STATE OF OHIO
DEPARTMENT OF PUBLIC WORKS
OHIO WATER RESOURCES BOARD

THE WATER RESOURCES OF MONTGOMERY COUNTY, OHIO



BULLETIN 12
JUNE 1948

Prepared in cooperation with
U.S. Geological Survey


THE DAYTON AREA
OFFICIAL U.S.A.F. PHOTOGRAPH

Bulletin 12

OHIO WATER RESOURCES BOARD

Columbus, Ohio

THE WATER RESOURCES OF MONTGOMERY COUNTY, OHIO

By

Stanley E. Norris

With sections on
Climate and surface-water resources
By William P. Cross

and
Glacial geology
By Richard P. Goldthwait

****

Prepared in cooperation with
the U. S. Geological Survey

June 1948

THE
OHIO WATER RESOURCES BOARD

COLUMBUS, OHIO
1948

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LETTER OF TRANSMITTAL

June 1, 1948

Dean Charles E. MacQuigg, Chairman
Ohio Water Resources Board
Columbus, Ohio

Dear Sir:

Herewith is the manuscript detailing the results of our intensive investigation of the water resources of Montgomery County, which I am recommending for publication as Bulletin 12.

You will find this bulletin a comprehensive analysis of both surface and ground water resources of the county. Interpretations of the hydrology and geology of the area are especially complete.

It is believed that this bulletin will serve as a guide to the development and conservation of the water resources of Montgomery County for many years to come.

Respectfully submitted

C. V. Youngquist
Chief Engineer

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INTRODUCTION

PURPOSE AND SCOPE OF THE REPORT

This report, which summarizes the results of an investigation of the water resources of Montgomery County, Ohio, is intended to serve as a guide for the development of farm, public, and industrial water supplies in Montgomery County.

More ground water is used in Montgomery County than in any other county of the State. Over 90,000,000 gallons per day is pumped, chiefly by the City of Dayton and its industries. This may be compared with an average daily consumption of about 500,000,000 gallons for the entire State. The continued growth in industry and population which seems assured for this county makes important a detailed knowledge of the hydrology and the geology of the area. Field investigations of the ground-water resources were made throughout 1946 and 1947 to determine the availability and the quality of the ground water, to study water-level trends, and to gather information on the geologic and ground-water conditions of the county. Records of stream flow have been obtained in Montgomery County on a continuing basis since 1913. The surface-water section of this report is the result of studies and analyses of these records.

DIVISION OF WORK AND ACKNOWLEDGMENTS

The collection and interpretation of most of the basic data of this report was by Stanley E. Norris, Geologist, U. S. Geological Survey, who is the principal author. The interpretation of the surface glacial deposits was made by Dr. Richard P. Goldthwait, Associate Professor of Geology, Ohio State University, who prepared the map of the unconsolidated deposits. (plate 2) The sections of the report on climate and surface-water resources were written in the fall of 1947 by William P. Cross, Hydraulic Engineer, U. S. Geological Survey, from records and data collected by the Surface Water Division of the U. S. Geological Survey.

Special thanks are given to W. W. Morehouse, Director of the Dayton Water Department, for providing office space and facilities for personnel working on this investigation. The writers are also indebted to the residents of Montgomery County who permitted measurements to be made in their wells, and to the officials of the many industries who gave valuable information about their wells and water supplies. Thanks are given the well drillers of the county, especially Donald J. Roe, Ira Barnes and Sons, J. D. Flory, Albert Boone, Earl Hollingsworth, J. J. Albers, D. S. and L. J. Williams,

R. R. Andrews, Edward Sullivan, M. C. Shank, W. O. Stout, Curtis and Cecil Conway, Cecil Glaser, Ray Martin, J. D. Phillips, and others who furnished logs or well data.

This report was prepared as part of a cooperative program of investigation of the water resources of Ohio by the Ohio Water Resources Board and the U. S. Geological Survey. The Ohio Water Resources Board is represented in the investigation by C. V. Youngquist, Chief Engineer, and R. J. Bernhagen, Chief Geologist. The Ground Water Division, U. S. Geological Survey, is represented in the investigation by E. J. Schaefer, District Engineer, working under the general supervision of A. N. Sayre, Geologist in Charge. The data on field tests of farm wells were worked up by D. W. Van Tuyl, Hydraulic Engineer, U. S. Geological Survey. The surface-water section of the report was prepared from records collected by the Division of Surface Water, U. S. Geological Survey, represented by O. H. Jeffers, Acting District Engineer, working under the general supervision of J. V. B. Wells, Chief.

The chemical analyses of samples of ground and surface water were furnished by W. F. White, District Chemist, and S. K. Love, Chief, Quality of Water Division, U. S. Geological Survey. C. V. Youngquist assisted the authors in the preparation of the chapter on the chemical quality of the water.

Acknowledgments are also due John C. Krolczyk and Evelyn Wheaton, of the Ohio Water Resources Board, for preparing the illustrations contained in this report.

PREVIOUS WORK AND SOURCES OF INFORMATION

The earliest report on the ground-water resources of Montgomery County was prepared by M. L. Fuller and F. G. Clapp of the U. S. Geological Survey, and appeared in 1912 as part of Water-Supply Paper 259. (1)*

The Works Progress Administration, in the latter part of 1933 and continuing into 1934, conducted a State-wide inventory of rural wells. In Montgomery County the survey was only partially completed, eight townships having been covered to varying degrees of thoroughness. In the survey an attempt was made to obtain information on the depth of wells, water levels, and the character of the water-bearing formations. These data are in the files of the Geology Department of Ohio State University.

*Numbers in parentheses refer to publications listed in the bibliography at the end of the text of the report.

The Ohio Geological Survey in 1944 published Bulletin 44, "Geology of Water in Ohio," by Dr. Wilber Stout and others (2). This is a general treatise on the ground-water resources of the State and contains a chapter on Montgomery County.

The Ohio Water Resources Board in the fall of 1944 conducted a survey to determine the amount of water used by the industries and the municipal water systems within the county, and these data are currently on file. In 1945 the Board published Bulletin 1, "Well Logs of Montgomery County" (3). This publication (now out of print) contains detailed records of over 100 wells, located mostly in the Dayton area. Most of these well logs, together with additional logs collected in the present investigation, are shown in graphic form in the appendix of this report. (See plates 48 to 51)

A report (4) prepared by the engineering firm of Metcalf and Eddy of Boston, Mass., and published in 1924, contains information on the quality of the ground water and the yield of wells in the Mad River area, northeast of Dayton.

References to the ground-water resources of the county have also been made in reports dealing primarily with the geology. The most important of these studies is Professor Foerste's, "Geology of Dayton and vicinity" (5), published in 1915.

The earliest records of ground-water levels in the county available for this study are those collected since 1933 by the National Cash Register Co. of Dayton. The U. S. Geological Survey began measuring water levels in wells in this area in 1942, the records being published annually in a series of water-supply papers (6) (7) entitled "Water levels and artesian pressure in observation wells in the United States."

Stream gaging on a continuing basis was begun in the Miami River Basin after 1913, and a few fragmentary records were obtained prior to this date. A few measurements of stream flow were made in 1824, and also in 1839, and these are discussed in the section on surface water. Since 1918 the Miami Conservancy District has carried on stream gaging on a continuing basis, since 1921 in cooperation with the U. S. Geological Survey. The stream-flow records are published in water-supply papers of the U. S. Geological Survey. All the stream-flow records for Ohio have been compiled by the Ohio Water Resources Board in cooperation with the U. S. Geological Survey and published by the Ohio State University Engineering Experiment Station (8).

Considerable information has been published on the flood of 1913. The U. S. Geological Survey published Water-Supply Paper 334 (9), and later the Miami Conservancy District prepared a report on this subject (10).

Among the major achievements of the Miami Conservancy District are the technical reports prepared by the engineering staff (11). These reports cover the technical phases of their project, and not only add much to the knowledge of the climate and hydrology of the Miami Valley, but also are important contributions to the sciences of hydraulics and flood control.

WORK PERFORMED IN THE PRESENT INVESTIGATION

The investigation on which this report is mainly based was begun in January 1946, when a field office of the U. S. Geological Survey and the Ohio Water Resources Board was established in Dayton. A well survey was conducted over the entire county during the summer months of 1946 by the writer, assisted by Alan W. Dailey of the Ohio Water Resources Board. Field measurements were made in more than 500 drilled wells to obtain data for the construction of a contour map (pl. 1) of the bedrock surface. Water-level measurements were also made in these wells and are shown on the map.

The consolidated formations underlying Montgomery County are dense, and because of this the casing in drilled wells can ordinarily be driven only to the top of the bedrock. In wells that are drilled into the rock, therefore, the length of casing usually can be taken as the depth to the rock surface. In wells where the length of casing is the same as the total depth of the well it may be assumed that the well finished in unconsolidated formations, bedrock not having been reached, or having just been reached. In the field survey these assumptions were used as a basis for acquiring the data for the bedrock contour map. Determination of the length of casing in wells was made with the aid of an electrical device invented by S. E. Norris. As a result of the survey, the configuration of the bedrock surface and the former drainage systems are known with a greater degree of accuracy than for any other comparable area of the State.

In addition to the casing length and the total depth of the well, the distance to the water surface was also measured. All measurements were calculated from the ground surface at the well. The field data were compiled on the standard U. S. Geological Survey topographic maps that make up the base maps of this report. Elevations of the bedrock surface were computed by subtracting the depth to bedrock from the elevation of the ground surface as determined from the map contours.

After completion of the main part of the bedrock survey, Dr. Goldthwait, assisted by the writer, spent several weeks in the field studying and mapping the glacial deposits.

A survey was then made, chiefly in the winter of 1946, of the principal industrial water users in the Dayton area. Information was obtained on depths of wells, amounts of water used, quality of water, character of the geologic formations and water-level fluctuations. Approximately 100 companies were contacted and information was obtained on more than 250 wells. This survey was then extended to include the industries and the municipal water systems of the other municipalities of the county.

Much information was obtained on the quality of the ground water during the course of the industrial-well survey. Many of the industries, as well as the municipalities, had records of chemical and bacteriological analyses of their water. More than 100 records of chemical analyses were obtained from these and other sources. Chemical analyses of the water from 15 representative wells distributed over the county were made by the Quality of Water Division of the U. S. Geological Survey in the spring of 1947. These complete analyses form the main basis for the conclusions reached in the section of this report on the quality of water in the county.

Field pumping tests were performed in the spring of 1947 on more than 30 upland farm wells in the county, chosen as representative of wells in various aquifers. The wells were pumped, usually by hand, and the drawdown and recovery rates were measured. From these data the transmissibilities of the formations and the specific capacities of the wells were determined. The information is discussed in the section on ground-water hydrology. This work, as well as most other phases of the present investigation, was done with the assistance of W. H. Nicholson, Jr., Engineering Aide of the U. S. Geological Survey.

Several more observation wells were established over the county in the course of this investigation, bringing the total of such wells to 50. Of these wells, 10 have been equipped with automatic water-stage recorders from which have been obtained continuous records of the water-level fluctuations. Three wells are equipped with tape and float gages, which are read weekly by local observers. Water levels in the remaining wells have been measured with a steel tape at intervals usually no longer than one week apart. A complete list of the observation wells in Montgomery County, together with their periods of record and other data, is given in table 1. The locations of the observation wells are shown on plates 4 and 21.

Throughout the course of this investigation local well drillers have been interviewed for information. They have furnished nearly 600 well logs which, along with most of those first published by the Ohio Water Resources Board in Bulletin 1, are to be found in graphic form in the appendix of this report. (See pls. 48 to 51)

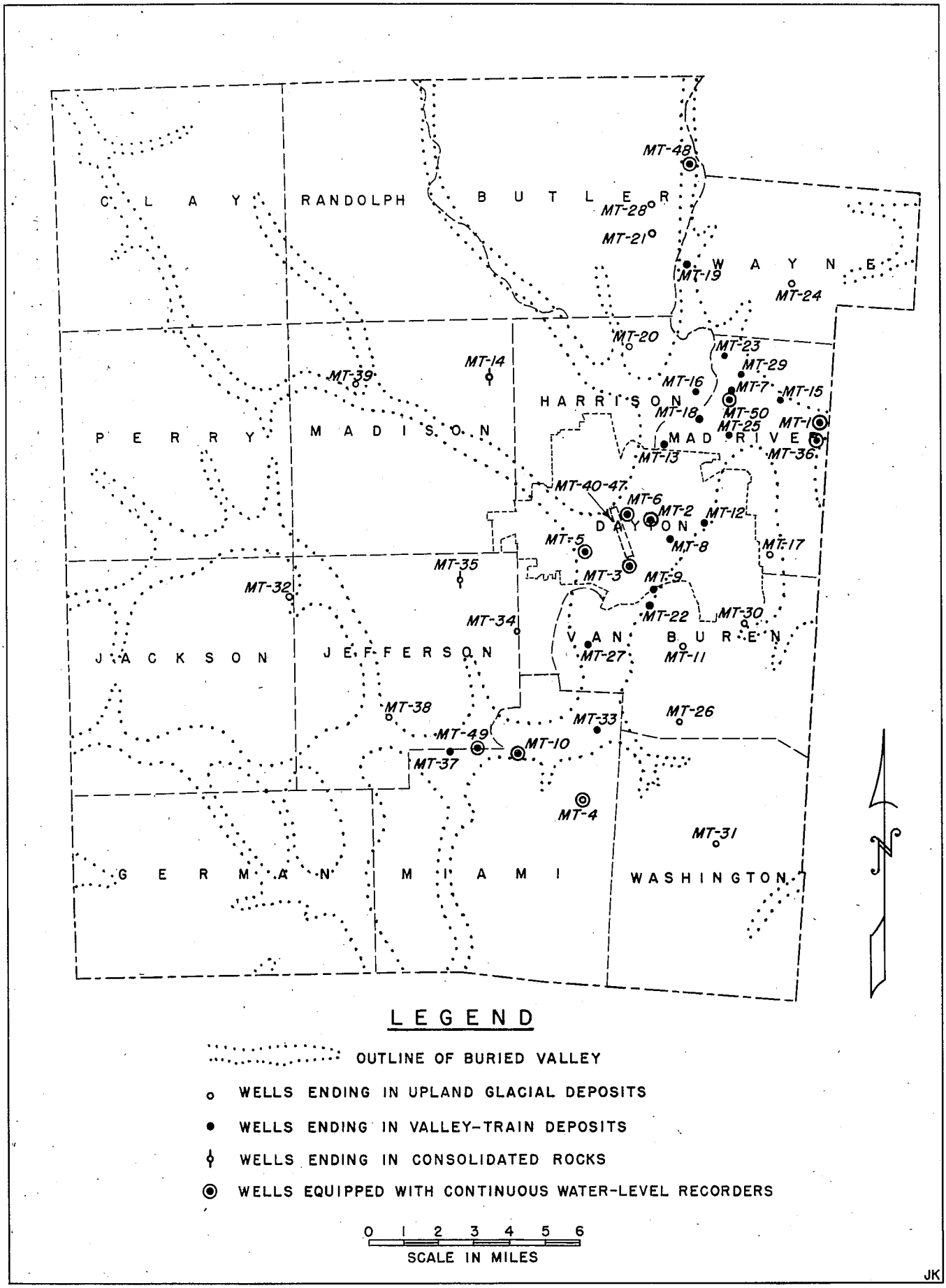


Plate 4. Map showing observation wells in Montgomery County, Ohio.

