) software, respectively. Radar rainfall data were extracted for the watershed for five major storms and converted to hourly rainfall using a Z-R convertor software developed at Purdue Calumet. Several layers of geospatial data were used to find SCS curve numbers (SCS, 1986), SCS unit hydrograph (McCuen 2005) and Muskingum channel routing parameters (Bedient et al 2008) (Figure 1) for different subwatersheds.

Figure 1. Initial Data Preparation
Traditionally, HEC HMS model calibrations are based on the 50 year or 100 year storms with priorities to match flood peak and time to peak. However, in this study, field data based calibration was attempted. USGS hourly observations and stage discharge relationship were used for this calibration. After calibrating the model using a few historic storms, it was verified with a few other storms. The 100 year flood event was then simulated to verify the stage levels observed at a nearby bridge.

**Observations:** Model calibration showed mismatches for both summer and winter storms. Model flow peaks did not match well with a storm prior to 1995. Recent land use changes in the system may be the reason for that.

**Acknowledgement:** Authors acknowledge the research grant support given by Little Calumet River Commission. Special thanks to Mr. Dan Repay, Deputy Director of Little Calumet River Commission for the valuable suggestions.

**References:**


Base flow is an important component of stream flow, which has the source from groundwater storage and other delayed sources such as shallow storage, lakes and interflow (Smakhtin, 2001). Base flow characteristics provide many threshold values for watershed based decisions such as water quality and quantity estimates. Annual mean base flow is a function of annual precipitation. Sharp rise in temperature, land use pattern changes and precipitation pattern influences the base flow from a watershed. Less snow fall and quick snowmelt are noticed recently. Increasing temperature thaws frozen soil more rapid and thus lowers the ground water level. Researches indicated spatial and temporal variability of base flow in the past (Hinton et al 1993, Rose 1996).

Hart Ditch, Salt Creek, Little Calumet River East Arm and Trail Creek watersheds were considered for this analysis (Figure 1). These watersheds are located in Lake, Porter and La Porte counties of Northwest Indiana. They are part of the hydrologic unit codes (HUCs) 07120003 (Little Calumet River and Grand Calumet River System) and 04040001 (Little Calumet East arm with Salt Creek and Trail Creek River System). United States Geological Survey (USGS) data for five observation stations (Hart Ditch [USGS gage No.05536190], Little Calumet River [05536195], Little Calumet River East Arm [04094000] and Trail Creek [04095380]) were used for this analysis.

Individual station-based analysis and regional analysis were done systematically by considering monthly, seasonal and annual flow data. Further, the behavior of 90%, 75% and 50% probability of exceedance values were calculated. An annual time series involving number of days in each year with those flow magnitudes was examined in this study. Further, 7Q10 analysis was also performed on individual station data and the results were used in this study.

**Observations:** Hart Ditch located in North West Indiana showed increasing trend in the base flow (Figure 1). This watershed is predominantly an urban character. On the other hand, little calumet east arm watershed which is dominated by crop and pasture land is not showing increasing trends in base flow (Figure 2).

**Acknowledgement:** Authors thank DNR, IDEM for research support.
References:


![Figure 1](image1.png)

**Figure 1.** Number of days in each year, with flows less than 26 cfs (50% Probability of Exceedance) at Hart Ditch, Munster, Lake County, North West Indiana

![Figure 2](image2.png)

**Figure 2.** Number of days in each year, with flows less than 31 cfs (50% Probability of Exceedance) at Little Calumet East Arm, Porter, Porter County, North West Indiana
One of the major difficulties in assessing environmental trends at sites experiencing low to moderate levels of pollution is obtaining sufficient data over a broad enough range of time to distinguish if apparent trends are real or not. Natural variation in environmental systems can hide real trends so that large data sets are needed to provide sufficient numbers to achieve statistical significance, if it is present. Our laboratory is fortunate enough to have worked at the Paducah Gaseous Diffusion Plant (PGDP) in McCracken County Kentucky from 1987 to 1991 and from 1997 to the present. However, even with this long period of study, typically we are limited to only a few data points each year at a given sampling location. Fortunately, two major outside data sources were available for our use. The effluents from the plant are monitored under the Kentucky Pollutant Discharge Elimination System (KPDES). These effluents therefore have large datasets available covering a very broad array of pollutants, including the metals and PCBs our lab is primarily focused on monitoring, over a long period of time. Additionally, three gauging stations are maintained on the two streams near the plant that receive effluents (Bayou Creek and Little Bayou Creek) and a fourth station on a nearby stream serves as an off-site reference stream (Massac Creek). These provide high quality, continuous flow data covering a very long period of time. Additionally sampling of other parameters was conducted from 1991-1995, filling a gap in our lab’s data set. Unfortunately, in both data sources, the time frame that metal and/or PCB data was collected did not extend as long as we had hoped, perhaps because of changing regulatory and monitoring requirements. However, they do permit certain analyses that would be impossible without them.

In order to assess the significance of flow level on the concentrations of different metals and PCB, statistical inference was conducted using unpaired two-sample t-tests. Here, the concentrations of different metals and PCB were compared between high and low flow days. Several graphs were produced to visualize relationships or differences
between different variables. These include combined plots to display relations of the measured outcomes between streams or effluents over time, and plots of PCB concentration vs. flow level on the day before.

