PROGRAMS AND ACTIVITIES OF THE KENTUCKY DISTRICT

WATER RESOURCES DIVISION, U.S. GEOLOGICAL SURVEY

Compiled by Lloyd H. Woosley, Jr. and Robert J. Faust

U.S. GEOLOGICAL SURVEY

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Louisville, Kentucky
1989

UNITED STATES DEPARTMENT OF THE INTERIOR

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GEOLOGICAL SURVEY

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INTRODUCTION

The U.S. Geological Survey (Survey), through its Water Resources Division, investigates the occurrence, quantity, quality, distribution, and movement of the surface and ground water that composes the Nation's water resources. The Survey is the principal Federal water-data agency and, as such, collects and disseminates about 70 percent of the water data currently being used by numerous State, local, private, and other Federal agencies to develop and manage our water resources. This nationwide program, which is carried out through the Water Resources Division's District offices and Regional offices, consists of the collection of basic hydrologic data, areal resource appraisal and interpretive studies, research projects, and the analysis and dissemination of the data and results of its investigations. Much of the work is a cooperative effort in which planning and financial support are shared by State and local governments. Other work is funded by Congressional appropriation to the Survey or is supported by other Federal agencies. The Survey also is responsible for the coordination of specific water-data acquisition activities by other Federal agencies.

This report contains a summary of the Kentucky District's water resources program, including a description of the Survey mission and program, District organization, funding sources and cooperating agencies, summary of hydrologic conditions (water year 1988), District activities, and a list of Survey publications and other publications relevant to the water resources of Kentucky.

Basic Mission and Program

U.S. Geological Survey Origin

The Survey was established by an act of Congress on March 3, 1879, to provide a permanent Federal agency to conduct the systematic and scientific "classification of the public lands, and examination of the geological structure, mineral resources, and products of national domain." An integral part of that original mission includes publishing and disseminating the earth-science information needed to understand, to plan the use of, and to manage the Nation's energy, land, mineral, and water resources.

Since 1879, the research and fact-finding role of the Survey has grown and been modified to meet the changing needs of the Nation it serves. As part of that evolution, the Survey has become the Federal Government's largest earth-science research agency, the Nation's largest civilian map-making agency, the primary source of data on the Nation's surface- and ground-water resources, and the largest employer of professional earth scientists. Today's programs serve a diversity of needs and users.

Along with its continuing commitment to meet the growing and changing earth-science needs of the Nation, the Survey remains dedicated to its original mission to collect, analyze, interpret, publish, and disseminate information about the natural resources of the Nation--providing "Earth science in the public service."

Mission and Program of the Water Resources Division

The mission of the Water Resources Division is to provide the hydrologic information and understanding needed for the optimum utilization, management, and protection of the Nation's water resources for the overall benefit of the people in the United States.

This is accomplished, in large part, through cooperation with other Federal, interstate, State, and local agencies, by:

* Collecting, on a systematic basis, data needed for the continuing determination and evaluation of the quantity, quality, and use of the Nation's water resources.

* Conducting analytical and interpretive water-resources appraisals describing the occurrence, availability, and the physical, chemical, and biological characteristics of surface and ground water and their interelation.

* Conducting supportive basic and problem-oriented research in hydraulics, hydrology, water chemistry and ecology, and related fields of science and engineering to improve the basis for field investigations and measurement techniques and to understand hydrologic systems sufficiently well to quantitatively predict their response to stress, either natural or manmade.

* Disseminating water data and the results of investigations and research through reports, maps, computerized information services, and other forms of public releases.

* Coordinating the activities of Federal agencies in the acquisition of certain water data.

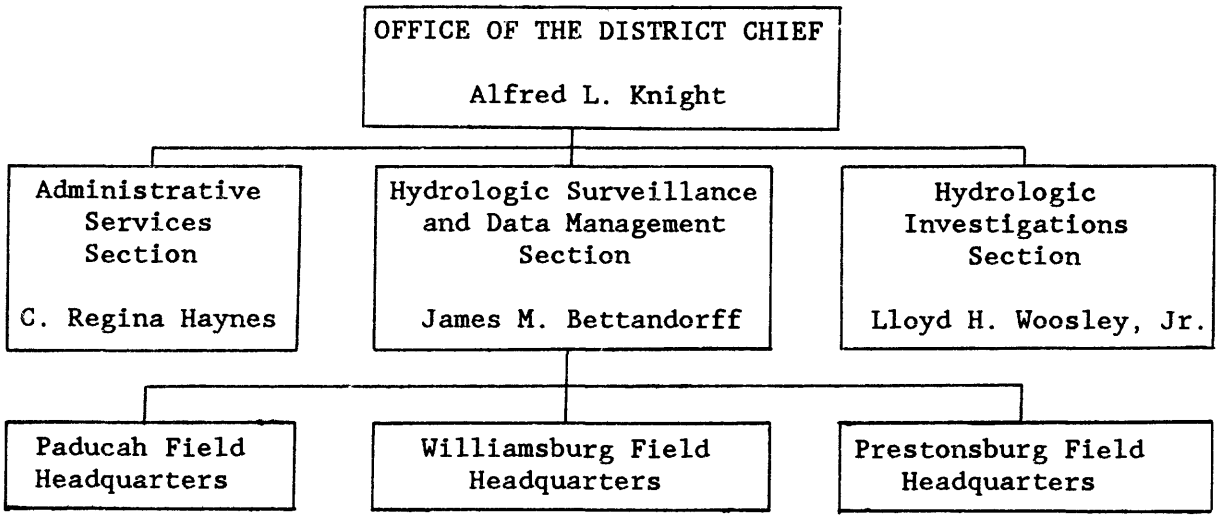
* Providing scientific and technical assistance in hydrologic fields to other Federal, state, and local agencies, to licensees of the Federal Energy Regulatory Commission, and to international agencies on behalf of the Department of State.

* Administering the provisions of the Water Resources Research Act of 1984 which include overseeing the State Water Resources Research Institutes and the Research Grants and Contracts Programs.

* Supports the provisions of the National Environmental Policy Act of 1969 and participates in the Geological Survey's conduct of natural resources surveys in response to the Comprehensive Environmental Response, Compensation, and Liability Act (Superfund Act) of 1980.

Kentucky District of the Water Resources Division

Organization



Kentucky District Addresses

Inquiries regarding activities described in this report may be directed to the District Office or Field Headquarters.

District Office	(502) 582-5241	U.S. Geological Survey 2301 Bradley Avenue Louisville, Kentucky 40217
Paducah Field Headquarters	(502) 443-1252	U.S. Geological Survey P.O. Box 770 Room 113, Post Office Building 5th and Broadway Paducah, Kentucky 42002
Williamsburg Field Headquarters	(606) 549-2406	U.S. Geological Survey P.O. Box 1028 Jackson Mall Office Building Office #2, Highway 25-W Williamsburg, Kentucky 40769
Prestonsburg Field Headquarters	(606) 886-9432	U.S. Geological Survey HCR 70, Box 540 Van Lear, Kentucky 41265

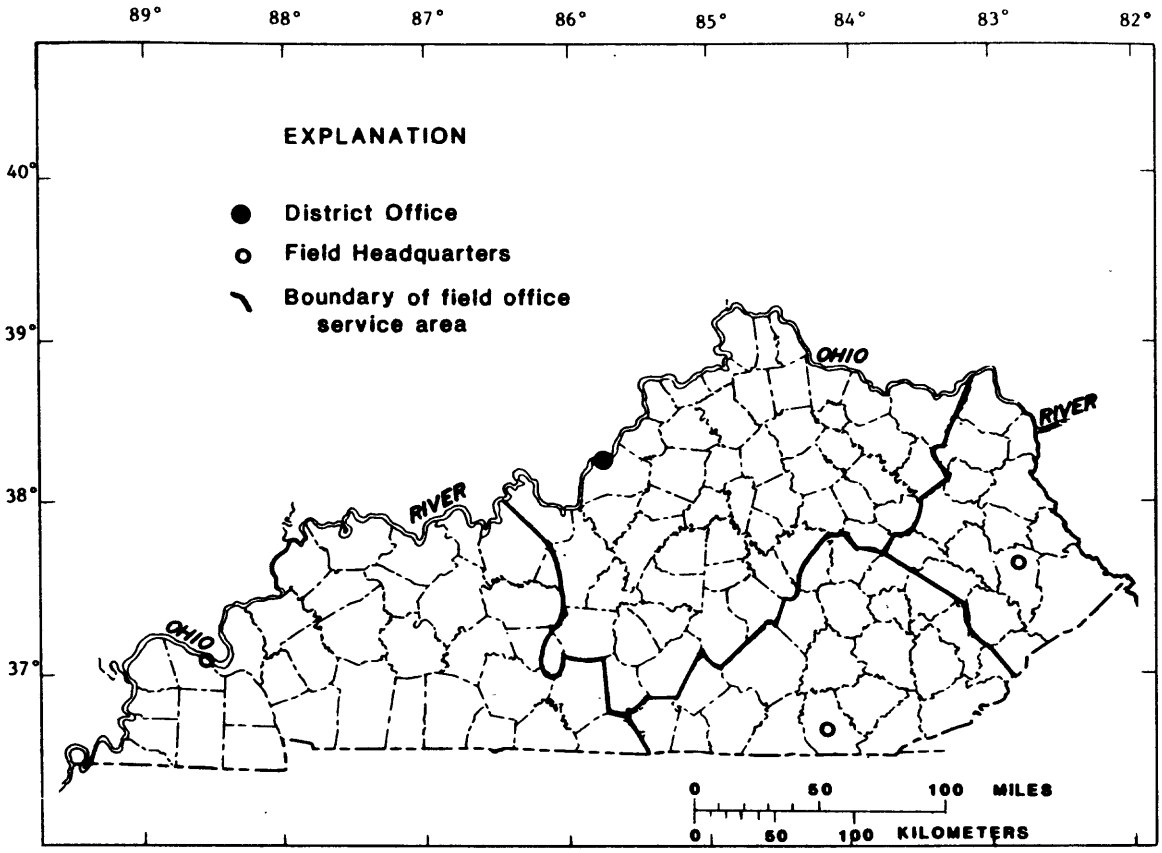
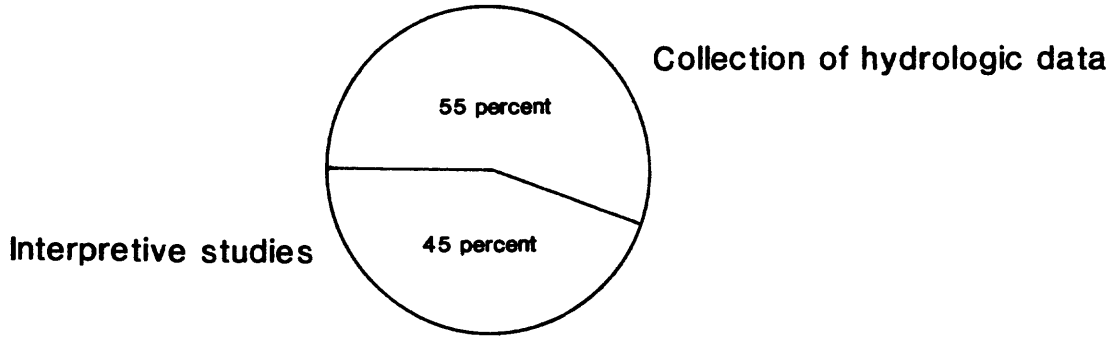


Figure 1.--Location of Survey offices in Kentucky.

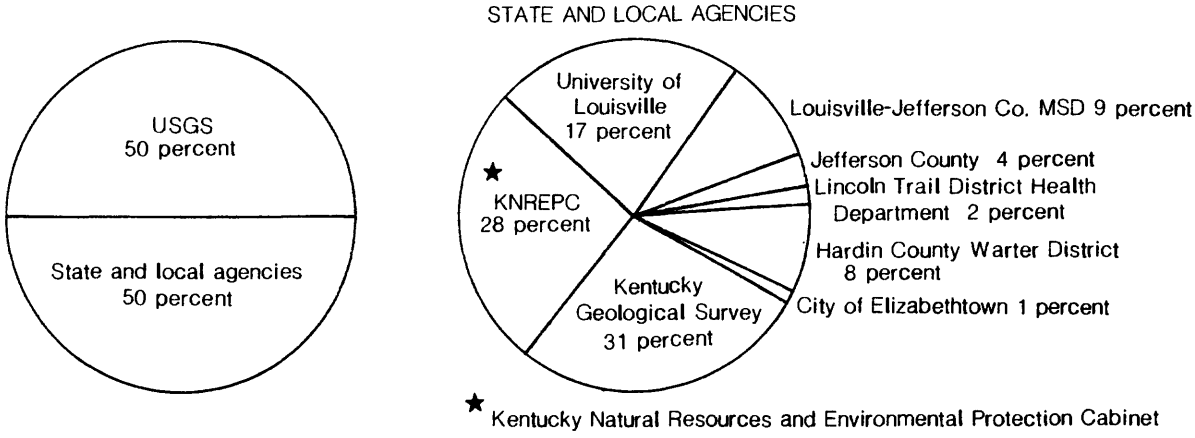
Types of Funding

The diagram below shows the percentage of the investigations for Federal fiscal year 1988 in the broad categories of collection of hydrologic data and interpretive studies:

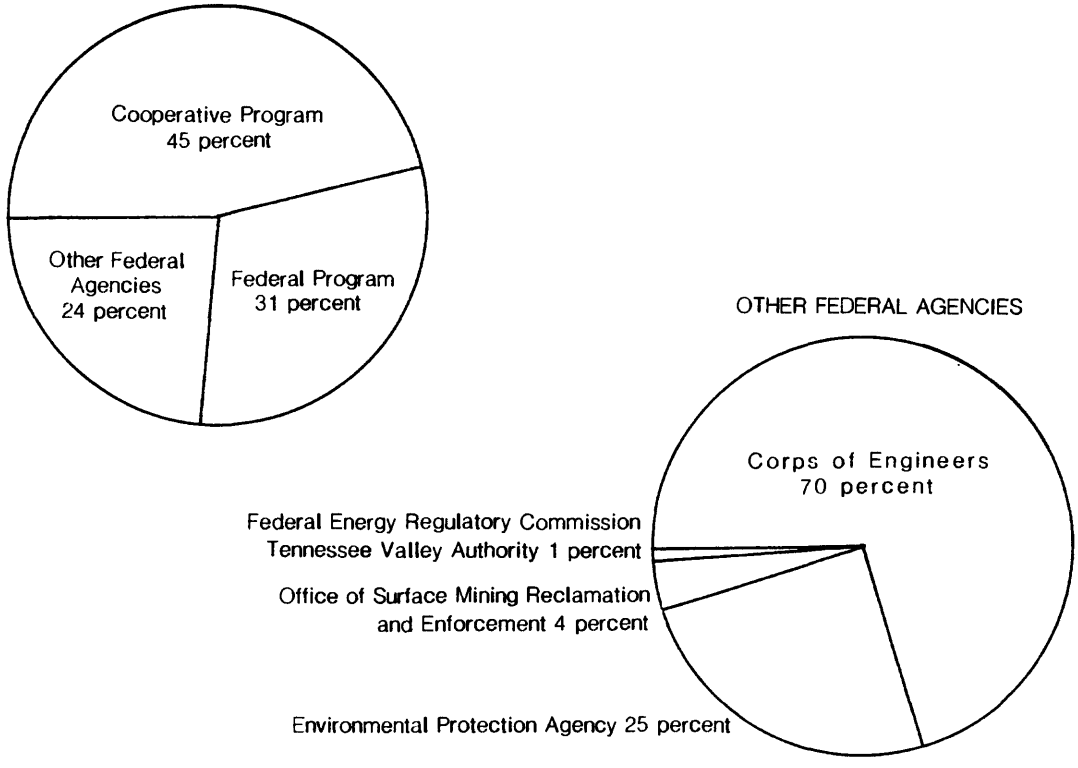


The investigations are directed toward obtaining the information needed by managers, planners, and regulators for the solution or alleviation of water-resources problems in Kentucky.

Investigations in the cooperative program are supported by funds and (or) services provided by State and local agencies, matched on a 50-50 basis by Federal funds (Federal-State Cooperative Program). In Federal fiscal year 1988 the financial support for these programs in Kentucky was about $1.3 million which was distributed as follows:



Other investigations and data collection activities are supported by funds transferred from other Federal agencies (OFA program), and funds appropriated directly to the Geological Survey (Federal program). In 1988 the entire program was $3.2 million and was distributed as follows:



Cooperating Agencies

Table 1.--Agencies supporting water-resources investigations by the Survey during Federal fiscal year 1988

State Agencies

Kentucky Geological Survey (KGS)
Kentucky Natural Resources and Environmental Protection Cabinet (KNREPC)
  Division of Water
  Division of Waste Management

Local Agencies

City of Elizabethtown
Hardin County Water District Number 1
Jefferson County Department of Public Works and Transportation
Kentucky Utilities Company
Lincoln Trail District Health Department
Louisville-Jefferson County Metropolitan Sewer District
Public Service Company of Indiana
University of Louisville

Federal Agencies

Department of the Army
  U.S. Corps of Engineers
    Huntington District
    Louisville District
    Nashville District
Department of the Interior
  Office of Surface Mining Reclamation and Enforcement (OSMRE)
Environmental Protection Agency (EPA)
Tennessee Valley Authority (TVA)

SUMMARY OF HYDROLOGIC CONDITIONS, 1988 WATER YEAR

Surface Water

Comparison of monthly mean and yearly mean streamflow for the 1988 water year and period of record are shown in figure 2 for three representative gaging stations. Mean annual streamflow in 1988 was below the long-term average throughout Kentucky. At gaging stations on unregulated streams, 1988 flow ranged from 30 percent of the long-term average for Cutshin Creek near Wooton (03280700) in eastern Kentucky, to a high of 100 percent of the long-term average at South Fork Kentucky River at Booneville (03320500) in eastern Kentucky.

Annual extreme flows during the 1988 water year were within historical extremes throughout the State and there were no significant floods. The annual maximum discharge at most stations was less than the 2-year recurrence interval, and all were less than the 10-year recurrence interval. Base flow varied throughout the State with several stations having minimum daily flow greater than the 20-year recurrence interval. However, almost all streamflow stations in Kentucky had minimum daily flow greater than that expected at the 10-year recurrence interval. The instantaneous maximum and daily minimum flows at selected long-term non-regulated stations and the recurrence interval for each are given in table 2.

Quality of Water

The Wilcoxon-Mann-Whitney rank sum test was performed on data from NASQAN sites Big Sandy River at Louisa (0321500), Salt River at Sheperdsville (03298500), Green River at Munfordville (03308500), and Ohio River at Dam 53 near Grand Chain (03612500). It was run on the randomly selected sites to verify if the means for three periods of record were equal. The test was calculated on sulfate dissolved, total phosphorus, nitrite plus nitrate, and residue of dissolved solids at 180 degrees Celsius. The periods of record were water years 1978 to 1982 (PR1), 1983 to 1987 (PR2), and 1988 (PR3). The summary of the significant results from the two-tailed test are shown in table 3. Very low values of probability (prob>T) indicate that the occurrence of equal means is unlikely and thus the means are considered to be significantly different. A significant difference between the means for sulfate dissolved was determined for the Big Sandy River at Louisa (03215000) for both PR1:PR2 and PR2:PR3. The means for sulfate dissolved were also significantly different at Ohio River at Dam 53 at Grand Chain (03612500) for PR2:PR3. Total phosphorus means were significantly different at both sites for PR1:PR2. The summary of values in table 4 shows that, for the periods with significant difference, values for sulfate dissolved increased and those for total phosphorus declined.