Table 1

Data on observation wells in Montgomery County

Well No.	Well owner	Location of well	Depth of well (feet)	Log No.	Type and period of record	Source of water	Highest water level: Date	Highest water level: Depth to water (feet)	Lowest water level: Date	Lowest water level: Depth to water (feet)	Remarks
Mt-1	City of Dayton	Mad River Twp., Sec. 18	57	209	Continuous - 3/ 6/42 to present	Valley train	----------	22	----------	3	Artificial recharge to aquifer
Mt-2	Dayton Power and Light Co.	Dayton, 118 E. 4th St.	52		Continuous - 5/27/42 to present	do.	March 1943	30	August 1944	21	Hydrograph of Mt-1 and Mt-2, Plate 24
Mt-3	Ohio Dept. of Highways	Dayton, Stewart St. and Patterson Blvd.	50	627	Weekly and continuous- 5/ 9/45 to present	do.	June 1947	45	December 1946	35	Hydrograph on Plate 23
Mt-4	Dayton Powder Plant	Miami Twp., Sec. 8	48		Continuous - 2/14/46 to 8/20/47	Upland gl. drift	----------	2	----------	1	
Mt-5	Kuhns Bros. Co.	Dayton, 1800 McCall St.	156		Continuous - 2/19/46 to present	Valley train	June 1947	41	December 1946	35	W/L fluctuates in response to passing freight trains. Hydro. Plate 23.
Mt-6	City of Dayton	Dayton, Third and Ludlow Sts.	60		Weekly and continuous - 2/ 5/46 to present	do.	March 1946	33	August 1946	26	
Mt-7	Mrs. Augusta Rich	Mad River Twp., SW ¼ sec. 25	59		Weekly - 2/ 5/46 to present	do.	June 1947	37	December 1946	30	
Mt-8	Advance Laundry	Dayton, 805 Quitman St.	32		Weekly - 2/ 6/46 to present	do.	January 1947	25	June 1947	21	
Mt-9	City of Oakwood	Dayton, Springhouse Rd. and Far Hills Ave.	69		Weekly - 2/ 6/46 to 7/30/47	do.	----------	43	----------	35	
Mt-10	West Carrollton Parchment Co.	Miami Twp., Sec. 21	120		Continuous - 9/25/47 to present	do.					
Mt-11	H. C. Huber	Van Buren Twp., Sec. 35	125		Weekly - 2/20/46 to 7/30/47	Upland gl. drift	----------	55	----------	53	
Mt-12	Hewitt Soap Co.	Dayton, 333 Linden St.	65		Weekly - 2/ 8/46 to 7/30/47	Valley train	July 1947	22	December 1946	16	
Mt-13	Northridge Ice Station	Mad River Twp., Sec. 5	about 50		Weekly - 2/ 5/46 to 8/ 6/47	do.	June 1947	12	November 1946	6	
Mt-14	Turner Quality Cleaners	Madison Twp., Sec. 12	68		Weekly - 2/20/46 to 7/30/47	Ordovician shale	April 1947	14	October 1946	8	Hydrograph on Plate 21
Mt-15	Geo. Boedeker	Mad River Twp., SE ¼ sec. 19	30		Weekly - 2/27/46 to 8/ 6/47	Valley train	June 1947	27	November 1946	18	
Mt-16	Leo Handwerker	Harrison Twp., SE ¼ sec. 11	25		Weekly - 3/13/46 to present	do.	June 1947	22	November 1946	15	
Mt-17	R. Kelley	Mad River Twp., Sec. 21	about 50		Weekly - 2/27/46 to 7/30/47	Upland gl.drift	June 1947	22	November 1946	13	Hydrograph on Plate 21
Mt-18	Walter Martin	Mad River Twp., SW ¼ sec. 36	54		Weekly - 3/ 6/46 to 10/9/46	Valley train	March 1946	20	October 1946	16	
Mt-19	----------	Butler Twp., Sec. 26	22		Weekly - 3/20/46 to 8/26/46	do.	March 1946	14	August 1946	11	
Mt-20	Ford Service Garage	Harrison Twp., E ½ sec. 4	about 60		Weekly - 3/ 6/46 to 8/ 6/47	Upland gl. drift	April 1947	30	November 1946	21	
Mt-21	Mr. Flatter	Butler Twp., W ½ sec. 27	23		Weekly - 3/ 6/46 to 9/27/46	do.	June 1946	Dry	September 1946	2	
Mt-22	C. F. Weckesser	Dayton, 635 W. Schantz Ave.	40		Weekly - 3/ 6/46 to 4/ 1/47	Valley train	----------	3	----------	4	
Mt-23	R. H. Hamiel	Mad River Twp., W ½ sec. 26	27		Weekly - 3/13/46 to 8/ 6/47	do.	June 1947	22	September 1946	10	
Mt-24	M. E. Lehman	Wayne Twp., Sec. 22	27		Weekly - 3/13/46 to 8/ 6/47	Upland gl. drift	June 1947	24	December 1946	10	
Mt-25	Jameson Electronic Labs	Mad River Twp., SW ¼ sec. 30	18		Weekly - 3/27/46 to 10/30/46	Valley train	----------	13	----------	8	Well in bottom of old gravel pit
Mt-26	John Colvard	Van Buren Twp., Sec. 34	37		Weekly - 3/20/46 to 4/ 2/47	Upland gl. drift	----------	33	----------	32	w/l held constant by spring and overflow
Mt-27	City of Dayton	Van Buren Twp., Sec. 18	33		Weekly - 3/20/46 to 7/30/47	Valley train	June 1947	16	December 1946	8	
Mt-28	Weston Auflerbach	Butler Twp., SE ¼ sec. 22	38		Weekly - 3/27/46 to 8/ 6/47	Upland gl. drift	February 1947	9	October 1946	5	
Mt-29	John Metzler	Mad River Twp., NE ¼ sec. 25	65		Weekly - 3/27/46 to 6/19/46	Valley train	----------	50	----------	49	
Mt-30	Henry Saunders	Van Buren Twp., E ½ sec. 25	55		Weekly - 3/27/46 to 7/30/47	Upland gl. drift	June 1947	25	December 1946	15	
Mt-31	H. R. Von Nieda	Washington Twp., N ½ sec. 25	13		Weekly - 3/27/46 to 7/30/47	do.	April 1947	12	December 1946	3	
Mt-32	Mr. Furguson	Jackson Twp., NE ¼ sec. 12	24		Weekly - 4/10/46 to 7/30/47	do.	June 1947	20	November 1946	8	Hydrograph on Plate 21
Mt-33	Mr. Hochwalt	Miami Twp., NE ¼ sec. 15	33		Weekly - 4/ 3/46 to 7/30/47	Valley train	June 1947	19	November 1946	11	
Mt-34	J. R. Baker	Jefferson Twp., NE ¼ sec. 13	27		Weekly - 4/ 3/46 to 4/ 2/47	Upland gl. drift	January 1947	7	October 1946	1	Well receives water from nearby spring flow.
Mt-35	Montgomery Co. Infirmary	Jefferson Twp., Sec. 2	37		Weekly - 4/ 3/46 to present	Ordovician shale	July 1947	13	October 1946	8	Hydrograph on plate 21
Mt-36	Wright Field AAF	Mad River Twp., Sec. 18	31	106	Continuous - 3/29/46 to present	Valley train	June 1947	22	April 1947	12	
Mt-37	E. Hartzell	Miami Twp., NW ¼ sec. 35	23		Weekly - 4/10/46 to 6/26/47	do.	June 1947	24	December 1946	16	
Mt-38	R. D. Gebhart	Jefferson Twp., N ½ sec. 28	23		Weekly - 4/10/46 to 5/28/47	Upland gl. drift	May 1947	9	December 1946	4	
Mt-39	----------	Madison Twp., SE ¼ sec. 8	52		Weekly - 4/24/46 to 7/10/46	Upland gl. drift	----------	36	----------	35	
Mt-40	Ohio Dept. of Highways, Well No. 2	Approx. 1200' N. of Mt-3 along River	37	628	Daily - Mar. '45 to Sept. '47	Valley train	June 1947	34	April 1945	26	
Mt-41	Ohio Dept. of Highways, Well No. 3	Approx. 1000' N. of Mt-40 along River	40	629	Daily - do.	do.	June 1947	32	December 1946	19	
Mt-42	Ohio Dept. of Highways, Well No. 4	Washington St. and Miami Blvd.	40	630	Daily - do.	do.	June 1947	33	November 1946	20	
Mt-43	Ohio Dept. of Highways, Well No. 5	Approx. 600' N. of Mt-42 at RR Bridge	40	631	Daily - do.	do.	June 1947	38	November 1946	23	
Mt-44	Ohio Dept. of Highways, Well No. 6	4th St. and Rob't. Blvd.	40	632	Daily - do.	do.	June 1947	26	October 1946	12	
Mt-45	Ohio Dept. of Highways, Well No. 7	2nd St. and Rob't. Blvd.	39	633	Daily - do.	do.	June 1947	28	December 1946	14	
Mt-46	Ohio Dept. of Highways, Well No. 8	Monument Ave. and Rob't Blvd.	39	634	Daily - do.	do.	June 1947	27	October 1946	17	Hydrograph on Plate 23
Mt-47	Ohio Dept. of Highways, Well No. 9	Opposite Stout St. and Patterson Blvd.	51	635	Daily - do.	do.	June 1947	32	December 1946	23	
Mt-48	Village of Vandalia	Butler Twp., Sec. 14	about 50		Continuous - July '44 to Sept. '47	do.					
Mt-49	Ohio Water Resources Bd.	Jefferson Twp., SE ¼ sec. 26	220	639	Continuous - 11/14/47 to present	do.	----------	20	----------	17	
Mt-50	Hugo Thompson	Mad River Twp., SW ¼ sec. 25	35		Continuous - 5/27/47 to present	do.	June 1947	31	October 1947	25	

GEOGRAPHY

LOCATION AND SIZE OF AREA

Montgomery County is in southwestern Ohio. Dayton, the county seat, is about 65 miles southwest of Columbus and 50 miles northeast of Cincinnati. Montgomery County is 36th in size of the 88 counties of the State, having an area of 455 square miles and containing 14 townships. It extends about 25 miles north and south and 20 miles east and west. On the topographic maps of the U. S. Geological Survey Montgomery County occupies parts of four quadrangles, namely, Brookville, Dayton, Miamisburg, and Waynesville. The location of Montgomery County with respect to adjoining counties is shown on plate 3.

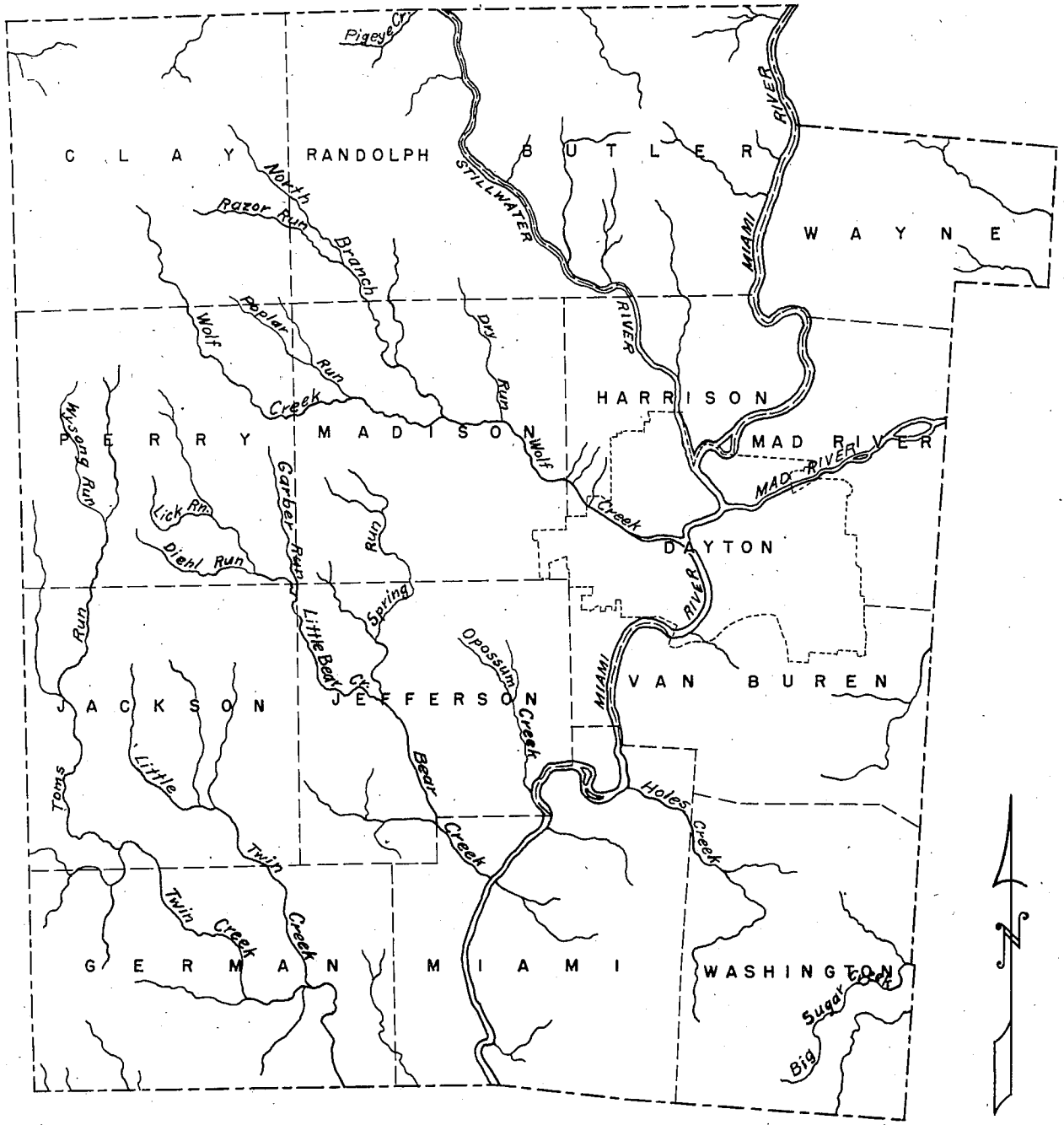
TOPOGRAPHY AND DRAINAGE

Montgomery County lies within the Till Plains section of the Central Lowland physiographic province. The northern and western parts of the county are characterized by flat till-plain topography, dissected by four main valleys which converge from the north to form the lowland area occupied by the city of Dayton. From Dayton the main valley continues its southerly course out of the county. Elevations on the divides generally exceed 1,000 feet above sea level, and the highest point in the county is about 1,100 feet, in the southeast part of the county in section 28 of Van Buren Township. The lowest point in the county is about 680 feet, along the Miami River near Chatauqua.

Montgomery County is almost entirely within the Miami River Basin, except for the southeast corner which drains into the Little Miami River. The Miami River, the fourth largest river in Ohio, drains an area of 2,595 square miles above Dayton. Three Miami River tributaries, the Mad River, Stillwater River, and Wolf Creek, converge fanwise from the north to join the master stream at Dayton. Twin Creek, which drains the southwestern part of the county, flows into the Miami River about 3 miles south of the county line. The present drainage system of the county is shown on plate 5, and the drainage area of the entire Miami River basin above Hamilton, in Butler County, is shown on plate 24.

CLIMATE

Ohio has a humid climate with normally abundant precipitation, well-distributed over the year. Summer temperatures are fairly high and winter temperatures are not severe. Droughts and destructive storms occur infrequently.



PRESENT DRAINAGE PATTERN

MONTGOMERY COUNTY

0 1 2 3 4 5 6

SCALE IN MILES

JK

Plate 5.

