Progress Report on the Ground-Water Resources of the Louisville Area Kentucky, 1949–55

By EDWIN A. BELL, ROBERT W. KELLOGG, *and* WILLIS K. KULP

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PROGRESS REPORT ON THE GROUND-WATER RESOURCES OF THE LOUISVILLE AREA, KENTUCKY, 1949-55

By Edwin A. Bell, Robert W. Kellogg, and Willis K. Kulp

ABSTRACT

In the Louisville area, the principal water-bearing formations are the glacial-outwash sand and gravel and, in places, the underlying limestone. During the period 1949 through 1955 pumpage from the two aquifers averaged about 30 mgd (million gallons per day). The pumpage was approximately in balance with the normal net recharge to the area but was only about 8 percent of the estimated potential supply of ground water, including induced infiltration from the river.

In the Louisville area, ground water is used chiefly for air conditioning and for industrial cooling. In the part of the area southwest of the city, ground water is used also for public supply.

High ground-water levels in 1937 resulted from the greatest flood of record. Subsequently, water levels generally declined in the entire Louisville area. In downtown Louisville, where ground water is used for air conditioning, the water level fluctuates seasonally in response to variations in the rate of pumping. In the heavily pumped industrial areas, where ground water is used for cooling, water-level fluctuations correlate with changes in rates of pumping caused by variations in production schedules. Levels were lowest during the years of World War II. During the period 1952-55, relatively low levels throughout the area reflected the effects of less than normal rainfall, summer drought, and sustained pumping.

Ground water in the Louisville area is very hard and generally of the calcium bicarbonate or calcium sulfate type. It is high in iron and sulfate content but is moderately low in chloride content. In water of the sand and gravel aquifer, the concentration of sulfate has increased gradually during the period 1949-54.

INTRODUCTION

The purpose of this report is to present currently available information on the ground-water resources of the Louisville area in a form that will be useful to persons concerned with the development and use of those resources. The correlation of water-level data with hydrologic and geologic factors affords a means of predicting water-level trends; thus, users of ground water may be informed of areas where ground-water problems may be expected because of low water levels.

PREVIOUS INVESTIGATIONS

Data on ground water in the Louisville area before 1937 are fragmentary, although ground-water problems were recognized before that time. In February 1937, after the great flood of the Ohio River, ground-water studies relative to overloaded sewers and flooded basements in the area were begun by Woolsey M. Caye, technical engineer for the Commissioners of Sewerage of Louisville. The recession of ground-water levels after the flood was accelerated by increased withdrawals for air conditioning and industrial use. Recognizing the need for continuing records of water-level fluctuations, the director of works of the city later in 1937 requested the Commissioners of Sewerage to continue the investigation begun by Mr. Caye, including periodic measuring of water levels in 15 observation wells. In 1941 the work was transferred to the Louisville Engineering Department.

In 1943 the Louisville Area Development Association requested the U.S. Geological Survey to begin an investigation of the ground-water resources in the Louisville area. During the period 1943–51 the work was done under cooperative agreements with the Geological Division of the Kentucky Department of Mines and Minerals, Jefferson County, and the City of Louisville. In 1952 ground-water investigations in the Louisville area were incorporated in the Statewide ground-water program in cooperation with the Kentucky Agricultural and Industrial Development Board. In 1956 the Kentucky Department of Economic Development superseded the Agricultural and Industrial Development Board as the cooperating agency. Special projects have been financed by the Rubber Reserve Company, an agency of the Federal Government; by Federal research funds; and by cooperation between the U.S. Geological Survey and the Louisville Water Company, an agency of the city. Twenty-two reports, in addition to annual water-level reports for 1944–55 that have been prepared as a result of those investigations are included in the list of references at the end of this report. Those reports describe the geology, hydrology, and availability of ground water in the area. Of special importance as the background for this report are the following reports:

1. Guyton, W. F., Stuart, W. T., and Maxey, G. B., 1944, Progress report on the ground-water resources of the Louisville area, Kentucky.
2. Hamilton, D. K., 1944, Ground water in the bedrock beneath the glacial outwash in the Louisville area, Kentucky.
3. MacCary, L. M., 1955, Map of the Louisville area, Kentucky, showing contours on the bedrock surface.
4. Rorabaugh, M. I., 1949b, Progress report on the ground-water resources of the Louisville area, Kentucky, 1945–49.
5. Rorabaugh, M. I., Schrader, F. F., and Laird, L. B., 1953, Water resources of the Louisville area, Kentucky and Indiana.

METHODS OF INVESTIGATION AND PRESENTATION OF DATA

In the Louisville area during the period 1949–55, a continuing program was maintained for the purpose of measuring water levels and temperatures and collecting water samples for chemical analysis. Data on pumpage, artificial recharge, and climate were compiled, and the net recharge to the sand and gravel aquifer was estimated annually. Information on new wells was furnished by owners and drillers.

In this report, hydrographs show water levels in feet above mean sea level (based on adjustment of 1912 as described by Rorabaugh, Schrader, and Laird, 1953, p. 5) in selected wells, and piezometric maps show water-level conditions existing in December 1949, 1952, and 1955. Maximum and minimum temperatures of ground water are shown on a map of the area. The chemical quality of the ground water and a summary of ground-water pumpage in the area are shown in tables and graphs. Well records (table 1) not previously published are included also.

All the basic data, except confidential pumping records for some companies, are available in the open files at the office of the U.S. Geological Survey, Ground Water Branch, Louisville, Ky.

The ground-water investigation on which this progress report is based was supervised by G. E. Hendrickson, district geologist of the U.S. Geological Survey, Louisville, who, in 1954, succeeded M. I. Rorabaugh, district engineer. Chemical analyses of water samples were made in the laboratory of the U.S. Geological Survey, Columbus, Ohio, under the supervision of G. W. Whetstone, district chemist.

ACKNOWLEDGMENTS

Many of the organizations, industries, and individuals that supplied ground-water data during the period 1943–49 continued to do so during the period 1949–55. Among these were the Corps of Engineers of the U.S. Army, the U.S. Weather Bureau, the Louisville Water Company, the Louisville Extension Water District, the Louisville and Jefferson County Metropolitan Sewer District, and many industries, consulting engineers, and well drillers.

WELL-NUMBERING SYSTEM

The Louisville area lies between 85° and 86° west longitude and 38° and 39° north latitude. The area has been subdivided into quadrangles by a grid of 1-minute meridians of longitude and 1-minute parallels of latitude. The wells in each of the quadrangles are numbered in the order inventoried. A well is designated by a composite of three numbers: the first indicates the minutes of longitude; the second, the minutes of latitude; and the third, the number of the well in that quadrangle. Thus, well 43–15–1 is the first well inventoried in the 1-minute quadrangle west of longitude 85°43′ W and north of latitude 38°15′ N.

LOCATION OF WELLS

Locations of observation wells, of wells where samples were taken for chemical analysis, and of wells inventoried in the Louisville area 1945 through 1955 are shown on plate 1. Records for those wells inventoried are listed in table 1. Records of wells inventoried previously are included in reports by Hamilton (1944), U.S. Geological Survey (1946), and Rorabaugh (1946 and 1956).

TABLE 1.—*Description of wells not previously published, inventoried in the Louisville area, Kentucky, 1945–55*

[Items marked with asterisk (*) indicate slotted pipe]

Type of well: Dn, driven; Dr, drilled.
Principal water-bearing material: SG, glacial-outwash sand and gravel; JS, Jeffersonville and Sellersburg limestones; L, Louisville limestone.
Use: D, domestic; In, industrial; Ir, irrigation; O, observation; Ps, public supply.

Lift: Al, airlift; GC, gasoline engine, centrifugal; JE, jet, electric; PE, piston, electric, PS, piston, steam; TE, turbine, electric.
Elevation: LSD, land-surface datum.

Well	Location	Owner	Driller	Date drilled	Type of well	Depth (ft)	Diameter (in)	Length of screen (ft)	Principal water-bearing material	Use	Lift	Elevation (ft above mean sea level)				Pumping data		Remarks
												LSD	Bedrock	Water level	Date	Yield (gpm)	Date	
41-16-5	River Rd. and Zorn Ave.	Pastime Boat Club.	Garrison	Aug. 1946.	Dr	99	6	10	SG	(1)	TE	435	336					
42-15-3	1860 Melwood Ave.	H. Fischer Packing Co.	Diehl Pump and Supply Co.	May 1952.	Dr	87	16	25	SG	In.	TE	427	340	408	May 1952			
42-16-42	River Rd. Beargrass Plant.	Louisville Gas and Electric Co.	Andriot-Davidson Co., Inc.	Sept. 1951.	Dr	101	18	20	SG	In.	TE	438	337	415	Nov. 5, 1951	1,000	Nov. 1951	Log available.
43-15-30	1726 Mellwood Ave.	General Distillers, Inc.	Birdwell	May 1949.	Dr	74	12		SG	In.		438	364					
31	1400 Story Ave.	Oertel Brewing Co.	Diehl Pump and Supply Co.	Aug. 1952.	Dr	116	16	20	SG	In.	TE	460	346	385	Aug. 15, 1952			Log available.
44-13-5	982 Eastern Parkway.	Kosair Crippled Children's Hospital.	do	Oct. 1952.	Dr	200	8					490	471					Dry. Bottom in Osgood formation. Log available.
44-15-29	129 River Rd.	Ohio River Sand Co.	do	1945	Dr	102	6		SG	In.	TE	441		406	Apr. 6, 1946			
30	609 East Main St.	Grocers Ice and Cold Storage Co.	Andriot-Davidson Co., Inc.	1946	Dr	108	12		SG	In.	TE	462				750	Oct. 1948	
31	923 Geiger St.	City Hide and Tallow Co.			Dr	85		15	SG	In.	PS	442				150		Unused.
32	301 East Main St.	Swift and Co.	Childers		Dr	100	6	10	SG	In.	TE	442				50		
33	412 Fehr Ave.	Fehr Brewing Co.	Diehl Pump and Supply Co.	Jan. 1950.	Dr	200	16-12		L(?)	In.	TE	464	340	393	Jan. 1950	170		16-in casing to 120 ft, 12-in hole in rock.
34	609 East Main St.	Grocers Ice and Cold Storage Co.	Birdwell	Mar. 1952.	Dr	200	6		L	In.		460	335	390	Feb. 27, 1952			Recharge well. Log available.

36	201 East Main St.	Armour and Co.	Childers	1940	Dr	100	6		SG	In.	TE							
45-12-11	2400 South Brook St.	Louisville Soy Products.	Andriot-Davidson Co., Inc.	July 1948.	Dr	100			L	In.		458	441	441	July 1945	130	July 1948	
12	Floyd and Farmington Sts.	General Mills, Inc.	Charles B. Venhoff.	Jan. 1953.	Dr	46	4		SG			463	417	449	Jan. 7, 1953			Test hole. Log available.
13	do	do	do	do	Dr	60	4		SG			464	404	454	do			Do.
14	215 West Central Ave.	American Air Filter Co.	Andriot-Davidson Co., Inc.	Aug. 1950.	Dr	35	12	10	SG	In.	TE	460						
16	South Louisville yards, Louisville and Nashville Railroad Co.	Municipal Sewer District.	E. Birdwell	Sept. 1954.	Dr	31	6		SG	O.		455	427	446	Oct. 1954			Data at Metropolitan Sewer District.
45-14-58	981 South 3d St.	Lincoln Income			Dr	179	8		SG	In	Al	456		393.49	Aug. 7, 1945			Well in basement 10 ft below land surface datum. Unused.
59	8th and Broadway Sts.	Sears and Roebuck Co.	Diehl Pump and Supply Co.	Oct. 1947.	Dr	112	15		SG			455	343					Log available.
60	do	do	do	do	Dr	119	6		SG	In.		455	336					Do.
61	4th and Guthrie Sts.	Byck Bros	do	May 1948.	Dr	121	8		SG	In.		460						
62	6th and Broadway Sts.	Courier Journal and Louisville Times.	do	1947	Dr	103	12	20	SG	In.	TE	457	337			280	1947	Well in basement 17 ft below land surface datum.
63	do	do	do	do	Dr	110	12	20	SG	In.	TE	457	337	390	September 1947.			Well in basement 10 ft below land surface datum.
64	do	do	do	do	Dr	110	12	20	SG	In.	TE	457	337					Do.
65	do	do	do	Jan. 1949.	Dr	172	12		SG	In.	TE	457	337	372.03	Sept. 6, 1949			Well in basement 14 ft below land surface datum. Rock wells changed to sand and gravel.
66	do	do	do	Apr. 1949.	Dr	173	12		SG	In.	TE	458	337	377.15	Oct. 19, 1953	260	May 23, 1949	Well in basement 17 ft below land surface datum. Rock well changed to sand and gravel. Log available.
67	817 South Floyd St.	Bradas & Gheens	Andriot-Davidson Co., Inc.	Nov. 1949.	Dr	229	10-8		L(?)	In.		458	349	385	Dec. 14, 1949	100	Dec. 14, 1949	Recharge well. 10-in casing to 109 ft, 8-in. hole in rock. Log available.

See footnotes at end of table.

TABLE 1.—*Description of wells not previously published, inventoried in the Louisville area, Kentucky, 1945–55*—Continued

Well	Location	Owner	Driller	Date drilled	Type of well	Depth (ft)	Diameter (in)	Length of screen (ft)	Principal water-bearing material	Use	Lift	Elevation (ft above mean sea level)				Pumping data		Remarks
												LSD	Bedrock	Water level	Date	Yield (gpm)	Date	
45-14-68	511 West Broadway.	Liberty National Bank.	Birdwell	1952	Dr	117	6	---	SG	In.	TE	455	338	---	---	40	---	
69	3d and Kentucky Sts.	Lincoln Income Life Insurance Co.	---	---	Dr	88	**12**	---	SG	In.	---	456	---	338.39	Mar. 30 1953	---	---	Well in basement 12 ft below land surface datum.
70	311 West Chestnut St.	Louisville Gas and Electric Co.	---	1946	Dr	100	8	---	SG	In.	---	459	---	---	---	100	---	
71	4th and York Sts.	Louisville Free Public Library.	Diehl Pump and Supply Co.	---	Dr	110	8	---	SG	In.	TE	453	343	379	January 1954	---	---	
45-15-63	7th and Walnut Sts.	Grand Theater	Andriot-Davidson Co., Inc.	June 1946.	Dr	122	6	15	SG	In.	---	460	338	---	---	75	June 1946	
64	1st and River Rd.	Denunzio Fruit Co.	Diehl Pump and Supply Co.	Apr. 1947.	Dr	120	---	---	SG	In.	TE	439	319	384	Sept. 4, 1947	100	Sept. 4, 1947	
65	242 East Main St.	Byrd Distilling Co.	Caldwell	---	---	93	1¼	5	SG	In	---	462	---	---	---	7	---	
66	4th and Walnut Sts.	Seelbach Hotel	Diehl Pump and Supply Co.	Dec. 1951	Dr	195	12–8	---	L(?)	In	---	463	335	---	---	---	---	12-in casing to 128 ft, 8-in hole in rock. Log available.
67	427 South 4th St.	Kaufman-Straus.	do	July 1953	Dr	192	16	20	SG	In	TE	462	334	---	---	500	---	Log available. Well screened from 106 to 128 ft.
68	8th and Cedar Sts.	A-M Engraving Co.	Charles B. Venhoff.	---	Dr	115	4	3	SG	In	---	461	346	---	---	---	---	
46-13-38	15th and Hill Sts.	Louisville Distributors.	Andriot-Davidson Co., Inc.	1936	Dr	106	10	15	SG	In	TE	472	---	407	Aug. 1941	500	---	
39	7th Street Rd. and Mix Ave.	B. F. Avery and Co.	---	1910	---	250	8	---	L(?)	In	Al	463	---	---	---	100	---	Well destroyed.
40	7th and Magnolia Ave.	Merchants Ice & Cold Storage Co.	Diehl Pump and Supply Co.	---	Dr	105	10	---	SG	In	TE	465	---	---	---	---	---	
41	7th and Shipp Sts.	Standard Sanitary Mfg. Co.	Andriot-Davidson Co., Inc.	July 1948	Dr	105	12	20	SG	In	TE	459	354	386	July 9, 1948	900	---	

42	1445 South 15th St.	Louisville Distributors.	do			108	10	15	SG	In	TE	474				500		
43	1481 South 11th St.	Jones-Dabney	Diehl Pump and Supply Co.	Mar. 1951	Dr	185	12-10		L	In	TE	460	348			250		12-in casing to 112 ft, 10-in. hole in rock.
44	do	do	do	Apr. 1951	Dr	220	12-10		L	In	TE	460	348			250		12-in casing to 112 ft, 10-in hole in rock. Log available.
46-14-28	17th and Broadway Sts.	American Tobacco Co.	do	Dec. 1945	Dr	113	12	20	SG	In	TE	456		381.38	Apr. 28, 1950			
29	1125 West Kentucky St.	Kroger Grocery Co.	Andriot-Davidson Co., Inc.	Before 1938	Dr	90	8	15	SG	In		459						
30	14th St. and Ormsby Ave.	Jefferson Ice and Fuel Co.	Diehl Pump and Supply Co.	Apr. 1949	Dr	184	12-10		JS	In		456	337	380	Apr. 5, 1949			Recharge well. 12-in casing to 119 ft, 10-in hole in rock. Log available.
31	17th and Broadway Sts.	American Tobacco Co.			Dr	95	8		SG	In		454		376.60	June 17, 1949			Unused.
33	13th and Breckinridge Sts.	Spalding Laundry Co.	Diehl Pump and Supply Co.	Apr. 1954	Dr	120	12	16	SG	In		455	335	382	Apr. 26, 1954			
46-15-8	14th and Cedar Sts.	Hirsch Bros.	Caldwell		Dr	133	8			In		460		380.52	Oct. 18, 1948			Unused.
47-11-7	Taylor and Berry Blvds.	Garden Acres Pharmacy.	Birdwell	May 1948	Dr	95	6		SG	In		456	361					Recharge well.
8	do	do	do	1948	Dn	88	6		SG	In	JE	456						
9	7th Street Rd. and Berry Blvd.	Arch Club	do	May 1948	Dr	101	6		SG	In	TE	455	354					
47-12-33	Early Times Distillery, Dixie Highway.	Brown-Forman Distillers.	Andriot-Davidson Co., Inc.	Feb. 1947	Dr	209	12-8		JS	In	TE	459	350					12-in casing to 109 ft, 8-in hole in rock. Log available.
35	Millers Lane and Dixie Highway.	Mr. Duffy	Charles B. Venhoff.	Dec. 1949	Dr	53	4-2		SG	D		465	412					
36	Early Times Distillery, Dixie Highway.	Brown-Forman Distillers.	Diehl Pump and Supply Co.	Feb. 1950	Dr	140	10		JS	In		463	359					Log available.
37	7th Street Rd.	Yellowstone, Inc.	Andriot-Davidson Co., Inc.		Dr	204	12		JS	In	TE	455				200	Oct. 9, 1956	
38	do	do	do	Dec. 1950	Dr	154	12-8		JS	In	TE	455	351			350	do	12-in casing to 104 ft, 8-in hole in rock.

