Kentucky Interagency Groundwater Monitoring Network

Annual Report
July 2015–June 2016

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

November 2016

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On the cover: Left: A dug domestic well in Greenup County is sampled as part of the Kentucky Geological Survey's study on methane in groundwater in the Berea oil and gas play. Photo by Richard Smath, Kentucky Geological Survey. Right: A drilled domestic well in Boyd County (the well is inside the concrete block structure) is sampled as part of the same study. Photo by Bart Davidson, Kentucky Geological Survey.

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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 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 18 years of the Network's existence. Annual reports summarizing these activities since 1999 are available on the Network website at www.uky.edu/KGS/water/gnet.

From July 2015 through June 2016, 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. 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.

2015-16 Activities and Accomplishments

Summaries of water-related projects performed by the ITAC agencies during the 2015-16 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.

Groundwater Data Collection

Groundwater data are generated through many avenues. Drilling wells, collecting and ana-

lyzing 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.

Below are summaries of projects related primarily to groundwater that were conducted by ITAC member agencies during the 2015-16 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 range in scope from statewide to basin management unit (BMU) scale (Fig. 1). In fiscal year 2015-16, 161 samples were collected from 75 sites (42 wells and 33 springs) across the state. Groundwater-quality data were provided in response to numerous information requests. Table 1 shows the number of sites by physiographic region and basin management unit and Figure 2 shows the location of the sites within physiographic regions. The following projects have been active during the reporting period.

Ambient Groundwater-Quality Monitoring Network. There were 118 samples collected from 49 permanent sites (22 water wells and 27 springs) across the state during the fiscal year, of which 44 were from water wells and 74 from springs (Fig. 3). Nineteen of these sites are public water suppliers (14 water wells and five springs). One site was no longer available for sampling during the fiscal year, but another was gained to replace it.

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.

