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WESTERN KENTUCKY DEEP SALINE RESERVOIR CO_2 STORAGE TEST: SHALLOW GROUNDWATER MONITORING RESULTS

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In 2007, the Kentucky General Assembly through House Bill 1 mandated that the Kentucky Geological Survey conduct research that "… shall include the drilling of deep wells in both coal fields (Illinois and Appalachian) in Kentucky, and performing the analysis necessary to estimate the potential for enhanced oil and gas recovery, enhanced coalbed methane recovery, or permanent storage of sequestration of carbon dioxide."

As part of this mandate, a deep test well was successfully drilled to a depth of 8,120 ft in Hancock County, Kentucky in 2009. The potential to inject and store carbon dioxide was successfully tested by injecting 323 tons of CO_2 on August 18, 2009 (phase I) and an additional 367 tons of CO_2 on September 22, 2010 (phase II). During phases I and II, CO_2 was injected into Knox Group saline aquifers below a depth of 3,570 ft. The deep test well was plugged and abandoned on October 18, 2011. Additional information about the drilling and testing of the deep test well can be reviewed by visiting the Kentucky Consortium for Carbon Storage Web site at www.uky.edu/KGS/kyccs.

In an effort to locate existing, shallow groundwater sites to monitor any potential groundwater changes associated with CO_2 injection, survey letters were sent to all identified owners of land parcels within the 2-mi area of review of the deep test well. Two domestic wells and two domestic springs were identified. One domestic well (MB1) is located on the same property as the deep test well. Groundwater-baseline sampling began at this site in December 2008. One domestic spring (RC1) is located just outside of the 2-mi area of review. Sampling at spring RC1 and the other two identified sites (well

GB1 and spring CA1) began in April 2009 in conjunction with the issued underground injection control permit.

The underground injection control permit states, "The permittee (KGS) will conduct an analysis on the two existing water wells and two springs within the Area of Review. Baseline samples shall be taken prior to injection. The water wells and springs shall be monitored quarterly for pH, bicarbonate (HCO_3), total dissolved solids (TDS), and turbidity. The sampling should begin on the effective date of this permit and every three months (quarterly) thereafter until permit expiration." Each site was sampled at least five times prior to phase I CO_2 injection. In addition to monitoring the four geochemical parameters required by the underground injection control permit, field measurements (specific conductance, dissolved oxygen, and temperature), metals, anions, dissolved inorganic carbon (DIC), total CO_2 (TCO_2), and δ13C of dissolved inorganic carbon were monitored. After phase I CO_2 injection, each site was sampled quarterly for field measurements, pH, turbidity, TDS, HCO_3, and TCO_2. In addition to these parameters, during the fourth quarter, each site was sampled for metals, anions, DIC, and δ13C of dissolved inorganic carbon. A similar sampling procedure was implemented following the completion of phase II injection.

Bicarbonate, TDS, pH, and turbidity data for well GB1 and springs RC1 and CA1 increased and decreased slightly over time, but post-injection values deviated very little from pre-injection values. Bicarbonate and TDS concentrations for well MB1 increased after each CO_2 injection, but began to increase approximately one month prior to each injection and were most likely related to increased groundwater recharge associated with increased precipitation. In addition to these data, δ13C values of the CO_2 injectate, local soil gas, and shallow groundwater indicate that injected CO_2 has not altered the local groundwater quality within the 2-mi area of review of the deep test well. Sampling of wells MB1 and GB1 and springs RC1 and CA1 is currently scheduled to continue through October 2013.

BASELINE SOIL PROPERTIES OF A CENTRAL KENTUCKY RIPARIAN BUFFER

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The Kentucky Division of Water labels agriculture as the leading source of stream impairments in the state, with 55% of streams not supporting their designated uses due to agriculture. Riparian buffers reduce nonpoint source pollution in agroecosystems by storing and cycling nutrients, stabilizing stream banks, increasing infiltration, and storing water. Specific information on riparian buffer maintenance is needed for agricultural producers to maximize the potential benefits to water quality through the utilization of riparian buffers. Understanding existing buffer soil properties and spatial variability will enhance management strategies to maximize riparian buffer function. Parallel transects were established at 2-m and 8-m distances from top-of-bank along a 650-m straightened agricultural stream section. In July 2010, soil samples were collected at 10-m intervals along transects, divided into 10-cm depth increments, and analyzed for soil texture, pH, nutrient content (P, K, Ca, Mg, and Zn), total C, and total N content. Soils along the 2m transect differed significantly from the soils along the 8m transect. The 2m transect soils had greater C content, higher pH, higher Ca and Zn, lower P, K, and Mg, greater sand content, and lower clay content than soils along the 8m transect location. Initial semivariogram analysis of C content indicates spatial structure along the 2m transect at 50m and along the 8m transect at 100m. This result suggests that buffer soil properties closer to the water body may be more variable than those further from the stream, requiring more careful management to maximize buffer efficacy.

NOTES

THE KENTUCKY WATER WELL DRILLER'S CERTIFICATION PROGRAM

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The primary purposes of the Kentucky Water Well Driller's Certification Program are to certify water and monitoring well drillers and to enforce well construction practices and standards. The program administers driller license, certification exams, provides driller training, attends the Kentucky Water Well Board meetings, manages the driller's database, oversees bonding and insurance requirements, inspects wells for compliance, and investigates citizen complaints.

The program began in 1985 under the authority of KRS 223.400. Initially, certification was only required for water well drillers. However, monitoring well drillers were added in 1992. Currently, 120 drillers are certified: 55 to drill monitoring wells only; 36 certified to drill both water and monitoring wells; and 29 certified for water wells only.

As public water lines have extended into rural areas, the number of water wells drilled has generally declined. For example, the highest number of water wells reported since the certification program was implemented was 2,774 in 1988, compared to less than 500 in 2011. The number of monitoring wells reported annually has also decreased during the last few years partly due to the slow economy.

The program provides numerous publications for well drillers and owners, including the Kentucky Driller Quarterly Newsletter, the Directory of Certified Water and Monitoring Well Drillers, Routine Water Well Maintenance and Disinfection Guide, Protecting Your Well and Water Supply, and Methane Gas and Your Water Well. These publications are available on the Division of Water web site at:

http://water.ky.gov/groundwater/Pages/WellDrillersProgram.aspx

The program enforces well construction standards and provides technical assistance to drillers, consultants, and the public. Drillers are required to submit well logs for each well they drill, and agency personnel also submit well and spring inspection reports. Over 62,000 wells and springs have been entered in the Groundwater database. Information on these sites includes depth to groundwater, location, construction details, and groundwater quality and quantity. Investigation of citizen complaints is an important part of the program, and often involves water quality sampling and downhole camera inspections.

