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GEOLOGICAL SURVEY CIRCULAR 240

GEOLOGY AND GROUND-WATER RESOURCES OF THE COVINGTON-NEWPORT ALLUVIAL AREA KENTUCKY

By Eugene H. Walker

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GEOLOGY AND GROUND-WATER RESOURCES OF THE COVINGTON-NEWPORT ALLUVIAL AREA, KENTUCKY

ABSTRACT

This report describes the ground-water resources of the Ohio valley at Covington and Newport, Ky., and the adjacent smaller cities on the river front. The area lies in Kenton and Campbell Counties in the northernmost part of Kentucky, on the south side of the Ohio River opposite Cincinnati, Ohio. The cities form the second most important industrial center of the State and had a total population of 120,867 according to the census of 1950.

The bedrock here exposed consists of shaly limestones of Late and Middle Ordovician age. With rare exceptions the yield of wells in bedrock is too small to supply the needs even of single families. The quality of the water is poor; the hardness averages more than 500 parts per million; iron and commonly sulfate and sodium chloride are present in objectionable quantities. The limestones of Middle and Early Ordovician age that lie beneath cover yield small amounts of salty and sulfurous water. At a depth of about 1,000 feet a series of sandy beds is capable of yielding considerable sulfurous brine.

Large supplies of water are available from the alluvial deposits of the Ohio River. The floor of an old bedrock channel lies beneath the cities at an elevation of about 365-375 feet, some 50 feet below the present bed of the river. Permeable sand and gravel fill this channel to a depth of 80 feet in some places and wedge out toward the margin of the valley. This coarse alluvium is covered by about 70 feet of silt and clay.

Water levels in wells stand close to or above the top of the sand and gravel, showing that the ground-water reservoir is almost full. This aquifer is recharged by rainfall percolating down through the overlying silt and clay, and to a lesser extent by the flow of water through the valley wall from the uplands. Movement of water is generally toward the Ohio River. Recharge from the Ohio River takes place when river level is higher than ground-water level, a condition that exists during floods, or even during low water in places where pumping has lowered the ground-water level below river level.

The water is of the calcium and magnesium bicarbonate type containing considerable amounts of sodium, sulfate, and chloride. The average amount of dissolved solids is 814 parts per million; average total hardness is 584 parts per million; average iron content is 3.6 parts per million. The water is alkaline and has an average pH of 7.4.

About 36 wells are in use, pumping 30 to 500 gallons a minute each. The total annual pumpage is close to 1,361 million gallons, or 3.7 million gallons a day. Most of the water is used for brewing and distilling, the rest for air conditioning and miscellaneous industrial purposes.

Considerably more water than is now pumped probably can be developed in this area, but test drilling and pumping tests should precede the planning of large installations.

INTRODUCTION

This report is one of a series on the occurrence of ground water in Kentucky that is being prepared by the Ground Water Branch of the U. S. Geological Survey. The State of Kentucky and the Federal Government are financing this program by agreement between the Agricultural and Industrial Development Board of Kentucky and the U. S. Geological Survey.

The index map of the state, figure 1, shows areas where work is in progress or has resulted in publication. The reports give information on the occurrence, movement, quantity, and quality of ground water and are planned to help in the orderly development and use of this natural resource.

The area covered by this report lies along the northern edge of Kenton and Campbell Counties, where Covington, Newport, Ludlow, Bromley, Dayton, and Bellevue occupy the valley lowland on the south bank of the Ohio River opposite Cincinnati, Ohio. The settled lowland forms a strip about 6 miles long along the valley and, with the exception of the Licking valley, is bordered on the south by bluffs that rise several hundred feet to the plateau surface of northern Kentucky.

The Kentucky Geological Survey published geologic maps of Campbell and Kenton Counties by W. H. Shideler in 1931. No detailed studies of ground water in this locality have previously been made although the Ground Water Branch investigated a few wells in 1944 and in 1947-48. Publications that contain some information on this area and that have been consulted are given in the list of references.

During parts of 1950 and 1951 an intensive canvass of all wells and test holes that could be located in the area was made, and the available data were recorded and compiled. Plate 1 shows the locations of wells and borings and table 2 is a tabulation of the data

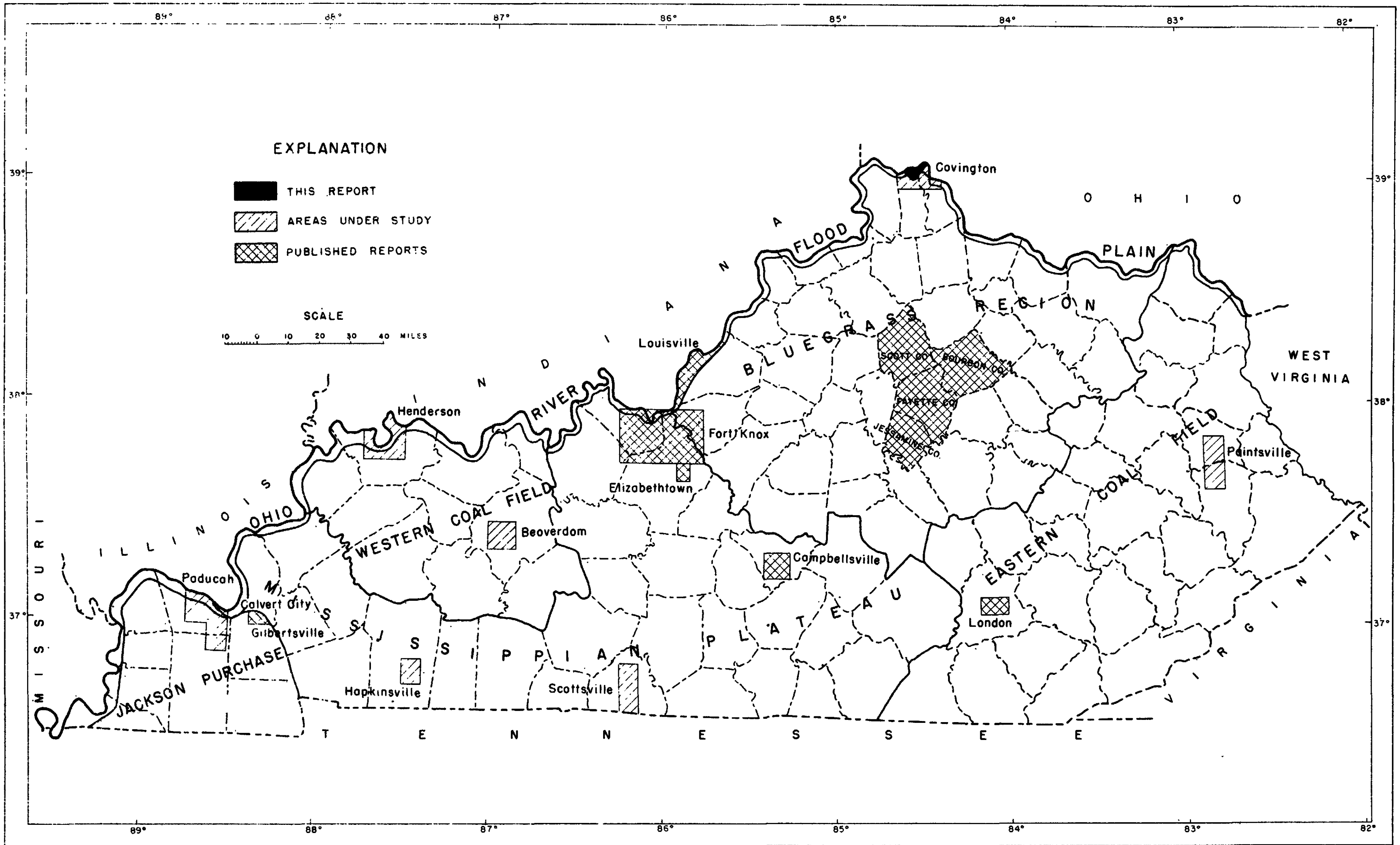

Figure 1. --Index map of Kentucky showing progress of ground-water investigations.

obtained. Plate 1 also shows the extent of the water-bearing alluvium. Logs of wells were gathered and are given in table 3. These well logs were used to construct the sections on plate 2, which show subsurface conditions.

Table 4 presents analyses of water from 19 wells; table 5 gives a summary of the analyses; and the quality of water from six representative wells is shown graphically on plate 2.

Figure 3 summarizes ground-water pumpage in the cities. Figure 4 shows rainfall, elevation of the Ohio River, and water-level fluctuations in two wells through 12 months.

Wells and borings are numbered in a system used by the Ground Water Branch in Kentucky. The state is divided into rectangles measuring 5 minutes of longitude and 5 minutes of latitude, and each rectangle is numbered from its longitude and latitude at its southeast corner. Within each 5-minute rectangle the wells are numbered in the order of investigation. Thus, well 8430-3905-1 is the first to have been enumerated in the rectangle bounded on the east by longitude 84°30' and on the south by latitude 39°05'. The well-location map, plate 1, covers only parts of several rectangles; wells outside the map area account for gaps in the numbered sequence given in table 2.

This report was prepared under the general supervision of A. N. Sayre, Chief, Ground Water Branch, and under the immediate supervision of M . I. Rorabaugh, district engineer in Kentucky. W. N. Palmquist, Jr., geologist in charge of the Covington field headquarters, assisted in the preparation of the report. Samuel Berman and R. G. Stevenson, Jr., formerly with the Ground Water Branch, collected many of the field data. The regional laboratory of the U. S. Geological Survey at Columbus, Ohio, under W. L. Lamar, district chemist, made 14 of the chemical analyses and was consulted in the preparation of the data on quality of water.

Individual well owners furnished much of the information basic to this report. The U. S. Corps of Engineers made available the records of many test holes drilled during the construction of the flood walls and levees protecting Covington and Newport. The firms of Jos. Koehne & Sons, Thurman Posey, and A. R. Posey of Cincinnati have drilled many wells in this area and provided useful logs. The Southern Railway System, J. S. Wearn, chief engineer, and the Chesapeake and Ohio Railway Co., L. T. Nuckols, chief engineer, furnished information on materials encountered during construction of piers for bridges in this area. Data on highway bridge piers were provided by Kentucky Department of Highways, E. D. Smith, bridge engineer.

During the course of this work the city of Covington, through Gordon Willis, city engineer, permitted the use of office space in the City Hall.

GEOGRAPHY

Topography and Settlement

Along most of the northern boundary of Kentucky, the Ohio River flows in a trench-like valley about a mile wide. Where the Licking River enters the Ohio from the south and Mill Creek from the north, the valley widens to several miles. Normal river level, controlled by navigation dams, is 441 feet above sea level. Much of the valley floor is a bench or terrace built of alluvial deposits and stands about 80 feet above the river, safe from all but such record-breaking floods as that of 1937. On both sides of the valley, wooded bluffs rise about 300 feet to a rolling plateau.

This favorable site at the junction of the Ohio, Licking, and Mill Creek valleys encouraged the early development of Cincinnati on the north side of the valley and Covington, Newport, and adjoining cities on the south. However, the Miami and Erie Canal, which led north up the Mill Creek valley, is now abandoned and the Licking River no longer carries freight worth mentioning. Only the Ohio River is now used to carry much freight. Railroads have supplanted the water routes up the Licking and Mill Creek valleys.

The 1950 census gives these figures for the population of the following Kentucky cities:

Covington	64,452
Newport	31,044
Bellevue	9,040
Dayton	8,977
Ludlow	6,374
Bromley	980
Total	120,867

Population increased little in the last decade because these town sites are fully occupied. The population of the surrounding towns on the uplands to the south is increasing, however.

Industrial Development

At present the Covington-Newport area is second only to Louisville as an industrial area in Kentucky. The Kentucky Industrial Directory, 1951-52, gives a figure of about 10,585 persons employed in industry. Thirty-one plants employ 50 or more persons; 11 of these employ 200 or more. The most important industry is metal working and several firms make precision and scientific equipment. The largest plant is the rolling mill of the Newport Steel Corp., with 2,596 employees.

