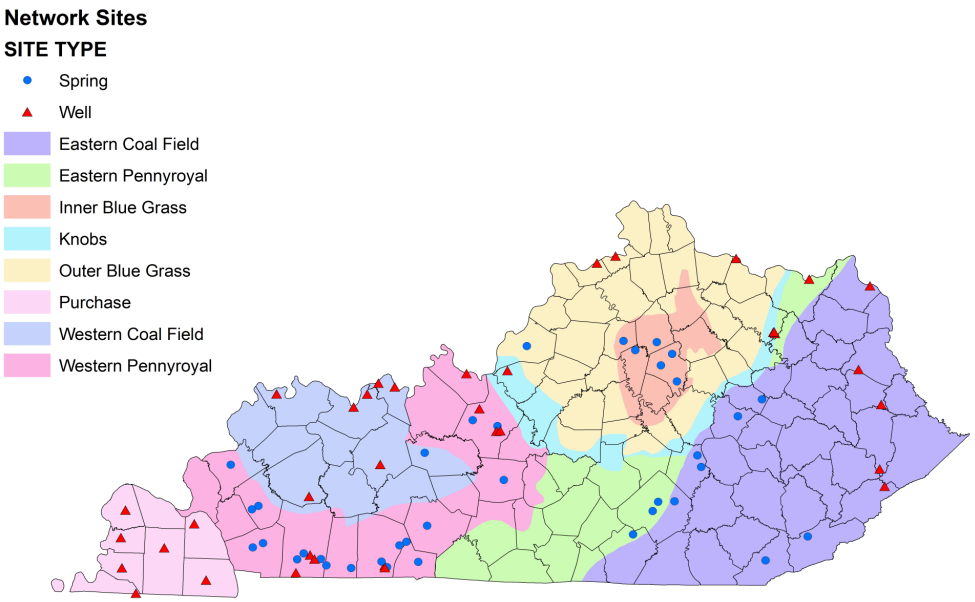
# Kentucky Interagency Groundwater Monitoring Network




## *Annual Report*
## *July 2013–June 2014*

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

# Kentucky Interagency Groundwater Monitoring Network

# Annual Report

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**On the cover: (Top)** Map of current sites in the Kentucky Groundwater Monitoring Network, maintained by the Kentucky Division of Water. (Bottom left) Well in Sloughs Wildlife Management Area, Henderson County. Photo by Robert J. Blair. (Bottom right) Reuben Ray Spring, Caldwell County. Photo by Robert J. Blair.

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# Kentucky Interagency Groundwater Monitoring Network Annual Report July 2013–June 2014

## Introduction

Groundwater is a vital resource to Kentucky. It is used extensively throughout the state 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 of paramount importance to the commonwealth and its citizens. The Kentucky Interagency Groundwater Monitoring Network was established in 1998 by the Kentucky General Assembly through KRS 151.625 to provide a means to characterize and increase knowledge about the commonwealth's groundwater resources. In order to provide oversight for the Groundwater Monitoring Network, the 1998 General Assembly also established an Interagency Technical Advisory Committee through KRS 151.629. This committee was tasked with assisting the Kentucky Geological Survey in the development, coordination, and implementation of the groundwater monitoring network. 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.

The participating network agencies continue to fulfill their obligation of collecting and providing groundwater-quality and other water-related data, as they have through the 16 years of the network's existence; the ITAC oversees communicating findings, sharing data, and promoting interagency cooperation. Annual reports summarizing these activities since 1999 are available on the network website at www.uky.edu/KGS/water/gnet.

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. Some public water-supply systems are considering switching from surface water to groundwater sources, because treatment and monitoring costs are lower. Other public systems are investigating groundwater sources for possible supplemental water supplies. Although many people who have relied on private wells or springs for domestic water supplies are switching to public systems, others will remain dependent on groundwater because of the cost of extending public water-supply systems to rural areas.

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.

From July 2013 through June 2014, more than 20 groundwater investigations and data-collection activities were carried out by ITAC member agencies. Groundwater and related surface-water information was communicated to the scientific and regulatory communities and to the public through various publications and presentations, as well as postings on websites. At least six presentations were given by ITAC agencies on surface-water activities. Exchange of groundwater data, including electronic transfer of analytical results between Division of Water and Kentucky Geological Survey databases, has continued on a regular basis through close cooperation between the Kentucky Division of Water and the Kentucky Geological Survey.

# 2013-14 Activities and Accomplishments

Summary statements of water-related projects performed by the ITAC agencies during the 2013-14 State fiscal year are presented below as an indicator of how the network goals are being addressed. Additional information regarding any of these projects can be obtained by contacting the reporting agency. Figure 1 shows the counties in which ITAC agencies conducted groundwater studies or projects during the fiscal year. Counties in which surface-water projects were conducted are shown in Figure 2.

## 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.

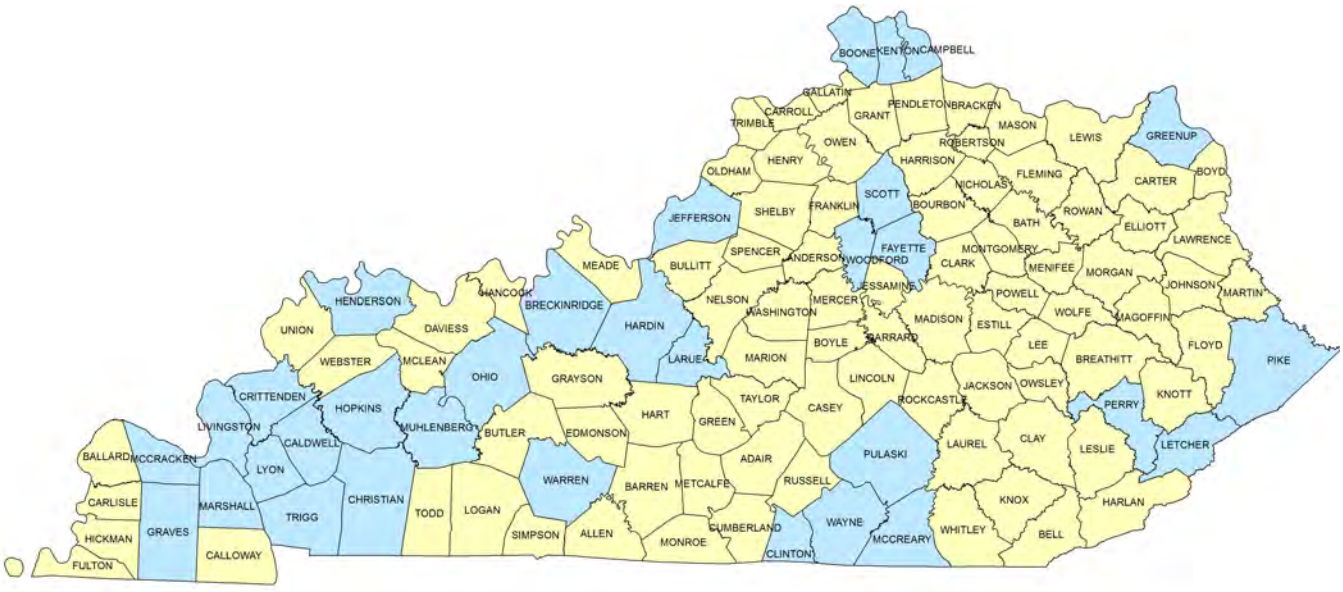


*Figure 1. ITAC member agencies had groundwater-related projects in counties shown in blue during the 2013-14 fiscal year.*

