UNITED STATES DEPARTMENT OF THE INTERIOR

MANUEL LUJAN, JR., Secretary

GEOLOGICAL SURVEY

Dallas L. Peck, Director

For additional information write to:

District Chief
U.S. Geological Survey
2301 Bradley Avenue
Louisville, Kentucky 40217

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U.S. Geological Survey
Books and Open-File Reports
Box 25425
Federal Center, Building 810
Denver, Colorado 80225
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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 interrelation.

* 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.

Kentucky District of the Water Resources Division

Organization

OFFICE OF THE DISTRICT CHIEF
Alfred L. Knight

Administrative Services Section
C. Regina Haynes

Hydrologic Surveillance and Data Management Section
James M. Bettandorff

Hydrologic Investigations Section
Lloyd H. Woosley, Jr.

Paducah Field Headquarters
Williamsburg Field Headquarters
Prestonsburg Field Headquarters

Kentucky District Addresses

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

<table>
<thead>
<tr>
<th>Location</th>
<th>Phone</th>
<th>Address</th>
</tr>
</thead>
</table>
| 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        | (606) 549-2406 | U.S. Geological Survey
Headquarters              |              | P.O. Box 1028                                                          |
                          |              | Jackson Mall Office Building                                           |
                          |              | Office #2, Highway 25-W                                                 |
                          |              | Williamsburg, Kentucky 40769                                           |
| Prestonsburg Field        | (606) 886-9432 | U.S. Geological Survey
Headquarters              |              | HCR 70, Box 540                                                       |
                          |              | Van Lear, Kentucky 41265                                               |
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:

**STATE AND LOCAL AGENCIES**

- University of Louisville 17 percent
- Louisville-Jefferson Co. MSD 9 percent
- Jefferson County 4 percent
- Lincoln Trail District Health Department 2 percent
- Hardin County Warter District 8 percent
- City of Elizabethtown 1 percent
- Kentucky Geological Survey 31 percent
- KNREPC 28 percent
- Kentucky Natural Resources and Environmental Protection Cabinet

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:

**Cooperative Program** 45 percent

- Federal Program 31 percent
- Other Federal Agencies 24 percent

**OTHER FEDERAL AGENCIES**

- Corps of Engineers 70 percent
- Federal Energy Regulatory Commission 1 percent
- Tennessee Valley Authority 1 percent
- Office of Surface Mining Reclamation and Enforcement 4 percent
- Environmental Protection Agency 25 percent
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

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<th>Mean Daily Streamflow in cubic feet per second</th>
<th>Mean Percent of average</th>
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<th>Mean Recurrence interval (years)</th>
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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

