

Kentucky Interagency
Groundwater
Monitoring Network

Annual Report
July 2011–June 2012

Bart Davidson, Compiler
Kentucky Geological Survey
University of Kentucky
Lexington, Kentucky

Kentucky Geological Survey
James C. Cobb, State Geologist and Director
University of Kentucky, Lexington

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Kentucky Interagency Groundwater Monitoring Network Annual Report July 2011–June 2012 Executive Summary

Adequate supplies of clean groundwater are essential to many of Kentucky's citizens, businesses, industries, and ecosystems. Regional and temporal variations in groundwater quantity and quality are not adequately known, however. For this reason, the 1998 Kentucky General Assembly directed the Kentucky Geological Survey to establish a long-term groundwater monitoring network (KRS 151.620 and 151.625). Known as the Kentucky Interagency Groundwater Monitoring Network, this entity collects groundwater data, characterizes groundwater quality, distributes groundwater information, improves coordination between agencies that use groundwater data, and facilitates data sharing. These activities are conducted in cooperation with the Interagency Technical Advisory Committee (ITAC), composed of representatives from nine State and Federal agencies and three from the University of Kentucky. The duties and responsibilities of this committee include developing a plan to coordinate agencies for overall characterization of the state's groundwater, reviewing the data-entry process to ensure that all groundwater data collected are placed into the Kentucky Groundwater Data Repository, establishing a long-term groundwater monitoring plan for the commonwealth, recommending priorities for the state's groundwater research needs, and annually reviewing and evaluating groundwater data collection and analysis.

The Kentucky Geological Survey is also charged with annually reporting network activities to the governor's office and the Legislative Research Commission. This report summarizes activities during the 2011-12 State fiscal year.

From July 2011 through June 2012, 28 data-collection programs were under way. Groundwater information was communicated to the scientific

and regulatory communities and to the public through 13 publications and 22 presentations, as well as postings on Web sites. Quarterly meetings of the Interagency Technical Advisory Committee provided an opportunity to coordinate groundwater-related efforts and share information among agencies. Exchange of groundwater data, including electronic transfer of analytical results between Division of Water and Kentucky Geological Survey databases, has proceeded through close cooperation between the Kentucky Division of Water and the Kentucky Geological Survey.

The Kentucky Interagency Groundwater Monitoring Network has been in existence for 14 years. During this time, significant progress has been made, but important work remains to be completed. Among the ongoing critical issues facing Kentucky are:

- Determining recharge areas for sampled wells and springs so water supplies can be protected
- Establishing monitoring sites in areas that are currently not monitored or where groundwater demand is expected to increase
- Optimizing the sampling frequency to account for natural variations in groundwater flow systems throughout the state
- Monitoring the rate of intrusion of nonpoint-source contaminants into groundwater systems so that effective prevention and remediation can be implemented
- Establishing standard procedures for assessing whether compromised well integrity is allowing surface contamination to reach groundwater supplies
- Standardizing reported information about sampling methods, field measurements,

- and sample-site descriptions to promote data sharing
- Developing a water-level monitoring network to track long-term land-use and climate effects on groundwater supplies
- Standardizing reporting procedures and database structures to facilitate electronic data sharing
- Providing increased public access to groundwater-quality data in order to increase awareness
- Determining sources and amounts of bacteria and other pathogens in both local and regional groundwater flow systems
- Investigating the amount of pharmaceutical and personal-care-product chemicals in water systems
- Evaluating amounts and effects of pesticide metabolites in groundwater
- Increasing the use of stable isotopes, caffeine, and other tracers to indicate contaminant sources and quantify groundwater ages and flow rates
- Quantifying how groundwater affects the quality and quantity of water in streams in terms of water-quality standards, total maximum daily loads, and designated uses.

Additional issues in the news that relate to groundwater have been discussed at recent ITAC meetings, including:

- The effect of metals in groundwater on public health
- The increase of emergent pharmaceuticals found in surface water and groundwater and their effect on the health of both humans and animals
- The rapid increase of geothermal energy development and how this process affects aquifers
- The impacts of natural gas fracturing (“fracking”) on aquifers
- The effects of stormwater injection into karst and alluvial systems
- The growing trend of nitrate spikes in some groundwater systems
- Groundwater nutrient contributions related to total maximum daily loads
- Expanding irrigation and how it affects the drawdown on aquifers in western Kentucky

The Kentucky Interagency Groundwater Monitoring Network will continue to address these issues. Recent advances have been the result of substantial agency commitment of State executive budget funds; one-time, competitive grants to the Kentucky Division of Water’s Groundwater Section and the Kentucky Geological Survey; and voluntary cooperation between agencies. An effective groundwater monitoring network requires sustained, recurring funding to maintain the long-term effort.

Introduction

Groundwater is used extensively throughout Kentucky for domestic, agricultural, commercial, and industrial purposes. Because of its connection with rivers, lakes, and wetlands, groundwater is also essential to the health of surface-water ecosystems. Determining the quality of this resource and protecting it from contamination are vital to the future of the commonwealth and its citizens. The Kentucky Interagency Groundwater Monitoring Network was established in 1998 by the Kentucky General Assembly to increase knowledge and awareness of groundwater resources. For 14 years, the network has met its obligation of collecting and interpreting data, communicat-

ing findings, sharing data, and promoting inter-agency cooperation. Previous annual reports for the network are posted at www.uky.edu/KGS/water/gnet.

The 1998 legislation also established the Interagency Technical Advisory Committee to assist the Survey in the development, coordination, and implementation of a groundwater monitoring network (KRS 151.629). The following agencies and organizations were asked to appoint a representative to the Interagency Technical Advisory Committee:

- Kentucky Department for Environmental Protection

- Kentucky Department for Natural Resources
- Kentucky Department of Agriculture, Division of Pesticide Regulation
- Kentucky Division of Conservation
- Kentucky Division of Forestry
- Kentucky Division of Public Health Protection and Safety
- Kentucky Division of Waste Management
- Kentucky Division of Water
- University of Kentucky, College of Agriculture
- University of Kentucky, Kentucky Geological Survey
- University of Kentucky, Kentucky Water Resources Research Institute
- U.S. Geological Survey, Kentucky Water Science Center.

Information provided by the Kentucky Division of Water indicates that more than 400,000 citizens rely on water from private wells and springs for drinking, cooking, and washing. Public water systems serving more than 1.25 million people also rely on groundwater as a source of drinking water. This dependence on groundwater resources will continue and may increase for economic reasons. Many public water-supply systems are considering switching from surface-water to groundwater sources because the required treatment and monitoring are less extensive and less expensive. Furthermore, many people who now rely on private wells or springs for domestic water supplies will remain dependent on groundwater because of the cost of extending public water-supply systems to rural areas and because groundwater supplies are more than sufficient in some areas of the commonwealth.