Table 2

Index of climatological records, Montgomery County

Station No.	Station	Location Lat.	Location Long.	Elevation (ft. above sea level)	Period and type of record
1	Dayton-Cooper Seminary	39°46'	84°12'	740	Precipitation and temperature Oct. 1844-July 1850; Jan.-Oct. 1856; May-Nov. 1858; Feb.-Mar. 1873; temperature only May 1855-Jan. 1856
2	Dayton-Cooperative (Boyer)	39°44'	84°09'	960	Precipitation and temperature Nov. 1882-Sept. 1886
3	Dayton-Cooperative (Boyer)	39°44'	84°09'	790	Precipitation and temperature Oct. 1886-Jan. 1924
4	Dayton-Weather Bureau	39°46'	84°10'	899	Weather Bureau Station - Aug. 1911-June 1933
5	Dayton-River Station	39°46'	84°12'	790	Precipitation May 1893-Dec. 1910
6	Dayton-Weather Bureau	39°46'	84°12'	771	Weather Bureau Station Jan. 1935-Mar. 1943. Elev. 741 after Jan. 1936
7	Dayton-Miami Conservancy District	39°46'	84°10'	899	Precipitation and temperature July 1933-Dec. 1935. Same as station 4
8	Dayton-Miami Conservancy District	39°45'	84°10'	745	Precipitation and temperature Jan. 1936
9	Dayton-Airport (Vandalia)	39°54'	84°12'	1000	Weather Bureau station Dec. 1943 to date
10	Germantown	39°38'	84°21'	814	Precipitation and temperature Dec. 1850-Jan. 1857; April 1914 to date
11	Miamisburg	39°38'	84°18'	678	Precipitation Sept. 1923 to date
12	Tadmor	39°54'	84°10'	780	Precipitation Jan. 1914-May 1920
13	Germantown Dam (MCD)*	39°38'	84°24'		Precipitation Mar. 1919 to date
14	Englewood Dam (MCD)				Precipitation Oct. 1919 to date
15	Taylorsville Dam (MCD)				Precipitation May 1918 to date
16	Sulphur Grove (MCD)	39°52'	84°06'		Precipitation Oct. 1940 to date
17	Maplewood (MCD)				Precipitation Aug. 1935 to date
18	Dayton (Kipling Drive, MCD)				Precipitation Oct. 1943 to date
19	Dayton (Kipling Drive, MCD)				Precipitation July 1941 to date

*Miami Conservancy District

The climate of Montgomery County is near the average for the State. The average annual temperature both at Dayton and at Germantown is 52.8° F. The range of daily temperatures averages 18°, and the extreme range for the period of record is 120° F., from -15° to 105° F. The average annual precipitation at Dayton is 37.72 inches. The average length of the growing season in Montgomery County is 189 days. The average date of the last killing frost in the spring is April 19, and that of the first killing frost in the fall is October 25.

The climatic data in this section are taken from the records of the U. S. Weather Bureau. The hydrologic year, October 1 to September 30, is used in tabulations to avoid splitting the snow season, and because October is the month of lowest average precipitation and stream flow. Storage in a stream basin is usually near a minimum at the end of the hydrologic year. Collection of climatological data in Montgomery County began in 1844; the names of the stations and the periods of record are given in table 2. All other climatological data in tabular form in this report are given in the appendix, in tables 23 to 31.

Precipitation

The record obtained from the rain gage established at Dayton in 1844 was intermittent until 1883. The short record obtained in the 1840's shows much more precipitation than has occurred in the 1940's, but the record is too short to be very conclusive. The monthly and annual precipitation records for Dayton, Dayton Airport (Vandalia), and Germantown are given in table 23 in the appendix. The annual precipitation at Dayton and Germantown is plotted on plate 6. A 10-year moving average is plotted on each of these diagrams to show the trends. Although these diagrams show that there have been periods of wet and dry years, no significant trends or cycles are evident. The driest year was 1895, but 1896 was abnormally wet. It would appear that the average precipitation is not changing appreciably, and that droughts and floods are no more or less frequent now than during the past 60 years. The average and the extremes of monthly rainfall at Dayton are given on plate 7, which shows that the rainfall is well-distributed over the year. The isohyetal map, plate 8, of the Miami River basin above Hamilton for the 25-year period 1921-45, indicates that the range of average annual precipitation in Montgomery County is from less than 37 inches to more than 40 inches. The range for the entire drainage basin is from 35 to 42 inches. The variations from the average monthly and annual rainfall at Dayton are shown in table 24, for the period 1921-45. This record shows that, although the mean for the period is 37.17 inches, 25 percent of the years had less than 31.26 inches and 25 percent of the years had more than 41.40 inches of precipitation.

Snowfall - The monthly and annual snowfall records at Dayton are given in table 25. It is evident that appreciably more snowfall occurred in the years before 1920 than in the years since, although part of the increase in the measured snowfall may be due to the fact that the collecting gage has been sheltered by new buildings in recent years. The Germantown record is too fragmentary to be used in comparison, and the Dayton Airport record is too short.

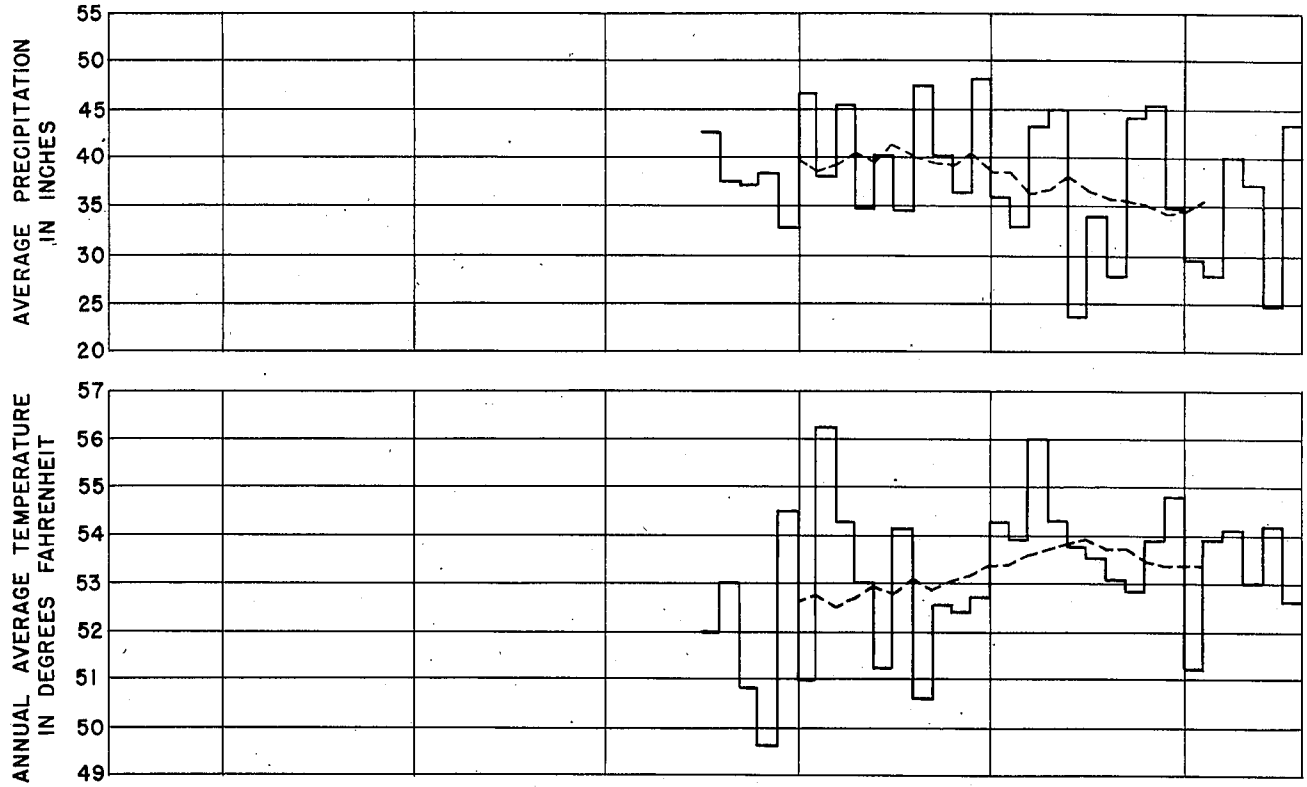
Snowfall is not generally a significant hydrologic factor in Ohio because it is usually small in quantity and stays on the ground for only a short time. Periods of below-freezing temperatures occur frequently but are usually of short duration.

Temperature

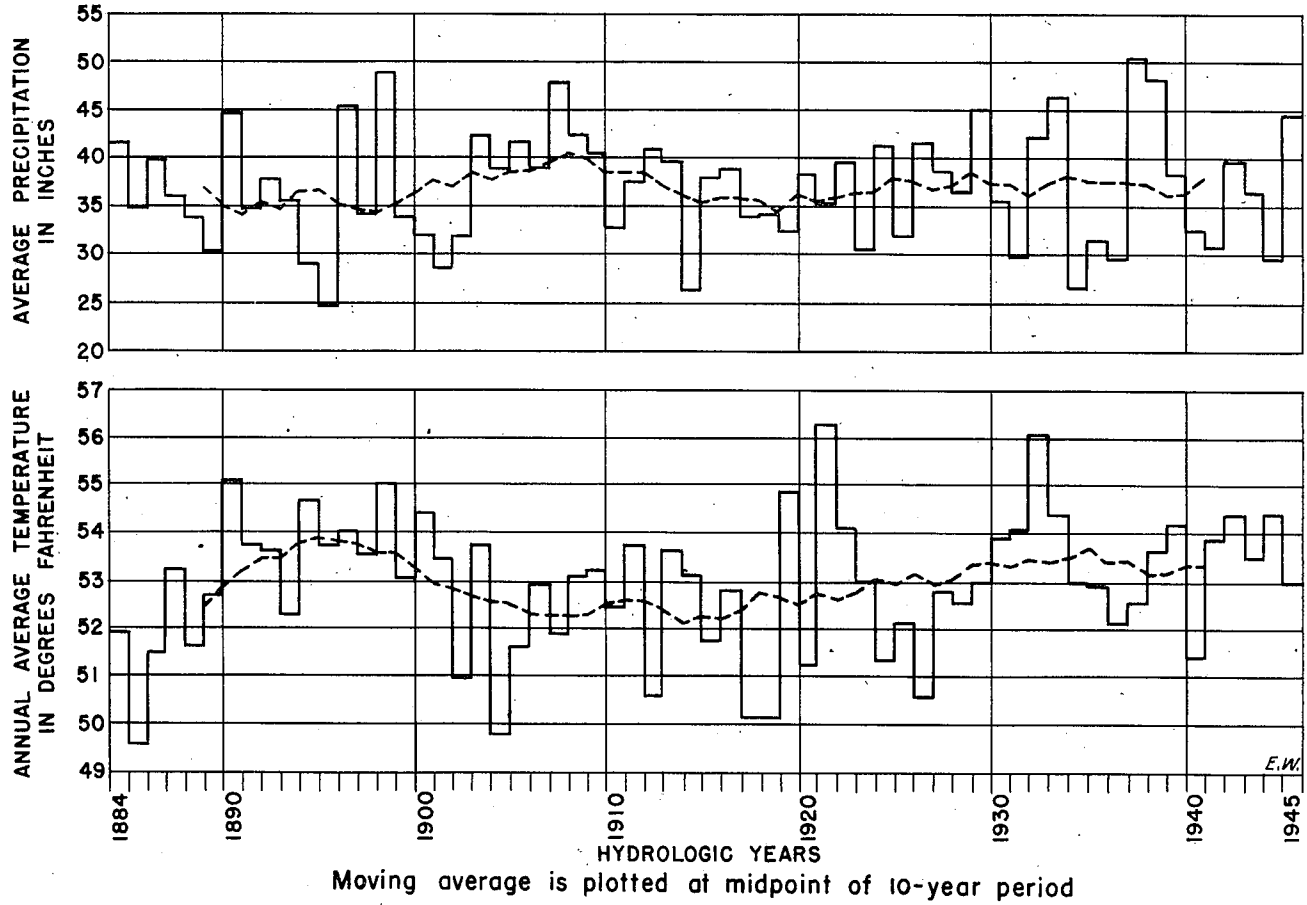
The monthly and annual temperature records for Dayton, Dayton Airport, and Germantown are given in table 26. The average monthly and annual temperatures at Dayton are given in table 27 and the annual averages as well as those for Germantown are plotted on plate 6. The monthly average and extreme temperatures at Dayton are plotted on plate 9. The 10-year moving averages of temperatures show periods above and below average, as do the precipitation records, but there appears to be no significant trend. Temperatures in the 1880's, for example, were below normal but in the 1890's they were above. It is often stated that temperatures prior to World War I were generally lower than in recent years. From the Dayton and Germantown records there may be some slight basis for such a conclusion, but the average temperatures have changed but slightly. The records are not long enough to allow positive conclusions to be drawn, and in the case of the Dayton station it is possible that the average temperatures are higher than they would be if the weather instruments were not sheltered by buildings. There appears to be little evidence of a changing climate. The isothermal map, plate 10, of the Miami River drainage basin above Hamilton indicates that the average temperature for Montgomery County for the period 1921-45 was about 53°F.

Wind velocity, humidity, and sunshine

The average monthly wind velocities at Dayton are tabulated in table 28, and the mean relative humidity, in percentage, is given in table 29. The humidities are rather high, but typical of Ohio's climate. The percentage of possible sunshine is listed for Dayton in table 30. All these tables are from available records collected since October 1920.