<table>
<thead>
<tr>
<th>Station number</th>
<th>PR Period of record</th>
<th>N Number of samples</th>
<th>X Mean of the ranks</th>
<th>s Standard deviation of the ranks</th>
<th>Prob&gt;T Probability of a difference of means</th>
<th>T Test result</th>
<th>Test result at test alpha level with pooled N-2 degrees of freedom</th>
</tr>
</thead>
<tbody>
<tr>
<td>03215000</td>
<td>1:2</td>
<td>53</td>
<td>38.46</td>
<td>23.63</td>
<td>2.6478</td>
<td>0.0097</td>
<td>1.9883</td>
</tr>
<tr>
<td></td>
<td></td>
<td>34</td>
<td>52.63</td>
<td>25.45</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2:3</td>
<td>34</td>
<td>18.75</td>
<td>11.01</td>
<td>2.3925</td>
<td>0.0218</td>
<td>2.0244</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6</td>
<td>30.42</td>
<td>11.02</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>03612500</td>
<td>2:3</td>
<td>30</td>
<td>17.12</td>
<td>10.54</td>
<td>4.0345</td>
<td>0.0002</td>
<td>2.0227</td>
</tr>
<tr>
<td></td>
<td></td>
<td>11</td>
<td>31.39</td>
<td>9.04</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Water-quality constituent</th>
<th>Sample size</th>
<th>Maximum</th>
<th>Minimum</th>
<th>Mean</th>
<th>Median</th>
<th>75</th>
<th>50</th>
<th>25</th>
<th>PR</th>
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</thead>
<tbody>
<tr>
<td>03215000</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sulfate dissolved (mg/L AS SO₄)</td>
<td>53</td>
<td>180.000</td>
<td>46.000</td>
<td>95.453</td>
<td>110.000</td>
<td>93.000</td>
<td>77.000</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>34</td>
<td>190.000</td>
<td>67.000</td>
<td>115.676</td>
<td>140.000</td>
<td>110.000</td>
<td>85.000</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>200.000</td>
<td>96.000</td>
<td>158.333</td>
<td>190.000</td>
<td>175.000</td>
<td>120.000</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>NO₂ + NO₃ dissolved (mg/L AS N)</td>
<td>29</td>
<td>1.300</td>
<td>.010</td>
<td>.451</td>
<td>.490</td>
<td>.410</td>
<td>.310</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>28</td>
<td>.800</td>
<td>.185</td>
<td>*.456</td>
<td>*.565</td>
<td>*.480</td>
<td>*.300</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Phosphorous total (mg/L AS P)</td>
<td>55</td>
<td>.360</td>
<td>.020</td>
<td>.080</td>
<td>.090</td>
<td>.050</td>
<td>.030</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>.190</td>
<td>.007</td>
<td>*.048</td>
<td>*.050</td>
<td>*.040</td>
<td>*.020</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>.180</td>
<td>.020</td>
<td>.062</td>
<td>.060</td>
<td>.040</td>
<td>.020</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Residue of dissolved solids at 180° Celsius (mg/L)</td>
<td>54</td>
<td>411.000</td>
<td>112.000</td>
<td>245.278</td>