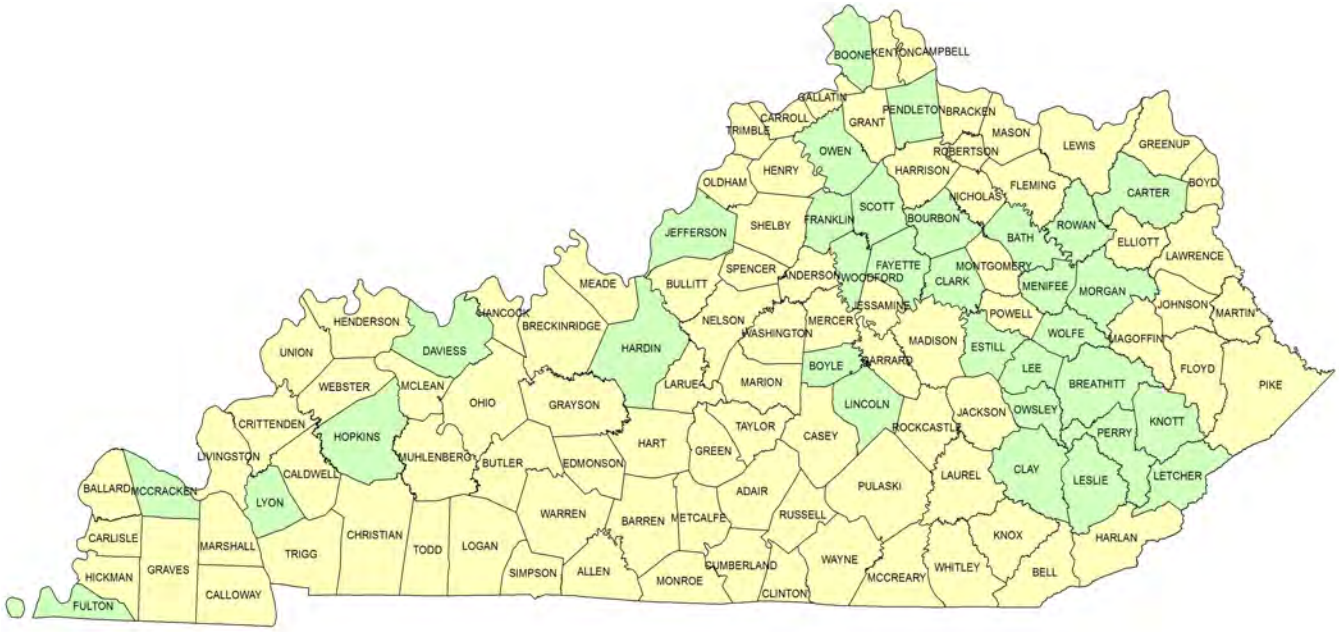


*Figure 2. ITAC member agencies had surface-water-related projects in counties shown in green during the 2013-14 fiscal year.*

Below are summaries of projects related primarily to groundwater that were conducted by ITAC member agencies during the 2013-14 fiscal year. Surface-water projects are listed in the "Other" section of this report.

### *Kentucky Division of Water, Watershed Management Branch, Groundwater Section*

The Groundwater Section of the Kentucky Division of Water's Watershed Management Branch maintains groundwater-quality monitoring and analysis programs. These studies are conducted in basin management units, or BMU's (Fig. 3), which were established by the Kentucky Division of Water in 1997. Each BMU contains one or more major river watersheds. Site-specific studies were conducted in smaller watersheds or other, more restricted regions. The following projects have been active during the reporting period.

**Ambient Groundwater Quality Monitoring Network.** There were 136 samples collected from 55 permanent sites (28 water wells and 27 springs) across the state during this fiscal year. There were 63 water well samples and 73 spring samples. Twenty-three of these sites are groundwater-source public water suppliers (18 water wells and five springs). Table 1 shows the number of sites by physiographic region and basin management unit and Figure 4 shows the physiographic regions in which the sites are located. Figure 5 shows Fred Mullins Spring, one of the sites of the Monitoring Network.

**Certified Well Drillers Program.** In 2014, the Kentucky Division of Water Groundwater Section issued 213 licenses to certified drillers: 40 water well, 84 monitoring well, and 68 dual licenses (Fig. 6).

**Table 1.** Spatial distribution of permanent groundwater-quality monitoring sites.

| *Physiographic Region* | *No. Sites* | *Basin Management Unit* | *No. Sites* |
|---|---|---|---|
| Bluegrass | 10 | 1–Kentucky River | 7 |
| Eastern Coalfield | 8 | 2–Salt and Licking Rivers | 10 |
| Ohio River alluvium | 10 | 3–Four Rivers, Upper & Lower Cumberland | 22 |
| Mississippian Plateau | 23 | 4–Green and Tradewater Rivers | 15 |
| Western Coalfield | 2 | 5–Big and Little Sandy Rivers and Tygarts Creek | 5 |
| Jackson Purchase | 6 | | |

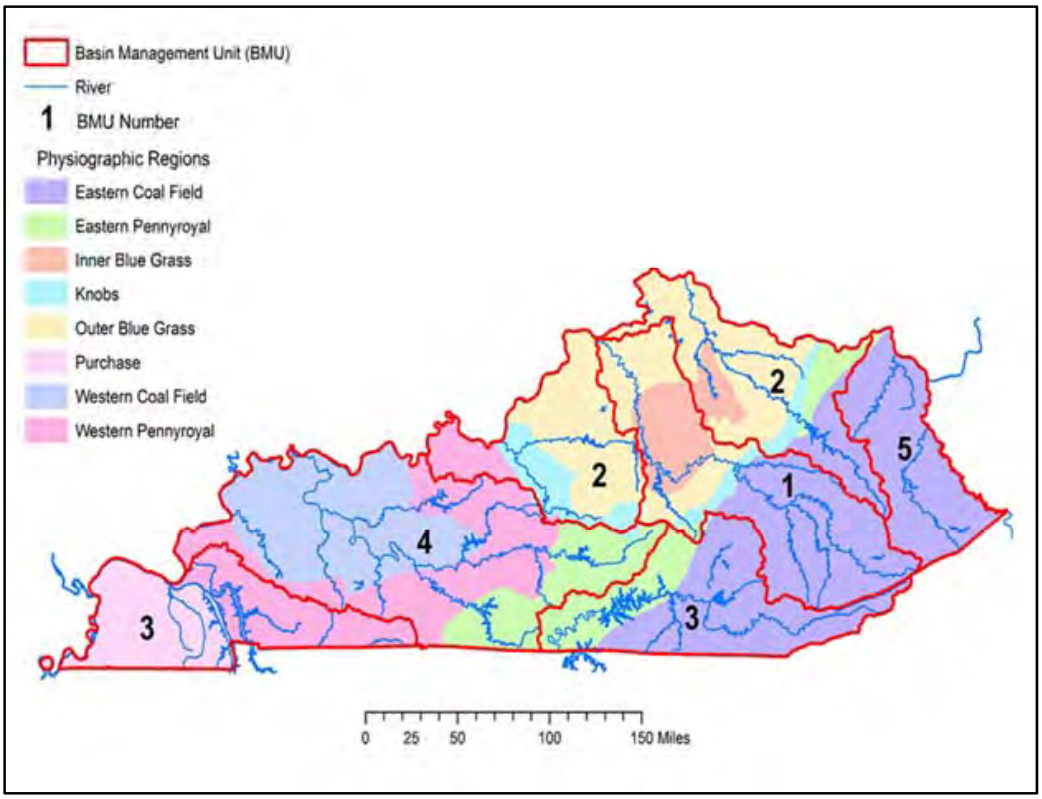


*Figure 3. Major rivers, basin management units, and physiographic regions in Kentucky.*