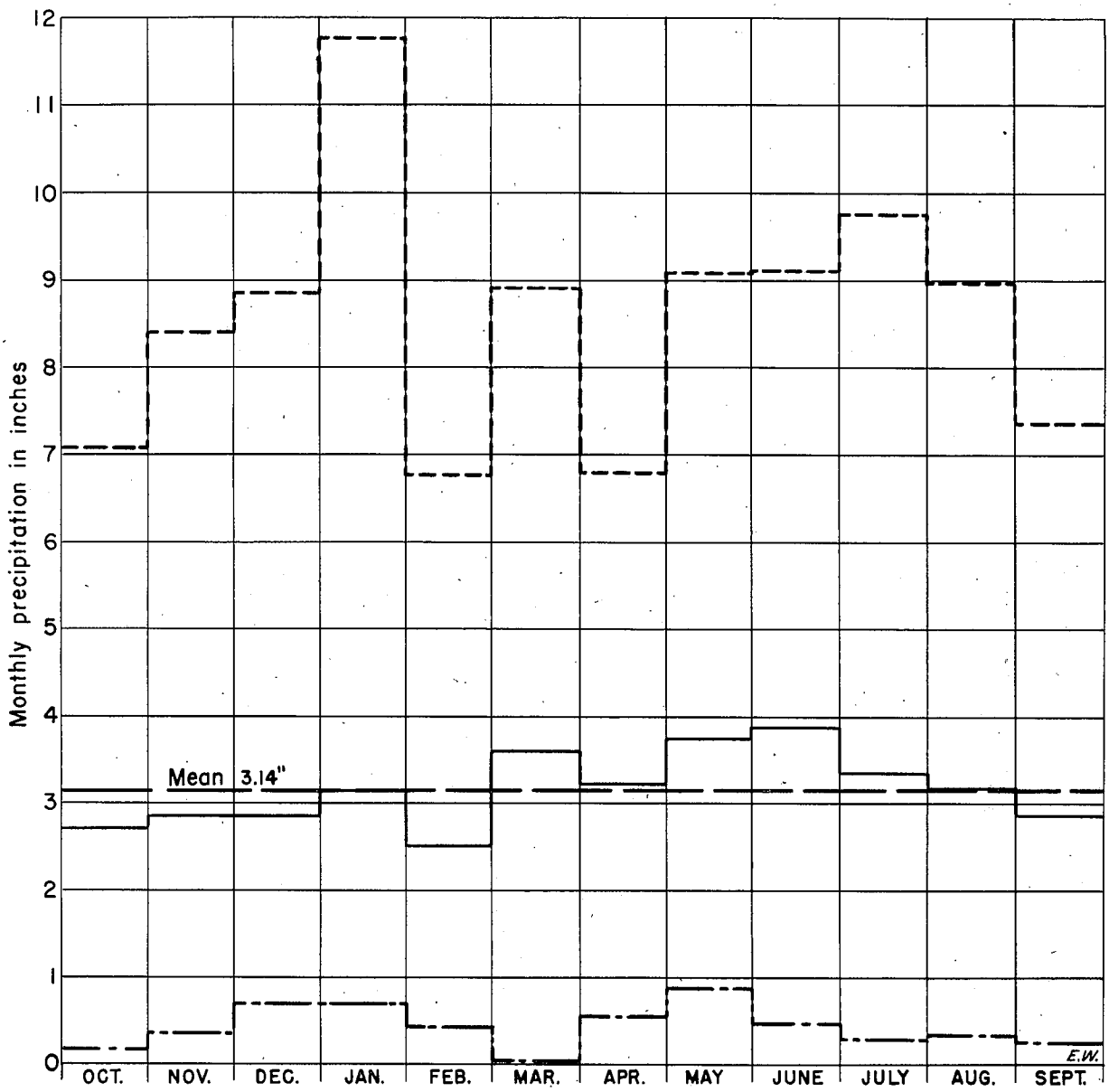


Annual and 10-year moving average precipitation and temperatures at Germantown.



Annual and 10-year moving average precipitation and temperatures at Dayton.

Plate 6.



LEGEND

- – – – – Maximum monthly precipitation of record at Dayton
- ——— Mean for each month for the entire record at Dayton
- ——·—— Minimum monthly precipitation of record at Dayton

Plate 7. Average, maximum, and minimum monthly precipitation at Dayton, 1921-45.

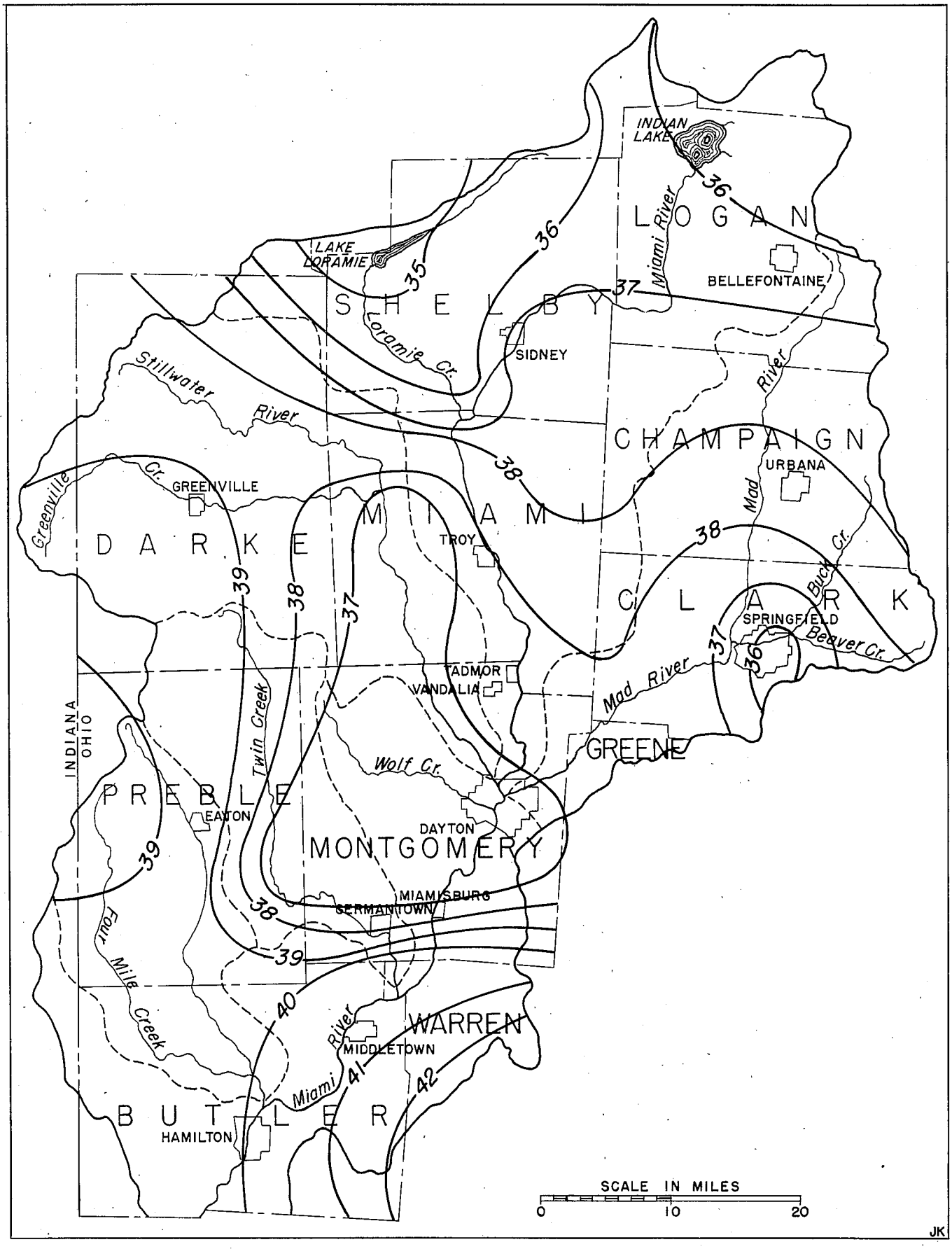
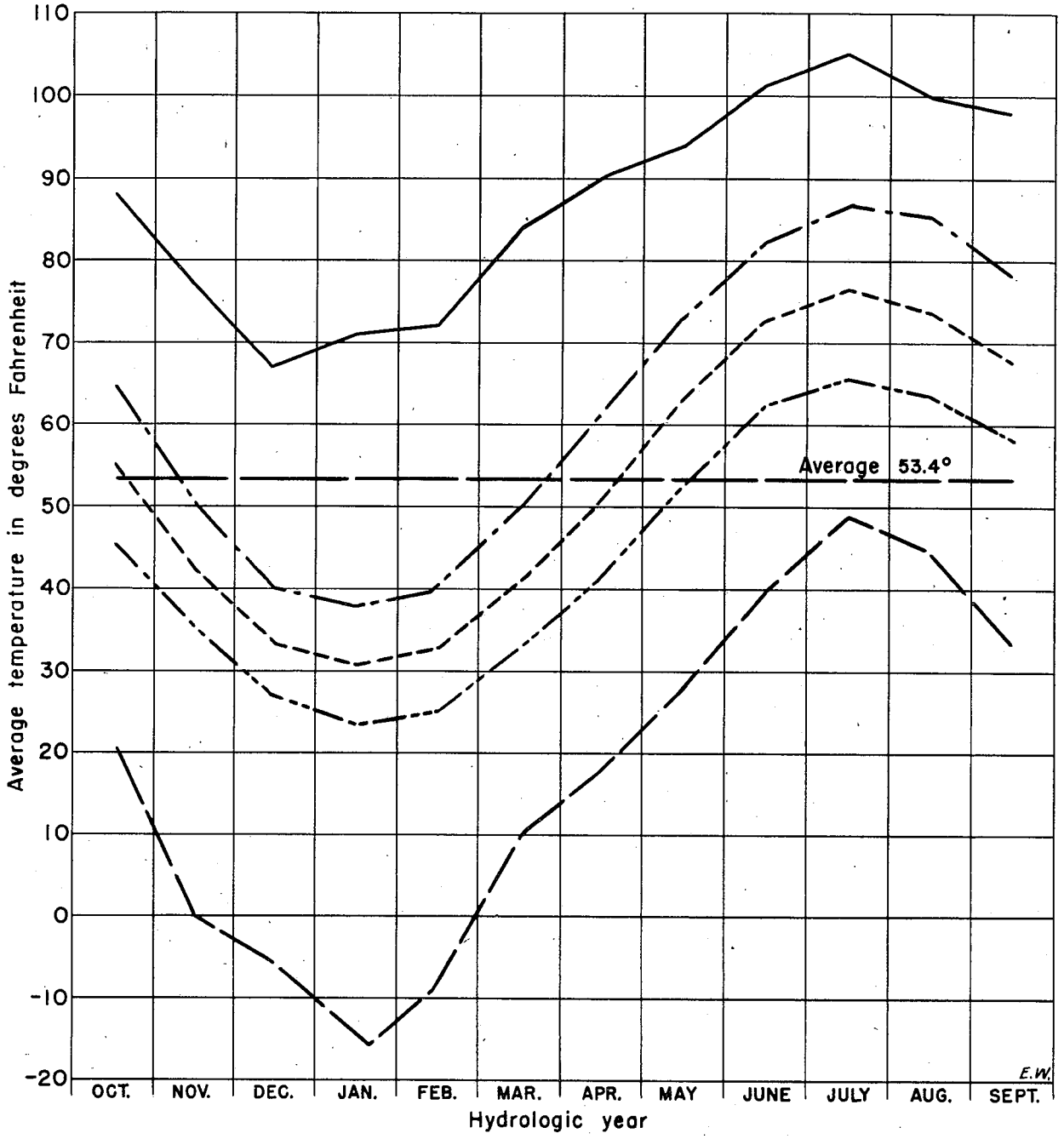


Plate 8. Isohyetal map of Miami River Basin showing lines of equal average annual precipitation in inches for period 1921-45.



LEGEND

Maximum temperature recorded
Monthly average maximum
Average
Monthly average minimum
Minimum temperature recorded

Plate 9. Average, maximum, and minimum temperatures at Dayton, 1921 – 45.

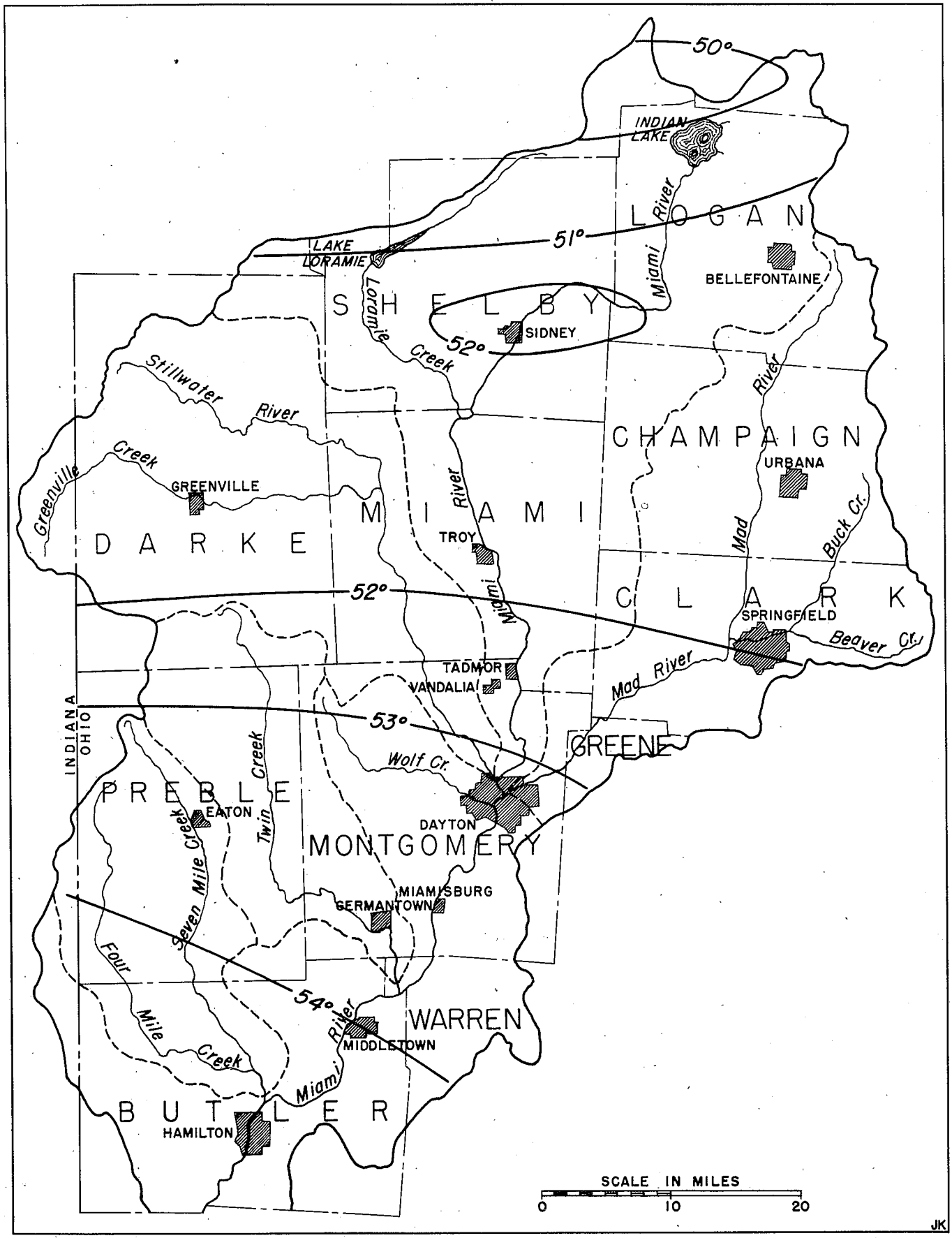


Plate 10. Isothermal map of Miami River Basin showing lines of equal average temperature in degrees F. for period 1921-45.

Evaporation

The evaporation and wind-movement records shown in table 31 have been obtained at the Weather Bureau station at Dayton Airport (Vandalia) since 1937. It is worthy of note that the measured evaporation rate from a standard evaporation pan for the seven warm-weather months for which records are obtained is greater than the rainfall for the same period, and approaches the annual precipitation figures.

POPULATION

The population of Montgomery County as determined by the 1940 census was 295,480. Of this number 223,914 were classed as urban, 18,765 as rural farm, and 52,801 as rural non-farm.

The population of the principal municipalities in 1940 is given as follows: Dayton 210,718, Miamisburg 5,544, West Carrollton 2,500, Germantown 2,095, Brookville 1,600, Trotwood 770, Beavertown 634, Centerville 561, New Lebanon 534, Englewood 531, Farmersville 446, Vandalia 378, and Union 280. Dayton, comprising an area of 24 square miles, ranked sixth in size among the cities of the State and fortieth in the United States. The total 1940 population of the county represented a 6-percent gain over the 1930 figure of 273,481, the largest increase of any county in the State for that period.

During the war the population of the county increased greatly and was estimated by the U. S. Bureau of the Census to have reached 338,688 on November 1, 1943, an increase of 14.7 percent over the 1940 total. During the war approximately 37,000 were inducted into the armed services from Montgomery County and most of these are not included in the population figure of 1943. Of this number about 29,000 had returned to the county by March 1947.