Significant quantities of groundwater are used for commercial and industrial applications, crop irrigation, livestock watering, mining, and thermoelectric power generation. Groundwater also sustains valuable ecosystems by providing base flow to streams, lakes, and wetlands. This is particularly important during moderate to severe droughts, such as those that occurred in 1999-2001, 2005-06, 2007-08, and 2011-12. In the absence of precipitation, groundwater base flow is the only source of water to maintain stream flow

and lake levels, and to preserve riparian and wetland ecosystems.

2011-12 Activities and Accomplishments

Brief summaries of work performed by the ITAC agencies during the 2011-12 State fiscal year are presented below to show how the major goals of the network are being addressed. Additional information regarding these projects can be obtained by contacting the responsible agency.

The Interagency Technical Advisory Committee met four times during the 2011-12 fiscal year: July 12, 2011, at the Kentucky Geological Survey in Lexington; October 11, 2011, at the Department for Environmental Protection in Frankfort; January 4, 2012, at the Kentucky Geological Survey in Lexington; and April 10, 2012, at the Division of Water in Frankfort. These meetings served as opportunities for networking and information sharing between committee members.

The Kentucky Geological Survey–Water Resources Section, the Kentucky Division of Water–Groundwater Branch, and the Kentucky Water Resources Research Institute served as the conference planning committee for the 56th annual Midwest Ground Water Conference, held September 19–21, 2011, in Lexington. Two preconference field trips were provided (Mammoth Cave and the Cane Run watershed). The keynote session was presented by David R. Wunsch, director of science and technology at the National Ground Water Association (a former employee of the Kentucky Geological Survey and a participant in the Interagency Technical Advisory Committee). The conference program included 22 oral presentations, six poster presentations, and three additional special banquet and luncheon speakers.

The Kentucky Water Resources Annual Symposium was held March 19, 2012, and was attended by approximately 120 participants. The program included presentations on the need for regulation of geothermal closed-loop borehole installations, strategies for effective management of nonpoint-source pollution in wellhead protection areas, karst monitoring at the Kentucky Horse Park, fluid evolution in the Knox Group reser-

voirs, and simulation of carbon dioxide storage in a deep saline reservoir.

Statewide and regional ambient monitoring programs evaluated groundwater that is not affected by point-source contamination and determined whether nonpoint-source chemicals such as sewage, pesticides, fertilizers, and volatile organic compounds have affected groundwater quality. These large-scale studies are conducted in basin management units (Fig. 1), which were established by the Kentucky Division of Water (1997) and include one or more major river watersheds. Site-specific studies were conducted in smaller watersheds or other, more restricted regions. These more specific studies were designed to evaluate the effects of particular land uses or unique hydrologic conditions on the quality of unregulated water supplies, such as roadside springs, used by the public.

Groundwater Data Collection

Groundwater data are generated through many avenues. Drilling wells, collecting and analyzing water samples, measuring water levels in

wells, and mapping recharge and discharge areas of karst systems provide the fundamental data needed to determine current groundwater quality, detect changes over time, and evaluate hydrogeologic hazards.

Kentucky Division of Water, Watershed Management Branch, Groundwater Section

The Groundwater Section of the Kentucky Division of Water, Watershed Management Branch, maintains an active groundwater sampling and analysis program. The following projects have been active during the report period.

Ambient Groundwater Monitoring Network. Regularly scheduled sampling continued for the statewide Ambient Groundwater Monitoring Network. This fiscal year 114 samples were collected from 55 sites (wells and springs) across the state. Groundwater-quality data were provided to numerous persons through information requests. Data were also included in statistical analyses for regional and watershed-based groundwater assessments.

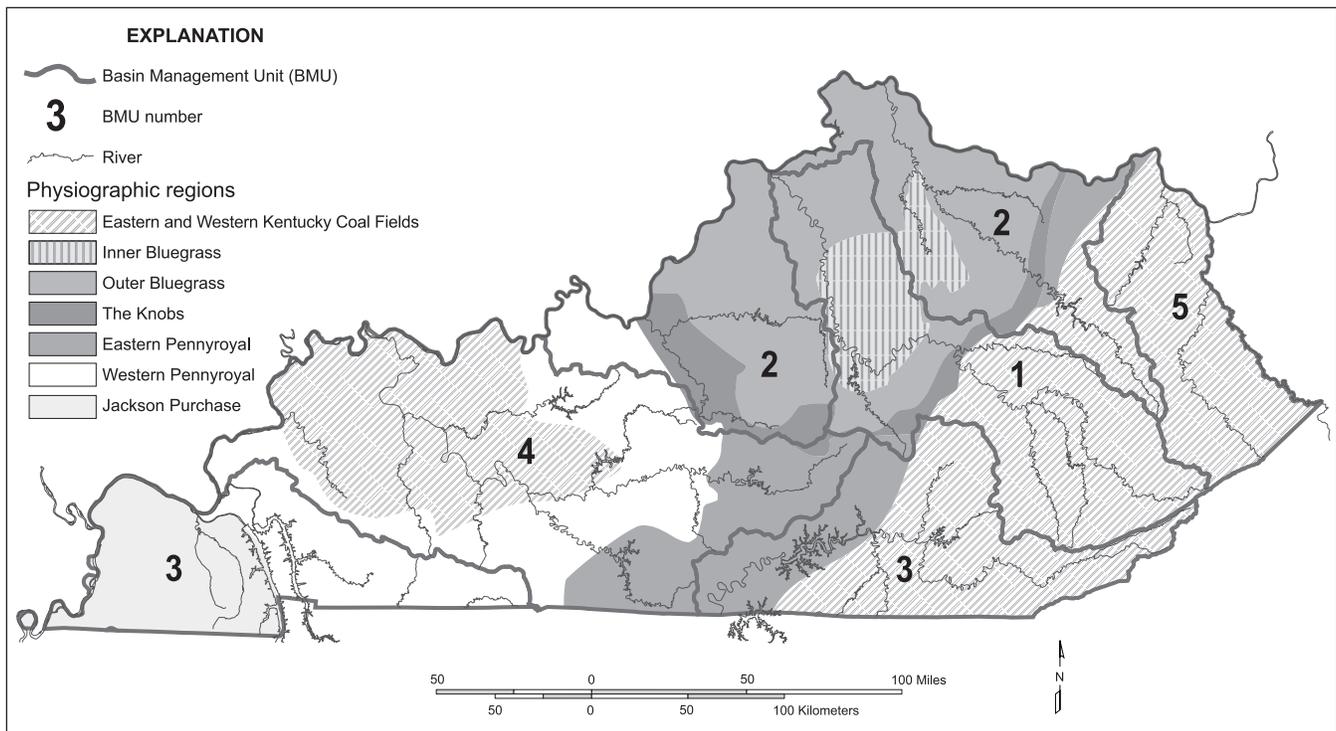


Figure 1. Major rivers, basin management units, and physiographic regions in Kentucky.