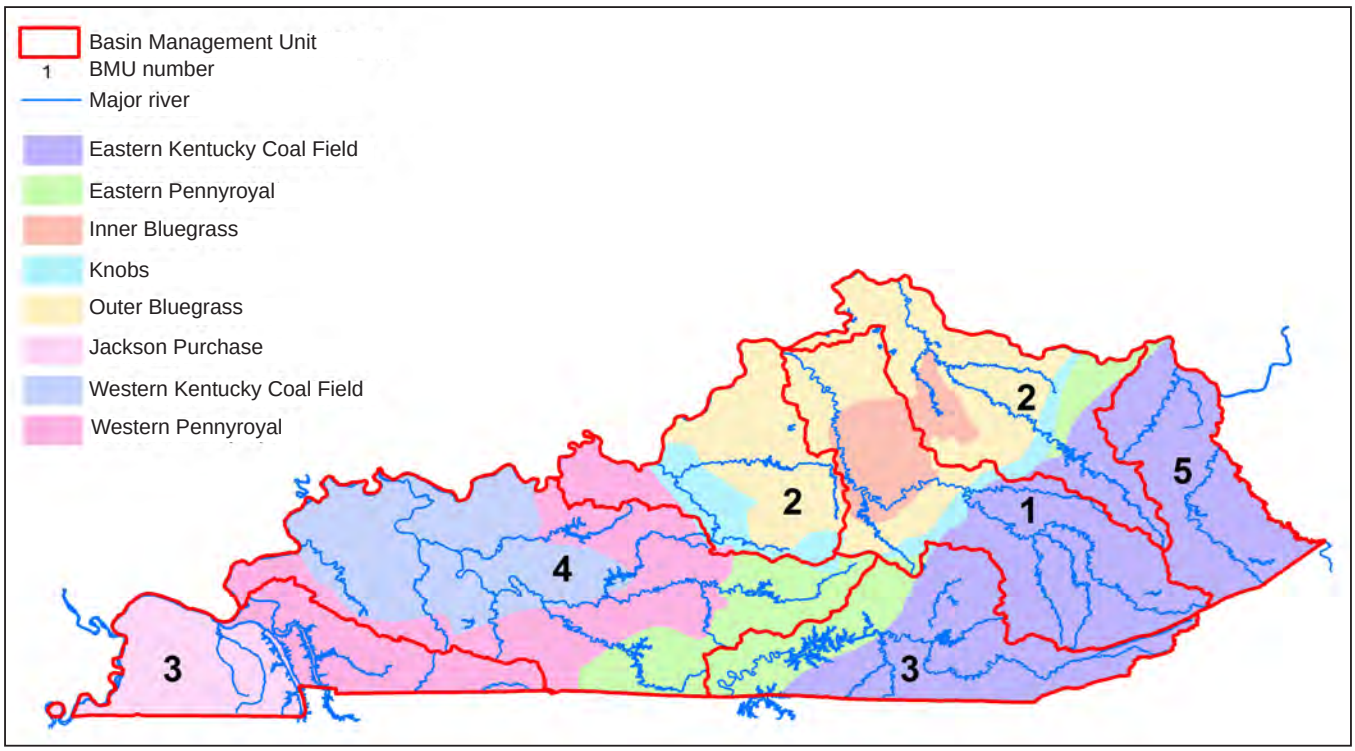

Figure 1. Major rivers, basin management units, and physiographic regions in Kentucky.

Table 1. Spatial distribution of permanent groundwater-quality monitoring sites.			
Physiographic Region	*Number of Sites*	*Basin Management Unit*	*Number of Sites*
Bluegrass	11	1—Kentucky River	7
Eastern Kentucky Coal Field	8	2—Salt and Licking Rivers	10
Ohio River alluvium	10	3—Four Rivers, Upper and Lower Cumberland	22
Mississippian Plateau	23	4—Green and Tradewater Rivers	15
Western Kentucky Coal Field	2	5—Big and Little Sandy Rivers and Tygarts Creek	5
Jackson Purchase	6		

Complaint and Technical Assistance Sampling. During fiscal year 2015-16, the Groundwater Section responded to 58 complaints about water-well and monitoring-well drilling, installation, construction, maintenance, and water-quality issues.

In response to these 58 complaints, 27 samples were collected by Groundwater Section personnel from 19 wells and four springs. As part of many water-well and spring inspections, the domestic drinking-water source is inspected and on-site technical assistance is provided.

Groundwater Protection Plan Program. The Groundwater Protection Plan program changed hands at the beginning of the 2015-16 fiscal year, and has taken a new direction. The focus is now on public outreach and education regarding activities that can threaten groundwater and which best management practices to use to protect the groundwater. A wide variety of individuals and companies throughout Kentucky should have GPPs, but the majority of inspections thus far have been at industrial sites and sites that store