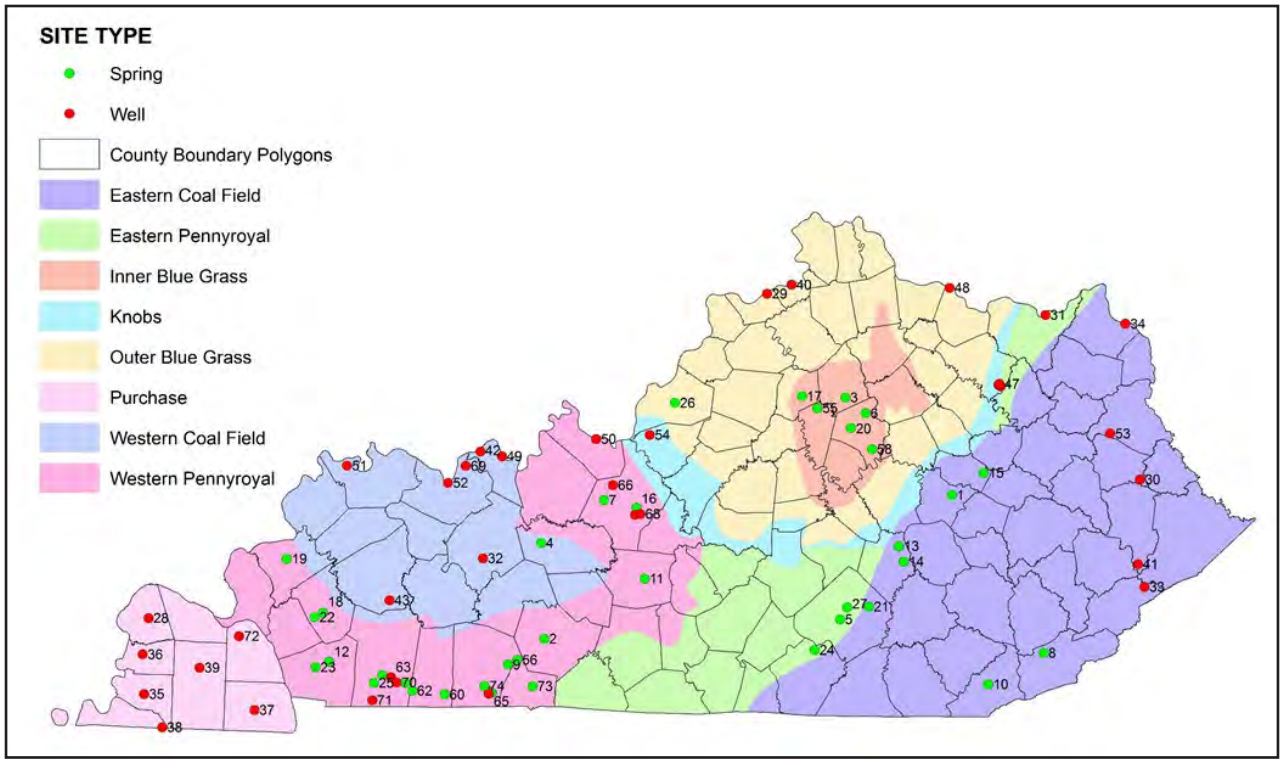


*Figure 4. Kentucky Interagency Groundwater-Quality Monitoring Network sites maintained by the Kentucky Division of Water. Table 2 indicates map number, Division of Water's AKGWA number, and sampling frequency for these sites.*

**Table 2.** AKGWA-number (Division of Water identification number) designations and sampling frequency, if available, for the network sites shown in Figure 4. These AKGWA numbers can be located using the repository website listed under "Website Information."

| *Map No.* | *AKGWA No.* | *Sample Frequency* | *Map No.* | *AKGWA No.* | *Sample Frequency* | *Map No.* | *AKGWA No.* | *Sample Frequency* |
|---|---|---|---|---|---|---|---|---|
| 1 | 90000045 | Q | 26 | 90002934 | Q | 51 | 00040944 | Q |
| 2 | 90000054 | Q | 27 | 90003064 | 5Q | 52 | 00065149 | Q |
| 3 | 90000055 | M | 28 | 00000811 | 5Q | 53 | 00068511 | Q |
| 4 | 90000456 | 5Q | 29 | 00007133 | 5Q | 54 | 00066923 | Q |
| 5 | 90000544 | 5Q | 30 | 00012311 | Q | 55 | 90001200 | Pest MOA |
| 6 | 90000552 | Q | 31 | 00014293 | 2Q | 56 | 90000624 | Pest MOA |
| 7 | 90000702 | Q | 32 | 00019489 | 5Q | 57 | 90001150 | Pest MOA |
| 8 | 90000703 | Q | 33 | 00028100 | 5Q | 58 | 90001201 | Pest MOA |
| 9 | 90000705 | M | 34 | 00029505 | 2Q | 59 | 90001460 | Pest MOA |
| 10 | 90000710 | 5Q | 35 | 00033887 | 5Q | 60 | 90001475 | Pest MOA |
| 11 | 90000798 | M | 36 | 00033904 | 5Q | 61 | 00055953 | Pest MOA |
| 12 | 90000854 | 2Q | 37 | 00033965 | 5Q | 62 | 90001485 | Pest MOA |
| 13 | 90001020 | Q | 38 | 00033972 | 5Q | 63 | 00011280 | Pest MOA |
| 14 | 90001051 | 5Q | 39 | 00037330 | 5Q | 64 | 90000458 | Pest MOA |
| 15 | 90001134 | Q | 40 | 00037376 | 5Q | 65 | 00029983 | Pest MOA |
| 16 | 90001137 | Q | 41 | 00039374 | 5Q | 66 | 00043250 | Pest MOA |
| 17 | 90001143 | M | 42 | 00041471 | Q | 67 | 00043253 | Pest MOA |
| 18 | 90001145 | 2Q | 43 | 00042984 | Q | 68 | 00043258 | Pest MOA |
| 19 | 90001149 | 2Q | 44 | 00043253 | 5Q | 69 | 00047172 | Pest MOA |
| 20 | 90001161 | Q | 45 | 80046811 | 2Q | 70 | 00047175 | Pest MOA |
| 21 | 90001254 | 5Q | 46 | 80046812 | 2Q | 71 | 00048659 | Pest MOA |
| 22 | 90001343 | 2Q | 47 | 80046813 | 2Q | 72 | 00055310 | Pest MOA |
| 23 | 90001344 | 2Q | 48 | 00065002 | Q | 73 | 90002823 | Pest MOA |
| 24 | 90001822 | Q | 49 | 00061858 | Q | 74 | 90000315 | Pest MOA |
| 25 | 90001857 | Q | 50 | 00061854 | Q | | | |

The Groundwater Section held its annual workshop and tradeshow for water-well and monitoring-well drillers in conjunction with the Kentucky Water Well Association in Louisville, March 5–7, 2014. The workshop serves as a major venue for licensed drillers to obtain the continuing education credits required by states with annual driller certification. Eighty-four licensed drillers and 13 nonlicensed drillers attended the workshop. Groundwater Section personnel taught two classes worth two credits. Attendees were from Kentucky, Indiana, Illinois, Ohio, Tennessee, and West Virginia. Total attendance for the workshop, including vendors and others, was 168.

**Well-Drilling Activities.** A total of 1,171 wells were drilled and reported to the Division in fiscal year 2013-14. They may be broadly classified into nine major categories: agriculture (74), domestic (65), monitoring and remediation (849), public (seven), industrial/commercial (three), geothermal (two), heat pump (two), other (19), and unknown (150). Plugging records were submitted for 2,009 wells that were decommissioned. The majority of the plugging records were from monitoring and remediation (1,998), domestic (five), industrial/commercial (four), and other (two) wells.

Use of domestic wells remains consistent on a county basis throughout Kentucky. The Eastern

*Figure 5. Fred Mullins Spring in Rockcastle County is an active Monitoring Network site and the source of Climax Bottled Water.*

Coal Field and Jackson Purchase areas continue to have the greatest percentage of households that rely on domestic wells as their primary source for potable water. According to 2010 census data, approximately 5 percent of Kentucky's population uses wells or springs as its primary drinking-water source.

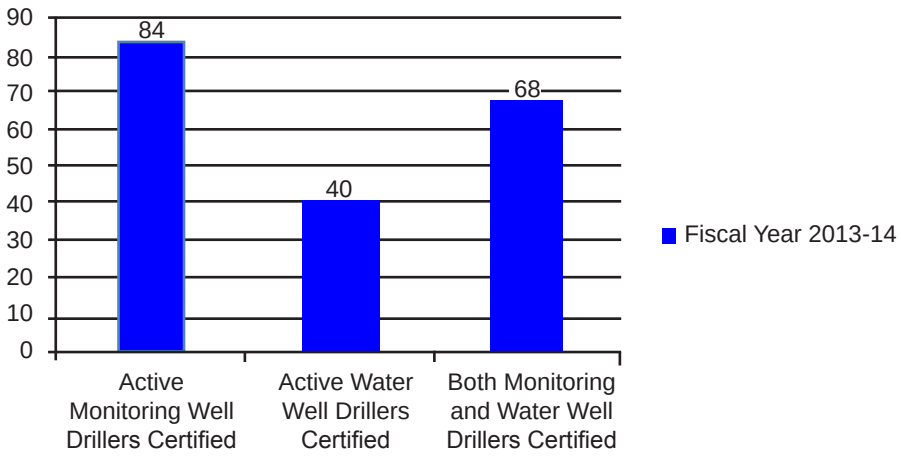


*Figure 6. Types of well-driller certifications presented during 2013-14.*

**Complaint Sampling.** During fiscal year 2013-14, the Groundwater Section responded to 47 complaints about water-well and monitoring well-drilling, installation, construction, maintenance, and water-quality issues. More than 90 percent of the responses resulted in samples being collected for water-quality analysis.

From the 47 complaints or technical assistance requests, 38 samples were collected from 25 wells and five springs. The majority of the samples were collected by Groundwater Section personnel. Many water-well and spring inspections, as well as requests for technical assistance, are completed with a comprehensive inspection of the domestic drinking-water source, professional advice, and onsite technical assistance.

**Groundwater Monitoring.** In fiscal year 2013-14, 212 samples were collected from 95 sites (54 wells and 44 springs) across the state. Groundwater-quality data were provided in response to numerous information requests. Data were also included in statistical analyses for regional and watershed-based groundwater assessments. Table 3 breaks down the total number of samples collected for the fiscal year.

**Nonpoint-Source Groundwater Assessments**. The Groundwater Section has three active nonpoint-source projects in various phases from final report drafting to reconnaissance to site selection.