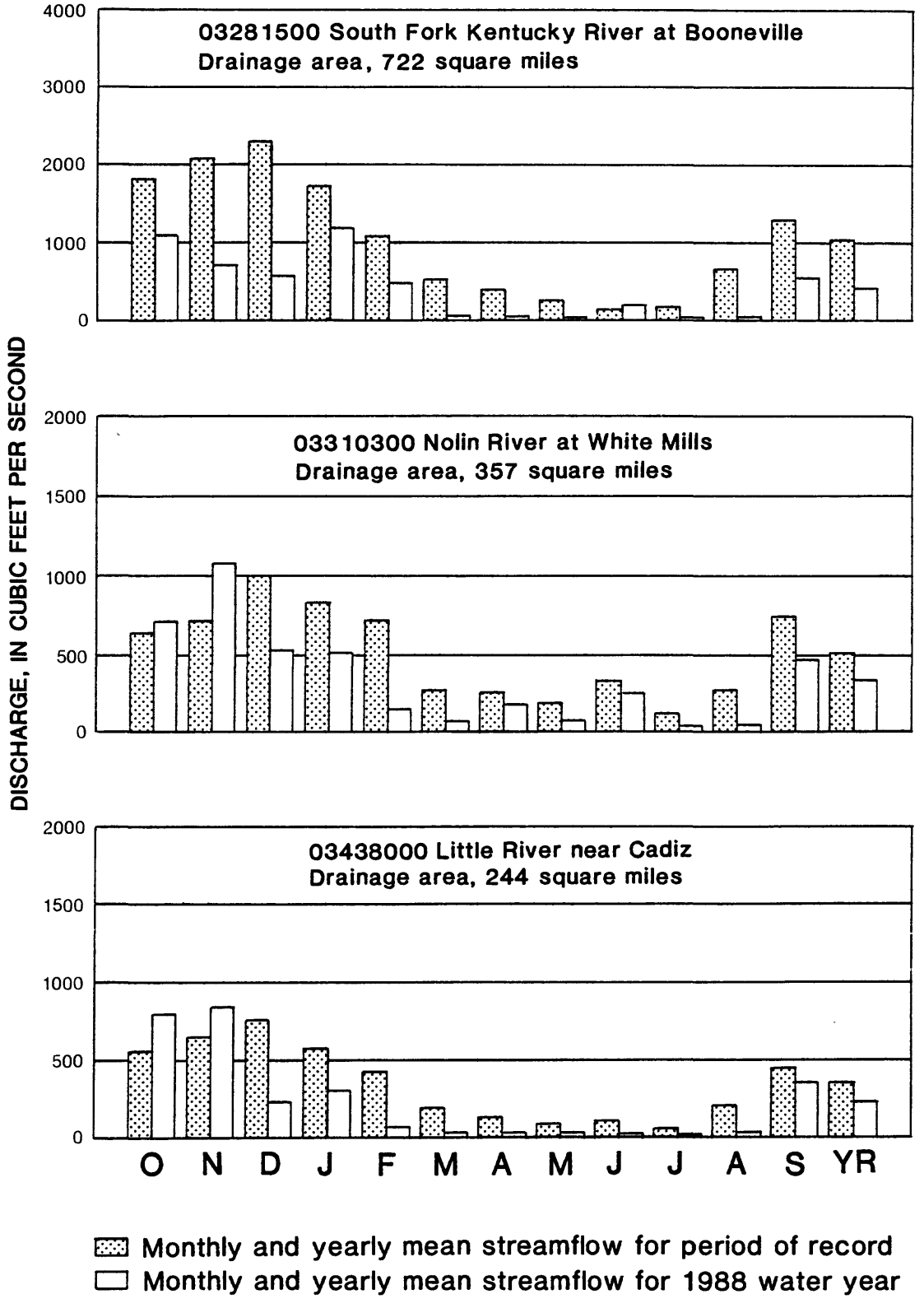


Figure 2.—Streamflow during 1988 water year compared with period of record for three representative gaging stations.

Table 2.--Mean, maximum, and minimum streamflow for water year 1988 and recurrence intervals at selected stations

Station number	Length of record (years)	Mean: Daily Streamflow in cubic feet per second	Mean: Percent of average	Maximum: Peak Streamflow in cubic feet per second	Maximum: Recurrence interval (years)	Minimum: Daily Streamflow in cubic feet per second	Minimum: Recurrence interval (years)
				BIG SANDY RIVER BASIN			
03210000	47	28.9	42	596	<2	1.2	<2
				LITTLE SANDY RIVER BASIN			
03216540	16	7.86	54	1,240	--	0	<10
				TYGARTS CREEK BASIN			
03216800	31	43.6	52	3,310	<2	0	<10
				CABIN CREEK BASIN			
03237900	16	19.5	67	4,440	--	0	<2
				LICKING RIVER BASIN			
03248500	50	68.3	40	1,370	<2	1.0	<10
03250100	21	74.5	60	-----	--	0	20
03251000	42	81.6	56	6,600	<5	0	2
03252000	35	181	65	6,160	<2	1.2	<2
03252500	50	432	58	1,280	<2	0	>20
				KENTUCKY RIVER BASIN			
03280600	31	117	41	4,870	<2	0	>20
03280700	31	27.4	30	1,760	<2	0	<10
03281040	16	91.4	35	5,990	--	.15	>20
03281100	24	246	108	4,770	<2	.34	<20
03281500	55	413	100	11,000	<2	4.3	<10
03282500	34	39.8	46	1,280	<2	0	<10
03283500	51	293	62	7,020	<2	7.3	<10
03285000	46	415	218	11,400	<2	0	<10
03289000	38	22.8	72	1,300	<5	.3	<10
				HARRODS CREEK BASIN			
03292460	20	20.7	57	3,900	--	0	<10
				BEARGRASS CREEK BASIN			
03293000	44	16.1	64	1,290	<2	.30	<10
				SALT RIVER BASIN			
03297845	9	39.4	80	-----	--	0	--
03298000	44	117	68	10,700	<5	0	--
03299000	50	218	65	15,500	<5	0	<10
03300400	16	390	65	17,000	--	0	>20
03301500	50	1,054	60	21,100	<2	6.3	<10
03302000	44	64.6	73	4,140	<10	2.8	2
				GREEN RIVER BASIN			
03307000	49	146	51	8,630	<5	1.0	<20
03310300	29	341	71	5,680	<2	36	<10
03310400	29	40.0	70	1,230	<2	3.7	>20
03311600	16	11.8	66	1,530	--	.09	>20
03318800	32	150	81	7,320	<10	0	<2
03320500	48	272	100	13,900	<10	0	<2
				CUMBERLAND RIVER BASIN			
03400500	48	69.7	50	1,430	<2	5.7	<10
03403910	20	233	43	8,820	<2	3.3	>20
03404900	15	37.8	46	1,220	<2	.03	>20
03406500	52	355	39	13,800	<2	4.3	<10
03407500	36	96.4	36	4,880	<2	0	<10
03410500	46	811	47	40,200	<2	18	10
03435140	15	21.0	63	4,670	--	0	<2
03438000	48	232	67	6,530	<2	9.8	<10
				MASSAC CREEK BASIN			
03611260	17	16.4	87	2,760	--	.14	<10
				BAYOU DE CHIEN BASIN			
07024000	43	65.8	63	1,830	<2	11	<2

Table 3.-- Summary of results from the Wilcoxon-Mann-Whitney two-tailed (alpha level of 0.05/2) rank sum test for sulfate and phosphorus contaminations at selected sites

PR Period of record
N Number of samples
X Mean of the ranks
s Standard deviation of the ranks
T Test result
Prob>T Probability of a difference of means
t Student's t-distribution value at test alpha level with pooled N-2 degrees of freedom

Station number	PR	N	X	s	T	Prob>T	t
			SULFATE DISSOLVED				
03215000	1:2	53	38.46	23.63	2.6478	0.0097	1.9883
		34	52.63	25.45			
	2:3	34	18.75	11.01	2.3925	.0218	2.0244
		6	30.42	11.02			
03612500	2:3	30	17.12	10.54	4.0345	.0002	2.0227
		11	31.59	9.04			
			TOTAL PHOSPHORUS				
03215000	1:2	55	48.03	23.44	2.6530	0.0096	1.9890
		30	38.78	24.06			
03612500	1:2	52	45.75	22.44	2.1806	.0321	1.9901
		30	34.13	24.57			

Table 4.--Summary of statistics for selected water-quality constituents in Big Sandy River and Ohio River sites

PR = Period of record: 1 = Water Years 1978-82; 2 = Water years 1983-87, 3 = Water year 1988

Water-quality constituent	Sample size	Descriptive statistics: Maximum	Minimum	Mean	Percent of samples in which values were less than or equal to those shown: 75	Median 50	25	PR
	03215000	BIG SANDY R AT LOUISA, KY						
Sulfate dissolved (mg/L AS SO_4)	53	180.000	46.000	95.453	110.000	93.000	77.000	1
	34	190.000	67.000	115.676	140.000	110.000	85.000	2
	6	200.000	96.000	159.333	190.000	175.000	120.000	3
NO_2 + NO_3dissolved (mg/L AS N)	29	1.300	.010	.451	.490	.410	.310	1
	28	.800	.185	*.456	*.565	*.480	*.300	2
	6	.660	.200	.367	.420	.355	.210	3
Phosphorous total (mg/L AS P)	55	.360	.020	.080	.090	.050	.030	1
	30	.190	.007	*.048	*.050	*.040	*.020	2
	6	.190	.020	.062	.060	.040	.020	3
Residue of dissolved solids at 180° Celsius (mg/L)	54	411.000	112.000	245.278	308.000	228.000	182.000	1
	35	445.000	131.000	286.400	354.000	282.000	209.500	2
	6	482.000	227.000	373.333	437.000	409.500	275.000	3
	03612500	OHIO RIVER AT DAM 53 NEAR GRAND CHAIN,IL						
Sulfate dissolved (mg/L AS SO_4)	40	75.000	26.000	44.475	52.000	43.500	37.000	1
	30	62.000	29.000	46.233	53.000	48.000	40.000	2
	12	88.000	41.000	59.750	62.500	56.000	54.500	3
NO_2 + NO_3 dissolved (mg/L AS N)	31	2.800	.320	1.045	1.350	.900	.675	1
	29	2.500	.210	1.152	1.500	1.100	.770	2
	6	1.900	.320	.937	1.400	.835	.330	3
Phosphorous total (mg/L AS P)	52	.470	.060	.153	.190	.135	.090	1
	30	.370	.020	.115	.150	.110	.060	2
	10	.470	.030	.131	.120	.060	.050	3
Residue of dissolved solids at 180° Celsius (mg/L)	39	265.000	128.000	184.923	207.000	184.000	150.500	1
	30	223.000	124.000	180.000	197.000	184.000	159.000	2
	6	243.000	175.000	196.500	196.000	190.000	185.000	3

* Value is estimated by using a log-probability regression to predict the values of data below the detection limit

As part of the National Water-Quality Assessment Program (NAWQA) in the Kentucky River basin pilot study, a synoptic survey was done in August of 1987 and repeated in 1988 to specifically describe water-quality conditions during sustained low-flow hydrologic condition. Dissolved oxygen, nutrients, chloride, and E. coli bacteria (1988) represent some of the constituents targeted for basinwide measurement. The concentration of dissolved oxygen in a stream is an important indicator of existing water quality and the ability of the stream to assimilate wastes and support a well balanced biological community. Critical dissolved oxygen conditions typically occur in the early morning hours (after oxygen is depleted by respiring aquatic plants), when water temperature is high (low DO saturation and high biochemical oxygen demand rates), and streamflow is low (less dilution of wastes). Nutrients, chloride, and bacteria are indicators of municipal wastewater inputs, particularly during low-flow conditions when point-source pollution is dominant. Nutrients can exert an oxygen demand directly, or indirectly by stimulating biological (phytoplankton) growth. Chloride concentrations are also associated with brines originating from oil and gas production areas.

During the 1987 low flow synoptic, 9 of the 74 sites sampled (12 percent) in the Kentucky River basin exhibited dissolved oxygen concentrations below 4 mg/L (the State ambient water-quality criterion). The minimum dissolved oxygen concentration (1.1 mg/L) was measured on Redlick Creek near Station Camp. A maximum dissolved oxygen concentration of 12.6 mg/L (159 percent of saturation) was measured on the Kentucky River at Brooklyn Bridge near Highbridge.

In 1988, the low flow synoptic of the Kentucky River basin revealed that 4 of the 74 sites (5 percent) exhibited DO concentrations below the 4 mg/L ambient criterion. Minimum DO concentration was observed to be 3.2 mg/L in the Dix River near Stanford. Several sampling sites on the Kentucky River mainstem exhibited DO concentrations in excess of saturation. The Kentucky River at Lock 7 had a concentration of 15.4 mg/L (208 percent of saturation). E. coli bacteria concentrations exceeded the proposed criterion of 126 colonies per 100 mL at 34 of 71 sites (48 percent). A maximum E. coli concentration of 26,429 colonies per 100 ml was measured on Benson Creek near Frankfort.

Also, as part of the Kentucky River basin NAWQA, a small reconnaissance study was begun to identify the types of synthetic organic chemicals in the surface waters of the Kentucky River basin. Whole water samples were collected during runoff events at 6 stream sites chosen to maximize the probability of detecting synthetic organic compounds (locations downstream of urban, agricultural, and petroleum production land uses). A variety of pesticides including atrazine; simazine; prometone; 2,4-D; diazinon; and dicamba were detected at low concentrations. Atrazine was detected at 5 of the 6 sites. A single sample from Elkhorn Creek near Frankfort exhibited a phenol concentration of 18 μg/L.

Water-quality conditions in the lower Cumberland, lower Tennessee, and lower Ohio Rivers near Paducah were assessed in late summer during worst-case conditions for dissolved oxygen and stream waste-assimilative capacity. The minimum dissolved oxygen concentration measured was 3.9 mg/L (53 percent of saturation and less than the Kentucky ambient water-quality criterion) and it occurred on the Tennessee River near Paducah. The minimum DO concentration measured on the lower Ohio River was 4.6 mg/L (61 percent of saturation).

Precipitation quality in the lower Ohio River valley was assessed at two locations downstream of Paducah. A median wetfall pH of 4.5 was determined from 33 weekly composite samples at Lock and Dam 53 on the Ohio River. The minimum pH recorded during the study was 3.36 at Lock and Dam 53. Median sulfate concentrations were 2.2 mg/L at each location. Dryfall constituents collected and composited over an 8-week period were dissolved in 100 mL of distilled water for analysis. Dryfall contained significant quantities of several constituents, including sulfate, potassium, chloride, calcium, ammonia, and nitrate. Fog samples, representing weekly composites, showed a median pH of 5.18 at Lock and Dam 53.

Results of the Louisville and Jefferson County Metropolitan Sewer District sampling network were compared to the Kentucky Water Quality Standards 401 KAR 5:031, Section 4, and several violations were noted. The dissolved oxygen standard was violated at over two-thirds of the sites at least once. Primary and secondary contact limits for fecal coliform were exceeded at most sites on several occasions, but these determinations were based on two samples per month and not the recommended five samples per month. At 23 of the 24 sites, zinc exceeded its standard and mercury also exceeded its standard at several sites. No other trace metals which were checked were in excess of their criteria.

Ground-Water Levels

The majority of observation wells in Kentucky are in the sand and gravel alluvial aquifer underlying Louisville and western Jefferson County. The fluctuation of ground-water levels in this aquifer is characterized by representative hydrographs of two observations well (figures 3 and 4).

Ground-water levels declined 4 to 5 feet in the downtown area of Louisville during 1985-88 after being stable during 1980-84. The decline resulted from increased pumpage and a deficit in precipitation of about 28 inches during 1985-88. The hydrograph in figure 3 of well 381447085454001 is characteristic of water-level changes in the downtown area.

Ground-water levels also declined in the western part of Jefferson County during 1985-88. The declines were 1 to 3 feet in wells near the Ohio River and 3 to 6 feet in wells away from the influence of the river. The hydrograph of well 381034085502601 in figure 4 is characteristic of water-level changes in western Jefferson County.

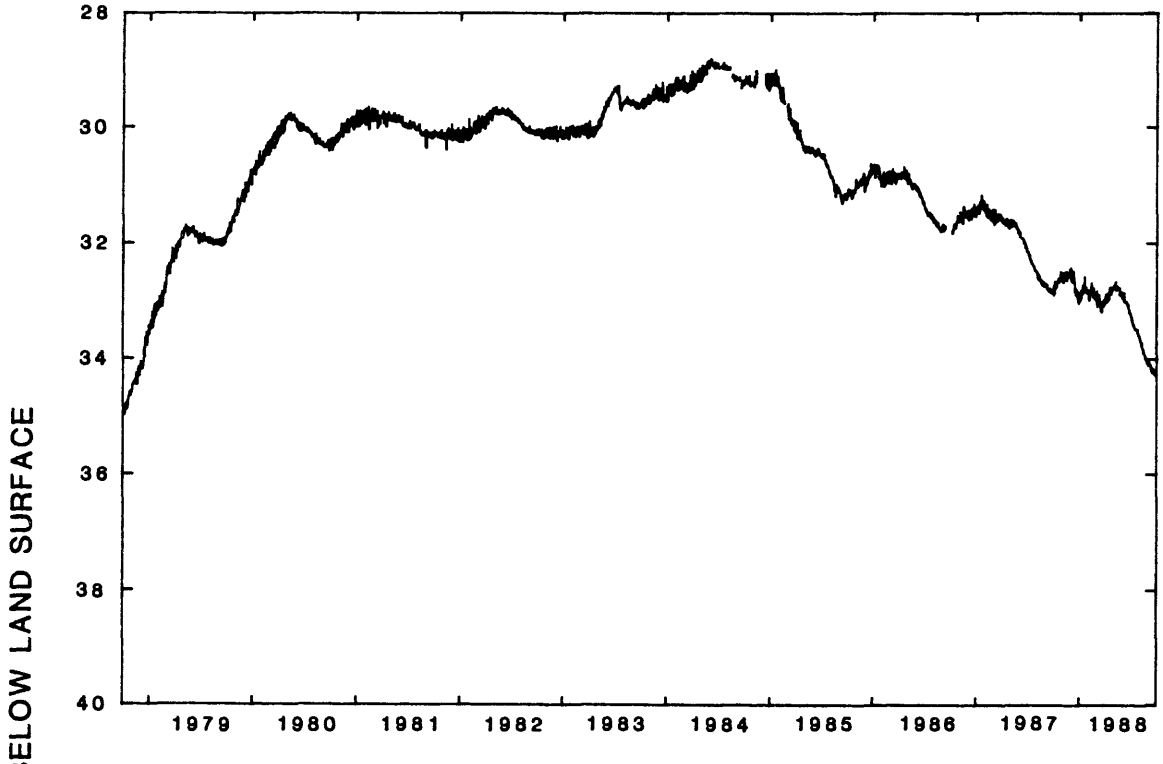


Figure 3.--Water level in observation well 81.