NOTES

INFLUENCES OF A *CLADOPHORA* BLOOM ON THE DIETS OF *AMBLEMA PLICATA* AND *ELLIPTIO DILATATA* IN THE UPPER GREEN RIVER, KENTUCKY

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Freshwater mussels cycle nutrients, link multiple trophic levels, and stimulate primary production. Mussels are typically classified in riverine systems, feeding on a combination of sestonic algae, bacteria, and detritus. Filamentous algal fragments have been found in digestive tracts, however, suggesting they may alternatively graze when macroalga are available as a food source. This study addressed two questions: (1) does growth of two species of mussels, *Amblema plicata* and *Elliptio dilatata*, differ in stream reaches with markedly different *Cladophora* cover, and (2) are their diets reflective of the availability of *Cladophora* during periods of rapid summer growth? The study took place in June – November 2011 in a 7^{th} –order reach of the upper Green River located at the Western Kentucky University Upper Biological Preserve in Hart County, Kentucky.

Seventy-two mussels were collected from shoal habitats. One of each species was placed into thirty experimental growth silos and returned to shoals in randomly assigned transects. The remaining 12 mussels, six per species, were used for initial growth and stable isotopic ratio data. Biomass levels of sestonic and filamentous algae were quantified monthly, including following the first major scouring event that removed most of the *Cladophora* from the study reach in early September. Mussels were sampled across four timepoints from areas of both very high (i.e., natural, *in-situ* levels) and very low (i.e., repeated removal) regions of *Cladophora* growth. Mussel growth was tracked by quantifying changes in shell length and total weight wet. Diet was assessed by comparing natural carbon ($^{13}C/^{12}C$ or $\delta^{13}C$) and nitrogen ($^{15}N/^{14}N$ or $\delta^{15}N$) isotopic ratios of several potential food resources and body tissues of both mussel species. Food resources included *Cladophora*, the vascular riverine macrophyte *Podostemum ceratophyllum*, riparian tree leaves, epilithic biofilm, transported organic matter (TOM) and colloidal dissolved organic matter. The TOM component was separated into two separate size fractions, 1000-100 μm and 100-1μm. Biofilm and both TOM components were partitioned, using a silica-based centrifugation technique, into separate algal and detrital fractions.

Analysis of covariance (ANCOVA) showed that the presence of *Cladophora* was not a significant predictor of overall growth for either mussel species. The $\delta^{13}C$ values ranged considerably from the macrophyte *P. ceratophyllum* (mean: $\delta^{13}C = -37.7 \pm 0.2$) to the 100–1μm TOM fraction ($\delta^{13}C = -28.3$) (Table 1). The algal and detrital $\delta^{13}C$ values were nearly identical for the 1000–100 μm fraction (-28.9 vs. -28.8) and also similar for the 100–1μm (-28.3 vs. -27.9) components. In contrast, the two epilithic biofilm components had markedly different $\delta^{13}C$ and $\delta^{15}N$ signatures. Mean $\delta^{13}C$ and $\delta^{15}N$ values for both mussel species were similar, but also shifted between July and August (Table 1). Mean $\delta^{13}C$ values for *A. plicata* shifted from -32.5 to -33.6 compared to a -32.6 to -33.7 shift for *E. dilatata*. During July the $\delta^{13}C$ signature for both mussel species was most closely aligned with that of epilithic biofilm. The temporal shift, however, between July and August suggested mussels were assimilating increasingly more *Cladophora* tissue during the rapid summer growth period.

Table 1. Mean $\delta^{13}C$ and $\delta^{15}N$ ± 1 S.E. values for consumers and food resources

Sample	n	Mean $\delta^{13}C$ ± S.E.	Mean $\delta^{15}N$ ± S.E.
Resources			
Podostemum ceratophyllum	5	-37.74 ± 0.21	8.11 ± 0.17
Cladophora	5	-34.20 ± 0.66	3.89 ± 0.11
terrestrial leaf litter	5	-30.87 ± 0.12	4.28 ± 0.10
detrital epilithic biofilm	1	-31.85	7.74
algal epilithic biofilm	1	-28.39	6.09
detrital TOM 1000–100 µm	1	-28.80	*14.36
algal TOM 1000–100µm	1	-28.90	*14.36
detrital TOM 100–1µm	1	-27.87	4.60
algal TOM 100–1µm	1	-28.34	4.49
Consumers			
Amblema plicata (Jul)	6	-32.51 ± 0.07	8.76 ± 0.09
Amblema plicata (Aug)	6	-33.56 ± 0.09	8.62 ± 0.12
Elliptio dilatata (Jul)	6	-32.55 ± 0.09	8.48 ± 0.08
Elliptio dilatata (Aug)	6	-33.67 ± 0.06	8.42 ± 0.07

*Sample size <10 ug N, therefore data must be interpreted with caution.

These findings provide evidence that both mussel species were assimilating benthic food resources, particularly epilithic detritus and perhaps *Cladophora*, during summer. There is little evidence that either species was feeding on either the algal or detrital component of TOM. Stable isotope data for all resources and both consumer species is upcoming for September and October.

USING ELECTRICAL RESISTIVITY TO LOCATE AN ABANDONED FLUORSPAR MINE AS A SUPPLEMENTAL WATER SOURCE FOR THE CITY OF MARION, KENTUCKY

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The primary drinking-water source for the city of Marion, KY, is a 42-acre reservoir known as Lake George. Lake George has a drainage area of approximately 750 acres and has an average depth, at the intake structure, of 30 ft. In 2007, extreme drought conditions resulted in a drawdown in the water level of 8 to 10 ft below the average depth, which was close to falling below the depth of the intake. Because of this drought-induced drawdown, the city of Marion began looking for alternate sources of raw water to supplement Lake George during future dry seasons.

The Lucille fluorspar mine, which was abandoned in the 1930's and is located on city property, provided an ideal potential alternate source of raw water. A detailed plan-view and cross-section map of the mine shows the depth of old workings (40–230 ft), shaft locations, and the location of a dewatering well, which was completed in an abandoned mine shaft. Surface features shown on the old mine map, which might be used to correctly orient the mine (shafts, water well, etc.) on recent aerial imagery, have long been removed. Consequently, the map could not be used to link old workings and shafts to surface features, so the location of the mine in the subsurface could not be determined. City officials asked researchers from the Kentucky Geological Survey to conduct an electrical-resistivity survey over the mine site to attempt to locate subsurface mine features (shafts and workings), which could be used as reference points to orient the mine map and serve as potential drilling targets to install test wells into the mine.

In 2010, eight electrical-resistivity profiles were measured on the property overlying the abandoned Lucille Mine. Seven parallel profiles transected the property from northwest to southeast and were spaced 50 ft apart. These profiles were approximately 400 ft long. The eighth profile was approximately 690 ft long and transected the property in a southwest-northeast direction, cutting across the first seven profiles. The electrode spacing for all profiles was 10 ft, and the two dimensional, direct-current resistivity data were collected using a dipole-dipole array. Although not conclusive without drilling confirmation, inversion results of all eight profiles show conductive anomalies, which may correlate with water-filled mine workings.

In 2011, in an effort to locate buried mine features, city of Marion Public Works personnel used backhoes to open shallow excavations at several locations on the abandoned mine property, and two buried water wells were located. Each well was videoed and gamma-ray logged by Kentucky Geological Survey personnel. Video and gamma-ray log results indicate that one of the wells is completed in an abandoned mine shaft. This well is believed to be the dewatering well on the mine map. The other well is believed to be the water-supply well previously used by Marion. Using the identified shaft location, the mine map can now be correctly oriented and can be used in conjunction with the electrical-resistivity data to propose a more cost-efficient and effective drilling program.