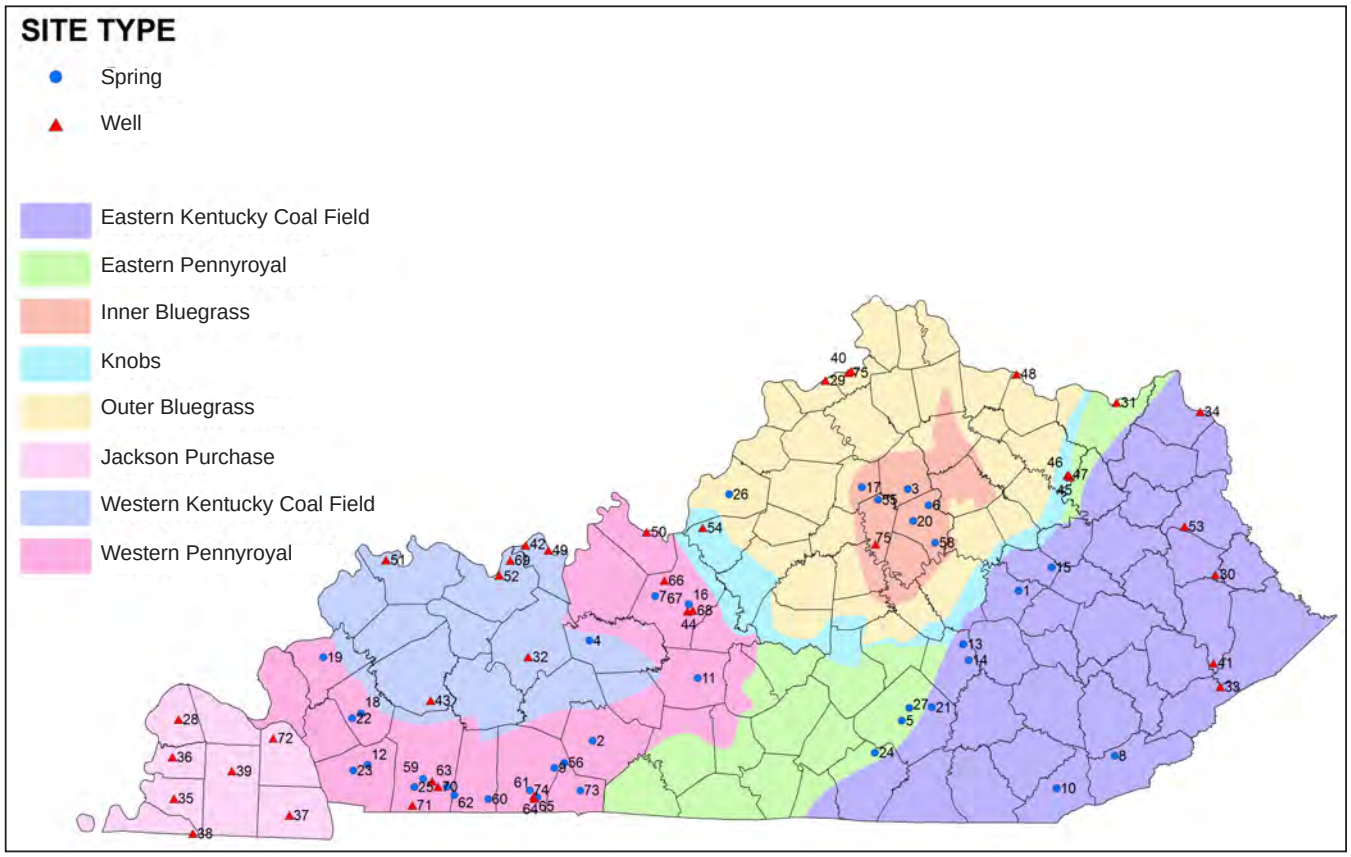

Figure 2. Sites of the Kentucky Interagency Groundwater Monitoring Network maintained by the Kentucky Division of Water. Table 2 shows map number, Division of Water's AKGWA (Assembled Kentucky GroundWAter) number, and sampling frequency for these sites.

Table 2. Assembled Kentucky GroundWAter numbers (Kentucky Division of Water identification number) and sampling frequency, if available, for the network sites shown in Figure 2. AKGWA numbers can be located using the Kentucky Groundwater Data Repository website. Q = quarterly. M = monthly. 5Q = every fifth quarter. 2Q = every second quarter. Pest. MOA = Pesticides Memorandum of Agreement. Sample times vary.

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	00066926	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	75	00697574	Q

large quantities of chemicals or fuel. Table 3 shows statistics on GPPs received, reviewed, and approved, and the number of field reviews completed by month through the end of the fiscal year.

Nonpoint-Source Groundwater Assessments. *The South-Central Karst Study* is expanding karst groundwater mapping south of Lake Cumberland. The study area covers parts of Pulaski, Clinton, Wayne, and McCreary Counties. Current work focuses on groundwater dye tracing and delineation of karst basins. Thus far, 38 tracer tests have been recovered at 30 springs. Further delineation of spring basins is needed, followed by selecting large spring monitoring sites. The project will use an integrated surface-water and groundwater assessment approach.

The *Statewide Pathogens Study* determines the occurrence of pathogens in groundwater, particularly in wells and springs providing domestic water supplies. A total of 210 sites—202 wells and eight springs—across Kentucky was sampled for total coliform, *E. coli*, iron-related, sulfate-reducing, and slime-forming bacteria, as well as caffeine. Results indicate that the presence of bacteria correlates with the type of well construction and maintenance practices. A secondary goal during sample collection is to educate well owners about proper maintenance and disinfection practices. A

Figure 3. Emily Denlinger samples Johnson Spring as part of the Ambient Groundwater Monitoring Network's midwest sampling run.

report is under administrative review and is expected to be completed by December 30, 2016.

Onsite Sewage Disposal Systems and Their Potential Effects on Groundwater will evaluate potential impacts of home septic systems on groundwater. The study is in the literature review stage, and site selection is under way. Sites are being evaluated, and some initial water-quality sampling has been conducted.

Special Projects. The Groundwater Section has worked on projects all over the state in the last fiscal year. The Section provided guidance and technical assistance to the city of Glasgow's Division of Stormwater Management to determine how to address possible stormwater and subsurface impacts from a Class V injection well, along with tracer tests to determine subsurface flow (Fig. 4). The Groundwater Section also worked with National Park Service staff to identify a potential source of contamination of a spring at Abraham Lincoln Birthplace National Historical Park. Section personnel observed monitoring-well installations and answered questions at the Big Sandy Power Plant fly-ash impoundment. A collaborative effort between Groundwater Section personnel and the Louisville Metropolitan Sewer District has begun to determine the source of a contaminant and the path it is traveling to end up in a spring off of Interstate 64 in Louisville. This project is continuing into the next fiscal year. Dye traces were provided to 11 county health departments and Division of Water regional offices to investigate subsurface hydraulic connections.