Climate

Records of temperature and precipitation have been kept at Cincinnati since about 1870; figure 2

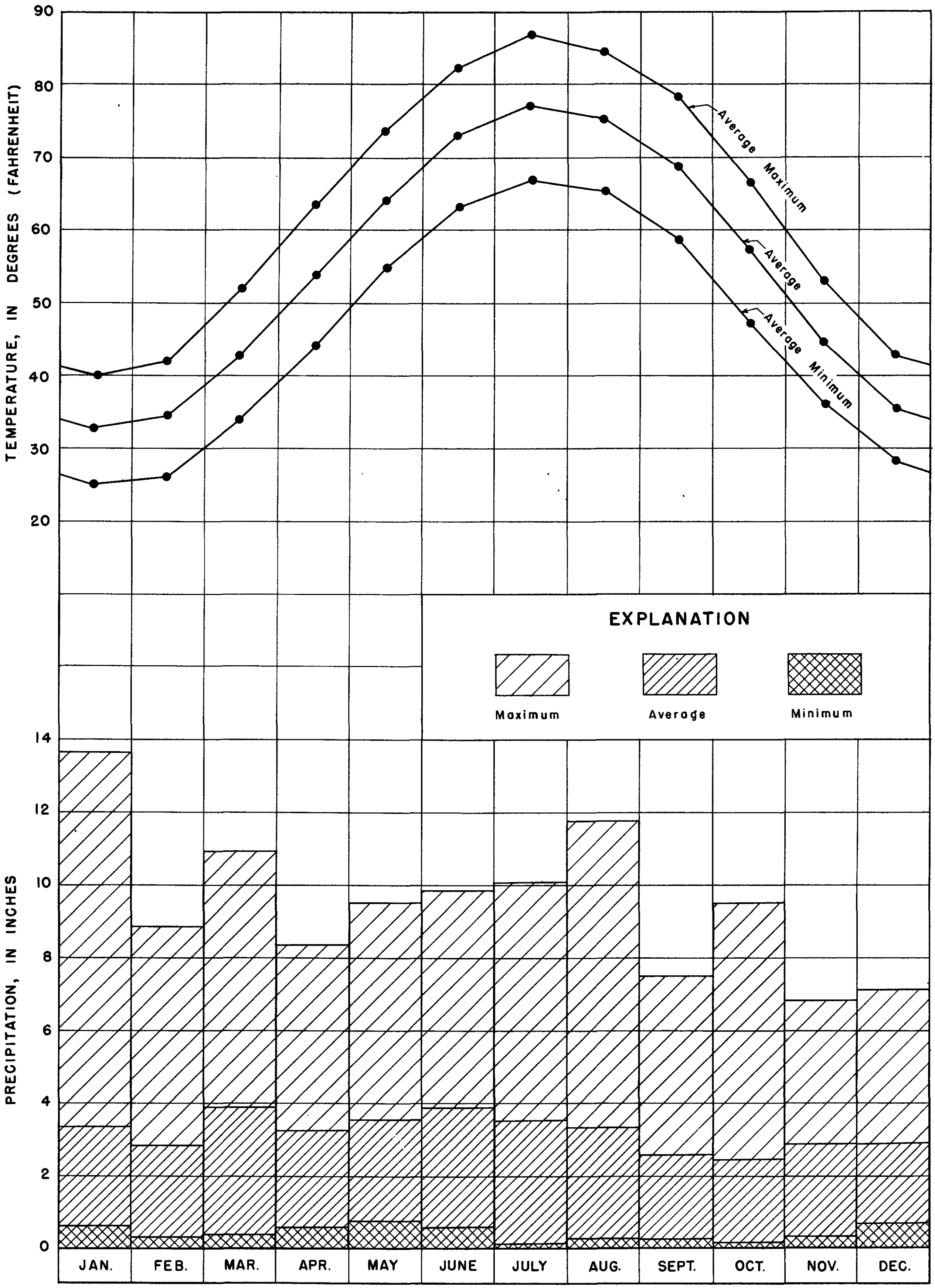

Figure 2.--Graphs showing monthly temperature and precipitation at Cincinnati, Ohio.

presents a graphical summary. The average annual precipitation of 38.55 inches is well distributed throughout the year. Slightly less than average precipitation is recorded in the late summer. The range in any month may be from less than 1 inch to more than 6 inches. The greatest annual precipitation of record is 57.90 inches in 1950; the least is 17.99 inches in 1901. About 18 inches of snow falls per year and the range has been from 5 inches in 1919 to 38.9 inches in 1910.

In an average summer the temperature reaches 90°F. or higher on about 26 days. During the average winter, temperature falls below 32°F. on 61 days.

The Ohio River usually rises during the winter months, but ordinarily not enough to cause inconvenience in the Covington-Newport area. Records dating back into the 1700's show 20 floods whose crests rose above 485 feet, invading the lower parts of the town sites. On the Cincinnati gage, flood stage is set at 52 feet, or 481.6 feet above sea level. Listed below are the five greatest floods of record:

Year	Stage, Cincinnati gage (feet)	Elevation of flood crest (feet)
1937	80	509.8
1773	76	505.8
1884	71.1	500.9
1913	69.9	499.7
1945	69.2	499.0

Flood walls now protect Newport and Covington against a flood even 3 to 4 feet higher than that of 1937.

GEOLOGY AND GROUND WATER

Introduction

The bedrock beneath uplands and valleys consists of thin alternating layers of limestone and shale of Ordovician age, inclined gently to the north. The bedrock yields little water to wells, and the quality of the water is generally poor. At a depth of about 1,000 feet the St. Peter sandstone yields brine.

Early in the glacial or Pleistocene epoch the Ohio River cut a valley about 400 feet deep, but later it filled this valley almost halfway with alluvium. The river has partially removed the fill, but it has not yet cut downward to the bottom of its old bedrock channel. Table 1 gives a summary of the formations and the occurrence of ground water in them. The lower part of the alluvium deposited by the river consists of permeable sand and gravel capable of storing and yielding large amounts of water to wells. The quality of the water, though very hard, is acceptable for most common purposes.

Bedrock

Lower and Middle Ordovician Formations

Wells in the northern Blue Grass region that penetrate the Lower Ordovician formations deeply enough usually encounter sandy, permeable zones that contain brine under artesian pressure. In Water-Supply Paper 233 Matson in 1906 mentioned two such wells in Covington and Newport. Both were abandoned and covered long ago, but their approximate locations are known.

Table 1.--Generalized section of the geologic formations exposed or penetrated in the Covington-Newport alluvial area, Kentucky

System	Series	Formation or group	Thickness (feet)	Description	Water-bearing characteristics
Quaternary.	Pleistocene and Recent.	Alluvium.	0-150	Sand and gravel overlain by silt and clay.	Moderate to large amounts of water of fair to excellent quality.
Ordovician.	Upper Ordovician.	Maysville group.	400-460	Alternating thin beds of limestone and shale.	Water in very small amounts and usually of poor quality.
		Eden formation.			
	Middle Ordovician.	Cynthiana formation.	120	Usually shaly limestone, with some purer limestone toward the base of the formation.	Small amounts of water of poor quality.
		Lexington group.	170	Mainly thick beds of limestone; occasional beds of shale.	Small amounts of water usually too salty and sulfurous for normal uses.
		Highbridge group.	400-425	Thick-bedded limestone.	
	Lower Ordovician.	St. Peter sandstone.	(?)	Limestone and dolomite with occasional sandy beds.	From the sandy zones good quantities of salty and sulfurous ("Blue Lick") water.

The well that was at the now vacant site of the Old '76 Distillery in the southern part of Newport has been plotted as 8425-3900-73 on plate 1. Reports are that the well was 1,250 feet deep, and that water flowed at the surface at a rate of 34 gallons a minute. The pressure was said to be sufficient to lift the water in a pipe 60 feet above the ground, or to about 590 feet above sea level.

An analysis from the report by Matson is given in table 4. The water is a sodium-chloride brine with large amounts of sulfate. Temperature of the water is not known, but it could not have been very warm because the water was used for cooling at the distillery. The water corroded pipes so much that the well was abandoned.

The other deep well that Matson mentions was at the former Hemingray glass factory at Second and Madison Streets in Covington, a site now occupied by Fries & Son Steel Co. The old well was probably not far from the well 8430-3905-4 on plate 1. Depth of the old well is unknown. Sometime before 1906 the owners plugged the well because sulfurous gas coming from it was objectionable in nearby homes, tarnishing silver and damaging furniture.

In 1947 the Sohio Oil Co. drilled a deep test well at the Latonia refinery in the Licking valley a short distance south of the area covered by plate 1. Water-bearing zones were penetrated at 547-556, around 786, and at 996 feet below land surface. Water rose from the last zone to within 36 feet of the surface, or to an elevation of 437 feet above sea level, considerably less than the head of 590 reported for the well at the Old '76 Distillery. Perhaps the Latonia refinery test would have encountered water under greater pressure if it had continued to greater depth. However, there is the possibility that water has been escaping from the old wells for decades, gradually reducing the original artesian pressure.

This artesian zone near the base of the Ordovician formations has long been considered to be the equivalent of the water-bearing St. Peter sandstone of the upper Mississippi basin States and is generally called by that name in Kentucky. However, there is some doubt that it is actually the continuation of the true St. Peter formation.

The overlying Highbridge and Lexington groups consist mainly of thickly bedded and fairly pure limestones. Where these rocks are exposed at the surface in the central Blue Grass counties to the south, the solvent action of circulating ground water on limestone has opened crevices large enough that the yield of wells is often good (Hamilton, 1950). In the Covington-Newport area these formations lie below the zone of much circulation; the few crevices and openings that occur are small and the water in them has long been stagnant and is almost always salty or sulfurous, if not both.

The Cynthiana formation, uppermost of the Middle Ordovician series, crops out on the bank of the Ohio River between Covington and Ludlow and may appear also in the Licking River valley in the southern part of this area. Probably this formation is the bedrock underlying much of the area covered by valley-filling alluvium.

Where exposed the Cynthiana formation consists of thin, slabby limestone beds with intervening shale and does not appear much different from the overlying Eden formation. Evidence of fossils rather than change in rock type locally determines the position of the boundary. The bedrock penetrated by test borings for the piers of the Chesapeake and Ohio railroad bridge across the Ohio is probably the Cynthiana formation, and the log of hole 8430-3905-32 (table 3) shows the typical alternation of limestone and shale beds, few of them as much as a foot thick.

The well 8425-3900-43, on the property of the Newport Steel Corp. in the Licking valley, is reported to be 250 feet deep and therefore extends 125 feet or more into the Cynthiana formation below the alluvium. According to the owners, this air-conditioning well has a sustained yield of 60 gallons a minute. The position of the foot of the casing in the well is unknown. It is possible that the well encountered one of the infrequent water-bearing crevices in the bedrock and is actually producing from the Cynthiana formation. However, it is more likely that a yield such as 60 gallons a minute comes from alluvium rather than from bedrock. Perhaps the casing ends in the alluvium; or if it is set on bedrock, there may be leakage from the alluvium down into the well. In any case, the well does not give evidence that other wells into the Cynthiana formation will yield the same amount of water.

The water from this well (see table 4) has a total hardness of 515 parts per million and is of the calcium carbonate type. It contains 4.4 parts per million of iron but only small amounts of other substances likely to be objectionable. The resemblance of this water to that from wells in alluvium gives reason to believe that it comes from alluvium rather than from bedrock.

Upper Ordovician Formations

The Upper Ordovician rocks are divided into the Eden formation and the overlying Maysville group. Both consist of thin limestones and shales and are essentially similar. The Maysville group crops out only on the uplands away from the area considered in this report and therefore is not described.

The Eden formation is exposed along valley walls and is the bedrock under parts of the area covered by alluvium. The formation is about 200 feet thick. It consists of alternating blue-gray shales and lighter-colored limestone beds. All gradations exist between calcareous shale and shaly limestone. Few individual beds are more than a foot thick. The beds are subject to weathering, which forms a yellow clay soil strewn with platy fragments of shale and limestone.

Exposed rocks show very few and small openings for the storage and movement of ground water. Measurement of water levels in wells in the Eden formation brings out the fact that water levels rise very slowly after rains, apparently because water can enter the ground only slowly.

Throughout northern Kentucky, wells in the Eden formation rarely furnish supplies adequate even for single homes, as shown by the extensive use of cisterns. Steady pumpage of even 2 or 3 gallons a minute soon exhausts most such wells.

The quality of water is generally poor. The average hardness of water from eight wells south of the alluvial area was more than 500 parts per million, and one sample had a hardness of 1,470 parts per million. Furthermore, in these waters there is almost always present an objectionable concentration of one or more of the following constituents: chloride, sulfate, nitrate, and iron.

Valley Alluvium

The boundary drawn on plate 1 shows the extent of the water-bearing alluvium and the sections in plate 2 illustrate the nature and thickness of the alluvial deposits. The brief history of the origin of the deposits that follows leads to an understanding of their distribution and nature.

Quaternary Geologic History

The portion of the Ohio valley in northern Kentucky and the deposits laid in it originated during the Pleistocene or glacial epoch, when the ice sheets that grew in Canada spread southward into the United States. When the final story of the river is written it will be a complicated one because there were at least four periods when ice accumulated, separated by intervals of climate not much different from the present; during all this time the river valley was being modeled. However, most of the water-bearing alluvium dates from the last or Wisconsin age when ice advanced as far south as the northern edge of Cincinnati before the climate warmed and caused it to melt.

Beneath much of the surface of Covington and Newport, the bedrock is at an elevation of about 375 feet, some 45 feet below the present channel of the Ohio River. Evidently at one time the river flowed at this level long enough to form the wide valley shown on plate 2. This buried valley floor no doubt dates from the time when the glaciers were largest. Because of the immense quantities of water present on land masses as ice, sea levels were 200 feet or more lower than at present, and the courses of rivers draining to the seas were lowered also.

The valley-filling alluvium of sand and gravel overlain by silt and clay probably was deposited during the melting and retreat of the ice, as the result of two causes: The water released from melting ice carried great volumes of rock fragments from the ice front into the Ohio valley; as the water returned to the sea, the sea level and the mouths of the rivers rose gradually, and the rivers therefore ran on lower gradients with less velocity and transporting power. As a result of heavy load and declining transporting power, the Ohio River became overloaded and began to fill its valley. During floods the material was shifted somewhat and spread, but gradually it accumulated to build up the river bed and valley bottom.