**Pesticides Memorandum of Agreement Project.** The Pesticides Memorandum of Agreement with the Kentucky Department of Agriculture funds groundwater-quality monitoring at four permanent sites (three springs and one well). Each site was sampled quarterly, for a total of 16 samples during the fiscal year. Pesticide data from all permanent monitoring sites are submitted to the Department of Agriculture annually.

**Western Pennyroyal Region Karst Study.** Tracer tests have been completed throughout the study area, which includes parts of Livingston, Crittenden, Caldwell, Lyon, and Trigg Counties. Groundwater tracing results were presented at the Kentucky Water Resources Research Institute 2013 annual symposium. Groundwater-quality monitoring at nine study area springs was completed in September 2013. Data analysis indicates that seven of the monitored springs were fully supporting and two springs were partially supporting for warm-water aquatic habitat. Three of the springs were fully supporting and six springs were partially supporting for primary contact recreation.

**Statewide Pathogens Study.** This project focused on the occurrence of pathogens in domestic-use groundwater supplies. Approximately 200 sites across Kentucky were sampled for total coliform, *E. coli*, iron-related, sulfate-reducing, and slime-forming bacteria, and caffeine. Results indicate that bacteria presence correlates with the type of well construction and well-maintenance practices. A secondary goal for this project was educating well owners about proper water-well maintenance and disinfection practices. These activities were conducted onsite during sample collection.

**Table 3.** Total samples collected by the Division of Water for fiscal year 2013-14.

| *Program* | *Wells* | *Springs* |
|---|---|---|
| Ambient Groundwater Quality Monitoring Network | 63 | 73 |
| Western Kentucky Karst Study | 0 | 27 |
| Pesticide MOA | 4 | 12 |
| Complaints | 28 | 5 |
| *Total Samples Collected* | 95 | 117 |

**South-Central Karst Study.** This project is focused on expanding karst groundwater mapping south of Lake Cumberland. The study area includes parts of Pulaski, Clinton, Wayne, and McCreary Counties. Work is currently focused on groundwater dye tracing and karst basin delineation. Thus far, 10 tracer tests have been recovered at 14 springs.

*Figure 7. Dye tracing being conducted in the city sewers of Somerset.*

Monitoring sites will be chosen following completion of the tracer tests and delineation of several karst basins. This project will use an integrated surface-water and groundwater assessment approach.

**Special Projects**. Dye trace assistance was provided to 18 county health departments, the Division of Mining Reclamation and Enforcement, U.S. Office of Surface Mining, Division of Waste Management, Lexington-Fayette Urban County Government, the City of Somerset (Fig. 7), and Division of Water regional offices to investigate subsurface hydraulic connections. The Groundwater Section also made several presentations about geology and groundwater at elementary schools in Woodford County for their annual Science Day events.

The Division of Water and the Kentucky Geological Survey assisted with the emergency response to a large fuel spill in Sloans Valley on January 30, 2014. A tanker crash on U.S. 27 released nearly 8,000 gallons of unleaded gasoline. Three tracer tests were conducted to determine the general subsurface pathways from the spill site to Sloans Valley Cave. Results of the tracer tests showed a direct connection between the spill site and the mapped cave system. This allowed the environmental contractors to properly focus their clean-up efforts.

### *U.S. Geological Survey*

**Louisville Water Company, Ohio River Alluvial Aquifer; Jefferson County, Kentucky.** 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 (Fig. 8). Ten 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 33 observation wells on a quarterly basis. These data assist the Louisville Water Company's efforts to operate and maintain a riverbank filtration system 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; Graves County, Kentucky.** The USGS collects real-time continuous water-level measurements from an observation well in Graves County that is included in the USGS National Ground-Water Climate Response Network—a nationwide network of long-term observation wells intended to monitor the effects of drought and other climate variability on the nation's groundwater resources (example shown in Figure 9). The water-level data for this well can be accessed at groundwaterwatch.usgs.gov or ky.water.usgs.gov. Two additional long-term observation wells 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 historical water-level data from other observation wells and additional information about the activities of the USGS's Kentucky Water Science Center are available on the USGS website at ky.water.usgs.gov.

*Figure 8. USGS scientists (foreground) making observations at an observation well completed in the Ohio River alluvial aquifer. A Louisville Water Company riverbank filtration structure is visible in the background.*

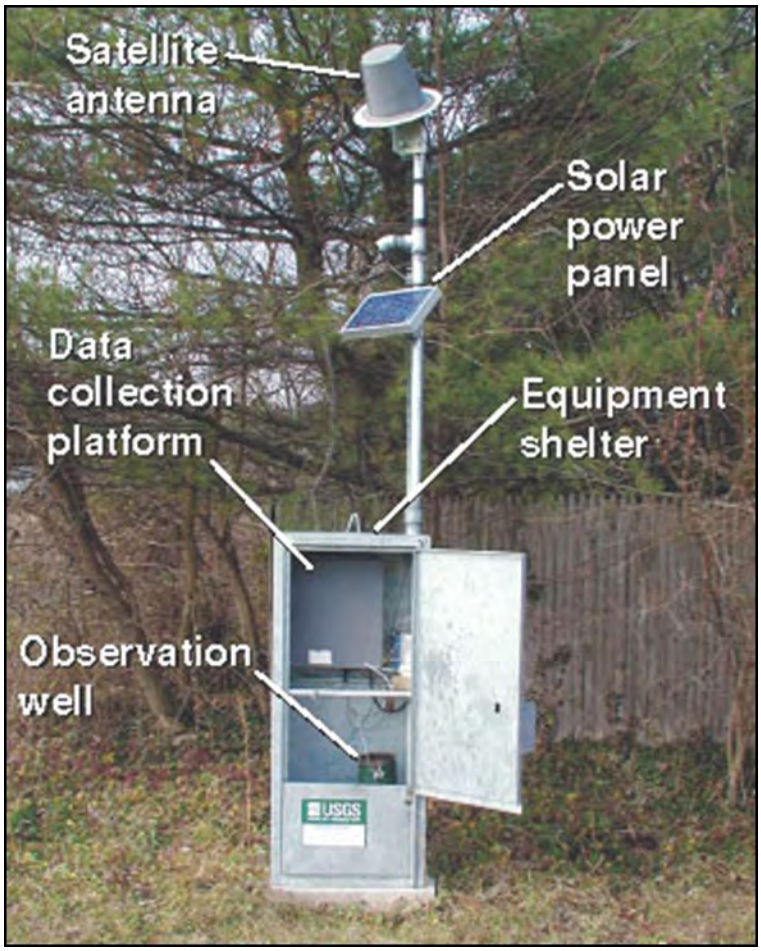


*Figure 9. Standard USGS groundwater-observation well.*

**Well-Integrity Survey of Abandoned Gas Wells near West Point, Hardin County, Kentucky.** 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 (Fig. 10). 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. In cooperation with the Directorate of Public Works, Environmental Management Division at the U.S. Army Garrison, Fort Knox, the USGS is using geophysical and hydrogeologic methods to identify abandoned or improperly plugged oil and gas wells that may be contaminating the freshwater aquifer with brine and to characterize the migration and dispersion of chlorides (Figs. 11–12).

**Hydrogeologic Reconnaissance, Well Inventory, and Aquifer Tests to Assess the Feasibility of Stormwater Injection Wells, Northern Kentucky Sanitation District No. 1 Service Area; Boone, Campbell, and Kenton Counties, Kentucky.** Hydrogeologic reconnaissance, well inventory, and site-specific aquifer test data are needed so that Northern Kentucky Sanitation District No. 1 managers can assess whether use of stormwater injection wells is technically or economically feasible for Class V underground injection and develop the necessary engineering-design specifications. The USGS will complete a basic well inventory in the service area, assess the structural integrity of identified wells (Figs. 13–14), collect basic hydrologic characteristics for the region, conduct aquifer tests; and document the findings in a USGS open-file report.

*Figure 10. High-chloride groundwater emerging from an abandoned gas well near West Point, Ky.*

*Figure 11. USGS scientists conduct a two-dimensional geophysical investigation of the groundwater near West Point, Ky.*

*Figure 12. Installation of a USGS groundwater-monitoring well near West Point, Ky.*

*Figure 13. After assessing well integrity, USGS and Northern Kentucky Sanitation District No. 1 Service Area personnel conduct an aquifer test at an existing well (inside the building to the left) in northern Kentucky.*


*Figure 14. Assessing well construction and integrity in northern Kentucky.*

### *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*

The Water Resources Section conducts research and collects data on Kentucky's groundwater and surface-water resources and provides assistance to State, federal, and local agencies, other university researchers, geoscientists and engineers in the private sector, and the general public. During fiscal year 2013-14, the section's activities were largely dominated by three issues: (1) sinkhole occurrences, (2) groundwater quality and availability, and (3) improving groundwater data availability.