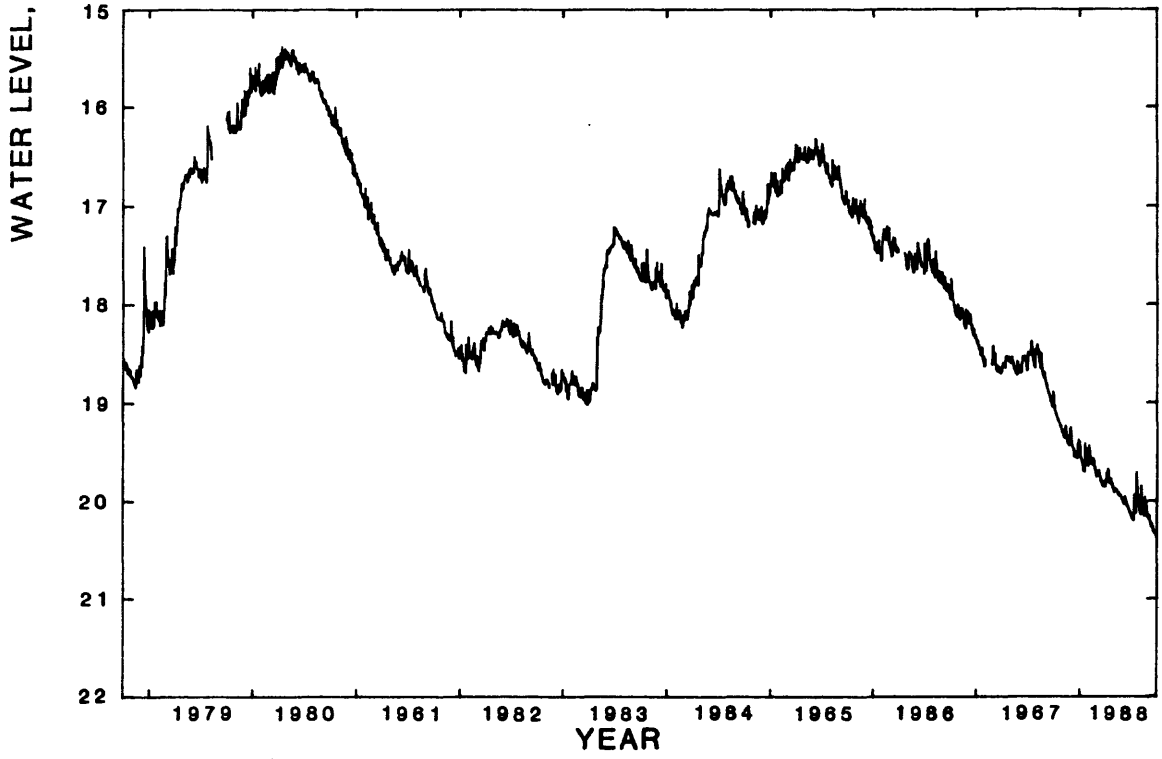


Figure 4.--Water level in observation well 28.

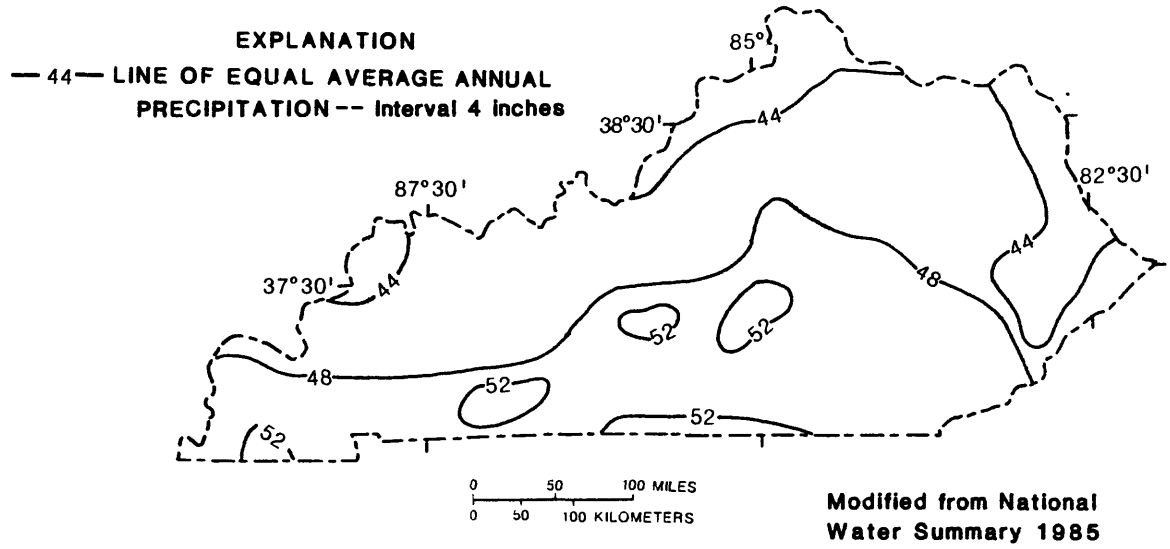


Figure 5.--Mean annual precipitation.

Kentucky has an abundance of water because precipitation averages about 40 inches in the northernmost part of the State and about 52 inches in the southern part. However, because of seasonal and areal variations in precipitation and areal variations in geology and topography, some areas experience water shortages during the summer and during drought periods.

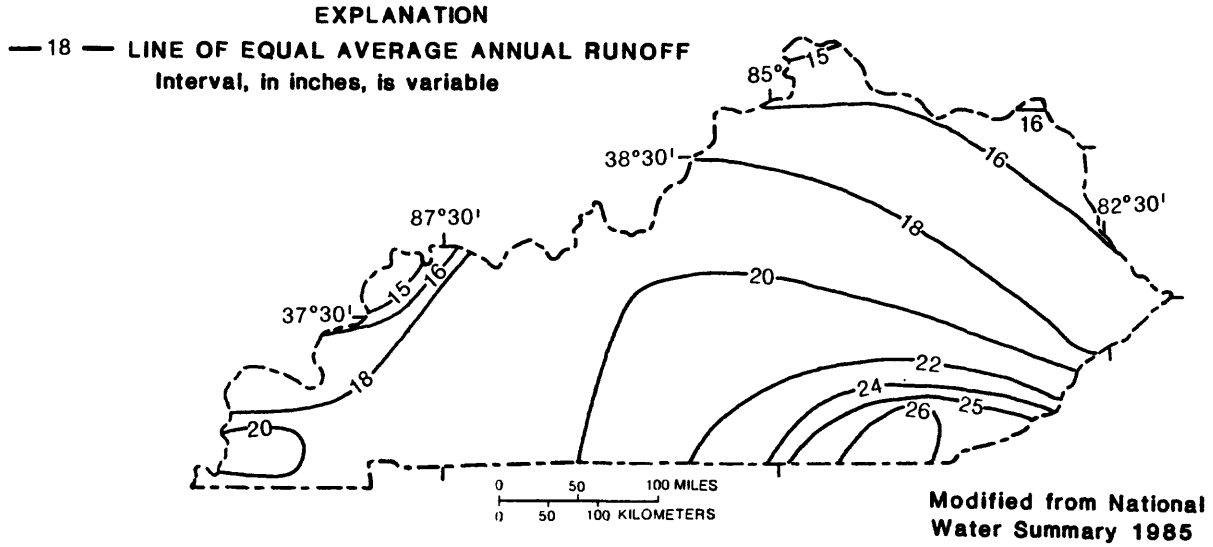


Figure 6.--Mean annual runoff, in inches.

Runoff in Kentucky ranges from less than 16 inches in the northern part to about 26 inches in the southeastern part. It averages about 18 inches for the State and is lowest during the summer and early fall and highest during the spring.

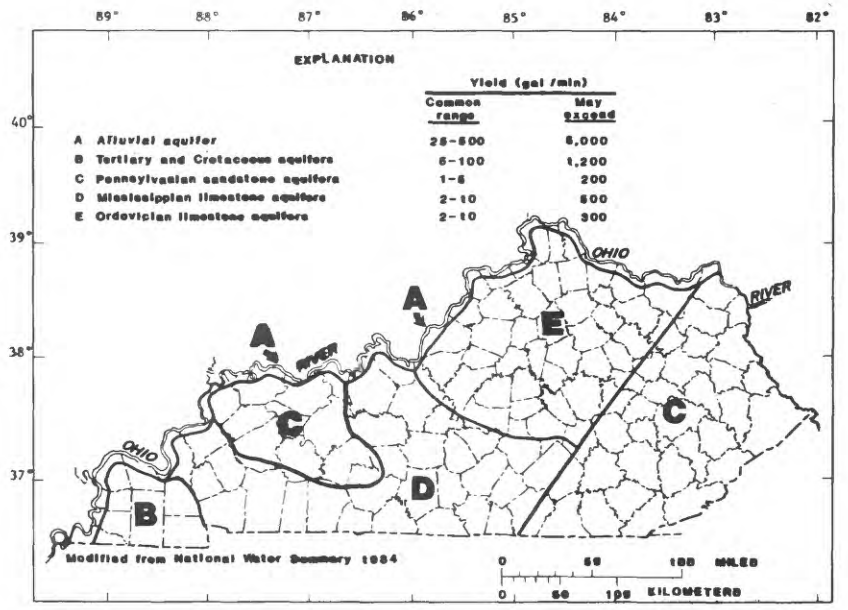


Figure 7.--Principal aquifers in Kentucky

The principal aquifers as modified from the National Water Summary 1984 (U.S. Geological Survey Water Supply Paper 2275) are shown in the above map. The table above the map gives the common and maximum yield of the aquifers.

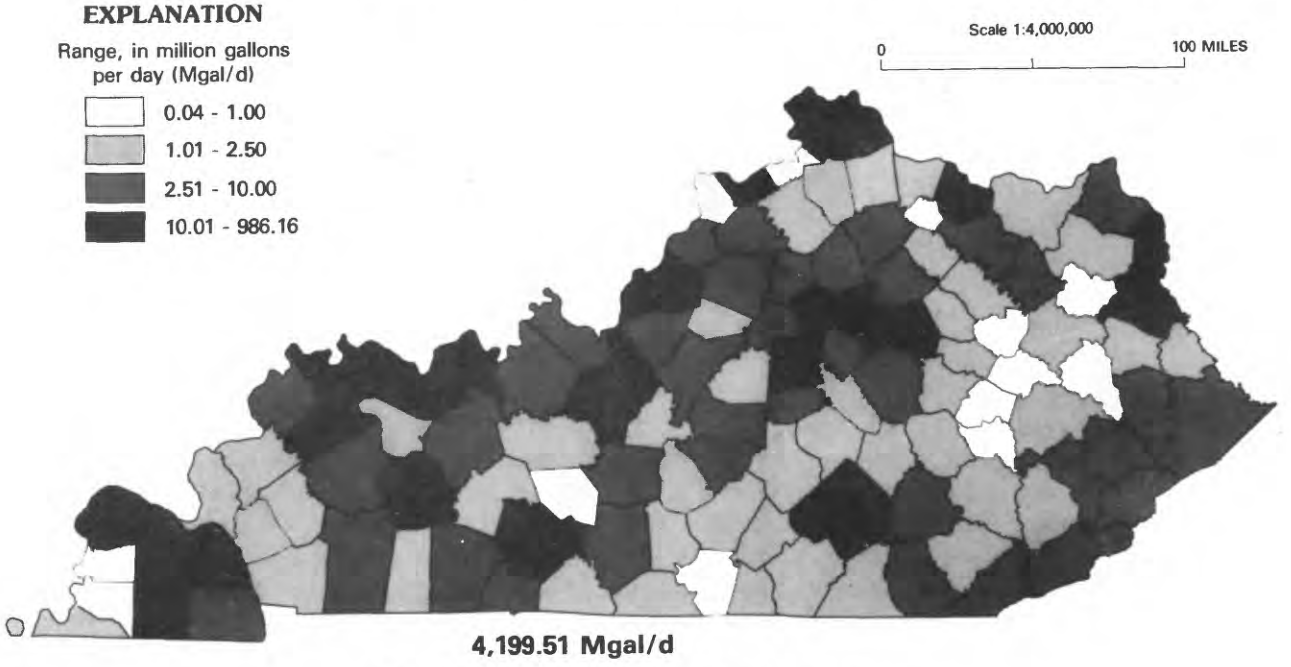


Figure 8.--Water use in Kentucky.

Water use in Kentucky is shown in the above map and taken from U.S. Geological Survey Water Resources Investigations Report 88-4043 by Clyde J. Sholar and V. David Lee. Most counties that use significant quantities of water are along the larger streams in the State or along the bordering rivers.

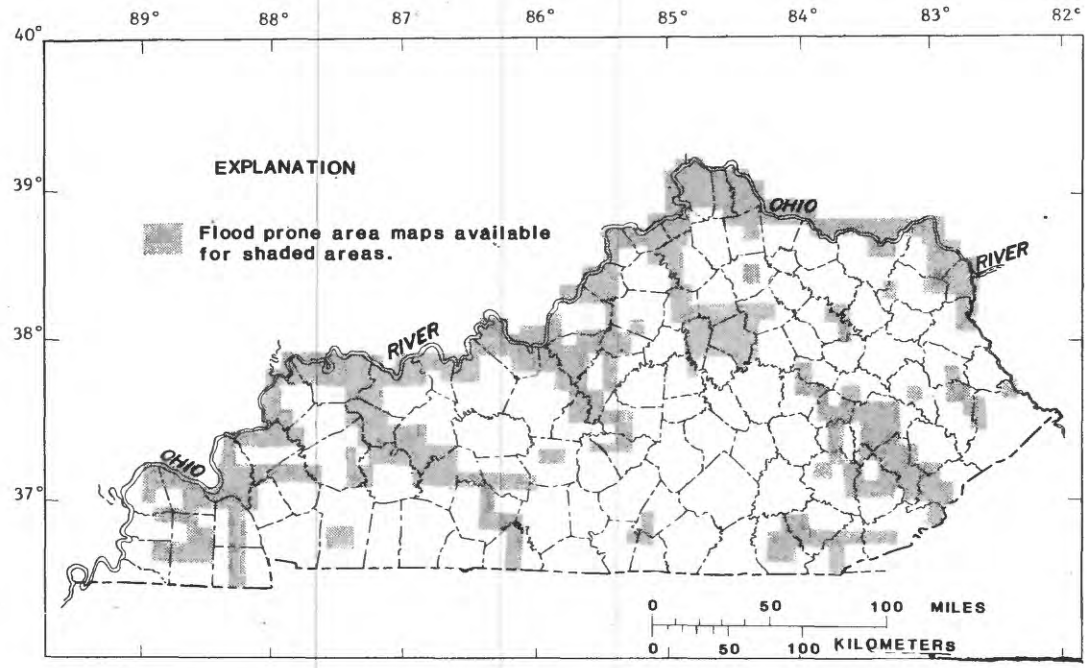


Figure 9.--Flood-prone area maps completed in Kentucky.

Flooding is a recurring problem along many streams in Kentucky. Major floods occur more frequently from November to May but flash floods can occur at any time. An index to flood-prone area maps is shown. More detailed maps, done for flood insurance studies, are available for some of the more heavily populated areas of the State.

KENTUCKY DISTRICT ACTIVITIES

The Water Resources Division, of the Survey conducts three major types of activities in Kentucky in order to provide hydrologic information and understanding needed for the best management and protection of Kentucky's and the Nation's water resources. These activities are listed below and described in the remainder of this section:

1. Data collection and dissemination
2. Water-resources appraisals (interpretive studies)
3. Applied and basic research

KY 00-001 SURFACE-WATER STATIONS

LOCATION: Statewide--See figure 10 for location of sites

PERIOD OF PROJECT: Continuous since 1938

PRINCIPAL INVESTIGATOR: James M. Bettandorff

FUNDING: Cooperative--KGS, KNREPC, and other Federal funds from the Corps of Engineers

PROBLEM: Surface-water information is needed for surveillance, planning, design, hazard warning, operation, management, and protection in water-related fields such as water supply, hydroelectric power, flood control, irrigation, bridge and culvert design, wildlife management, pollution abatement, flood-plain management, and water-resources development. To provide this information an appropriate data base is necessary.

OBJECTIVE: To collect surface-water data sufficient to satisfy needs for current-purpose uses, such as assessment of water resources, operation of reservoirs and other hydrologic control structures, forecasting, assimilation of waste, discharge data to accompany water-quality measurements, compact and legal requirements, and research or special studies. To collect data necessary for analytical studies to define for any location the statistical properties of, and trends in, the occurrence of water in streams, lakes, and reservoirs for use in planning and design.

APPROACH: Standard methods of data collection will be used as described in the series, "Techniques of Water Resources Investigations of the United States Geological Survey." Intermittent streamflow records will be collected instead of continuous records where they serve the required purpose.

PROGRESS: Daily discharges were computed for 110 streamflow sites in the State (fig. 10) and stored in a computer in the District Office. Sixty-one of these sites are equipped with satellite relay telemetry equipment which provide data on a real-time basis. In Water Year 1988, approximately 200 measurements were made at 90 low-flow sites to document the extreme drought conditions in early June 1988. Five continuous-record gaging stations were installed; one for the National Water Quality Assessment program, and four for the Louisville-Jefferson County Metropolitan Sewer Department project. Direct and indirect measurements are being made at five sites in the Upper Cumberland River basin for the Corps of Engineers to define streamflow ratings. Numerous streamflow data requests were answered during the year. Streamflow data, site descriptions, and map locations for streamflow stations are published in "Water resources data for Kentucky" annual reports. Throughout the summer, and especially during the drought period, data were supplied to Survey headquarters and regional offices of the KNREPC and the major water supplier for the city of Lexington and surrounding areas. For the latter, data were provided on a daily basis at several sites and streamflow measurements at these sites were made on a weekly basis. Minor updates were made to the District Flood Plan. All data were collected in conformance with the District quality-assurance requirements.

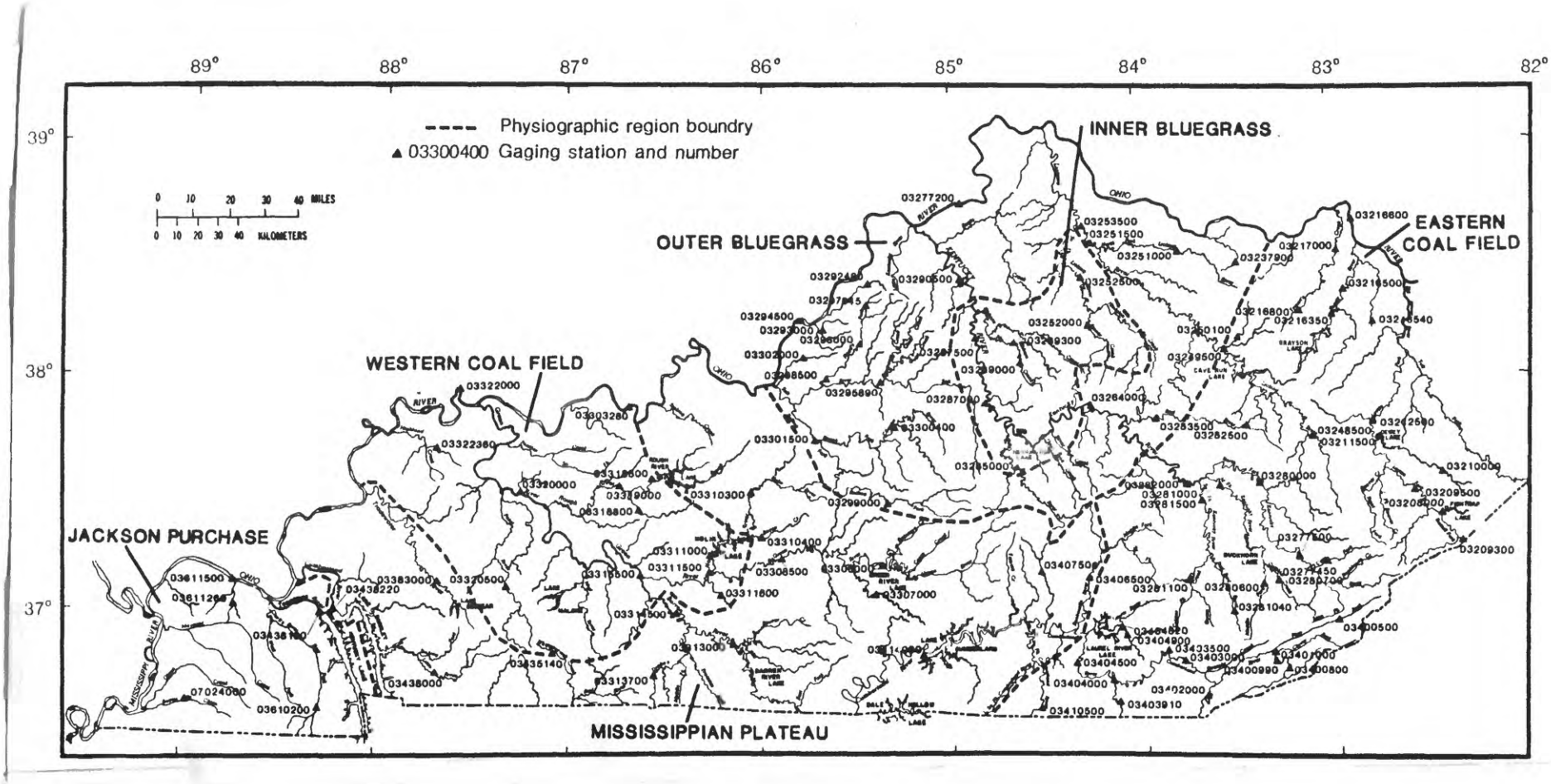


Figure 10.--Location of gaging stations in Kentucky.