The sharp break from sand and gravel to overlying silt and clay indicates some widespread change in conditions in the Ohio basin. Probably the sand and gravel accumulated as long as the melting ice within the Ohio basin fed abundant water to tributary streams, which enabled them to carry coarse deposits in bulk to the Ohio. After all ice had melted from the basin these streams, losing their vigor, carried mostly fine-grained material such as silt and clay.

The alluvial deposits in the valley of the Licking River consist mainly of silt and clay, because the limestones and shales that occupy most of the drainage area weather to such fine-grained material rather than to particles the size of sand and gravel. The rising level of the alluvial fill in the Ohio valley dammed the Licking River and caused a pool of slack or slowly moving water to extend far upstream; in this pool the silt and clay settled out of suspension. No sharp junction exists between the deposits of the Licking and the Ohio Rivers where these valleys join, but the sand and gravel of the Ohio valley grade or interfinger into the silt and clay of the Licking valley.

Patches of alluvial deposits along the valley margin at elevations of 540 feet above sea level, or 165 feet above the buried channel, show that the valley was once filled to that elevation. Erosion after filling of the valley has planed the deposits down to the present elevation of the town sites, about 480 to 520 feet.

Detailed Description

The greatest known thickness of alluvium under Covington and Newport is about 150 feet (pl. 2). Bedrock elevations, where known, are given in inclined figures on plate 1. Inspection of these elevations shows that the deepest part of the old valley, with the thickest alluvium, lies south of the present river channel. It runs under the central part of Newport and Covington, and in the western part of Covington, turns northward under the Chesapeake and Ohio railroad bridge. Section CC', plate 2, shows clearly how bedrock lies close to the bottom of the present river channel, descends under the central part of Newport, and rises against the southern wall of the valley.

The sections also illustrate that in general the lower half of the alluvium is sand and gravel, the upper half silt and clay. Section CC' reveals that the basal coarse deposits rise gradually toward the valley wall of bedrock, but wedge out beneath silt and clay before reaching the surface.

The section AA', extending from the Ohio River southeastward across Covington and up the Licking River valley, reveals how the coarse basal deposits in the Ohio River valley merge into the fine-grained deposits of the Licking River and thin to but a few feet of coarse material immediately above bedrock.

Various cuts and banks expose the silt and clay section of the alluvium, and a number of the well logs in table 3 give descriptions of it. It consists mainly of fine silt with varying quantities of clay, usually enough to make the material somewhat plastic, and steep banks in and near the towns occasionally give trouble by slumping and sliding. Close examination shows that indistinct thin laminations occur but at a distance the material seems homogeneous. It is generally yellow at the surface, and gray or blue at a depth of more than about 10 or 20 feet.

Table 2.--Records of wells and test borings in the Covington-Newport alluvial area, Kentucky.

(1/ For location of well see plate 1. 2/ r = reported. Note: All wells are drilled.)

Well number	Location 1/	Owner or name	Driller	Date completed	Altitude above sea level (feet)	Depth of well (feet)	Diameter of well (inches)	Principal water-bearing bed: Depth to top of bed (feet)	Thickness (feet)	Character of material	Geologic horizon	Water level: Below land surface 2/ (feet)	Date of measurement	Method of lift	Approximate capacity of well (gallons per minute)	Use of water	Remarks
8425-3900-3	1564 Water St., Covington.	Jos. N. Rice Co.	Jos. Koehne & Son	-	492	111	8	100	10	Sand and gravel.	Alluvium	r 54	-	Vertical turbine	60	Industrial	Log and analysis available.
43	Licking Pike, Newport.	Newport Steel Corp.	-	1925	490	250 (?)	8	-	-	Rock	Ordovician	-	-	Air lift.	100	Air conditioning	Analysis available.
44	439 Thornton St., Newport.	Newport Dairy	-	1945	495	110	6	-	-	-	-	r 50	-	Vertical turbine	35	Cooling and condensing.	Unused.
61	Licking Pike, Newport.	Newport Steel Corp.	A. D. Cook	1935	495	113	-	46	63	Sand and gravel.	Alluvium	44.5	Sept. 1935	None	150	None	Well abandoned. Log available.
62	do.	Heckett Engineering	T. Posey	1948	500	116	6	-	-	do.	do.	-	-	-	6	None	Abandoned and covered.
63	704 East 17th St., Covington.	C. R. Warneford	-	1946	495	113	6	105	8	do.	do.	52.2	July 1951	Jet pump.	33	Swimming pool	Undesirably high in iron. Temperature 54° to 56°.
64	15th St. and Licking River.	City of Covington	U. S. Corps of Engineers.	-	491	100	-	94	6+	do.	do.	-	-	-	-	-	U. S. Corps of Engineers test boring D-13-2. Log available.
65	Oliver St. and Licking River.	do.	do.	-	482	34	-	33	1+	do.	do.	-	-	-	-	-	U. S. Corps of Engineers test boring DU-13-2. Log available.
66	12th St. and Licking River.	City of Newport	do.	-	500	60	-	55	5+	Sand	do.	13	-	-	-	-	U. S. Corps of Engineers test boring L-6. Log available.
67	10th St. and Licking River.	do.	do.	-	492	54	-	51	3+	do.	do.	-	-	-	-	-	U. S. Corps of Engineers test boring S-23. Log available.
68	Licking River bridge.	Chesapeake & Ohio Railway Co.	Chesapeake & Ohio Railway Co.	1926	502	53	-	-	-	-	-	-	-	-	-	-	Chesapeake & Ohio Railway Co. test boring A. Log available.
69	do.	do.	do.	1926	491	46	-	-	-	-	-	-	-	-	-	-	Chesapeake & Ohio Railway Co. test boring B. Log available.
70	do.	do.	do.	1926	491	57	-	-	-	-	-	-	-	-	-	-	Chesapeake & Ohio Railway Co. test boring C. Log available.
71	do.	do.	do.	1926	488	80	-	-	-	-	-	-	-	-	-	-	Chesapeake & Ohio Railway Co. test boring D. Log available.
72	do.	do.	do.	1926	490	70	-	-	-	-	-	-	-	-	-	-	Chesapeake & Ohio Railway Co. test boring E. Log available.
73	Licking River Pike, 1,500 ft. south of railroad bridge.	Old '76 Distillery	-	-	530	1,250	3	-	-	Sandy limestone.	St. Peter	-	-	-	-	-	Artesian head reported 590 ft. above sea level 1906. Flow was 34 gallons per minute. Well abandoned. Analysis available.
8425-3905-1	7th and Monmouth Sts. Newport.	American National Bank.	Jos. Koehne & Son	-	510	149	8	82	67+	Sand and gravel.	Alluvium	-	-	Electric pump.	75	Air conditioning	Log and analysis available.
2	601 Columbia St., Newport.	George Wiedemann Brewing Co.	do.	Sept. 1933	510	111	12	73	38+	do.	do.	60.5	Sept. 1933	do.	400	Cooling and condensing.	Log and partial analysis available.
3	711 Monmouth St., Newport.	Hippodrome Theatre	do.	-	510	147	-	70	77	do.	do.	70	-	do.	125	Air conditioning	Log available.
4	324 East 4th St., Newport.	Highland Dairy	A. R. Posey	1921	508	125	-	-	-	do.	do.	-	-	do.	100	Cooling and condensing.	Furnished water for Newport during 1937 flood. Analysis available.
5	5th and Clay Sts., Dayton.	Wadsworth Watch Case Co.	Jos. Koehne & Son	-	510	90	8	10	80+	do.	do.	43	Nov. 1945	do.	235	Air conditioning and cooling.	Log and analysis available.
6	do.	do.	do.	1945	510	115	8	10	104+	do.	do.	56	Nov. 1948	do.	235	do.	Log available.
9	601 Columbia St., Newport.	George Wiedemann Brewing Co.	T. Posey	1950	490	125	-	-	-	do.	do.	-	-	do.	250	Industrial	Partial analysis available.
10	do.	do.	do.	-	490	125	-	-	-	do.	do.	-	-	do.	250	do.	Analysis available.
11	do.	do.	do.	-	490	125	-	-	-	do.	do.	-	-	do.	250	do.	Partial analysis available.
12	do.	do.	do.	-	485	125	-	-	-	do.	do.	-	-	do.	250	do.	Do.

8423-3905-13	18 East 5th St., Newport.	G. Schmidt	Jos. Koehne & Son	1950	505	125	12	55	70+	Sand and gravel.	Alluvium	74	1950	Vertical turbine	490	Air conditioning	Temperature 58°. Log available.
14	716 Monmouth St., Newport.	State Theatre	-	-	510	170	-	-	-	do.	-	-	-	-	150	do.	
15	610 Washington Ave., Newport.	Hyde-Park Clothes, Inc.	-	-	518	60	4	-	-	-	-	-	-	-	-	None	Unused since 1937.
16	37 East 11th St., Newport.	Cloverleaf Dairy	Jos. Koehne & Son	1932	520	112	-	-	-	-	-	-	-	-	-	None	Last used 1935. Insufficient quantity of water.
22	Central Bridge, Newport to Cincinnati.	State of Kentucky	-	1890	-	-	-	-	-	-	-	-	-	-	-	-	Pier 8. Bedrock at 430 (?) ft.
27	Washington Ave. and Ohio River.	City of Newport	U. S. Corps of Engineers.	-	481	50	-	31	19+	Sand and gravel.	Alluvium	-	-	-	-	-	U. S. Corps of Engineers test boring D-1. Log available.
28	3d and 6th Sts.	do.	do.	-	480	30	-	24	6+	do.	do.	-	-	-	-	-	U. S. Corps of Engineers test boring D-69. Log available.
29	Linden Ave. and Ohio River.	do.	do.	-	487	40	-	32	8+	Sand and silt.	do.	-	-	-	-	-	U. S. Corps of Engineers test boring D-5-20. Log available.
30	Park Ave. and Ohio River.	do.	do.	-	490	40	-	35	5+	Sand	do.	-	-	-	-	-	U. S. Corps of Engineers test boring D-5-29. Log available.
31	Columbia St. and Ohio River.	do.	do.	-	482	25	-	15	10+	do.	do.	-	-	-	-	-	U. S. Corps of Engineers test boring D-5-53. Log available.
32	Monmouth St. and Chesapeake & Ohio railroad, Newport.	Kentucky Department of Highways.	Kentucky Department of Highways.	1935	537	77	-	52	25+	Sand and gravel.	do.	-	-	-	-	-	Kentucky Department of Highways test boring M-2. Log available.
33	do.	do.	-	1935	548	38	-	24	14	do.	do.	-	-	-	-	-	Kentucky Department of Highways test boring M-7. Log available.
8430-3900-1	115 Pike St., Covington.	New England Distilling Co.	T. Posey	1918	525	112	10	-	-	do.	do.	r 64	-	Electric pump.	75	Cooling and condensing.	Drilled to rock. Temperature 56°.
2	do.	do.	do.	-	525	113	10	-	-	do.	do.	75	9-25-44	do.	275	do.	Do.
3	do.	do.	do.	1940	525	153	10	70	83	do.	do.	r 70	1940	do.	375	do.	12 ft. drawdown at 375 gallons per minute. Log available.
4	do.	do.	do.	1945	525	154	10	-	-	do.	do.	86	3-19-45	do.	300	do.	Drilled to rock.
79	1002 Madison Ave., Covington.	Dr. Gillman	F Farris	-	530	138	6	-	-	do.	do.	-	-	do.	50	Air conditioning	
80	224 East 20th St., Covington.	Summe and Ratterman	-	-	520	150	6	-	-	do.	do.	41.22	7-21-50	None	-	None	Unused. Observation well.
81	1813 Holman St., Covington.	Shirley Theatre	Jos. Koehne & Son	-	525	60	-	-	-	do.	do.	-	-	Electric pump.	-	Air conditioning	Unused.
84	524 Reidlan St., Covington.	Monarch Ice Cream Co., Inc.	do.	-	525	94.5	6	82	12.5+	do.	do.	r 40.5	-	None	-	Industrial	Unused. Log and partial analysis available.
88	530 Reidlan St., Covington.	Bavarian Brewing Co., Inc.	do.	-	525	100	6	88	12+	do.	do.	r 65	-	Electric pump.	50	Cooling and condensing.	Log available.
91	7th St. and Madison Ave., Covington.	Madison Theatre	-	-	515	130	6	-	-	do.	do.	-	-	do.	125	Air conditioning	
95	7th St. and Washington Ave., Covington.	Broadway Theatre	-	-	520	135	6	-	-	do.	do.	-	-	do.	125	do.	Analysis available.
96	Patton St. and Eastern Ave., Covington.	C. Rice Packing Co.	T. Posey	-	510	90	6	-	-	do.	do.	-	-	do.	40	Industrial	Do.
99	635 Main St., Covington.	Family Theatre	Jos. Koehne & Son	-	525	176	-	-	-	do.	do.	-	-	do.	-	Air conditioning	Unused.
100	Newport	Newport Steel Corp.	A. D. Cook	-	492	109	-	81	19+	do.	do.	r 44	-	-	-	None	Well is covered. Log available.

Table 2.--Records of wells and test borings in the Covington-Newport alluvial area, Kentucky--continued.