Also in 2011, preliminary water-quality samples were collected from the old dewatering well completed in the mine shaft. Groundwater sampled from the well had a fluoride concentration of 3.5 mg/L, which is above the secondary maximum contaminant level of 2.0 mg/L. The city of Marion plans to have the dewatering well pumped to determine potential drawdown in the mine and to collect additional water samples during pumping to see if the quality of the mine water changes over time.

NUTRIENT AND FECAL MICROBE ASSESSMENT OF THE WATER QUALITY OF TATES CREEK, MADISON COUNTY, KENTUCKY

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Tates Creek is a significant tributary to the Kentucky River that has shown high levels of microbial and nutrient pollution in the past (Kentucky River Watershed Watch). We sampled the waters of Tates Creek more comprehensively by collecting stream water at 25 stations along its 13-mile length from its headwaters to the Kentucky River. Most samples were collected at the confluence of major tributaries to also assess the water quality of tributary streams. Samples were collected four times between May and August 2011 during dry periods as well as immediately after a rainfall event. We measured ammonium (NH_4^+), nitrate (NO_3^-), and phosphate (PO_4^{3-}) concentrations using colorimetry. Microbial samples were measured for total coliform and *Escherichia coli* using IDEXX Colilert-18 media and methods.

Background levels of NH_4^+, NO_3^- and PO_4^- are typically ~0.3 mg/L, 5 mg/L, and 1.0 mg/L, respectively. Thus, phosphate concentration almost always exceeds EPA criteria for freshwater (0.1 mg/L). Background levels of nutrient concentrations generally increase during rainfall events, presumably because nutrients are flushed into the stream. Background counts of *E. coli* are typically ~100 cfu/mL but *E. coli* counts reached 1,000 to 2,419 cfu/mL immediately following rain events. Some areas also show microbial counts far in excess of background levels. Microbe counts tend to be high in the headwaters of Tates Creek where we suspect leaky and/or broken sewage lines are responsible for high *E. coli* counts. Other high counts also occur adjacent to active pasture. Thus, fecal microbe pollution in Tates Creek occurs from both human and bovine sources.

A sewage treatment plant existed approximately two miles from the headwaters of Tates Creek and noticeably affected water quality. Upstream of the plant, nutrient levels are low, whereas nutrient concentration, especially NH_4^+ and PO_4^-, were markedly increased at the plant's outflow. These nutrients then decreased steadily in concentration downstream to background levels. In contrast, when the plant was operating fecal microbe counts were high upstream from the plant, but fell to near-zero levels at its outflow, and then increased anew downstream. The treatment plant went off line on 19 July 2011 and subsequent sampling showed nutrient levels no longer spike immediately downstream. *E. coli* counts remained high upstream and downstream of the plant because stream waters are no longer diluted by plant outflow that carried almost no microbes. A companion study sampled stream biota before and after the plant shut down. Thus, we will be able to note any changes in stream biota attributable to changing nutrient levels.

NOTES

DETERMINING THE EFFECTIVENESS OF CONDUCTIVITY AS A STREAM QUALITY INDICATOR IN SOUTHERN APPALACHIA USING GIS

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The objective of this study was to compare several methods of stream quality analysis; dissolved oxygen, pH, temperature, rapid habitat assessment, macroinvertebrate health data, salamander data, metals analysis, and conductivity to determine whether or not the conductivity readings agreed with the results of the other stream quality analysis methods. The data used in this study were collected by various individuals and the parameters determining the "good" and "bad" cutoff ranges were based on literature review and were selected by the researchers who collected the data. The study sites were all first order headwater streams within the Line Fork watershed in Letcher County, Kentucky, with varying land-use histories; pre-SMCRA (Surface Mining Control and Reclamation Act of 1977), post-SMCRA, and undisturbed old growth forest. The datasets were incorporated into ArcGIS and the technique known as geographic overlay analysis was employed to visually compare the various parameters with conductivity. The results of this study did not match the expected outcome. No correlation between conductivity and the other measures of stream quality was found. Minor correlations were observed; however, no definite relationships were determined.

NOTES

SUSPENDED SEDIMENT CONCENTRATION IN BRUSHY CREEK WATERSHED, KENTUCKY

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Suspended sediment concentration (SSC) can be used as a proxy for environmental health of stream water. For example, large sediment loads can cause harm to aquatic life and are a mechanism for introducing and transporting fecal microbes. We measured SSC of the Brushy Creek watershed, located in Rockcastle, Pulaski, and Lincoln Counties, where the Easter Kentucky University Eastern Kentucky Environmental Research Institute (EK-ERI) has been conducting an assessment of the watershed. Two auto sampling units were placed in Brushy Creek to collect water samples for determination of SSC. The units collect samples every 14 hours for a two-week period, then samples are retrieved for analysis, and new sample bottles are loaded into the auto samplers. Sediment sampling was conducted between January 2011 and November 2011. We measured sediment transport during dry, wet, and storm periods. Retrieved samples were brought to the laboratory where sediments were filtered and weighed to determine SSC. The SSC data have been evaluated along with records of rainfall events, as recorded by the UK Agriculture weather station located in Somerset. The results are somewhat intermittent because of difficulties encountered in locating and operating the sampling units, and because of the extremely flashy nature of the stream system.

Significant rainfall events caused increased flow in Brushy Creek and increased sediment transport, which was reflected in SSC. We see evidence of increased suspended sediment concentration on days that had rain events, but there are also days that have significant rainfall but little sediment activity. On these days of rainfall but little suspended sediment can be attributed to the 30 mile distance between Somerset, where the rainfall data is collected, and the location of the watershed. Since rainfall does not occur uniformly, rain may occur at the monitoring station at Somerset but little or no rain may fall in the watershed.

NOTES

RETAIL DRINKING WATER SHELF SPACE AS A MEASURE OF SURFACE WATER QUALITY IN SOUTHERN APPALACHIA

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Seven Kentucky counties were considered in this exploratory study to establish whether floor space devoted to bottled water in a franchised retail grocery location is a reliable secondary measure of environmental water quality. Two counties were located in central Kentucky, while five counties were located in the southeastern Appalachia region, also known as "coal country". In order to help control for varying population sizes and consumer buying habits, floor space also devoted to soft drinks, aseptically packaged juices, milk, and bread were observed and floor space was assessed as a ratio of total square feet devoted to grocery items at each individual store. Bread was used as a staple product control for liquid items, which may be bought as a replacement for drinking water in the home.

Environmental surface water specific conductivity was obtained from three water quality databases (the Eastern Kentucky Environmental Research Institute, the Kentucky Geological Survey/Division of Water, and the Kentucky Watershed Watch). The greatest challenge was to identify best methods for geographically grouping and relating water quality data samples to the grocery store data. A geographic information system (GIS) was used to spatially group these data using five different strategies: a buffer of individual grocery stores, a buffer of roads within grocery store buffer, watersheds, area development districts, and counties.