Since the war the population of the county has continued to increase and was estimated by the Dayton Chamber of Commerce to have been about 365,000 in March 1947. Metropolitan Dayton, which includes most of five townships, was estimated to have had a population of approximately 325,000 at that time, the city of Dayton accounting for 250,000.

Industries and trade

Manufacturing in Dayton, especially "light manufactoring, precision work," accounted for 45.4 percent of the total employment in 1940. In comparison this percentage was 38.3 for Cleveland, 23.7 for Columbus, and 51.4 for Youngstown. Of the 1940 employed labor force of 101,805 in Metropolitan Dayton, 43.6 percent was classified in the manufacturing category of machine operators, craftsmen, foremen, etc. about the same ratio, compared to other categories, as for the highly industrialized Youngstown-Canton-Akron area. In Montgomery County, according to the census, the "value added by manufacturing" to finished products amounted to 59 percent, this ratio being exceeded in the United States by only two other areas - Hartford, Connecticut, and Rochester, New York.

In 1940 a total of 109,988 people were gainfully employed in Montgomery County. Of these, almost half the manufacturing workers were employed in the production of machinery, especially refrigerators and air-conditioning equipment, office machines, and machine-shop products. Automotive parts accounted for 11.8 percent and foundry products 7.1 percent. Printing and publishing, the next largest industry, employed 7 percent of the manufacturing workers.

The largest manufacturing establishment in the county is the General Motors Corp., whose five divisions, headed by Frigidaire, employed 19,000 people in 1939, or 41.6 percent of the total manufacturing employees. The National Cash Register Co., one of Dayton's oldest firms, employed 14.3 percent, or 6,868 people, at that time. The McCall Corp., publisher of "McCalls" and other magazines, employed 2.6 percent of the manufacturing employees in 1939, and the Dayton Malleable Iron Co. and its subsidiary, GHR. Foundry, accounted for 2.2 percent. Fifteen other firms, each employing between 300 and 1,000 people, together accounted for 16.1 percent. In 1939 the total experienced male labor force in all categories numbered 66,330. In 1940 Dayton was in first place in Ohio, with average weekly per-capita earnings of $33.57. In hourly earnings Dayton ranked third, with an average of 88.7 cents.

During the war period Dayton industries expanded greatly, the plant expansion due to Federal funds alone amounting to $100,000,000. This expansion, great as it was, amounted to only 5 percent of the value of war-supply contracts let in the Dayton area through 1944. During this period three new major industries were added and facilities were increased in at least 12 existing plants. War-supply contracts during the 4-year period ending with 1944 amounted to 5.5 times the total value of all manufactured products in 1939. This may be compared to a 3.3 ratio for the country as a whole.

The largest single war item was ordnance production which was accomplished mainly by the conversion of the Frigidaire Division of the General Motors Corp. and the National Cash Register Co. Aircraft parts became the second largest item. Peak employment in war-time industry was reached late in 1943, when approximately 84,200 were employed. This is an increase of about 75 percent over the 1939 figure of 48,117.

Important adjuncts to the economic life of the county are the Army air bases of Wright and Patterson Fields, located 10 miles northeast of Dayton in Greene County. Before the war these installations employed about 2,000 people, mostly residents of the Dayton area. With the war-time expansion of the Army Air Forces, the headquarters of the Air Technical Service Command and the Air Service Command were established at Wright Field. Peak employment at the fields reached in August 1943, was estimated at 41,500.

In 1939 there were three times as many persons employed in manufacturing as in retail trade in Montgomery County - a relationship typical of the highly industrialized cities of the State. At that time net sales amounted to $8,016 per employee, slightly less than the average for the State. Per-capita retail sales in Dayton amounted to $502 in 1939, above all but two leading Ohio cities. In 1939 Dayton's share of the State sales in the wholesale market was 4.5 percent.

Agriculture

In 1940 there were 4,163 farms in Montgomery County, comprising 234,799 acres or 78.9 percent of the total land area. Although only 3.5 percent of the employed population was engaged in agriculture and only 6.3 percent was classified as rural-farm, Montgomery County in 1940 ranked fourth in the State, with $5,191,000 in farm products. The gross farm income averaged $43 per acre in 1939, the highest in the State, the average for all counties being $30 per acre.

The principal crops produced in Montgomery County are corn, wheat, and soy beans. In 1940, 2,500,881 bushels of corn was harvested from 50,351 acres, and 571,610 bushels of winter wheat from 28,679 acres. The total value of livestock in 1940 was approximately $2,000,000.

The trend in 1945 seemed to be toward fewer farms of larger size. This was the case despite the fact that much farm land had gone into home building plats, some of which were classified as small farms. According to the U. S. Bureau of the Census, there were 3,612 farms in 1945 with an average size of 64.0 acres. The average size in 1940 was 56.4 acres. In 1945 production of corn had declined somewhat from the 1940 yield, to 1,931,118 bushels, whereas winter wheat showed an increase to 576,318 bushels.

The Montgomery County Agricultural Adjustment Administration office reported that total farm land in 1946 amounted to 236,203 acres on 177,301 acres, of which crops were produced. Permanent pasture made up 11,404 acres; commercial orchards and vegetable growing accounted for 323 acres. The average value of all farm land in 1946 was estimated to be about $200 per acre.

Mineral resources

The most important mineral resources of Montgomery County are the glacial-outwash deposits of sand and gravel. The areas of these deposits are shown on plate 2. Most of the workable deposits are in the lowland areas at the northern and eastern edges of the city of Dayton, in the Oakwood-Southern Hills area to the south, and along the Miami River between Dayton and West Carrollton. Many small private pits have been opened over the county and more than 20 commercial pits are currently in operation. A canvass of 17 of the principal producers revealed that in 1946 their total excavation amounted to 470,973 yards of sand and gravel, having a value at the pits of $371,525. Most of the material was used in construction work, about one-fourth the total being used as road material. Two sand pits are operated just south of Dayton by companies making sand-cement building blocks. In 1946 over 16,000 cubic yards of sand was dug for this purpose.

The next most important mineral resource of the county is limestone, produced from a single large quarry about a mile south of Phillipsburg in the NW ¼ sec. 14, Clay Township. The stone obtained is from the Cedarville dolomite. The operators of this quarry took out approximately 150,000 tons of stone in 1946, the major part of which was crushed and used as road material. Approximately 30,000 tons was made into agricultural lime, and about 15,000 tons into metallurgical flux. In former years at least 10 other quarries were operated over the county, but all these are now abandoned.

Transportation and public utilities

Four railroads - New York Central, Pennsylvania, Baltimore and Ohio, and Erie - serve Dayton and Montgomery County. More than 80 interstate freight truck lines and freight-forwarding companies have stopover or terminal facilities in Dayton, and 15 motor truck lines operate out of the city. At least six local and interstate bus lines operate in Montgomery County over an excellent system of highways. The National Road (U. S. Highway 40), as well as U. S. Highways 25 and 35, pass through the county.

Dayton has more automobile traffic per capita than any of the other large cities of Ohio. For several years Montgomery County has led the State in the number of automobiles owned per capita.

The area is particularly well served by air lines operating from the Dayton Municipal Airport at Vandalia. Two major scheduled air carriers together operate 36 flights daily. At least six smaller non-scheduled airline carriers of passengers and freight operate from the Dayton airport, averaging well over 1,000 flights monthly.

Natural gas is brought into Montgomery County by two transmission lines operated by the Dayton Power and Light Co., which serves all the principal towns except Brookville. Gas is furnished to Brookville by the Western Ohio Public Service Co. Electric power is furnished by the Dayton Power and Light Co. to all the users in the county with the exception of the National Cash Register Co. and the City of Miamisburg, which have their own power stations. The Dayton Power and Light Co. has its main power plant, called the Frank M. Tait Station, located along the Miami River in southern Dayton. The company also has another plant under construction along the Miami River between Miamisburg and Chatauqua. This plant will be known as the O. H. Hutchins Station. The Dayton Power and Light Co. has low dams in the river at both these stations for recirculation of the water taken from the river for condensing purposes.

Telephone service is provided Dayton and most of Montgomery County by the Ohio Bell Telephone Co. The Ohio Standard Telephone Co. has exchanges at Liberty, Englewood, and Trotwood, which serve those communities. Part of the northern section of the county is served by the Troy-Tipp City Telephone Co., from its exchange at Tipp City, in Miami County.

GROUND-WATER RESOURCES

GROUND-WATER HYDROLOGY

Occurrence of ground water

Most of the water occurring below the surface of the ground is contained in a natural reservoir in the rocks, called the zone of saturation. Water occurring in unconsolidated deposits, such as sand and gravel, and in some porous consolidated formations, occupies the pore spaces between the individual particles. The size, shape and arrangement of the constituent particles determine the amount of water that can be stored. In consolidated rocks, such as most limestones and shales, water occurs mainly along the joint and bedding planes and in fracture and solution openings.

Above the water table ground water occurs in suspension in what is called the weathering zone, or zone of aeration. According to its occurrence, water in this zone is classified as soil water, intermediate water, and capillary fringe water, the latter rising above the water table in capillary interstices.

Movement of ground water

Movement of water in permeable water-bearing formations in the zone of saturation is caused by differences in hydraulic head in different parts of the formation. The relationship among the various factors governing the quantity of flow in permeable water-bearing formations is best expressed by Darcy's law which may be stated mathematically as follows:

$$Q = TIW$$

Where Q = flow in gallons a day through a strip of the water-bearing formation 1 foot wide with a depth equal to the saturated thickness of the formation

T = coefficient of transmissibility in gallons per day per foot of width of saturated formation, under a hydraulic gradient of 100 percent

I = hydraulic gradient in feet per foot in the direction of flow

W = width of the water-bearing formation in feet, at right angles to the direction of flow

The value of the factor T (transmissibility) in the above expression of Darcy's law is governed by the thickness and the physical properties of the water-bearing formation, particularly the size and arrangement of the individual particles making up the formation. These physical properties of a water-bearing formation determine the frictional resistance of the formation to the flow of ground water.

Darcy's law sometimes applies approximately to consolidated rock formations where the water moves through fractures and solution channels, provided these openings are small in comparison with the width and depth of the formation and that the rate of movement is low.

Artesian and water-table conditions

The level to which water rises in wells may be called the piezometric or pressure indicating surface. Where the top of the zone of saturation is not formed by an impermeable formation, the piezometric surface occurs at the same elevation as the upper limit of the zone of saturation and the ground water is said to occur under water-table conditions. The upper surface of a body of ground water that is held above the main zone of saturation by impermeable material is called a perched water table. The water table is seldom a perfectly level surface as would be the case in a surface reservoir. In general, the water table follows approximately the configurations of the land surface.

Where the water in the zone of saturation is confined between two impermeable formations, and the piezometric surface of the water-bearing formation is above the zone of saturation, the ground-water is said to occur under artesian conditions. The water contained in an artesian formation is therefore under pressure derived from the water level in the intake area. This definition does not imply that wells tapping an artesian formation need necessarily flow. An artesian well flows only if the elevations of the intake area and that at the well, less the losses in head due to friction and leakage through the confining bed, is sufficiently great to cause the head to be above the surface at the well.

Ground water in different places in Montgomery County occurs under both water-table and artesian conditions in both the consolidated and unconsolidated formations.

Ground-water recharge

Recharge to a water-bearing formation under natural conditions is derived from precipitation on its intake area and from stream flow.

The amount of ground-water recharge received from direct precipitation is dependent on many factors, including the amount and seasonal distribution of precipitation, the type and condition of the soil and

vegetal cover, and the geology and topography. In Ohio the greatest ground-water recharge is generally received from precipitation in the first 6 months of each year, when soil conditions are most favorable and when plants are dormant, so that loss by transpiration and evaporation are at a minimum.

Recharge from stream flow may occur in two ways: by flooding of streams over areas where intake facilities are suitable or by infiltration through the stream beds where the adjacent water table is lower than the stream. Under natural conditions in Ohio, as in most other humid regions, ground-water levels are usually above stream levels and infiltration through stream beds occurs only for short periods in times of high stream flow. However, where ground-water levels are lowered below stream levels by pumping from wells, the ground-water gradients are reversed and water flows continuously from streams into the ground. Under such conditions stream flow may be the major source of ground-water recharge in an area. Pumping may also result in more recharge from floods by providing more storage space in the aquifer, even where recharge is not induced during periods of lower stream flow.

Ground-water recharge may be increased also by pumping from wells in areas where the water table is normally close to the ground surface. This increase is accomplished by reducing transpiration and evaporation losses from the water table and by providing additional storage space in the aquifer.

Recharge may also be increased artificially by various forms of water spreading, or by the use of recharge wells. A form of artificial recharge is used at the Dayton Water Department well field on Rohrer's Island, where water is diverted from the Mad River into infiltration ditches and ponds. This installation is discussed in more detail later in this report. Recharge wells are used in some places to conduct water into the ground, but where this is practiced water free from silt and iron is desirable to avoid clogging of the wells and the pore spaces in the aquifer.

Ground-water discharge and recovery

Ground water may discharge from an aquifer in several ways. Where the water table is close to the ground surface, water is evaporated from the capillary fringe and transpired to the atmosphere by plants. The other principal means is discharge into streams through seeps and springs.

In an aquifer from which no water is pumped the average recharge over a long period is approximately equal to the average discharge; that is, the amount recharged from precipitation and from

streams is balanced by the amount discharged through seeps and springs and by evaporation and transpiration. Pumping of wells introduces a new factor into the hydraulic system of an aquifer. When pumping begins, most of the water is taken from storage in the immediate vicinity of the pumping well. As pumping continues, more water is conducted from greater and greater distances to the pumping well and less is removed from storage in the immediate vicinity of the well. Thus hydraulic gradients are created around the pumping well, which form a characteristic "cone of depression." This cone expands until water levels are lowered in the discharge area of the formation sufficiently to reduce the discharge by the amount of the pumping, or until water levels are lowered in the intake area of the formation sufficiently to induce additional recharge in the amount being pumping, or a combination of both. If the average recharge is less than the amount of water pumped, ground-water levels will decline continuously until they are lowered to the bottoms of the pumping wells or until the discharge is reduced.

Consideration of the above factors is especially important in developing large ground-water supplies. The greater the distance of a pumping well from either the recharge or the discharge area of a formation, the greater must be the lowering of water levels in the pumping well before stability of pumping levels is attained. If wells are improperly located, excessive lowering of water levels may occur locally in an aquifer even though sufficient recharge is available.

In Montgomery County most of the large ground-water supplies are obtained in the gravel aquifers in the stream valleys. Most of the natural discharge of the ground water in these areas is into the streams, and where a sufficient thickness of gravels exists below the stream beds recharge from stream flow is usually available. Generally it may be stated that in these areas the greatest amount of natural discharge will be cut off and the greatest amount of recharge from stream flow induced, with a minimum lowering of ground-water levels, if wells are located as close to the streams as possible and are properly spaced to avoid interference with each other.

Comparison of physical properties of upland aquifers in Montgomery County from field tests of wells

As previously stated, the capacity of a formation to transmit water is called its transmissibility. Transmissibility may be determined from field pumping tests by several methods described by Wenzel (12). One method is by analysis of the rate of recovery of the water level in a well after pumping has stopped. When a cone of depression has been developed around a pumping well, a difference in hydraulic head exists between the water in the well and the water in the surrounding material. When pumping is stopped the recovery of the water level in the well is rapid at first and then slowly tapers off in response to the decreasing difference

of head. The rate at which recovery occurs is related both to the transmissibility of the aquifer through which the water travels to reach the well and to the storage properties of the aquifer.