Table 3.—Groundwater Protection Plan Program statistics during fiscal year 2015-16.

Month and Year	*Number Received*	*Number Reviewed*	*Number Approved*	*Field Reviews*
Aug. 2015	3	3	1	0
Sept. 2015	1	0	0	0
Oct. 2015	7	4	2	9
Nov. 2015	3	4	3	0
Dec. 2015	8	6	0	0
Jan. 2016	7	10	3	1
Feb. 2016	10	10	5	6
March 2016	5	7	5	10
April 2016	11	6	4	1
May 2016	14	6	3	3
June 2016	4	10	4	5
Totals	73	66	30	35

Figure 4. David Jackson, supervisor of the Kentucky Division of Water's Groundwater Section, flushes the Trista Lane sinkhole in Glasgow to prepare for a dye injection.

Figure 5. Scotty Robertson observes the installation of a monitoring well at the Big Sandy Power Plant, located along the Ohio River near Louisa.

Certified Well Drillers Program. In 2015-16, the Kentucky Division of Water's Groundwater Section issued 151 licenses to certified drillers: 39 water-well, 58 monitoring-well, and 54 dual licenses. The license-renewal period continues beyond the end of the fiscal year, however, so this may not be a full accounting of drillers certified in Kentucky.

Well-Drilling Activities. A total of 525 wells was drilled and reported to the Division in fiscal year 2015-16. They may be broadly classified into nine major categories: agriculture (11), domestic (40), monitoring and remediation (422; Fig. 5), public (one), industrial/commercial (three), geothermal (zero), and other (48). Plugging records were submitted for 669 decommissioned wells. The majority of the plugging records were from the monitoring and remediation category (645), but records were also submitted for domestic (two), industrial/commercial (four), agriculture (two), and other (16) wells.

Use of domestic wells remains consistent throughout Kentucky. The Eastern Kentucky Coal Field and Jackson Purchase Region continue to have the greatest percentage of households that rely on domestic wells as their primary source for potable water. According to 2015 census data, an estimated 3.5 million Kentuckians are served by 475 public water systems that rely on groundwater, in whole or part, as their source. An additional 0.8 million Kentuckians not connected to public water systems rely on private wells, springs, or other sources for their drinking water.

U.S. Geological Survey

USGS Climate Response Network. The U.S. Geological Survey, as directed by Congress, is establishing a climate response network of groundwater wells. Each climate division in the country will eventually have at least one real-time monitoring well in a climate-responsive aquifer that is not affected by withdrawals or nearby surface water (Fig. 6). Kentucky will have four climate-response networks with wells: (1) Graves County (the existing Viola well), (2) approximately 9 miles east of Elizabethtown, (3) 6 miles southwest of Lexington, and (4) 1 mile north of Middlesboro. Data from these wells will provide information to describe the natural variability in groundwater levels attributed to weather and climate. These data will be made available to the public through websites operated by the USGS Kentucky Water Science Center (waterdata.usgs.gov/ky/nwis/current/?type=gw) and the USGS Climate Response Network (groundwaterwatch.usgs.gov).

Louisville Water Co., Ohio River Alluvial Aquifer, Jefferson County. The U.S. Geological Survey, in cooperation with the Louisville Water Co., maintains a network of 43 water-level observation wells in the northeastern part of the Ohio River alluvium in Jefferson County. Ten of the

Figure 6. A USGS station measures and transmits groundwater levels in real time.

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 help the Louisville Water Co. operate and maintain a riverbank filtration system using a network of supply wells constructed to draw and naturally filter river water through the sand and gravel aquifer near the Payne Water Treatment Plant.

Well-Integrity Survey of Abandoned Gas Wells Near West Point, Hardin County. 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. 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 11,000 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.

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. 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 to develop the necessary engineering-design specifications. USGS is working through a local partnership to identify pilot locations for stormwater injection wells. Once the locations are identified, test wells will be installed, a series of aquifer tests will be conducted, and water-quality samples will be taken to characterize the hydrogeologic conditions and quantify the groundwater quality. Resulting data and information will be used to further assess stormwater injection potential.