KY 00-002 GROUND-WATER STATIONS

LOCATION: Statewide--See figures 11, 12, 13, and 14 for well locations.

PERIOD OF PROJECT: Continuous since January 1949

PRINCIPAL INVESTIGATOR: Douglas D. Zettwoch

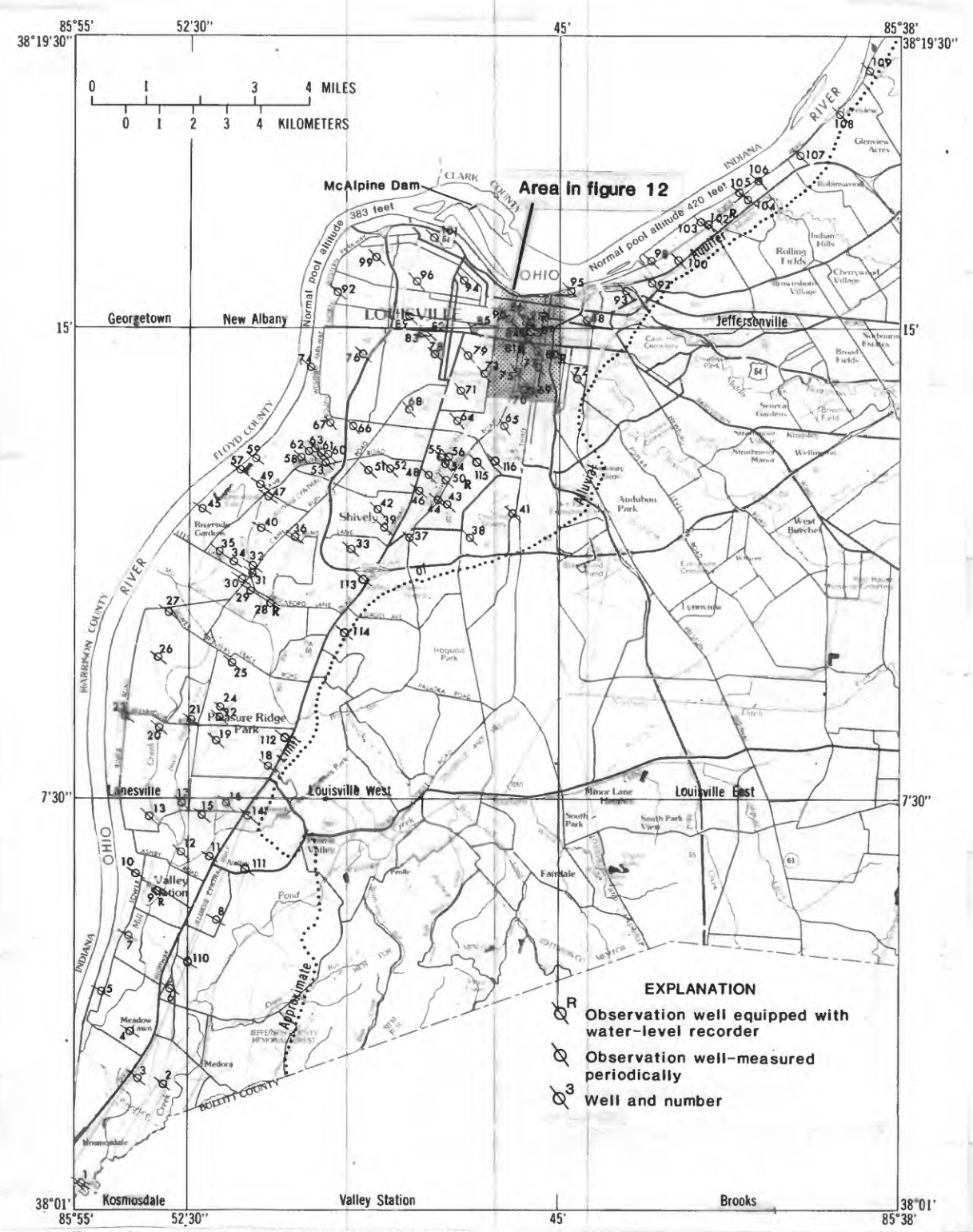
FUNDING: Cooperative--Jefferson County Public Works and Transportation Department, KNREPC, and the city of Elizabethtown

PROBLEM: Long-term water-level records are needed to evaluate the effects of natural (climatic) and man-made (pumping and injection) variations on the recharge to and discharge from ground-water systems, to provide a data base from which to measure the effects of man's actions and natural events, to assist in the prediction of future supplies, and to provide for management and protection of the resource.

OBJECTIVE: To collect water-level data sufficient to provide a minimum long-term data base so that the general response of the hydrologic system to natural climatic variations and induced stresses is known and potential problems can be defined early enough to allow proper planning, management, and protection. To provide a data base against which the short-term records acquired in areal and site-specific studies can be analyzed.

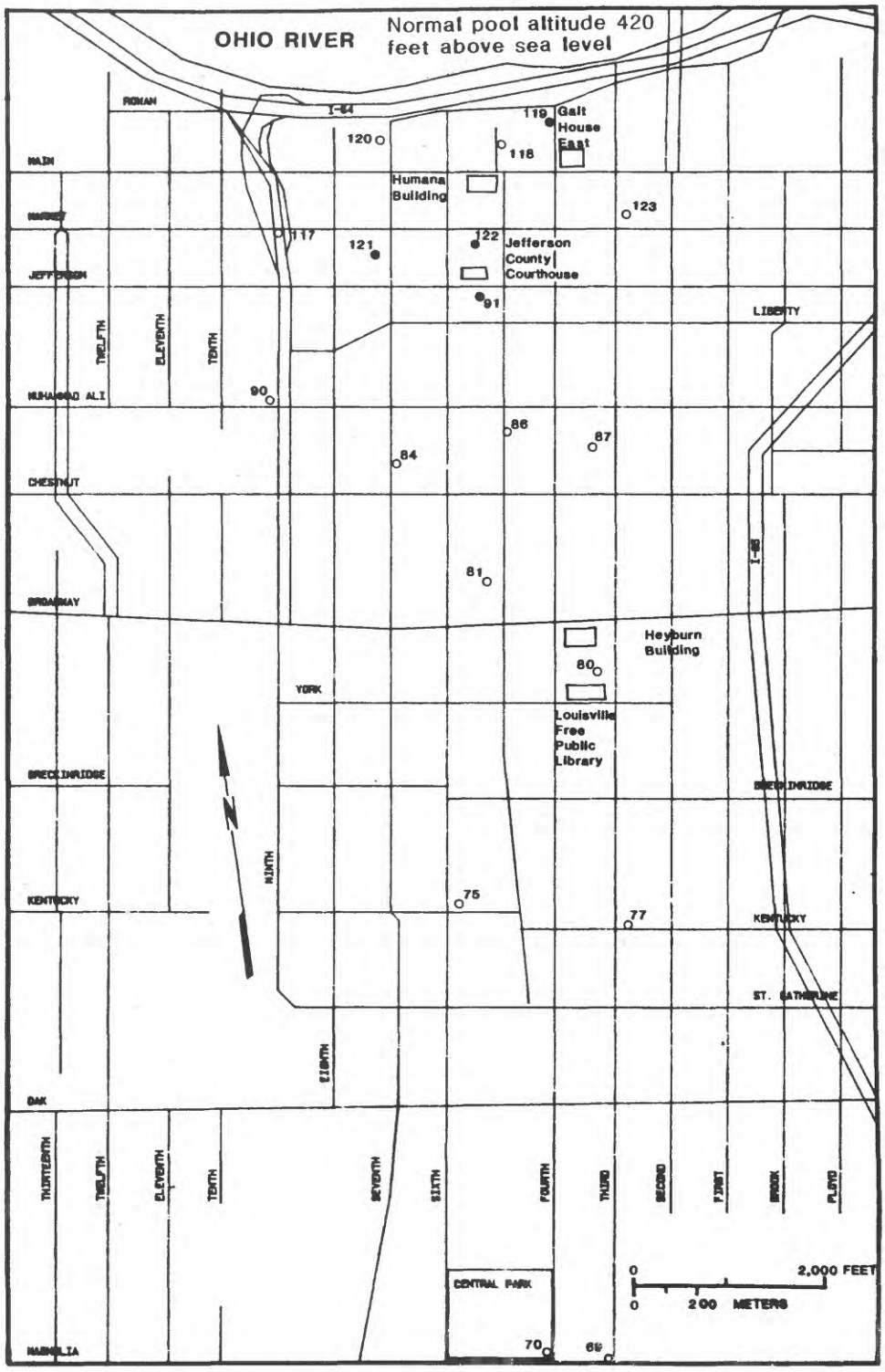
APPROACH: Evaluation of regional geology allows broad, general definition of aquifer systems and their boundary conditions. Within this framework, along with some knowledge of the stress on the system in time and space and the hydrologic properties of the aquifers, a subjective decision can be made on the most advantageous locations for observation of long term system behavior. This subjective network can be refined as records become available and detailed areal studies of the ground-water system more closely define the aquifers, their properties, and the stresses to which they are subjected. Standard methods of data collection will be used as described in the series, "Techniques of Water Resources Investigations of the United States Geological Survey."

PROGRESS: Continuous water-level recorders were operated at 19 wells and semi-annual water-level measurements were made at 121 wells in Kentucky. Most of the wells are in the sand and gravel alluvial aquifer underlying Louisville and southwest Jefferson County. Hydrographs, water levels, site descriptions, and map locations for these wells are published in the "Water resources data for Kentucky" annual reports. A report, "Ground-Water Levels in the Alluvial Aquifer at Louisville, Kentucky, 1982-87," by Robert J. Faust and Mark A. Lyverse was also published in August 1987. Three wells in Hardin County, Kentucky, near the city of Elizabethtown's water-treatment plant have continuous recorders to monitor water levels in this area. Two wells in Kentucky, one in Graves County and another in Louisville are monitored for national water level trends. Fifteen wells were added to the State network in November, 1988. All data were collected in conformance with District quality-assurance requirements.



Base from U.S.Geological Survey 1:24,000 quadrangles named in figure

Figure 11.---Location of observation wells in Jefferson County.



EXPLANATION

o70 **OBSERVATION WELL AND NUMBER**

•91 **OBSERVATION WELL--Equipped with temperature probe**

Figure 12.--Location of observation wells in downtown Louisville.

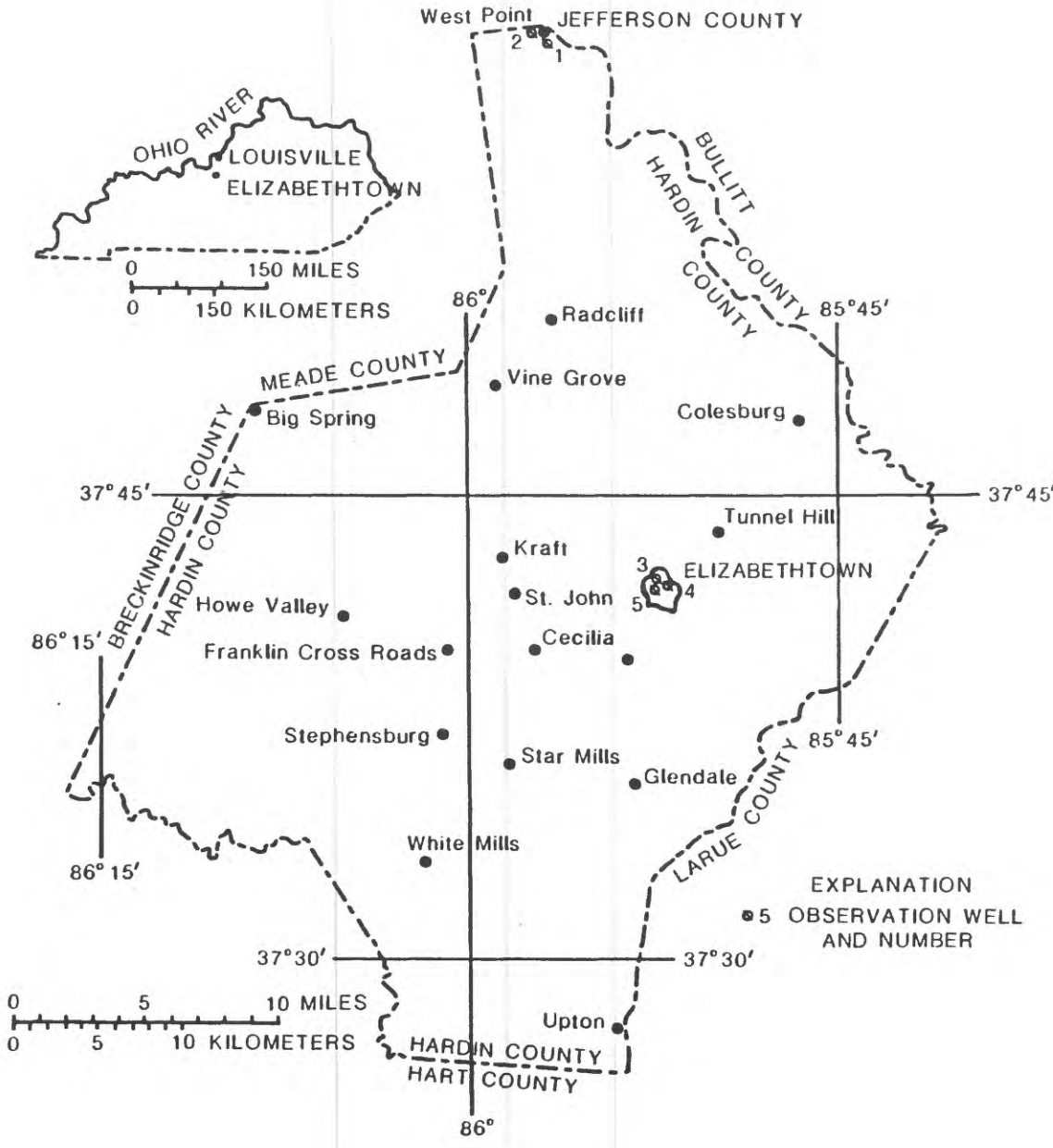


Figure 13.--Location of observation wells in Hardin County.

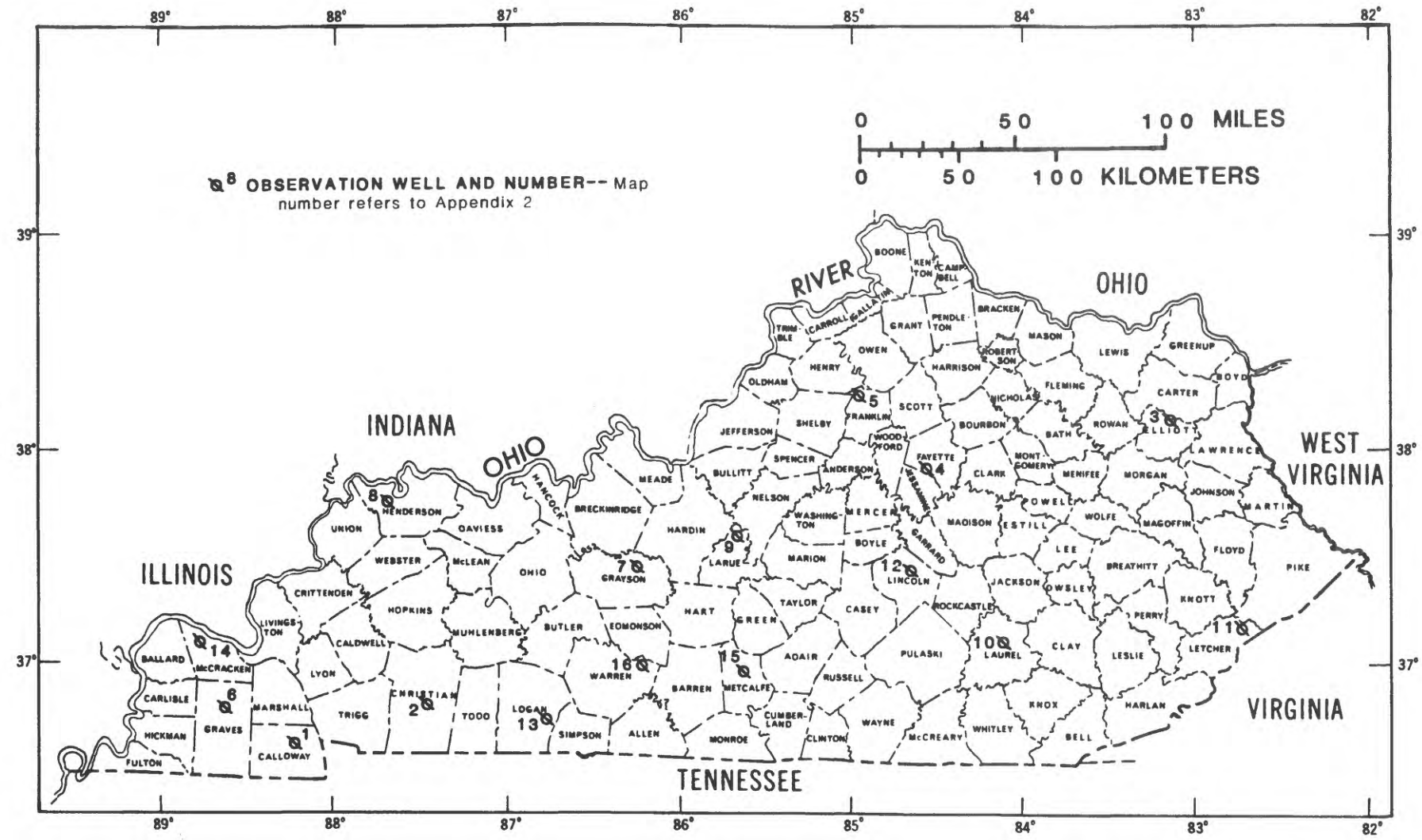
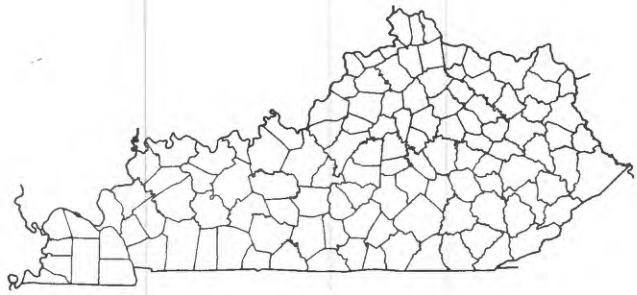


Figure 14.--Location of observation wells in Kentucky.