([1] For location of well see plate 1. [2] r = reported. Note: All wells are drilled.)

Well number	Location [1]	Owner or name	Driller	Date completed	Altitude above sea level (feet)	Depth of well (feet)	Diameter of well (inches)	Principal water-bearing bed: Depth to top of bed (feet)	Principal water-bearing bed: Thickness (feet)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic horizon	Water level: Below land surface [2] (feet)	Water level: Date of measurement	Method of lift	Approximate capacity of well (gallons per minute)	Use of water	Remarks
8430-3900-101	Newport	Newport Steel Corp.	A. D. Cook	1918	492	61	10	-	-	Sand and gravel.	Alluvium	48.2	6-4-51	-	-	None	Unused since 1936.
102	115 Pike St., Covington	New England Distilling Co.	T. Posey	1951	585	153	-	-	-	do.	do.	70	Feb. 1951	Electric pump.	350	Cooling and condensing.	Analysis available.
103	224 East 20th St., Covington.	Summe and Ratterman	-	-	580	150±	-	-	-	do.	do.	-	-	-	-	None	Unused. Observation well.
104	584 Reidlan St., Covington.	Monarch Ice Cream Co., Inc.	Jos. Koehne & Son	1951	525	-	-	-	-	-	-	-	-	Electric pump.	50	Cooling and condensing.	
105	Saratoga St. and Licking River.	City of Covington	U. S. Corps of Engineers.	-	494	45	-	-	-	-	-	-	-	-	-	None	U. S. Corps of Engineers test boring D-21. Log available.
106	9th St. and Licking River.	do.	do.	-	492	35	-	-	-	-	-	-	-	-	-	do.	U. S. Corps of Engineers test boring D-22. Log available.
107	12th St. and Licking River.	do.	do.	-	490	80	-	-	-	-	-	-	-	-	-	do.	U. S. Corps of Engineers test boring D-13-1. Log available.
108	Licking River bridge	Chesapeake & Ohio Railway Co.	Chesapeake & Ohio Railway Co.	1926	503	65	-	-	-	-	-	-	-	-	-	do.	Chesapeake & Ohio Railway Co. test boring F. Log available.
8430-3905-1	34 West 5th St., Covington.	Elks Club	Jos. Koehne & Son	1947	510	115	6	40	75+	Sand and gravel.	Alluvium	-	-	Electric pump.	200	Air conditioning	Log and analysis available.
2	7th St. and Madison Ave., Covington.	J. P. Coppin Co.	do.	-	503	110	6	54	56+	do.	do.	55.5	-	do.	160	do.	Log available.
4	2d St. and Madison Ave., Covington.	Fries & Son Steel Constr. & Eng.Co.	-	1937	490	85	6	-	-	do.	do.	73	-	Electric turbine.	500	Industrial	Unused. Temperature 57°.
5	2d St. and Scott Blvd., Covington.	City Products Corp.	Jos. Koehne & Son	1940	490	84	10	40	44+	do.	do.	-	-	Electric pump.	125	do.	Log and analysis available.
6	do.	do.	A. R. Posey	1918	490	82	10	-	-	do.	do.	-	-	do.	80	do.	
7	do.	do.	-	-	490	86	8	-	-	do.	do.	-	-	do.	30	do.	
8	Madison Ave., Covington	Liberty Theatre	T. Posey	-	515	110	6	-	-	do.	do.	-	-	do.	125	Air conditioning	Analysis available.
9	4th and Philadelphia Sts., Covington.	Bavarian Brewing Co., Inc.	Jos. Koehne & Son	-	505	117	10	-	-	do.	do.	-	-	do.	350	Industrial	Do.
10	322 Elm St., Ludlow.	Ludlow Theatre	Acme	-	520	142	-	-	-	do.	do.	-	-	do.	75	Air conditioning	
11	Newport	Newport Steel Corp.	A. D. Cook	1935	497	115	-	61	48	do.	do.	61	1935	-	-	-	Abandoned and covered. Log available.
12	do.	do.	do.	1935	494	120	-	79	5	do.	do.	-	-	-	-	-	Do.
13	do.	do.	do.	1935	495	100	-	88	7	do.	do.	-	-	-	-	-	Do.
14	2d St. and Scott Blvd., Covington.	City Products Corp.	-	-	492	-	10	-	-	do.	do.	-	-	Electric pump.	80	Cooling and condensing.	Last used in 1932.
15	do.	do.	A. R. Posey	1918	492	-	-	-	-	do.	do.	-	-	None	120	None	Last used in 1937. Observation well.
16	627 Scott Blvd., Covington.	Sweetzer and Burns	Pat Mills	1944	515	126	6	-	-	do.	do.	-	-	Electric turbine.	100	Air conditioning	Temperature 58°.
17	Central Bridge, Newport to Cincinnati.	State of Kentucky	-	1890	-	-	-	-	-	-	-	-	-	-	-	-	Pier 7. Bedrock 430 (?) ft.
18	do.	do.	-	1890	-	-	-	-	-	-	-	-	-	-	-	-	Pier 6. Bedrock 432 ft.
19	do.	do.	-	1890	-	-	-	-	-	-	-	-	-	-	-	-	Pier 5. Bedrock 426 ft.
20	do.	do.	-	1890	-	-	-	-	-	-	-	-	-	-	-	-	Pier 4. Bedrock 442 ft.
21	3d St. and Ohio River.	City of Newport	U. S. Corps of Engineers.	-	485	84	-	20	4+	Silt, sand, and clay.	Alluvium	20	-	-	-	-	U. S. Corps of Engineers test boring D-5-90. Log available.
22	Madison Ave. and Ohio River.	City of Covington	do.	-	488	86	-	46	38	Sand and gravel.	do.	-	-	-	-	-	U. S. Corps of Engineers test boring D-14-2. Log available.
23	Washington Ave. and Ohio River.	do.	do.	-	492	55	-	47	7+	do.	do.	-	-	-	-	-	U. S. Corps of Engineers test boring D-14-3. Log available.

8430-3905-24	Philadelphia St. and Ohio River.	City of Covington	U. S. Corps of Engineers.	-	488	60	-	52	8+	Sand and gravel.	Alluvium	-	-	-	-	-	U. S. Corps of Engineers test boring D-14-5. Log available.
25	Main St. and Ohio River.	do.	do.	-	484	41	-	20	21+	do.	do.	-	-	-	-	-	U. S. Corps of Engineers test boring DU-14-3. Log available.
26	Crescent St. and Ohio River.	do.	do.	-	488	50	-	44	6+	do.	do.	-	-	-	-	-	U. S. Corps of Engineers test boring DU-14-4. Log available.
27	Madison Ave. and Ohio River.	do.	do.	-	465	26	-	18	8+	do.	do.	-	-	-	-	-	U. S. Corps of Engineers test boring F-57. Log available.
28	Court St. and Ohio River.	do.	do.	-	486	50	-	-	-	-	do.	-	-	-	-	-	U. S. Corps of Engineers test boring F-74. Log available.
29	6th St. and Licking River.	City of Newport	do.	-	494	57	-	51	6+	Sand and gravel.	do.	-	-	-	-	-	U. S. Corps of Engineers test boring L-1. Log available.
30	Philadelphia St. and Ohio River.	City of Covington	do.	-	486	57	-	50	7+	do.	do.	-	-	-	-	-	U. S. Corps of Engineers test boring L-7. Log available.
31	6th St. and Licking River.	City of Newport	do.	-	459	37	-	31	6+	do.	do.	-	-	-	-	-	Do.
32	Ohio River bridge	Chesapeake & Ohio Railway Co.	Chesapeake & Ohio Railway Co.	1926	428	69	-	2	51	do.	do.	-	-	-	-	-	Chesapeake & Ohio Railway Co. test boring 13. Log available.
33	do.	do.	do.	1926	485	113	-	52	58	do.	do.	-	-	-	-	-	Chesapeake & Ohio Railway Co. test boring 15. Log available.
34	do.	do.	do.	1926	422	48	-	0	48	do.	do.	-	-	-	-	-	Chesapeake & Ohio Railway Co. test borings 7-12, 14. Composite log available.
35	do.	do.	do.	1926	420	44	-	0	44	do.	do.	-	-	-	-	-	Chesapeake & Ohio Railway Co. test borings 1-6, 13. Composite log available.
36	do.	do.	do.	1926	488	115	-	45	65	do.	do.	-	-	-	-	-	Chesapeake & Ohio Railway Co. test boring 16. Log available.
37	Ohio River bridge	Southern Railway System.	Southern Railway System.	-	-	-	-	-	-	-	-	-	-	-	-	-	Southern Railway System bridge pier 3. Bedrock at 423 ft.
38	do.	do.	do.	-	-	-	-	-	-	-	-	-	-	-	-	-	Southern Railway System bridge pier 4. Bedrock at 415 ft.
39	do.	do.	do.	-	-	-	-	-	-	-	-	-	-	-	-	-	Southern Railway System bridge pier 5. Bedrock at 425 ft.
40	4th St. bridge, Licking River.	Kentucky Department of Highways.	Kentucky Department of Highways.	-	-	-	-	-	-	-	-	-	-	-	-	-	Kentucky Department of Highways bridge pier 3. Bedrock at 406 ft.
41	do.	do.	do.	-	-	-	-	-	-	-	-	-	-	-	-	-	Kentucky Department of Highways bridge pier 4. Bedrock at 406 ft.
43	44-46 Walnut St., Cincinnati, Ohio.	Churngold Corp.	-	1930	490	72	12	51	21	Sand and gravel.	Alluvium	46	1930	Electric turbine	-	Industrial	U. S. Geological Survey number in Ohio is 303-2. Log available.

Table 3.--Logs of wells and test borings in the Covington-Newport alluvial area, Kentucky

(Test borings logged by engineers; all others logged by drillers.)

Well number: 8425-3900-3.
Owner: Jos. N. Rice Co.
Location: 1564 Water Street, Covington.
Altitude of land surface: 492 feet above mean sea level.
Static water level: 54 feet below land surface (reported).

	Thickness (feet)	Depth (feet)
Fill	3	3
Clay, yellow	27	30
Loam, blue	55	85
Hard pan	15	100
Muddy sand and gravel	10	110
Bottom	1	111

Well number: 8425-3900-61.
Owner: Newport Steel Corp.
Location: Newport Rolling Mill, Newport.
Altitude of land surface: 495 feet above mean sea level.
Static water level: 44.5 feet below land surface, September 1935.

	Thickness (feet)	Depth (feet)
Fill	3	3
Clay, yellow	26	29
Clay, blue	11	40
Clay, blue, and gravel	6	46
Gravel and boulders, dry	11	57
Sand, fine	9	66
Sand, water packed	29	95
Sand, gravel and rock	14.5	109.5
Shale	4	113.5

Well number: 8425-3900-64; U. S. Corps of Engineers test boring D-13-2.
Owner: City of Covington.
Location: 15th Street and Licking River, Covington.
Altitude of land surface: 491 feet above mean sea level.

	Thickness (feet)	Depth (feet)
Clay, sandy	5	5
Clay	44	49
Sand	6	55
Clay, sandy	39	94
Sand and gravel	6+	100

Well number: 8425-3900-65; U. S. Corps of Engineers test boring DU-13-2.
Owner: City of Covington.
Location: Oliver Street and Licking River, Covington.
Altitude of land surface: 482 feet above mean sea level.

	Thickness (feet)	Depth (feet)
Silt and clay	21	21
Sand, silt, clay	3	24
Silt and clay	6	30
Sand, silt, clay	3	33
Gravel, sand, silt	1+	34

Well number: 8425-3900-66; U. S. Corps of Engineers test boring L-6.
Owner: City of Newport.
Location: 12th Street and Licking River, Newport.
Altitude of land surface: 500 feet above mean sea level.
Static water level: 13 feet below land surface.

	Thickness (feet)	Depth (feet)
Cinders and sand	9	9
Silt, clayey	21	30
Silt, sandy	2	32
No sample	1	33
Silt, sandy	22	55
Sand	5+	60

Well number: 8425-3900-67; U. S. Corps of Engineers test boring S-23.
Owner: City of Newport.
Location: 10th Street and Licking River, Newport.
Altitude of land surface: 492 feet above mean sea level.

	Thickness (feet)	Depth (feet)
Cinders, fill	17	17
Silt, clayey	34	51
Sand	3+	54

Well number: 8425-3900-68; Chesapeake & Ohio Railway Co. test boring A.
Owner: Chesapeake & Ohio Railway Co.
Location: Licking River railroad bridge, Newport.
Altitude of land surface: 502 feet above mean sea level.

	Thickness (feet)	Depth (feet)
Cinders, fill	4	4
Clay	16	20
Sand and clay	31	51
Limestone bedrock		51

Well number: 8425-3900-69; Chesapeake & Ohio Railway Co. test boring B.
Owner: Chesapeake & Ohio Railway Co.
Location: Licking River railroad bridge, Newport.
Altitude of land surface: 491 feet above mean sea level.