**Sinkholes and Karst-Related Activities**. The sinkhole that occurred on February 12, 2014, at the National Corvette Museum in Bowling Green, Ky., captured the attention of national and international media, as well as the general public. The sinkhole collapsed the museum's SkyDome exhibit area floor, causing significant damage to the building and eight vintage Corvette cars on display. KGS staff members from the Water Resources and Geologic Hazards Sections joined Dr. Jason Polk, professor of geology at Western Kentucky University, to inspect the sinkhole on February 20 (Fig. 15). Sinkholes are common in the karst area around Bowling Green, and are numerous in the vicinity of the museum's location. The formation of the sinkhole beneath the museum floor appeared to have been triggered by the collapse of bedrock forming the roof of a large, relatively dry, and previously unknown remnant cave passage. The exact circumstances that triggered the bedrock collapse are unknown at this time but are the subject of an ongoing investigation. Water Resources staff, Dr. Polk, and other geologists from WKU have begun more direct collaboration to investigate sinkhole occurrence and other karst hazards in Kentucky and expect to conduct joint research in these areas in the future.

In the weeks and months following the Corvette Museum sinkhole, requests for interviews and information from print and television media increased dramatically, as well as calls and emails from homeowners concerned about sinkholes. Water Resources staff inspected more than 65 sinkholes on private property and provided information to homeowners to help remediate the sinkholes. Presentations on sinkholes and karst hazards were given at engineering training seminars hosted in Somerset, Bowling Green, and Paducah by the Kentucky Society of Professional Engineers. Presentations were also give at the Nature's Call to Action II Conference, the KGS annual meeting, and the Association of American State Geologists' annual meeting.

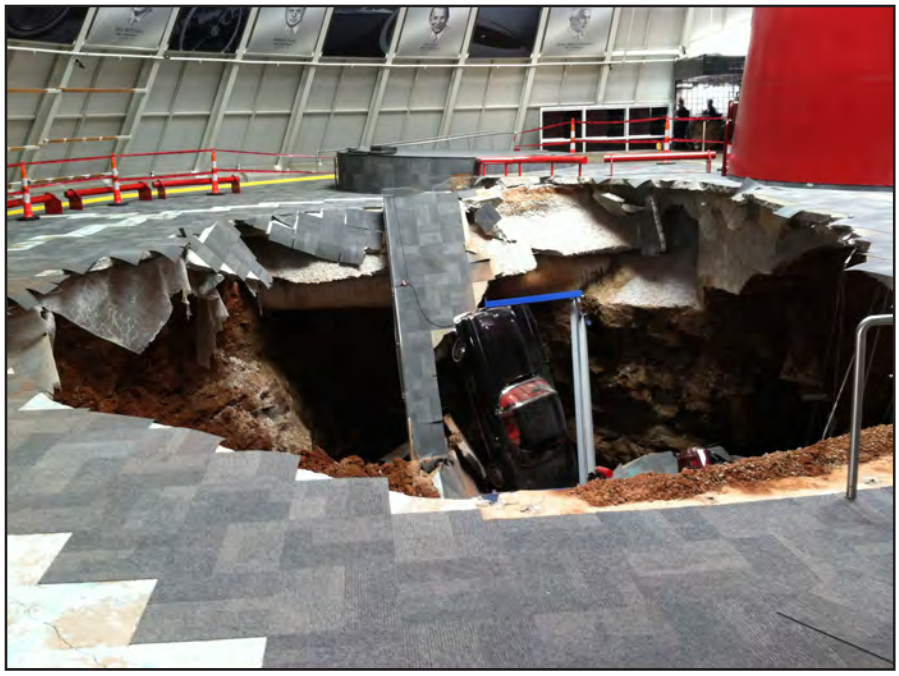

*Figure 15. Sinkhole that developed in early 2014 at the National Corvette Museum in Bowling Green, Ky.*

Water Resources staff have also been working to improve sinkhole mapping using LiDAR (light detecting and ranging) technology in Jefferson County, and on a karst hydrology study in the Cane Run Basin in Fayette and Scott Counties. Since 1997, the

Water Resources Section has collected information about the occurrence of cover-collapse sinkholes in Kentucky, maintaining an inventory of these features that describes their locations, physical characteristics, and topographic and geologic settings. A GIS file of sinkholes identified and mapped throughout the state at a scale of 1:24,000 was prepared in 2003 and is available for download at www.uky.edu/KGS/gis/sinkpick.htm. The recently improved availability of high-resolution LiDAR digital topographic data sets has provided a new avenue for improved mapping of surface features such as sinkholes, particularly in urbanized and suburbanized areas. In 2013-14, Water Resources personnel continued using LiDAR data and new data-processing methods developed during the previous year to improve sinkhole identification and mapping. Results obtained thus far demonstrate that approximately four times more probable sinkholes have been identified from LiDAR mapping than the number identified from contoured depressions visible on topographic maps. Field inspection indicates that the Section's LiDAR data-processing method is 80 percent successful in identifying new sinkholes (Fig. 16).

Collaborative work continued with the UK College of Agriculture, Food and Environment on the Cane Run Basin karst hydrology project. The main objectives are to gather field data needed to quantitatively measure the discharge of groundwater and calculate the discharge concentrations of potential contaminants such as nitrate, phosphorus, fecal bacteria, and suspended sediments in the karst aquifer beneath the Cane Run surface drainage basin in Fayette and Scott Counties. Data were collected and analyzed using a variety of methods, including quantitative dye-tracer tests, Doppler sonar, borehole flowmeter, and continuous water-quality monitoring at a station at the Kentucky Horse Park. Continuous high-resolution water-level and in situ groundwater-quality data (pH, specific conductance, and temperature) have been collected from wells drilled directly into the Royal Spring karst conduit—the major cave stream passage that underlies and drains part of the approximately 15,000 acres of the Cane Run Basin—in order to help characterize flow conditions in the karst aquifer that affect the discharge of subsurface water and contaminants through the conduit. The data and findings obtained by this project are helping the UK College of Agriculture, Food and Environment and the Lexington-Fayette Urban County government design and implement best management practices to improve stormwater disposal and water quality in the Cane Run Basin, a tributary of North Elkhorn Creek.

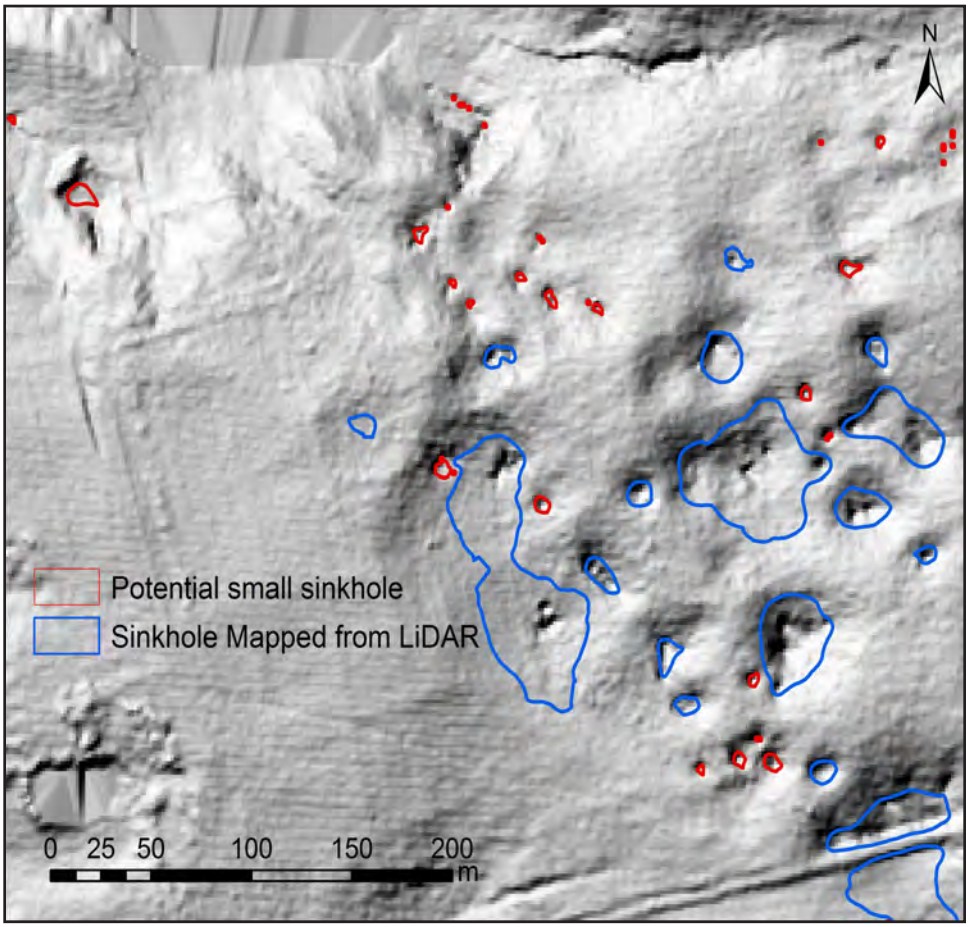


*Figure 16. Depressions identified by LiDAR as possible sinkholes, many of which have been field-verified.*

**Groundwater Quality and Availability.** Several ongoing and new projects in the Water Resources Section address issues related to groundwater quality and availability.