KY 00-003 WATER-QUALITY STATIONS

LOCATION: Statewide--See figure 15 for location of sites



PERIOD OF PROJECT: Continuous since 1949

PRINCIPAL INVESTIGATOR: Rene G. Garcia

FUNDING: Other Federal funds from the Corps of Engineers and Survey (National Stream-Quality Accounting Network)

PROBLEM: Water-resources planning and water-quality assessments require a nationwide base level of relatively standardized information. For the planning, management, protection, and assessment of the water resource, the physical, chemical, and biological quality of the streams, lakes, reservoirs, and ground water must be defined and monitored.

OBJECTIVE: To provide a data base of water-quality information for use in broad Federal and State planning, management, protection, and assessment programs; and to provide data for State and Federal management of streams, lakes, reservoirs, and ground water.

APPROACH: Operate a network of water-quality stations to provide concentrations, time trends, and loads of water-quality constituents as required by planning, management, and protection agencies. Standard methods of data collection will be used as described in the series, "Techniques of Water Resources Investigations of the United States Geological Survey."

PROGRESS: Sampling at eight National Stream-Quality Accounting Network (NASQAN) stations was completed for the 1988 water year. Six NASQAN stations were sampled bi-monthly and two were sampled quarterly. Four flow-through monitors were in operation at stream sites at the beginning of the year. The four monitors continuously measure water temperature, specific conductance, pH, and dissolved-oxygen concentration. These data were used by the Corps of Engineers in the management of its water-resources program. Numerous requests for water-quality data were answered during the year. Water-quality data, site descriptions, and map locations for these stations are published in the "Water resources data for Kentucky" annual reports. All data were collected in conformance with NASQAN and District quality-assurance requirements.

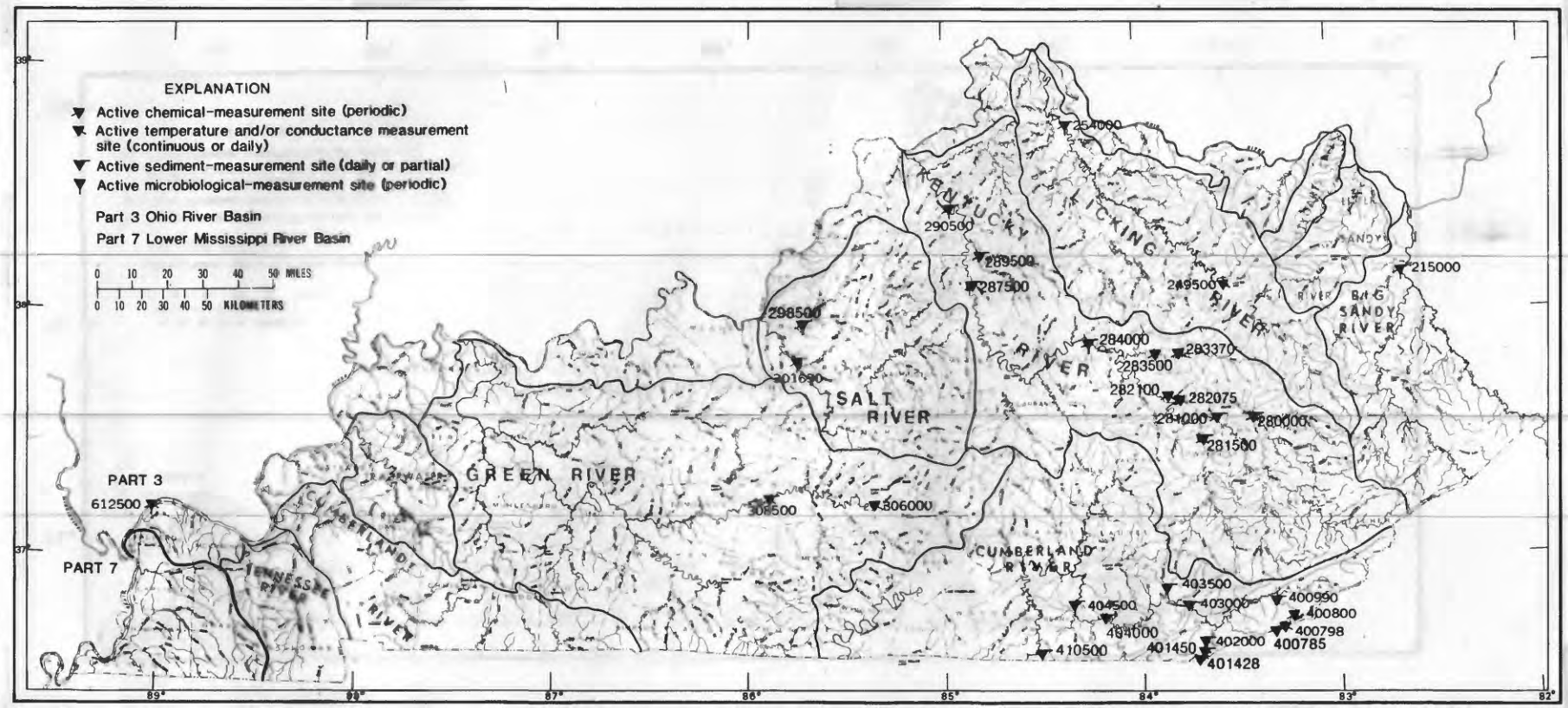
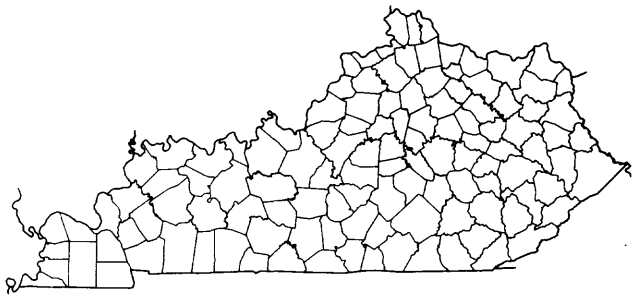


Figure 15.—Location of surface water quality stations in Kentucky.

KY 00-004 SEDIMENT STATIONS

LOCATIONS: Statewide--See figure 15 for location of sites



PERIOD OF PROJECT: Continuous since July 1951

PRINCIPAL INVESTIGATOR: Clyde J. Sholar

FUNDING: Survey and other Federal funds from the Corps of Engineers and Survey

PROBLEM: Water-resource planning and water-quality assessments require a nationwide base level of relatively standardized information. Sediment con-centration and discharges in streams must be defined and monitored.

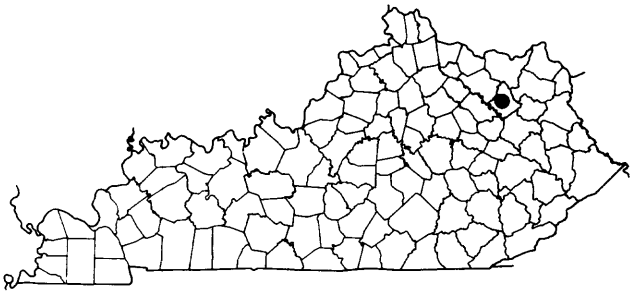
OBJECTIVE: To provide a bank of sediment data for use in broad Federal and State planning, management, protection, and assessment programs and to provide data for State and Federal management of intra- and interstate waters.

APPROACH: A network of sediment stations is operated to provide spatial and temporal trends of sediment concentration, sediment loads, and particle size of sediment being transported by streams. Data collection and computations are performed according to methodology described in Survey Techniques of Water-Resources Investigations (TWRI), Book 3, Chapters C2 and C3. Laboratory analyses are performed according to TWRI Book 5, Chapter C1.

PROGRESS: Collection and analysis of suspended-sediment samples continued on a daily and storm-event basis at 11 continuous streamflow stations. Special studies included bedload sampling at one station as part of a pilot program to demonstrate and evaluate techniques and methods of data collection and analysis. Sediment data, site descriptions, and map locations for these stations are published in the "Water resources data for Kentucky" annual reports.

KY 00-005 ATMOSPHERIC DEPOSITION STATION

LOCATION: Rowan County



PERIOD OF PROJECT: Continuous since October 1983

PRINCIPAL INVESTIGATOR: Dennis L. McClain

FUNDING: Survey (National Trends Network)

PROBLEM: Data on the chemical quality of atmospheric deposition are needed to provide a baseline against which future changes in atmospheric-chemical quality can be evaluated. These data also are an essential input to studies designed for assessment of possible aquatic and terrestrial effects related to acidic atmospheric deposition. Until recently, there has been no uniform data-collection effort aimed at providing a consistent precipitation chemical quality data base on a national scale. There are a number of regional studies currently underway but these differ slightly in methods of collection and analysis and do not provide uniform national coverage. Man's influences on the chemical quality of precipitation and effectiveness of any mitigative strategies cannot be determined without national network coverage.

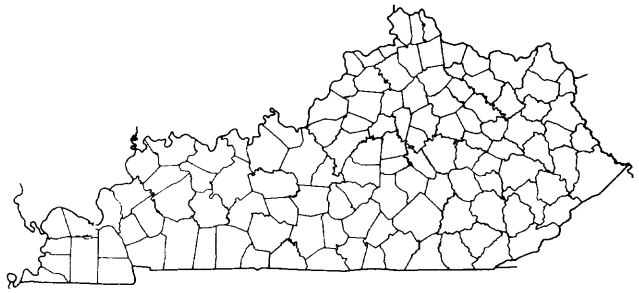
OBJECTIVE: To determine variations in atmospheric deposition that occur on a week-to-week basis, and to collect wet- and dry-deposition products for analysis of elements and compounds that can contribute to the chemical composition of surface waters.

APPROACH: Maintain a monitoring station as part of the National Trends Network, a Federal interagency cooperative program. Make on-site measurements, process samples, and submit samples to an analytical laboratory. Verify data retrievals and report on results.

PROGRESS: Continue to operate the station and store records in the Survey's national water data storage and retrieval system. Chemical data, site description, and map location for the station will be published in "Water resources data for Kentucky."

KY 79-007 WATER USE IN KENTUCKY

LOCATION: Statewide



PERIOD OF PROJECT: Continuous since October 1978

PRINCIPAL INVESTIGATOR: Clyde J. Sholar

FUNDING: Cooperative--KNREPC

PROBLEM: The water resources of Kentucky are being used more extensively with each passing year. Although information has been developed as to the occurrence and quality of the resource, relatively little has been done to describe where, how, and in what quantities water is being used. Without such information, decision makers cannot resolve many critical problems such as water-quality residuals, environmental impact, energy development, and resources allocation. Methods for comprehensive acquisition of water-use data have not been developed. Data now in the files of State and Federal agencies contain many deficiencies and are not in a form suitable for automatic storage and retrieval.

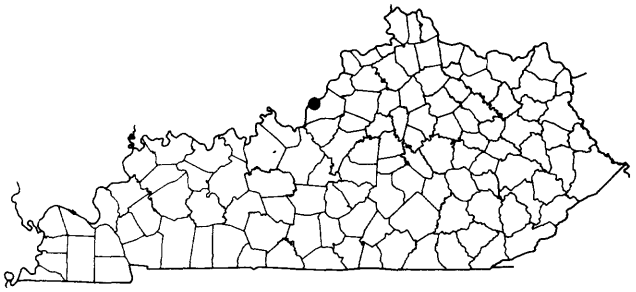
OBJECTIVE: To identify sources of water-use data; develop and evaluate techniques for collecting water-use data, especially data not in State agency files; identify requirements for a water-use data handling system; select and implement a Kentucky water-use data handling system; and develop a system to verify water-use data reported to the State.

APPROACH: Establish at the State level, facilities for the collection, management, and dissemination of water-use data. Data collection and management will be done by the Kentucky Natural Resources and Environmental Protection Cabinet, the State agency that has legislative responsibility for water-use regulation in Kentucky.

PROGRESS: The Kentucky Water-Use Program has a framework for the collection of monthly withdrawal information. The data are entered into the New State Water-Use Data System (NewSWUDS) developed by the Survey. NewSWUDS has evolved through the continued handling of site-specific and area-based water-use data, and an understanding of the District's needs and the needs of other State, Federal, and local agencies in Kentucky. Aggregated information for all water-use categories were compiled for entry in the reports to be published as "Estimated Use of Water in the United States, 1985" and the "National Water Summary, 1987." Withdrawals by county for eight major categories of use were published in a report "Water Use in Kentucky, 1985" Clyde J. Sholar and V. David Lee. A paper was published in the Proceedings of and a poster exhibit was shown for the American Water Resources Association Symposium on Water-Use Data for Water Resources Management held in Tucson, Arizona, in August 1988. The papers emphasized water use in the Kentucky River basin. Special studies have included the evaluation of major public-supply and self-supplied industrial and commercial water systems, their sources of supply, and the adequacy of these systems to meet demands in times of drought for a 27-county area of western Kentucky (report published 1986) and for the Kentucky River basin (report in preparation). The District also provided names, addresses, and latitude and longitude locations for all municipal water systems in the State for the EPA Municipal Well Project being coordinated by the Survey.

KY 84-063 GROUND-WATER MODEL, LOUISVILLE

LOCATION: Jefferson County



PERIOD OF PROJECT: October 1983 to September 1989

PRINCIPAL INVESTIGATOR: Mark A. Lyverse

FUNDING: Cooperative--University of Louisville

PROBLEM: Historically, the alluvial aquifer underlying the Louisville area has been subjected to variable pumping rates, changing river levels, and varying recharge. In the period since 1962-84, water levels rose and caused concern about potential damage to basements and building foundations in and near the downtown area. In 1984, the resumption of ground-water use for heating and cooling began and the County and State are faced with regulating withdrawals from and reinjection of water into the aquifer.

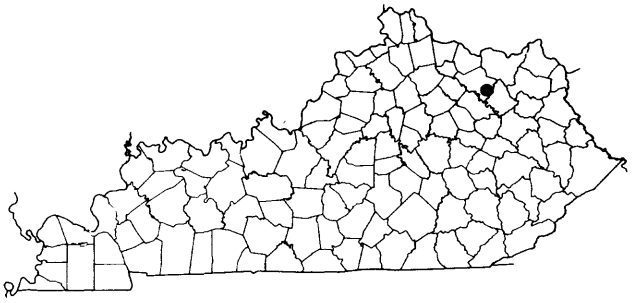
OBJECTIVE: To develop a ground-water flow model capable of simulating regional ground-water flow in the alluvial aquifer in the Louisville area, refine the understanding of the hydrology of the alluvial aquifer in the area, and compare management alternatives of various pumping schemes.

APPROACH: Design a conceptual model from existing data describing the hydrologic system. Construct a two-dimensional, finite-element flow model to simulate ground-water flow. Modify the calibrated model for convenient use by water-management agencies.

PROGRESS: The project is in the final stages of completion with a report to be published early in 1989. Included with the report will be a ground-water flow model which can be applied by regulatory and planning agencies for developing aquifer-management plans and for decision-making. Based upon the results of this project, more detailed modeling is desirable involving a solute transport simulation model to assess potential water-quality problems, specifically temperature, that may develop with increased ground-water use in the Louisville-Jefferson County metropolitan area.

KY 85-068 SEDIMENTATION AND EROSION RATES AT THE MAXEY FLATS RADIOACTIVE WASTE BURIAL SITE

LOCATION: Fleming County



PERIOD OF PROJECT: October 1984 to September 1988

PRINCIPAL INVESTIGATOR: Mark A. Lyverse

FUNDING: Survey (Nuclear Waste Hydrology Program)

PROBLEM: Increased flow from the plastic covered surface at the Maxey Flats Radioactive Waste Burial Site, a Superfund site, has changed the sediment-transport characteristics of stream channels when compared to natural surface runoff. Consequently, the rates of erosion and gully formation along the hillsides have been altered. Estimates for the rate of slope retreat and trench-cap erosion are needed for management of the site.

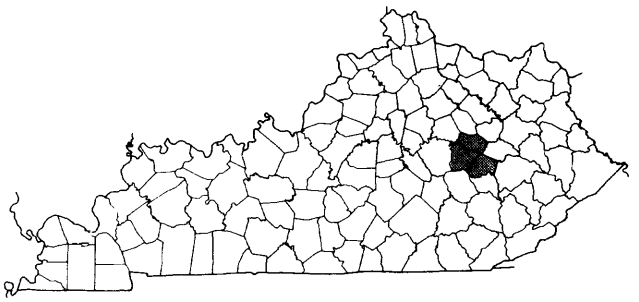
OBJECTIVE: To measure the fluvial processes and mass movement occurring at the waste burial site, and to compare and evaluate data on erosion measured at the site with data calculated from various sediment-transport equations.

APPROACH: Detachment of sediment on the upland areas will be measured using lines of erosion pins. Sediment delivery by the ephemeral streams discharging from the site to perennial streams downstream will be measured by sampling for suspended sediment using automatic stage-activated samplers. Sediment-yield and transport equations will be evaluated to determine their applicability to erosional processes at Maxey Flats.

STATUS: Data collection is complete and a project report will be published in 1989.

KY 85-069 ASSESSMENT OF GROUND- AND SURFACE-WATER CONDITIONS IN OIL AND GAS PRODUCING AREAS WITHIN THE KENTUCKY RIVER BASIN

LOCATION: Lee, Estill, and Powell Counties



PERIOD OF PROJECT: October 1986 to September 1989

PRINCIPAL INVESTIGATORS: Ron D. Evaldi and James A. Kipp (KGS)

FUNDING: Cooperative--KGS

PROBLEM: The occurrence of brine in both ground and surface water has posed two problems within the Kentucky River basin. On one hand, the oil and gas industry is required to delineate all aquifers containing ground water of drinking-water quality where enhanced-recovery procedures are being used, and the industry is required to dispose of brine produced with oil and gas in an environmentally acceptable manner. This leads to considerable cost. On the other hand, it is generally thought that brine occurs naturally approximately 100 feet beneath regional surface drainage throughout eastern Kentucky. Because of this, there have been many instances of reported brine pollution of both ground- and surface-water resources in which a definitive source of the brine is unknown.

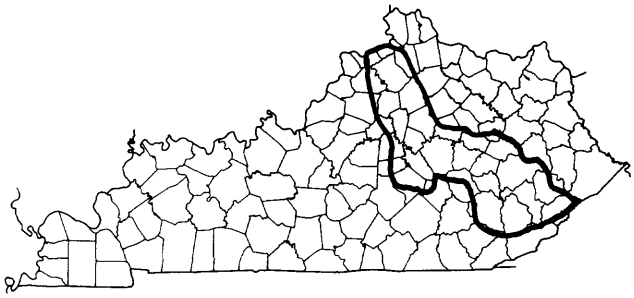
OBJECTIVE: To verify current conceptual hydrologic/constituent transport models applicable to typical oil and gas exploration and production activities in the Kentucky River basin; determine the chemical character typical of ground water and surface streams draining the oil and gas fields in the study area; develop estimates of the mass transport for those chemical constituents present; assess the potential impact of these constituents on downstream water quality; and where possible, relate the hydrology, chemical quality, and constituent-mass transport to compiled ancillary data, such as oil and gas production methods and rates, geology, and other land uses.