<td>308.000</td>
<td>228.000</td>
<td>182.000</td>
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<tr>
<td></td>
<td>35</td>
<td>445.000</td>
<td>131.000</td>
<td>286.400</td>
<td>354.000</td>
<td>282.000</td>
<td>209.500</td>
<td>2</td>
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<tr>
<td></td>
<td>6</td>
<td>482.000</td>
<td>227.000</td>
<td>373.333</td>
<td>437.000</td>
<td>408.500</td>
<td>275.000</td>
<td>3</td>
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<td>03612500</td>
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<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sulfate dissolved (mg/L AS SO₄)</td>
<td>40</td>
<td>75.000</td>
<td>26.000</td>
<td>44.475</td>
<td>52.000</td>
<td>43.500</td>
<td>37.000</td>
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<td>30</td>
<td>62.000</td>
<td>29.000</td>
<td>46.233</td>
<td>53.000</td>
<td>48.000</td>
<td>40.000</td>
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<tr>
<td></td>
<td>12</td>
<td>88.000</td>
<td>41.000</td>
<td>59.750</td>
<td>62.500</td>
<td>56.000</td>
<td>54.500</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>NO₂ + NO₃ dissolved (mg/L AS N)</td>
<td>31</td>
<td>2.800</td>
<td>.320</td>
<td>1.045</td>
<td>1.350</td>
<td>.900</td>
<td>.675</td>
<td>1</td>
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<tr>
<td></td>
<td>29</td>
<td>2.500</td>
<td>.210</td>
<td>1.152</td>
<td>1.500</td>
<td>1.100</td>
<td>.770</td>
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<tr>
<td></td>
<td>6</td>
<td>1.900</td>
<td>.320</td>
<td>.937</td>
<td>1.400</td>
<td>.835</td>
<td>.330</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Phosphorous total (mg/L AS P)</td>
<td>52</td>
<td>.470</td>
<td>.050</td>
<td>.153</td>
<td>.180</td>
<td>.135</td>
<td>.080</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>.370</td>
<td>.020</td>
<td>.113</td>
<td>.150</td>
<td>.110</td>
<td>.060</td>
<td>2</td>
<td></td>
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<tr>
<td></td>
<td>10</td>
<td>.470</td>
<td>.030</td>
<td>.131</td>
<td>.120</td>
<td>.060</td>
<td>.050</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Residue of dissolved solids at 180° Celsius (mg/L)</td>
<td>39</td>
<td>265.000</td>
<td>128.000</td>
<td>184.923</td>
<td>207.000</td>
<td>184.000</td>
<td>150.500</td>
<td>1</td>
<td></td>
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<tr>
<td></td>
<td>30</td>
<td>223.000</td>
<td>124.000</td>
<td>180.000</td>
<td>197.000</td>
<td>184.000</td>
<td>159.000</td>
<td>2</td>
<td></td>
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<tr>
<td></td>
<td>6</td>
<td>243.000</td>
<td>175.000</td>
<td>196.500</td>
<td>196.000</td>
<td>190.000</td>
<td>185.000</td>
<td>3</td>
<td></td>
</tr>
</tbody>
</table>