As expected, not all strategies were successful. Relationships between grocery commodities and average were found at the watershed, area development district, and county levels. The most promising relationships were found on the county level between conductivity and all five commodities observed. The results suggest that retail shelf space devoted to bottled water could be a reliable measure of surface water quality in coal country. There is also a relationship between surface water quality and per capita income, as well as a relationship between per capita income and retail floor space devoted to basic grocery commodities. These results suggest that where per capita income is lower, more individuals buy staple grocery commodities. Also, where per capita income is lower, surface water quality is poorer. Because the grocery store sample was small, further research is required in order to resolve issues with statistical reliability.

NOTES

MAPPING WATER QUALITY IN COAL COUNTRY:
THE GIS WATERSHED DELINEATION PROJECT

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Since 2006, the Eastern Kentucky Environmental Research Institute has conducted a widespread water sampling project throughout the three major watersheds that drain Kentucky's Appalachian coalfields: The Kentucky, the Big Sandy, and the Upper Cumberland. Together these watersheds form the "Big Dip."

Over the course of four summers, more than 60 trained students and volunteers tested 1,648 water sites for varying water quality parameters as well as geo-referencing each water sample site. In summer 2010, a GIS analysis was initiated. Using the Arc Hydro program within ArcMap, the land area related to each individual water sample point was mapped. These delineations show the area of land that water from a specific point runs off and drains into. The result was a detailed map identifying each sampling point and the land area upstream that it drains—including any sites that are "nested" or within the drainage area of another site. Using the National Land Cover Dataset, the land cover type for each individual watershed was established. Next, using statistical analysis within ArcMap, the percentage of each land use within each individual watershed was calculated. By doing so, a solid connection was established between the water quality from each sample site, the watershed area that contributed to the water quality effect, and the scope of anthropogenic involvement within the watershed. Particular land uses of interest included those identified as "barren land" since these are typically associated with heavy mining activity, and represent either reclaimed mines, mountaintop removal sites, or longwall mine sites.

NOTES

WATER QUALITY IN EASTERN KENTUCKY: THE RELATIONSHIP BETWEEN WATER QUALITY AND POVERTY AT THE CENSUS TRACT LEVEL

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The goal of this study was to determine if there is a positive correlation between Eastern Kentucky's poor water quality and its rampant high poverty rate. Between 2006 and 2009, more than 1600 first- and second- order streams throughout Appalachian Kentucky were sampled for baseline diagnostic water quality measures, including dissolved oxygen, pH, conductivity, temperature, turbidity, and iron levels. These data were compared with census tract level socioeconomic data to examine whether there is a relationship between poor water and poor people. In general, the results indicate that there is little relationship between water quality indicators and sociodemographics such as urban vs. rural; income and education rates, or unemployment and poverty rates. The lack of a relationship between water quality and socioeconomic characteristics may be because poor water quality is so pervasive that it affects everyone in the region, regardless of status. The other explanation may be that, on the whole, the region is relatively socioeconomically homogenous. The typical patterns of clustered or stratified income from neighborhood to neighborhood do not hold true throughout much of Appalachian Kentucky. Differences in household income and poverty rates do not vary greatly from census tract to census tract, so there are very few "wealthy" areas in the region.

NOTES

LABORATORY CALIBRATION OF EXPERIMENTAL VELOCITY AND SEDIMENT CONCENTRATION SENSORS TO MONITOR WATER AND THE ENVIRONMENT

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The focus of this research is (i) the creation and verification of inexpensive instrumentation for sediment transport measurements within intelligent sensor networks, and (ii) the design of wireless intelligent features for minimizing cost and energy while maximizing sensor reliability and accuracy of sediment transport measurements. Recent advancement in sensor network technology promotes inexpensive, small size, and low power requirement sensors due to their faster installation, ability to safely monitor during hazardous conditions, and capability of capturing processes at scales relevant to a wide range of research. The newly developed velocity sensors are called velocity bend sensors (VBS) due to their operating mechanism. Water velocity causes the sensor, which acts as a strain gage, to bend and change the electrical resistance of the sensor. The light attenuation sediment sensors (LASS) use a cadmium sulfide light dependent resistor to measure light intensity. The light intensity in water follows the Beer-Lambert distribution in which light intensity is related to the depth of water and sediment concentration and is impacted by other constituents within the water column. Velocity bend sensors, light attenuation sediment sensors, and inexpensive pressure sensors are constructed followed by calibration and verification of the sensors in an experimental hydraulics laboratory. *Salamander* is the Serial Amphibious Linear Arrays of Micro And Nano Devices for Environmental Research, and the tool provides a versatile, instrumentation platform for deploying hydraulics and water quality sensors within stream networks. *Salamander* outfitted for estimating sediment flux at cross-sections in a

stream will be equipped with the velocity bend sensors, light attenuation sediment sensors and inexpensive pressure transducers. Within the field-deployed Salamander unit, algorithms are used to approximate velocity and sediment distribution and thereafter compute sediment flux for a stream location. Wireless intelligent features are currently being designed and implemented for use of *Salamander* within the stream network of a watershed. The sensor topology should agree with the functioning of the physical stream network, and we make use of this concept by using sensor connectivity to minimize cost and maximize data quality. To reduce costs, algorithms will interpret data collected to activate or deactivate sensors based on data gradients and thresholds. For quality assurance, an algorithm will interpret data between related sensors and nodes and deactivate or flag as possibly erroneous data. So far, results of this new technology include the design of wireless communication capabilities and circuitry for the velocity and TSS sensors along with relationships between sensor output and measured parameters. Full implementation of the project is ongoing at this time and includes collaboration between Civil Engineers at UK and Electrical Engineers at U of L. The velocity bend sensor and light attenuation sediment sensor are expected to provide measurements at temporal and spatial scales in order that parameter fluxes operating at the process-scale can be integrated within the larger scale monitoring network. Data provided by the sensors of suspended sediment load derived from the watershed can be used to calibrate hydrologic and suspended sediment transport models. The sediment monitoring network will be set up at a location where sediment fingerprinting is occurring which will provide insight into the source of the sediment. By the end of the research period, new techniques will have been developed so that instrumentation can be quickly set up in any watershed to capture in real time the hydrologic and sediment fluxes.

DELINEATION OF SOLUTE INPUTS TO THE HEADWATERS PORTION OF THE CANE RUN/ROYAL SPRING BASIN OF NORTH-CENTRAL KENTUCKY

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The Cane Run watershed, located within Fayette and Scott Counties in north-central Kentucky, is underlain by a karst aquifer that discharges to Royal Spring, which is the primary source of water for the city of Georgetown. Karst aquifers are more susceptible to contamination than conventional porous or fractured-rock aquifers because of focused recharge with minimal filtration. Water quality of karst springs can exhibit short-lived degradation following storm events. Heightened levels of contamination may compromise both aquatic life and public water supplies. Water quality of the Cane Run/Royal Spring basin is thought to have been compromised by pollution from agricultural, industrial, and residential sources. Non-point-source pollution has resulted in excess nutrients and bacteria throughout the watershed. Consequently, Cane Run has been listed by the Kentucky Division of Water as a priority stream for cleanup.