In Montgomery County recovery measurements were made on approximately thirty 5 5/8-inch-diameter farm wells, located on the uplands in the western part of the county, and thought to be fairly representative of these wells in the various upland aquifers. The data obtained were used to determine coefficients of transmissibility by means of the recovery method mentioned above. The results obtained from the pumping tests are presented to provide a means of comparison of the water-yielding possibilities of the aquifers tested.

In addition to the rate of recovery in these wells, the drawdown was measured in each well near the end of each test and the specific capacities of the wells were computed. The specific capacity of a well is defined as the yield per unit of drawdown, usually stated in gallons per minute per foot of drawdown. Specific capacity is also a crude measure of the water-yielding properties of an aquifer. The results of the field tests are summarized in table 3 as follows:

Table 3

Summary of field tests of farm wells in Montgomery County

Formation	Av. coefficient of transmissibility	Number of wells	Average spec. cap. gpm per ft.	Number of wells
Upland glacial drift	951	13	1.51	12
Limestone,(Silurian)	501	7	0.99	7
Shale,(Ordovician)	245	2	0.72	5

Transmissibilities in the upland glacial drift ranged from 82 to 3,700, in the Silurian limestone from 52 to 2,790, and in Ordovician shale from 62 to 428. Specific capacities of the wells in the upland glacial drift varied from 0.23 to 2.88, those in the limestone ranged from 0.29 to 2.85, and those in the shale from 0.26 to 2.50. For purposes of comparison, the average specific capacity of 17 large-diameter ($17\frac{1}{2}$ to 38-inch) wells in the City of Dayton well field on Rohrer's Island in the Mad River was 117. Specific capacities of two 26-inch diameter wells of the Dayton Power and Light Co., located along the Miami River at Chatauqua, were 1,011 and 1,360. These wells obtain water from highly permeable outwash gravels.

Methods of recovery and amount of ground-water used in rural areas

Development of wells

On the basis of the survey of drilled wells made in 1946, and on data collected by the Works Progress Administration in 1933-34, it is estimated that in rural areas of Montgomery County there are approximately 3,000 large-diameter dug wells, about 2,000 drilled wells, and about 500 driven wells.

The average depth of 807 dug wells in the county, as determined from the Works Progress Administration survey, was 25 feet. Most of them are located in the upland areas of the county and derive water from the glacial till. They are generally equipped with hand pumps and yield on the average from 2 to 10 gallons per minute.

The drilled wells in Montgomery County that are used for farm and domestic supplies are cased most commonly with 5 5/8-inch diameter open-end galvanized-iron casing. Only a few are equipped with well screens. They are provided with hand lift pumps, electrically driven deep-well piston pumps, or ejector-type pumps. Most of these wells yield from 5 to 15 gallons per minute. The results of the 1946 drilled-well survey are given in table 4.

Table 4

Data on drilled rural wells measured in Montgomery County in 1946

Township	Wells in consolidated rocks				Wells in glacial drift		
	No. of wells	Av. depth (feet)	Av. depth to water (feet)	Average Thickness of aquifer (feet)	No. of wells	Av. depth (feet)	Av. depth to water (feet)
Butler	18	60	17	30	20	69	12
Clay	46	62	11	18	23	67	10
German	11	92	55	19	37	83	35
Harrison	1	81	--	26	33	87	34
Jackson	10	81	15	38	39	74	22
Jefferson	13	71	17	15	40	80	23
Mad River	--	--	--	--	27	104	55
Madison	8	49	12	23	22	61	20
Miami	7	72	26	17	20	89	30
Perry	23	71	14	20	43	86	20
Randolph	13	63	17	31	9	70	42
Van Buren	7	96	19	28	18	95	19
Washington	10	87	13	32	15	74	17
Wayne	10	53	14	22	17	59	12

Driven wells in Montgomery County consist usually of $1\frac{1}{4}$ or $1\frac{1}{2}$ inch pipe, perforated near the lower end and fitted with a drive point. These wells are equipped with small-capacity pitcher-type suction pumps and can be used only where the water table is within about 22 feet of the ground surface. Driven wells are especially common along lower Wolf Creek, in southeast Madison Township, and are scattered in various places along all the major streams. They are generally driven only a few feet into the glacial-outwash gravels along the streams.

Development of springs

Springs are abundant in Montgomery County, especially in the northern part along the outcrop of the base of the Brassfield limestone. Water migrates downward through cracks and fissures in the limestone and moves along the top of the underlying impermeable Ordovician shale to issue as springs where the contact zone is above stream level. The largest of these limestone springs in the county is believed to be on the George Antrim farm in the $SW\frac{1}{4}$ sec. 13, Butler Township. There are at least four well-defined spring zones at this place, which combine to produce a flow of about 700 gallons a minute, as determined by Mr. Collins Wight, Hydraulic Engineer and former director of the Dayton Water Department. Another large spring in the $NW\frac{1}{4}$ sec. 30, Wayne Township, has a flow, estimated by Mr. Wight, of 200 gallons a minute. Two large springs also occur in the $NW\frac{1}{4}$ sec. 3, Randolph Township, and have a combined flow, according to Mr. Wight, of about 100 gallons per minute.

In other parts of the county, outside the areas underlain by Silurian limestone, springs are occasionally found in the glacial deposits where water follows the upper surfaces of local impermeable layers. The average flow of all types of springs, as determined from Works Progress Administration records of 96 typical springs, was 5 gallons per minute. The springs in Montgomery County are used chiefly for farm purposes.

Methods of recovery and amount of ground water used by industries and municipalities

Areas of industrial and municipal ground-water pumpage in Montgomery County are shown on plate 11. Pumpage by industrias and commercial establishments amounted to an average of about 49,958,000 gallons per day in 1946, and pumpage by municipalities in the same year averaged about 40,817,000 gallons per day. The total pumpage in Montgomery County thus amounted to 90,775,000 gallons per day, nearly one-fifth of the average daily pumpage for the entire State.

Table 5

Principal Industrial and Commercial Ground-Water Users in Montgomery County (1946)
All supplies taken from valley-train deposits, except those of the United Fireworks Co. and the Dayton Municipal Airport, whose supplies come from Ordovician shale and Silurian limestone, respectively.

Company	Location	Main use of water	Average daily pumpage	No. of prod. wells	Av. depth of wells (feet)	Av. depth to water (feet)	Well-log references
Frigidaire Div., GM Corp.	Van Buren Twp., NE ¼ sec. 16	Air conditioning and industrial processing	8,330,000	6	118	25	49, 96, 97, 147, 148, 149
Miami-Oxford Paper Co.	West Carrollton	Paper making	5,186,000	18	65		62
National Cash Register Co.	Southeast Dayton	Industrial processing	5,068,000	8	102		465, 469, 470, 471, 472, 52, 54, 480
Dayton Power and Light Co., Frank M. Tait Station	South Dayton	Cooling	5,025,000	5	92	28	27,554, 575, 576, 577
Aetna Paper Co.	Southwest Dayton	Paper making	2,962,000	3	138	26	521, 522
Wright Field AF	Mad River Twp., Sec. 18	General purpose	2,435,000	13	61	20	172, 173, 17, 12, 168, 169, 170, 171, 105, 106, 174, 10, 175, 99
Dayton Rubber Co.	West Dayton	Industrial processing	2,200,000	3	199	39	23, 93, 581
Delco Pdts. Div., GM Corp.	Central Dayton	Industrial processing	1,835,000	7	126	32	126, 531, 532, 533, 534, 535, 588
West Carrollton Parchment Co.	West Carrollton	Paper washing	1,600,000	1	100	20	746
Miamisburg Paper Co.	Miamisburg	Paper making	1,440,000	3	75	24	82, 83, 84
*City Ice and Fuel Co.	Central and West Dayton	Ice making	1,438,000	4	165	35	
Gibbons Arcade Bldg.	Central Dayton	Air conditioning and sanitation	1,209,000	3	75		
Frigidaire Office Bldg.	North Dayton	Air conditioning	793,000	1	104		
Airtemp, Inc.	North Dayton	Industrial processing and cooling	720,000	2	92	14	
Terminal Cold Storage and Ice Co.	Central Dayton	Ice making	720,000	2	109	21	
*Dayton Power and Light Co. Longworth and Third Sts. Sta.	Central Dayton	Generation of steam	653,000	4	161	20	25, 573, 574, 555, 556
Moraine Products Div., GM Corp.	Southwest Dayton	Industrial processing	540,000	4	97	39	536, 537
Air Reduction Sales Co.	Van Buren Twp., NE ¼ sec. 16	Cooling and processing	500,000	1	150	20	
Sunshine Biscuit Co.	Southwest Dayton	do.	500,000	3	112	34	108, 523, 524, 525
*Lake Coal and Ice Co.	Central and southwest Dayton	Ice making	452,000	3	104	17	
The Sheffield Corp.	East Dayton	Cooling	436,000	1	75		102
Rike-Kumler Co.	Central Dayton	Air conditioning	429,000	2	119	16	140
Miami Valley Brewing Co.	Central Dayton	Processing	400,000	2	50		
Gem City Ice Cream Co.	West Dayton	Cooling	315,000	2	110		448
Baltimore and Ohio RR	East Dayton	Boilers and cleaning	276,000	1	90	16	29, 31
Master Electric Co.	East Dayton	Industrial processing	250,000	1	56	33	438
Neals Dairy Farms	South Dayton	Cooling	237,000	1	72	38	
Himes Bros. Dairy	Southwest Dayton	Cooling and cleaning	225,000	2	166	45	
Specialty Paper Co.	South Dayton	Paper making	220,000	1	135	32	107
Dayton Steel Foundry	Southwest Dayton	Industrial processing	206,000	1	60	24	20
Miami Hotel	Central Dayton	Sanitation	200,000	2	60		
National Foundry and Furnace Co.	Southwest Dayton	Cooling	185,000	1	95	35	
The Elder and Johnson Co.	Central Dayton	Air conditioning	173,000	2	138	16	104
Wm. Focke and Sons Co.	Northeast Dayton	Processing	154,000	1	110		
Dayton Rust Proofing Co.	Northeast Dayton	Industrial processing	150,000	2	114		
Red Wing Creamery	Southeast Dayton	Cooling	140,000	1	120	39	103
Ol-Fashion Brewing Co.	Southeast Dayton	Processing	125,000	1	90		
Wolf Creek Soap Co.	West Dayton	Cooling and processing	123,000	1	81		
Borden Finch Farms	Central Dayton	Cooling and cleaning	120,000	2	101	31	526
Hewitt Soap Co.	East Dayton	Soap making	112,000	3	70	25	437, 439
Crystal Laundry Co.	Central Dayton	Laundry	107,000	2	26		
Sears Roebuck Co.	Central Dayton	Air conditioning	104,000	1	192	30	125
Germantown Rendering Co.	German Twp., Sec. 19	Processing	103,000	3	63	20	508
Gibbons Hotel	Central Dayton	Sanitation	100,000	1	120	15	
Globe Laundry Co.	Southwest Dayton	Laundry	90,000	1	121	16	
Troy Pearl Laundry	Central Dayton	Laundry	80,000	1	130	29	129
Premier Rubber Co.	North Dayton	Processing	78,000	2	125	14	445
Dayton Power and Light Co. Fourth St. Station	Central Dayton	Cooling	74,000	1	140		
Simons, Worden, White and Co.	West Dayton	Sanitary and boilers	74,000	1	52	18	
Univis Lens Co.	Northwest Dayton	Processing	71,000	1	135	32	100
The United Fireworks Co.	Jefferson Twp., Sec. 3	Boilers	70,000	3	80	43	
East Dayton Tool and Die Co.	North Dayton	Air conditioning	69,000	1	71	19	91
Hall's Laundry	Central Dayton	Laundry	53,000	1	87		
Metropolitan Clothing Co.	Central Dayton	Air Conditioning	51,000	1	200	14	
McCook Bowling	North Dayton	Air conditioning	50,000	1	71		443
Peoples Transit Co.	Southwest Dayton	Sanitary and cleaning	50,000	1	84		
Gas and Electric Bldg.	East Dayton	Air conditioning	47,000	1	78		
Kurz-Kasch Co.	Southwest Dayton	Processing	45,000	1	98		
American Envelope Co.	West Carrollton	Processing	42,000	1	61		
Kroger Co.	Southwest Dayton	Sanitary and Cooling	41,000	1	80		46
Grocer's Coop. Dairy Inc.	North Dayton	Cleaning and sanitary	40,000	1	67	9	
Kuhn's Bros. Co.	Southwest Dayton	Processing and cooling	40,000	2	123	40	
Loew's Theater	Central Dayton	Air conditioning	38,000	1	115		
Davies-Young Soap Co.	Northeast Dayton	Soapmaking	35,000	2	55	8	
Donenfeld's, Inc.	Central Dayton	Air conditioning	30,000	1	110		440
Moraine Box Co.	Van Buren Twp., Sec. 18	Sanitary	30,000	1	150		
Economy Linen Service	North Dayton	Laundry	27,000	1	26	10	
McCrory's Store	Central Dayton	Air conditioning	27,000	1	102		
Miami Valley Coop. Prod. Ass'n.	Central Dayton	Cooling and cleaning	25,000	1	126	16	
Moler's Belmont Dairy	Southeast Dayton	Cooling and cleaning	24,000	1	85		
Mulford's Dayton Plant	Southwest Dayton	Processing	23,000	2	65	35	
Sanitary Laundry Co.	North Dayton	Laundry	20,000	1	71		
S. S. Kresge Co.	Central Dayton	Air conditioning	15,000	1	100		
Moraine Hotel	Central Dayton	Air conditioning and sanitary	15,000	1	128	21	
Fm. Bur. Fert. and Rend Plant	Northeast Dayton	Boilers	14,000	1	76	14	446
Brownell Boiler Works	Northeast Dayton	Processing	13,000	1			
Dayton Packing Co.	Northeast Dayton	Sanitary and cleaning	10,000	1	110		
Otterbein Press	West Dayton	Sanitary	10,000	1	64	45	
Shoemake Guernsey Fms., Inc.	Southeast Dayton	Cooling and cleaning	10,000	1	66	20	
Standard Register Co.	Central Dayton	Air conditioning	10,000	1	100		
Dayton Municipal Airport	Vandalia	Sanitary and cleaning	8,000	1	68		
Gondert and Lienesch	Central Dayton	Boilers	6,000	1	80		
Crume Brick Co.	Southwest Dayton	Boilers	5,000	1	25		
Plaza Theater	Miamisburg	Air conditioning	2,000	1	80		
		Total	49,958,000				

*Includes two plants
Static water level figures taken at various times--not necessarily true for present.

Table 5 lists individually the main commercial and industrial ground-water users of the county, gives the amount of water pumped daily by each one in 1946, the use to which the water was put, and well data. Table 6 lists all the municipalities of the county which have public supplies, gives their average daily pumpage for 1946, and well data. Table 7 gives, for general reference, the amounts of water usually required for home, farm, and various industrial uses.

Most of the large ground-water supplies of Montgomery County are obtained from wells in the glacial-outwash gravels (valley-train deposits) along the principal streams. The wells range in depth from about 30 to as much as 200 feet, most wells being between 80 and 120 feet deep. The diameters of these wells range from 6 to 38 inches, the most common sizes being between 8 and 18 inches. The wells are generally provided with screens at the bottom, from 5 to 40 feet in length. Yields of individual wells range from less than 200 to more than 4,000 gallons per minute, this latter figure being exceeded by two 26-inch diameter wells of the City of Dayton well field along Mad River. Most of the wells in glacial outwash yield between 750 and 1,500 gallons per minute.