* 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.
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.

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.

EXPLANATION
Range, in million gallons per day (Mgal/d)
- 0.04 - 1.00
- 1.01 - 2.50
- 2.51 - 10.00
- 10.01 - 986.16

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.
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
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.
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.
Figure 11.—Location of observation wells in Jefferson County.
OHIO RIVER Normal pool altitude 420 feet above sea level

EXPLANATION

Ο7О OBSERVATION WELL AND NUMBER
Ο91 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.
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 concentration 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.
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."
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.
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.
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.
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.
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.
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.
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

PRINCIPAL 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.
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.
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.
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, groundwater 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 groundwater flow in karst and fractured-rock terranes;

--Assist EPA staff in overviewing the efforts of Principal Responsible 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 Responsible 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

<table>
<thead>
<tr>
<th>Map number</th>
<th>Station number</th>
<th>Station name</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>03302030</td>
<td>Pond Creek at Pendleton Road near Louisville</td>
</tr>
<tr>
<td>2</td>
<td>03294570</td>
<td>Mill Creek at Orell Road near Louisville</td>
</tr>
<tr>
<td>3</td>
<td>03302000</td>
<td>Pond Creek near Louisville (at Manslick Road - Gaging Station)</td>
</tr>
<tr>
<td>4</td>
<td>03294520</td>
<td>Mill Creek at Rockford Lane at Shively (DISCONTINUED)</td>
</tr>
<tr>
<td>5</td>
<td>03292550</td>
<td>South Fork Beargrass Creek at Winter Avenue at Louisville (Gaging Station)</td>
</tr>
<tr>
<td>6</td>
<td>03292500</td>
<td>South Fork Beargrass Creek at Trevilian Way at Louisville (Gaging Station)</td>
</tr>
<tr>
<td>7</td>
<td>03293000</td>
<td>Middle Fork Beargrass Creek at Old Cannons Lane at Louisville (Gaging Station)</td>
</tr>
<tr>
<td>8</td>
<td>03293200</td>
<td>Middle Fork Beargrass Creek at Beals Branch Road at Louisville</td>
</tr>
<tr>
<td>9</td>
<td>03301950</td>
<td>Spring Ditch at Private Drive below Hanses Drive near Okolona</td>
</tr>
<tr>
<td>10</td>
<td>03293530</td>
<td>Muddy Fork at Mockingbird Valley Road at Louisville</td>
</tr>
<tr>
<td>11</td>
<td>03292475</td>
<td>Goose Creek at U.S. Hwy 42 near Glenview Acres</td>
</tr>
<tr>
<td>12</td>
<td>03292480</td>
<td>Little Goose Creek near Harrods Creek</td>
</tr>
<tr>
<td>13</td>
<td>03292474</td>
<td>Goose Creek at Old Westport Road</td>
</tr>
<tr>
<td>14</td>
<td>03298100</td>
<td>Pope Lick at Pope Lick Road near Middletown</td>
</tr>
<tr>
<td>15</td>
<td>03298000</td>
<td>Floyds Fork at Fisherville (Gaging Station, No Mini-Monitor)</td>
</tr>
<tr>
<td>16</td>
<td>03298150</td>
<td>Chenoweth Run at Gelhaus Lane near Fern Creek</td>
</tr>
<tr>
<td>17</td>
<td>03301900</td>
<td>Fern Creek at Old Bardstown Road</td>
</tr>
<tr>
<td>18</td>
<td>03301940</td>
<td>Northern Ditch at Okolona (at Preston Highway)</td>
</tr>
<tr>
<td>19</td>
<td>03301850</td>
<td>Fishpool Creek at Bost Road at Okolona</td>
</tr>
<tr>
<td>20</td>
<td>03301880</td>
<td>Southern Ditch at Minors Lane near Okolona</td>
</tr>
<tr>
<td>21</td>
<td>03298200</td>
<td>Floyds Fork near Mount Washington (at Bardstown Road)</td>
</tr>
<tr>
<td>22</td>
<td>03298250</td>
<td>Cedar Creek at Thixton Road near Louisville</td>
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<tr>
<td>23</td>
<td>03298300</td>
<td>Pennsylvania Run at Mt. Washington Road near Louisville</td>
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<tr>
<td>24</td>
<td>03294550</td>
<td>Mill Creek Cutoff near Louisville (at Hwy 1230 - Cane Run Road - Gaging Station)</td>
</tr>
<tr>
<td>25</td>
<td>03292473</td>
<td>Harrods Creek near Prospect (Grab Samples Only)</td>
</tr>
<tr>
<td>26</td>
<td>03297980</td>
<td>Long Run near Fisherville</td>
</tr>
</tbody>
</table>
Selected references on water resources in Kentucky are listed below; many of them are available for reference at the Survey office in Louisville or the Kentucky Geological Survey office in Lexington and at larger public and university libraries. The publications are grouped as follows: (1) Survey publications that (a) can be obtained from the Survey, (b) are released to the open file and can be inspected at specific offices, and (c) can be obtained only from NTIS; (2) reports prepared by the Survey in cooperation with specific agencies and published by the cooperating agencies, and (3) other publications such as technical journal article reprints. New reports published by the Survey are announced monthly in "New Publications of the Geological Survey." Subscriptions to this monthly list are available free on request to the U.S. Geological Survey, 329 National Center, Reston, Virginia 22092.