APPROACH: Establish gaging stations equipped with mini-monitors on Big Sinking Creek (Lee County), Furnace Fork (Estill County), and Cat Creek (Powell County). Conduct monthly sampling at the three gaging stations and at tributary streams in the Furnace Fork basin. These data will be supplemented with the results from the NAWQA pilot study (KY 86-071) to assess the effect of brine on the quality of the water resource within the Kentucky River basin. Relate water quality in streams to the level of oil and gas production upstream of the sampling sites. Characterize ground-water quality in the Cat Creek and Furnace Fork basins and determine the effects of oil and gas production on ground-water quality. Compute brine loading rates for the three mini-monitor sites and selected sites on the Kentucky River.

PROGRESS: Field investigations will be completed in March 1989. The "Water resources data for Kentucky" annual report of water year 1988 will include project data collected during the water years 1987-88.

KY 86-071 SURFACE WATER QUALITY ASSESSMENT OF THE KENTUCKY RIVER BASIN (HYDROLOGIC ACCOUNTING UNIT 051002)

LOCATION: Kentucky River basin in East Central Kentucky



PERIOD OF PROJECT: April 1986 to September 1991

PRINCIPAL INVESTIGATOR: James L. Smoot

FUNDING: Survey (National Water Quality Assessment Program-pilot project)

PROBLEM: The Kentucky River basin is the most densely populated river basin in Kentucky and is projected to be the area of most growth. Water-quality data have been collected at 430 sites in the basin by the Survey, the Army Corps of Engineers, the Environmental Protection Agency, the Office of Surface Mining Reclamation and Enforcement, and the Forest Service, as well as various State agencies. These data have not been evaluated basin-wide. There is a need for an assessment of the temporal and spatial variability in these data to delineate water-quality conditions, trends, and problems. Such a study will aid those charged with prioritizing the monitoring, regulation, and mitigation of water-quality problems in the basin, as well as identify present and emerging water-quality impacts.

OBJECTIVE: To increase the understanding of the variability of water quality in the Kentucky River basin both on a historical and real-time basis, and to identify both the sources and processes that significantly contribute to water-quality degradation in the basin. To better define the extent and seasonality of apparent problems. To evaluate the adequacy of existing sampling networks for describing water quality in the basin and the identification of additional sampling or monitoring needs.

APPROACH: The initial task of the study is to assess the existing water-quality data that are readily available. An analysis of basin land use will also be made to identify general areas of the basin where specific land use related non-point sources of pollution occur. A fixed-station, fixed-interval sampling network will be established. Sampling site selection will be made to augment the existing ambient monitoring networks and to adequately cover areas of the basin affected by non-point sources (principally from coal mining, oil and gas production, agriculture, and urban development).

Synoptic studies of the basin will be performed during high-flow and low-flow periods. The high-flow study results will be used to adjust the fixed-station sampling network to best reflect the non-point sources (assuming that high flow is usually the critical period for non-point sources). Constituents sampled will coincide with those most likely transported from non-point sources. Low-flow synoptic studies will concentrate on defining the basin effects from point sources and ground-water base flow contributions, and will be used for network refinements.

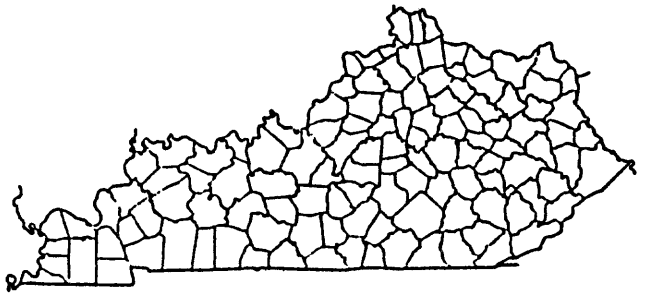
The synoptic studies will be used to identify water-quality problem areas in the basin. The most severe problem areas will then be studied in detail on a small scale to define the characteristics of the source/effect relations (see KY 85-069). These detailed studies would attempt to define environmental influences on the fate of the problem constituents.

The fixed-station, fixed-interval sampling will be used along with historical data to develop and track water-quality trends. A base level of data collection at these network sites would be anticipated to continue beyond the study period to provide a historical data base for use in future basin studies.

PROGRESS: A Project Liaison Committee was established and has met routinely since the project began. A project description report was published in 1987. A project work plan has been prepared and is being implemented. Specifically, the historical data base has been compiled and statistically analyzed. An interpretive report on the historical data base is near completion and will be published in 1989. The fixed-station network was developed with the use of geographic information system technology and implemented in April 1987. The data from the network for water year 1987 were published in the 1987 data report. In addition, one bottom material and two low-flow synoptic surveys have been performed.

KY 86-072 REGIONALIZATION OF LOW-FLOW CHARACTERISTICS OF KENTUCKY STREAMS

LOCATION: Statewide



PERIOD OF PROJECT: July 1987 to September 1989

PRINCIPAL INVESTIGATOR: Kevin J. Ruhl

FUNDING: Cooperative--KNREPC

PROBLEM: Information on low-flow characteristics of Kentucky streams is of prime importance for optimum utilization and management of the streams. Low-flow information can be used to determine whether an industry requiring water can be operated without water storage facilities. Low-flow information is also essential to surface water quality management where the amount of water for dilution, assimilation, and transport of waste constituents is a critical factor. With the current emphasis on water quality, the need for low-flow information is very important to regulatory agencies concerned with waste disposal into streams. The anticipated needs for low-flow estimates are expected to increase throughout the State.

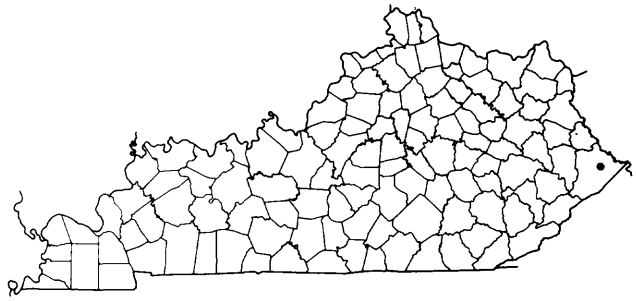
OBJECTIVE: To develop a statewide, long-term low-flow network consisting of current stream-gaging stations supplemented by additional stations, where needed, and a number of partial-record stations; to derive low-flow frequency values at the continuous- and partial-record streamflow stations; and to develop methods of estimating low-flow frequency values at ungaged sites using regionalization and regression techniques.

APPROACH: Evaluate the existing stream-gaging network and identify areas where additional continuous-record information is needed. Select a number of partial-record sites with input from the KNREPC. Collect streamflow information at these sites throughout the project period. Statistical analyses of low-flow values from continuous- and partial-record stations will be performed using procedures and standards described in the series, "Techniques of Water Resources Investigations of the United States Geological Survey." Streamflow recession and/or variability indexes from continuous-record gaging stations will be used in conjunction with geologic information to define homogeneous low-flow regions. Regression analyses will be performed relating low-flow frequency values to various parameters including basin characteristics. From these analyses, techniques will be developed to estimate low-flow frequency values at ungaged sites.

PROGRESS: Areas in the State have been identified where additional low-flow information is needed using input from the KNREPC. Additional gaging-station locations have been identified. Partial-record sites have also been selected and flow at these stations has been measured at least twice. Frequency analysis has been performed for all continuous-record gaging stations including discontinued sites. Trend analysis is also being performed as part of these analyses.

KY 88-074 MOVEMENT OF GROUND WATER NEAR FISHTRAP LAKE

LOCATION: Pike County



PERIOD OF PROJECT: October 1987 to September 1989

PRINCIPAL INVESTIGATOR: Robert J. Faust

FUNDING: Other Federal funds from the Office of Surface Mining Reclamation and Enforcement

PROBLEM: The characteristics of ground-water movement down steep-sloped valley walls in the coal-bearing rocks of eastern Kentucky and in similar areas of the Appalachian Plateaus and Valley and Ridge Provinces of the eastern United States is poorly understood. Bench mining on steep slopes and strip mining on ridge tops is commonly permitted in eastern Kentucky on the basis that the effects of mining are hydrogeologically isolated from downgradient water supplies. However, fractures and permeable beds may transmit ground water from mine areas to downgradient water supplies.

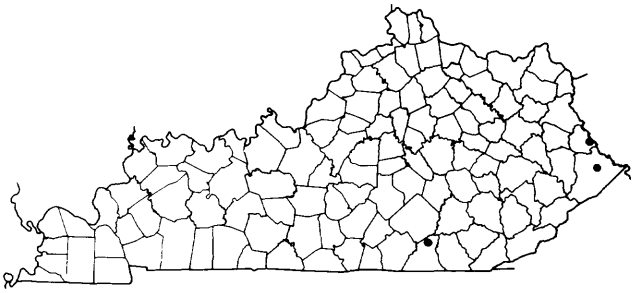
OBJECTIVE: To determine if ground-water moves down a steep slope through several hundred feet of coal bearing rocks at a site in Pike County. To determine if the movement is primarily near land surface or if there is significant movement through deeper fractures and permeable beds.

APPROACH: Dye will be injected at a depth of about 60 feet in a well high on a ridge and the movement of dye will be monitored in fourteen downgradient wells and piezometers plus any seeps, springs, and streams near the base of the ridge. After the system has time to purge itself of dye, a second dye injection and monitoring will be done with the dye being injected at least 200 feet below land surface. The results of these dye tests will be used to confirm the conceptual model of ground-water movement down steep slopes in coal-bearing rocks.

PROGRESS: A liter of dye along with 200 gallons of water was injected in a ridge-top well on December 3, 1987. Monitoring of downgradient wells failed to detect any dye movement for several months, and on June 30, 1988, another liter of dye along with 3,000 gallons of water was injected in the same ridge-top well. No dye had been detected in downgradient wells as of the end of September 1988. Below normal precipitation since the dye injections is believed to be the cause of the slowness in detecting dye movement in downgradient wells.

KY 88-075 EVALUATION OF POST-MINING, HYDROLOGIC IMPACTS ASSOCIATED WITH ABOVE-DRAINAGE, UNDERGROUND COAL MINING SITES IN SELECTED AREAS OF EASTERN KENTUCKY

LOCATION: Martin, McCreary, and Pike Counties



PERIOD OF PROJECT: October 1987 to September 1990

PRINICPAL INVESTIGATOR: Karen S. Wilson

FUNDING: Other Federal Funds from the Office of Surface Mining Reclamation and Enforcement

PROBLEM: The OSMRE has found that post-mining, hydrologic impacts associated with above drainage, underground coal mining sites in eastern Kentucky are significant. Data indicate that there is water-quality degradation and interbasin transfer of surface and ground water, and that the hydraulic head created by the accumulated ground water results in seepage of water along the contour of the abandoned works causing blow-outs and hydraulically induced landslides. A better understanding of post-mining effects is needed in order that regulatory agencies can assess the potential for hydrologic impacts during the permitting process prior to the issuance of the mining and reclamation permit.

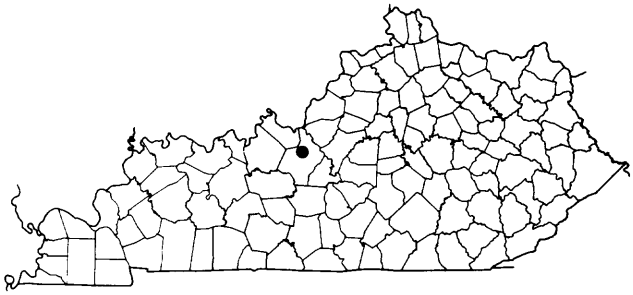
OBJECTIVE: To refine a conceptual model of the ground-water system at closed, above-drainage, underground coal mining sites in selected areas of eastern Kentucky. To identify, in broad terms, the extent; qualify, and if possible quantify the potential significance; and identify the potential mechanisms which result in hydrologic impacts associated with the closed mining sites.

APPROACH: In cooperation with the OSMRE, available data from permit files and other sources, including Survey records, will be compiled for candidate study sites. Based upon an evaluation of available data and field inspections, additional data needs will be developed and specific study plans tailored to each site developed. Field investigations will begin late in 1988 to obtain data needed to verify water occurrence in abandoned mine works, and to determine the occurrence, movement, and quality of ground and surface water. Hydrologic impacts will be identified and, through a better understanding of the system, potential mechanisms which result in those impacts will be quantified.

PROGRESS: Work plans for sites in Martin, McCreary, and Pike Counties were completed and are being reviewed by OSMRE.

KY 88-076 WATER AVAILABILITY IN NORTHWEST HARDIN COUNTY

LOCATION: Hardin County



PERIOD OF PROJECT: October 1987 to September 1989

PRINCIPAL INVESTIGATOR: Donald S. Mull

FUNDING: Cooperative--Hardin County Water District Number 1

PROBLEM: The Hardin County Water District Number 1 (HCWD#1) provides water to approximately 7,000 customers in north central Kentucky. At present, HCWD#1 obtains water from four wells in the Ohio River alluvial aquifer and from a well that taps a conduit draining to Pirtle Spring, a large karst spring. Two of the alluvial wells have contamination from unknown sources of chlorides, oil and grease, and radionuclides, and the yield from the well near Pirtle Spring is inadequate to meet the water demands of the system. Therefore, additional sources of water are needed to enable HCWD#1 to provide a reliable supply of water to the consumer.

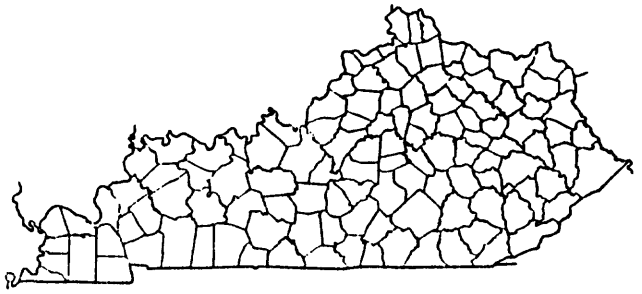
OBJECTIVE: To determine the water-bearing characteristics, especially yield, of the limestone aquifer in areas determined to be most favorable for development based on test drilling and aquifer tests, determine the adequacy and reliability of the Rough and Salt Rivers to augment existing ground-water supplies, and identify the positive and negative hydrologic and environmental aspects associated with developing a water supply at the sites determined to be suitable from a supply standpoint.

APPROACH: Existing data on wells and large springs, aerial photographs, geology, and water-quality data will be evaluated to further develop a conceptual ground-water model of the study area. Potentiometric maps and fracture-trace analysis will be used to identify candidate areas for test drilling. Three to five test wells will be drilled at each site. Yield-drawdown aquifer tests will be performed where high yields are indicated. Water samples will be analyzed to determine water-quality characteristics. Analysis of the low-flow characteristics of the Salt and Rough Rivers will determine the adequacy and reliability of these sources to augment existing water supplies.

PROGRESS: As a result of fracture-trace analysis and evaluation of well yields, candidate areas for test wells have been identified. Drilling of test wells and aquifer tests was accomplished in the fall of 1988. A well inventory and evaluation of surface-water resources are near completion. Test wells near the existing well field in the Ohio River alluvial aquifer were drilled and water samples analyzed.

KY 88-077 GEOGRAPHICAL INFORMATION SYSTEM DATA BASE
FOR HYDROLOGIC ACTIVITIES IN KENTUCKY

LOCATION: Statewide



PERIOD OF PROJECT: October 1988 to September 1991

PRINCIPAL INVESTIGATOR: Timothy D. Liebermann

FUNDING: Cooperative--University of Louisville and City of Elizabethtown

PROBLEM: Geographic information system (GIS) technology has evolved as a way to assemble and analyze diverse data relating to specific geographical areas with location of the data serving as a basis of the information system. This technology has undergone significant changes during the past few years as computer hardware and software have improved. In addition, our understanding of how such technology can be used to address hydrologic issues has also changed and matured. Therefore, it is important that data structures and computational procedures be developed for efficient storage, retrieval, and analysis of spatially indexed data, and that GIS technology for mapping, monitoring, analysis, and modeling be applied to a wide variety of environmental planning and water-resources problems or uses. GIS technology can also serve researchers and Federal, state, and local agencies which need timely and accurate information for water-resource assessments, problem identification and rapid assessment, and program development.

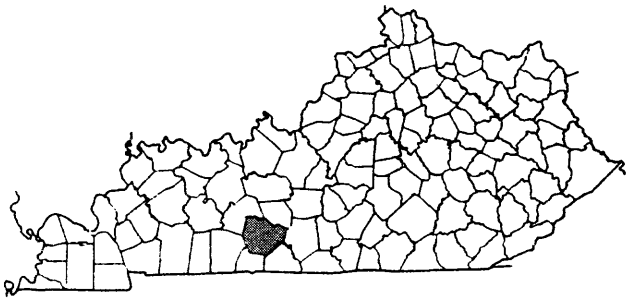
OBJECTIVE: To integrate a GIS data base with existing data systems; develop a hydrology related data base for Kentucky; test and demonstrate methods and procedures for compilation, display, and analysis using the GIS technology; develop techniques to advance and support water-resources research and the use of GIS technology; manage, update, and maintain a GIS data base; and produce periodic maps and/or publications

APPROACH: Hydrology related data from various sources such as the Survey, EPA, KNREPC, KGS, and the U.S. Soil Conservation Service will be assembled, evaluated for adequacy, and entered into the GIS data base system. The data base will include but will not be limited to streamflow data, basin characteristics, geology, soils data, land use, aquifer characteristics, ground-water site data, water use, water-quality data, sediment data, and sources of water-quality contamination. Compiling and developing such a data base and the technology to use such a system will be a multi-year effort. The completion of this effort will depend on the amount and quality of data from various sources; the priorities set with regards to the order of data entry; research needs; and State, Federal, and local needs.

PROGRESS: The project was initiated in late 1988; however the sharing of GIS data bases between Federal, State, and local agencies began prior to the project. This cooperation is fostered by the mutual need for a wide variety of computerized data and the goal to minimize any duplication. In addition, in October 1988, the Survey initiated a cooperative project with the city of Elizabethtown to demonstrate the use of GIS technology related to hydrology related data in the development of quality-growth plans for rapidly developing areas.

KY 88-078 ANTHROPOGENIC CONTAMINATION OF THE LOST RIVER KARST GROUND-WATER BASIN

LOCATION: Warren County



PERIOD OF PROJECT: July 1988-September 1992

PRINCIPAL INVESTIGATOR: Kevin D. White

FUNDING: Survey (Toxic Substances Hydrology Program)

PROBLEM: The Lost River ground-water basin in south-central Kentucky exhibits serious organic chemical contamination problems due primarily to leakage from underground toxic chemical storage tanks in the Bowling Green area. Although the storage site has undergone partial remediation, it remains a primary source of ground-water contamination. Additional sources of organic chemical contaminants have been documented and include: (1) leaking underground gasoline-storage tanks, (2) partially remediated sludge ponds within an industrial park, (3) septic-tank discharges into sinkholes or into the thin soil system, and (4) drainage wells that transfer surface runoff directly into the karstified subsurface. Not only are the chemicals from these sources a threat to individual water supplies and rare aquatic life in the local caves, but upon vaporizing they become concentrated in the cave atmosphere and can rise into buildings on the surface. Numerous evacuations, at least two Environmental Protection Agency "emergency responses," and a Center for Disease Control "Health Advisory" attest to the hazardous fume problems in this ground-water basin. In addition to the problems from toxic fumes, water-supply wells in the area are threatened. Numerous dye traces have substantially defined the subsurface-flow routes so that each of the major sources of contamination can be isolated. However, there is need for process-oriented research to define the fate and transport of the contaminating organic chemicals in this karst environment.

OBJECTIVE: To define the fate, transport, and biochemical interactions of toxic anthropogenic organic compounds in this karst ground-water environment.

APPROACH: A detailed approach for the investigation will be described in a study plan being developed during the period August 1988 to June 1989. The study plan will be submitted to the Survey Toxic Substances Hydrology--Ground-Water Contamination Program Coordinator for acceptance in July 1989.