Pesticides Memorandum of Agreement Project (Pest MOA). The Pest MOA with the Kentucky Department of Agriculture covers four permanent sampling sites (three springs and one well) in western Kentucky. Each site was sampled quarterly for a total of 16 samples during the fiscal year. Pesticide data from these sites and the Ambient Groundwater Monitoring Network sites are submitted to the Department of Agriculture annually.

Complaint Sampling. The Division of Water responds to complaints about groundwater and investigates as requested by the general public. In this fiscal year the division collected 40 samples from 40 sites in response to complaints. The majority of these samples were collected by Groundwater Section personnel. Several other water wells and springs were inspected in response to requests from citizens for technical assistance, for which analytical samples were not collected.

Nonpoint-Source Groundwater Assessments. The division currently has five active nonpoint-source projects in various phases from final report drafting to study area reconnaissance and site selection.

Groundwater-Quality Assessment in Sinking Creek and Beargrass Creek Watersheds (NPS0303). The final report for this project is currently being written. Groundwater-quality monitoring and tracer tests have been completed. The impact of nutrients, pesticides, and bacteria on groundwater in both watersheds was noted. Presentations on groundwater infiltration of the sanitary sewer system in the Beargrass Creek Watershed, Jefferson County, have been made at water-resource conferences and to a community watershed group.

Elkhorn Creek Sub-basin (BMU 5) Groundwater Study (NPS0604). This project focuses on assessing groundwater quality of domestic wells along Elkhorn Creek in southeastern Pike County and northeastern Letcher County. All water-quality samples have been collected and their chemistry analyzed. Each well used in this study will be sampled for total coliform and *E. coli* bacteria. Biological activity reaction tests will also be conducted at each well; these tests include iron-related bacteria, sulfate-reducing bacteria, and slime-forming

bacteria. Preliminary work on the draft report is currently in progress.

West Pennyriple Karst Study (NPS0704). Work on this project began in late fall of 2008. Tracer tests are currently being conducted throughout the study area, which is in Livingston, Crittenden, Caldwell, Lyon, and Trigg Counties. Thus far, 36 tracer tests have been recovered from 28 springs, and 17 spring basins have been partially or fully delineated. Following completion of the tracer tests and delineation of several karst groundwater basins, monitoring sites will be chosen. Project monitoring will use the integrated surface water and groundwater assessment approach.

Statewide Pathogens Study (NPS0803). This project is studying the occurrence of pathogens in groundwater. In particular, the focus is on water wells and springs providing domestic water supplies. Approximately 200 sites across Kentucky will be sampled for total coliform, *E. coli*, iron-related, sulfate-reducing, and slime-forming bacteria, and caffeine. Although this research will be statewide, priority will be given to areas with the highest domestic groundwater use, specifically the Eastern Kentucky Coal Field and Jackson Purchase Region. A press release soliciting sampling sites was picked up by many local news outlets and received widespread and positive feedback. More than 200 monitoring sites have been identified, and sample collection is under way.

South Central Karst Study (NPS0903). Funding for this project was just recently made available, and work has commenced with a literature and map review of the study area. This project will focus on expanding karst groundwater mapping efforts south of Lake Cumberland. The study area includes parts of Clinton, Wayne, and McCreary Counties. Following completion of the tracer tests and delineation of several karst groundwater basins, monitoring sites will be chosen. This project will take an integrated surface-water and groundwater assessment approach.

Wellhead Protection Program. The program continues to focus on completing 5-year updates for groundwater systems throughout Kentucky while integrating new technology into the process. The program purchased Trimble Yuma tablet comput-

ers to facilitate GIS integration of wellhead protection plans and accompanying contaminant-source inventories. When complete, each contaminant-source inventory will be available to the water systems and general public as a digital data set. New "Water Supply Protection Area" signs have been developed and will be distributed for placement by the Department of Transportation in the next few months. The Wellhead Protection Program continues to work on educational materials to raise awareness about protecting groundwater for public water supplies and the communities they serve.

Special Projects. The division conducted 26 tracer tests for karst mapping projects and groundwater technical assistance. We also assisted eight county health departments, the Division of Abandoned Mine Lands, Morehead State University, and the Frankfort Sewer Department with dye traces to investigate localized contamination.

Adding Karst Data to the National Hydrography Dataset. Following the success of the pilot study conducted in conjunction with the Kentucky Geological Survey, the division has expanded its efforts to integrate karst data into the USGS's National Hydrography Dataset. Incorporating previously omitted subsurface flow data into the dataset provided several benefits: (1) demonstrated local deviation of karst drainage from topographic watershed divides, (2) established a baseline for mapping karst features and groundwater flow paths within the dataset, and (3) improved accuracy and applicability of information used for hydrologic modeling, research, and field investigation. Thus far, karst data for parts of the West Fork of the Red River, Upper Green River, Barren River, Rough River, and the South Fork of the Licking River have been successfully integrated into the dataset. This represents nearly 35 percent of the digitally available karst flow data for Kentucky. Results of this project have been presented at professional conferences.

Complaint Response. The division has responded to at least 10 complaints about the presence of methane gas in water wells, alleged to have been caused by natural gas exploration or deep coal mining. Dissolved gases in water wells are potentially hazardous in the wells and homes. Methane and hydrogen sulfide gases are common in wells

constructed into the geologic strata of the Eastern Kentucky Coal Field. Methane and hydrogen sulfide are prevalent in the rocks of this region, particularly in coal seams, and in conjunction with petroleum deposits. Iron and sulfur bacteria commonly occur in wells throughout eastern Kentucky. These bacteria are not known to be harmful to health but are a nuisance, causing red, orange, brown, or black stains to plumbing fixtures, along with sulfurous "rotten egg" odors (hydrogen sulfide) and red or orange coloration of the water. The division has published a guide for well owners about managing such issues. This guide recommends and explains regular well maintenance, proper venting, and precautionary measures. The Division of Water recommends that a water-well driller holding a current license in Kentucky be used to modify the wells.

Proposed Legislation. The Kentucky Groundwater Association in conjunction with the Kentucky Water Well Certification Board proposed a revision to KRS 223 to include certification of drillers who install geothermal closed-loop vertical boreholes (HB 561). The proposal, requested by Kentucky's certified water-well and monitoring-well drillers with the backing of both boards, would have required licensing and certification of geothermal drillers, as well as promulgating regulations for construction and reporting standards. HB 561 was introduced to the Tourism Development and Energy Committee, but failed to make it out of committee and did not receive a formal vote. This was because of concerns from the Kentucky Department for Environmental Protection about associated revenue projections and implementation costs. Plans have been made to file this bill again in the 2013 legislative session with the addition of provisions to address funding concerns.