See footnotes at end of table.

TABLE 1.—*Description of wells not previously published, inventoried in the Louisville area, Kentucky, 1945–55*—Continued

Well	Location	Owner	Driller	Date drilled	Type of well	Depth (ft)	Diameter (in)	Length of screen (ft)	Principal water-bearing material	Use	Lift	Elevation (ft above mean sea level)				Pumping data		Remarks
												LSD	Bedrock	Water level	Date	Yield (gpm)	Date	
47-12-39	7th Street Rd.	Yellowstone, Inc.	Diehl Pump and Supply Co.	1952	Dr	104	12	15	SG	In	TE	456	352			300	Oct. 9, 1956	
40	do	Joseph E. Seagram & Sons, Inc.	do	Mar. 1952	Dr	200	12		JS	In		460	346					Recharge well.
47-13-12	17th and Hill Sts.	Coca-Cola Bottling Co.	do	May 1954	Dr	122	12	15	SG	In	TE	465	344	390	May 6, 1954			
13	Bernheim Lane	National Distillers Products, Corp.		1948	Dr	90	6		SG	O		460		405.70	Apr. 27, 1954			
47-14-22	18th and Howard Sts.	Brown-Forman Distillers.	Diehl Pump and Supply Co.	Dec. 1953	Dr	140	12–10		L	In	TE	450	334					12-in casing to 116 ft, 10-in hole in rock.
48-12-16	Ralph Ave	Stitzel-Weller Distillery, Inc.		Mar. 1939		92	10		SG	In		465		420	Mar. 1939			Unused.
48-13-3	Cane Run Rd.	Reinstedler Bros.		Mar. 1931	Dr	110	8		SG	Ir	TE	461		431	Mar. 1931	120		
4	Cane Run Rd. and Bells Lane.	H. Reinstedler	Charles B. Venhoff.	1944	Dn	80	2		SG	D	PE							
48-14-19	31st and Broadway Sts.	Falls City Brewing Co.	Diehl Pump and Supply Co.	Apr. 1949	Dr	185	16		L (?)	In	TE	455	362	385	Apr. 18, 1949	1,500		Log available.
20	3111 Woodland Ave.	Parkland Ice & Coal Co., Inc.	Birdwell	1946	Dr	104	12		SG	In	PE	450						
21	do	do	do	1947	Dr	104	12		SG	In	PE	450						Unused.
22	do	do	do	1949	Dr	126	12		L(?)	In	PE	450						Recharge well.
23	28th St. and Garland Ave.	Louisville Transit Co.	Diehl Pump and Supply Co.	Apr. 1954	Dr	97	12		SG	In								
24	31st and Broadway Sts.	Falls City Brewing Co.	do	Nov. 1955	Dr	190	16		L(?)	In	TE	452	355	376	Nov. 18, 1955	200	Nov. 18, 1955	
48-15-19	210 Amy Ave	Klarer Provision Co.	Koch		Dr	53	6		SG	O		453		409.35	Apr. 9, 1946			Well destroyed.

20	do	do	do		Dr	45	6		SG	In		450						Unused. Well dry, Apr. 9, 1946.
21	do	do	do		Dr	45	6		SG	In		450						Unused.
22	41st and Market Sts.	Park Theater		July 1948	Dr	45			SG	In		446				100	July 1948	
48-16-17	445 North 35th St.	Park & Tilford Distillers Corp.	Andriot-Davidson Co.. Inc.	July 1945	Dr	71	18	20	SG	In		420	349	385	July 1945	125	Aug. 1945	
18	do	do	do	May 1949		170	6					456	410					Dry. Log available.
49-10- 3	2024 Rockford Lane.	E. T. James	Paul Baugh	1946	Dn	80	2		SG	D	PE							
49-11- 3	2106 Garrs Lane.	A. Beamiss			Dr	80	2		SG	D	JE							
49-13-41	Bells Lane	B. F. Goodrich Chemical Co.			Dn	97	2		SG	O		446		364.49	Jan. 11, 1945			
42	do	Bond Bros.	Diehl Pump and Supply Co.	July 1952	Dr	110	10	29	SG	In	TE	447		373	Sept. 7, 1955	350	Oct. 1. 1956	
43	do	B. F. Goodrich Chemical Co.	Ohio Drilling Co.	Mar. 1944	Dr	110	18	30	SG	In	TE	448		365	Mar. 13, 1944	600	Oct. 9, 1956	
50- 8- 2	Greenwood Rd.	Captain Allen	Paul Baugh		Dr	54	2		SG	D								Well in basement.
50-11-10	Cane Run Rd.	George Dienes		1948	Dr	92	6		SG	Ir	TE	450						
11	Crums Lane	Val Hartlage	Paul Baugh	1945	Dn	70	3		SG	D	PE							
50-12-20	Camp Ground Rd.	Z. C. Long	Charles B. Venhoff.	Sept. 1953	Dn	88	2		SG	D	JE							
21	Plant No. 5, Camp Ground Rd.	Reynolds Metals Co.	Diehl Pump and Supply Co.	Apr. 1953	Dr	112	16		SG	In	TE	450						
22	Plant No. 3, Camp Ground Rd.	do	do	July 1953	Dr	205	16-8		L	In	TE	450	337					Sealed at bedrock. Screened in sand and gravel.
50-13-57	Bells Lane at Ohio River.	National Carbide Corp.	Ranney Water Collector Corp.	1945	(2)	120	156	(3)	SG	In	TE	385				2,700	Nov. 1946	
58	Bells Lane	do			Dr	98	6		SG	O		450		381.38	Aug. 26, 1947			
60	Lower Paddys Run.	City of Louisville (?)		June 1953.	Dr	70	12		SG			412	341	375.5				Relief well.
64	Bells Lane	National Carbide Corp.	Diehl Pump and Supply Co.	Jan. 1956.	Dr	101	6	30	SG	O		444	342	366.72	Jan. 26, 1956			
65	do	do	do	Mar. 1956.	Dr	107	6		SG	O		450	342	369.19	June 6, 1956			
70	Plant No. 5, Camp Ground Rd.	Reynolds Metals Co.	do	Dec. 1953.	Dr	113	12	15	SG	In	TE	457	344	373	Dec. 2, 1953	150		

See footnotes at end of table.

TABLE 1.—*Description of wells not previously published, inventoried in the Louisville area, Kentucky, 1945–55*—Continued

Well	Location	Owner	Driller	Date drilled	Type of well	Depth (ft)	Diameter (in)	Length of screen (ft)	Principal water-bearing material	Use	Lift	Elevation (ft above mean sea level)				Pumping data		Remarks
												LSD	Bedrock	Water level	Date	Yield (gpm)	Date	
50-13-75	Bells Lane	National Carbide Corp.		Oct. 1954.	Dr	111	6		SG	In	TE	446		366	Oct. 12, 1954			
76	do	do	Diehl Pump and Supply Co.	Mar. 1956.	Dr	109	16	20	SG	In	TE	450	340					
77	do	do	do	Jan. 1956.	Dr	107	6		SG	O		448	341	367.01	Jan. 26, 1956			
78	do	do	do	Mar. 1956.	Dr	106	16	21	SG	In	TE	448	343					
79	do	do	do	Jan. 1956.	Dr	108	6		SG	O		449	341	368.31	Jan. 26, 1956			Unused.
51-11-5	Camp Ground Rd.	Thieneman Bros.				90	6		SG	Ir		454		402	Dec. 3, 1952			
52-10-4	Lower River Rd.	American Builders Supply Co.	Diehl Pump and Supply Co.	Oct. 1953.	Dn	115	12		SG	In	TE							
52-12-1	Ohio River bank south of Bramer Lane.	Stauffer Chemical Co.	Caisson Wells, Inc.	Apr. 1952.	Dr	80	6	*10	SG		GC	412	332	397.36	Apr. 17, 1952	73	Apr. 17, 1952	Test well. Well destroyed.
3	do	do	do	do	Dr	80	6	*10	SG		GC	412	332	397.36	do			Do.
4	do	do	do	do	Dr	80	6	*10	SG		GC	412	332	397.45	do	72	Apr. 18, 1952	Do.
5	do	do	do	do	Dr	74	6	*10	SG		GC	408	334	400.34	Apr. 26, 1952	85	Apr. 30, 1952	Do.
6	do	do	do	do	Dr	74	6	*10	SG		GC	408	334	400.30	do	85	Apr. 29, 1952	Do.
7	do	do	do	May 1952.	Dr	73	6	*10	SG		GC	408	335	399.51	May 6, 1952	77	May 7, 1952	Do.
8	do	do	do	do	Dr	73	6	*10	SG		GC	408	335	399.50	do	80	May 6, 1950	Do.
9	do	do	do	do	Dr	68	6	*10	SG		GC	403	335	394.77	May 14, 1952	72	May 14, 1952	Retained for use as observation well.

10	Ohio River bank south of Bramer Lane.	Stauffer Chemical Co.	Caisson Wells, Inc.	May 1952.	Dr	68	6	*10	SG	----	GC	403	335	394.68	May 14, 1952	72	May 14, 1952	Test well. Well destroyed.
11	do	do	do	do	Dr	69	6	*10	SG	----	GC	403	335	397.79	May 19, 1952	85	May 25, 1952	Do.
12	do	do	do	do	Dr	69	6	*10	SG	----	GC	403	335	397.13	do	80	May 24, 1952	Do.
13	do	do	do	June 1952.	Dr	104	6	*10	SG	----	Al	441	337	400.06	June 2, 1952	80	June 2, 1952	Do.
14	do	do	do	do	Dr	104	6	*10	SG	----	Al	441	337	399.88	do	140	do	Do.
15	Camp Ground Rd.	do	Diehl Pump and Supply Co.	Oct. 1952.	Dr	113	16	22	SG	In	TE	451	339	396.07	June 9, 1953	----	----	
16	do	do	do	do	Dr	112	16	22	SG	In	TE	450	338	396.13	do	752	June 13, 1953	
17	do	do	do	do	Dr	115	16	22	SG	In	TE	453	338	396.57	do	609	August 1953	
18	do	do	do	do	Dr	108	16	22	SG	In	TE	447	339	396.70	do	720	Sept. 17, 1953	
53- 6- 2	Lower River Rd. and Bethany Lane.	Louisville Extension Water District.	do	Nov. 1947.	Dr	121	16	34	SG	Ps	TE	449	328	398	Oct. 20, 1947	----	----	Log available.
3	do	do	do	do	Dr	121	16	20	SG	Ps	TE	450	329	399	Jan. 5, 1945	----	----	
53-10- 2	Cane Run Rd.	Louisville Gas and Electric Co.	Birdwell	May 1953.	Dr	102	12	---	SG	In	----	---	---	----	----	----	----	High iron content reported.
4	do	do	do	do	Dr	102	12	---	SG	In	----	---	---	----	----	----	----	Do.

[1] Swimming pool.
[2] Collector.
[3] Length of screen, 1,407 feet.

DESCRIPTION OF AREA

GEOGRAPHY

The Louisville area, as described in this report, includes the area within the city limits and the adjacent areas of the Ohio River flood plain northeast of the city to Harrods Creek and southwest nearly to Kosmosdale. It ranges in width from half a mile to 6 miles, is about 30 miles long, and covers about 60 square miles.

The part of the area along the river northeast of Louisville is used chiefly for recreational purposes, whereas that southwest of the city, formerly cultivated for truck crops, is being developed as industrial, commercial, and residential sites. Most of the industrial sites are near the river.

GEOLOGY

The consolidated rocks underlying the Louisville area are limestones and shales of Silurian, Devonian, and Mississippian age. During Pleistocene time the Ohio River cut its valley into those rocks to a maximum depth of nearly 130 feet below the present flood plain. That valley, bounded on both sides by bedrock hills, was later filled to its present level with glacial-outwash sand and gravel and river deposits of Pleistocene and Recent age.

The bedrock formations in the Louisville area are of fairly uniform thickness and dip toward the west at about 40 feet per mile. Between Harrods Creek and Goose Creek the glacial-outwash deposit of sand and gravel is underlain chiefly by the Laurel dolomite and the Waldron shale of Silurian age. From Goose Creek southwestward to the west-central part of the city and to Shively, the deposit of sand and gravel is underlain by the Louisville limestone of Silurian age and by the Jeffersonville and Sellersburg limestones of Devonian age. In the northwestern part of the city, the deposit of sand and gravel is underlain by the New Albany shale of Devonian age; west and southwest of Shively it is underlain by the New Albany shale and by the New Providence shale of Mississippian age.

Deposits of Pleistocene age include the glacial-outwash sand and gravel ranging from 0 to 100 feet in thickness, overlain by a blanket of silt and clay as much as 40 feet thick. Very thin deposits of Recent clay and silt cover portions of the flood plain. The sand-and-gravel deposit is thinnest in the northwestern part of the city; the silt and clay is thickest near the river.

CLIMATE

The climate of the Louisville area is generally temperate and humid. The weather is quite changeable, but extreme conditions generally do not last long. The temperature rarely exceeds 100° F in summer and rarely falls below 0° F in winter; the mean annual temperature is 56.5° F. The frost-free period lasts, on the average, from early April until October. The normal annual precipitation at Louisville is 41.47 inches. All climatological data are from reports prepared by the U.S. Weather Bureau. Monthly precipitation for the period 1937–55 is shown graphically on plate 7.

OCCURRENCE OF GROUND WATER

Open joints and larger solution passages in solid rocks, spaces between grains of solid rock, and spaces between particles of unconsolidated rocks may contain water; if such openings are interconnected, the water moves in the direction of the hydraulic gradient. The amount of water stored within and the movement of water to and from a ground-water reservoir depend on hydrologic and geologic conditions.

Precipitation is the ultimate source of ground water. Some of the precipitation percolates downward to the ground-water body; some enters openings at rock outcrops and percolates laterally toward points of lower altitude; and some infiltrates the bed and banks of a surface-water body to reach an adjacent ground-water reservoir.