PROGRESS: Project study plan are being developed.

OTHER WATER RESOURCES ACTIVITIES OF THE KENTUCKY DISTRICT

As part of its responsibility to provide information on water to all water users, the Survey is involved in numerous other activities in addition to regular programs of data collection and hydrologic investigations. One of these functions is to serve as a Federal or Survey representative on advisory committees and task forces established for specific purposes. Some of the current special activities are described below:

Committee and Task Force memberships.--Members of the District staff are working members and advisors to several committees and task forces. Included are the Governor's Ground-Water Advisory Council, the Governor's Water Supply Task Force, the Governor's Maxey Flats Advisory Committee, the Non-Point Source Advisory Committee of the Kentucky Division of Water, Advisor to the OSMRE Steering Committee for Hydrologic Studies in Kentucky, Technical Review Committee for the Master Stormwater Management Plan of the Louisville-Jefferson County Metropolitan Sewer District, Drought Advisory Task Force of the Kentucky Division of Water, the Advisory Committee of the Ohio River Basin Commission, Advisory Committee of the Council of State Governments, the Drought Monitoring Advisory Task Force of the Kentucky Division of Water, and the Louisville Ground-Water Development Task Force.

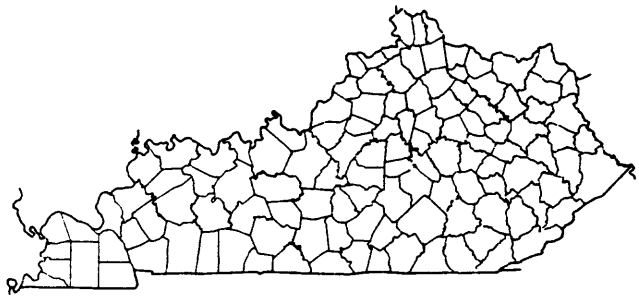
Review of Environmental Impact Statements and other Federal agency reports.--The Water Resources Division reviews Environmental Impact Statements for Federal projects to ensure that available hydrologic data are used, that they are used correctly, and that the impacts of the proposed action on water resources is accurately assessed. Periodically, the District is also asked to review reports and projects of other Federal agencies, primarily because of the Survey's hydrologic expertise and impartiality.

Assistance to other agencies and individuals.--In addition to the Survey's formal programs and studies, water data, earth-science information, and technical assistance are provided to other agencies addressing specific problems. The District continually receives calls, visits, and mail requests for information on streamflow data, ground-water availability, and water quality from landowners, consultants, public officials, and business concerns. In addition, District staff participate as judges for local, regional, State science fairs, and serves as advisors for Master's thesis candidates. Federal regulations prohibit activity that encroaches on the work of professional consultants, but much information and assistance are provided to professional engineers, geologists, and other consultants as well as State, local, and other Federal agencies.

Other data collection programs, interpretive studies, and technical assistance programs.--The District is implementing numerous other data collection programs, interpretive studies, and technical assistance programs which due to either their short-term nature, special purpose, or unique aspects have not been given a specific project number. The following pages provide information for those programs and studies in progress during 1988.

APPLICATION OF DYE TRACING TECHNIQUES FOR DETERMINING SOLUTE-TRANSPORT CHARACTERISTICS OF GROUND WATER IN KARST TERRANES

LOCATION: Karst Areas of Kentucky and the Nation



PERIOD OF PROJECT: September 1987 to September 1988

PRINCIPAL INVESTIGATOR: Donald S. Mull

FUNDING: Other Federal funds from the Environmental Protection Agency

PROBLEM: Some of the most serious incidents of ground-water contamination, nationwide, have been reported in karst terranes. Because of the extreme vulnerability of such ground-water systems to contamination, water-management and protection agencies need an understanding of characteristics of pollutant transport within the systems.

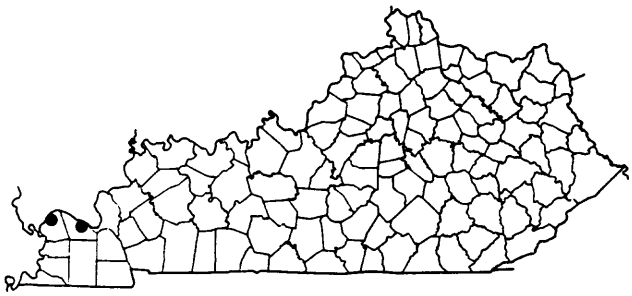
OBJECTIVE: To prepare a manual which provides a review of the hydrogeology of karst terranes, summarizes concepts and techniques for dye tracing, and describes and demonstrates the application of dye-trace data to determine solute-transport characteristics of ground water in karst terranes.

APPROACH: Utilize the results of District research in karst hydrogeology, experience of individual researchers, other published material, dye-tracing procedures, and the analysis and application of dye-trace data used for determining ground-water flow and solute-transport characteristics in the Elizabethtown, Kentucky, area to prepare the manual to be published by EPA.

PROGRESS: The manual was printed in November.

INVESTIGATION OF ACID PRECIPITATION AND WATER-QUALITY PARAMETERS IN THE OHIO RIVER AND THEIR CORROSIVE EFFECTS ON LOCK AND DAM 52 AND 53

LOCATION: Ballard and McCracken Counties



PERIOD OF PROJECT: July 1987 to September 1989

PRINCIPAL INVESTIGATOR: Kevin D. White

FUNDING: Other Federal funds from the Corps of Engineers

PROBLEM: The Corps of Engineers maintains and operates two lock and dam facilities (numbers 52 and 53) on the Lower Ohio River which are slated to be replaced by the proposed Olmsted project. Corrosion of the galvanized-steel components, the uncoated sheet-pile lock walls, and coated pipes and armor plating is severe at Lock and Dam 53, and to a lesser degree, is a problem at Lock and Dam 52. These structures must remain operative until the proposed Olmsted replacement project can be completed. The operative lifetime of the two facilities is not known. Localized severe corrosion problems in the Lower Ohio River may have implications for the Olmsted project and for other lock and dam locations throughout the Ohio River valley. Preliminary investigations have implicated sulfate concentrations in the river and the presence of significant sulfate-reducing bacteria in the water column and bottom sediment near the dam sites as the cause of the corrosion problems. However, Survey review of data obtained from the NASQAN site at Dam 53 (KY 00-003) indicates that sulfate concentrations in the Ohio River at Dam 53 are equal to or less than sulfate concentrations at upstream locks and dams on the Ohio River. Thus, other factors may be contributing to the corrosion problems.

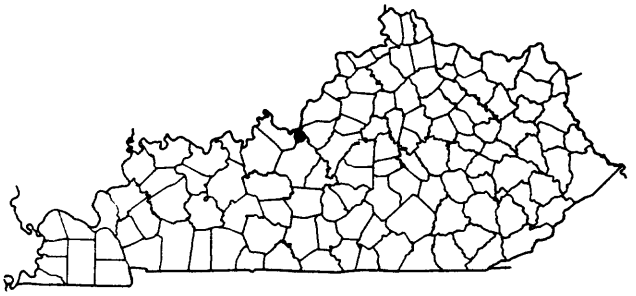
OBJECTIVE: To define the occurrence and quality of acid precipitation at Lock and Dams 52 and 53 on the Ohio River, assess the effects of acid precipitation on the metallic portions of Lock and Dams 52 and 53 (corrosion), determine the water and sediment quality in the immediate vicinity of Lock and Dams 52 and 53, evaluate the water- and sediment-quality data in regard to its potential for causing metal corrosion, and identify the source of the corrosion-causing constituent(s).

APPROACH: Collect atmospheric precipitation, river-water, and bottom-sediment samples in the immediate vicinity of Lock and Dams 52 and 53 over a period of one year. Atmospheric precipitation (wetfall, dryfall, and fog) will be collected continuously and processed on a weekly basis at each lock and dam location. Water and sediment samples will be collected bimonthly (every other month) both upstream and downstream of the lock and dam facilities. Obtain water-quality profiles using in-situ methods under various flow conditions. With the identification of the corrosion causing process, additional environmental sampling will be performed.

PROGRESS: Data collected through the summer of 1988 do not indicate any unusual riverine water-quality causative factors which may accelerate corrosion of the structures. Rainfall pH typically is acidic (pH 4.2) and could contribute slightly to accelerated corrosion. The investigation is proceeding into other areas to further identify possible environmental influences on corrosion rates, including sediment-load determinations from historical data.

INVESTIGATION OF THE EXTENT AND POTENTIAL SOURCES OF GROUND-WATER CONTAMINATION IN THE OHIO RIVER ALLUVIAL AQUIFER IN THE VICINITY OF THE WELL FIELD SERVING THE HARDIN COUNTY WATER DISTRICT NUMBER ONE

LOCATION: Hardin County near West Point



PERIOD OF PROJECT: October 1987 to September 1988

PRINCIPAL INVESTIGATOR: Mark A. Lyverse

FUNDING: Cooperative--Hardin County Water District Number 1

PROBLEM: HCWD#1 obtains part of its water supply from a well field near West Point in the Ohio River alluvial aquifer. The alluvial aquifer also provides water for the city of West Point and the U.S. Army Installation at Fort Knox. It is one of the largest well fields in Kentucky serving as the exclusive or principal source of drinking water for over 50,000 people. Over the past several years, water samples collected from numerous supply wells have been contaminated with significant concentrations of chlorides. Local water managers have speculated that the source of the chlorides may be the residuals from abandoned salt storage piles dating back to the nineteenth century. In addition, the area is a former natural gas field and is currently the site of a natural gas storage field within the limestone beneath the alluvium. The area is also under active, but limited, exploration for oil. Two of the HCWD#1 supply wells have produced water containing small quantities of oil and grease. Geophysical logs and water samples from a number of wells in the area have also revealed elevated levels of radioactivity. The radioactivity was reported as gross-alpha particle activity.

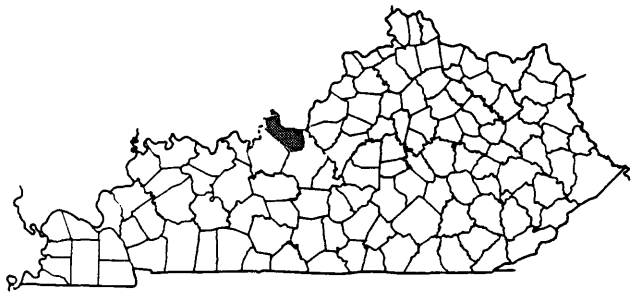
OBJECTIVE: To define the areal extent of chloride, oil and grease, and radionuclide contaminant plumes and map contaminant migration through the well field based on available and new data; identify potential and specific sources of these contaminants in the HCWD#1 supply wells; and determine the potential impact due to the presence of an identified contaminant plume(s) on wells drilled at selected sites within the aquifer boundary.

APPROACH: Compile, review, and evaluate available data on land- and water-use, wells, geology, hydrology, and ground-water quality. Supplement this available data with additional data obtained from well inventories, drilling of observation wells, and water-quality sampling. Conduct a surface geophysical survey (electro-magnetic) to indirectly delineate the areal extent of the chloride contamination plume.

PROGRESS: Field work was completed in early 1988 and a report will be published in 1989.

GROUND-WATER QUALITY AT SELECTED SITES IN MEADE COUNTY

LOCATION: Meade County



PERIOD OF PROJECT: October 1987 to September 1989

PRINCIPAL INVESTIGATOR: Donald S. Mull

FUNDING: Cooperative--Lincoln Trail District Health Department

PROBLEM: Use of an unregulated and unrecognized public-water supply, Buttermilk Falls Spring, resulted in an infectious hepatitis outbreak in Meade County in 1982. One person died and 69 became ill. Because of this event and the vulnerability of ground water to contamination in karst terrane, concern has been expressed as to the general perception that the quality of the ground-water resource in Meade County is unacceptable for individual-domestic water-supply use.

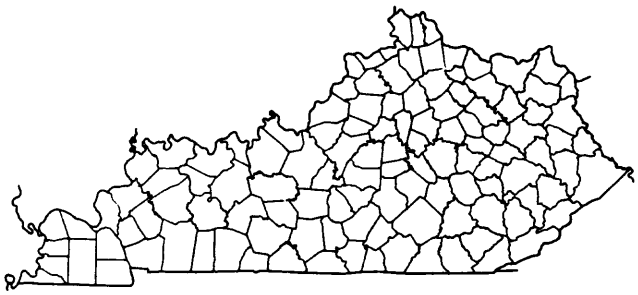
OBJECTIVE: To define the quality of water in the aquifers being used for private water supplies throughout the county.

APPROACH: Select sampling sites and collect water samples from springs and wells tapping the aquifers commonly used for domestic water supply in the county. Buttermilk Falls Spring will be included in the sampling program. Establish a one-year duration sampling program which optimizes areal coverage; spatial, temporal, and seasonal variability; and water-quality parameter coverage. Analyze data with respect to State and Federal drinking water criteria and standards.

PROGRESS: Field work was completed early in 1988 and a report will be published early in 1989.

SUPERFUND PROGRAM TECHNICAL ASSISTANCE PROGRAM

LOCATION: Sites located throughout the State



PERIOD OF PROJECT: Continuous since 1986

PRINCIPAL INVESTIGATOR: Donald S. Mull and Karen S. Wilson

FUNDING: Other Federal funds from the Environmental Protection Agency

PROBLEM: The EPA has responsibility for implementing the Superfund Amendments and Reauthorization Act (otherwise known as CERCLA, SARA, or Superfund) in Kentucky. At selected sites, EPA has requested technical assistance from the Survey in addressing hydrologic issues. Under a Memorandum of Agreement between the two Federal agencies, the Kentucky District is currently providing support during the remedial investigation and remedial action process at four sites in Jefferson, Hardin, and Fleming Counties, and has completed work at a site in Campbell County.

OBJECTIVE AND APPROACH: To provide a wide range of technical support to the EPA. Such support can include but not be limited to:

--Geologic coring, drilling of monitoring wells, and installation of piezometers;

--Soil, ground-water, and surface-water quality sampling;

--Water-level measurements, streamgaging, and surveying;

--Design, implementation, and interpretation of aquifer tests;

--Interpretation of site data and review of project work plans and technical reports;

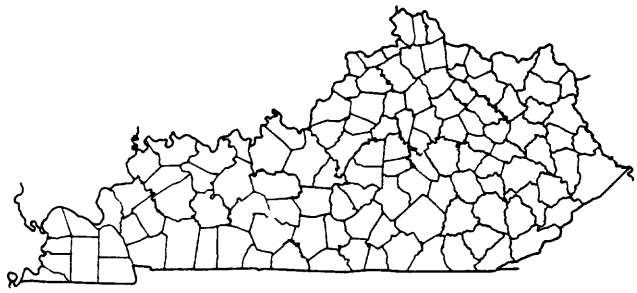
--Perform qualitative or quantitative dye traces to define directional trends or solute-transport characteristics of ground-water flow in karst and fractured-rock terranes;

--Assist EPA staff in overviewing the efforts of Principal Responsibile Parties during site investigation and remediation.

PROGRESS: Field investigations have been performed at the following sites: Distler Farm site in Jefferson County, Distler Brickyard site in Hardin County, and Newport Dump site in Campbell County. All field work was performed in conformance with EPA hazardous-waste site-safety requirements and quality-assurance protocols. Technical support, other than data collection is being provided at the Maxey Flats Radioactive Waste Burial Site in Fleming County and the Howe Valley Landfill Site in Hardin County.

KENTUCKY CONTROLLED AND UNCONTROLLED HAZARDOUS WASTE SITE TECHNICAL ASSISTANCE PROGRAM

LOCATION: Sites located throughout the State



PERIOD OF PROJECT: Continuous since 1982

PRINCIPAL INVESTIGATOR: Karen S. Wilson

FUNDING: Cooperative--KNREPC

PROBLEM: The Kentucky Division of Waste Management has the responsibility for implementing a program to prevent environmental degradation from controlled and uncontrolled hazardous and solid-waste storage, treatment, and disposal sites. As the lead agency for implementing the Federal Resource Conservation and Recovery Act (RCRA) and Kentucky's solid and hazardous waste statute (KRS 224), the Division has requested technical assistance from the Survey in addressing hydrologic issues.

OBJECTIVES AND APPROACH: To provide a wide range of technical support to the State. Such support can include but not be limited to:

--Geologic coring, drilling of monitoring wells, and installation of piezometers;

--Soil, ground-water, and surface water quality sampling;

--Water-level measurements, streamgaging, and surveying;

--Design, implementation, and interpretation of aquifer tests;

--Interpretation of site data and review of project work plans and technical reports;

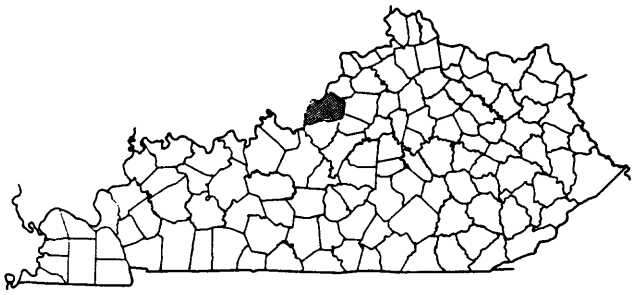
--Perform qualitative or quantitative dye traces to define directional trends or solute-transport characteristics of ground-water flow in karst and fractured rock terranes;

--Assist Division staff in overviewing the efforts of Principal Responsibile Parties during site investigation and remediation.

PROGRESS: Extensive field work is continuing at the Maxey Flats Radioactive Waste Burial Site in Fleming County. All field work is being performed in conformance with State and EPA site-safety and quality-assurance protocols. Technical support, other than field work, is being provided at RCRA and uncontrolled waste sites throughout the State.

WATER QUALITY OF THE STREAMS IN JEFFERSON COUNTY

LOCATION: Jefferson County



PERIOD OF PROJECT: January 1988 to January 1990

PRINCIPAL INVESTIGATOR: Kevin J. Ruhl

FUNDING: Cooperative--Louisville and Jefferson County Metropolitan Sewer District (MSD)

PROBLEM: The quality of water in many streams and drainage channels in Jefferson County is potentially impacted by a variety of urban developments, including septic-tank leachate, sewage treatment plant discharges, urban stormwater runoff, agricultural and lawn chemical applications, and landfill-leachate discharges. In order to effectively manage the surface-water resource in the County, it is necessary to develop a clear understanding of the hydraulics and present water-quality conditions of the major streams and watersheds in Jefferson County.

OBJECTIVES: To determine the current water-quality conditions in select streams throughout the range of flow conditions and seasons; identify problem stream segments requiring further study, including those segments being impacted by point and non-point sources of pollution; establish streamflow information (discharge) for selected streams; and provide a data base for addressing the wide variety of hydrologic and environmental issues.

APPROACH: Establish a network within the County for obtaining continuous and instantaneous streamflow and water-quality data at selected locations. The location of the network sites is shown in figure 15, and a listing of the sites is given in table 3. Data collection responsibilities are shared by MSD and the Survey.

PROGRESS: The sampling network became operative February 1, 1988. Data collected during the 1988 water year will be published in the annual data report. Data is actively being used by MSD and the Survey to address water-resource issues in the metropolitan area. A parallel ecological study is being conducted by MSD under a grant from the Virginia Environmental Endowment.