U.S. Geological Survey

Louisville Water Company, Ohio River Alluvial Aquifer, Jefferson County. The USGS, in cooperation with the Louisville Water Company, maintains a network of 43 water-level observation wells in the northeastern part of the Ohio River alluvium in Jefferson County. Twenty-one of the wells are equipped with continuously recording pressure transducers that measure depth to water and water temperature. Water-level measurements are taken

at the other 22 observation wells on a quarterly basis. These data assist the Louisville Water Company's efforts to operate and maintain river-bank infiltration using a network of water-supply wells constructed to draw and naturally filter river water through the sand and gravel aquifer near the Payne Water-Treatment Plant.

Groundwater-Level Data Collection. The USGS collects real-time continuous water-level measurements from an observation well in Graves County that is included in the USGS National Groundwater Climate Response Network – a nationwide network of long-term observation wells intended to monitor the effects of droughts and other climate variability on the nation's groundwater resources. The water-level data for this well can be accessed via the Internet at groundwaterwatch.usgs.gov or ky.water.usgs.gov. Two additional long-term observation wells located in downtown Louisville are also maintained by the USGS and are used to collect continuous water-level data from the Ohio River alluvial aquifer. These data, historical water-level data from other observation wells, and additional information about the activities of the USGS-Kentucky Water Science Center are available on the USGS Web site at ky.water.usgs.gov.

Well-Integrity Survey of Abandoned Gas Wells Near West Point. Abandoned and unrecorded natural-gas wells may act as conduits for the contamination of groundwater supplies by oil- and gas-field brines and other pollutants. The casings of abandoned wells may eventually develop leaks, which, if not properly plugged, can allow pollutants to reach freshwater aquifers that supply drinking water. Such is the situation in the Fort Knox well field near West Point, Ky. Many of the drinking-water supply wells for Fort Knox have chloride concentrations in excess of secondary maximum contaminant levels of 250 mg/L, some as high as 1,900 mg/L. The USGS, working in cooperation with the U.S. Army Corps of Engineers and the Army installation at Fort Knox, is presently conducting a geophysical and hydrogeologic investigation of the Ohio River alluvial aquifer at the Fort Knox well field to identify abandoned or improperly plugged oil and gas exploration wells that may be contributing brine contamination to the

freshwater aquifer and to characterize the migration and dispersion of chlorides.

Kentucky Department of Agriculture

The Kentucky Department of Agriculture-Technical Support Branch continued to receive monitoring data from the Division of Water under its memorandum of agreement. The memorandum covers 16 samples yearly from four sites. It is supplemented by the Division of Water's Ambient Groundwater Monitoring Program.

Kentucky Geological Survey, Water Resources Section

Cumberland Gap Tunnel Roadway Subsidence. KGS and the Kentucky Transportation Center at the University of Kentucky installed four test borings into the roadbed of the northbound tunnel. A known quantity of limestone aggregate was placed into 2-inch-diameter stainless steel baskets suspended in these borings to monitor for aggregate dissolution as groundwater beneath the roadbed flowed through the baskets. This project was intended to be a multiyear study; however, funding became available to replace the limestone roadbed in the tunnel with granite, and the test borings were destroyed in the process. Aggregate was discovered to have been lost from the baskets, even though they were installed for a much shorter time than expected. More analysis will be conducted on the dissolution data. KGS continues to maintain a weir and water-level recorder in the tunnel to monitor groundwater flow.

Cane Run Watershed. Water Resources Section staff and faculty in the University of Kentucky College of Agriculture and the Department of Earth and Environmental Sciences successfully located and drilled into the Royal Spring conduit at the Kentucky Horse Park on July 6, 2010. Fecal bacteria, nitrate, and suspended sediment are problems in this springshed.

Three methods have been used to calculate the cross section of the cave: downhole video, Doppler sonar, and quantitative groundwater tracing. Both the downhole video and Doppler sonar are line-of-sight instruments and cannot determine the cross section of the peripheral conduits in the anastomotic zone. Several attempts to obtain an accurate video image of the cross-section geometry

and to determine the dimensions of the conduit have had limited success.

The Doppler sonar was useful in determining passage size. Spreadsheets were developed to perform vector analysis, which showed the direction of flow and speed of the suspended material and the coordinates of the observation location. Algorithms were developed to test the data using parameters recommended by the manufacturer of the equipment for characteristics of echoes off of solid objects.

Quantitative groundwater tracing has been the most effective tool for determining discharge, because the data generated by it reflect the increasing width and depth of flow as the higher and normally air-filled conduits begin to discharge. The quantitative tracing is dependent on the occurrence of desirable flow conditions and our ability to respond, however.

KGS began observing groundwater quality at this site in May 2011. The wells have been equipped with stage recorders, a velocity meter, a 12-volt pump to collect samples, and a water-quality sonde and data logger. Most of the current effort is to characterize the water quality and develop a more precise rating curve to calculate the discharge. These data will help characterize the sources of contamination and develop a detailed knowledge of the hydrogeology of the Inner Bluegrass.

Karst Activities. In cooperation with the Kentucky Division of Water, KGS completed and released the karst groundwater basin map for the Tell City 30 x 60 minute quadrangle. A major revision of the karst map of the Somerset 30 x 60 minute quadrangle has recently been completed and is now available. The manuscript of the map of the Hopkinsville quadrangle is well under way. Statistical analysis is also being used to link geologic strata to the occurrence of past sinkholes and the probability of future sinkholes as part of a continuing effort to develop sinkhole maps.

Groundwater Contaminant Modeling at the Paducah Gaseous Diffusion Plant. Historical operations at the Paducah Gaseous Diffusion Plant have released hazardous, nonhazardous, and radioactive wastes to the environment, including PCB's (polychlorinated biphenyl), TCE (trichloroethene), multiple isotopes of uranium,

and technetium-99. TCE and technetium-99 contamination is widespread at the plant. The site is an EPA National Priority List Superfund site. Using the most recent version of a groundwater and contaminant transport model designed to help with remediation at the site, future migration of TCE plumes for the next 100 years was simulated under several potential source-area remedial scenarios specified in a previous land-acquisition study for the Paducah site. KGS will continue to develop and operate the model to incorporate newly collected hydrostratigraphic data.