In the Louisville area the principal water-bearing formation is the glacial-outwash sand and gravel. It is recharged naturally by precipitation that penetrates the flood plain, by infiltration from the river, and by inflow from the bedrocks forming the sides and bottom of the containing valley. From areas of recharge, the ground water moves slowly toward points of lower water elevations and is discharged through wells in the area or to the river. The sand-and-gravel aquifer yields water to wells throughout the Louisville area except in the northwestern part of the city. The thickness of saturated sand and gravel in the Louisville area in December 1955 is shown in plate 2. In the sand-and-gravel aquifer, many of the wells discharge 100 to 500 gpm (gallons per minute), and a few wells discharge more than 1,000 gpm. A "collector" well discharges as much as 2,700 gpm.

A second water-bearing formation is the limestone underlying a part of the area of glacial-outwash sand and gravel. Most of the wells producing water from the bedrock formations are in the west-central part of the city. Yields of the bedrock wells range from 0 to 1,500 gpm.

Plate 2 is an isopach map of the saturated portion of the sand and gravel in the Louisville area drawn from data collected prior to December 31, 1955. Both isopach and contour maps represent conditions by a series of lines. The lines on an isopach map, however, instead of connecting points of equal elevation, as on a contour map, connect points of equal thickness. In plate 2 the isopach lines, or isopachs, connect points of equal thickness of the saturated portion

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of the sand and gravel. Isopachs represent differences in elevation between two surfaces. Therefore, a "low" on plate 2 may indicate either high bedrock, a low water table, or both.

The limestone bedrock that forms an aquifer in places probably is hydraulically connected with the sand and gravel. Large yields are obtained from wells in the limestone in a fairly well defined zone trending northeastward in the west-central part of the city. One well tapping the limestone in that area is reported to discharge 1,500 gpm.

USE OF GROUND WATER

In the Louisville area, ground water is used chiefly for industrial cooling and for air conditioning. In the southwestern part of the area, ground water is used for irrigation on truck farms and for domestic supplies. The Louisville Extension Water District started pumping ground water in 1948 and has steadily expanded its facilities to supply much of the southwestern part of the area, which formerly depended on individual wells for domestic and irrigation needs.

PUMPAGE

Most of the pumping of ground water in the Louisville area is concentrated in four smaller areas designated as the downtown subarea, south distillery subarea, Rubbertown subarea, and west-central subarea. Records of pumpage were collected annually from users withdrawing more than 100,000 gpd (gallons per day), and estimates of the remaining pumpage were made. The general pattern of the areal distribution of pumpage did not vary appreciably during the period 1949–55. Figure 1 shows the distribution of pumpage during 1954.

The estimated average pumpage for the years 1937 through 1955 by the various industries in the Louisville area is shown in table 2. If water, after being used, was returned to the ground, the amount returned was deducted from the total pumpage; thus the tabulations are net withdrawals. Not included in the table is the pumpage, estimated as about 1 mgd, for irrigation on truck farms, for domestic use, and for public supply in the southwestern part of the area. The pumpage of ground water by the Louisville Extension Water District is shown in figure 2.

From changes in water levels and an estimated coefficient of storage of 0.2, changes in storage within the heavily pumped industrial areas were computed for each year in the period 1943–55. The coefficient of storage of an aquifer is defined as the volume of water it releases from or takes into storage per unit surface area of the aquifer per unit change in the component of head normal to that surface. The annual net recharge to the area during this period also was computed by adding algebraically the sum of pumpage and the estimated changes in

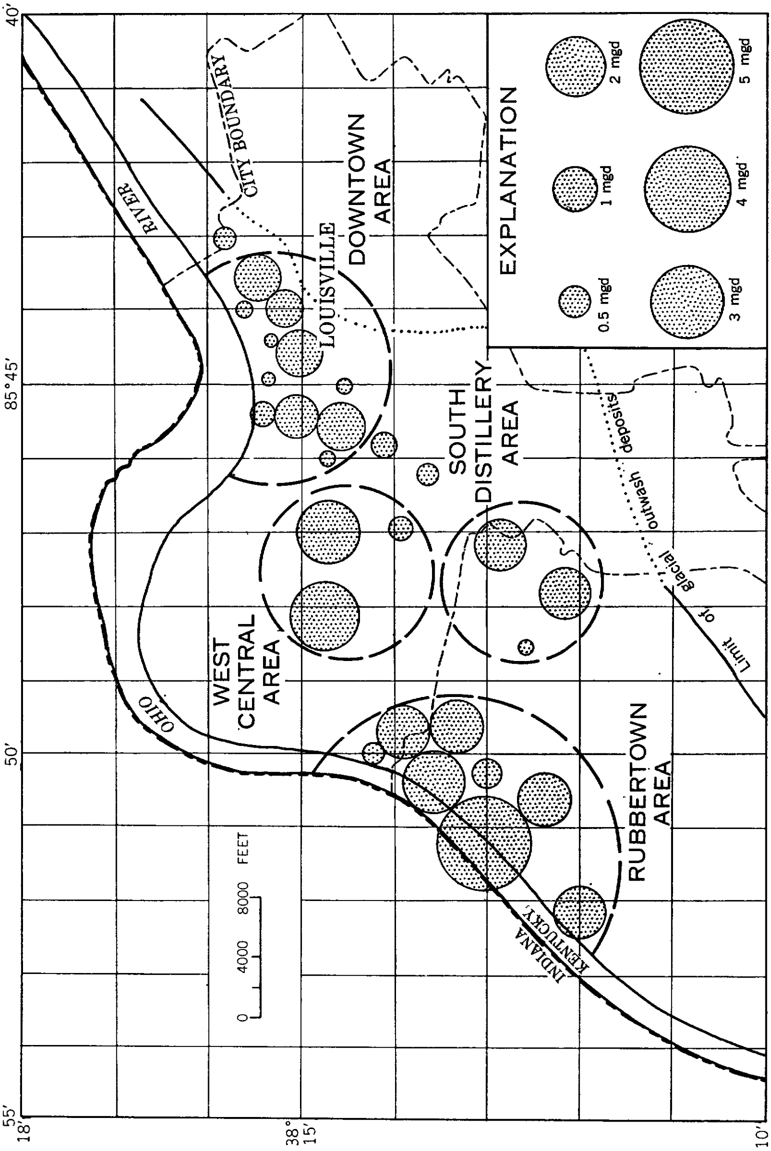


FIGURE 1.—Map showing distribution of pumpage of ground water in the Louisville area, Kentucky, 1954.

TABLE 2.—*Estimated withdrawals of ground water by industries in the Louisville area, 1937–55, and artificial recharge, 1944–55*

[Artificial recharge has been deducted from total withdrawal to obtain net withdrawal in millions of gallons per day]

Industries	1937	1938	1939	1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954	1955
Estimated average daily net withdrawals of ground water in millions of gallons per day																			
Distilling	6.2	6.1	6.5	10.5	14.9	16.7	17.2	9.6	8.4	4.6	6.1	3.9	4.1	4.7	5.9	3.6	4.1	4.9	4.1
Rubber and chemical manufacturing	------	------	------	------	.2	4.6	17.0	19.9	11.4	9.7	7.1	7.7	8.1	9.8	11.7	12.0	11.5	11.7	14.0
Metal working	2.2	2.2	2.3	2.4	4.1	4.3	3.9	3.7	3.2	3.5	3.6	3.2	2.8	1.7	1.2	1.0	1.3	1.4	1.5
Oil refining	4.9	4.9	4.9	4.7	4.6	4.6	3.9	4.2	3.0	3.4	3.2	2.9	2.9	3.0	3.1	2.6	2.2	1.6	1.7
Brewing	5.3	5.6	5.3	5.2	4.1	4.1	3.8	3.6	3.2	3.2	3.2	3.5	3.2	3.5	3.5	3.3	3.3	3.2	3.2
Air conditioning	3.9	3.9	3.8	3.8	3.7	3.6	3.7	3.7	3.7	3.5	3.3	3.2	3.0	2.8	2.9	2.7	3.0	3.0	3.1
Ice making	4.1	4.1	4.1	4.2	3.6	3.2	2.9	2.9	2.2	2.9	2.0	1.4	.8	.5	.4	.5	.2	.1	.1
Meat packing	2.4	2.4	2.3	2.2	2.6	2.5	2.0	2.1	2.0	1.8	1.2	1.1	1.0	1.0	1.0	1.3	1.7	.9	.9
Miscellaneous	1.4	1.4	1.4	1.7	2.0	1.9	1.9	1.9	1.9	.8	.9	.9	.7	.8	.5	.7	.6	.4	.4
Tobacco processing	2.5	2.6	2.5	2.2	1.9	1.7	1.2	.9	.9	.5	1.2	1.4	.7	.6	.6	.6	.8	.8	.9
Gas and Electric	.8	.9	.8	.8	.8	.8	.9	.8	.9	.9	.9	.9	.9	.4	.2	.1	.1	.0	------
Food manufacturing	.7	1.0	1.5	1.3	1.1	.9	.8	.7	.6	.6	.5	.5	.2	.2	.1	.1	.1	.1	.1
Dairying	2.2	2.2	2.2	2.2	2.2	2.3	2.3	2.2	2.2	1.8	1.5	1.3	1.3	.7	.7	.3	.4	.5	.6
Total net withdrawl	36.6	37.3	37.6	41.2	45.8	51.2	61.5	56.2	43.6	37.2	34.7	31.9	29.9	29.8	31.8	29.0	29.3	28.7	30.7
Estimated average daily pumpage, classified as to source																			
From wells in sand and gravel	32.7	33.0	33.9	36.7	42.1	47.4	57.3	49.7	35.1	30.8	27.5	25.8	25.4	25.7	28.0	25.0	24.6	24.2	26.0
From wells in limestone	3.9	4.3	3.7	4.5	3.7	3.8	4.2	6.5	8.5	6.4	7.2	6.1	4.5	4.1	3.8	4.0	4.7	4.5	4.7
Artificial recharge (not included in above figures)	------	------	------	------	------	------	------	.8	.8	.6	1.1	1.3	1.3	1.6	1.6	1.5	1.6	1.1	1.6

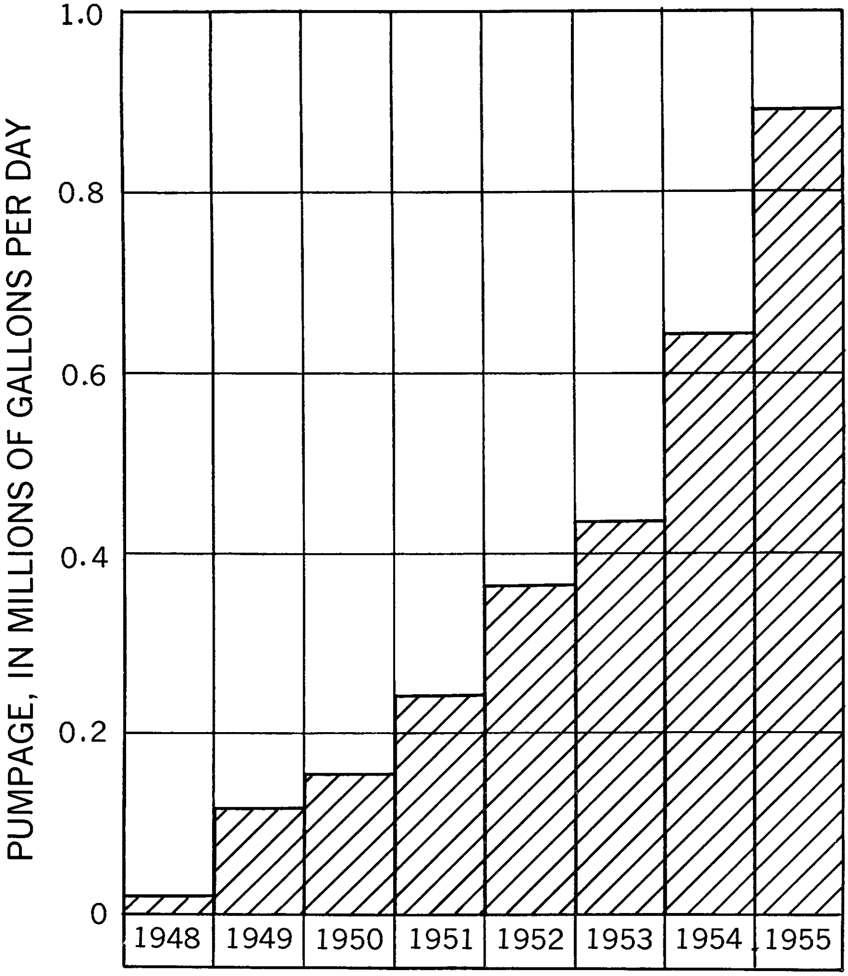


FIGURE 2.—Graph showing pumpage of ground water by Louisville Extension Water District, 1948–55.

storage. These estimates of changes in storage and in net recharge are shown in the following table:

Estimated change in storage and estimated net recharge in the Louisville area, 1943–55
[In millions of gallons per day]

	1943	1944	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954	1955
Estimated change in storage	−20	−14	+12	−1	−2	+2	+1	+5	0	−2	−7	−10	−4
Estimated natural recharge	42	42	56	36	33	34	31	35	32	27	22	19	27

The total pumpage by industries for each year from 1937 to 1955 and the estimated change in storage for each year from 1943 to 1955 are shown graphically in figure 3. Pumpage other than for industries

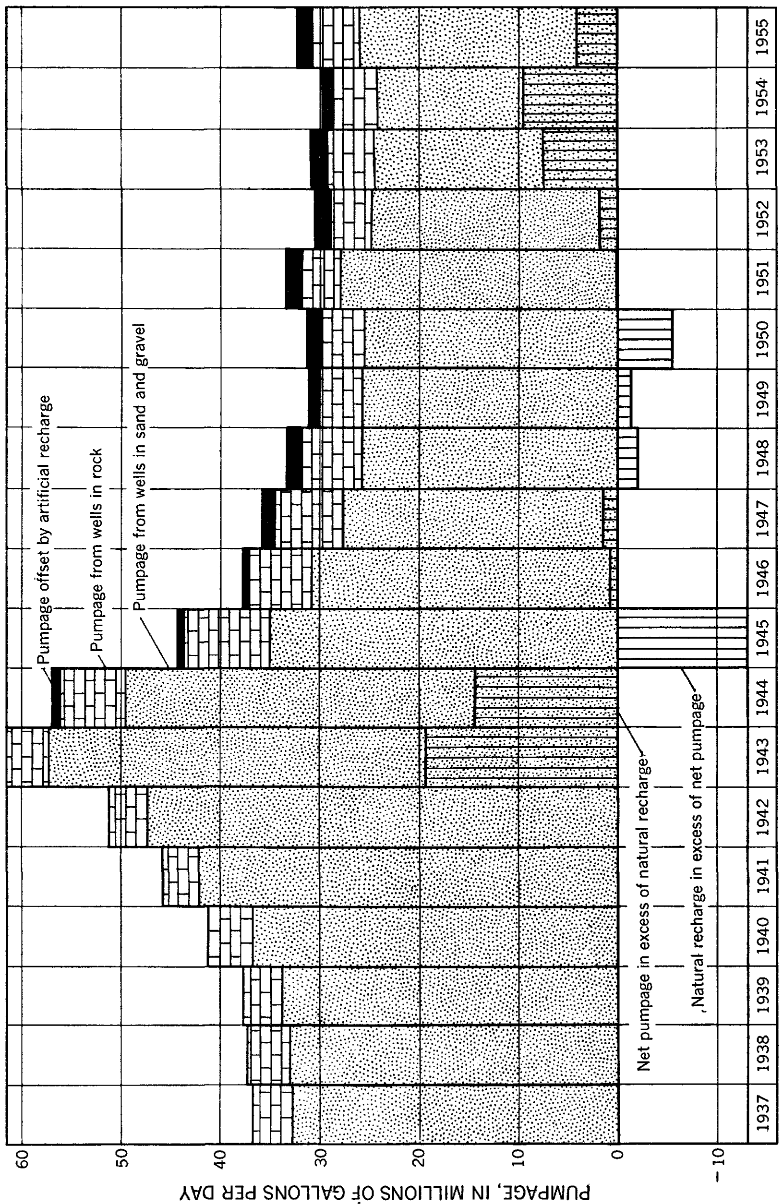


FIGURE 3.—Graphs showing pumpage, 1937–55, and changes in storage, 1943–55, in the Louisville area, Kentucky.

was not large enough to affect the water level except locally. The pumpage in 1943 and 1944 greatly exceeded the net recharge to the area, and water levels declined. The pumpage in 1945, though large, was more than balanced by greater than normal net recharge due to the infiltration effects of the second highest flood of record in the area. From 1946 to 1952, pumpage and net recharge were in fairly good balance except in 1950 when the effects of the greatest annual precipitation of record resulted in a gain of storage. Although withdrawal was approximately stabilized at an average of about 30 mgd from 1949 through 1955, pumpage exceeded net recharge during 1953 through 1955 by appreciable amounts. Droughts during the summers of 1952 to 1955 resulted in excessive losses of soil moisture, and the less-than-normal precipitation during the late fall, winter, and early spring of those years, after satisfying the soil-moisture deficiency, did not recharge the aquifer in a net amount equal to the pumpage.