This study was initiated in late summer 2012 with the purpose of delineating solute inputs into the headwaters of the basin in north Lexington over a one-year period. Field parameters (temperature, specific conductance, pH, and dissolved oxygen), selected ions (chloride, sulfate, nitrate, and ammonium), and stable isotopes of water (deuterium and oxygen-18) have been monitored biweekly at seven sites within the basin. Chloride and stable isotopes of hydrogen and oxygen are conservative (i.e., unaffected by chemical reactions at ambient temperatures) but are affected by evaporation. Those parameters are thus useful for examining mixing of waters from different sources. Nitrate and ammonium are nutrients that can originate from agricultural sources (e.g., fertilizer and animal waste) or from leakage of sanitary sewers. Temperature, specific conductance, and pH have been measured in the field using a multi-parameter probe. Dissolved oxygen is being measured using the Winkler titration method. Ions are being analyzed via ion chromatography (sulfate and chloride in the UK Environmental Resources and Training Laboratory; ammonium and nitrate in the UK Department of Forestry). Oxygen-18 and deuterium will be analyzed in the UK Department of Earth and Environmental Sciences using a gas-source, continuous flow, isotope-ratio mass spectrometer. These same parameters will be monitored at regular intervals at two sites during two storm events, tentatively in March and June, using ISCO automated samplers.

We will use graphical and statistical analyses to examine spatial and temporal (both seasonal and event-scale) trends in water-quality parameters. Graphical techniques will include bivariate plots. Principal component and hierarchical cluster analyses will be performed using MATLAB software. Spatial variations in water-quality parameters will be displayed within a comprehensive geodatabase of the basin using ArcGIS.

NOTES

IMPACT OF NITROGEN FERTILIZATION ON SOIL MICROBIAL RESPIRATION AND PHENOL OXIDASE ACTIVTY

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Anthropogenic nitrogen inputs are known to alter extracellular enzymes which in turn mediate transformation reactions of soil organic matter. Past studies have noted that inorganic N fertilization negatively impacts soil phenol oxidase activity in relatively undisturbed (no-tillage) agroecosystems and forest systems. These responses have been correlated with soil organic matter concentration and dissolved organic carbon export. It is unclear whether decomposition rates of soil organic matter, as measured by respiration, are affected by N inputs in no-tillage systems. This study was undertaken to measure microbial respiration and phenol oxidase activity in no-till soil (Maury silt loam) under the influence of increasing N fertilization rates (0, 168 and 336 kg N ha^{-1} as NH_4 NO_3). Phenol oxidase activity values decreased 1.4- and 1.6-fold with the addition of 168 and 336 kg N ha^{-1} when compared with the control. Reductions in phenol oxidase activity with N input were magnified when data were expressed on a soil organic carbon basis. Respiration rates based on carbon dioxide release were reduced with N inputs and were negatively correlated with available (water-extractable) nitrate. Although the exact mechanism explaining the suppression in soil respiration rate with N input is not known, the results suggest that soil organic carbon is less prone to decomposition with N additions in no-tillage agroecosystems. Future work will address the possibility of mineral stabilization of soil organic carbon and the impact of N on other extracellular enzymes.

NOTES

BY-PROXY MONITORING OF AQUEOUS NITRATE PHOTOLYSIS AND THE EFFECT OF HYDROXYL RADICAL

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A model by which we may grasp the full extent of Earth's atmospheric conditions is far from complete. There is an immense expanse where air and water meet, such as that of the oceans, rivers, lakes, and snow packs; these unaccounted sources significantly contribute to the atmospheric chemistry of our Earth and must be accounted for if we are to accurately model atmospheric conditions. The purpose of our research is to advance our understanding of the production of toxic NO_x (= $NO + NO_2$) and ozone (O_3) at the surface of water reservoirs, a mechanism that is poorly characterized. A significant input may come from reactions of nitrate ion (NO_3^-) following exposure to sunlight (or other sources of ultraviolet light). Unraveling the reactions that follow photolysis of NO_3^- is critical in evaluating its role in the production of pollutant gases. Through the use of infrared (IR) spectroscopy, previous work has asserted that nitrate concentrations are split between two different molecular structures. Over time, the relative concentrations of the two structures shift due to influences within the immediate environment. We have examined the influence of hydroxyl radicals (OH·) upon nitrate using hydrogen peroxide as a radical source. Benzoic acid is used as a reporter by which we observe radical concentration. Thus, changes to the aqueous NO_3^- IR spectrum can be correlated to hydroxyl radical concentrations. Spectra were collected every five minutes for eight hours following a brief UV irradiation of the sample. The impact of temperature is assessed as well, both on the shift in peak intensities and on the kinetics of the reaction network. At this early stage of the project, we will present our preliminary data on aqueous nitrate at various temperatures, and the use of benzoic acid as a hydroxyl radical reporter. Through use of this array of variables, the role of hydroxyl radical in the production of NO_x and O_3 will be clarified, so that models of the creation of these pollutants from natural resources can be refined and included into global climate change predictions.

NOTES

DATA MINING THE DIGITAL TERRAIN: USING LiDAR "BARE EARTH" AND "MODEL KEY" RETURNS TO ASSESS WATERSHED TOPOGRAPHY

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Accurate topographic data are critical for watershed modeling and management. High quality LiDAR derivative products, such as digital terrain models (DTM), digital surface models (DSM) and contour lines are becoming commonplace as a result of increasing data availability, together with a growing variety of software tools. LiDAR point clouds are routinely classified into "ground" (or "bare earth") returns, and "model key" points – in essence a thinned-out subset of that class (ASPRS, 2012). The sensitivity of LiDAR measurements to very low, ground-level vegetation and micro relief creates the need to generate contour lines that are reflective of modeled – if not true, bare earth conditions. To that effect, contour lines are routinely derived from model key points to avoid the vagaries inherent in wholesale "ground" point elevations.

LiDAR survey data from the Kentucky portion of the Risk MAP Initiative were acquired in the Upper Cumberland River watershed (HUC 05130101), on April 2010 (FEMA 2010a). Survey points were collected at approximately 1.0 m ground sampling distance with no snow on the ground, rivers at or below normal levels, and under cloud-free conditions; points were assigned classes of: "ground" and "model key" in accordance with current classification schemas (FEMA, 2010b; USGS, 2010). A .las tile covering 2.323 square kilometers corresponding to the urban-forested land interface in the city of Corbin in Whitley County was used for this analysis (Kentucky Geography Network, 2012).

QCoherent™ LP360™ v.2011.1.54.0 and Esri® ArcGIS® Desktop v.10.0 SP3 were used to sample the LiDAR point cloud and to generate data sets and analytical derivatives. Elevation and slope ranged between 492.5 and 332.3 meters (mean= 369.8 meters; standard deviation= 28.1 m), and between 81.6 and 0 (mean=12.1 degrees; standard deviation= 10.0). Sets of contour lines were extracted from model key and "ground" digital elevation models (DEM-k and DEM-g, respectively). Geometric congruity between the two types of contour lines was sometimes appreciable, but more often than not discrepancies were substantial (*Figure 1*). Focal statistics derived from a normalized bare earth digital elevation model (DEM-n), created by subtracting DEM-g from the DEM-k are used to provide critical information on terrain rugosity and morphology, while at the same time to help explain some of the variation in LiDAR intensity values.