Survey PROFESSIONAL PAPERS

Professional papers are sold by the U.S. Geological Survey, Books and Open-File Reports, Box 25425, Federal Center, Building 810, Denver, Colorado 80225.


813-A. Summary appraisal of the Nation’s ground-water resources-Ohio Region, by R.N. Bloyd, Jr., 1974.
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1356. Geology and ground-water resources of the Henderson area, Kentucky, by E.J. Harvey, 1956.

1359. Geology and ground-water resources of the Prestonsburg quadrangle, Kentucky, by W.E. Price, Jr., 1956.

1360-B. Ground water in northeastern Louisville, Kentucky, by M.I. Rorabaugh, 1956.


1411. The deep channel and alluvial deposits of the Ohio Valley in Kentucky, by E.H. Walker, 1957.

Survey WATER-SUPPLY PAPERS--Continued


1798-G. Sedimentation in Plum Creek Subwatershed No. 4, Shelby County, North-Central Kentucky, by Peter W. Anttila, 1970.


1819-C. Summary of hydrologic conditions of the Louisville area, Kentucky, by E.A. Bell, 1965.


Survey WATER-SUPPLY PAPERS--Continued


Survey CIRCULARS

Single copies of circulars still in print are available free from the above-listed Denver, Colorado address.

240. Geology and ground-water resources of the Covington-Newport alluvial area, Kentucky, by E.H. Walker, 1953.


Survey CIRCULARS--Continued

526. Stream quality in Appalachia as related to coal-mine
554. Hydrology for urban land planning--a guidebook on the
hydrologic effects of urban land use, by L.B. Leopold, 1968.
556. Estimated use of water in the United States, 1965, by C.R.
601-A. Water for the cities--the outlook, by W.J. Schneider and A.M.
Speiker, 1969.
601-D. Water as an urban resource and nuisance, by H.E. Thomas and
W.J. Schneider, 1970.
601-E. Sediment problems in urban areas, by H. P. Guy, 1970
601-F. Hydrologic implications of solid-waste disposal, by W.J.
Schneider, 1970.
601-H. Role of water in urban planning and management, by W.J.
601-I. Water facts and figures for planners and managers, by J.H.
601-J. Extent and development of urban flood plains, by W.J.
Schneider and J.E. Goddard, 1974.
631. Disposal of liquid wastes, by injection underground--neither
myth or millenium, by A.M. Piper, 1969.
643. Reconnaissance of selected minor elements in surface water of
the United States, October 1970, by W.H. Durum, J.D. Hem, and
645. A procedure for evaluating environmental impact, by L.B.
Leopold and others, 1971.
670. Fluvial-sediment discharge to the oceans from the
conterminous United States, by W.F. Curtis, J.K. Culbertson,
676. Estimated use of water in the United States in 1970, by C.R.
Murray and E.B. Reeves, 1972.
685. Dissolved-solids discharge to the oceans from the
703. Water demands for expanding energy development, by G.H. Davis
719. The National Stream Quality Accounting Network (NASQAN)--some
questions and answers, by J.F. Ficke and R.O. Hawkinson,
1975.
765. Estimated use of water in the United States in 1975, by C.R.
Murray and E.B. Reeves, 1977.
1001. Estimated use of water in the United States in 1980, by W.B.
Survey HYDROLOGIC INVESTIGATIONS ATLASES

Hydrologic Investigations Atlases and other maps are sold by the U.S. Geological Survey, Map Distribution, Federal Center, Building 810, Box 25286, Denver, Colorado 80225.


72 to 75. Geology and hydrology of alluvial deposits between the *** areas, Ohio River Valley, Ky., 1963-64. 72, Hawesville and Cloverport areas. 73, South Portsmouth and Manchester Islands. 74, Lewisport and Owensboro. 75, Cattlesburg and South Portsmouth.

91. Geology and hydrology of alluvial deposits along the Ohio River in the Henderson area, Ky., 1964, by J.T. Gallagher.

92, 93. Availability of ground water in the *** quadrangle, Jackson Purchase region, Ky., 1964. 92, Farmington. 93, Dexter.

94 to 98. Geology and hydrology of alluvial deposits between the *** areas, Ohio River valley, Ky., 1964. 94, Manchester Islands and Silver Grove. 95, Wolf Creek and West Point. 96, Spottsville and Reed. 97, Ethridge and Twelvemile Island. 98, Newport and Warsaw.
Survey HYDROLOGIC INVESTIGATIONS ATLAS--Continued

110, 111. Geology and hydrology of alluvial deposits along the Ohio River in the *** area, Ky., 1964. 110, Stanley. 111, Southwestern Louisville and West Point.


124, 125. Availability of ground water in the *** quadrangle, Jackson Purchase region, Ky., 1964. 124, Hazel. 125, Lynnville.

129, 130. Geology and hydrology of alluvial deposits between the *** areas, Ohio River Valley, Ky., 1964. 129, Uniontown and Wickliffe. 130, Prospect and Southwestern Louisville.


199. Preliminary map of the conterminous United States showing depth to and quality of shallowest ground water containing more than 1,000 parts per million dissolved solids, by J.H. Feth and others, 1965.


221. Map showing altitude of the base of fresh water in coastal plain aquifers of the Mississippi Embayment, by E.M. Cushing, 1966.


Survey HYDROLOGIC UNIT MAPS

Hydrologic Unit Maps are sold at the above-listed Denver address.

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NUMBERED OPEN-FILE REPORTS

82-0640. Hydrology of the Somerset area, Kentucky, by R.W. Davis.
82-0641. Water Supplies for the London-Corbin area, Kentucky, by R.W. Davis.
NUMBERED OPEN-FILE REPORTS--Continued


86-535. Data from test drilling to trace movement of ground water in coal-bearing rocks near Fishtrap Lake in Pike County, Kentucky, by R.W. Davis, 1986.