Geochemical Modeling of CO₂, Brine, and Reservoir Rock Interactions in the Knox Group, western Kentucky. To understand the long-term fate of CO₂ injected into the Knox reservoirs, the Water Resources Section and the Energy and Minerals Section developed geochemical models to simulate reactions among CO₂, brine, and rock-forming minerals. The models were built using a robust data set collected from the KGS No. 1 Blan well, including stratigraphy, core porosity and permeability, petrographic and mineralogy determined by X-ray diffraction, brine chemistry, and temperature and pressure measurements. Kinetic batch models and one-dimensional radial reactive transport models were used to evaluate the migration of the injected CO₂, mineral dissolution, and precipitation. Results from these models suggest that the mineral trapping capacity of the Knox dolomite rocks for CO₂ is small and that the majority of the CO₂ will remain in aqueous or supercritical/gas phases for a long time.

Private Well Initiative. KGS completed a project with the Centers for Disease Control and Prevention in Atlanta. The CDC has initiated a nationwide project to identify and characterize private drinking-water sources, primarily wells and springs, that are not covered by the Safe Drinking Water Act. Funded through the Kentucky Division of Water, KGS targeted four data sets discovered during the previous year's project for entry into the Kentucky Groundwater Data Repository. These included the Division of Conservation/Farm Bureau, the Division of Mine Reclamation and Enforcement citizen complaint data, USGS historic groundwater-quality data, and groundwater data collected for master's theses and doctoral dissertations. Some of

these data were in paper format, and were scanned, processed through optical character recognition, and transferred to digital format. Other data were already in digital format, but had to be rearranged into the Kentucky Groundwater Data Repository's format for final entry. In total, data for more than 4,000 wells, 70 springs, and 5,700 analyses are being added to the repository as a result of the project.

Emerging Contaminant Sampling. KGS sampled six watersheds in Kentucky (56 sampling sites) for 17- β estradiol (estrogen) and fluoroquinolones (antibiotics), which are both classified as emerging contaminants. Two of the watersheds are located in the Jackson Purchase Region (Bayou de Chien and Clarks River), two in central Kentucky (Floyds Fork and South Elkhorn Creek), one in northern Kentucky (Banklick Creek), and two in eastern Kentucky (Licking River). In addition to water-quality samples, when possible, field measurements (pH, specific conductance, dissolved oxygen, temperature, and total dissolved solids) were recorded and stream discharge was measured. Sampling and analysis was funded in part by the U.S. Department of Agriculture–National Institute of Food and Agriculture's Southern Regional Water Program and the USGS's State Water Resources Research Institute Program.

Assessment of the Effect of CO₂ Injection on Local Groundwater Quality in Hancock County. KGS monitored shallow groundwater at one carbon storage project overseen by the Energy and Minerals Section. The Hancock County-based project investigated the feasibility of injecting CO₂ into deep saline aquifers. The shallow groundwater was sampled to characterize the local quality and assess any changes in quality that may be associated with CO₂ injection. Groundwater sampling in Hancock County is scheduled to continue through October 2013.

Assessment of CO₂ Injection on Local Groundwater Quality in Hopkins County. The Water Resources Section and the Energy and Minerals Section completed shallow groundwater monitoring for two pilot carbon storage and enhanced oil recovery projects overseen by the Energy and Minerals Section. Groundwater was sampled and bulk and isotopic chemistry was measured to

characterize water chemistry before, during, and after CO₂ injection. At the Sugar Creek pilot site (Hopkins County), groundwater in Pennsylvanian sandstone aquifers was monitored for approximately 2½ years using four existing wells near Sugar Creek Oil Field and three wells drilled specifically for groundwater monitoring at the field. Approximately 7,200 tons of CO₂ were injected into the Mississippian Jackson Sandstone oil reservoir from May 2009 to May 2010 (more information below); monitoring during this period and for a year afterward showed that CO₂ injection did not affect the shallow groundwater chemistry, suggesting successful containment of CO₂ in the Jackson Sandstone. Results of the study were documented in a final report issued to the U.S. Department of Energy that will be released as an open-file report through the Illinois State Geological Survey.

Analysis of Formation Water Chemistry in the Appalachian and Illinois Basins. The Water Resources Section and the Energy and Minerals Section continued to evaluate water chemistry data from deeper aquifers and reservoirs. Historic measurements are being conducted, as well as recent measurements primarily from CO₂ sequestration investigations. The historic measurements come mostly from oil and gas wells, and most measurements were conducted in the late 1960's and early 1970's. The total number of measurements is approximately 1,000 and includes data from 107 out of Kentucky's 120 counties. The historic data have been entered into a database organized by geologic province (Appalachian and Illinois Basins, Cincinnati Arch) and by county. Compiled data include well location, sample depth, sample formation, and anion and cation values. The quality of the data from the Appalachian Basin and Cincinnati Arch have been checked using charge-balance analysis.

New measurements were conducted at the Sugar Creek and Euterpe pilot sites in Hopkins and Henderson Counties, respectively. CO₂ was injected into the Mississippian Jackson Sandstone at Sugar Creek field and Mississippian Cypress Sandstone at Euterpe field at depths from 1,800 to 1,850 feet below the ground surface. At Euterpe, the amount of CO₂ (80 tons) and duration of injection (four days) were much less than at Sugar Creek (approximately 7,200 tons over 1 year). The col-

lected data from both sites provide an opportunity to analyze the spatial and temporal evolution of brine chemistry in response to CO₂ injection.

Analysis of the historic water chemistry data from the Appalachian and Illinois Basins showed that formation waters in the Cambrian-Ordovician Knox Group reservoirs were less saline than would be predicted by salinity trends observed in shallower and younger Paleozoic strata. Starting in 2011 and continuing into 2012, Marty Parris of the Energy and Minerals Section has been working with scientists at the USGS in Nashville to study the origin of Knox formation waters using standard bulk and isotopic chemistry measurements (e.g., δ¹⁸O and δD for H₂O). In addition, the age of dilute Knox waters in the Jessamine and Nashville Dome areas was estimated using the cosmogenic isotope ³⁶chlorine, which has a half-life of 301,000 years. The measurements suggest that, despite similar chemistry, dilute Knox groundwater in the Jessamine Dome area is older than 1.5 million years, whereas that in the Nashville Dome area could be less than 1,000 years old.

Distribution of Groundwater Information

One of the most important functions of the Groundwater Monitoring Network is translating analytical data from water-level measurements and groundwater analyses into readily available, useful information and presenting it to the public. During the 2011-12 fiscal year, groundwater information was communicated via short reports, oral and poster presentations at meetings and conferences, and posting on Web sites. Major reports and presentations are listed below.