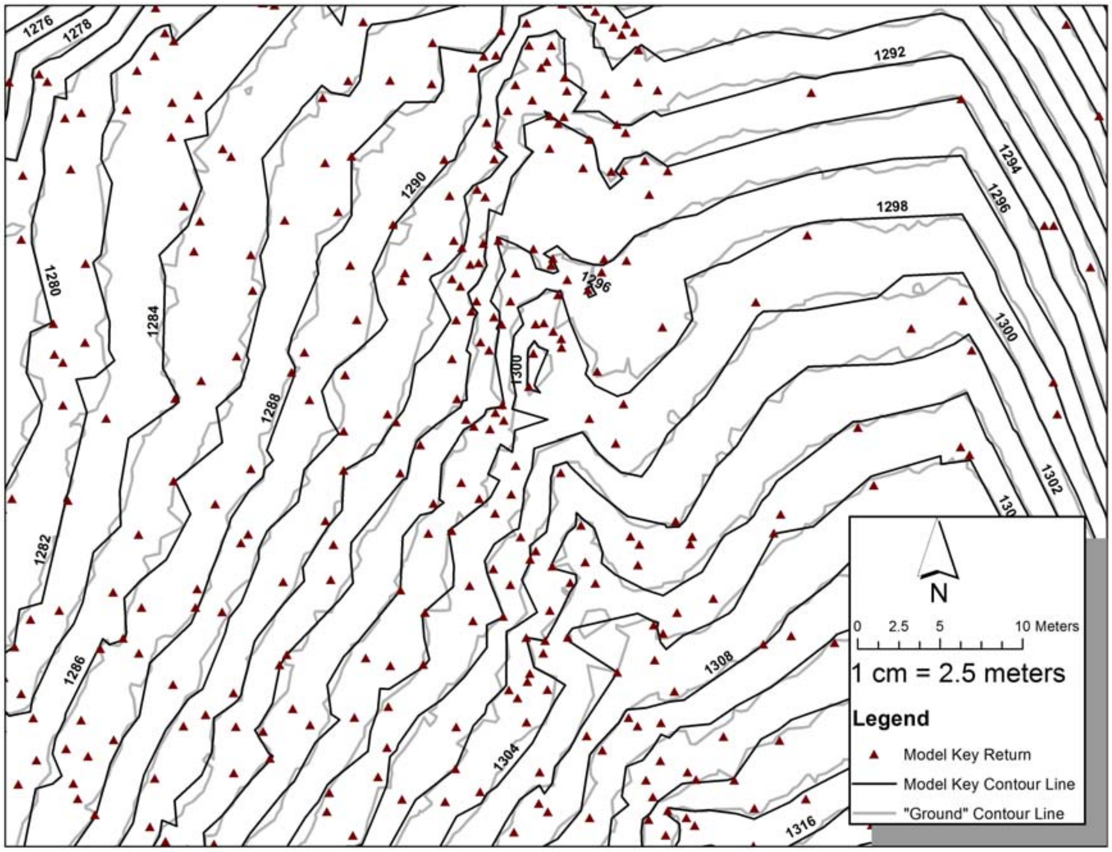

Figure 1. LiDAR model key returns and contour lines comparison to "ground" contour lines. See text for explanation.

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THE WATERSHED ATLAS PROJECT

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This interactive poster presentation demonstrates an approach that utilizes publically available geospatial data from the Kentucky Geography Network and other federal sources to visualize landscape indicators to describe watersheds. Initial grounding for this work can be found in Jones et al. (1997). By viewing the landscape from a watershed perspective, this atlas is intended to present an understanding of land use management decisions, as well as insight into how those decisions affects waterways and water. This project used the Hydrologic Unit Code (HUC)14 watersheds as the fundamental unit of analysis. Each of the 9,109 HUC14 subwatersheds spanning 13 river basins is described using over 100 indicators. All the indicators are in a format that allows visualization in tabular, graph, and map forms.

The atlas is divided into six sections by the following themes: Geographic Introduction, Geomorphic, Human, Vegetative, Riparian, and Specialty Indicators. An indicator glossary is included to provide source information and a description of each analysis. The geographic introduction section provides base information to introduce the basin and its subwatersheds and waterways in the context of notable landmarks. The second section provides a geomorphic watershed characterization that focuses on data attributes such as size, elevation, aspect, terrain, etc. Section three addresses the human modified aspects such as impervious cover, impervious cover change over time, and roadways in relationship to water resources, etc. Section four details the vegetative land cover of the watersheds with specific indicators focusing on percentage of agriculture and forest, as well as the relationship of agriculture on land slopes of three-percent and greater. In addition, this section characterizes changes in land cover type that occurred between 2001 and 2005 as well as 2001 and 2006. Section five focuses on stream and riparian area characteristics, and section six focuses on specialty indicators such as pollutant discharge elimination system points and regulated dams.

The primary benefit of characterizing the landscape from a watershed perspective is the ability to recognize the human influenced impacts using a flexible data approach

(Hawkins et al., 2000; Patil, 2002). This atlas can be used as a tool to identify landscape characteristics that are relevant to land management decisions particularly when water resources are concerned. For example, when watershed plans need to be made to reduce nutrient loading or identifying restoration potential (USEPA, 2005) these data can be used. A watershed-based approach for making decisions requires cities, counties, and states to recognize that though they may appear to be distinct entities, ecological features and processes connect them. This is an inherent argument for land decisions to be made with watershed characterizations in mind.

At this point in the process, there has been invested approximately two computer-processing years to develop this atlas. We expect another several calendar months of work to complete the planned indicators for the HUC14 scale subwatersheds. Once completed, these indicators will be derived for all the HUC12 scale subwatersheds to begin researching scale relationships.

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POTENTIAL FOR LEVELS OF ARSENIC AND CHROMIUM IN DRINKING WATER TO CONTRIBUTE TO THE HIGHER CANCER RATES FOR EASTERN KENTUCKY CITIZENS AS COMPARED TO THE REST OF THE STATE

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Various sources have indicated that elevated amounts of heavy metals like arsenic (As) and chromium (Cr) in the drinking water and soil of Appalachia play a causative role in the region's high lung and colorectal cancer rates. In order to test the plausibility of the hypothesis that drinking water may be contributing to the recognized problem, the Division of Water (DOW) examined the levels of arsenic and chromium both in public and private water supplies statewide. We did not investigate levels of As and Cr in the soils.

We gathered monitoring data for treated drinking water from Kentucky's 519 Public Water Systems (PWS) ranging in size of as few as six (6) to as many as 730,611 customers. Monitoring data were also evaluated from commercial bottled water facilities. Assessed data included PWS monitoring from the past eleven years, January 2000 through September 2011. Drinking water data from 702 wells for arsenic and 498 for chromium were also evaluated and presented as part of the discussion. It should be noted that many of these samples were obtained from private drinking water wells sampled in response to a well owner's concern; therefore, the wells may bias the sampling towards problem areas.