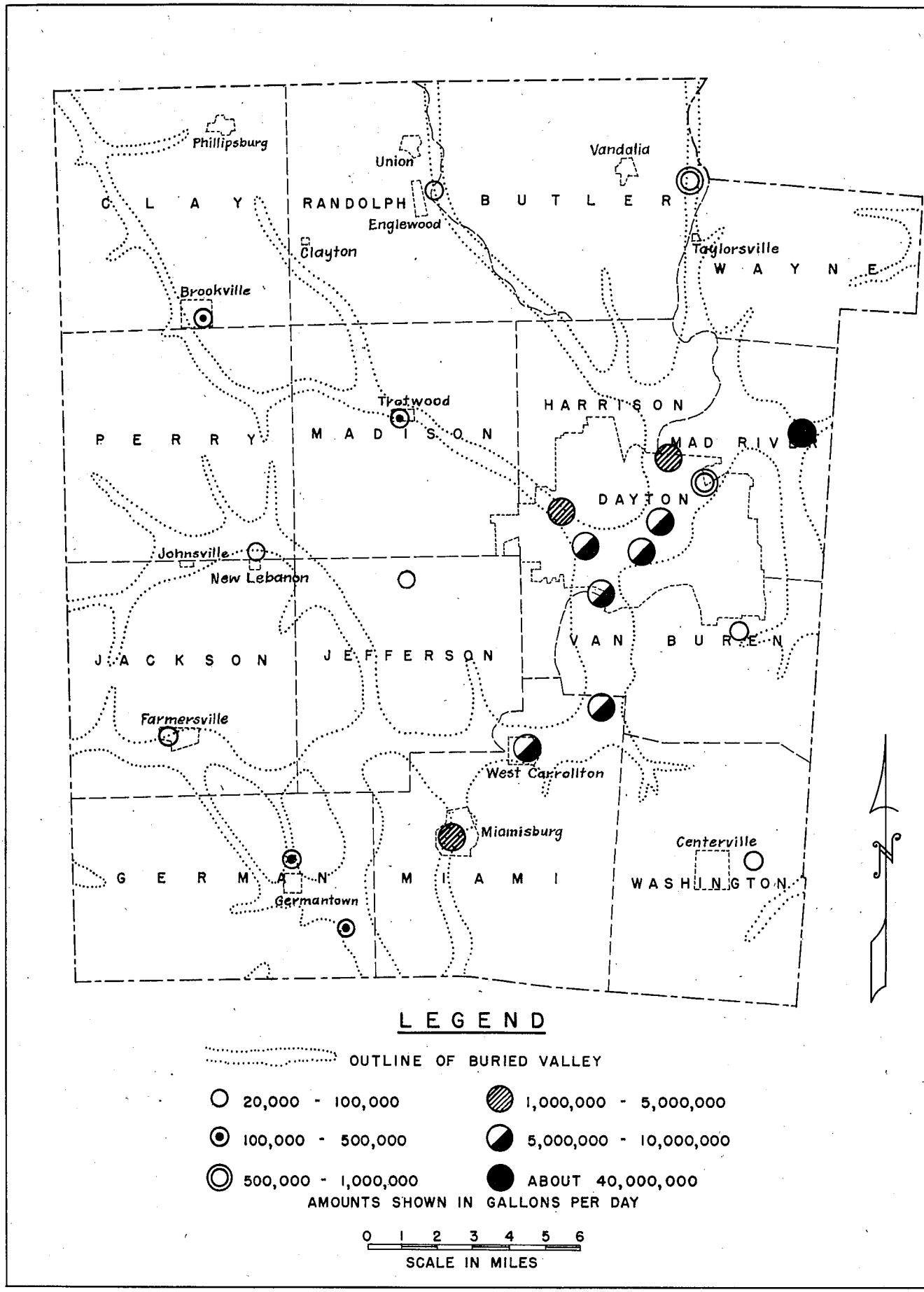


Plate II. Map showing the principal ground-water pumpage in Montgomery County, Ohio, 1946.

Table 6

Ground-water pumpage of municipal water systems
of Montgomery County in 1946
(All supplies taken from valley-train deposits, except Centerville supply, and possibly part or all of Brookville supply)

Municipality	Av. daily pumpage (gal)	Method of treatment	Number of wells	Av. depth of wells (ft.)	Well-log references
Dayton	37,630,000	Chlorine disinfection only	24 main wells	75	177-200
Oakwood	800,000	do.	2	70	589, 590
Miamisburg	767,600	do.	7	51	63, 64, 65, 66, 67, 68, 80
Vandalia	700,000	do.	3	64	2, 90
West Carrollton	225,000	do.	2	100	
Brookville	200,000	do.	4	75	
Germantown	175,000	None	3	33	150, 583, 584, 585, 586
Trotwood	125,000	do.	5	41	
Centerville	75,000	Softening-lime-soda process	No wells; water taken from old limestone quarry.		
New Lebanon	60,000	None	1	167	127
Englewood	40,000	do.	1	35	
Farmersville	20,000	do.	2	152	137
Total pumpage	40,817,000				

Table 7

Average water requirements for home, farm, and certain industrial uses

Domestic requirements

Per capita consumption for the household (gallons per day) 30

Required flow of water (gallons per minute during period of use)

Bath	6 - 10
Lavatory	3 - 5
Tank closet	5
Valve closet	30
Shower	5
Sink	5 - 10
Laundry tub	6 - 10
Garden hose	3 - 5
Continuous drinking fountain	1½

Farm requirements

Stock requirements (each animal)	Gallons per day
Horse	10
Cow, milch	25 - 30
Cow, dry, or steer	12
Hog	2
Sheep	1½

Industrial processes

Steel, highly finished	65,000 gal. per ton
Oil refining	777 gal. per bbl.
Coal washing	200 gal. per ton
Byproduct coke	3,600 gal. per ton coal
Tanning	800 gal. per 100 lb.
Paper making	30 gal. per lb.
Production of electric power by steam	80 gal. per kw.-hr.
Boiler operation, 50 - 7000 hp	3 - 500 gal. per minute

THE GEOLOGY AND WATER-BEARING PROPERTIES OF THE CONSOLIDATED ROCKS

Stratigraphy and structure

Montgomery County is underlain by the sedimentary rocks listed in table 8. These rocks consist of limestone, dolomite, and shale. Limestone is composed chiefly of calcium carbonate, $CaCO_3$, derived largely from the remains of marine organisms. Dolomite is made up of the mineral dolomite, $CaCO_3 \cdot MgCO_3$, or of calcium carbonate with varying amounts of magnesium carbonate ($MgCO_3$). Shale is formed by the consolidation of silt or clay.

The most important structural feature of southwestern Ohio is the broad Cincinnati arch. The crest of this structure crosses the middle of Montgomery County in a northeasterly direction and the strata along its axis plunge to the northeast approximately 5 feet per mile. The dip of the rocks on the flanks of the anticline is less than 1 foot per mile in Montgomery County. Erosion has exposed a section of rocks in Montgomery County extending from the Cedarville dolomite of Silurian age to shales of the Maysville group of Ordovician age. The areal distribution of these rock systems is shown on the geologic map, plate 1.

Ordovician system

Beds of pre-Eden age

During the period 1886-1888 about a dozen wells were drilled into the so-called Trenton limestone ("Birdseye limestone" of some reports) in Montgomery County in search of oil or gas. The Trenton horizon of the driller, which is from 500 to 550 feet thick, is reached in this county at depths ranging from about 800 feet in low areas in the southern part of the county to about 1,150 feet in the upland areas in the north. The meager information that is available about certain of these old wells indicates that the lower part of the Trenton generally yielded fairly large amounts of salt or "black sulphur" water. According to old newspaper accounts, a well in the northern part of Miamisburg was drilled to the depth of 1,300 feet and encountered a large flow of brine in the Trenton that rose within 300 feet of the top of the well. A more recent Trenton test was drilled about 1920 at the present site of Wright Field, in sec. 17, Mad River Township. According to Mr. J. A. Brownell, who was instrumental in having it drilled, the well went to the depth of 1,250 feet, and salt water from the Trenton rose within about 800 feet of the surface. Mr. Brownell said the well was bailed for 24 hours with no appreciable lowering of the water level. Specific mention of water is not made in the available records

Table 8

STRATIGRAPHIC SEQUENCE OF THE ROCKS ABOVE THE
SO-CALLED TRENTON LIMESTONE OF DRILLERS, MONTGOMERY COUNTY

SYSTEM	GROUP	FORMATION	CHARACTER OF MATERIAL	WATER-BEARING PROPERTIES	AVERAGE THICKNESS (feet)
Silurian	Beds of Niagara age	Cedarville dolomite	massive, porous	Generally good water supplies available for farm and domestic requirements, except from the Osgood shale. Wells ordinarily yield from 6 to 15 g.p.m. A few wells yield from 100 to 200 g.p.m. Water very hard. Important spring horizon at base of system.	50+
		Springfield dolomite	well-bedded, dense		14
		Euphemia dolomite of Foerste	massive, porous		8
		Laurel dolomite	well-bedded, dense		5
		Osgood formation	Shale, carcareous, with limestone beds		15
		Dayton limestone	Limestone or dolomite, well-bedded, dense		8
	Beds of Clinton age	Brassfield limestone	fossiliferous, massive to irregularly bedded		30
Ordovician	Richmond Maysville Eden group undifferentiated		Shale, soft, calcareous, interbedded with thin hard limestone layers; called Cincinnati shale in old reports.	Wells generally yield no water, or seldom more than 1 g.p.m. Water is sometimes highly charged with iron or salt compounds. Where water is present it generally occurs in top few feet of strata.	980
	Beds of pre-Eden age	So-called Trenton limestone of drillers	Limestone or dolomite with some shale.	Generally yields salt water at base.	500

The strata below the so-called Trenton limestone of drillers consist of several hundred feet of predominantly limestones, dolomites, and shales. These strata are not a source of fresh water.

of other Trenton wells in this county, but the many references in the literature of the oil-boom period to the "salt water" datum suggest that brine or perhaps sulfur water has frequently been encountered in or at the base of this formation.

Apparently only one well was drilled below the upper part of the Trenton horizon in the county, and it was located on the northwest corner of Schantz and Far Hills Avenues in southern Dayton. This well went to a depth of 2,440 feet (13), penetrating limestones of Black River age and the St. Peter sandstone below the Trenton (1). Salt water was found in this well in the Trenton at the depth of 1,360 feet, and also below the Trenton at the depth of 1,450 feet. The water from the lower level rose within 200 feet of the surface.

Eden group

The Eden group consists of about 500 feet of interbedded calcareous shales and shaly limestones, similar lithologically to the overlying Maysville and Richmond groups. The Eden group lies many feet below the surface in Montgomery County and has very poor water-bearing properties. Therefore wells are seldom drilled into these rocks. About the only wells that have been drilled into the Eden group are those that were drilled to the underlying Trenton limestone of drillers in search of oil or gas. One well was drilled at Miamisburg in 1887. On May 31, 1887, this well had reached a depth of 575 feet, and the newspaper "Dayton Daily Journal" commented on it as follows: "...the company has not been annoyed by water. It is a dry well. There has not been a bucket of water in it since drilling began." In 1947 the U. S. Government drilled a 6-inch test well in the Miamisburg area to a depth of approximately 474 feet. Several gas pockets were encountered in this well but practically no water.

Maysville and Richmond groups

Rocks of Maysville and Richmond groups are the oldest rocks exposed in Montgomery County. The Maysville group is made up of two formations comprising five members, and the Richmond is divided into several formations having at least eight members. The smaller units, as well as the groups themselves, are differentiated on the basis of their fossil content. These two rock groups are made up of a total of more than 450 feet of soft, puttylike blue-gray or greenish clay shales, interbedded with thin hard layers of blue-gray crystalline limestone. The limestone layers average between 1 and 5 inches in thickness and may make up from 25 to 50 percent of the whole formation. The outcrop of the Maysville group is confined to small areas in the southern part of the county, along Twin Creek in German Township

and along the Miami River in Miami Township. The Richmond group is exposed widely throughout Montgomery County, especially in the southern and eastern parts.

The shales and shaly limestones of these groups of rocks offer extremely poor possibilities for the development of ground-water supplies. The limestones are dense in texture, not very porous, and relatively impervious to percolating water. The interbedded clay shale is fine-grained and also dense in texture. Practically the only storage in these rocks is near the top where weathering has locally opened fracture or bedding planes. Because of the presence of pyrite and other minerals, any water found is likely to be charged with iron or sulfur compounds. Numerous wells have been drilled into these rocks in Montgomery County with, as one prominent driller expresses it, perhaps one of ten yielding sufficient water for a farm or residence. Results of drilling in these shales in the Shiloh area, in sec. 6 and 8 of Harrison Township, offer a typical example of their water-bearing properties. The average depth to the underlying shales at Shiloh is about 30 feet and dozens of wells have been drilled into these formations, many wells proving dry and only an occasional well furnishing more than barely enough water for household requirements. Other areas where comparatively numerous wells have been drilled into the shales include the highlands in the Miamisburg area, and areas near Little York and Taylorsville, to mention only a few.

Only two exceptions are known within this county where relatively large water suppiies are obtained from the Ordovician shales. These supplies are at the Blossom Hill Dairy in sec. 2, Jefferson Township, and the United Fireworks Co., located in sec. 35, Jefferson Township. Plate 12A is a photograph showing the contact between the Ordovician shales and the Silurian limestones at the latter place.

The Blossom Hill Dairy has two 8-inch wells 108 feet deep and extending about 70 feet into the shale. The yield from both these wells is about 120 gallons per minute, and the daily pumpage at the plant is about 50,000 gallons. The supply at the United Fireworks Co. is developed from three wells about 80 feet deep that encounter the shale only 7 feet below the ground surface. The average yield of each of the United Fireworks Co. wells is about 40 gallons a minute. The daily pumpage is about 70,000 gallons.

Largely on the basis of the 1946 well survey and the results of the field tests of farm wells given in table 3, it seems probable that nowhere within this county can adequate water supplies for home or farm be generally expected from small-diameter wells in the Ordovician shales. The average yield of the few wells that do encounter water in these rocks is about 1 gallon per minute with a large drawdown of the water level and a slow rate of recovery. In many cases drilled wells in the shale act primarily as reservoirs, the water



Fig. A. Contact between the Brassfield limestone formation (Silurian System) and the Ordovician shale along Union Road in section 3, SW, Jefferson Township.

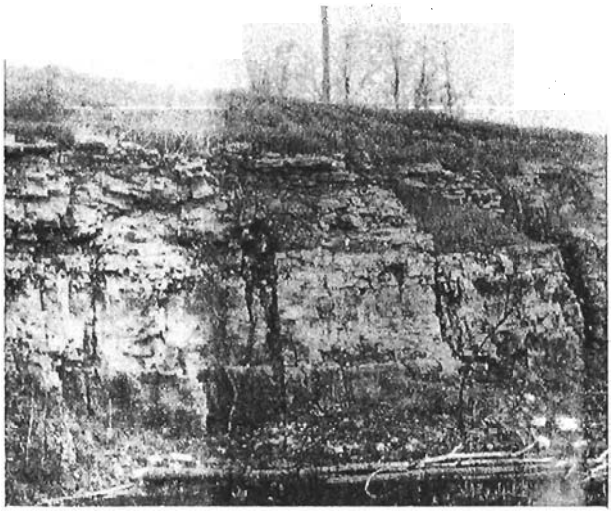


Fig. B. Exposure of the Brassfield limestone in section 12, Jefferson Township, showing the difference between its upper and lower sections.