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's mission is to collect and disseminate information vital to the proper use, management, and protection of the commonwealth's ground- and surface-water resources. As a nonregulatory water-monitoring and research unit, the Water Resources Section is the commonwealth's principal source of unbiased water data and analysis. The Section is charged by legislative mandates to manage the State's official repository for groundwater information (KRS 151.035) and oversee establishment of a long-term groundwater monitoring network (KRS 151.625). In 2015-16, the Section conducted research to better characterize Kentucky's ground- and surface-water resources, document and assess sinkhole- and karst-related hazards,

and provide scientific information and technical assistance on a variety of water and related environmental issues to State, federal, and local agencies; University of Kentucky and other university researchers, geoscientists, and engineers working in the public and private sectors; and the general public. The following projects have been under way in fiscal year 2015-16.

Assessing Methane in Shallow Groundwater for the Berea Sandstone and Rogersville Shale Play Area, Eastern Kentucky. The Water Resources Section, in collaboration with GSI Environmental of Austin, Texas, collected and analyzed groundwater samples from existing wells in Greenup, Carter, Boyd, Lawrence, Johnson, and Elliott Counties. The objectives of this project were to obtain an understanding of baseline groundwater chemistry throughout the study area and to use isotope data to evaluate possible sources of methane detected in the groundwater. Groundwater samples were analyzed for major cations and anions, metals, and dissolved gases including methane. Wells with elevated methane concentration were also analyzed for carbon and hydrogen isotopes.

During the project, KGS researchers sampled domestic wells and one public water-supply well. The well locations were selected from the Kentucky Groundwater Data Repository, as well as by consulting University of Kentucky agricultural county Extension Service agents, Kentucky Rural Water Association personnel, and referrals from other participants. Hand-dug (Fig. 7), drilled (Fig. 8), and public wells, both active and inactive, were sampled.

Before collecting each water sample, two pressure-tank volumes (where applicable) of well water were purged to ensure that sampled groundwater was representative of the aquifer, and pH, conductivity, and turbidity were checked with meters every 3 to 5 minutes until levels were stable (Fig. 9). Forty-three of the 51 sampled wells had pressure tanks. After field parameters stabilized, a sample was taken and placed on ice for delivery to three laboratories; major and minor constituents and metals were analyzed by the Kentucky Geological Survey laboratory, dissolved gases and methane were analyzed by Eurofins

Figure 7. Bart Davidson and well owner Walter Black check the water level in a hand-dug well in Boyd County near Ashland.

Figure 8. Sampling a drilled well at an old sawmill near Louisa in Johnson County. Well is at left center, and the green hose is attached to a riser pipe.

Laboratory in Pennsylvania, and stable isotopes were analyzed by IsoTech Laboratories in Illinois. The results indicate that methane is a relatively common constituent in shallow groundwater in eastern Kentucky and the methane detected in groundwater is derived primarily from bacterial sources from the CO_2 reduction pathway.

Kentucky Groundwater Observation Network. The Water Resources Section continued work on creating a new long-term observation-well network to assess the quantity and availability of the state's groundwater resources. Data collected by

Figure 9. Effervescence from methane in purge water from a domestic drilled well in Johnson County.

the network should help predict the occurrence and severity of droughts and evaluate the potential impacts of drought conditions on ground- and surface-water resources throughout Kentucky. Groundwater samples will also be routinely collected from the network wells to help provide baseline data needed to better characterize natural variations in quality and help identify, assess, and track possible effects of nearby human activities related to energy production, agriculture, or urban development. Wells were completed or monitored during 2015-16 in the following areas:

Jackson Purchase Region. Four observation wells were installed in October 2015. Two of the wells are installed on the Murray State University Hutson School of Agriculture West Farm and two on private property in Clinton, Hickman County. The Murray State wells are completed in the Lower Wilcox and McNairy aquifers. The Hickman County wells are completed in the Upper Claiborne and Middle Claiborne aquifers. Each well was instrumented with a pressure transducer in November 2015 and continuous groundwater-elevation data are currently being collected.

Specific-capacity tests were performed on three irrigation wells in the Clarks River National Wildlife Refuge in November 2015. Groundwater-quality samples were collected for each well in conjunction with the specific-capacity tests.

Western Kentucky Coal Field. An observation well at the Kentucky Geological Survey's Western Kentucky Office in Henderson was completed in alluvium and instrumented with a pressure transducer in October 2010. Groundwater-elevation data were collected at this site through fiscal year 2015-16.

Inner Bluegrass Region. One well is being monitored at the Kentucky Horse Park near Georgetown.