	Thickness (feet)	Depth (feet)
Cinders, fill	3	3
Clay	25	28
Sand and clay	6.5	34.5
Clay	6.5	41
Limestone bedrock	5	46

Well number: 8425-3900-70; Chesapeake & Ohio Railway Co. test boring C.
Owner: Chesapeake & Ohio Railway Co.
Location: Licking River railroad bridge, Newport.
Altitude of land surface: 491.4 feet above mean sea level.

	Thickness (feet)	Depth (feet)
Cinders	3.5	3.5
Clay	32.5	36
Sand and clay	2.5	38.5
Clay	1.5	40
Clay and sand	3	43
Clay	3	46
Clay and sand	1.5	47.5
Limestone bedrock	9.8	57.3

Well number: 8425-3900-71; Chesapeake & Ohio Railway Co. test boring D.
Owner: Chesapeake & Ohio Railway Co.
Location: Licking River railroad bridge, Covington.
Altitude of land surface: 488 feet above mean sea level.

	Thickness (feet)	Depth (feet)
Cinders	4	4
Clay	22	26
Clay and sand	24	50
Clay	7	57
Clay and sand	23	80

Well number: 8425-3900-72; Chesapeake & Ohio Railway Co. test boring E.
Owner: Chesapeake & Ohio Railway Co.
Location: Licking River railroad bridge, Covington.
Altitude of land surface: 490 feet above mean sea level.

	Thickness (feet)	Depth (feet)
Cinders	4	4
Clay	14.5	18.5
Sand and clay	47	65.5
Clay, blue, hard	4.8	70.3

Well number: 8425-3905-1.
Owner: American National Bank.
Location: 7th and Monmouth Streets, Newport.
Altitude of land surface: 510 feet above mean sea level.

	Thickness (feet)	Depth (feet)
Sandy clay	82	82
Sand, gray	13	95
Sand	23	118
Sand, fine	8	126
Sand and gravel	20	146
Sand, fine	2	148
Sand, coarse, and gravel	1	149

Well number: 8425-3905-2.
Owner: George Wiedemann Brewing Co.
Location: 601 Columbia Street, Newport.
Altitude of land surface: 510 feet above mean sea level.
Static water level: 60.5 feet below land surface, September 27, 1933.

	Thickness (feet)	Depth (feet)
Fill	4	4
Clay loam	22	26
Sandy loam	14	40
Clay loam, yellow	29	69
Loam, blue	4	73
Gravel	6	79
Loam, blue	2	81
Gravel, coarse	8	89
Loam, blue	1-1/2	90-1/2
Sand and gravel	16-1/2	107
Gravel, coarse	4-1/3	111-1/3

Well number: 8425-3905-3.
Owner: Hippodrome Theatre.
Location: 711 Monmouth Street, Newport.
Altitude of land surface: 510 feet above mean sea level.
Static water level: 70 feet below land surface.

	Thickness (feet)	Depth (feet)
Loam	18	18
Gravel	3	21
Sand	7	28
Loam	42	70
Sand, fine	62	132
Gravel	11	143
Loam	2	145
Gravel	2	147
Bedrock		147

Well number: 8425-3905-5.
Owner: Wadsworth Watch Case Co.
Location: 5th and Clay Streets, Dayton.
Altitude of land surface: 510 feet above mean sea level.
Static water level: 43 feet below land surface, November 1945.

	Thickness (feet)	Depth (feet)
Loamy sand, brown	10	10
Muddy gravel, dry	39	49
Muddy sand and gravel, dry	16	65
Sand and gravel, water-bearing .	25	90

Well number: 8425-3905-6.
Owner: Wadsworth Watch Case Co.
Location: 5th and Clay Streets, Dayton.
Altitude of land surface: 510 feet above mean sea level.
Static water level: 56 feet below land surface, November 1948.

	Thickness (feet)	Depth (feet)
Loamy sand, brown	10	10
Muddy gravel, dry	39	49
Muddy sand and gravel, dry	14	63
Sand and gravel, water-bearing	31	94
Sand, fine	2	96
Sand, coarse, and gravel, pea	16	112
Sand-gravel, dead	1-1/2	113-1/2
Sand, fine, and boulders	1	114-1/2

Well number: 8425-3905-13.
Owner: G. Schmidt.
Location: 18 East 5th Street, Newport.
Altitude of land surface: 505 feet above mean sea level.
Static water level: 74 feet below land surface, 1950.

	Thickness (feet)	Depth (feet)
Cinders	1	1
Clay, yellow	11	12
Sand, fine, and clay	10	22
Clay, blue	10	32
Loamy sand, fine	4	36
Loam, blue	19	55
Sand and gravel, dry	23	78
Sand, gray	45	123
Sand, gray, and stray gravel	1-3/4	124-3/4

Well number: 8425-3905-27; U. S. Corps of Engineers test boring D-1.
Owner: City of Newport.
Location: Washington Avenue and Ohio River, Newport.
Altitude of land surface: 481 feet above mean sea level.

	Thickness (feet)	Depth (feet)
Silt, sand, and brick	7	7
Silt and clay	13	20
Sand and silt	11	31
Gravel and sand	19	50

Well number: 8425-3905-28; U. S. Corps of Engineers test boring D-69.
Owner: City of Newport.
Location: 3d and 6th Streets, Newport.
Altitude of land surface: 480.4 feet above mean sea level.

	Thickness (feet)	Depth (feet)
Sand, silt, and clay	24	24
Sand, coarse, and gravel, small	6	30

Well number: 8425-3905-29; U. S. Corps of Engineers test boring D-5-20.
Owner: City of Newport.
Location: Linden Avenue and Ohio River, Newport.
Altitude of land surface: 486.6 feet above mean sea level.

	Thickness (feet)	Depth (feet)
Cinders, slag	32	32
Sand, silt	8	40

Well number: 8425-3905-30; U. S. Corps of Engineers test boring D-5-29.
Owner: City of Newport.
Location: Park Avenue and Ohio River, Newport.
Altitude of land surface: 490 feet above mean sea level.

	Thickness (feet)	Depth (feet)
Cinders	21	21
Sand and fill	14	35
Sand	5	40

Well number: 8425-3905-31; U. S. Corps of Engineers test boring D-5-53.
Owner: City of Newport.
Location: Columbia Street and Ohio River, Newport.
Altitude of land surface: 481.7 feet above mean sea level.

	Thickness (feet)	Depth (feet)
Silt	15	15
Sand	10	25

Well number: 8425-3905-32; Kentucky Department of Highways test boring M-2.
Owner: Kentucky Department of Highways.
Location: Monmouth Street and Chesapeake & Ohio railroad, Newport.
Altitude of land surface: 537 feet above mean sea level.

	Thickness (feet)	Depth (feet)
Sand and clay	52	52
Sand and gravel	25+	77

Well number: 8425-3905-33; Kentucky Department of Highways test boring M-7.
Owner: Kentucky Department of Highways.
Location: Monmouth Street and Chesapeake & Ohio railroad, Newport.
Altitude of land surface: 548 feet above mean sea level.

	Thickness (feet)	Depth (feet)
Sand and clay	24	24
Sand and gravel	14	38
Bedrock		38

Well number: 8430-3900-3.
Owner: New England Distilling Co.
Location: 115 Pike Street, Covington.
Altitude of land surface: 525 feet above mean sea level.
Static water level: 70 feet below land surface, 1940 (reported).

	Thickness (feet)	Depth (feet)
Clay, blue	70	70
Sand and gravel, dry	10	80
Sand and gravel	10	90
Sand	15	105
Gravel, coarse	5	110
Gravel, mixed	15	125
Sand and gravel	28	153
Bedrock		153

Well number: 8430-3900-84.
Owner: Monarch Ice Cream Co., Inc.
Location: 524 Reidlan Street, Covington.
Altitude of land surface: 525 feet above mean sea level.
Static water level: 40.5 feet below land surface (reported).

	Thickness (feet)	Depth (feet)
Clay (?)	62	62
Silt	17	79
Clay, yellow, and sand	3	82
Gravel, yellow	10	92
Gravel, gray	2-1/2	94-1/2

Well number: 8430-3900-88.
Owner: Bavarian Brewing Co., Inc.
Location: 530 Reidlan Street, Covington.
Altitude of land surface: 525 feet above mean sea level.
Static water level: 65 feet below land surface (reported).

	Thickness (feet)	Depth (feet)
Fill	4	4
Clay	26	30
Lime, blue	24	54
Sand and clay	18	72
Muddy sand and filthy water	16	88
Sand and gravel	6	94
Sand, dry	1-1/2	95-1/2
Sand, gray, and gravel	4-1/2	100

Well number: 8430-3900-100.
Owner: Newport Steel Corp.
Location: Newport Rolling Mill, Newport.
Altitude of land surface: 492 feet above mean sea level.
Static water level: 44 feet below land surface (reported).

	Thickness (feet)	Depth (feet)
Slag	6	6
Clay, yellow	22	28
Clay, blue	4	32
Hard pan	4	36
Clay, blue	45	81
Sand, fine, water	7	88
Gravel and boulders, water-bearing	12	100

Well number: 8430-3900-105; U. S. Corps of Engineers test boring D-21.
Owner: City of Covington.
Location: Saratoga Street and Licking River, Covington.
Altitude of land surface: 494 feet above mean sea level.

	Thickness (feet)	Depth (feet)
Fill	3	3
Silt	6	9
Silt and sand	6	15
Sand and gravel	7	22
Silt	4	26
Sand	3	29
Silt	6	35
Sand and silt	10	45

Well number: 8430-3900-106; U. S. Corps of Engineers test boring D-22.
Owner: City of Covington.
Location: 9th Street and Licking River, Covington.
Altitude of land surface: 492 feet above mean sea level.

	Thickness (feet)	Depth (feet)
Fill	6	6
Clay and gravel	6	12
Sand, clay, and silt	13	25
Clay and silt	3	28
Clay, silt, and gravel	7	35

Well number: 8430-3900-107; U. S. Corps of Engineers test boring D-13-1.
Owner: City of Covington.
Location: 12th Street and Licking River, Covington.
Altitude of land surface: 490 feet above mean sea level.

	Thickness (feet)	Depth (feet)
Clay	44	44
Sand, silty	36	80

Well number: 8430-3900-108; Chesapeake & Ohio Railway Co. test boring F.
Owner: Chesapeake & Ohio Railway Co.
Location: Licking River railroad bridge, Covington.
Altitude of land surface: 502.5 feet above mean sea level.

	Thickness (feet)	Depth (feet)
Sand	18	18
Clay and sand	10	28
Clay and sand	17	45
Sand and clay	20	65

Well number: 8430-3905-1.
Owner: Elks Club.
Location: 34 West 5th Street, Covington.
Altitude of land surface: 510 feet above mean sea level.

	Thickness (feet)	Depth (feet)
Clay, yellow	30	30
Loamy sand, yellow	10	40
Sand, fine, and gravel	10	50
Loamy sand, yellow	15	65
Sand, fine	5	70
Sand, coarse, and gravel	30	100
Loamy clay	5	105
Sand, coarse, and gravel	10	115

Well number: 8430-3905-2.
Owner: J. P. Coppin Co.
Location: 7th and Madison Avenue, Covington.
Altitude of land surface: 505 feet above mean sea level.
Static water level: 55.5 feet below land surface.

	Thickness (feet)	Depth (feet)
Clay, yellow	5	5
Loamy clay, blue	49	54
Gravel, heavy dry	10	64
Gravel, heavy, water-bearing	14	78
Gravel, small	7	85
Sand, heavy, and gravel	15	100
Sand and gravel	10	110

Well number: 8430-3905-5.
Owner: City Products Corp.
Location: 2d and Scott Boulevard, Covington.
Altitude of land surface: 490 feet above mean sea level.

	Thickness (feet)	Depth (feet)
Fill	6	6
Clay, blue	8	14
Clay, yellow	26	40
Dirt and gravel	13	53
Sand and gravel	21	74
Sand and gravel	10	84

Well number: 8430-3905-11.
Owner: Newport Steel Corp.
Location: Newport Rolling Mill, Newport.
Altitude of land surface: 497 feet above mean sea level.
Static water level: 61 feet below land surface, 1935.

	Thickness (feet)	Depth (feet)
Cinder fill	9	9
Clay, yellow	16	25
Clay, blue	15	40
Clay, yellow, and gravel	5	45
Sandy clay	16	61
Sand, very fine, water	37	98
Sand, coarse, and gravel, water	2	100
Sand, water	9	109
Limestone	6	115

Well number: 8430-3905-12.
Owner: Newport Steel Corp.
Location: Newport Rolling Mill, Newport.
Altitude of land surface: 494 feet above mean sea level.

	Thickness (feet)	Depth (feet)
Fill	8	8
Clay, yellow	22	30
Clay, blue	20	50
Clay, hard, blue, and rock	3	53
Clay, soft, blue, and rock	6	59
Clay, yellow, sandy	11	70
Clay, blue, and boulders	9	79
Sand, coarse, and gravel, water-bearing	5	84
Limestone	36	120

Well number: 8430-3905-13.
Owner: Newport Steel Corp.
Location: Newport Rolling Mill, Newport.
Altitude of land surface: 495 feet above mean sea level.