ARTIFICIAL RECHARGE

Artificial recharge in the heavily pumped areas of Louisville was begun in 1944 as a means of conserving ground water. The most successful operation, at Joseph E. Seagram & Sons Distillery, was the recharging with city water through a collector well at an average rate of 1,130 gpm for short periods in the winter and spring of each of the years 1944 to 1947.

In 1947, after a sewer-rental law was passed, artificial recharge as a means of disposing of used (warm) water was tried by more than 20 companies. Although recharging through pits was tested by two companies, all successful artificial recharging in the Louisville area has been done through wells. Some water pumped from the sand and gravel was recharged to the same aquifer; some was recharged through wells penetrating limestone; and some water pumped from limestone was recharged through wells in the sand and gravel.

Several attempts at artificial recharge failed or were otherwise unsatisfactory. Some recharge wells were so near the pumped well or wells that, in time, the warm recharge water was repumped. Some screens in the recharge wells were clogged by silt or sand carried in the pumped water, or encrusted by precipitation of dissolved solids caused by temperature and pressure changes in the water.

A few of the recharge operations did not last long, but several have been maintained successfully and are still active. The artificial recharge in the Louisville area from 1944 to 1955 ranged from about 0.6 to 1.6 mgd. (See table 2.)

WATER-LEVEL FLUCTUATIONS

Water-level fluctuations are directly related to the changes in ground-water storage that result from recharge to and discharge from an aquifer. Water-level fluctuations range from sharp rises or declines of short duration to gradual rises or declines of long duration. Rapid changes in the stage of a stream hydraulically connected with a ground-water body and recharging through or pumping from a well cause sharp rises or declines of the water level in nearby wells; the cyclic effects of natural recharge to and natural discharge from an aquifer result in seasonal rises and declines of the water levels; the effects of a series of wet or dry years and of long-term artificial recharging or pumping in an area result in rises or declines of longer duration.

In an area where the hydraulic characteristics of the aquifer are known, water-level fluctuations serve as a measure of the net effect of recharge to and discharge from the area.

Most of the Louisville area was inundated during the 1937 Ohio River flood, and ground-water levels were very high. The recession of the floodwaters was followed by a general lowering of ground-water levels, and subsequent pumping for air conditioning and for industrial cooling resulted in a further decline. During the war years, 1944 and 1945, water levels declined to critical lows because of constant pumping at high rates in industrial areas. In the first few years after the war, a reduction in pumpage coupled with greater than normal precipitation caused water levels to rise again. However, in the period 1952–55 recharge was less than normal because of summer droughts, natural discharge increased because of persistently low river stages, and, in some parts of the area, the rate of pumping increased. The result was another decline of water levels.

Water-level contours in the Louisville area in December 1948, December 1952, and December 1955 are shown in plates 3, 4, and 5, respectively. Plate 5 is a generalized contour map showing ground-water levels as of December 1955. It does not show the effect of certain pumped wells near the river. (See Water-Supply Paper 1405, fig. 30, p. 143.) In December 1948 the water level in the Rubbertown subarea was about 25 feet higher than in 1945, when it was at a critical low. The water level declined about 12 feet from 1948 to 1952, however, despite the fact that the water level in unpumped parts of the Louisville area was unusually high. The water level was low throughout much of the Louisville area in December 1955.

Plate 6 shows the net change in water level during the period December 1948 to December 1955. In the Louisville area west of longitude 85°43′ and north of latitude 38°10′, an average net decline of water levels of about 4 feet during that period represents an estimated loss in ground-water storage of nearly 6 billion gallons, or an average of about 2.3 mgd.

GROUND-WATER CONDITIONS IN SUBAREAS

In describing the ground-water conditions of the Louisville area, six subareas are considered separately. In addition to the four previously designated heavily pumped areas, two subareas of relatively minor pumpage are defined—the northeast subarea and the southwest subarea.

NORTHEAST SUBAREA

The northeast subarea extends 6 miles along the Ohio River flood plain from Harrods Creek on the northeast to Zorn Avenue on the southwest. It is used principally for recreation. As most of the subarea is only a few feet above normal river level, it frequently is flooded in the winter and spring. Water levels generally are close to the land surface and respond rapidly to changes in the river stage. During long periods when the river is at normal-pool stage, 420 feet above mean sea level (Ohio River datum), ground-water levels are near, or slightly above, the river level. Gage readings at Dam 41 are referenced to Ohio River datum. In illustrations relating river stages to ground-water levels, the river stages are converted to the adjustment of 1912, which is 0.47 foot lower than the Ohio River datum. The hydrograph of well 40–17–5 in plate 9 is typical of hydrographs of wells in the subarea.

The total quantity of water pumped from wells in this subarea is negligible. Rorabaugh (1956, p. 159) estimated the available ground water, including infiltration that may be induced from the river in the 6-mile stretch, to be about 280 mgd.

DOWNTOWN SUBAREA

The downtown subarea, north of Oak Street and extending from 10th Street to Zorn Avenue, is chiefly commercial but includes a few industries. During the period 1949–55 the average ground-water pumpage in that area was gradually reduced from about 11 to 7 mgd. The reduction was due to a reduction in demand for water by industries, largely as a result of installation of cooling towers, and to increased use of city water.

Recharge to the downtown subarea occurs chiefly by infiltration from the Ohio River in the area from Zorn Avenue to the dam and by lateral seepage of water that has entered the aquifer at higher altitudes.

Plate 7 shows graphs of river level (upper pool), precipitation, and water level in four wells in the downtown subarea. The downward trend of the water level, as shown by the hydrograph for wells 45–14–1 and 45–15–36, began when the 1937 flood receded, and it continued because of ground-water withdrawals. The annual cyclic fluctuations of water level are due to variations in rates of pumping for air conditioning; pumping is greatest and water levels decline during the hotter part of the year (usually April through September), and pumping is least and water levels recover during the cooler part of the year. The low water level in 1955 reflected 3 successive years of low river stage and summer drought. The hydrographs of wells 43–15–1 and 44–15–6 show the rise of the water table due to infiltration during high river stages and the decline of the water table when the river returns to normal stage; they show also the general trends related to pumping. The sharp decline of the water level in 1954 at well 43–15–1 was caused by nearby dewatering operations during construction of a floodwall pumping station.

SOUTH DISTILLERY SUBAREA

The south distillery subarea, east of Cane Run Road and extending from Algonquin Parkway to Crums Lane and Berry Boulevard, includes the sites of seven distilleries. Nearly all the ground water pumped in the subarea is used by the distilleries, although a small amount is pumped for irrigation. During the years 1940–42 the distilleries produced industrial alcohol for wartime use; pumping rates were increased rapidly and in 1942 reached a maximum of a little more than 11 mgd. During the period 1945–55 pumpage ranged from about 2.5 to 5 mgd.

Recharge to the south distillery subarea is by downward percolation of precipitation and by inflow from upgradient areas. During the springs of 1944 to 1947, large amounts of city water were recharged to the aquifer through a "collector" well.

Plate 7 shows graphs of pumpage, water levels, and precipitation in the south distillery subarea. The hydrograph for well 46–11–2, near the valley wall away from the area of heavy pumping, shows the effects of natural recharge from precipitation and from inflow of ground water from the valley wall, and of discharge toward the cones of depression of pumped wells. The hydrograph for well 47–12–1 shows the high water level resulting from the 1937 flood and the steady decline caused by wartime pumping. It also shows a general recovery of the water level from 1944 through 1952 and a decline during 1953 and 1954. The recovery correlated with reduced pumpage and with greater than normal natural recharge; the later water-level decline occurred when pumpage reportedly remained fairly constant, indicating that the recharge to the area had decreased. The hydrograph for well 47–12–4, near the "collector" well, shows sharp rises of water level during the springs of 1944 to 1947 when the "collector" well was used in recharging the aquifer with city water; it shows also rises during the winters and springs of 1949 and 1950 when pumping was discontinued and city water was used.

RUBBERTOWN SUBAREA

The Rubbertown subarea, west of Cane Run Road and extending from Virginia Avenue southward to Lees Lane, includes manufacturing plants engaged in the production of synthetic chemicals and plants of several other industries. Nearly all the ground water pumped in that area is used by the industries for cooling; a very small amount is pumped for irrigation. Of all the Louisville subareas, the Rubbertown subarea is the most heavily pumped. Owing to rapid industrial expansion in that subarea during World War II, pumpage of ground water increased to about 24 mgd in 1944. After the war, pumping was reduced and from 1947 to 1949 was about 11 mgd. During the period 1950–55, pumpage in the Rubbertown subarea ranged from about 13 to 16 mgd.

Recharge to the Rubbertown subarea occurs by downward percolation of precipitation, inflow from upgradient areas, and, especially during flood periods, infiltration of river water.

Plate 7 shows graphs of pumpage, river level (lower pool), precipitation, and water level in five wells in and near the Rubbertown subarea. The hydrograph for well 49–10–1, south of the heavily pumped area and away from the river, shows chiefly the effects of natural recharge to and natural discharge from the aquifer. The hydrograph for well 53–10–1, near the river, shows effects of river infiltration during flood periods and subsequent recessions after the floods. Hydrographs for wells 49–13–22 and 49–13–24 show direct correlation with pumpage; the fluctuation in well 49–13–24 is greater because that well is closer to the effective center of pumping than is well 49–13–22. The sharp decline of water levels from 1942 to 1945 reflected greatly increased pumping in the area, and the lows of 1944 and 1945 corresponded with maximum pumpage.

In 1944 conservation measures including artificial recharge, operation of cooling towers, refrigeration, recirculation, and redesign of plant equipment were put into effect. Some gains in ground-water storage resulted from the effects of the 1945 Ohio River flood, the second highest of record. However, the ultimate solution to the problem of the wartime decline in ground-water level was the greatly reduced rate of pumping when production was curtailed at the end of the war. Because of the reduced rate of pumping after 1944, the water level in the Rubbertown subarea recovered to postwar highs in 1948 and 1949. Subsequent increases in production accompanied by an increased rate of pumping caused water levels to decline to relatively low levels. If the rate of pumping in that area continues to increase, the water level will continue to decline to a position as low as or even lower than that of 1945.

A sharp rise of the water level in well 49–13–24 in 1953 reflected a decrease in the withdrawal of ground water because of the siphoning of river water to "collector" well 50–13–57.

WEST-CENTRAL SUBAREA

The west-central subarea, between 10th Street and 30th Street (Kentucky and Indiana Terminal Railroad) and north of Algonquin Parkway, contains many types of industries. Nearly all the ground water pumped in that area is used for industrial cooling. The rate of pumping decreased from a maximum of a little more than 16 mgd in 1944 to less than 6 mgd in 1949. From 1949 through 1955 the rate of pumping remained fairly constant at about 5 mgd. About 85 percent of the water pumped from the limestone aquifer in the entire Louisville area comes from wells in the west-central subarea, but only 3 percent of the total pumped from the sand and gravel aquifer comes from wells in this subarea.

The west-central subarea is unfavorably situated with respect to natural recharge. Shale bedrock at altitudes higher than river pool stage in the northern part of the subarea and clay deposits in the western part form barriers that impede infiltration of river water to the sand and gravel aquifer. Lateral seepage of water through the aquifer from the east and south is intercepted in part by wells in other areas. Recharge by downward percolation of precipitation is probably small because nearly half the area is covered by buildings or is paved.

Plate 7 shows graphs of pumpage, water levels, and precipitation in the west-central subarea. Comparison of the hydrograph for wells 46–14–1 and 46–14–28 with the pumpage graph shows that in the west-central subarea the water level does not correlate directly with pumping. The lack of correlation suggests that the effect of pumping in surrounding areas obscures the effect of local pumping.

SOUTHWEST SUBAREA

The southwest subarea extends southward from the south distillery and Rubbertown subareas to near Kosmosdale, a town that is 2.3 miles southwest of Orell but is not shown because it is beyond the limit of the map. Formerly the subarea was rural, but the farms are being replaced by residential and commercial developments, and industrial sites are being developed near the river. For many years ground water for domestic use and for irrigation was pumped from many small wells so widely spaced that no part of the subarea was heavily pumped. In 1948 the Louisville Extension Water District began the development of a well field for a public-supply system at Lower River Road and Bethany Lane. The growth of the District is indicated by the increase in its yearly pumpage of ground water.

(See fig. 2.) Expansion of its facilities from 1948 through 1955 afforded service to much of the subarea formerly dependent on individual wells.

Recharge to the subarea occurs by downward percolation of precipitation, inflow from the bedrock adjoining the flood plain, and infiltration of river water during high river stages. Rorabaugh and others (1953, p. 47) estimated the potential recharge to the sand and gravel aquifer by induced infiltration from the river to be about 40 mgd.

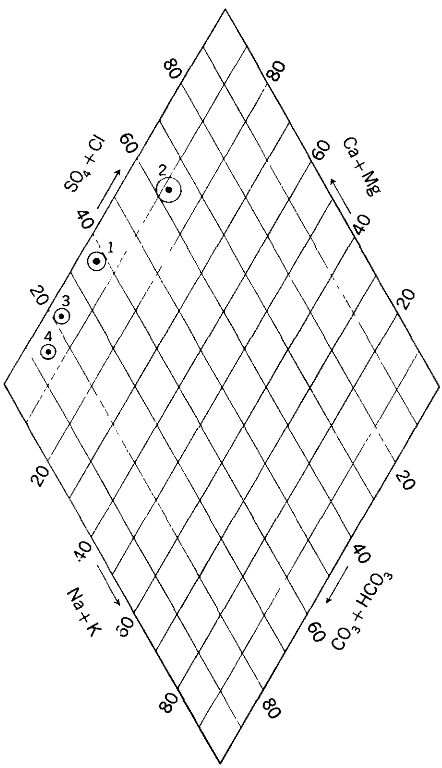
Water levels in the southwest subarea are affected chiefly by natural recharge and by discharge to the river. In wells away from the river, cyclic fluctuations of water levels denote seasonal gains in ground-water storage due to recharge from precipitation during the non-growing period, November to April, and subsequent loss in storage during the period in which vegetation intercepts most of the water that enters the soil. The hydrograph for well 51–8–1 (pl. 15) is typical of those which show a time lag of 3 to 4 months between the beginning of the nongrowing period and the beginning of the water-level rise; this lag represents the time required for precipitation to infiltrate to the ground-water body. A buildup of water storage during several wet years, including 1950, the wettest year of record, is shown by the upward trend during the years 1948 to 1952, in which latter year levels were at highs of record. Conversely, a loss in ground-water storage during several dry years is shown by the steady decline during the years 1952 through 1955. The levels in 1955 were at or near the lows of record.

In wells near the river, water levels respond quickly to changes in river stage. The graph of well 54–7–1 (pl. 15) exemplifies this characteristic.

CHEMICAL QUALITY OF GROUND WATER

During the period 1949–52, the ground-water sampling program continued and approximately 40 samples, each from a different well, were collected annually; during the previous 4 years, 1945–48, an average of 45 samples had been taken annually. In 1953, 1 sample was collected for a comprehensive analysis, 13 for partial analysis, and an additional 41 for determinations of hardness and sulfate. In 1954, 15 samples were collected for comprehensive analysis and 2 for partial analysis. In 1955, 1 sample was collected for comprehensive analysis.

With negligible error, the ionized constituents of most natural waters may be considered as three major cations, which are in chemical equilibrium with three major anions. If potassium (K) is grouped with sodium (Na), and carbonate (CO_3) with bicarbonate (HCO_3), the cation constituents are calcium (Ca), magnesium (Mg), and sodium and potassium (Na and K), and the anion constituents are carbonate and bicarbonate (CO_3 and HCO_3), sulfate (SO_4), and chloride (Cl). The sum of the concentrations of the three cation constituents is considered the total concentration (100 percent) of cations in solution; similarly, the sum of the concentrations of the three anion constituents is considered the total concentration of anions in solution. If each cation is expressed as the percentage of total equivalents per million of cations and each anion as the percentage of total equivalents per million of anions, the percentages of equivalents per million of each of the four groups of ions indicated on the sides of the diamond-shaped diagram (see figs. 4 and 5) determine the position of each chemical analysis plotted within the diagram. Thus the chemical character of a water is shown graphically as relative concentrations of the four major groups of ions. The total concentrations of these ions are indicated by a circle whose area is approximately proportional to the dissolved-solids content.