Despite the expanded data set, few conclusions could be made. While the data sets available were large, the data pertinent to particular sites was still quite limited in scope, often only covering a few years or was limited to flow. At one site on Little Bayou Creek, Zn levels were significantly higher (p <0.004) during high flow events. This stream receives effluent from an area where Zn based anticorrosive paints have been in use for years. Additional analyses using the more general parameter of conductivity as a measure of dissolved material in the water may prove useful as many of these data are available from our lab’s data set as well as the two other databases.
Land use and management have important impacts on soil physical and soil hydraulic properties. Soil structure is influenced by soil use and management. The objective of this work is to characterize soil properties that related to soil hydrology and soil physics under two land use systems, pasture and cropland; and to show the impacts of soil management on soil structure. Data presented in this abstract are first measurements in an ongoing project.

A research site (4125 m²) at Spindletop Research farm, Lexington KY, with two land use types, i.e., pasture and cropland was established. Sixty sampling points with a regular distance of 5 m are laid out in four transects. Part of the total of 60 points are four nests of six measurement points each being located in the middle of each transect. Within these nests, sampling locations are separated by 1 m distance. The nested sampling design was chosen in order to quantify the variability structure of each of the variables and their spatial association. Soil water content was measured using a capacitance probe for 10-cm vertical depth increments down to 1 m depth. Aggregate size distribution analysis was performed using the dry sieving method. Sixty soil cores (356.5 cm³) were taken from both management zones for gas diffusion, air filled porosity, and bulk density measurements from a depth of 4-10 cm. Oxygen diffusivity in these undisturbed cores was measured using a quasi-stationary approach. Prior to the measurement, each soil core was equilibrated in a pressure plate apparatus to control air filled porosity. The soil sample was then attached to a gas chamber in which the oxygen concentration was lowered at the beginning of the experiment. Air samples were taken from the chamber and analyzed in a gas chromatograph. Based on the oxygen concentration increasing over time, the apparent gas diffusion coefficient was computed.

The pasture management has lower bulk density than the cropped management. Soil water storage measurements taken on September 16th (cropland site) and 17th (pasture site) of 2010 for 1 m depth showed that there is a significant difference between pasture soil and cropland soil (Fig. 1). Cropland soil had higher soil water storage and higher soil moisture content in the top 0.1 m than pasture soil. Soil water content can be influenced by evapotranspiration because the measurements were taken on two following days (no rain events were recorded on these two days). Soil water storage shown in figure 1 does not reflect the soil water retention capability.

Aggregate size distribution analysis for four aggregate classes (>2, 2-0.25, 0.25-0.05, <0.05 mm) was performed for samples taken from the cropland site. The class >2 mm was the dominating aggregate size and the class <0.05 mm contained the lowest fraction in the aggregate size distribution (Figs. 2 and 3). In the top soil (0-0.15 m), macro aggregates (>2 mm) were lower than in the subsequent depth from 0.15 to 0.30 m by 10% of the mean. Other aggregate classes 0.25-2, 0.05-0.25, and <0.05 mm were higher in the top than in the deeper layer by 9, 22, and 27% of the mean, respectively.
Relative oxygen diffusivity varied between 0.02 and 0.08 and air filled porosity varied between 0.06 and 0.16 cm$^3$ cm$^{-3}$ in the pasture soil under 1/3 bar pressure (approximately field capacity). The result indicates that gas diffusivity is controlled by air filled porosity. Average relative oxygen diffusivity for five soil cores taken from the cropland site was lower than that for the pasture soil (30 cores) by 38%.

Fig. 1: Soil water storage, calculated by summation of ten depths (0-1 m depth), and soil water content for the top 0.1 m measured using the capacitance probe. Soil moisture content and storage measurements were not calibrated; therefore, the units are percentage.

Fig. 2: Aggregate size distribution in cropland soil for two aggregate classes in two different soil depths.

Fig. 3: Aggregate size distribution in cropland site for two aggregate classes in two different soil depths.
Communicating with the general public about environmental risks can be challenging. The complexity of scientific and remediation issues, along with different levels of baseline technical and historical knowledge among stakeholders, urban legends, deeply-entrenched beliefs, and a lack of public trust, problematize unidirectional communication models. During the focus group stage of the Paducah Gaseous Diffusion Plant (PGDP) Community Future Vision Project, researchers from the Kentucky Research Consortium for Energy and the Environment worked with participants to identify more than 100 questions and credible information sources related to potential future land uses for the National Priority List Superfund site. For subsequent public information meetings in McCracken and Ballard Counties, the research team developed a unique interface for educating the public about the past, present and future of the site, as well as the science and cleanup implications related to specific land use decisions. After prioritizing, synthesizing, and paring down the focus group list to 30 questions, the research team created a unique, interactive, gameshow-based slide presentation, featuring multiple-choice questions, which audience members answered anonymously using keypads. The distribution of audience answers for each question was shown to the group before the correct answer, supporting data, and a source citation were displayed onscreen. After each question and answer, audience members had the opportunity to ask follow-up questions of the research team. At the end of the session, comment cards were provided, allowing individuals who disagreed with specific answers to refer the team to alternative information sources. Process evaluations from both public meetings illustrated that participants positively viewed the interactive format.