UNNUMBERED OPEN-FILE REPORTS

Beaber, H.C., 1970, A proposed streamflow data program for Kentucky.
Hopkins, H.T., 1966, Water resources of the Fayette County area, Kentucky.
Otton, E.G., 1948, Geology and ground-water resources of the London area, Kentucky.
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Pree, H.L., Jr., and Walker, W.H., 1952, Memorandum on the geology and ground-water resources of the Calvert City-Gilbertsville area, Marshall County, Kentucky.
Rorabaugh, M.I., 1946, Ground-water resources of the southwestern part of the Louisville area, Kentucky.
Rorabaugh, M.I., 1949, Progress report on the ground-water resources of the Louisville area, Kentucky.
Ryder, P.D., 1975, Ground-water in the alluvium along the Licking River between Covington and Butler, Kentucky.
Ryder, P.D., 1975, Ground-water in the alluvium along the Levisa Fork of the Big Sandy River between Louisa and Pikeville, Kentucky.
Sublett, H.E., 1945, Chemical quality of ground water in the Louisville, area, Kentucky.
Swisshelm, R.V., Jr., 1974, Low-flow characteristics of Kentucky streams.

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Survey WATER-RESOURCES INVESTIGATIONS REPORTS

Reports in this series are identified as WRI, WRIR, WRI/NTIS or WRI/OF. All reports are available for inspection at the Louisville, Kentucky and Reston, Virginia offices of the U.S. Geological Survey. WRI/NTIS reports may be purchased either as microfiche or hard copy from the National Technical Information Service (NTIS), U.S. Department of Commerce, Springfield, Virginia 22161; the NTIS ordering number is given in parentheses at the end of the citation. WRI, WRIR, and WRI/OF reports are available from the U.S. Geological Survey, Books and Open-File Reports, Box 25425, Federal Center, Building 810, Denver, Colorado 80225.

WRI/OF 4-75 Ground water in the alluvium along the Cumberland River between Smithland, Kentucky and Barkley Dam, by P.D. Ryder, 1975.
WRI/OF 53-73 Ground water in the alluvium along the Green River between its mouth and Woodbury, Kentucky, by P.D. Ryder, 1974.
WRI/OF 76-113 Ground-water resources of the Lexington, Kentucky area by R.J. Faust, 1977.
WRIR 77-24 Theoretical draw-down due to simulated pumpage from the Ohio River alluvial aquifer near Siloam, Kentucky, by J.M. Kernodle, 1977.
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<td>79-21</td>
<td>Selected chemical quality characteristics in streams of Kentucky, 1970-75</td>
<td>J.F. Santos</td>
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<td>Derivation of homogenous streamflow records for the Green River Basin, Kentucky</td>
<td>T.W. Hale</td>
<td>1979</td>
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<td>80-202</td>
<td>Ground-water resources in the Cumberland River Basin, Kentucky-Tennessee</td>
<td>D.R. Rima and D.S. Mull</td>
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<td>81-137</td>
<td>Hydrology of Area 14, Eastern Coal Province, Kentucky</td>
<td>F. Quinones and others</td>
<td>1981</td>
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<td>81-215</td>
<td>Effects on water quality of coal mining in the basin of the North Fork Kentucky River</td>
<td>K.L. Dyer</td>
<td>1983</td>
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<td>81-423</td>
<td>Hydrology of Area 33, Eastern Region, Interior Coal Province, Indiana and Kentucky</td>
<td>D.J. Wangsness and others</td>
<td>1981</td>
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<td>81-690</td>
<td>Availability and quality of water from underground coal mines in Johnson and Martin Counties, Kentucky</td>
<td>D.S. Mull, S. Cordivola, and D.W. Risser</td>
<td>1981</td>
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<td>81-809</td>
<td>Hydrology of Area 15, Eastern Coal Province, Kentucky and Tennessee</td>
<td>D.W. Leist, D.S. Mull, and M. Young</td>
<td>1982</td>
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<td>81-1118</td>
<td>Hydrology of Area 17, Eastern Coal Province, Tennessee and Kentucky</td>
<td>M. Gaydos and others</td>
<td>1982</td>
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<td>Hydrology of Area 13, Eastern Coal Province, Kentucky, Virginia, and West Virginia</td>
<td>J.L. Kiesler, Jr. and others</td>
<td>1983</td>
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<tr>
<td>82-505</td>
<td>Hydrology of Area 34, Interior Coal Province, Kentucky, Indiana and Illinois</td>
<td>F. Quinones, K.L. York, and R.O. Plebuch</td>
<td>1983</td>
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<td>83-4152</td>
<td>Fluvial sedimentation of Kentucky streams</td>
<td>R.F. Flint</td>
<td>1984</td>
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<td>83-4233</td>
<td>Problems of rising ground-water levels in urban areas with special reference to the Louisville, Kentucky area</td>
<td>D.V. Whitesides, R.J. Faust, and D.D. Zettwoch</td>
<td>1983</td>
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<td>83-4240</td>
<td>Evaluation of ground-water quality data from Kentucky</td>
<td>C.L. Sprinkle, R.W. Davis, and D.S. Mull</td>
<td>1983</td>
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<td>84-4057</td>
<td>Ground-water hydrology of the Elizabethtown area, Kentucky</td>
<td>D.S. Mull and M.A. Lyverse</td>
<td>1984</td>
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<td>84-4073</td>
<td>Leaching study of oil shale in Kentucky with a section on hydrologic reconnaissance of the oil shale outcrop in Kentucky</td>
<td>S.S. Leung and others</td>
<td>1984</td>
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<td>84-4091</td>
<td>Review of buried crystalline rocks of eastern United States in selected hydrogeologic environments potentially suitable for isolating high-level radioactive wastes</td>
<td>R.W. Davis</td>
<td>1984</td>
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<td>84-4102</td>
<td>Potentiometric surface and water quality in the principal aquifer, Mississippian Plateaus region, Kentucky</td>
<td>R.O. Plebuch, R.J. Faust, and M.A. Townsend</td>
<td>1985</td>
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A preliminary evaluation of the precipitation runoff modeling system, Beaver Creek basin, Kentucky, by D.E. Bower, 1985.