	Thickness (feet)	Depth (feet)
Fill	8	8
Clay, yellow	25	33
Clay, blue	55	88
Sand, white, water-bearing	7	95
Limestone	5	100

Well number: 8430-3905-21; U. S. Corps of Engineers test boring D-5-90.
Owner: City of Newport.
Location: 3d Street and Ohio River, Newport.
Altitude of land surface: 485 feet above mean sea level.
Static water level: 20 feet below land surface.

	Thickness (feet)	Depth (feet)
Fill	11	11
Silt, clay	9	20
Silt, sand, clay	4	24

Well number: 8430-3905-22; U. S. Corps of Engineers test boring D-14-2.
Owner: City of Covington.
Location: Madison Avenue and Ohio River, Covington.
Altitude of land surface: 488 feet above mean sea level.

	Thickness (feet)	Depth (feet)
Silt and clay	5	5
Cinders and sand	26	31
Silt, sandy, clayey	15	46
Sand and gravel	38	84
Limestone	2	86

Well number: 8430-3905-23; U. S. Corps of Engineers test boring D-14-3.
Owner: City of Covington.
Location: Washington Avenue and Ohio River, Covington.
Altitude of land surface: 492 feet above mean sea level.

	Thickness (feet)	Depth (feet)
Debris	8	8
Silt, clayey	39	47
Silt, sandy, clayey	1	48
Sand, gravel, clay	7+	55

Well number: 8430-3905-24; U. S. Corps of Engineers test boring D-14-5.
Owner: City of Covington.
Location: Philadelphia Street and Ohio River, Covington.
Altitude of land surface: 488 feet above mean sea level.

	Thickness (feet)	Depth (feet)
Debris	19	19
Cinders, sand	8	27
Silt, clayey	7	34
Cinders	5	39
Silt, clayey	13	52
Gravel and sand	8+	60

Well number: 8430-3905-25; U. S. Corps of Engineers test boring DU-14-3.
Owner: City of Covington.
Location: Main Street and Ohio River, Covington.
Altitude of land surface: 484 feet above mean sea level.

	Thickness (feet)	Depth (feet)
Silt, sandy, clayey	11	11
Silt, clayey	6	17
Silt, sandy, clayey	3	20
Gravel, sand	21	41

Well number: 8430-3905-26; U. S. Corps of Engineers test boring DU-14-4.
Owner: City of Covington.
Location: Crescent Street and Ohio River, Covington.
Altitude of land surface: 488 feet above mean sea level.

	Thickness (feet)	Depth (feet)
Debris	7	7
Silt, sandy, clayey	27	34
Sand, silty, clayey	10	44
Gravel, sand, silt	6+	50

Well number: 8430-3905-27; U. S. Corps of Engineers test boring F-57.
Owner: City of Covington.
Location: Madison Avenue and Ohio River, Covington.
Altitude of land surface: 463 feet above mean sea level.

	Thickness (feet)	Depth (feet)
Sand and silt	2	2
Cinders	6	8
Silt, sandy, clayey	10	18
Gravel and sand	8+	26

Well number: 8430-3905-28; U. S. Corps of Engineers test boring F-74.
Owner: City of Covington.
Location: Court Street and Ohio River, Covington.
Altitude of land surface: 486 feet above mean sea level.

	Thickness (feet)	Depth (feet)
Alluvium	47	47
Bedrock (?)	3	50

Well number: 8430-3905-29; U. S. Corps of Engineers test boring L-1.
Owner: City of Newport.
Location: 6th Street and Licking River, Newport.
Altitude of land surface: 494 feet above mean sea level.

	Thickness (feet)	Depth (feet)
Cinders, fill	11	11
Silt, clayey	4	15
Silt, clayey, sandy	36	51
Gravel	1	52
Gravel and sand	5	57

Well number: 8430-3905-30; U. S. Corps of Engineers test boring L-7.
Owner: City of Covington.
Location: Philadelphia Street and Ohio River, Covington.
Altitude of land surface: 486 feet above mean sea level.

	Thickness (feet)	Depth (feet)
Debris	23	23
Silt, clayey	27	50
Sand and gravel	7+	57

Well number: 8430-3905-31; U. S. Corps of Engineers test boring L-7.
Owner: City of Newport.
Location: 6th Street and Licking River, Newport.
Altitude of land surface: 459 feet above mean sea level.

	Thickness (feet)	Depth (feet)
Silt, clayey	10	10
Silt, clayey, sandy	21	31
Sand	6+	37

Well number: 8430-3905-32; Chesapeake & Ohio Railway Co. test boring 13.
Owner: Chesapeake & Ohio Railway Co.
Location: Ohio River railroad bridge, Covington.
Altitude of land surface: 428 feet above mean sea level.

	Thickness (feet)	Depth (feet)
Mud and sand	2	2
Sand and gravel	51	53
Limestone and shale	1.2	54.2
Limestone	.9	55.1
Shale, soft	.3	55.4
Limestone	.1	55.5
Shale, soft	1.1	56.6
Shale, hard	.2	56.8
Shale, soft	1.2	58.0
Shale, hard	.1	58.1
Shale, soft	1.0	59.1
Limestone	.6	59.7
Shale, soft	.2	59.9
Limestone	.3	60.2
Shale, soft	.1	60.3
Limestone	.5	60.8
Shale, soft	.4	61.2
Shale, hard	.1	61.3
Limestone	.4	61.7
Shale, hard	.1	61.8
Limestone	.5	62.3
Shale, hard	.2	62.5
Shale, soft	.3	62.8
Limestone	.4	63.2
Shale, hard	.4	63.6
Shale, soft	1.3	64.9
Limestone	.2	65.1
Shale, soft	.8	65.9
Limestone	.2	66.1
Shale, soft	.6	66.7
Limestone	.6	67.3
Shale, soft	1.1	68.4
Mud	.1	68.5
Shale, soft	.7	69.2

Well number: 8430-3905-33; Chesapeake & Ohio Railway Co. test boring 15.
Owner: Chesapeake & Ohio Railway Co.
Location: Ohio River railroad bridge, Covington.
Altitude of land surface: 485 feet above mean sea level.

	Thickness (feet)	Depth (feet)
Cinders and fill	3	3
Clay and sand	22	25
Clay, soft	10	35
Clay, soft, blue	17	52
Clay, hard, blue, and sand and gravel	10	62
Sand, coarse, and gravel	43	105
Sand, coarse, gravel, boulders	5	110
Limestone and shale	3	113

Well number: 8430-3905-34; Composite of Chesapeake & Ohio Railway Co. test borings 7-12, 14.
Owner: Chesapeake & Ohio Railway Co.
Location: Ohio River railroad bridge, Covington.
Altitude of land surface: 422 feet above mean sea level.

	Thickness (feet)	Depth (feet)
Sand and gravel, occasionally gravel and boulders at base	48	48
Limestone and shale		48

Well number: 8430-3905-35; Composite of Chesapeake & Ohio Railway Co. test borings 1-6, 13.
Owner: Chesapeake & Ohio Railway Co.
Location: Ohio River railroad bridge, Covington.
Altitude of land surface: 420 feet above mean sea level.

	Thickness (feet)	Depth (feet)
Sand, sand and gravel, usually coarse gravel at base	44	44
Limestone and shale		44

Well number: 8430-3905-36; Chesapeake & Ohio Railway Co. test boring 16.
Owner: Chesapeake & Ohio Railway Co.
Location: Ohio River railroad bridge, Covington.
Altitude of land surface: 488 feet above mean sea level.

	Thickness (feet)	Depth (feet)
Pavement	2	2
Fill, cinders and slag, etc.	41	43
Clay, soft, blue	2	45
Sand, gravel, clay	1	46
Sand, coarse	3	49
Sand, coarse, and gravel	57	106
Sand, clay, gravel	3	109
Sand, hard, clay and gravel	1	110
Clay, hard, and gravel	2	112
Limestone and shale	3	115

Well number: 8430-3905-43 (U. S. Geological Survey number in Ohio 303-2).
Owner: Churngold Corp.
Location: 44-46 Walnut Street, Cincinnati, Ohio.
Altitude of land surface: 490 feet above mean sea level.
Static water level: 46 feet below land surface.

	Thickness (feet)	Depth (feet)
Basement of building		5-1/4
Loam, yellow and blue	9-3/4	15
Gravel, no sand	17	32
Loam, yellow and gravel	19	51
Sand and gravel	21	72
Bedrock		72

Some of the well logs show layers of sand within the silt and clay, but these are probably lenses that do not continue far. Stray beds of peatlike material and partly fossilized logs occur near the base of the silt and clay. The fine grain sizes prevalent in these deposits result in low permeability of the saturated zones which yield only trifling amounts of water to wells.

The lower, coarse alluvial deposits are not exposed at the surface in this area, so information on their nature comes from well logs and from exposures elsewhere along the Ohio valley. The change from overlying silt and clay to sand and gravel is fairly abrupt. The deposits tend to grow coarser from top to bottom. Sand usually is encountered first, then gravel in increasing quantity, and directly above bedrock the gravels are in places very coarse or even bouldery.

As a rule these river-laid sands are clean and sharp-edged and consist mainly of quartz grains. Most of the sand of the old deep channel is coarse, ranging in diameter from 0.5 to 1.0 millimeter. The pebbles, cobbles and occasional boulders are well-rounded and consist mostly of hard rocks such as sandstone, granite, and quartzite transported from the north by glacial action, though fragments of limestone are common. Toward the edge of the Ohio valley, especially at the junction of the Licking valley, silt and clay make up a larger fraction of the gravel beds and drillers report dirty or muddy gravel.

The yields of wells show that the sand and gravel have good porosity and permeability for storage and movement of water.

Yield of Wells and Pumpage

Wells are drilled with percussion tools into the coarse water-bearing alluvium and the holes must be kept open with casing; screen is set, the length of screen depending on the requirements as judged by the driller. Most of the wells recently drilled, especially those expected to yield 100 gallons a minute or more, are drilled through the entire section of sand and gravel to bedrock. The diameters of wells range from 6 to 12 inches.

Pumpage rates from individual wells are reported to be from about 30 to 500 gallons a minute. The average of all the reported rates is nearly 180 gallons a minute. Many of the low yields reported indicate low demand and small pump capacities rather than low permeability of the formation. However, there is no doubt that where the sand and gravel become thin near the margin of the valley wall or toward the Licking valley the yields finally diminish to nothing. At present not enough information is available to draw boundaries separating areas where different yields are possible. Wells drilled in the marginal zones ordinarily will be less productive, and sometimes unsuccessful.

Certain wells drilled in areas where the sand and gravel are thickest had capacities of at least 500 gallons a minute and with larger pumps might have yielded considerably more. Little can be said of the sustained maximum yield of wells, because the answer would require pumping tests designed to reveal storage capacity and transmissibility of the deposits, and distance to the source of water.

Figure 3 presents a summary of pumpage and type of use of ground water. Only a few of the owners of the 36 wells known to be in use could give accurate figures on the pumpage from their wells, so for most wells estimates were made based on the capacities of the pumps and the approximate time they operated per day and through the year.

Only 14 of the 36 wells are pumped through the whole year. The remaining 22 are in use mainly in the warmer months, 14 for air conditioning and 8 for cooling, condensing, and miscellaneous industrial purposes.

Total yearly pumpage in Covington is 1,010 million gallons. Almost half this total is pumped during the summer season of 4 to 4-1/2 months, at a rate of about 3.3 million gallons a day. During the rest of the year, the pumping rate is about 2.4 million gallons a day.

Total yearly pumpage in Newport is about 300 million gallons. Summer pumpage exceeds that during the rest of the year. Wells in Dayton pump about 45 million gallons a year. Pumpage of about 4 million gallons a year from one well in Ludlow is not plotted on the graphical summary.

As figure 3 shows, the brewing and distilling industries use 74 percent of all the water pumped, air conditioning uses 14 percent, and food-processing and miscellaneous industries use the remaining 12 percent.

Source and Movement of Water

Evidence available from water-level measurements and chemical quality of ground water suggests that the sand and gravel aquifer gets recharge from the valley wall, from the surface, and from the Ohio and Licking Rivers.

The amount of water that moves from the uplands down through bedrock of the valley wall into the aquifer is probably small, because the rocks are relatively impermeable. No doubt more water seeps down slope through the soil above bedrock than moves through rock. Probably more important as a source is the percolation of rainfall through the upper fine-grained alluvium. Insufficient data are available locally to make a sound estimate of the recharge from this source. However, at Louisville (Rorabaugh, 1946) where the flood-plain deposits are similar, the annual recharge from precipitation is about 15 percent of the annual rainfall, or about 6 inches of water. Recharge from this source occurs mainly during the winter months when evaporation and transpiration by plants are at a minimum. Because of dependence on winter rainfall, recharge may vary much from year to year.