Publications

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- Beck, E.G., Waninger, S., Counts, R., Wedding, D., Tapp, J., and Zhu, J., 2012, Using electrical resistivity to locate an abandoned fluorspar mine as a supplemental water source for the city of Marion, Kentucky [abs.]: 2012 Kentucky Water Resources Annual Symposium, Abstracts with Programs, Lexington, Ky., March 19, 2012, p. 67.
- Beck, E.G., Wedding, D., Parris, T.M., and Williams, D.A., 2012, Western Kentucky deep saline reservoir CO₂ storage test: Shallow groundwater monitoring results [abs.]: 2012 Kentucky Water Resources Annual Symposium, Abstracts with Programs, Lexington, Ky., March 19, 2011, p. 59.
- Blair, R.J., Ray, J.A., O'dell, P.W., Marbert, B.S., and Goodmann, P.T., 2012, Integrated surface water and groundwater assessment of large springs in the Green River Basin: Kentucky Division of Water, 77 p.
- Davidson, B., 2012, Enhancing the capacity for environmental and public health surveillance of unregulated drinking water in Kentucky through digitization of selected groundwater data: University of Kentucky Research, Centers for Disease Control Private Drinking Water Initiative, Foundation Contract 200-2009-31909, 7 p.
- Fogle, A.W., and Davidson, B., 2011, Groundwater resource maps for Kentucky: 56th Annual Midwest Groundwater Conference, Lexington, Ky., September 19-21, 2011, p. 19.
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Zhu, J., Currens, J.C., and Dinger, J.S., 2011, Challenges of using electrical resistivity method to locate karst conduits – A field case in the Inner Bluegrass Region, Kentucky: *Journal of Applied Geophysics*, v. 75, no. 3, p. 523–530.

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Zhu, J., Parris, T.M., Bowersox, J.R., and Harris, D.C., 2012, Simulating long-term fate of CO₂ for a western Kentucky deep saline reservoir CO₂ storage test [abs.]: 2012 Kentucky Water Resources Annual Symposium, Abstracts with Programs, Lexington, Ky., March 19, 2012, p. 57.

Presentations

Beck, E.G., 2012, Well construction and well camera findings in Kentucky and Southern Region: Kentucky Division of Water personnel well camera workshop, Lexington, Ky., January 19, 2012.

Beck, E.G., 2012, Well videos from the Southern Region: Kentucky Geological Survey annual seminar, Lexington, Ky., May 18, 2012.

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water Conference, Lexington, Ky., September 19–21, 2011.

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Keefe, P.K., 2011, Groundwater protection plan requirements and regulated activities: 56th annual Midwest Groundwater Conference, Lexington, Ky., September 19–21, 2011.

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- Von Gruenigen, C.E., and Moore, J.E., 2012, Surface water – Groundwater interactions as they pertain to contamination prevention for drinking water systems in Kentucky: Kentucky Water and Wastewater Operators annual conference, Louisville, Ky., April 15–19, 2012.
- Westerman, A.L., and O'dell, P.W., 2012, 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: Kentucky Water Resources Annual Symposium, Lexington, Ky., March 19, 2012.
- Zhu, J., and Hampson, S., 2012, PGDP groundwater modeling support activities update: Kentucky Research Consortium for Energy and Environment quarterly meeting, Lexington, Ky., May 24, 2012.
- Zhu, J., and Hampson, S., 2012, Predicting groundwater contaminant plume migration at the Paducah Gaseous Diffusion Plant: Kentucky Geological Survey Annual Seminar, Lexington, Ky., May 18, 2012.
- Zhu, J., Parris, T.M., Bowersox, J.R., and Harris, D.C., 2011, Geochemical modeling of CO₂, brine, and reservoir rock interactions in the Knox Group, western Kentucky: American Geophysical Union 2011 fall meeting, San Francisco, Calif., December 5–9, 2011.
- Zhu, J., Parris, T.M., Bowersox, J.R., and Harris, D.C., 2012, Simulating long-term fate of CO₂ for a western Kentucky deep saline reservoir CO₂ storage test: Kentucky Water Resources Annual Symposium, Lexington, Ky., March 19, 2012.
- Zhu, J., Parris, T.M., Bowersox, J.R., and Harris, D.C., 2012, Geochemical modeling of CO₂, brine, and reservoir rock interactions in the Knox Group, western Kentucky: Kentucky Geological Survey Annual Seminar, Lexington, Ky., May 18, 2012.

Web Site Information

The Kentucky Geological Survey provides online access to information about water wells and springs at kgs.uky.edu/kgsweb/DataSearching/Water/WaterWellSearch.asp. These data are useful to the public, well drillers, consultants, and researchers. KGS also maintains a Web site for the Kentucky Interagency Groundwater Monitoring Network (www.uky.edu/kgs/water/gnet), which contains links to current and previous annual reports of the network and to the Web sites of the ITAC agencies and organizations.

KGS has compiled information about hydrology, geology, topography, water supply, and water quality from maps, reports, and data collected from 1940 to the present at www.uky.edu/kgs/water.

Statewide groundwater data in the Kentucky Groundwater Data Repository can be accessed at kgs.uky.edu/kgsweb/DataSearching/watersearch.asp. The database covers water wells and springs and groundwater-quality data. Several alternatives are available for viewing groundwater information on both interactive and static maps, and for creating graphical representations of groundwater-quality data.

The Kentucky water-well and spring search engine was accessed by the public 6,745 times during fiscal year 2011-12 (an 11 percent increase over the previous year), and 752 downloads were made. It remains the second most popular search engine on the KGS Web site, after the one for oil and gas records. Users can search for wells or springs by county, 7.5-minute quadrangle, or a radius from a user-provided latitude/longitude location. Resulting data can be displayed on maps or downloaded for use in GIS packages.

The Kentucky groundwater-quality data search engine was accessed by the public more than 1,133 times during fiscal year 2011-12, and 302 downloads were made. Users can select from hundreds of parameters in 13 major categories, some of which are herbicides, pesticides, inorganics, metals, nutrients, volatile organic compounds, and petroleum hydrocarbons. Resulting data can be downloaded, displayed on maps, or used to generate graphs comparing groundwater-quality data by physiographic region or watershed basin.

For more information on groundwater-quality or water-well and spring data, contact the Survey at (859) 323-0524.

Interagency Coordination

Cooperation among agencies and research organizations that collect, analyze, and use groundwater data reduces monitoring costs, improves program efficiency, and promotes data sharing. The Kentucky Interagency Technical Advisory Committee on Groundwater provides a forum for participating organizations to meet on a quarterly basis and discuss groundwater issues.

Many programs benefit from the Division of Water's willingness to collect and analyze groundwater samples to support various projects. The Division of Water also samples groundwater and surface water for nonpoint-source constituents in support of projects for the Division of Pesticide Regulation. The Division of Water and the Kentucky Geological Survey regularly answer inquiries from the public and communicate with staff of the Kentucky Rural Water Association. KGS staff has been meeting with County Extension Service agents and Area Development District personnel throughout the commonwealth to promote awareness of hydrogeologic issues. Many of the ITAC agencies are also members of the Kentucky Agricultural Water Quality Authority or cooperate with the authority and participate in their meetings. Members of both the Division of Water and the Kentucky Geological Survey regularly participate in meetings of State and Federal agencies and citizens' groups that have interests in groundwater resources.