A groundwater flow and transport model was developed to test the potential outcomes of different remedial actions in the aquifer system at the Paducah Gaseous Diffusion Plant, where a variety of radioactive and nonradioactive hazardous wastes were released in the past. The outcomes will be used to assist U.S. Department of Energy and other federal and State resource managers and contractors in remediating groundwater at the site.

The potential impacts of sulfur dioxide, when injected with carbon dioxide, on the Knox Formation in western Kentucky are being studied. Sulfur dioxide is one of the common residual gases in emissions from coal-fired power plants. Injecting sulfur dioxide with carbon dioxide is an attractive option because of the economic and environmental benefits. Computer modeling is being used to simulate the potential effects of the injection. Results suggest that adding sulfur dioxide can enhance chemical reactions among rock minerals, formation liquid, and injected gases, possibly changing physical properties such as porosity and permeability of the Knox rocks. These findings are significant in determining whether the Knox Formation can be used for carbon sequestration.

Water Resources staff helped various State and local officials assess groundwater availability for agricultural irrigation or municipal water wells. In collaboration with Kentucky Division of Water staff, high-yield irrigation wells in parts of the Jackson Purchase and Western Pennyroyal were inventoried, and made preliminary assessments about the suitability of these aquifers to provide the large withdrawals needed to economically operate large center-pivot irrigation systems. Recent increases in grains grown for biofuel production in Kentucky have resulted in increased interest in using groundwater for irrigation during drier parts of the growing season. Water Resources staff also participated in an irrigation forum sponsored by the Kentucky Corn Growers and Small Grain Growers Associations.

Future projects currently under development by the Water Resources Section that address various agricultural and other needs for improved groundwater data include a re-established long-term statewide network of groundwater observation wells, and aquifer testing and mapping projects in the Jackson Purchase, Western Pennyroyal, and other areas. Water wells have been inspected and borehole video and geophysical log data were collected to evaluate the suitability of wells for future aquifer testing or water-level monitoring (Fig. 17).

**Groundwater Data Repository.** The Kentucky Groundwater Data Repository, initiated in 1990 by the Kentucky Geological Survey under mandate from the Kentucky legislature (KRS 151:035 [www.lrc.ky.gov/Statutes/statute.aspx?id=2074]), was established to archive and disseminate groundwater data collected by State agencies, other organizations, and independent researchers. The database currently contains information on more than 97,000 water wells and 5,300 springs, and 50,000 suites

*Figure 17. A gamma logging tool is inserted into a water-supply well in Hopkins County to help determine the rock type of the aquifer, since no driller's log was available for the well.*

of water-quality analyses (containing millions of individual analyte results). The database contains data from more than 15 State, federal, academic, and private agencies, but the largest contributor continues to be the Kentucky Division of Water. The repository can be accessed at kgs.uky.edu/kgsweb/DataSearching/watersearch.asp.

In fiscal year 2013-14, the Division of Water supplied four uploads of water-well and water-quality data to the Survey, which were entered into the database and made available to the public. In July 2013, nearly 300,000 scanned digital images of original drillers' logs, and associated documents were placed online in October. A major benefit is that all information visible on the original drillers' logs, including hand-written notes or drawings, can now be reviewed and used as desired. These uploads take place twice a year. In a new initiative, data from the repository are being compiled into a Kentucky groundwater atlas Web page. To date, more than 40 draft maps have been generated showing water-quality trends, groundwater levels, and water-well distribution and yield rates. Range-of-value maps for 32 water-quality parameters are currently available from the repository's groundwater-quality search engine at kgs.uky.edu/kgsweb/DataSearching/Water/WaterQualSearch.asp. Data available from aquifer tests from across the state are also being compiled and will be made available in the near future via the digital atlas site.

**KGS Laboratory.** In the fall of 2013, the KGS Laboratory Services were restructured and administratively placed in the Water Resources Section to enhance collaboration and opportunities for synergistic research (Fig. 18). As a consequence, the laboratory is better able to support the research and data needs of Water Resources Section hydrogeologists and their UK collaborators—for example, by analyzing samples collected for the Cane Run Basin project. As before, the KGS laboratory continues to provide other KGS researchers, University of Kentucky departments, and various State agencies with analyses of rock, oil, gas, and water samples collected throughout the state. For example, shale samples were analyzed for a KGS Energy and Minerals Section project investigating the total organic carbon content of the Utica Shale. Another project analyzed water from several deep wells, including brine water from the Knox Formation. Samples taken by UK Department of Civil Engineering researchers were analyzed to help determine the water quality of the South Elkhorn watershed. Water samples were analyzed for a Kentucky Transportation Cabinet project and for the Kentucky Watershed Watch program, which monitors the quality of the state's surface waters and wetlands.

The laboratory also houses, maintains, and oversees the scheduling of its X-ray diffraction instrument for students and research staff within the University of Kentucky research community. Several students from the UK Department of Earth and Environmental Sciences worked with laboratory personnel and equipment on different research projects, looking at both water and shale samples.

*Figure 18. The Kentucky Geological Survey water-quality laboratory.*

Samples from the UK Department of Mining Engineering were analyzed by X-ray fluorescence, and a visiting scholar from China worked with KGS researchers and laboratory personnel to learn coal and coke testing techniques.

### *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 (Figs. 19–20). The investigations may be a result of diminished water-well quality or quantity. In addition, the Division investigates surface water in connection with 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 2013-14 fiscal year, the Division received 62 new requests for inspections. Fifty two inspections were completed; of these, 10 concluded that mining activity had had an adverse impact on a citizen's well or property. Of the 10 adverse impact determinations, one was the result of diminished well-water quality, five were the result of loss of well-water quantity, one was related to seeps or landslides (or both), one was related to subsidence of a mine, and one was caused by methane in the well.

*Figure 19. Pressure tank for a water well (located behind the tank), which was investigated because the owner thought the well's high iron content may have been caused by local coal mining.*

*Figure 20. A stream in eastern Kentucky with heavy iron staining, reported by a concerned citizen.*

## Distribution of Groundwater Information

One of the most important functions of the Interagency Technical Advisory Committee and 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 2013-14 fiscal year, groundwater information was communicated via short reports, oral and poster presentations at meetings and conferences, and posting on websites. Publications and presentations generated by ITAC agency personnel for both groundwater and surface water are listed below.

### *Publications—Groundwater*

Beck, E.G., 2014, Determining the presence of 17-β estradiol and fluoroquinolones in five Kentucky watersheds: Kentucky Geological Survey, ser. 12, Contract Report 62, 22 p.

Beck, E.G., 2014, The Rochester Valley channel sandstone aquifer: A potential source of groundwater in the Western Kentucky Coal Field [abs.]: Kentucky Water Resources Symposium Proceedings and Abstracts, p. 65.

Blair, R.J., and Davidson, B., 2014, The Kentucky Interagency Groundwater Monitoring Network: Expanded monitoring programs [abs.]: 9th National Monitoring Conference, p. 59.

Davidson, B., 2013, Kentucky Interagency Groundwater Monitoring Network annual report, July 2012–June 2013: Kentucky Geological Survey, 20 p.

Davidson, B., and Blair, R.J., 2014, The Kentucky Interagency Groundwater Monitoring Network: A collaborative effort in groundwater resource characterization [abs.]: 9th National Monitoring Conference, p. 47.

Davidson, B., Curl, D.C., and Taylor, C.J., 2014, New features available on the Kentucky Groundwater Data Repository [abs.]: Kentucky Water Resources Symposium Proceedings and Abstracts, p. 57.

Davidson, B., and Smath, R.A., 2013, Review of local health department bacteria data for entry into the Kentucky Groundwater Data Repository: Kentucky Geological Survey, ser. 12, Contract Report 61, 11 p.