Rate of flow of water from the Ohio and Licking Rivers to the aquifer, or from the aquifer to the rivers, depends on the permeability of the deposits and differences in water levels. Where connection exists, river water enters the aquifer during floods and

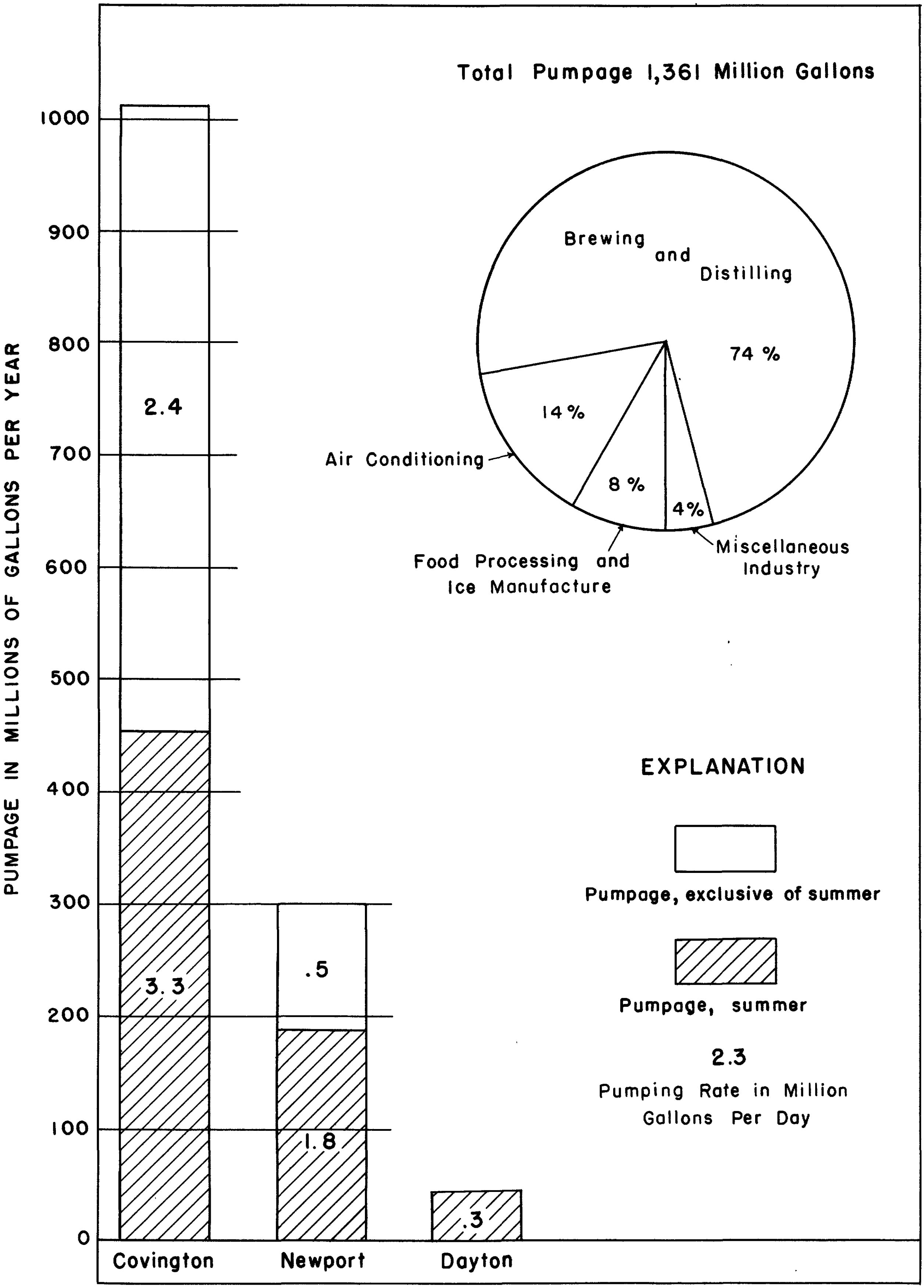

Figure 3.--Graphs showing yearly and seasonal pumpage, and distribution by use, of ground water in the Covington-Newport area, 1951.

returns to the river during low-water periods. Infiltration to the aquifer during low-river stages is presently developed at only a few places where pumping lowers the level of ground water below that of the river. Generally in the area there is loss of ground water to the rivers; this water, which can be salvaged by pumping, is available for future development.

The graphs in figure 4 present water-level fluctuations in two wells, the elevation of the Ohio River, and rainfall. The hydrograph of well 8430-3900-103, which is 8,500 feet south of the Ohio River, shows water-level fluctuations influenced little or not at all by river stage or by pumping. After commencement of the winter recharge to the soil and rock of the surrounding uplands and to the surface in the immediate vicinity, the water level rises slowly with a lag reaching into summer because of slow movement through the formations. Decline starts in late summer and continues until the effects of winter recharge are felt in January. Range of fluctuation recorded to date is barely more than 2 feet.

The occasional rapid but small fluctuations in the water level in this well correlate with changes in barometric pressure rather than with precipitation. In this well, as in various others in the area, the water first met in the sand and gravel rose in the hole because it was confined under pressure beneath the silt and clay; in other words, artesian conditions exist in parts of the area. Artesian wells act as barometers, for high barometric pressures force the water down the well, and low pressures during storms allow the water level to rise.

Water level in well 103 stands at an elevation of about 480 feet above sea level, in contrast with the normal low-water stage of about 442 feet of the Ohio and Licking Rivers. The gradient toward the Licking River, 2,500 feet away, is 15.2 feet per thousand feet; toward the Ohio River, 8,500 feet away, the gradient is 4.5 feet per thousand feet. The very steep gradient toward the Licking River indicates that permeability in that direction is extremely low.

The slope of the ground-water surface shows overall movement toward the rivers, and data from Louisville show the probability that the aquifer is recharged by downward percolation. Data on quality of the ground water confirm these ideas. Diagrams below section BB', plate 2, show the chemical character of water along the line of section; the height of the columns is a measure of the total dissolved solids. Water from wells near the valley walls resembles in quality that from rock wells to the south, but progressing toward the Ohio River the dissolved solids and hardness gradually decrease. This change is thought to be due to dilution by water from above as the whole body of water moves slowly riverward.

The observation well 8430-3905-15 is about 300 feet south of the Ohio River, and close to several wells that are pumped in summer. Water level during most of the year follows the rises and falls of the river. Pumping from early July to late September lowers the local ground-water level below river level. Study of the shape of the drawdown curve shows that connection exists between river and aquifer so that water moves from the river bed into the aquifer. The chemical data plotted on section BB', plate 2, give further evidence of the infiltration. Water from the nearby pumped well, 8430-3905-5, is lower in dissolved solids than any other water sampled in this area and closely resembles the water of the river, the near source.

The connection with the river is not as good as the geologic sections on plate 2 suggest. The length of time required for the recovery of water level after pumping shows that the rate of flow from the river source is slow. The exact cause of this slow rate of flow is not known. However, at many places along the Ohio River a blanket of clay or mud covers the bank and extends out over the river bed, partially sealing the river bed from the underlying coarse deposits. Within the coarse deposits of the aquifer occasional layers of silt or clay interfere with free vertical movement of water. As a result, the zone where recharge occurs may be a considerable distance from the well.

The following conclusions may be stated. A small part of the water comes from the valley wall; a larger part from downward seepage from the flood plain. When the Ohio River is at high stages, river water moves into the aquifer, and infiltration can be developed during low water by pumping of wells near the river. Over most of the area water moves toward the river and is diluted by recharge from precipitation on the surface, which lowers hardness and mineral content on the way. Water that enters the aquifer from the river, either naturally or induced by pumping, has the best quality.

Quality of Water

All natural waters contain mineral substances dissolved from the soil and rock with which the water has been in contact. Because ground water moves slowly through small subsurface openings it normally contains more dissolved solids than the stream water of the same region. During the course of rainless periods, ground-water seepage provides more and more of the low-water flow of streams, and at such times the quality of water in most streams approaches the quality of the regional ground water at shallow depths. Surface runoff due to rain intermittently dilutes stream waters to lower concentrations. The quality of the ground water here is fairly constant year after year, though at some places heavy pumpage causes changes in quality; quality of the surface water varies widely from high to low water.

Ground water has an advantage over most surface waters in that it is usually free of suspended material, such as clay and silt, which would have to be filtered from the water. Also, the uniform quality of ground water from a particular source permits simpler treatment for the reduction or removal of undesirable characteristics, particularly for small supplies. Usually ground water is less contaminated from waste materials and frequently can be obtained at the spot where needed. For these reasons ground water generally is used for small supplies. When available, ground water is used also for large supplies, but the cost of the treatment that may be necessary should be considered. One major disadvantage is that much ground water contains objectionable quantities of iron and/or manganese.

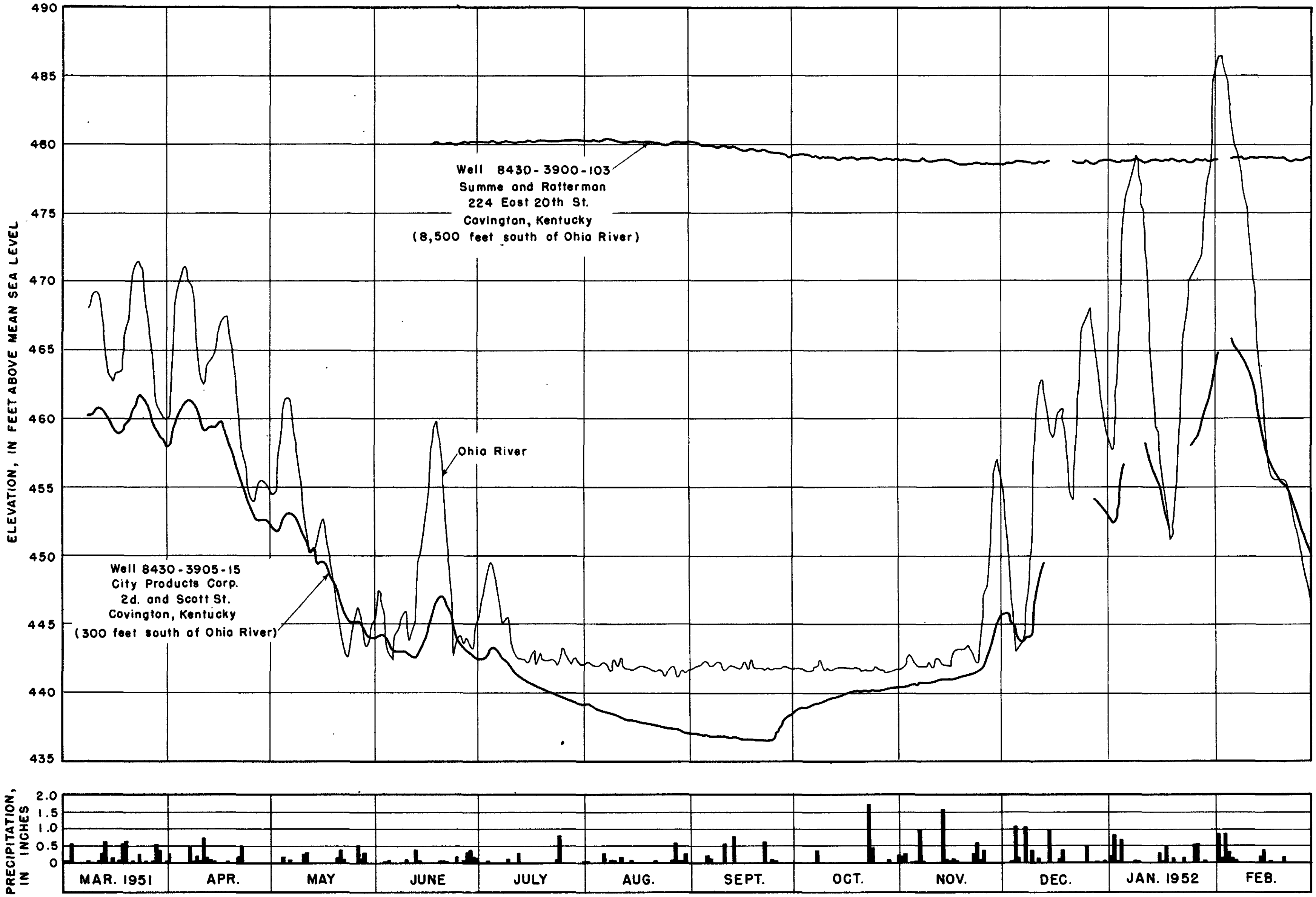

Figure 4.--Graphs showing fluctuation of water levels in two observation wells, Ohio River stage, and precipitation in the Covington-Newport area, 1951-52.