Western Pennyroyal Region. A project with the city of Elizabethtown that includes an aquifer test has been under way this fiscal year. Four local wells were used for observation during the aquifer test, and a report on the test and monitoring of one of the city's water-supply wells was submitted to city officials.

University of Kentucky Education and Research Center in Princeton. Aquifer tests were performed on two irrigation wells completed in limestone bedrock in July 2015. Groundwater-quality samples were collected from each well. An unused irrigation well was instrumented with a pressure transducer in April 2016 to collect continuous groundwater-level data. Data from the aquifer tests, groundwater-level monitoring, and additional karst hydrogeologic work expected to be conducted in late 2016 will aid the Center in locating a site on which to install a high-yield well, which will supply water to a pivot irrigation system.

Hydrostratigraphy of the Claiborne Aquifer System. Nine water wells in the Jackson Purchase Region were gamma-ray logged. Logs from these and other wells were used by a UK Department of Earth and Environmental Sciences graduate student to create cross sections of the Claiborne aquifer system in Fulton and Hickman Counties. The student also created structure and isopach maps of hydrostratigraphic units within the Claiborne aquifer system.

Rock and Water Analytical Laboratory. The KGS laboratory analyzes water, coal, and rock samples for KGS and other University of Kentucky researchers. In addition, laboratory manager Jason Backus and analyst Andrea Conner collaborated with and trained students from numerous UK departments in analyses, techniques, and instrumentation that the lab use daily.

During the year, the KGS laboratory worked with the KGS Water Resources Section, the KGS Energy and Minerals Section, and the UK re-

search community. One monitoring project at the Wendell H. Ford Training Site for the Kentucky National Guard looked at water-quality parameters twice a year for 91 sites. Monitoring for the Cane Run project continues twice a week, as well as assessing water quality for an ongoing statewide KGS project. The laboratory also analyzed groundwater samples from eastern Kentucky for the KGS–GSI Environmental project assessing water quality in the Berea play.

Total organic carbon determination and shale/coal analysis was performed for the KGS Energy and Minerals Section on a routine basis for projects on the Berea play and rare earth elements. Total carbon and inorganic carbon were tested in order to determine a total organic carbon value for approximately 200 samples. A UK Department of Earth and Environmental Sciences student was taught how to perform inorganic carbon analysis with the coulometer and total carbon analysis with the combustion analyzer. Total sulfur and proximate and X-ray fluorescence elemental analysis was also performed on the samples.

A large project was conducted with the UK Mining Engineering Department to determine concentrations of rare earth elements in coal ash and byproducts. Approximately 750 samples were processed, digested, and analyzed in the KGS laboratory.

Samples from Dr. Ming Gong of the UK Chandler Medical Center continue to be analyzed for sodium and potassium, using inductively coupled argon plasma–optical emission spectroscopy. The goal is to investigate the uptake and transport of these elements in certain organs in mice.

Work with the Kentucky Watershed Watch program continues. Samples from the Kentucky River watershed during low flow were analyzed for nutrients and total metals concentrations.

The lab participated in the STEM (science, technology, engineering, and mathematics) project led by Dr. Alan Fryar of the UK Department of Earth and Environmental Sciences. Samples from several sites were submitted every other week for analysis over the spring and fall semesters. This project brought high school and middle school science teachers into the University research community for hands-on experience.

Tours of the lab were given to six different groups, including professional groups, high school students, and undergraduate and graduate geology students from UK and Morehead State University.

Teaching is becoming an increasingly larger responsibility for the lab. Twenty-two UK students were taught analysis techniques and given assistance in their research. Four students from the UK Department of Earth and Environmental Sciences were taught total organic carbon/shale analysis. Twelve students from across the University, including the departments of Mining Engineering, Chemistry, Plant and Soil Science, Materials Science, and Chemical Engineering, were taught X-ray diffraction principles and techniques. Five UK Department of Earth and Environmental Sciences graduate students were taught X-ray fluorescence principles and techniques and used X-ray fluorescence for their research.

Groundwater Data Repository. The Kentucky Groundwater Data Repository contains data for more than 102,000 wells, including domestic, public, industrial, monitoring, and agricultural wells. In addition, data from more than 5,200 springs and 45,000 sample suites (representing millions of individual analytical results) are available. The data in the Repository were compiled from more than 15 agencies, but the largest contributor continues to be the Kentucky Division of Water. Well and sample data collected through the Division of Water's Certified Well Driller Program and the Kentucky Interagency Groundwater Monitoring Network are uploaded to the Repository approximately once every quarter, providing users with 24/7 access to the most recent groundwater data available. Scanned water-well drillers' logs and associated documents are uploaded to the Repository approximately every 6 months.