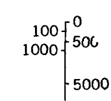


Percentage equivalents per million

Well	No.	Dissolved solids (ppm)	Type of aquifer
48-12-6	1	526	Sand and gravel
50-12-3	2	858	Sand and gravel
50-12-10	3	356	Sand and gravel
51-11-3	4	341	Sand and gravel

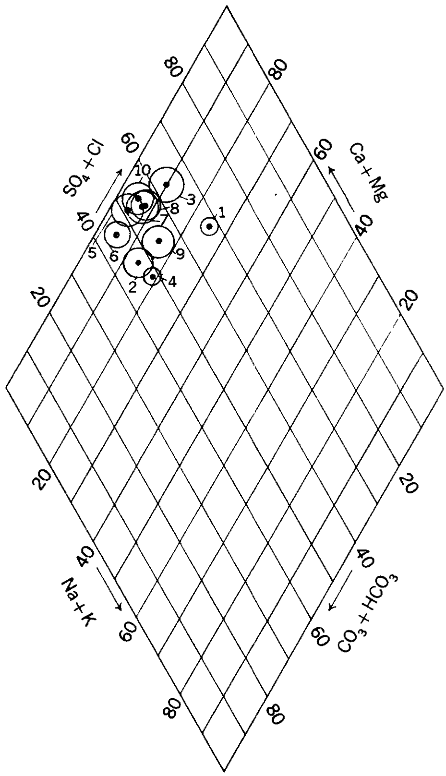
Wells in area underlain by shale

Area of circle indicates dissolved solids in parts per million, thus:



SCALE OF DIAMETERS

FIGURE 4.—Diagram showing chemical character of water in sand and gravel underlain by shale, Louisville area, Kentucky, 1954.

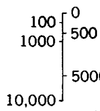


Percentage equivalents per million

Well	No.	Dissolved solids (ppm)	Type of aquifer
44-15-29	1	368	Sand and gravel
45-14-6	2	1021	Sand and gravel
45-14-62	3	1584	Sand and gravel
45-15-66	4	493	Sand and gravel
47-12-6	5	1217	Sand and gravel
47-12-18	6	886	Limestone
47-14-4	7	1269	Sand and gravel
47-14-18	8	1343	Limestone
48-14-19	9	1188	Limestone
48-14-15	10	1154	Sand and gravel

Wells in area underlain by limestone

Area of circle indicates dissolved solids in parts per million, thus:



SCALE OF DIAMETERS

Figure 5.—Diagram showing chemical character of water in limestone and in sand and gravel underlain by limestone, Louisville area, Kentucky, 1954.

The procedure in utilizing this geochemical diagram for the interpretation of water analyses is fully described by Piper (1944).

The ground water in the sand and gravel overlying limestone bedrock is similar to that in the sand and gravel overlying shale bedrock in that both are high in calcium and magnesium. The greatest difference in the plot of the ground waters of the two areas of sand and gravel is in the sulfate concentrations. In the water from the sand and gravel overlying limestone bedrock, sulfate has a range of equivalents per million from 47 to 67, whereas the corresponding range in the water from the sand and gravel overlying shale bedrock is from 14 to 63.

The significance of the various dissolved mineral constituents commonly found in water and the physical properties of natural waters are shown in table 3.

Figure 6 shows the areal distribution of sulfate content of ground water in the Louisville area for 1953–54. Figures 7 to 11 show in graphical form the changes in the concentration of iron and sulfate

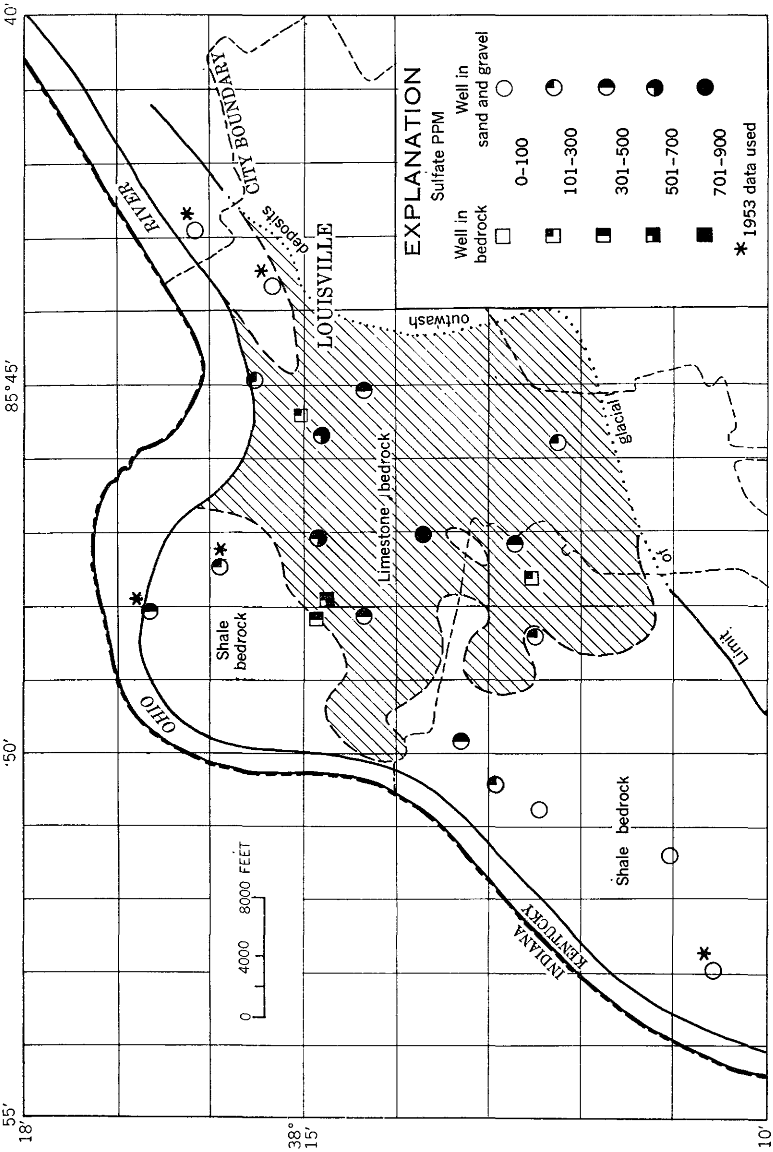


FIGURE 6.—Map showing sulfate content of water samples from selected wells in the Louisville area, Kentucky, 1953-54.

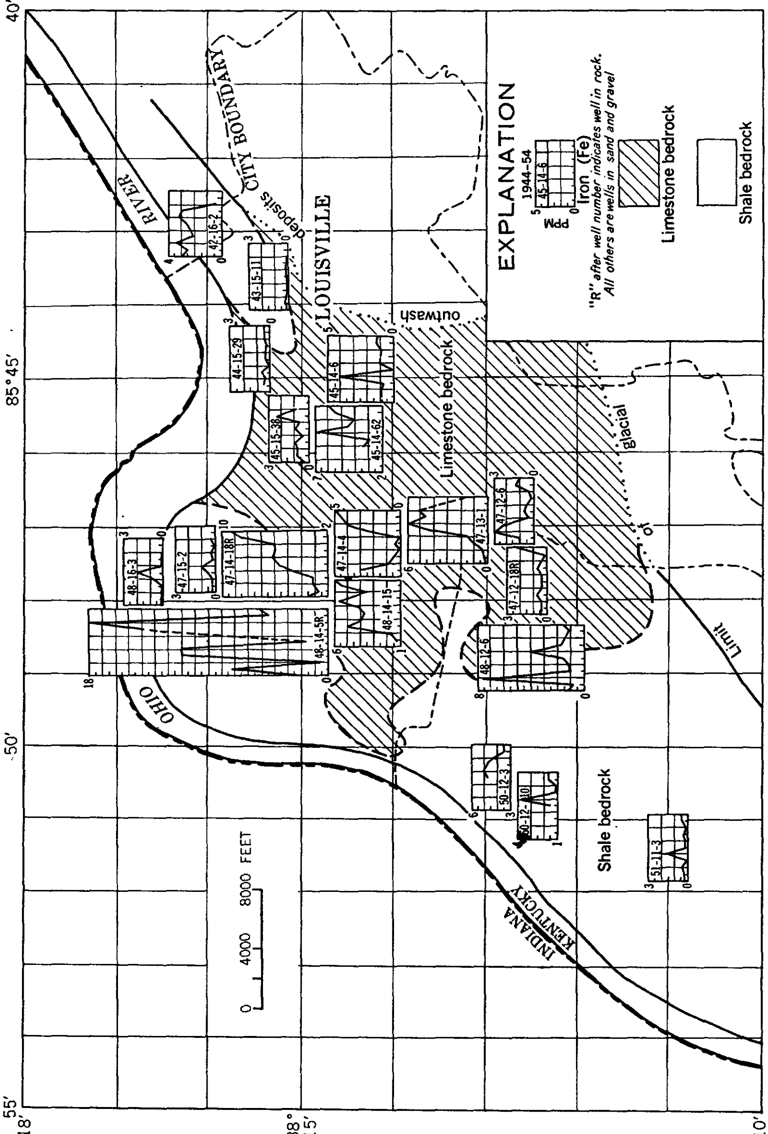


Figure 7.—Map with graphs showing changes in iron content of water samples from selected wells in the Louisville area, Kentucky, 1944–54.

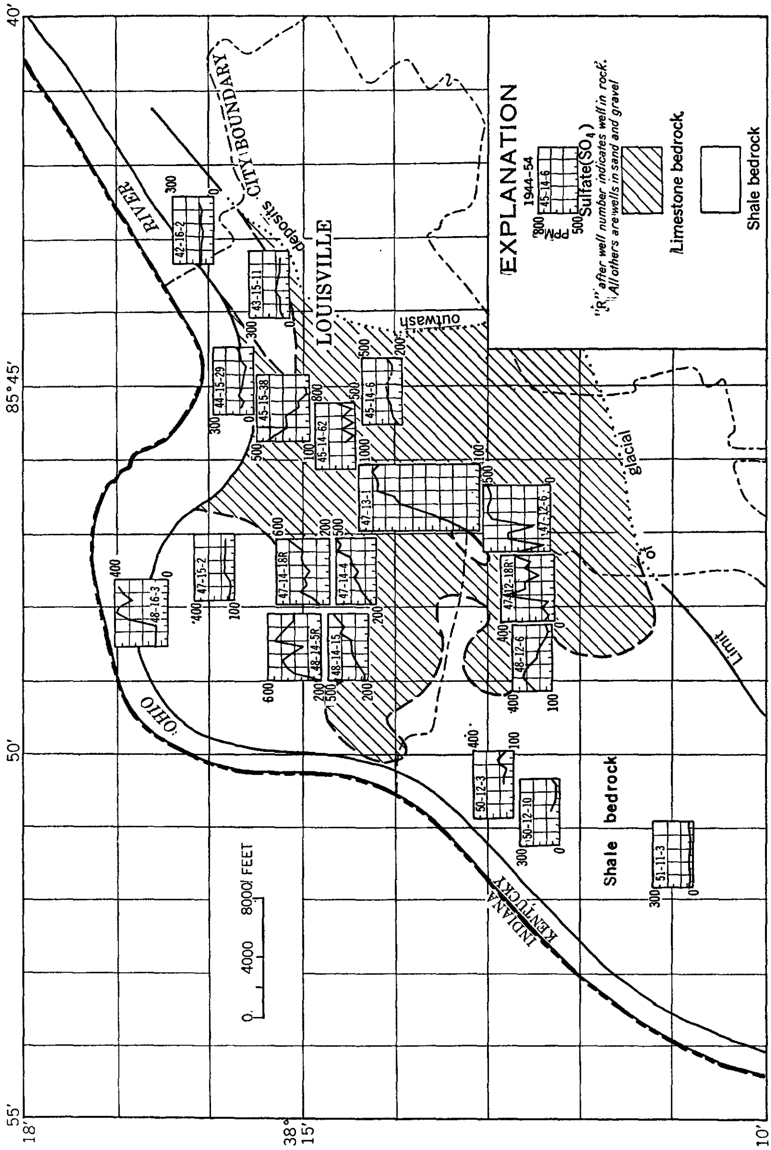


FIGURE 8.—Map with graphs showing changes in sulfate content of water samples from selected wells in the Louisville area, Kentucky, 1944–54.

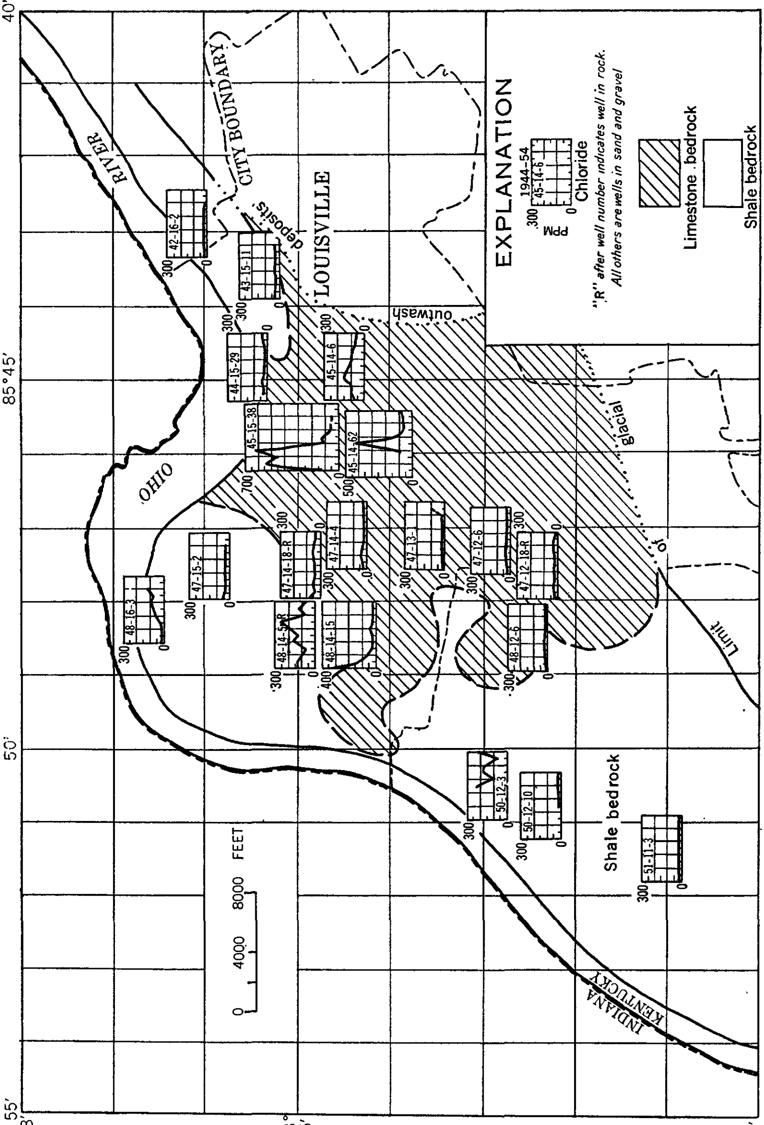


FIGURE 9.—Map with graphs showing changes in chloride content of water samples from selected wells in the Louisville area, Kentucky, 1944–54.

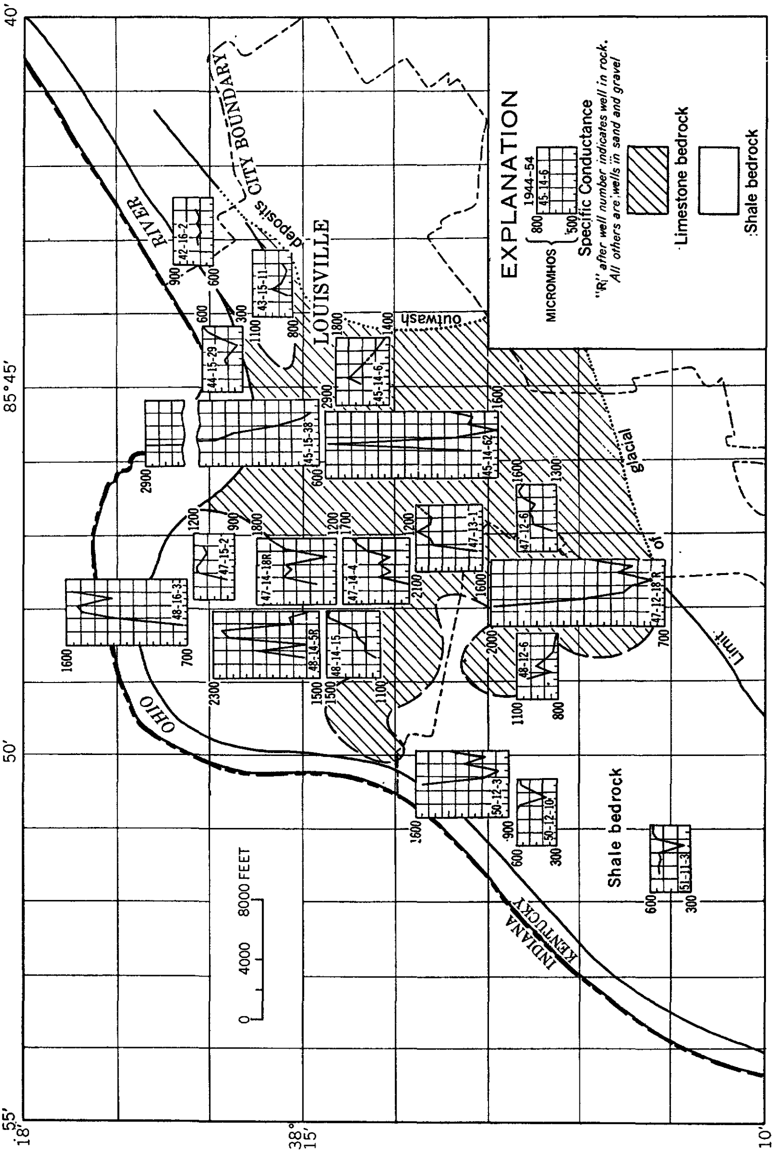


Figure 10.—Map with graphs showing changes in specific conductance of water samples from selected wells in the Louisville area, Kentucky, 1944–54.