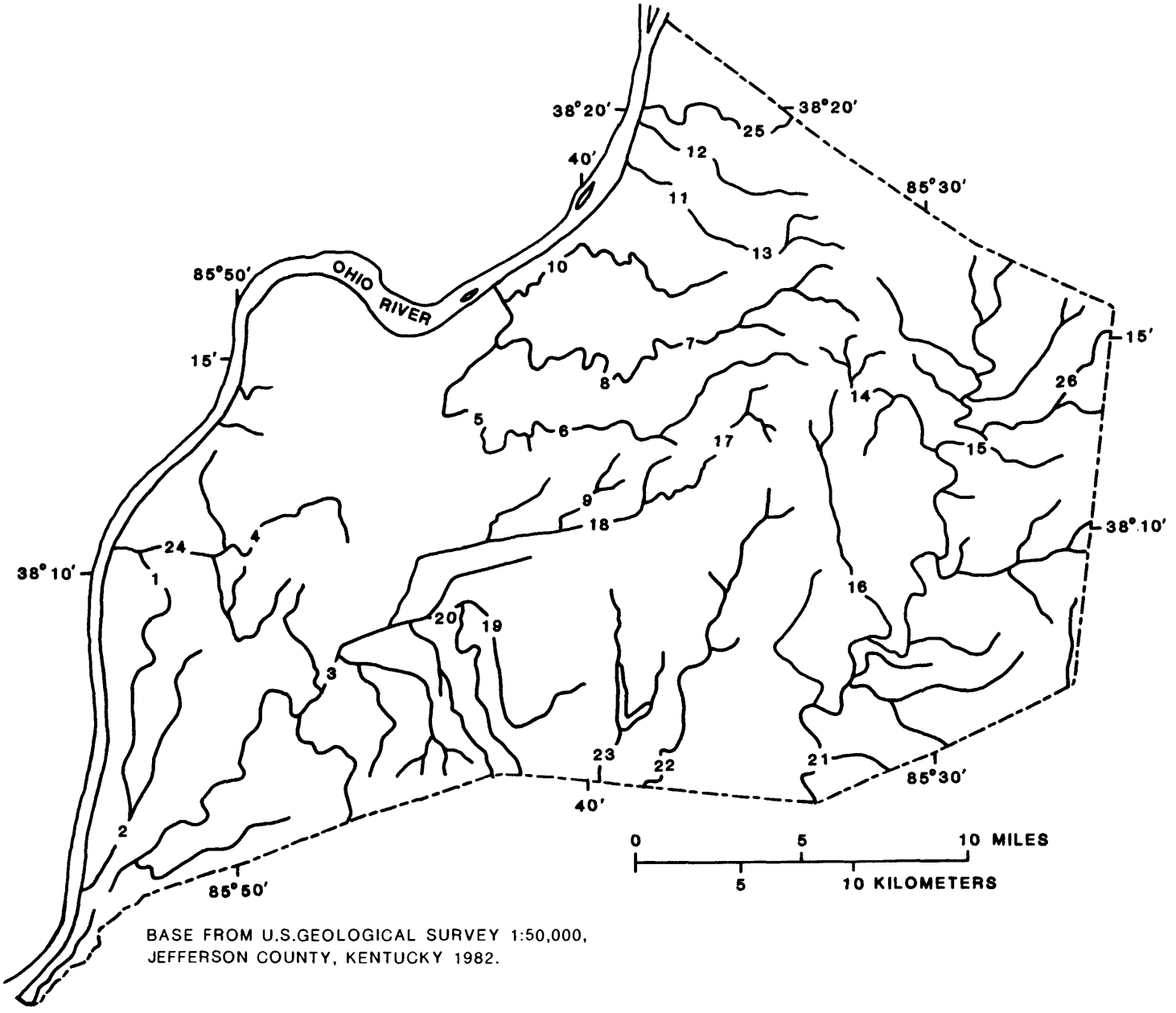


Figure 16.--Sampling stations on streams in Jefferson County. (Map number refers to table 5).

Table 5.--Sampling stations on streams in Jefferson County, Kentucky

Map number	Station number	Station name
1	03302030	Pond Creek at Pendleton Road near Louisville
2	03294570	Mill Creek at Orell Road near Louisville
3	03302000	Pond Creek near Louisville (at Manslick Road - Gaging Station)
4	03294520	Mill Creek at Rockford Lane at Shively (DISCONTINUED)
5	03292550	South Fork Beargrass Creek at Winter Avenue at Louisville
6	03292500	South Fork Beargrass Creek at Trevilian Way at Louisville (Gaging Station)
7	03293000	Middle Fork Beargrass Creek at Old Cannons Lane at Louisville (Gaging Station)
8	03293200	Middle Fork Beargrass Creek at Beals Branch Road at Louisville
9	03301950	Spring Ditch at Private Drive below Hanses Drive near Okolona
10	03293530	Muddy Fork at Mockingbird Valley Road at Louisville
11	03292475	Goose Creek at U.S. Hwy 42 near Glenview Acres
12	03292480	Little Goose Creek near Harrods Creek
13	03292474	Goose Creek at Old Westport Road
14	03298100	Pope Lick at Pope Lick Road near Middletown
15	03298000	Floyds Fork at Fisherville (Gaging Station, No Mini-Monitor)
16	03298150	Chenoweth Run at Gelhaus Lane near Fern Creek
17	03301900	Fern Creek at Old Bardstown Road
18	03301940	Northern Ditch at Okolona (at Preston Highway)
19	03301850	Fishpool Creek at Bost Road at Okolona
20	03301880	Southern Ditch at Minors Lane near Okolona
21	03298200	Floyds Fork near Mount Washington (at Bardstown Road)
22	03298250	Cedar Creek at Thixton Road near Louisville
23	03298300	Pennsylvania Run at Mt. Washington Road near Louisville
24	03294550	Mill Creek Cutoff near Louisville (at Hwy 1230 - Cane Run Road - Gaging Station)
25	03292473	Harrods Creek near Prospect (Grab Samples Only)
26	03297980	Long Run near Fisherville

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Appendix 1

Surface-water stations in Kentucky in 1988 and type of data collected

[Letters after station name designate type of data: (d) discharge, (c) chemical, (b) biological (t) water temperature, (s) sediment]

	Station number in figures 10 and 15
OHIO RIVER BASIN	
Ohio River:	
BIG SANDY RIVER BASIN	
Levisa Fork (head of Big Sandy River):	
Levisa Fork below Fishtrap Dam, near Millard (d)	208000
Russell Fork at Haysi, VA (d)	208500
Russell Fork at Elkhorn City (d)	209300
Levisa Fork at Pikeville (d)	209500
Johns Creek near Meta (d)	210000
Johns Creek near Van Lear (d)	211500
Levisa Fork at Paintsville (d)	212500
Big Sandy River at Louisa (c,b,s)	215000
LITTLE SANDY RIVER BASIN	
Little Sandy River below Grayson Dam, near Leon (d)	216350
Little Sandy River at Grayson (d)	216500
East Fork Little Sandy River near Fallsburg (d)	216540
Ohio River at Greenup Dam (d)	216600
TYGARTS CREEK BASIN	
Tygarts Creek at Olive Hill (d)	216800
Tygarts Creek near Greenup (d)	217000
CABIN CREEK BASIN	
Cabin Creek near Tollesboro (d)	237900
LICKING RIVER BASIN	
Licking River near Salyersville (d)	248500
Licking River at Farmers (d,t)	249500
North Fork Triplett Creek near Morehead (d)	250100
North Fork Licking River near Lewisburg (d)	251000
Licking River at McKinneysburg (d)	251500
Stoner Creek (head of South Fork Licking River) at Paris (d)	252000
South Fork Licking River at Cynthiana (d)	252500
Licking River at Catawba (d)	253500
Licking River at Butler (c,b,s)	254000
Ohio River at Markland Dam (d)	277200
KENTUCKY RIVER BASIN	
North Fork Kentucky River (head of Kentucky River):	
Carr Fork near Sassafras (d)	277450
North Fork Kentucky River at Hazard (d)	277500
North Fork Kentucky River at Jackson (d,c,s)	280000
Middle Fork Kentucky River near Hyden (d)	280600
Cutshin Creek at Wooton (d)	280700
Middle Fork Kentucky River at Tallega (d,c,s)	281000
Kentucky River:	
Red Bird River (head of South Fork Kentucky River) near Big Creek (d)	281040
Goose Creek at Manchester (d)	281100
South Fork Kentucky River at Booneville (d,c,s)	281500
Kentucky River at lock 14, at Heidelberg (d)	282000
Red River near Hazel Green (d)	282500
Red River at Clay City (d)	283500
Kentucky River at lock 10, near Winchester (d,c,b,s)	284000
Dix River near Danville (d)	285000
Kentucky River at lock 6, near Salvisa (d)	287000
Kentucky River at lock 4, at Frankfort (d,c,s)	287500
Elkhorn Creek:	
South Elkhorn Creek at Fort Spring (d)	289000
South Elkhorn Creek near Midway (d)	289300
Elkhorn Creek near Frankfort (c,b,s)	289500
Kentucky River at lock 2, at Lockport (d,c,b,t,s)	290500
HARRODS CREEK BASIN	
Harrods Creek near La Grange (d)	292460
BEARGRASS CREEK BASIN	
Middle Fork Beargrass Creek at Louisville (d)	293000
Ohio River at Louisville (d)	294500
SALT RIVER BASIN	
Brashears Creek at Taylorsville (d)	295890
Floyds Fork:	
Floyds Fork near Crestwood (d)	297845
Floyds Fork at Fisherville (d)	298000
Salt River at Shepherdsville (d,c,b,s)	298500
Rolling Fork near Lebanon (d)	299000
Beech Fork at Maud (d)	300400
Rolling Fork near Boston (d)	301500
Rolling Fork near Lebanon Junction (c,b,s)	301630
Pond Creek near Louisville (d)	302000
Ohio River at Cannelton Dam (d)	303280
GREEN RIVER BASIN	
Green River near Campbellsville (d,t)	306000
Russell Creek near Columbia (d)	307000
Green River at Munfordville (d,c,b,t,s)	308500
Nolin River at White Mills (d)	310300
Bacon Creek near Priceville (d)	310400
Nolin River at Kyrock (d)	311000

Surface-water stations in Kentucky in 1988 and type of data collected--Continued

	Station number in figures 10 and 15
OHIO RIVER BASIN--Continued	
GREEN RIVER BASIN--Continued	
Ohio River--Continued	
Green River at lock 6, at Brownsville (d)	311500
Beaverdam Creek at Rhoda (d)	311600
Barren River near Finney (d)	313000
West Fork Drakes Creek (head of Drakes Creek) near Franklin (d)	313700
Barren River at Bowling Green (d)	314500
Green River at lock 4, at Woodbury (d)	315500
Rough River at Falls of Rough (d)	318500
Caney Creek near Horse Branch (d)	318800
Green River at lock 2, at Calhoun (d)	320000
Pond River near Apex (d)	320500
Ohio River at Evansville, IN (d)	322000
HIGHLAND CREEK BASIN	
Highland Creek:	
Beaverdam Creek near Corydon (d)	322360
Ohio River at Uniontown Dam (d)	322420
TRADEWATER RIVER BASIN	
Tradewater River at Olney (d)	383000
CUMBERLAND RIVER BASIN	
Poor Fork (head of Cumberland River) at Cumberland (d)	400500
Martins Fork above Smith (d,s)	400785
Martins Fork Lake at Martins Fork Dam near Smith (c,t)	400798
Martins Fork near Smith (d,c,t)	400800
Clover Fork at Harlan (d,s)	400990
Cumberland River near Harlan (d)	401000
Bennett's Fork at Middlesboro (d,s)	401428
Stoney Fork near mouth at Middlesboro (d,s)	401450
Yellow Creek near Middlesboro (d,s)	402000
Cumberland River near Pineville (d,s)	403000
Cumberland River at Barbourville (d,s)	403500
Clear Fork at Saxton (d)	403910
Cumberland River at Williamsburg (d,s)	404000
Cumberland River at Cumberland Falls (d,s,c,t)	404500
Laurel River at Municipal Dam near Corbin (d)	404820
Lynn Camp Creek at Corbin (d)	404900
Rockcastle River at Billows (d)	406500
Buck Creek near Shopville (d)	407500
South Fork Cumberland River near Stearns (d,c,s,t)	410500
Cumberland River near Rowena (d)	414000
Red River:	
Whippoorwill Creek near Claymour (d)	435140
Little River near Cadiz (d)	438000
Barkley-Kentucky Canal near Grand Rivers (d)	438190
Cumberland River near Grand Rivers (d)	438220
TENNESSEE RIVER BASIN	
Clarks River at Almo (d)	610200
MASSAC CREEK BASIN	
Massac Creek near Paducah (d)	611260
Ohio River at Metropolis, IL (d)	611500
Ohio River at lock and dam 53, near Grand Chain, IL (c,t,s)	612500
LOWER MISSISSIPPI RIVER BASIN	
Bayou De Chien near Clinton (d)	024000

Appendix 2

Observation wells in Kentucky in 1988

Well	Local number or owner	Map number in figures 11 and 12	R=wells equipped with recorder
JEFFERSON COUNTY			
380122085545001	80-1	1	
380252085530601	79-3	2	
380308085533501	79-4	3	
380341085534501	83-1	4	
380423085541501	2	5	
380434085525101	E-1-d	6	
380517085535201	77-1	7	
380532085515301	51-5-2, (76-1)	8	
380606085531301	53-6-1, (RR-46)	9	R
380616085532801	53-6-4, (TW-3)	10	
380637085521301	D-1-d	11	
380709085531101	C-5-d	13	
380715085512001	C-2-d	14	
380716085521801	52-7-2, (RR-47)	15	
380718085515802	C-3-s	16	
380718085524202	C-4-m	17	
380755085510701	78-4	18	
380816085520701	52-8-1	19	
380843085530701	B-3-d	20	
380843085522801	B-2-d	21	
380846085520101	B-1-d	22	
380850085534701	78-2	23	
380852085515901	51-8-1	24	
380940085514001	81-1	25	
380955085531801	83-2	26	
381032085525601	78-3	27	
381034085502601	50-10-2, (RR-30)	28	R
381050085511001	51-10-1, (RR-29)	29	
381102085512102	51-11-2	30	
381108085511301	51-11-4, (RR-31)	31	
381123085491401	49-11-1, (RR-32)	33	
381130085515001	51-11-1	35	
381139085502301	81-2	36	
381142085475702	47-11-4, (RR-42)	37	
381143085465801	46-11-2, (RR-25)	38	
381155085483401	48-11-1	39	
381157085510201	51-11-6, (RR-39)	40	
381204085455301	CP-16	41	
381207085484601	48-12-15, (RR-41)	42	
381209085472101	47-12-3, (C-7)	43	
381212085473801	47-12-2, (C-6)	44	
381213085521701	52-12-2, (RR-22)	45	
381221085475001	47-12-1, (C-5)	46	
381222085505201	50-12-16, (RR-27)	47	R
381224085474001	47-12-19, (Early Times #1)	48	
381229085510201	Triangle Refinery #1	49	
381246085470601	47-12-4, (Seagrams TW #2)	50	R
381250085484901	48-12-1, (C-2)	51	
381251085483501	48-12-2, (C-3)	52	
381251085500501	50-12-18, (RR-35)	53	
381256085471501	47-12-14, (TW-2)	54	
381257085471801	47-12-15, (TW-4)	55	
381259085471502	47-12-16, (TW-1)	56	
381259085511002	51-13-1, (RR-21)	57	
381305085501302	Reynolds Metals #1	58	
381309085505302	50-13-56, (RR-24)	59	
381313085495501	49-13-25, (TW-2)	60	
381315085501401	50-13-65, (TW-11)	61	
381315085502602	50-13-79, (NC-TW-D)	62	R
381316085502101	50-13-77, (TW-12)	63	
381320085464101	CP-15	64	
381324085460401	46-13-25, (Amer. Std.)	65	
381331085491601	49-13-40, (RR-26)	66	
381332085494001	49-13-5, (TW-10)	67	
381338085481601	CP-8	68	
381346085453801	45-13-2, (St. Patricks well)	69	
381346085454201	CP-1	70	
381355085465901	46-13-34, (Lou. Cooperage)	71	
381400085445001	CP-61	72	
381406085463001	78-1	73	
381417085500301	50-14-4, (RR-23)	74	
381424085454602	CP-12A	75	
381428085485701	78-6	76	
381430085452602	45-14-69, (Conna #3)	77	

Well	Local number or owner	Map number in figures 11 and 12	R=wells equipped with recorder
JEFFERSON COUNTY Cont.			
381430085472501	CP-17	78	
381441085465301	46-14-13, (Bernheim #3)	79	
381441085452701	45-14-71, (A-2)	80	R
381447085454001	45-14-66, (CJ&T #5)	81	R
381453085474501	47-14-10, (Kroger)	82	
381500085454701	78-5	84	
381501085464601	CP-10	85	
381503085453301	45-15-36, (Ky. Towers)	86	
381503085452601	Stewart's #5	87	
381504085443202	CP-7A	88	
381505085475701	CP-5	89	
381508085455701	CP-4	90	
381514085453502	CP-11A	91	R
381536085492801	CP-2	92	
381538085434401	78-7	93	
381539085465201	CP-9	94	
381540085443701	44-15-6, (M&M #1)	95	
381543085480101	CP-14	96	
381553085431602	M-2	97	
381604085430501	43-16-8, (WC-1)	98	
381607085483601	CP-3	99	
381613085421901	42-16-18, (WC-14)	100	
381628085473101	CP-13	101	
381638085415801	41-16-3, (WC-4)	102	R
381648085421201	42-16-15, (WC-5)	103	
381653085413302	WC-9A	104	
381701085414002	WC-8A	105	
381722085405801	40-17-3, (WC-11)	106	
381742085402001	40-17-5, (WC-13)	107	
381827085392401	39-18-1, (WC-26)	108	
381904085384801	38-19-2, (WC-27)	109	
380458085523201	86-4	110	
380619085512301	86-3	111	
380827085503001	86-5	112	
381011085491601	86-1	113	
381102085485601	86-2	114	
381247085463301	CP-18	115	
381246085463201	CP-18A	116	
381517085455501	86-6	117	R
381527085453001	86-7	118	R
381524085452301	86-8	119	R
381528085454201	86-9	120	R
381518085454401	86-10	121	R
381518085453402	86-11	122	R
381518085451801	87-1	123	R

		Map number in figure 13	
HARDIN COUNTY			
375948085574801	2	1	
375958085575401	1	2	
374035085525401	OW-1-82	3	R
374037085524801	TW-2-82	4	R
374046085523501	OW-1-81	5	R

		Map number in figure 14
CALLOWAY COUNTY		
363634088191601	Joe Parks	1
CHRISTIAN COUNTY		
365142087270401	Western State Hospital	2
ELLIOTT COUNTY		
380425083091901	Roy Adkins	3
FAYETTE COUNTY		
375928084362001	M.A. Kehrt	4
FRANKLIN COUNTY		
382031084553901	Harp Road Test Well	5
GRAVES COUNTY		
365210088391301	J. Whittemore	6

Observation wells in Kentucky in 1988--Continued

Well	Local number or owner	Map number in figure 14	R=wells equipped with recorder
GRAYSON COUNTY			
372822086165801	City of Leitchfield	7	
HENDERSON COUNTY			
374441087421001	Town of Corydon	8	
LARUE COUNTY			
374151085413201	George Kennedy	9	
LAUREL COUNTY			
370757084045001	J.R. Hale	10	
FLETCHER COUNTY			
371033082374301	Chesapeake & Ohio Railroad Co.	11	
LINCOLN COUNTY			
372739084402101	Omer Lewis	12	
LOGAN COUNTY			
365046086444901	W.D. Appling	13	
MCCRACKEN COUNTY			
370551088510401	State of Kentucky	14	
METCALFE COUNTY			
370211085364301	Alec Russell	15	
WARREN COUNTY			
3703420860801	Earl Estes	16	