Collaboration With Kentucky Division of Water Sampling. The Kentucky Division of Water is responsible for sampling about 60 sites (both wells and springs) across Kentucky that comprise the Kentucky Interagency Groundwater Monitoring Network (www.uky.edu/KGS/water/gnet). Most samples are collected quarterly or twice a year by Division of Water personnel on 12 different sampling runs across the state. In February

2016, KGS personnel began sampling three sites in the north-central run: McConnell Springs and Russell Cave Spring in Fayette County, and Royal Spring in Scott County. The Environmental Services Branch Laboratory in Frankfort continues to analyze these samples. KGS appreciates the collaborative spirit of the Division of Water in allowing our participation in this sampling.

Kentucky Division of Mine Reclamation and Enforcement

The Field Support Section of the Division of Mine Reclamation and Enforcement investigates groundwater 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 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 2015-16 fiscal year, the Division received 62 new requests for inspections. Fifty-two inspections were completed; of these, 10 found 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 water quality, five were the result of loss of 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.

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 2015-16 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 members or affiliated personnel are listed below.

Publications

Beck, E.G., Blue, L.Y.., and Atwood, D.A., 2015, Quality of water from tile drains in fields treated with poultry litter in McLean County, Kentucky: Kentucky Geological Survey, ser. 12, Information Circular 32, 25 p.

Cooper, M., Beck, E.G., and Woolery, E.W., 2016, Integrated geophysical methods for correlating the Upper Mississippi Embayment aquifer system hydrostratigraphy: Jackson Purchase, western Kentucky, U.S.A. [abs.]: Geological Society of America Abstracts with Programs, v. 48, no. 3, doi 10.1130/abs/2016SE-273579, gsa.confex.com/gsa/2016SE/webprogram/Paper273579.html [accessed 10/27/2016].

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Presentations

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Beck, E.G., 2016, Overview of hydrogeology, groundwater use, and monitoring in the Jackson Purchase: Four Rivers Basin team meeting, Benton, Ky., Feb. 4, 2016.

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Cherry, M.A., 2016, Investigation of fecal contamination in the Little River Basin, Kentucky, using microbial source tracking and fecal indicator bacteria, 2013-2014, Kentucky Water Science Center: Kentucky Water Resources Annual Symposium, Lexington, Ky., March 28, 2016.

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Resources Annual Symposium, Lexington, Ky., March 28, 2016.
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Website Information

Statewide groundwater data in the Kentucky Groundwater Data Repository can be accessed at kgs.uky.edu/kgsweb/DataSearching/watersearch.asp. The Repository database covers water wells, springs, and groundwater-quality

data. Several alternatives are available for viewing groundwater information on both interactive and static maps, and for creating graphic representations of groundwater-quality data.

The Kentucky Geological Survey 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.

The Kentucky Water-Well and Spring search engine was accessed by the public 7,046 times during fiscal year 2015-16, resulting in 459 downloads. This search engine remains the second most popular 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 5,317 times during the year, and the Karst Potential Map layout on the KGS Geologic Map Service was accessed 2,672 times.

The Kentucky Groundwater-Quality Data search engine was accessed by the public more than 900 times during fiscal year 2015-16, resulting in 86 downloads. 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 618 times, and the groundwater-quality data plotting service was accessed 95 times.

In addition to the Repository data, 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. 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 Agriculture 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 data set 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 jointly report on groundwater quality throughout the state. During 2015-16, 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, 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.

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.

Reducing forest cover increases water yield, whereas establishing forest cover decreases water yield. Water yield is the amount of surface water and groundwater leaving a watershed. On average, removing 10 percent of forest cover increases 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, revealed that water quality and quantity was the second most important concern about forests by the citizens of the commonwealth, highlighted in a statewide survey of the most important issues affecting the state's forest resources. The Division, along with stakeholder input, delineated seven major forest priority areas across the commonwealth in which to focus a collaborative strategy to maintain sustainable forests and as a basis for improving water quality and quantity (Fig. 10).

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 BMPs mandated by the Kentucky Agriculture Water Quality Plan.

For the 2015-16 fiscal year, 4,448 harvest inspections were performed, resulting in 326 enforcement actions.