Calibration and verification of a streamflow model for the Kentucky River near Lexington and Frankfort, Kentucky, by C.J. Sholar, 1985.


Assessment of ground-water contamination in the alluvial aquifer near West Point, Kentucky, by Mark A. Lyverse and Michael D. Unthank, 1988.

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Miscellaneous Field Study maps are sold by U.S. Geological Survey, Map Distribution, Federal Center, Building 810, Box 25286, Denver, Colorado 80225.


MF-865-H Map showing low flows, average flows, and drainage areas in Kentucky River Area Development District, by R.W. Davis, 1978.
These reports can be obtained from the Director and State Geologist, Kentucky Geological Survey, or they may be consulted in the offices of the Director and State Geologist, Kentucky Geological Survey, University of Kentucky, Lexington, Kentucky; the District Chief, Water Resources Division, U.S. Geological Survey, Louisville, Kentucky; or the Chief Hydrologist, Reston, Virginia.


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OTHER PUBLICATIONS BY THE STAFF OF THE U.S. GEOLOGICAL SURVEY

Address inquiries about the availability of these reports to the publishers. Most reports are available at large public and University libraries.


OTHER PUBLICATIONS BY THE STAFF OF THE U.S. GEOLOGICAL SURVEY--Continued


Guyton, W.F., 1945, Depleted wells at Louisville recharged with city water: Water Works Engineer, v. 98, no 1, p. 18-20.


OTHER PUBLICATIONS BY THE STAFF OF THE U.S. GEOLOGICAL SURVEY--Continued


Rorabaugh, M. I., 1953, Analysis of ground water lowering adjacent to open water: American Society of Civil Engineers Proceedings, v. 118.


Rorabaugh, M. I., 1956, Prediction of ground-water levels on basis of rainfall and temperature correlation: American Geophysical Union Transactions, v. 37, no. 4, p. 436-441.


Schrader, F. F., 1956, Streamflow in Kentucky: Kentucky Department of Economic development, Frankfort.


OTHER PUBLICATIONS BY THE STAFF OF THE U.S. GEOLOGICAL SURVEY--Continued


SOURCES OF WATER RESOURCES INFORMATION IN THE U.S. GEOLOGICAL SURVEY

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Questions about water resources in general or about the water resources of specific areas of the United states can be directed to the Hydrologic Information Unit. This office will also answer inquiries about the availability of reports of water-resources investigations.

Hydrologic Information Unit
U.S. Geological Survey
420 National Center
Reston, Virginia 22092

Kentucky Water Resources

Questions specific to water resources in Kentucky can be directed to the Kentucky District Office. This office will answer inquiries about reports and other Kentucky water-resources publications.