Table 4.--Chemical analyses of water from wells in the Covington-Newport alluvial area, Kentucky

Well number	Depth of well (feet)	Water-bearing formation	Date of collection	Temperature (°F)	pH	Specific conductance at 25°C (micromhos)	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrite (NO_2)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$	
																					Total	Noncarbonate
8425-3900-3	111	Alluvium	2- 4-52	56	7.3	836	15	8.6	0.15	124	27	19	0.7	456	41	33	0.2	-	5.6	516	420	47
43	250 (?)	Bedrock	2-11-52	68	7.4	988	16	4.4	.35	136	43	20	1.9	558	26	46	.3	-	26	602	515	59
73b	1,250	St. Peter sandstone	4- 8-07	-	-	-	14	.3	-	360	182	3,700		581	456	6,400	-	-	-	11,680	-	-
8425-3905-1	149	Alluvium	3-19-51	56	7.5	1,130	19	6.1	-	100	59	44	6.8	472	161	42	.1	.1	.3	666	492	105
2a	111	do.	2- 9-51	-	7.6	-	-	1.4	.5	146	44	-	-	528	172	46	-	-	-	-	540	-
4	125	do.	3- 7-51	59	7.3	1,030	17	.20	-	105	60	21	4.0	448	150	40	.1	.0	.5	667	507	142
5	90	do.	3- 7-51	59	7.4	1,060	14	.18	-	104	60	33	3.9	432	112	41	.3	.0	61	668	508	152
9a	125	do.	2- 9-51	-	7.5	-	-	3.6	.5	172	62	-	-	609	168	53	-	-	-	-	678	-
10a	125	do.	2- 9-51	-	7.4	-	-	2.0	trace	210	65	-	-	617	288	115	-	-	-	-	785	-
10	125	do.	2- 4-52	58	7.0	1,410	18	3.0	.96	204	58	45	4.0	570	258	79	.1	-	.7	1,003	750	280
11a	125	do.	3- 1-51	-	7.1	-	-	5.2	10-15	230	91	-	-	646	336	157	-	-	-	-	940	-
12a	125	do.	3- 1-51	-	7.0	-	-	5.6	.6	190	68	-	-	568	244	120	-	-	-	-	745	-
8430-3900-84	94.5	do.	1-20-50	56	-	1,740	-	5.0	-	-	-	-	-	683	288	104	-	-	2.2	-	862	-
95	135	do.	6-21-50	58	7.6	1,780	14	6.6	-	150	56	167		584	191	204	.3	-	1.2	1,080	604	126
96	90	do.	5-31-50	58	7.7	2,810	2.0	.25	-	47	30	527		580	11	630	3.9	-	.1	1,520	241	0
102	153	do.	8-29-51	58	7.3	1,790	18	11	.36	210	72	109	3.4	640	225	200	.1	-	1.6	1,188	820	296
8430-3905-1	115	do.	6-19-50	59	7.8	1,500	12	5.5	-	126	49	138		556	130	157	.5	-	1.6	880	516	60
5	84	do.	5-25-50	56	8.1	635	10	.59	-	68	20	32		246	37	56	.5	-	2.0	365	252	50
8	110	do.	6-20-50	58	7.3	1,640	14	1.5	-	172	54	116		558	190	162	.3	-	23	1,040	651	194
9	117	do.	6-21-50	57	7.6	643	11	1.6	-	80	19	33		276	69	35	.3	-	.4	383	278	52

Unless noted, analyses were made at U. S. Geological Survey regional laboratory at Columbus, Ohio.

a. Analyses made by Calgon, Inc., Pittsburgh, Pa., for George Wiedemann Brewing Co.

b. Sample contained 4 ppm aluminum. Palmer, Chase, 1909, Quality of the underground waters in the Blue Grass region, in Matson, G. C., Water resources of the Blue Grass region, Kentucky: U. S. Geol. Survey Water-Supply Paper 233, p. 212.

Table 5.--Summary of quality of water from wells and Ohio River in the Covington-Newport area, Kentucky [1/]

(Dissolved constituents given in parts per million.)

Constituent	Wells				Ohio River at Cincinnati Water Works		
	Maximum	Minimum	Average	Number of determinations used in average	Maximum concentration, November 1946	Minimum concentration, March 1935	Average for 1950
pH	8.1	7.0	7.4	18	-	-	-
Specific conductance at 25° C. (micromhos)	2,810	635	1,357	14	-	-	-
Silica (SiO_2)	18	2	13.9	14	-	-	-
Iron (Fe)	11	.18	3.6	20	0.01	0.02	0.01
Manganese (Mn)	.36	.15	.5	7	-	-	-
Calcium (Ca)	230	47	143	18	78.1	21.6	29.9
Magnesium (Mg)	91	19	52	18	17.2	1.4	6.0
Sodium (Na)	109	19	42	7	-	-	-
Potassium (K)	6.8	.7	3.5	7	-	-	-
Bicarbonate (HCO_3)	646	276	528	19	47.6	29.3	45.1
Sulfate (SO_4)	336	11	163	19	205.4	49.7	65.5
Chloride (Cl)	630	33	122	19	98	13.4	21
Fluoride (F)	3.9	.1	.5	13	-	-	-
Nitrite (NO_2)	.1	.0	.03	3	-	-	-
Nitrate (NO_3)	61	.1	9.0	14	-	-	-
Dissolved solids	1,520	365	814	13	553	123	191
Hardness as $CaCO_3$:							
Total	940	241	584	19	266	60	100
Noncarbonate	296	0	120	13	227	36	63

1/ Analysis of brine from St. Peter sandstone, well 8425-3900-73, is excluded from figures.

Ground water is insulated by the aquifer and maintains a relatively constant temperature, whereas stream temperature fluctuates from season to season. In this area the yearly temperature range of the Ohio River is from the freezing point to about 85°F., and the water in summer is too warm to be efficient as a cooling agent for some industrial processes. Scattered data show that the average temperature of local ground water from sand and gravel is about 56° to 58°F. as it comes from the wells.

Table 4 presents the analyses of water from the sampled wells shown by symbol on plate 1. Table 5 gives figures on the maximum, minimum, and average content of the various dissolved substances in the ground water and, for comparison, the water of the Ohio River. In these tables the dissolved substances are given in parts per million by weight. These figures can be converted to grains per gallon by multiplying by 0.0584. Analyses from six representative wells are presented graphically beneath section BB', plate 2.

The usual ionic constituents in natural waters are calcium, magnesium, sodium, potassium, bicarbonate (and a small amount of carbonate in some), sulfate, chloride, and nitrate. Small but significant quantities of fluoride also are present in some ground waters. The ions of calcium, magnesium, sodium, and potassium are called cations or metallic ions and sometimes are referred to, loosely, as "bases." Each of these cations possesses either one or two positive electrical charges. The acid ions, or anions, include bicarbonate, carbonate, sulfate, chloride, fluoride, and nitrate. These anions possess either one or two negative charges.

The cations and anions will combine to form chemical compounds such as sodium chloride which is common salt. However, in parts per million this combination does not take place unit for unit, for 22.997 parts per million of sodium will combine exactly with 35.457 parts per million of chloride. In order to express chemical combinations as well as to show water analyses graphically, the quantities may be expressed in chemical combining weights or equivalents per million. Parts per million may be converted to equivalents per million by dividing the parts per million by the reacting value of the constituent. Then, a unit equivalent of a cation such as sodium will combine exactly with a unit equivalent of a anion such as chloride to form a unit equivalent of the compound sodium chloride.

When parts per million are converted to equivalents per million, the sum of all the cations (bases) should equal the sum of all the anions (acid ions) within limits of practical analytical procedure, because these ions are in equilibrium and were dissolved from the rocks and soils in proportions as shown by the equivalents per million. Thus, in the bar diagrams on plate 2 the left-hand column of bases and the right-hand column of acids are the same height.

Hydrogen-ion concentration (pH) is an index of the acidity or alkalinity of water. A pH value higher than

7.0 indicates alkalinity; a value below 7.0 indicates acidity. Dissolved solids are the residue after evaporation of the water and consist mainly of dissolved mineral constituents, and some organic material and water of crystallization. When water is evaporated the bicarbonate is converted to carbonate with loss of carbon dioxide. Specific conductance is a measure of the ability of the water to conduct electric current and varies with the type and the quantity of the dissolved solids.

Silica (SiO_2) is released in small amounts to ground water by almost all types of rocks. It contributes to the formation of scale in pipes and boilers. Iron (Fe), when more than 0.3 part per million is present, stains laundry and utensils and makes the water objectionable for beverages, food processing, and ice making. On the average these waters have 3.6 parts per million of iron. Manganese (Mn), another element widely distributed in small amounts, is associated with iron and is objectionable for similar reasons. Calcium (Ca) and magnesium (Mg) are derived from limestones, calcareous rocks, and dolomite. These two elements are responsible for the hardness and scale-forming properties of these waters. Sodium (Na) and potassium (K) exist in all rocks, and deep bedrock water in this area is rich in these elements.

Bicarbonate (HCO_3) in combination with calcium and magnesium forms compounds that give the water a carbonate or temporary hardness that can be reduced by boiling, with, however, attendant precipitation of scale on utensils and pipes. Sulfate (SO_4) usually comes from certain minerals such as gypsum found sparingly in calcareous rocks. The wastes from industries using sulfur compounds, and water draining from coal-mining operations, may contribute large amounts of sulfate to surface and ground waters.

Chloride (Cl) is commonly associated with sodium as sodium chloride, common salt, a main constituent of the deep brines here. When present in larger-than-average quantities in the shallow waters, contamination from industrial brines or from sewage is suggested. Fluoride (F) is widely distributed but usually in minute amounts. When more than 1.5 parts per million is present in drinking water, the permanent teeth of young children may become mottled. On the other hand, many health authorities now believe that a smaller quantity than the above, up to 1.0 part per million, is beneficial in inhibiting decay of teeth. Nitrate (NO_3) is one of the end products of decay of organic matter and it may, though not necessarily, indicate contamination. If more than 10 parts per million is present, the possibility of pollution by industrial wastes or sewage should be examined, though the values for naturally occurring nitrate often exceed 10 parts per million. Studies show a relationship between high nitrate in drinking water and the disease called infant cyanosis ("blue babies") that occurs in babies up to about 5 months old. Waters having more than about 45 parts per million of nitrate (as NO_3) are currently considered by some authorities to be unsafe for baby feeding.

Hardness is the characteristic of water of particular interest to the average household consumer. The harder a water is, the more soap must be unprofitably consumed in neutralizing the hardness before a lather is produced. These waters, with an average hardness of 584 parts per million, rank as very hard.

Examination of the data, especially as simplified in the representative analyses on section BB', plate 2, shows these ground waters to be of the calcium and magnesium bicarbonate type, with considerable amounts of sodium, sulfate, and chloride. As a minor constituent, iron is present in objectionable amounts.

Though the relative proportions of the several dissolved substances vary little, the dissolved solids and hardness decrease from the valley wall toward the Ohio River. The explanation lies in the source and movement of water as described in a previous section. Most of the water in the alluvium at the edge of the valley has come from the bedrock of the valley wall, where it acquired high mineral content. During movement toward the river dilution occurs by water seeping down from the surface, and close to the river there is more dilution from infiltering river water.

The analyses of water from certain wells provide exceptions to the generalizations stated above. For example, well 8425-3900-3 lies in the valley of the Licking River and draws water from alluvium of a different nature than that of the Ohio valley, where most of the other sampled wells are located. A corresponding difference in quality might be expected. The analysis reveals higher proportions of calcium and bicarbonate, and lower proportions of sodium, sulfate, and chloride than the averages for wells in the Ohio valley. Dissolved solids and hardness are lower than the general average of all wells. Similar to the above is the analysis of the water from well 8425-3900-43, which as mentioned previously probably comes from the alluvium up the Licking valley.

The water from well 8430-3900-96 contains 1,520 parts per million of dissolved solids; the sum of sodium and potassium is 527 parts per million; and the value for chloride is 630 parts per million. These are the highest concentrations found in any well yielding water from the alluvium. The hardness of 241 parts per million and sulfate content of 11 parts per million are the lowest encountered. These considerable differences from the averages strongly suggest local pollution of the ground water from industrial waste.

The water that formerly flowed from the abandoned deep well to the St. Peter sandstone, number 8425-3900-73, is a sulfurous brine with 11,680 parts per million of dissolved solids. "Blue Lick" is the name applied to waters of this general type in northern Kentucky.

CONCLUSIONS

The data in this report reveal that beneath most of the alluvial area there is a ground-water reservoir of sand and gravel, as much as 80 feet thick in places but pinching out at the edge of the valley. The principal sources of the water are from vertical percolation, from the bed of the Ohio River, and from the valley wall.

In considering favorable sites for well locations, several factors should be considered. Near the valley wall the sand and gravel are thinner, finer in grain, and more apt to interfinger with lenses of silt and clay than elsewhere; moreover, the quality of the water there is poorest. Such a site is therefore unfavorable. If large quantities of water are required, wells should be located where the sand and gravel are thickest and coarsest and afford the most storage space. For best quality of water, favorable sites are near the bank of the river, where river water entering the sand and gravels dilutes the ground water to lower-than-average hardness and concentration. At such sites the temperature of the ground water is likely to reflect the changing temperature of the river water and to vary several degrees above and below 57°F., the approximate temperature of water from wells little affected by river infiltration.

With the data at hand no prediction can be made of the safe yield of the reservoir - a term here defined as the average amount that could be withdrawn each year, into the indefinite future, without progressive decrease of yield or significant deterioration of quality. A program to determine the safe yield would involve the drilling of numerous test holes to learn more about the texture and boundaries of the sand and gravel deposits, observation of water levels and collection of pumpage figures over several years, and pumping tests. From such data estimates could be made of the available storage space, potential rates of flow of water, efficiency of the connection between the river bed and reservoir, and changes in quality that would result from heavy pumping.

In spite of the lack of quantitative data it is considered that the ground-water reservoir is capable of furnishing considerably more water than is currently being withdrawn, especially if proper spacing between wells is maintained. If large installations are contemplated near the present sites of heavy pumping, or if yields larger than any obtained so far are desired, the sites should first be tested by means of borings and pumping tests designed to furnish information on storage, transmissibility rates of the sand and gravel, and distance to the source of water.

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