Groundwater Data Sharing

Sharing data is an essential function of the Interagency Groundwater Monitoring Network. Data transfers between agencies provide each group access to a larger database than any agency could develop independently, thereby improving evaluations of groundwater quality and suitability for various uses, threats to groundwater quality, and the effects of mining, logging, agricultural practices, urbanization, waste disposal, and oil and gas production. Sharing data also reduces the overall expense and increases the efficiency of monitoring efforts.

Data have been transferred electronically between the Division of Water groundwater database and the Kentucky Groundwater Data Repository and between the Kentucky Geological Survey analytical laboratory and the Division of Water's Groundwater Section since 1992. There has also been a high level of collaboration and data sharing between KGS and the Groundwater Section during the reporting period, as the agencies are jointly reporting on groundwater quality throughout the state. During 2011-12, electronic data files of water-well, spring, and groundwater-quality data were transferred from the Division of Water to the Kentucky Geological Survey, and have been uploaded to the Kentucky Groundwater Data Repository. Uploads from the Division of Water occur on average once a quarter, allowing end-users to access the most recent well and spring data available.

Other Activities

ITAC agencies are involved in many activities concerning surface-water quality and public education about water resources. Although these projects do not directly address issues raised by the 1998 Kentucky General Assembly, they are important contributions because of the close interconnection of groundwater and surface-water systems in Kentucky. Some of these activities are listed below.

University of Kentucky Environmental and Natural Resource Issues (ENRI)

Task Force

The Kentucky Well Education Web Site. This Web site (www.ca.uky.edu/enri/downwell) is a joint project between ENRI and the Kentucky Geological Survey. The Web site contains information on well types and well construction, along with simplified descriptions of Kentucky Division of Water regulations regarding general well construction and specific types of wells. The Web site provides video and photographic examples of problems that may occur in wells and gives advice on solutions. This site is maintained by ENRI.

ENRI Web Site. The ENRI Web site (www.ca.uky.edu/enri) contains information (e.g., publications, radio scripts, activities) on groundwater. In addition, the site includes information on watersheds,

stormwater, nutrient management, the Kentucky Agriculture Water Quality Act, and the Kentucky Water Awareness Month packet. Also included on the site is an Upcoming Events page that provides information on current events such as Groundwater Awareness Week and Kentucky Water Awareness Month. The site is maintained by Ashley Osborne, ENRI extension associate.

“See Blue Go Green” Web Site. This Web site (www.ca.uky.edu/gogreen) contains information for all Kentuckians regarding “green” topics (e.g., drinking water, stormwater, wastewater, water quality, etc.). The site includes publications, fact sheets, radio scripts, displays, lesson plans, activities, and links. It is maintained by Ashley Osborne, ENRI extension associate.

ENRI Quarterly E-News. The ENRI E-News (www.ca.uky.edu/enri/newsletter.php) is distributed to county Extension agents and other natural resource professionals throughout Kentucky. E-News includes information about current research, resources (e.g., new publications, training, etc.), and events, and is coordinated by Ashley Osborne, ENRI extension associate.

Kentucky Rain Garden Program. The ENRI Task Force and UK Horticulture Department installed 17 rain gardens at various locations throughout the state (e.g., county Extension offices, 4-H camping facilities, local parks, schools). At each installation, workshops were offered to a total of 140 county Extension agents, master gardeners, and local citizens. At the conclusion of each workshop, attendees rated their level of understanding regarding rain gardens prior to and after the presentation. The feedback indicated that attendees’ knowledge of rain gardens increased substantially after they attended a workshop. The evaluations also indicated a high level of potential that one or more stormwater/water-quality best management practices would be adopted.

40 Gallon Challenge. The ENRI Task Force received funding from the Southern Region Water Program to administer the 40 Gallon Challenge Water Conservation Program in Kentucky. Visit www.40gallonchallenge.org to see the total number pledges and gallons of water saved daily.

Consumer Radio Tips. Amanda Gumbert, UK water quality liaison, and Ashley Osborne, ENRI extension associate developed and recorded 60-second radio scripts, “Daily Tips for Conserving Water” and “Groundwater Awareness Week.”

Kentucky Water Awareness Month Packet. Each May, citizens across Kentucky celebrate Water Awareness Month. This program first began in 1996 as an educational tool of the University of Kentucky Cooperative Extension Service. Each year, program materials are developed at the state level, and distributed via listserv to each of the 120 county Extension offices. Counties across the commonwealth celebrate Kentucky Water Awareness Month by participating in activities such as after-school programs, environmental day camps, and homemaker club meetings. The 2012 Kentucky Water Awareness Month materials are available online at www.ca.uky.edu/enri/kwam2012.php. The packet is coordinated by Ashley Osborne, ENRI extension associate.

4-H₂O Ambassador Program. The 4-H₂O Ambassador Program addresses concepts related to watershed education. Each of the four curriculum units focuses on a specific question about water quality and watersheds, and includes hands-on activities (e.g., chemical, physical, and biological water analysis). Curriculum is available online at www.ca.uky.edu/enri/4H2O.htm. The program received the Outstanding Special Project Award in the fall 2011 Southern Regional Water Program Conference.

Cane Run Watershed Project. The University of Kentucky has led watershed-based planning, monitoring, and educational efforts as part of the Cane Run Watershed Assessment and Restoration Project. This project is coordinated by Steve Higgins and Amanda Gumbert.

Activities in the Cane Run watershed include the following:

- Continued facilitation of the Cane Run watershed council
- Led tours of the Cane Run watershed for UK Natural Resources Conservation and Management program courses, watershed professional development training

for teachers, and State, Federal, and local agencies

- Acquired additional funding for stream-buffer and water-quality research in the Cane Run watershed, as well as additional funding for student and community education efforts
- Sponsored a watershed festival for community outreach and education

Kentucky Division of Forestry

Forested land provides important benefits to both groundwater and surface water in rural and urban landscapes. Forests absorb rain, trap and filter pollutants, recharge groundwater, slow storm runoff, sustain late-season flows, reduce flooding, maintain watershed stability and resilience, and provide critical habitat for fish and wildlife. Studies show that the percentage of forested land in a source-water area is one of the most important factors in determining water quality. The more forested land in a source area, the better the water quality and lower the treatment costs. Watersheds with less forested land have higher water temperatures and also higher levels of fecal coliform bacteria, turbidity, and nutrients.