In evaluating the PWS data, we pooled the information based on physiographic regions including the Eastern Coal Fields (27 counties), Western Coal Fields (10 counties), Bluegrass (44 counties), Mississippi Plateau (31 counties), and Jackson Purchase (8 counties). For purposes of evaluation of the groundwater data, additional regional groupings included the Ohio River Alluvium and an economic region referred to as the Golden Triangle, an area bounded by Louisville, Lexington and Northern Kentucky.

Arsenic and Chromium do not occur at levels of concern in any PWS across the state, including the commercial bottled water facilities. In fact, monitoring indicates that levels of As and Cr in public drinking water are consistently below possible health effects levels (i.e., below MCLs: total As is 0.010 mg/L and total Cr is 0.10 mg/L). Of the monitoring data collected over the last eleven years from the 519 PWS in Kentucky, **only one MCL violation was noted for any metal, including As and Cr (i.e., antimony in a December 2004 sampling at a PWS in Knox County).**

We examined the well data using the traditional EPA statistical averaging method and a second method known as the central tendency analysis (average, median). In the majority of the samples, metal concentrations were below the analytical detection limit and the two methods included that data in the analysis.

Total As and Cr levels were below concentrations of concern (MCLs) in groundwater in all regions of Kentucky including the Eastern and Western Coal Fields. Both statistical analysis methods resulted in similar low levels of As and Cr for each region.

Arsenic and chromium were not found at levels of concern in drinking water supplies in the Commonwealth of Kentucky, including water supplied by private drinking water wells and Public Water Systems. Speculation that the citizens living in the Eastern Kentucky Coal Field are uniquely exposed to heavy metals like arsenic and chromium in their drinking water supplies above those in other regions of the Commonwealth, does not appear to be a valid theory. In fact, statewide analytical sampling data from both public drinking water systems and drinking water wells indicates the levels of heavy metals are generally below that of health concern levels.

PATHOGEN TOTAL MAXIMUM DAILY LOAD
FOR SOUTH ELKHORN CREEK WATERSHED

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The study area is 170 square miles comprising the watersheds of the South Elkhorn Creek and its tributaries, Wolf Run, Town Branch, Steeles Run, and Lee Branch. Pathogens, as indicated by fecal coliform bacteria, impair the watershed for Primary Contact Recreation. The impairment was based on water samples taken during the primary contact recreation period of 2002. An HSPF computer model of the study area was developed to assess the current conditions and develop the TMDL. Sources of the impairment that were investigated and modeled included nonpoint sources such as agricultural and urban runoff, and point sources such as wastewater treatment plants and sanitary sewer overflows. After the model was calibrated for the hydrologic behavior of the watershed using rainfall and stream flow data, the model was calibrated to simulate the buildup and transport of fecal coliform bacteria. Literature provided initial estimates of fecal buildup from the various sources, but these estimates required further calibration to best fit the observed laboratory data. Using the calibrated model, pathogen load reductions were simulated until the model predicted in-stream concentrations of fecal coliform bacteria which satisfied the state water quality standards. The state water quality standards in terms of fecal coliform for the primary contact recreation season include a chronic criterion and an acute criteriian. The chronic criterion states that fecal coliform cannot exceed 200 colonies per 100 ml measured as a geometric mean of at least five samples over a 30 day period, and the acute criterion states that no more than 20% of the individual samples can exceed 400 colonies per 100 ml. The simulated load (after reductions) resulting in the simultaneous satisfaction of both standards became the basis for the TMDL values. To achieve the TMDL, illegal point sources (straight pipes, failing septic systems, and sewer overflows or system leaks) needed to be eliminated. The percentage of load reductions required for nonpoint sources was most commonly 25%.

NOTES

NUTRIENT TMDL FOR TOWN BRANCH/WOLF RUN WATERSHED

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The study area is 40 square miles comprising the watersheds of the Town Branch and Wolf Run creeks. Nutrients, as indicated by the limiting nutrient phosphorus, impair the watershed for Warm Water Aquatic Habitat. The impairment was based on water samples taken from March 2009 to March 2010. An HSPF computer model of the study area was developed to assess the current conditions and develop the TMDL. Sources of the impairment that were investigated and modeled were nonpoint sources such as agricultural and urban runoff, and point sources such as wastewater treatment plants and sanitary sewer overflows. After the model was calibrated for the hydrologic behavior of the watershed using rainfall and stream flow data, the model was calibrated to simulate the buildup and transport of phosphorus. Literature provided initial estimates of phosphorus buildup from the various sources, but these estimates required further calibration to best fit the observed laboratory data. Using the calibrated model, phosphorus load reductions were simulated until the model predicted in-stream concentrations of phosphorus which satisfied the state water quality targets. The state is in the process of developing nutrient standards, and at the time this study was conducted the state set a target for phosphorus of 0.3 mg/L measured as a geometric mean over a one year period. The simulated load (after reductions) resulting in the satisfaction of the target became the basis for the TMDL values. To achieve the TMDL, illegal point sources (straight pipes, failing septic systems, and sewer overflows or system leaks) needed to be eliminated. The model indicated that conditions measured by the target process did not require reductions for nonpoint sources, but did necessitate a substantial reduction in the phosphorus concentration of the wastewater treatment plant discharging within the watershed.

NOTES

ANALYZING MONTHLY TRENDS OF RAINFALL AND TEMPERATURE IN NORTHWEST INDIANA
TO EXAMINE CLIMATE CHANGE

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Long term monthly trends of rainfall and monthly mean temperatures were examined using the Seasonal Mann Kendall testing procedure in this study. The main objective of this work is to study the changes in low flow regime in northwest Indiana and understand the influence of rainfall, temperature and landuse pattern changes. Three rainfall stations with daily rainfall observations of 50 years or more were considered for this purpose (Table 1).

Table 1. Monthly Rainfall and Mean Monthly Temperature observations (Data Source NOAA)

Station Name	**Data Available from**
La Porte	Apr 1897
Valparaiso	Jan 1900
Lowell	Aug 1963

A non parametric testing procedure called the Mann-Kendall (MK) test was used for analyzing trends in the single station data series. The MK test is popularly used to identify trends in climatological time series (Zhang et al 2001). Chronological series are used in this method. When a time series with seasonal fluctuations is analyzed, a slight change was proposed by Hirsch and Slack (1984). In this seasonal MK test, S_i is calculated using for each season considered (Helsel and Hirsch, 2002). When S is positive, it indicates an upward trend and negative value indicates a downward trend.

When the test was conducted on monthly mean temperatures and monthly rainfall, the results were not showing trends at 95% confidence level. However, the variations of "S" were captured and presented in Figure 1 and 2 for Valparaiso Station. February to June showed an increasing mean monthly temperature and July to October showed a decreasing trend. November showed an increasing rainfall trend at 95% confidence limit.