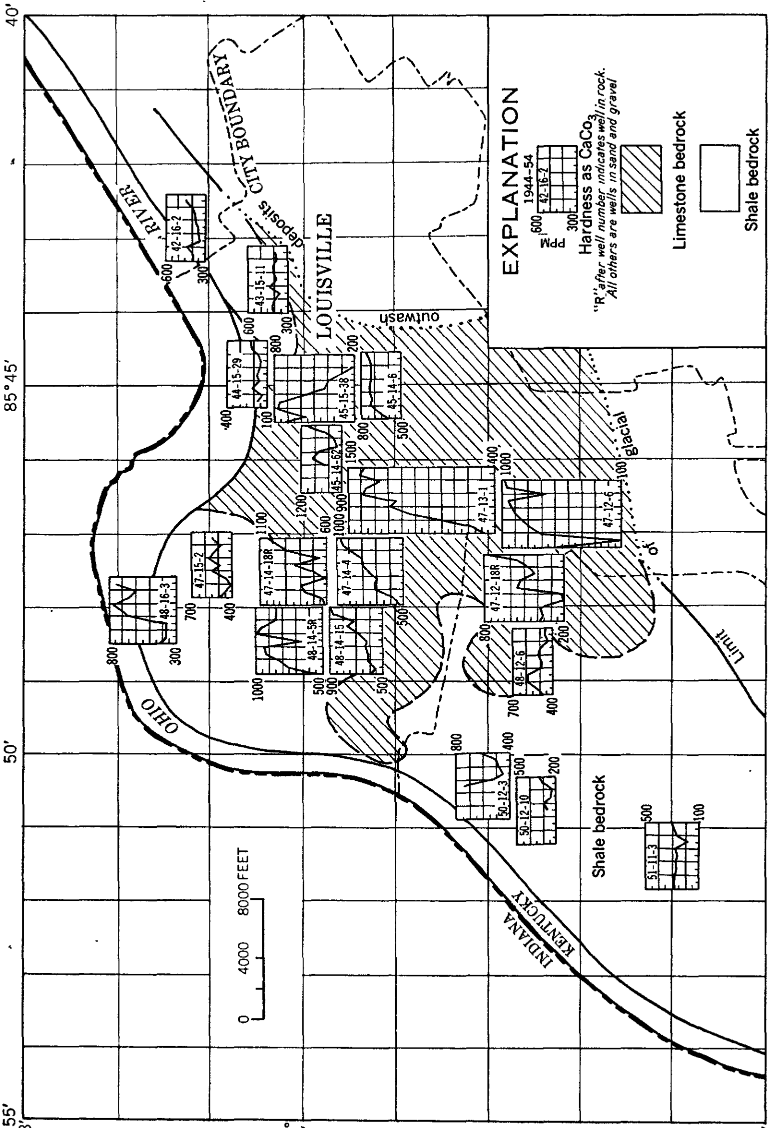


FIGURE 11.—Map with graphs showing changes in hardness of water samples from selected wells in the Louisville area, Kentucky, 1944-54.

and changes in specific conductance and hardness for 19 selected wells over the period 1944–54. Tables 4 and 5 indicate the trends of the chemical quality of the ground water in the Louisville area during the period 1949–54. Fourteen selected wells, of which eleven obtain water from the sand and gravel and three from the Louisville limestone, were used in the calculation of the various averages.

TABLE 3.—*Source and significance of dissolved mineral constituents and physical properties of natural waters*

Constituent or physical property	Source or cause	Significance
Silica (SiO_2)	Dissolved from practically all rocks and soils, usually in small amounts from 1 to 30 ppm. High concentrations, as much as 100 ppm, generally occur in highly alkaline waters.	Forms hard scale in pipes and boilers. Carried over in steam of high pressure boilers to form deposits on blades of steam turbines. Inhibits deterioration of zeolite-type water softeners.
Iron (Fe)	Dissolved from practically all rocks and soils. May be derived also from iron pipes, pumps, and other equipment. More than 1 or 2 ppm of soluble iron in surface waters usually indicate acid wastes from mine drainage or other sources.	On exposure to air, iron in ground water oxidizes to reddish-brown sediment. More than about 0.3 ppm stains laundry and utensils reddish brown. Objectionable for food processing, beverages, dyeing, bleaching, ice manufacture, brewing, and other processes. U.S. Public Health Service drinking-water standards state that iron and manganese together should not exceed 0.3 ppm. Larger quantities cause unpleasant taste and favor growth of iron bacteria.
Manganese (Mn).	Dissolved from some rocks and soils. Not so common as iron. Large quantities often associated with high iron content and with acid waters.	Same objectionable features as iron. Causes dark brown or black stain.
Calcium (Ca) and magnesium (Mg).	Dissolved from practically all soils and rocks, but especially from limestone and dolomite. Calcium is dissolved from gypsum. Calcium and magnesium are found in large quantities in some brines. Magnesium is present in large quantities in sea water.	Cause most of the hardness and scale-forming properties of water; soap consuming. (See hardness). Waters low in calcium and magnesium desired in electroplating, tanning, dyeing, and textile manufacturing.
Sodium (Na) and potassium (K).	Dissolved from practically all rocks and soils. Found also in ancient brines, sea water, some industrial brines, and sewage.	Large amounts, in combination with chloride, give a salty taste. Moderate quantities have little effect on the usefulness of water for most purposes. Sodium salts may cause foaming in steam boilers and a high sodium ratio may limit the usefulness of water for irrigation.
Bicarbonate (HCO_3) and carbonate (CO_3).	Action of carbon dioxide in water on carbonate rocks such as limestone and dolomite.	Bicarbonate and carbonate produce alkalinity. Bicarbonates of calcium and magnesium decompose in steam boilers and hot-water facilities to form scale and release corrosive carbon dioxide gas. In combination with calcium and magnesium cause carbonate hardness.
Sulfate (SO_4)	Dissolved from rocks and soils containing gypsum, iron sulfides, and other sulfur compounds. Usually present in mine waters and in some industrial wastes.	Sulfate in water containing calcium forms hard scale in steam boilers. In large amounts, sulfate in combination with other ions gives bitter taste to water. Some calcium sulfate is considered beneficial in the brewing process. U.S. Public Health Service drinking-water standards recommend that the sulfate content should not exceed 250 ppm.
Chloride (Cl)	Dissolved from rocks and soils. Present in sewage and found in large amounts in ancient brines, sea water, and industrial brines.	In large amounts in combination with sodium gives salty taste to drinking water. In large quantities increases the corrosiveness of water. U.S. Public Health Service drinking-water standards recommend that the chloride content should not exceed 250 ppm.
Fluoride (F)	Dissolved in small to minute quantities from most rocks and soils.	Fluoride in drinking water reduces the incidence of tooth decay when the water is consumed during the period of enamel calcification. However, it may cause mottling of the teeth depending on the concentration of fluoride, the age of the child, amount of drinking water consumed, and susceptibility of the individual. (Maier, 1950).

TABLE 3.—*Source and significance of dissolved mineral constituents and physical properties of natural waters*—Continued

Constituent or physical property	Source or cause	Significance
Nitrate (NO_3)	Decaying organic matter, sewage, and nitrates in soil.	Concentrations much greater than the local average may suggest pollution. There is evidence that more than about 45 ppm of nitrate (NO_3) may cause a type of methemoglobinemia in infants, sometimes fatal. Water of high nitrate content should not be used in baby feeding (Maxcy, 1950). Nitrate has been shown to be helpful in reducing intercrystalline cracking of boiler steel. It encourages growth of algae and other organisms which produce undesirable tastes and odors.
Dissolved solids	Chiefly mineral constituents dissolved from rocks and soils. Includes any organic matter and some water of crystallization.	U.S. Public Health Service drinking-water standards recommend that the dissolved solids should not exceed 500 ppm. Waters containing more than 1,000 ppm of dissolved solids are unsuitable for many purposes.
Hardness as $CaCO_3$.	In most waters nearly all the hardness is due to calcium and magnesium. Free acids and all the metallic cations other than the alkali metals also cause hardness.	Consumes soap before a lather will form. Deposits soap curd on bathtubs. Hard water forms scale in boilers, water heaters, and pipes. Hardness equivalent to the bicarbonate and carbonate is called carbonate hardness. Any hardness in excess of this is called noncarbonate hardness. Waters having hardness of 60 ppm or less are considered soft; 61 to 120 ppm, moderately hard, 121 to 200 ppm, hard; more than 200 ppm, very hard.
Specific conductance (micromhos at 25° C).	Ionized mineral constituents in the water.	Specific conductance is a measure of the capacity of the water to conduct an electric current. Varies with concentration and degree of ionization of the constituents. Varies with temperature; reported at 25° C.
Hydrogen-ion concentration (pH).	Acids, acid-generating salts, and free carbon dioxide lower the pH. Carbonates, bicarbonates, hydroxides, phosphates, silicates, and borates raise the pH.	A pH of 7.0 indicates neutrality of a solution. Values higher than 7.0 denote increasing alkalinity; values lower than 7.0 indicate increasing acidity. The pH is a measure of the activity of the hydrogen ions. Corrosiveness of water generally increases with decreasing pH. However, excessively alkaline waters also may corrode metals.
Temperature		Affects usefulness of water for many purposes. For most uses, a water of uniformly low temperature is desired. Shallow wells show some seasonal fluctuations in water temperature. Ground waters from moderate depths usually are nearly constant in temperature, which is near the mean annual air temperature of the area. In very deep wells the water temperature generally increases on the average about 1° F with each 50- to 100-foot increment of depth. Seasonal fluctuations in temperatures of surface waters are comparatively large, depending on the depth of water, but do not reach the extremes of air temperature.

In maintaining the yearly water-sampling program, sometimes a sample could not be obtained from a well sampled the preceding year but was obtained from a second well of similar construction at approximately the same location. If the second well has the same depth as the first and obtains water from the same aquifer, the water is generally similar to that of the first well.

The following pairs of wells meet the conditions described above and for purposes of illustrations are used as an entity in figures 6–11, in table 5, or in both: Wells 48–14–17 and 48–14–15, 42–16–42 and 42–16–2, 43–15–31 and 43–15–11, 47–13–12 and 47–13–1, 48–14–19 and 48–14–5.

TABLE 4.—*Chemical analyses of water from wells in the Louisville area, Kentucky, 1949–55*

[Chemical constituents given in parts per million. Depth: Asterisk (*) indicates limestone aquifer; otherwise aquifer is sand and gravel]

Well	Owner	Depth of well (ft)	Date collected	Temperature (°F)	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$	Specific conductance at 25° C (micromhos)	pH	Color
42-16-2	Louisville Gas and Electric Co.	82	Aug. 30, 1949	58		2.6						346		77	18		0.0		350	698		
			Aug. 15, 1950	58		3.2						350		89	20		.7		372	726		
			Sept. 4, 1951	58		3.0						328		88	26	0.1	.8		372	703		
			Aug. 15, 1952	61		.88						408		75	7.5	.1	.1		398	734		
			Dec. 18, 1952	57	16	.44	0.73	134	27	11	1.1	388	0	135	12	.1	.0	532	448	798	7.6	
42	do	101	Oct. 9, 1953	57										99					440			
43-15-11	Oertel Brewing Co., Inc.	91	Sept. 1, 1949	59		.12						386		94	39		5.0		385	879		
			Aug. 30, 1950	59		.19						406		86	42		7.6		404	852		
			Oct. 5, 1951	59		.04						404		77	38	.1	8.3		416	849		
			Aug. 15, 1952	59		.08						405		76	39	.0	10		382	874		
31	do	116	Oct. 9, 1953	59										74					392			
44-13-2	Durkee Famous Foods	61	Sept. 6, 1949	60		.18						446		227	48		54		582	1,250		
			Aug. 30, 1950	61		.17						540		224	42		42		588	1,200		
			Oct. 26, 1951	60		.09						424		180	44	.0	38		514	1,080		
			Aug. 12, 1952	60		.16						441		198	41	.1	43		525	1,160		
			Oct. 20, 1953	60										163					513			
44-14-5	J. V. Pilcher Manufacturing Co.	89	Aug. 13, 1949	62		.23						542		154	66		59		642	1,350		
			Aug. 30, 1950	62		.09						540		163	70		66		638	1,320		
			Aug. 15, 1952	65		.10						457		233	61	.1	75		610	1,350		
			Dec. 18, 1952	63	18	.23	.00	208	41	62	10	448	0	275	76	.2	74	990	690	1,420	7.6	1
			Oct. 9, 1953	60										146					622			
44-15-15	Stoll Oil Refining Co.	111	Aug. 12, 1952	61		.29						120		72	28		1.4		179	430		
			Dec. 18, 1952	58	12	.49	.5	46	8.7	14	2.1	122	0	60	20	.2	.0	220	150	372	7.9	4
			Oct. 9, 1953	60										76					183			
16	do		Sept. 1, 1949	59		.37						114		62	20		1.9		151	388		
			Sept. 6, 1950	61		.60						124		58	18		1.4		146	373		
			Oct. 22, 1951	58		.43						116		47	14	.4	.5		138	341		
29	Ohio River Sand Co., Inc.	102	Sept. 1, 1949	57		.28						108		84	26		1.5		179	429		
			Aug. 18, 1950	58		.30						108		70	22		1.0		152	376		
			Oct. 22, 1951	61		.18						104		54	12	.1	1.0		150	329		
			Aug. 12, 1952	58		.27						124		81	25	.1	.9		168	445		
			Sept. 22, 1953	64		.32						120	0	95	42	.1	1.7		222	551		
			Oct. 22, 1954	60	11	.35	.35	67	15	32	3.2	119	0	124	53	.1	1.2	368	230	598	7.7	5
30	Grocers Ice and Cold Storage Co.	110	Aug. 31, 1949	60		.15						216		68	30		2.3		249	574		
			Sept. 6, 1950	61		.17						224		68	31		8.7		256	569		
			Oct. 26, 1951	60		.14						228		51	28		3.7		242	551		
			Aug. 15, 1952	60		.09						223		53	31	.3	12		240	579		
			Oct. 9, 1953	62										57					256			