Dinger, J. S., Currens, J.C., Zhu, J., Webb, S., Rister, B.W., Graves, R.C., Allen, D.L., and Scully, T.C., 2013, Hydrogeologic investigations of pavement subsidence in the Cumberland Gap Tunnel, Kentucky: Kentucky Geological Survey, ser. 12, Report of Investigations 27, 21 p.

Williamson, T.N., Taylor, C.J., and Newson, J.K., 2013, Significance of exchanging SSURGO and STATSGO data when modeling hydrology in diverse physiographic terrains: Soil Science Society of America Journal, v. 77, no. 3, p. 877–889.

Zhu, J., and Hampson, S., 2014, Reassessment of the extent of the groundwater contamination plume at the Paducah Gaseous Diffusion Plant: Kentucky Geological Survey, ser. 12, Contract Report 60, 18 p.

Zhu, J., Parris, T.M., Bowersox, J.R., and Harris, D.C., 2013, Modeling $CO_2$–brine–rock interactions in the Knox Group: Implications of a deep carbon storage field test in western Kentucky: Applied Geochemistry, v. 37, p. 29–42.

### *Publications—Surface Water*

Jenkins, S., Osborne, A., and Agouridis, C., 2013, Planting along your stream, pond, or lake: University of Kentucky College of Agriculture, Food and Environment, HENV 202, 8 p., www2.ca.uky.edu/agc/pubs/HENV/HENV202/HENV202.pdf [accessed 10/29/2014].

Lee, B.D., 2013, How water use impacts septic system performance: University of Kentucky College of Agriculture, Food and Environment, HENV 509, 8 p., www2.ca.uky.edu/agc/pubs/HENV/HENV509/HENV509.pdf [accessed 10/29/2014].

Lee, B.D., Munshaw, G., Durham, R.E., Mickelbart, M.V., and Powell, T., 2013, Native plant landscaping of septic systems: University of Kentucky College of Agriculture, Food and Environment, HENV 508, 8 p., www2.ca.uky.edu/agc/pubs/HENV/HENV508/HENV508.pdf [accessed 10/29/2014].

Osborne, A., Cocanougher, J., and Gumbert, A., 2013, Understanding and protecting Kentucky's watershed: University of Kentucky College of Agriculture, Food and Environment, HENV 206, 3 p., www2.ca.uky.edu/

agc/pubs/HENV/HENV206/HENV206.pdf [accessed 10/29/2014].
Osborne, A., and Jenkins, S., 2013, What is a watershed?: University of Kentucky College of Agriculture, Food and Environment, HENV 204, 8 p., www2.ca.uky.edu/agc/pubs/HENV/HENV204/HENV204.pdf [accessed 10/29/2014].
Osborne, A., Jenkins, S., and Agouridis, C., 2013, Stormwater: University of Kentucky College of Agriculture, Food and Environment, HENV 203, 8 p., www2.ca.uky.edu/agc/pubs/HENV/HENV203/HENV203.pdf [accessed 10/29/2014].

### *Presentations—Groundwater*

Beck, E.G., 2013, Quality of groundwater from private domestic wells in the Jackson Purchase Region, Kentucky: 2013 Water Education Summit, Chattanooga, Tenn., Sept. 24–26, 2013.
Beck, E.G., 2014, Intro to rocks and sinkholes: Jeffers Bend Environmental Center, Hopkinsville, Ky., April 18, 25, 2014.
Beck, E.G., 2014, Quality of groundwater from private domestic wells in the Jackson Purchase Region, Kentucky: University of Kentucky Extension Water Education for Teachers Workshop, Princeton, Ky., Nov. 7, 2014.
Beck, E.G., 2014, The Rochester Valley channel sandstone aquifer: A potential source of groundwater in the Western Kentucky Coal Field: Kentucky Water Resources Symposium, Lexington, Ky., March 10, 2014.
Beck, E.G., 2014, Water well videos from the Southern Region: University of Kentucky Extension Water Education for Teachers Workshop, Princeton, Ky., November 7, 2014.
Blair, R.J., and Davidson, B., 2014, The Kentucky Interagency Groundwater Monitoring Network: Expanded monitoring programs: 9th National Monitoring Conference, Cincinnati, Ohio, April 28–May 1, 2014.
Bolster, C.H., Groves, C., and Polk, J., 2014, Transport of agricultural contaminants through karst soil: Kentucky Water Resources Annual Symposium, Lexington, Ky., March 10, 2014.
Currens, J.C., Shelton, B., Taylor, C.J., Zhu, J., and Webb, S.E., 2014, Kentucky Horse Park Karst Water Instrumentation System (KWIS): Kentucky Water Resources Annual Symposium, Lexington, Ky., March 10, 2014.
Davidson, B., 2014, Overview of the geology of Kentucky: Kentucky Groundwater Association Drillers' Tradeshow, Louisville, Ky., March 6, 2014.
Davidson, B., and Blair, R.J., 2014, The Kentucky Interagency Groundwater Monitoring Network: A collaborative effort in groundwater resource characterization: 9th National Monitoring Conference, Cincinnati, Ohio, April 28–May 1, 2014.
Davidson, B., Curl, D.C., and Taylor, C.J., 2014, New features available on the Kentucky Groundwater Data Repository: Kentucky Water Resources Annual Symposium, Lexington, Ky., March 10, 2014.
Landrum, C., Kim, D., Zourarakis, D., and Mueller, T., 2014, Spatiotemporal relevance of soil moisture's interaction with measured soil-terrain parameters: Kentucky Water Resources Annual Symposium, Lexington, Ky., March 10, 2014.
Mallette, S.L., 2014, Results of the statewide groundwater pathogen study: Kentucky Water Resources Annual Symposium, Lexington, Ky., March 10, 2014.
Parris, T.M., Webb, S.E., Grider, J., and Thomas, B., 2014, Formation water chemistry of Cambrian-Ordovician Knox Group strata, KGS Hansen Aggregates No. 1 well, Carter County, Kentucky: Kentucky Water Resources Annual Symposium, Lexington, Ky., March 10, 2014.
Price, D.J., 2014, Water quality monitoring of the McConnell Springs, Lexington, Kentucky: Kentucky Water Resources Annual Symposium, Lexington, Ky., March 10, 2014.
Price, D.J., and Plueger, P.E., 2014, Water quality monitoring of the McConnell Springs stormwater quality wetland pond and Gainesway pond: Kentucky Water Resources Annual Symposium, Lexington, Ky., March 10, 2014.
Pryshlak, T., and Sawyer, A., 2014, Permeability heterogeneity and its effects on hyporheic zone exchange: Kentucky Water Resources Annual Symposium, Lexington, Ky., March 10, 2014.

Taylor, C.J., 2013, Availability of groundwater for agricultural irrigation: Groundwater data needs: Joint Kentucky Small Grain Growers Association—Kentucky Small Grain Promotion Council annual business meeting, Louisville, Ky., Aug. 8, 2013.

Taylor, C.J., 2013, Kentucky groundwater data: What do we have? What do we need?: Kentucky Agricultural Science Monitoring Committee executive meeting, Murray, Ky., July 23, 2013.

Taylor, C.J., 2013, Overview of groundwater availability for agricultural irrigation: AgriBusiness Association of Kentucky annual meeting, Louisville, Ky., Nov. 5–7, 2013.

Taylor, C.J., 2014, Hydrogeologic characterization methods used in karst: A contrast to the Darcian aquifer model: Workshop on Aquifer Characterization, Groundwater Behavior in the Subsurface Environment, Kentucky Section–American Institute of Professional Geologists, Lexington, Ky, May 29, 2014.

Taylor, C.J., 2014, Sinkholes and karst flooding: What role could climate change play?: Nature's Call to Action II Conference, Kentucky Transportation Cabinet, Frankfort, Ky., April 9, 2014.

Taylor, C.J., 2014, Strategy and considerations for a statewide groundwater monitoring network: Kentucky Geological Survey annual seminar, Lexington, Ky., May 16, 2014.

Zhu, J., Taylor, T.P., and Currens, J.C., 2013, Using LiDAR to map karst sinkholes in Floyds Fork watershed, central Kentucky: 58th Annual Midwest Ground Water Conference, Bismark, N.D., Sept. 23–25, 2013.

Zhu, J., Taylor, T.P., and Currens, J.C., 2014, Improving karst sinkhole mapping in Kentucky using LiDAR: Kentucky Water Resources Annual Symposium, Lexington, Ky., March 10, 2014; Association of American State Geologists annual meeting, Lexington, Ky., June 9, 2014.