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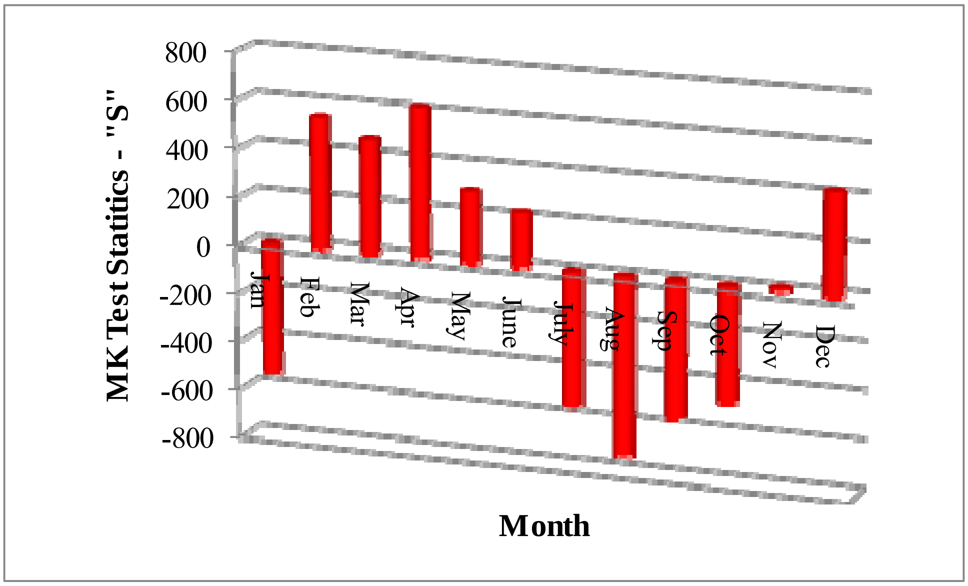

Figure 1. Monthly Temperature Variations – Valparaiso MK-Test Statistics

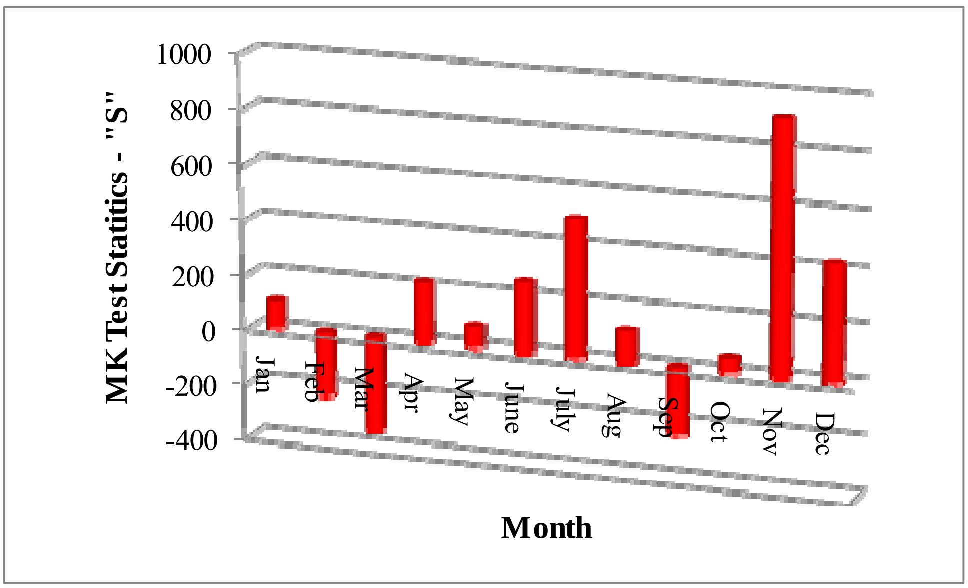

Figure 2. Monthly Rainfall Variations – Valparaiso MK-Test Statistics

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EXAMINING CLIMATE CHANGE INDICES OF INDIANA

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Introduction

This research examines climate change indices to understand the changes in Indiana rainfall patterns during the last 30 years. For this purpose, daily rainfall data from 1950 to 2010 were used. In total, 57 rain gage stations located in Indiana were considered for this analysis.

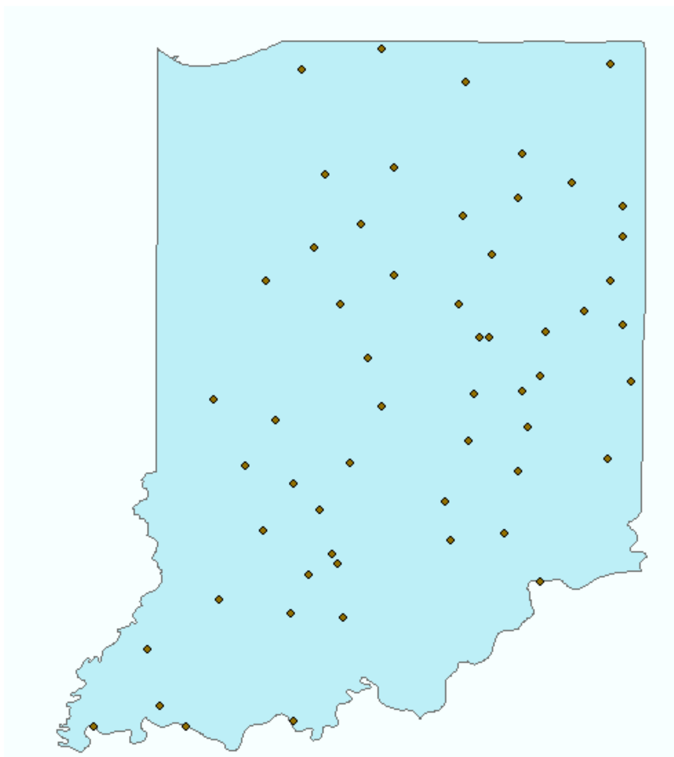

Figure 1. Rain gage stations considered in this analysis

Analysis

Climate indices namely maximum one day precipitation (RX1day), maximum five day precipitation (RX5day), simple daily index, count of precipitation days with observed daily rainfall greater than 10 mm (R10mm), count of precipitation days with observed daily rainfall greater than 20 mm, consecutive dry days (CDD), and consecutive wet days (CWD) were calculated using the rainfall data. Daily series were split into two groups (1950 to 1980 and 1981 to 2010). Climate indices were calculated for the two time periods for all the regions and the indices were documented (Table 1). Climate indices in group 1 and group 2 were compared to check variation. Further, calculated indices were compared by dividing Indiana into four sub regions (northeast, northwest, southeast and southwest). The numbers of rain gage stations considered in each region are also given in Table 1. After finding the indices for individual stations, they were averaged for each sub region.

Table 1. Regional climate change indices RX1day, RX5day and CDD

		RX1day		RX5day		CDD	
Sub regions	**Number of Stations**	**1950-1980**	**1981-2010**	**1950-1980**	**1981-2010**	**1950-1980**	**1981-2010**
North East	16	4.64	4.94	7.28	7.83	6429	6271
North West	10	5.67	5.96	7.65	9.91	6563	6079
South East	12	4.58	4.77	7.08	7.29	6519	6318
South West	19	5.85	5.83	8.67	9.22	6647	6539

In the recent 30 years, more wet days were observed. RX1day indicates that in three subregions (northeast, northwest and southeast), there was an increase in the maximum one day precipitation. It remained the same in the southwest sub region of Indiana. On the other hand, 5 day maximum rainfall fall increased in all of the regions. Consecutive dry days decreased in all the regions. Northwest had a large decrease indicating increased precipitation activity.

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References:

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