36	Armour and Co.	100	Sept. 28, 1953	60									44					174			
45-12-14	American Air Filter Co., Inc.	35	Oct. 13, 1953	65									201					520			
			Nov. 4, 1954	66		3.9					396	0	162	22	.1	.1		478	1,100	7.2	
45-13-6	Dean Milk Co., Inc.	*180	Aug. 31, 1949	63		2.5					570		362	52		.0		832	1,520		
			Aug. 7, 1950	59		1.3					582		403	53		.2		852	1,550		
			Oct. 26, 1951	59		2.0					284		323	42	.0	1.0		535	1,110		
			Aug. 13, 1952	60		1.7					594		305	39	.1	.2		540	1,430		
45-14-6	Oscar Ewing	100	Aug. 31, 1949	60		.19					541		307	112		21		742	1,650		
			Aug. 30, 1950	64		1.1					560		333	105		10		722	1,600		
			Aug. 15, 1952	61		.98					586		276	70		10		720	1,490		
			Sept. 22, 1953	61		1.3					580	0	279	61	.0	8.8		740	1,470		
			Oct. 22, 1954	61	17	1.2	1.1	212	58	49	10	568	0	310	59	.0	3.0	1,020	768	1,430	7.6	5
26	Brown Hotel Co.	112	Sept. 28, 1953	61									582					972			
50	Ewing-Von Allmen Dairy.	110	Aug. 31, 1949	59		2.2					604		408	59		8.4		874	1,670		
			Sept. 6, 1950	60		2.9					606		457	56		12		912	1,680		
			Oct. 26, 1951	60		2.9					308		527	50	.1	.5		760	1,430		
			Aug. 15, 1952	60		2.4					589		575	49	.1	4.0		750	1,810		
			Sept. 28, 1953	60									585					1,090			
62	Courier-Journal and Louisville Times.		Aug. 26, 1949	61		2.8					504		514	452		.8		1,120	2,870		
			Aug. 18, 1950	60		7.0					554		603	109		.3		1,080	1,910		
			Oct. 4, 1951	60		4.5					544		520	65	.0	.6		948	1,610		
			Aug. 14, 1952	60		4.1					545		592	68		.0		960	1,820		
			Sept. 22, 1953	60		5.4					554	0	531	68	.0	.6		1,040	1,800		
			Oct. 26, 1954	60	12	5.8	2.6	327	85	52	5.6	575	0	655	90	.1	.3	1,580	1,170	1,980	7.8	5
66	do.	*190	Aug. 29, 1949	60		2.8					538		483	90		.2		944	1,830		
			Aug. 18, 1950	60		5.5					549		469	86		.5		1,010	1,820		
70	Louisville Gas and Electric Co.	100	Sept. 28, 1953	63									211					510			
45-15-9	Ben Snyder Department Store.	98	Sept. 28, 1953	62									82					328			
21	Commerce Building Corp.	102	Sept. 28, 1953	61									56					232			
38	Seelbach	100	Sept. 1, 1949	61		.92					340		177	123		.2		438	1,240		
			Sept. 6, 1950	62		.63					316		188	50		.1		402	924		
			Oct. 22, 1951	70		2.3					316		117	34	.1	.1		316	724		
			Aug. 18, 1952	70		.83					166		130	51	.1	.1		228	640		
66	Seelbach	*128	Sept. 22, 1953	64		.44					312	0	184	49	.1	1.9		444	966		
			Oct. 25, 1954	63	16	.23	.70	98	23	32	6.8	262	0	129	43	.1	3.3	493	340	765	7.3	2
46-13-26	Pepsi-Cola Co.	112	Aug. 25, 1949	57		1.4					524		522	40		.0		860	1,620		
			Aug. 17, 1950	59		1.3					540		506	34		.0		944	1,560		
44	Jones-Dabney Co.	*185	Oct. 26, 1951	59	19	2.6	2.3	286	92	42	11	592	0	544	122	.2	2.5	1,480	1,100	1,930	7.1	5
			Sept. 23, 1953										577					1,140			
46-14-20	Jefferson Fuel and Ice Co.	105	Oct. 7, 1953	60									562					1,030			
47-11-7	Gardens Acres Pharmacy.	88	Oct. 13, 1953	62									307					826			
47-12-6	Joseph E. Seagrams and Sons, Inc.	100	Aug. 25, 1949	58		.68					544		440	36		.3		904	1,480		
			Aug. 18, 1950	58		.48					564		470	18		.7		924	1,510		
			Sept. 10, 1951	59		.23					584		471	17		1.0		960	1,460		
			Aug. 13, 1952	59		.33					619		454	16	.0	.9		675	1,560		
			Sept. 22, 1953	58		1.3					600	0	453	18	.0	1.4		968	1,580		
			Oct. 26, 1954	58	21	1.1	2.1	270	73	17	3.9	600	0	471	19	.0	.5	1,220	976	1,550	7.2	5

TABLE 4.—*Chemical analyses of water from wells in the Louisville area, Kentucky, 1949–55*—Continued

Well	Owner	Depth of well (ft)	Date collected	Temperature (°F)	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$	Specific conductance at 25° C (micromhos)	pH	Color
47-12-18	Brown Forman Distillers Corp.	*214	Aug. 23, 1949	57		.36						386		225	27		0.0		555	1,010		
			Aug. 30, 1950	57		.38						394		227	12		.0		528	950		
			Oct. 16, 1951	57		.61						372		109	31	0.1	.2		428	788		
			Aug. 13, 1952	58		.27						400		229	29	.1	.2		455	1,040		
			Dec. 11, 1952	56	23	.29	1.1	156	39	13	2.0	420	0	213	12	.4	.0	674	550	951	6.9	1
			Nov. 17, 1953	57	21	.01		154	39	11	1.8	416	0	194	10	.1	.0	662	544	949	6.8	1
			Oct. 27, 1954	58	15	2.3	.35	198	56	16	2.8	490	0	299	19	.0	.1	886	723	1,220	7.1	0
21	Yellowstone, Inc.	100	Aug. 25, 1949	58		1.0						426		368	14		.0		722	1,220		
			Aug. 17, 1950	58		1.2						467		357	11		.3		734	1,230		
			Oct. 12, 1951	58		.80						304		328	13		.1		570	1,150		
			Aug. 13, 1952	58		.67						460		298	9.5		.2		480	1,170		
			Oct. 6, 1953	57										417					896			
28	Frankfort Distilleries, Inc.	110	Aug. 29, 1949	57		.60						425		174	14		2.9		445	947		
			Sept. 18, 1950	58		.43						438		178	14		4.9		514	963		
			Oct. 19, 1951	57		.32						420		160	14	.1	2.5		516	893		
			Aug. 13, 1952	58		.26						443		142	13		2.3		355	902		
			Oct. 6, 1953	57										151					500			
47-13-1	Coca-Cola Bottling Co.	110	Aug. 25, 1949	60		4.4						634		744	16		1.3		1,150	1,990		
			Aug. 7, 1950	60		5.9						623		867	18		5.1		1,380	2,090		
			Oct. 12, 1951	59		4.6						640		855	18	.1	1.6		1,360	1,990		
			Aug. 13, 1952	60		5.1						500		869	20	.1	.8		1,260	1,980		
			Sept. 23, 1953	61										907					1,410			
12	do.	123	Oct. 28, 1954	61		13						614	0	853	17	.0	.1		1,380	2,090	6.7	
47-14-3	Brown Forman Distilleries Corp.	*214	Aug. 25, 1949	59		2.3						484		362	24		.0		749	1,330		
			Oct. 5, 1950	58		2.8						512		394	26		.1		798	1,370		
			Oct. 24, 1951	59		3.9						528		416	26		.1		840	1,350		
			Aug. 18, 1952	58		2.2						554		438	31	.0	.1		865	1,510		
			Dec. 17, 1952	58	18	5.6	2.3	264	79	28	3.6	534	0	531	30	.1	.0	1,260	985	1,570	7.5	1
			Sept. 23, 1953	58										530					1,000			
4	do.	107	Oct. 29, 1949	58		.39						505		347	29		.1		759	1,350		
			Oct. 19, 1950	59		1.0						544		384	33		.0		800	1,420		
			Oct. 24, 1951	59		2.3						532		398	28		.1		810	1,340		
			Aug. 18, 1952	59		4.0						519		487	25	1.7	.1		880	1,520		
			Oct. 8, 1953	58		4.4						564	0	473	29	.0	.0		960	1,600		
			Oct. 28, 1954	59	22	4.8	2.7	262	78	30	4.4	575	0	500	32	.0	.1	1,270	978	1,620	7.1	1

18	Tube Turns, Inc.	*165	Aug. 25, 1949	63	--	5.7	--	--	--	--	620	--	354	36	--	.2	--	715	1,530	--	--
			Oct. 19, 1950	62	--	6.2	--	--	--	--	626	--	391	46	--	.1	--	846	1,560	--	--
			Oct. 26, 1951	63	--	5.9	--	--	--	--	320	--	420	57	.0	1.0	--	650	1,290	--	--
			Aug. 14, 1952	61	--	6.0	--	--	--	--	605	--	407	45	.1	.1	--	895	1,580	--	--
			Oct. 8, 1953	60	--	8.4	--	--	--	--	602	0	460	40	.0	.0	--	968	1,660	--	--
			Oct. 28, 1954	60	20	9.1	3.4	278	81	37	4.1	590	0	526	43	.0	.1	1,340	1,030	1,710	7.1	2
47-15-2	Nick Warisse Baking Co.	47	Aug. 26, 1949	61	--	.19	--	--	--	--	446	--	168	40	--	75	--	492	1,180	--	--
			Sept. 6, 1950	61	--	.32	--	--	--	--	447	--	171	37	--	82	--	562	1,140	--	--
			Oct. 2, 1951	61	--	.10	--	--	--	--	436	--	166	40	.0	66	--	544	1,110	--	--
			Aug. 14, 1952	61	--	.28	--	--	--	--	435	--	168	36	.1	51	--	485	1,130	--	--
			Oct. 8, 1953	61	--	--	--	--	--	--	--	--	163	--	--	--	--	540	--	--	--
48-12-6	Stitzel-Weller Distillery, Inc.	91	Aug. 24, 1949	57	--	1.6	--	--	--	--	394	--	223	8.0	--	1.4	--	488	964	--	--
			Aug. 16, 1950	57	--	4.0	--	--	--	--	386	--	216	8.0	--	.0	--	520	895	--	--
			Oct. 19, 1951	57	--	1.7	--	--	--	--	404	--	188	6.5	.0	.0	--	500	846	--	--
			Aug. 20, 1952	57	--	1.3	--	--	--	--	371	--	153	9.0	--	.1	--	444	829	--	--
			Dec. 12, 1952	57	18	1.3	1.0	138	28	6.1	2.2	368	0	159	10.0	.0	.0	547	460	800	7.7	1
			Sept. 22, 1953	57	--	1.1	--	--	--	--	372	0	139	10.0	.0	.4	--	460	826	--	--
			Oct. 27, 1954	57	16	1.4	.27	130	31	8.3	2.2	355	0	151	12	.0	.2	526	453	804	7.5	1
10	National Distillers Products Corp.	*190	Sept. 28, 1949	56	--	1.4	--	--	--	--	336	--	142	118	--	.8	--	446	1,120	--	--
			Sept. 11, 1950	60	--	--	--	--	--	--	327	--	118	24	--	.0	--	366	739	--	--
			Oct. 11, 1951	56	--	1.8	--	--	--	--	344	--	142	24	--	.0	--	452	807	--	--
			Aug. 26, 1952	56	--	1.9	--	--	--	--	361	--	172	164	.1	.0	--	472	1,450	--	--
48-13-4	Henry Reinstedler	80	Oct. 16, 1953	58	--	--	--	--	--	--	--	--	507	--	--	--	--	880	--	--	--
48-14-5	Falls City Brewing Co.	*175	Aug. 25, 1949	59	--	1.6	--	--	--	--	469	--	346	124	--	1.9	--	656	1,600	--	--
			Sept. 11, 1950	61	--	--	--	--	--	--	614	--	547	186	--	.2	--	1,000	2,170	--	--
			Oct. 3, 1951	61	--	14	--	--	--	--	604	--	514	262	.0	1.0	--	960	2,240	--	--
			Aug. 12, 1952	62	--	18	--	--	--	--	567	--	462	73	.0	.1	--	860	1,720	--	--
15	Reynolds Metals Co.	112	Aug. 23, 1949	58	--	3.7	--	--	--	--	442	--	323	26	--	.8	--	620	1,220	--	--
			Oct. 19, 1950	59	--	4.1	--	--	--	--	464	--	325	40	--	.0	--	672	1,270	--	--
			Oct. 3, 1951	59	--	5.7	--	--	--	--	480	--	420	27	.0	.1	--	764	1,280	--	--
			Aug. 14, 1952	60	--	3.5	--	--	--	--	479	--	397	27	.1	.1	--	720	1,370	--	--
			Sept. 30, 1953	60	--	5.3	--	--	--	--	516	0	434	26	.0	.0	--	880	1,490	--	--
			Oct. 27, 1954	59	21	5.8	.48	238	75	23	2.4	520	0	462	26	.0	.1	1,110	903	1,480	7.3	0
19	Falls City Brewing Co.	*108	Oct. 8, 1953	60	--	4.4	--	--	--	--	520	0	416	109	.1	1.1	--	860	1,730	--	--
			Oct. 28, 1954	59	21	5.1	3.7	231	67	68	4.8	540	0	410	74	.2	.2	1,190	854	1,590	7.1	1
21	Parkland Ice and Coal Co., Inc.	184	Oct. 7, 1953	59	--	--	--	--	--	--	--	--	491	--	--	--	--	898	--	--	--
24	Falls City Brewing Co.	*186	Nov. 18, 1955	60	20	8.3	2.8	222	58	42	4.5	565	0	371	43	.2	.0	1,090	792	1,494	7.0	1
48-16-3	Park and Tilford Distillers Corp.	73	Aug. 30, 1949	59	--	2.1	--	--	--	--	412	--	393	76	--	26	--	686	1,500	--	--
			Sept. 7, 1950	59	--	.12	--	--	--	--	416	--	362	95	--	31	--	772	1,520	--	--
			Oct. 2, 1951	60	--	.05	--	--	--	--	408	--	289	67	.1	21	--	650	1,250	--	--
			Aug. 12, 1952	59	--	.11	--	--	--	--	411	--	342	122	.2	17	--	605	1,560	--	--
			Oct. 8, 1953	59	--	--	--	--	--	--	--	--	378	--	--	--	--	752	--	--	--
4	Schott's Dairy	*196	Aug. 24, 1949	58	--	4.4	--	--	--	--	398	--	9.9	732	--	1.8	--	316	2,870	--	--
			Sept. 7, 1950	58	--	6.9	--	--	--	--	338	--	2.9	278	--	.1	--	236	1,340	--	--
			Oct. 25, 1951	59	--	5.8	--	--	--	--	364	--	1.0	280	.7	2.5	--	216	1,400	--	--
			Aug. 12, 1952	60	--	6.0	--	--	--	--	354	--	2.9	198	.4	.2	--	206	1,130	--	--
49-10-3	E. T. James	80	Oct. 15, 1953	--	--	--	--	--	--	--	--	--	26	--	--	--	--	216	--	--	--
49-11-3	A. Beamiss	80	Sept. 24, 1953	58	--	--	--	--	--	--	--	--	30	--	--	--	--	304	--	--	--

TABLE 4.—*Chemical analyses of water from wells in the Louisville area, Kentucky, 1949–55*—Continued

Well	Owner	Depth of well (ft)	Date collected	Temperature (°F)	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$	Specific conductance at 25° C (micromhos)	pH	Color
49-13-21	Bond Bros.	111	Aug. 23, 1949	60		2.5						300		185	10		0.1		438	810		
			Aug. 16, 1950	58		4.7						322		260	11		.1		520	912		
			Oct. 26, 1951	58		3.4						328		279	10	0.1	.0		550	921		
			Aug. 14, 1952	57		2.9						210		268	10	.1	.2		435	890		
			Oct. 1, 1953	56										276					544			
34	B. F. Goodrich Co.	115	Sept. 1, 1949	60		2.7						328		288	44		1.0		595	1,090		
			Aug. 16, 1950	58		2.9						348		291	48		.3		616	1,090		
			Aug. 30, 1951	58		2.6						136		315	23	.0	.2		452	843		
			Aug. 14, 1952	58		2.2						347		292	12	.1	.1		550	1,030		
43	do.		Oct. 6, 1953	58		2.5						410	0	378	38	.1	.0		736	1,360		
			Oct. 27, 1954	58	16	3.5	1.3	202	54	29	3.1	456	0	356	33	.1	.1	956	728	1,290	7.3	3
49-14-4	Louisville Refining Co.	115	Aug. 23, 1949	58		3.0						385		140	36		.0		432	898		
			Aug. 16, 1950	59		4.2						466		179	36		.2		556	1,030		
			Sept. 7, 1951	59		2.7						432		154	49		1.2		544	1,000		
			Aug. 13, 1952	59		3.0						368		152	29	.0	.0		470	934		
			Dec. 12, 1952	58	15	7.2	1.4	148	36	21	2.5	484	0	118	27	.0	.0	614	520	931	7.6	1
			Oct. 1, 1953	59										108					474			
50- 8-1	Valley Whiskey Store (formerly Bill's Auto Service).		Aug. 23, 1949	65		.54						404		97	18		35		404	862		
			Aug. 16, 1950	69		.20						416		100	23		49		428	899		
50- 9-3	W. H. Fluhr	51	Aug. 23, 1949	65		.19						293		54	1		3.1		294	534		
			Aug. 16, 1950	65		.07						294		47	1.8		6.6		278	517		
			Oct. 26, 1951	59		.50						250	14	44	2.8	.0	8.1		274	487		
			Aug. 13, 1952	65		.08						289		54	2.5	.1	7.0		282	542		
50-11-10	George Dienes	92	Oct. 16, 1953	57										33					282			
11	Val Hartlage	70	Oct. 16, 1953	58										26					246			
50-12-1	E. I. du Pont de Nemours Co.	110	Mar. 29, 1951	59	17	2.2		61	20	18	6.9	193	0	56	46	.1	1.5	348	235	554	7.6	2
			Oct. 6, 1953	55										63					304			
3	do.	109	Aug. 23, 1949	58		4.6						366		179	232		.2		754	1,530		
			Aug. 17, 1950	57		5.0						345		183	92		.2		542	1,070		
			Aug. 30, 1951	59		4.7						132		156	182		1.7		448	988		
			Aug. 13, 1952	60		4.2						202		189	179	.1	.5		485	1,230		
			Oct. 6, 1953	59		3.4						358	0	206	62	.0	1.1		534	1,090		
			Oct. 27, 1954	64	19	3.5	2.9	180	49	34	6.7	385	0	158	207	.0	1.6	858	651	1,360	7.0	2
10	do.	111	Aug. 23, 1949			1.5						314		68	4		.1		280	596		
			Aug. 17, 1950	58		3.7						323		45	7		.3		302	567		
			Aug. 30, 1951	57		1.1						166		39	6	.1	1.0		226	364		
			May 23, 1952	57	15	1.0	.36	76	24	6.9	1.6	309	0	40	7	.1	.7	299	290	553	7.3	2
			Aug. 13, 1952	57		1.0						232		39	5.8	.0	.6		220	456		
			Sept. 30, 1953	58		1.6						310	0	37	11	.0	.4		306	557		
			Oct. 27, 1954	58	16	1.7	.44	85	27	5.0	1.8	312	0	60	6.5	.1	.1	356	322	586	7.5	6