### *Website 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 website 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 websites 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 6,989 times during fiscal year 2013-14, and 566 downloads were made. It remains the second most popular search engine on the KGS website, 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 latitude/longitude location. Resulting data can be displayed on maps or downloaded for use in GIS packages. The associated Water Wells and Springs map service was accessed 6,697 times during the year, and the Karst Potential Map layout on the KGS Geologic Map Service was accessed 3,101 times.

The Kentucky Groundwater-Quality Data search engine was accessed by the public more than 1,045 times during fiscal year 2013-14, and 210 downloads were made. Users can select from hundreds of parameters in 14 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. The water-quality map was accessed 764 times, and the groundwater-quality data plotting service was accessed 77 times.

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 have been meeting with county Extension Service agents and Area Development District personnel throughout the commonwealth to promote awareness of hydrogeologic issues. Some 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 2013-14, electronic files of water-well, spring, and groundwater-quality data were transferred from the Division of Water to the Kentucky Geological Survey quarterly, and scanned drillers' logs twice a year. These data were uploaded to the Kentucky Groundwater Data Repository, thereby 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 Task Force*

**The Kentucky Well Education Website.** This website (www2.ca.uky.edu/enri/downwell) is a joint project between ENRI and the Kentucky Geological Survey. The website 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 website provides video and photographic examples of problems that may occur in wells and gives advice on solutions. This site is maintained by ENRI.

**ENRI Website.** The ENRI website (www2.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. The site is maintained by ENRI.

**"See Blue Go Green" Website.** This website (www2.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 ENRI.

**ENRI Quarterly E-News.** The ENRI E-News (www2.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. This information is provided online and is sent via email listserv to all 120 county Extension agents in Kentucky.

**Taking Runoff by Storm: Stormwater Best Management Practices and Rain Garden Program.** Runoff of contaminants in stormwater from impervious surfaces (roads, parking lots, rooftops) has a negative impact on water quality in urban communities. Many of Kentucky's cities and towns are encouraging residents and businesses through tax incentives to reduce the impacts of urban runoff and improve water quality. The ENRI Task Force, together with host county Extension agents, through a collaboration between the Master Gardener Program and the Tracy Farmer Institute for Sustainability and the Environment, developed a workshop to help homeowners and communities implement residential best management practices. These one-day workshops used a hands-on approach to educate participants about stormwater and what residential homeowners can do to reduce associated pollution from stormwater runoff. Stormwater best management practices were discussed in a classroom setting and then participants constructed a demonstration rain garden within their community (Figs. 21–22). Resources available to the workshop participants included PowerPoint notes and a rain garden manual. This program began in 2011. Since 2011, 35 workshops have been presented to more than 350 participants in Boone, Bourbon, Boyd, Boyle, Breathitt, Calloway, Carter, Christian, Daviess, Fayette, Graves, Greenup, Hardin, Hopkins, Jefferson, Kenton, Laurel, Leslie, Mason, Marshall, Mercer, Nelson, Nicholas, Pendleton, Rowan, Taylor, Washington, Wayne, Whitley, and Woodford Counties.

**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-

*Figure 21. A rain garden and rain barrel were installed during a county Extension agent workshop at the North Central 4-H Camp in Nicholas County.*

*Figure 22. A rain garden and rain barrel were installed at the Mason County Intermediate School.*

school programs, environmental day camps, and homemaker club meetings. The 2014 Kentucky Water Awareness Month materials are available online at www2.ca.uky.edu/enri/kwam2014.php. The packet is coordinated by Ashley Osborne, ENRI extension associate.

**2013 Project Water Education for Teachers Workshop.** A survey conducted in 2009 by the Kentucky Environmental Education Council supports the continued need for water education in the commonwealth. Of the surveyed participants, 26 percent identified water pollution as the number one environmental problem in Kentucky. The majority of surveyed participants were not able to correctly identify the major sources of water pollution, however (i.e., runoff from fields, pavements, and lawns). In November 2013, two one-day Project WET (Water Education for Teachers) workshops were conducted. Project WET, an award-winning, international water-resources education program, includes hands-on activities to be used in formal and nonformal settings for K-12 youth. Twenty-five educators from across Kentucky received the newly revised Project WET Curriculum and Activity Guide 2.0, which contains 64 multidisciplinary water-related activities. Counties involved were Fulton, Franklin, McCracken, Lyon, Hardin, Hopkins, Breathitt, Lincoln, Fayette, Bath, Lee, Rowan, Estill, Pendleton, Menifee, Morgan, Boone, Scott, Wolfe, Owen, and Clark.

**Robinson Center Natural Resources and Environmental Science (NRESci) Academy.** The Robinson Center NRESci Academy is a three-year program designed for middle- and high-school students to explore our environment and discover more about our water, forestry, soil, and wildlife resources in the Appalachian region. Youth from 36 counties in eastern Kentucky can apply to the program, although only 16 per year are accepted into the academy. The water-resources portion of the academy was led by the ENRI Task Force, and included classroom and hands-on instruction on watersheds, nonpoint-source and point-source pollution, and water quality. Counties involved in 2013-14 were Perry, Leslie, Letcher, Breathitt, Owsley, Wolfe, Clay, Carter, and Knott.

### *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 mm in conifers, 25 mm in deciduous hardwoods, and 10 mm 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. 23).

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.

For the state fiscal year of July 1, 2013, to June 30, 2014, a total of 3,232 harvest inspections were performed, resulting in 300 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.

The Division also addresses 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 good 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 decon-

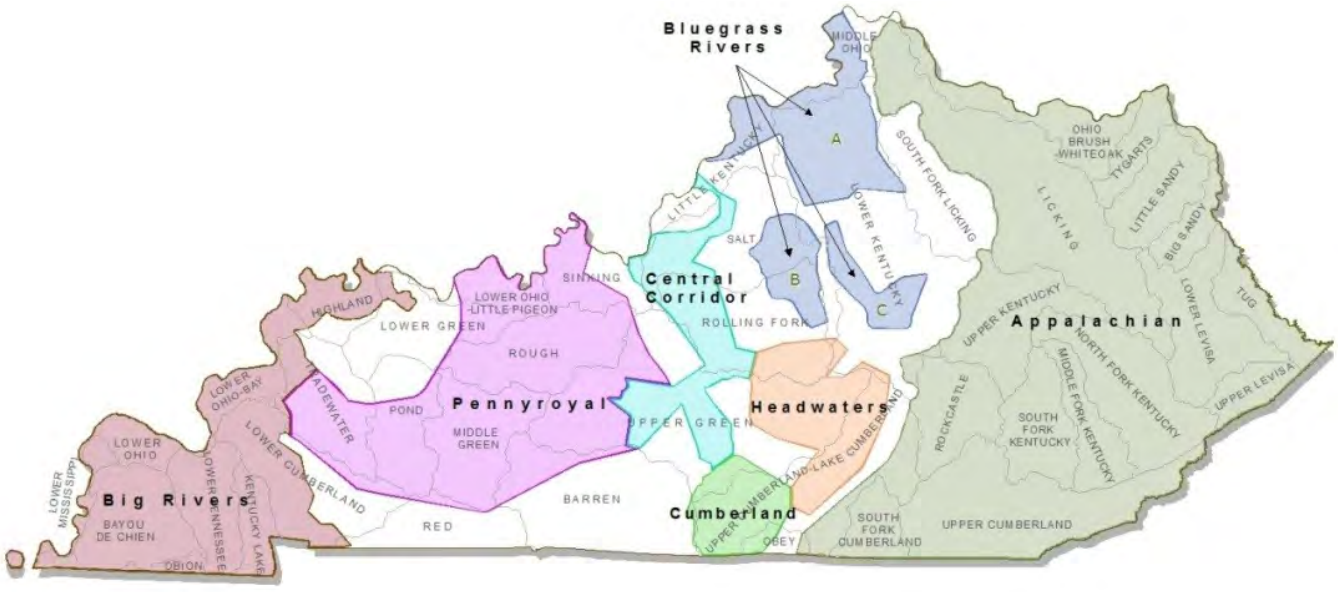


*Figure 23. Kentucky forest priority areas and watersheds.*

taminate 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.

Watershed restoration projects initiated this year in which Division of Forestry personnel provided technical assistance include:

- targeted bottomland hardwood management plans and educational outreach for the lower Green River landowners in western Kentucky
- work on the Red Bird River restoration project led by the U.S. Forest Service and the Kentucky Waterways Alliance in southeastern Kentucky.
- Cooperative Conservation Partnership Initiative in Rowan County (Triplett Creek watershed) to address water quality as well as forest health, wildlife habitat, and wildfire hazard conditions on public and private land.