Alfred L. Knight, District Chief
U.S. Geological Survey
2301 Bradley Avenue
Louisville, Kentucky 40217

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The OWDC (Office of Water Data Coordination) is the focal point for interagency coordination of ongoing and planned water-data acquisition activities of all Federal agencies and many non-Federal organizations. The "National Handbook of Recommended Methods for Water-Data Acquisition," indexes to the "Catalog of Information on Water Data," and other publications are available from OWDC. For further information, write:

Office of Water Data Coordination
U.S. Geological Survey
417 National Center
Reston, Virginia 22092

National Water Data Exchange

NAWDEX (National Water Data Exchange) maintains a computerized data system that identifies sources of water data and indexes information on the water data available from the sources. The NAWDEX Program Office and local Assistance Centers assist data users in locating sources of water data, identifying sites at which data have been collected, and obtaining specific data. For further information, write:

National Water Data Exchange
U.S. Geological Survey
421 National Center
12201 Sunrise Valley Drive
Reston, Virginia 22092

National Water Data Storage and Retrieval System

WATSTORE (National Water Data Storage and Retrieval System) is the water data base of the U.S. Geological Survey. It contains data on stream discharge (flow) and stage (height), reservoir and lake storage, ground-water levels, well and spring discharge, and the quality of surface and ground water. For information about types and acquisition of data, write:

Alfred L. Knight, District Chief
U.S. Geological Survey
2301 Bradley Avenue
Louisville, Kentucky 40217
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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 Beys, 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 BASIN

Ohio River at Greenup Dam (d) 216800

TYGARTS CREEK BASIN

Tygarts Creek at Olive Hill (d) 216800
Tygarts Creek near Greenup (d) 217000

CABIN CREEK BASIN

Cabin Creek near Tulesboro (d) 237900

LICKING RIVER BASIN

Licking River near Salyersville (d) 248500
Licking River at Farmers (d,c) 249500
North Fork Triplrett 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 BASIN

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 Byden (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) 281150
Kentucky River at lock 14, at Heidelberg (d) 282000
Red River near Hazel Green (d) 282500
Red River at Clay City (d) 282550
Kentucky River at lock 10, near Winchester (d,c,b,s) 284000
Dix River near Danville (d) 285000
Kentucky River at lock 6, near Savisa (d) 287000
Kentucky River at lock 4, at Frankfort (d,c,s) 287500
Elkhorn Creek:

South Elkhorn Creek at Port Spring (d) 288000
South Elkhorn Creek near Midway (d) 288500
Elkhorn Creek near Frankfort (c,b,s) 288550
Kentucky River at lock 2, at Lockport (d,c,b,t,s) 290050

HARROG CREEK BASIN

Barroda Creek near La Grange (d) 292460

BEARGRASS CREEK BASIN

Middle Fork Beargrass Creek at Louisville (d) 293000

OHIO RIVER BASIN

Ohio River at Louisville (d) 294500

SALT RIVER BASIN

Brashears Creek at Taylorsville (d) 295580
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 Haud (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 BASIN

Ohio River at Cannelton Dam (d) 303280

GREEN RIVER BASIN

Green River near Campbellsville (d,t) 306900
Russell Creek near Columbia (d) 307000

GREEN RIVER BASIN

Green River near Muncordville (d,c,b,t,s) 308500
Nolin River at White Mills (d) 310300
Bacon Creek near Priceville (d) 311000
Nolin River at Kyrock (d) 311000

86
Surface-water stations in Kentucky in 1988 and type of data collected--Continued

Station number in figures 10 and 15

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## Appendix 2

### Observation wells in Kentucky in 1968

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88
### Observation wells in Kentucky in 1988—Continued

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Map number in figure 13

| Call number in figure 14 | | |
| Joe Parks | 1 | |
| Western State Hospital | 2 | |
| Roy Adkins | 3 | |
| M.A. Kehrt | 4 | |
| Harp Road Test Well | 5 | |
| J. Whittemore | 6 | |

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### Observation wells in Kentucky in 1988—Continued

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