Reduction of forest cover increases water yield whereas establishment of forest cover decreases water yield. Water yield is the amount of surface water and groundwater leaving a watershed. On

average, removal of 10 percent of forest cover was found to increase water yield by 40 millimeters in conifers, 25 millimeters in deciduous hardwoods, and 10 millimeters in brush and grasslands. Although simply removing forest increases the water yield, placing an impervious barrier such as pavement, roofing, or exposed rocks from mining further increases these yields.

The Kentucky Statewide Assessment of Forest Resources and Strategy, known as the Kentucky Forest Action Plan, released in June 2010 by the Kentucky Division of Forestry, also revealed that water quality/quantity was the second most important concern of the citizens of the commonwealth, highlighted in a statewide survey of the most important issues facing the state’s forest resources. The division, along with stakeholder input, delineated seven major forest priority areas across the commonwealth to focus a collaborative strategy in maintaining sustainable forests and as a basis for improving water quality and quantity (Fig. 2).

The primary objective of the division’s Timber Harvest Compliance Program is to ensure that commercial timber harvesting operations use best management practices to protect water quality from nonpoint-source pollution. This program enforces the minimum performance standards of BMP’s mandated by the Kentucky Agriculture Water Quality Plan.

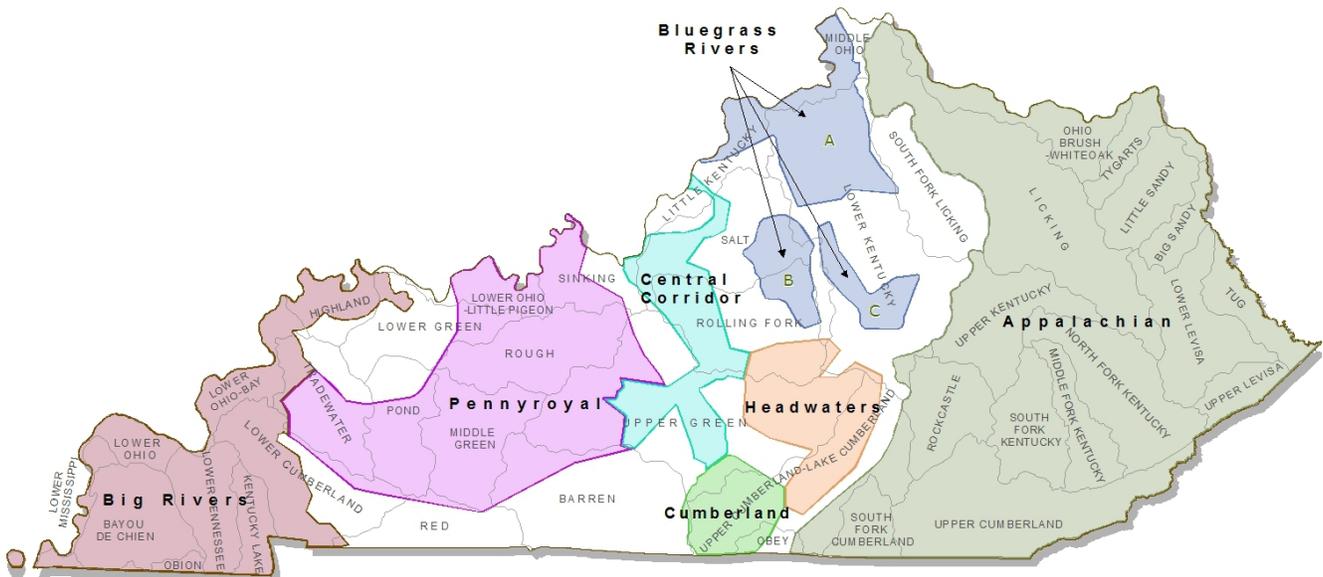


Figure 2. Kentucky forest priority areas and watersheds.

For the state fiscal year of July 1, 2011, to June 30, 2012, a total of 5,148 harvest inspections were performed, resulting in 432 enforcement actions. A BMP monitoring study from a recent statewide survey indicated that 68 percent of the applicable BMP's were implemented on the sites examined.

The division's Forestry Stewardship Program is also proactively involved with mitigating water-quality concerns by providing technical assistance in practice plans for riparian buffer development under the auspices of the U.S. Department of Agriculture-Natural Resources Conservation Service's Conservation Reserve Program. Statewide, 56 practice plans were completed, encompassing 250 acres for the fiscal year.

The division is also addressing water quality by promoting the agroforestry concept of strategically incorporating trees into the agricultural landscape in order to protect water resources and meet landowner objectives. This integrated watershed approach is very effective in promoting water quality and many times proving economical to the landowner when implemented.

Mitigating stormwater issues is a component of the division's Urban Forestry Program. The division's urban forestry specialists are involved with educating community leaders about the many benefits of trees in the urban setting, one of which is phytoremediation, or the use of trees to decontaminate soils or water. Urban forestry specialists and foresters at the division are also involved in the Cane Run Watershed Council, addressing water-quality concerns in the Lexington and Georgetown urban interface.

New watershed restoration projects initiated this year with Division of Forestry personnel providing technical assistance include

- targeted bottomland hardwood management plans and educational outreach for the lower Green River landowners in western Kentucky
- work on the Floyds Fork project in Jefferson County
- work on the Red Bird River Restoration project led by the U.S. Forest Service and the Kentucky Waterways Alliance in southeastern Kentucky.

Four of the five Kentucky Division of Water focus watersheds have division personnel assigned to work collaboratively with local groups in watershed management of the area.

Kentucky Division of Mine Reclamation and Enforcement

The Field Support Section of the Division of Mine Reclamation and Enforcement conducts groundwater investigations at the request of citizens of the commonwealth. The investigations may be a result of diminished water-well quality or quantity. In addition, the division also conducts surface-water investigations, including investigations of diminished quality, stream loss, or flooding. Investigations are also conducted as a result of landslides, methane migration, or other problems related to coal mining in the Eastern and Western Kentucky Coal Fields.

During the 2011-12 fiscal year, the division received 65 new requests for inspections. Eighty-eight inspections were also completed; of these, 21 concluded that mining activity had had an adverse impact on a citizen's well or property. Four of these were the result of diminished well-water quality, five were the result of loss of well-water quantity, two were the result of methane migration into a water well, seven were related to seeps or landslides (or both), and three were caused by various issues related to surface water.

Although the 2011-12 year was relatively normal, the division has seen an increase in reported methane migration cases, in which gases enter a citizen's water well. The division has worked with the Kentucky Division of Oil and Gas on several of these complaints in order to determine the source of the gas.

Funding

Most of the activities during the reporting period were investigations of identified or suspected groundwater-quality problems and were possible only because the agencies involved were able to obtain funding from outside sources. As noted in previous annual reports, the availability of these funds is decreasing. A stable source of recurring funding is essential if groundwater issues are to be addressed proactively, which will best serve the needs of citizens, resource managers, and environmental regulators.

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