The Division's Forestry Stewardship Program proactively mitigates 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, 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 educate community leaders about the many benefits of trees in the urban setting, one of which is phy-

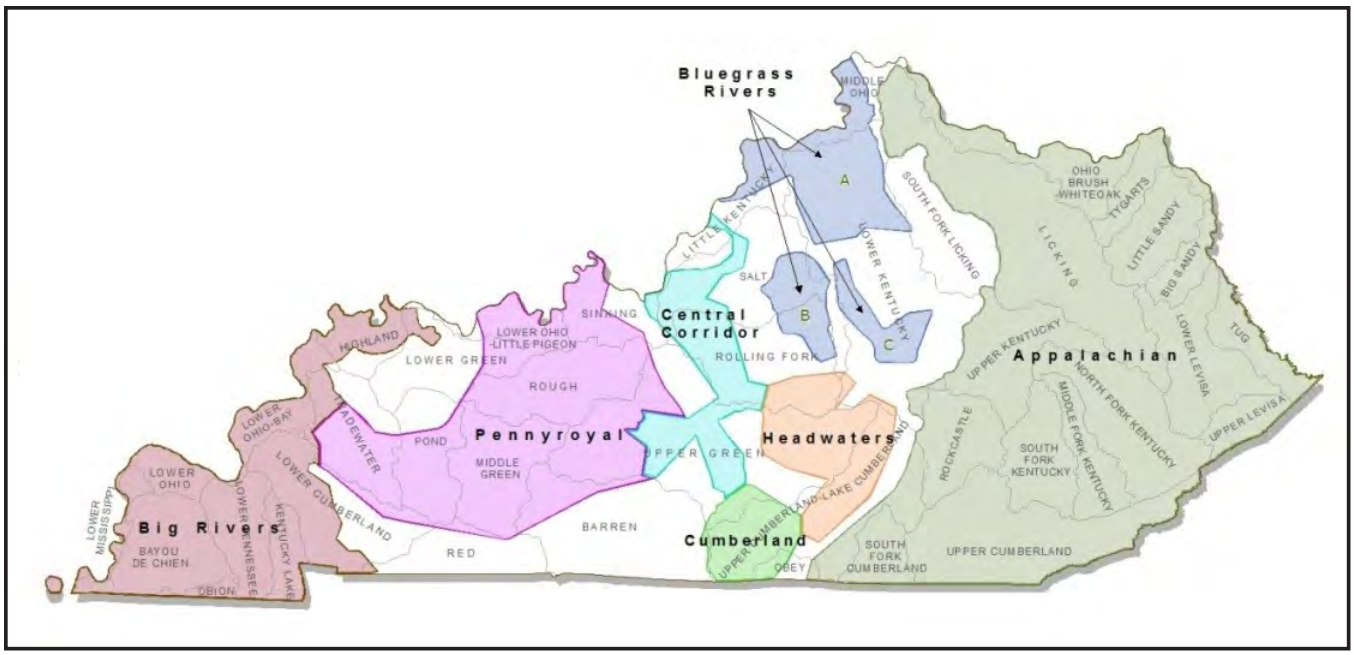

Figure 10. Kentucky forest priority areas and watersheds.

toremediation, or the use of trees to decontaminate soils or water. Urban forestry specialists and foresters at the Division in fiscal year 2015-16 were involved in Lexington's Reforest the Bluegrass, in which more than 400 citizen volunteers planted more than 3,000 tree seedlings at Hisle Park (Fig. 11). The Reforest Northern Kentucky event took place in Covington's Devou Park, and more than 331 volunteers planted more than 1,800 seedlings. Reforest Frankfort was another great success: 493 volunteers planted 2,000 seedlings at Kentucky State University. Kentucky Division of Forestry personnel assisted with planning these events, and served as crew leaders. The Kentucky Community Tree Recovery Campaign continued this year, thanks to the sponsorship of the Arbor Day Foundation, Fed Ex, NASCAR, and Erie Insurance Group. The campaign began in 2014 to assist replanting efforts in counties affected by the March 2012 tornadoes. The five counties that were sponsored this year were Bath, Rowan, Lawrence, Grant, and Montgomery. A total of 25,000 seedlings were given to local residents and planted at public tree-planting events in these counties.

Figure 11. Approximately 400 citizens plant more than 3,000 seedlings at Hisle Park in Fayette County at a Reforest the Bluegrass event in April 2016.

County judge/executives from 91 counties signed Arbor Day proclamations for their respective counties, designating a specific day to celebrate Arbor Day. The Division sold or gave away 121,281 tree seedlings for use in a variety of Arbor Day activities.