20	Z. C. Long	88	Sept. 30, 1953											140					442			
21	Reynolds Metals Co.	112	Sept. 30, 1953	57										214					510			
50-13-3	Louisville Gas and Electric Co.	116	Aug. 23, 1949	57		.46						198		167	48		14		324	779		
			Oct. 2, 1953	53										50					191			
4	do	113	Aug. 16, 1950	58		.16						204		57	14		14		219	474		
			Aug. 10, 1951	55		.22						158		48	12	.1	11		184	396		
			Aug. 14, 1952	54		.22						166		58	13	.2	5		184	432		
			Dec. 11, 1952	54		.16	.00	58	14	11	1.9	164	0	59	19	.2	.0	254	200	434	7.6	0
60	U.S. Army Corps of Engineers	70	Sept. 11, 1953	56										55					232			
51-11-3	Kaufman Bros.	48	Aug. 23, 1949	62		.17						276		33	4		27		264	517		
			Aug. 16, 1950	72		.23						302		25	5		24		274	530		
			Aug. 15, 1951	64		.32						201		24	5.2	.0	16		189	347		
			Aug. 13, 1952	67		.91						282	9	28	4.2	.2	8.2		267	514		
			Dec. 10, 1952	56	15	.19	.00	80	23	8.2	2.0	322	0	33	6.0	.2	17	326	296	550	7.7	1
			Sept. 14, 1953	62		.39						320	0	36	5.0	.2	10		288	574		
			Oct. 27, 1954	61	18	.53	.04	80	27	7.9	1.5	344	2	36	5.2	.1	3.5	341	310	576	8.3	5
5	Theinemen Bros.	90	Sept. 24, 1953	59										26					278			
51-12-2	E. I. DuPont de Nemours Co.	110	Sept. 30, 1953	55										90					292			
7	do	115	Sept. 30, 1953	58										47					320			
52-10-4	American Builders Supply Co.	115	Oct. 15, 1953	58										14					268			
52-11-6	Rubber Reserve Co.	115	Sept. 24, 1953	60										3.3					272			
52-12-18	Stauffer Chemical Co.	110	Oct. 14, 1953	58										30					304			
53-6-3	Louisville Extension Water District.	120	Aug. 29, 1949	60		2.8						284		19	2		.0		246	458		
			Aug. 14, 1951	68	18	2.6	.00	61	21	3.7	1.5	282	0	12	2.2	.2	.5	255	240	457	7.4	7
			Aug. 15, 1952	57	17	2.7	.46	64	20	2.2	1.4	283	0	18	3.5	.1	.6	262	243	474	7.3	2
			Oct. 2, 1953	57										18					252			
53-10-3	Henry Huflage	65	Aug. 14, 1951	65		.09						212		20	4.5	.2	3.3		194	478		

TABLE 5.—*Average concentration of chemical constituents and properties of water from selected wells in the Louisville area*

Constituent	Glacial outwash sand and gravel aquifer									3 wells in limestone aquifer		
	Average—11 wells			7 wells in sand and gravel underlain by limestone			4 wells in sand and gravel underlain by shale					
	1949	1954	Net change 1949–54	1949	1954	Net change 1949–54	1949	1954	Net change 1949–54	1949	1954	Net change 1949–54
Iron (Fe) ppm	1.8	3.6	+1.8	1.8	4.6	+2.8	2.0	1.8	−0.2	2.6	5.5	+2.9
Sulfate (SO_4) do	297	344	+47	394	482	+88	126	101	−25	308	412	+104
Chloride (Cl) do	49[1]	44[1]	−5	41[1]	34[1]	−7	62	58	−4	62	45	−17
Hardness as $CaCO_3$ do	660	740	+80	782	915	+133	447	434	−13	642	869	+227
Specific conductance at 25° C micromhos	1,327	1,279	−48	1,570	1,535	−35	902	832	−70	1,380	1,507	+127

[1] Data for well 45-14-62 not used in calculation.

Tables 4 and 5 and figures 6–11 show that ground water in the Louisville area is generally very hard and high in iron and sulfate content but moderately low in chloride content; however, owing to infiltration of river water, the ground water near the river is softer and not so high in sulfate content. During the 6 years preceding 1955, marked changes occurred in the quality of the ground water. Analyses of samples from wells in the limestone bedrock and from wells in sand and gravel overlying limestone bedrock show that the hardness and the iron and sulfate concentrations increased considerably, whereas the chloride concentration decreased somewhat. The analyses of samples from wells overlying shale bedrock show a different sort of change in that hardness, specific conductance, iron, sulfate, and chloride decreased; the decrease in hardness and sulfate content was especially great.

The similarity in 1954 between the concentration of the constituents in samples from rock wells and in samples from wells drawing water from the sand and gravel overlying limestone suggests a hydraulic connection between the limestone and the overlying sand and gravel. The possibility of this connection was advanced by Rorabaugh (1949b). The difference between the change in quality of water from wells in sand and gravel overlying limestone bedrock and that in water from wells in sand and gravel overlying shale bedrock is further evidence of such a connection.

TEMPERATURE OF GROUND WATER

The average temperature of ground water in the Louisville area is about 58° F. Plate 8 shows maximum and minimum temperatures (1945–55) for selected wells in the Louisville area.

Northeast of Louisville along the river, the ground-water temperature ranges from about 52° to about 66°F, the lowest temperature occurring in the summer and the highest in the winter, owing to the amount of time required for the water to move from the river to the well. River water entering the aquifer has a seasonal range of about 32° to 85°F. The seasonal range in the wells, however, is much smaller. This is due to heat exchange between the water and the sand and gravel that tends to equalize the temperatures of the water and the sand and gravel.

In the Rubbertown subarea the average ground-water temperature is lower and the seasonal range of temperature is wider than elsewhere in the Louisville area. These differences are due to the operation of the navigation dam. Above the dam a constant pool elevation is maintained except during those floods which exceed the capacity of the reservoir formed by the movable dam. The maintenance of the upper-pool elevation augments the natural fluctuations in the lower pool. Because most floods or high stages occur in winter and spring, more river water of low temperature than of high temperature enters the aquifer during any one year; and, because of the maintenance of the upper-pool level at the expense of the lower pool, more low-temperature water enters the aquifer below the dam than above it. When the river level is low and the temperature high during the summer, recharge of river water to the aquifer is not so great.

The increased recharge due to greater differences in head during the cold season probably is greater than the increase of recharge due to lower viscosity in the warm season.

WATER-LEVEL DATA

MEASUREMENTS OF WATER LEVELS

Water levels in wells are measured by the wetted-tape method, or by means of recording gages whose readings are checked by tape. A steel tape, graduated in hundredths of feet along its entire length, is used with a small weight attached so that the tape will hang straight. The lower 2 or 3 feet of the tape is chalked, generally with blue carpenter's chalk. The tape is lowered into the well; when the chalked portion enters the water, a convenient foot mark on the tape is held at a fixed measuring point. When the tape is withdrawn from the well, the chalked portion shows a clear demarcation of the water line. Thus, the difference (recorded to hundredths) between the total length of tape below the measuring point and the wetted portion of the tape is the depth to water below the measuring point.

During the period 1949 through 1955, records of water levels were obtained in 14 selected wells equipped with automatic recording gages. Recording gages were maintained on 7 of the 14 wells through the entire period and on the other 7 for part of the time. At the end of 1955, 11 recording gages were in operation.

Depths to water were measured weekly in 6 wells and at 5-week intervals in 132 wells.

HYDROGRAPHS

The elevation of the measuring point, in feet above mean sea level, has been determined for nearly all observation wells in the Louisville area. Ground-water elevations in feet above mean sea level were computed and hydrographs were plotted.

Plates 9 to 15 are hydrographs for entire period of record for each of 137 observation wells in the Louisville area.

The following table lists the observation wells in which water levels have been measured at various times but which are not presented as hydrographs in this report.

Observation wells for which hydrographs are not included in this report

[Type of measurement: R, recording gage; T, tape. All the data for these wells are available at the office of the U.S. Geological Survey, Ground Water Branch, Louisville, Ky.]

Well	Owner	Location	Years of record	Type of measurement	Water-supply paper in which water-level measurements are published	Remarks
38-19-1	Harrods Creek	Upper River Rd	1943-50	T	1017, 1024, 1072, 1097, 1127, 1157, 1166.	Land-surface datum.
38-20-2	W. W. Liter	Near Harrods Creek.	1944-52	T	1017, 1024 1072, 1097, 1127, 1157, 1166.	Do.
42-16-17	Louisville Water Co.	River Rd	1946-48	R	1072, 1097, 1127	Well destroyed.
43-11-1	L. Cave	1324 Morgan St	1943-54	T	1017, 1024, 1072, 1097, 1127, 1157, 1166.	Land-surface datum.
45-14-4	Blue Boar Cafeteria.	4th and Broadway Sts.	1943-46	T	1017, 1024, 1072	Intermittent record.
46-13-3	Brown & Williamson Tobacco Corp.	16th and Hill Sts	1950-52	T	1166	Owner's well 7.
6	do	do	1943-44	T	1017	Owner's well 2.
11	Joseph E. Seagram & Sons Co.	7th Street Rd	1943-44	T	1017	Owner's test well 5.
46-15-1	Merchants Ice & Cold Storage Co.	19th and Walnut Sts.	1948	T	1127	
47-12-8	Joseph E. Seagram & Sons Co.	7th Street Rd	1944-45	T	1017, 1024	Owner's well 2.
9	do	do	1944-45	R	1017, 1024	Owner's well 3.
23	do	do	1944	T		Owner's well 4.
24	do	do	1944	T		Owner's well 5.
30	do	do	1944	T		Owner's test well 1.
48-10-1	L. A. Sanders	Dixie Highway	1944	T	1017	Dug well.
49-12-1	Henry Bramer, Jr.	Camp Ground Rd.	1943-45	T	1017, 1024	
49-13-2	Aetna Oil Co	Algonquin Parkway.	1943-44	T	1017	Owner's well 2.
42	Bond Bros	Bells Lane	1952-55	T		
50- 9-2	Harvey Fluhr	Dixie Highway and Lower Hunters Trace.	1944	T	1017	
50-11-1	George Dienes	Crums Lane and Cane Run Rd.	1944	T	1017	
50-13-1	Standard Oil Co	Bells Lane	1942-44	T	1017	Owner's well 2; destroyed.
2	do	do	1942-44	T	1017	
28	National Carbide Corp.	do	1944	R	1017	Ranney test well 1; well destroyed.
29	do	do	1944-45	R	1017, 1024	Ranney test well 3.
41	do	do	1944-45	T	1017, 1024	Ranney test well 4.
42	do	do	1944-45	T	1017, 1024	Ranney test well 5.
51-12-9	E. W. Owen	Fern Leaf Rd	1944-55	T	1017, 1024, 1072, 1097, 1127, 1157, 1166.	
10	C. A. Speith	Bramers Lane	1943-44	T	1017	
52- 9-1	Mrs. F. B. Smith	Lower River Rd	1943-44	T	1017	Dug well.
52-10-1	George Nalley	Murrays Lane and Cane Run Rd.	1944	T	1017	
3	Rubber Reserve Co.	Murrays Lane and Lower Hunters Trace.	1945; 50-55.	T	1024, 1166	Well obstructed; intermittent record.
52-11-1	Mr. Snyder	Lees Lane and Camp Ground Rd.	1943-44	T	1017	
53- 5-1	R. P. Moreman	Lower River Rd. near Bethany Lane.	1943-44	R	1017	
53- 8-1	R. McGinnis	Cane Run Rd. and Greenwood Rd.	1944	T	1017	
54- 3-1	Mr. Vaughn	Lower River Rd. at Mill Creek.	1943-44	T	1017	
55- 1-1	W. R. Baker	Dixie Highway near Kosmosdale.	1943-48	T	1017, 1024, 1072, 1097, 1127.	

SUMMARY AND CONCLUSIONS

Water-level fluctuations are directly related to changes in ground-water storage. In the Louisville area during the period 1949–55, an average net loss of ground-water storage of about 2.3 mgd was estimated from changes of water levels and from an assumed coefficient of storage of 0.2.

During the period 1939–48, the annual average withdrawal of groundwater by industries increased from 37.6 mgd in 1939 to a peak of 61.5 mgd in 1943, and declined to 31.9 mgd in 1948. In contrast, during the period 1949–55 the greatest annual average withdrawal was 31.8 mgd in 1951, and the least was 28.7 mgd in 1954. The average withdrawal of 30.7 mgd in 1955 was almost exactly that of 1943.

During the period 1949–52, pumpage was about in balance with recharge to the area, except in 1950 when recharge exceeded pumpage by an estimated 5.4 mgd as a result of the greatest annual precipitation of record. During the period 1953–55, pumpage exceeded recharge by appreciable amounts as a result of the drought conditions of 1952 to 1954. The net loss of ground-water storage of 9.6 mgd in 1954 was the greatest since 1944.

Although pumpage was fairly constant in the area during the period 1949–55, other hydrologic conditions varied considerably and water-level fluctuations reflected those variations. In the unpumped area southwest of the city, in 12 years of record from 1944 through 1955, water levels were highest in 1951 and 1952 and lowest in 1955. During the period 1952–55, the water level in well 52–7–2 declined about 8.5 feet.

Ground water in the Louisville area is very hard, very high in iron content, and generally of the calcium bicarbonate or calcium sulfate type. During the 6 years 1949 through 1954, water in the limestone and in the sand and gravel overlying limestone steadily increased in sulfate and iron content and in hardness but decreased in chloride content. The increasing hardness and the increasing iron and sulfate content of water from sand and gravel underlain by limestone bedrock may be due, wholly or in part, to recharge from the limestone. The cause of the increases in water from the limestone itself is not clear, but the increases may be due to pump-induced upward movement of more highly mineralized water from the lower part of the limestone, whose ground-water circulation presumably is slow under natural conditions. The sampling program in the future will be designed to fill in present gaps in information and to continue the records of quality of water in the various areas and under various conditions of development.

The series of hydrographs show water levels in observation wells in the Louisville area. As all the water levels are expressed in feet above mean sea level, they may be compared directly with each other.

If the infiltration that may be induced from the river in the subareas northeast and southwest of Louisville, respectively, is included, the potential ground-water supply in the Louisville area is about 360 mgd. The pumping rate of 30.7 mgd in 1955 represents about 8 percent of the estimated potential supply. In the development of new well fields, if the wells are spaced so as to eliminate or minimize interference and if they are so placed as to induce river infiltration, large supplies of ground water can be obtained.

Water-level fluctuations show that in the heavily pumped areas a net withdrawal of about 30 mgd is about equal to the normal net recharge to these areas. If the pumpage is increased or decreased appreciably, the aquifer will lose or gain storage and water levels will decline or rise accordingly. The present (1955) downward trend of water levels in some of the wells in the heavily pumped areas indicates that, at least locally, the rate of withdrawal is greater than the net recharge.

Uninterrupted long-term records of water levels are a means of accurately determining trends and making reasonably good correlations of ground-water conditions with geologic, hydrologic, and hydraulic factors.

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