Fig. C. Contact between the Dayton and Brassfield formations three miles north of Montgomery County, showing the character of the bedding.

entering the well between the bottom of the casing and the top of the bedrock. As a 5 5/8-inch diameter casing has a capacity of about 1 gallon per foot, considerable storage is possible in a deep well and is available for intermittent pumping. In instances where no water is found in glacial materials above the shale, most drillers recommend moving to a new location as far away as the property lines permit and drilling a new well to the top of the shale, rather than drilling an equivalent footage into the shale at the original location.

There are only a few areas in Montgomery County where it is necessary to haul water in dry periods. The poorest ground-water areas are in portions of German, Miami, and central Jackson Townships, and limited areas in Jefferson and Van Buren Townships. In these areas the Ordovician shales are overlain by thin glacial till which also yields meager water supplies.

The water levels in two typical shale wells - Mt 14, located at the northwest edge of Dayton, and Mt 35, west of Dayton at the County Infirmary have been measured, usually at weekly intervals, since the spring of 1946. The hydrographs of these wells are shown on plate 13, in comparison to hydrographs of typical upland wells drilled into the glacial drift. Fluctuations occur in all wells in response to precipitation, though the magnitude of the fluctuations in the shale wells is less than in those of the other wells.

Silurian system

Beds of Clinton (?) age

The Brassfield limestone is the only formation of Clinton (?) age in Montgomery County and in early reports was called the "Clinton limestone". Lithologically the Brassfield occurs in two distinct phases. The lower part of the formation is evenly bedded, massive, light gray in color, and contains few fossils. The upper part of the formation is comparatively thin bedded and so irregular that it is almost impossible to trace a single bed more than a few feet. It is extremely fossiliferous and, on the outcrop, dark gray to pinkish in color. Small fossil crinoid fragments are abundant along bedding planes in the upper part of the Brassfield and may make up as much as 50 percent of some of the beds. The average thickness of the upper part of the Brassfield is about 10 feet, and the total thickness of the formation in Montgomery County is about 30 feet. Plate 12B is a photograph of an exposure of the Brassfield limestone showing the difference between its upper and lower parts.

At places near the base the Brassfield contains a coarsely granular layer made of limestone sand. This is the "firestone" layer, so called because this stone was formerly used for hearths and chimneys. The

firestone layer is found at only one locality in Montgomery County, at the county line in sec. 2, Butler Township. The firestone layer is porous and probably is a potentially better water-bearer than the rest of the formation, but because of its limited distribution it is not regarded as significant within this county.

The Brassfield limestone occurs at the surface in patches and irregular belts over large areas in the northern and northwestern parts of the county, and in outliers in other parts. Because of its stratigraphic position above the softer Ordovician shales, it is the principal outcropping bed in Montgomery County.

As a general rule the Brassfield limestone can be depended on to yield adequate water supplies for farm or domestic use, especially at the base of the formation where it overlies the impervious Ordovician shales. Percolating waters concentrated along this contact zone have enlarged cracks or other openings by solution to form a prominent spring zone in the northern part of the county. Many drillers carry wells in Silurian rock through this contact zone and a few feet into the underlying shale.

Wells in the Brassfield limestone generally yield up to 15 gallons per minute, a few wells yield 100 gallons per minute, and an occasional well yields more than 100 gallons per minute. The largest known supply developed chiefly from the Brassfield limestone is at the Aeroproducts Division of General Motors Corp., at Vandalia. This company has three wells, each 135 feet in depth, which are used to furnish a reserve supply when needed. These wells enter bedrock at about 60 feet and penetrate 55 feet of Silurian rocks, mostly the Brassfield limestone, before entering the Ordovician shales. Two of the wells are 10 inches in diameter and have capacities of 80 gallons per minute each. The other well is 12 inches in diameter and its capacity has varied from 160 to nearly 200 gallons per minute.

In a few areas the basal part of the Brassfield limestone contains small quantities of crude oil which may contaminate wells. Such an area is in the NW $\frac{1}{4}$ sec. 22, Perry Township, where several gallons of oil were skimmed from the water in a Brassfield well. Another area where wells are contaminated by oil is along Union Road, about 2 miles due south of Trotwood in Madison Township. At this place the source of the oil is conjectural, though in all probability it is derived from the base of the Brassfield or from the top of the underlying shale.

The areas in Montgomery County where most rural water supplies are obtained from the Brassfield limestone are in parts of Clay, Randolph, Butler, Wayne, and Van Buren Townships, and in the central parts of Perry, Madison, and Washington Townships.

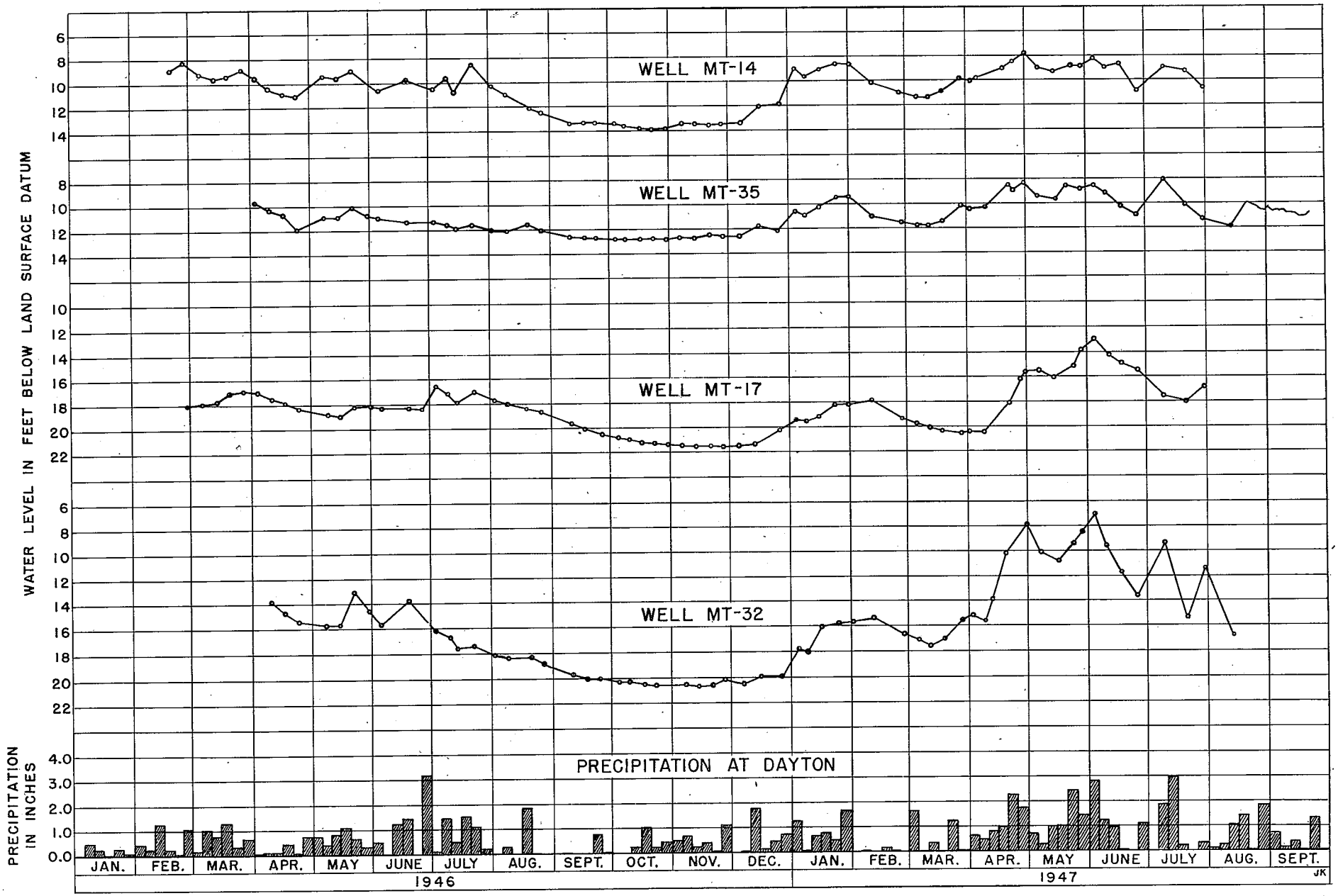


Plate 13. Hydrographs of wells in upland glacial deposits (MT-17 and 32), and of wells in Ordovician shale (MT-14 and 35), compared to precipitation.

Beds of Niagara age

Above the Brassfield limestone, and resting conformably on it, occur beds of Niagara age, comprising the six formations listed in table 8. These strata consist of more than 100 feet of limestone and dolomite with a 15-foot shale bed near the base of the section.

The basal formation of the sequence of Niagara age is the Dayton limestone. This rock is dolomitic in composition, white in color, and of compact, dense texture. As shown on plate 12C, it is remarkably even bedded, the beds being up to 18 inches thick in the lower portion and becoming thinner toward the top of the formation.

The Osgood formation, which overlies the Dayton limestone, is a gray calcareous clay shale in its lower part, and contains beds and lenses of shaly limestone towards the top. As with most shales of this type, the Osgood is not a source of water and it is important chiefly as a horizon marker.

The rocks of Niagara age above the Osgood formation in Montgomery County comprise four formations in ascending order, the Laurel dolomite, Euphemia dolomite of Foerste, Springfield, and Cedarville dolomites, having a total thickness of more than 70 feet. The Cedarville dolomite, at the top of the section, is a massive, porous dolomite having good water-bearing properties. The three formations underlying the Cedarville are more evenly and thinly bedded, somewhat dense, and not as porous.

The average yield of the wells drilled into the rocks of Niagara age in this county ranges from 5 to 15 gallons per minute, and a few wells yield as much as 100 gallons per minute. One such well of large capacity is owned by Mr. H. G. Klemp of Route 2, Brookville, and is in the northwest part of sec. 2, Clay Township. This is a 12-inch diameter well drilled 45 feet into the rock, which was encountered 15 feet below the ground surface. The capacity of this well is described by Mr. Klemp as follows: "If no air is let into the top of the casing the well will supply 100 gallons per minute all day long." Mr. Klemp added that the capacity of the well drops to about 60 gallons per minute if air is let into the casing.

Recharge to the Silurian rocks in this county must come primarily from direct precipitation, because the larger streams flow in valleys that are cut well below the base of the Silurian rocks. The recharge probably occurs slowly because the Silurian rocks are capped by relatively impermeable glacial till throughout most of the county. The water-bearing characteristics of these rocks are extremely variable. Wells only a short distance apart and penetrating the rocks to the same depths and horizons may show large differences in capacity. Generally they yield sufficient water for most farm requirements after penetrating the rocks about 20 feet.

In a few places cracks or other openings in the Silurian rocks are filled with mud derived from the weathering of the rocks and concentrated by percolating water. These mud seams made some wells unusable because the water does not become clear. During the well survey this condition was found in a well in sec. 25, Clay Township. Water from the well was gray in color from the suspended mud, which settled thickly in containers. Sometimes these mud seams can be effectively sealed off in a well, and, as they are rarely of wide lateral extent, wells are often relocated on the possibility of avoiding them at another location.

Rocks of Niagara age occur above the Brassfield limestone over wide areas, principally in the northern and northwestern parts of the county, and to a lesser extent in the outlier area in the southeast in Van Buren and Washington Townships. Outcrops of the formations of Niagara age are uncommon in this county. Four feet of the Dayton limestone and a small portion of the Osgood formation are exposed at the abandoned quarry 1 mile northeast of Centerville, in Washington Township. The Springfield and Cedarville dolomites are well-exposed at a former lime kiln in sec. 29, Wayne Township, and the Cedarville is quarried on a 30-foot face about 1 mile south of Phillipsburg, in Clay Township. Locations of rock outcrops are shown on plate 1.

The areas in Montgomery County where most rural water supplies are obtained from rocks of Niagara age are Clay, Randolph, Butler, and Wayne Townships in the northern part of the county.

THE GEOLOGY AND WATER-BEARING PROPERTIES OF THE UNCONSOLIDATED DEPOSITS

Most of the thick mantle of clay, gravel, sand, and stones that now covers Montgomery County was left by the continental ice sheets of Pleistocene age. Four times in the last million years deep snows accumulated over vast areas in Canada and northern United States and became gradually compacted into glacial ice. At least two of these ice sheets or glaciers spread southward as far as southern Ohio. The latest ice sheet, that of the Wisconsin stage, advanced within a few miles of Cincinnati and covered Montgomery County for several thousand years. The Wisconsin glacier melted off this area about 30,000 years ago.

The glacial stage that preceded the Wisconsin is called the Illinoian stage. The Illinoian ice advanced farther south than any of the other glaciers to reach a point slightly south of Cincinnati. Illinoian drift is not exposed in Montgomery County but has been penetrated by some wells and deep excavations. The Illinoian glacier is believed to have melted off this area some 200,000 years ago.

The Illinoian stage was not the oldest glaciation of Ohio, for it is evident from drainage changes that at least one earlier ice sheet approached Montgomery County. Probably it never quite reached this area, for its drift has not been recognized in wells here. This pre-Illinoian glacier is thought to have been that of the Kansan stage, which occurred about 600,000 years ago.

The bedrock surface and former drainage systems of Montgomery County

Preglacial topography in Montgomery County

Before glaciation, Montgomery County probably resembled that part of the Bluegrass region of Kentucky that lies just south of the glacial border. The topography of both areas had a similar origin with respect to both structure and stratigraphy. They are areas of regional uplift in which rocks of Upper Ordovician age, with a border of lower Silurian limestones, are exposed at the surface. The present Bluegrass area has a fairly smooth, gently rolling surface deeply dissected by short tributaries and broad, entrenched rivers (14), similar to the bedrock topography of Montgomery County. The covering of glacial drift over Montgomery County has subdued the former relief and masked all but the most prominent features of the ancient drainage.

Preglacial (Teays Stage) drainage

The earliest recognizable drainage system in Ohio is called the Teays and all streams in existence at that time are referred to as "Teays Stage" drainage. The Teays system, it is thought, antedated the earliest of the glacial stages of the Pleistocene epoch and is regarded as late Tertiary. The master Teays River rose in the Piedmont area in the southeastern part of the United States and flowed across Ohio in a northwesterly direction in a course that lay a few miles to the north of Montgomery County.

Montgomery County, because of a drainage divide in the north, was not drained by the main Teays River, but by a large tributary named the Hamilton River. The Hamilton River flowed southward through Butler and Hamilton Counties and entered the Teays River somewhere in Indiana.

The Hamilton River entered Montgomery County from the east near the boundary line between Mad River and Van Bureau Townships (see pls. 1 and 14). From this point the Hamilton flowed westward to Dayton, cutting the part of its valley now occupied by the Mad River. At Dayton the Hamilton River received the waters of three large tributaries, whose courses are now occupied by the Miami River, Stillwater River, and Wolf Creek. These tributaries terminated in the

uplands of Montgomery County at col areas, respectively at Tadmor, Englewood, and Arlington, as shown on plate 14. From Dayton to West Carrollton the Hamilton River cut a broad course that is now occupied by the Miami River. From West Carrollton the preglacial Hamilton flowed westward through Ellerton and thence southward past Germantown to the county line. Near Ellerton the Hamilton was joined by two large tributaries, both of which entered Montgomery County from the west. The width of the Hamilton valley in this county is 3 miles in places.

A col, or drainage divide, existed at Miamisburg in Teays time, separating two short, opposite-flowing Hamilton tributaries. Cols also existed at points about 2 miles north and about 3 miles northwest of Germantown.

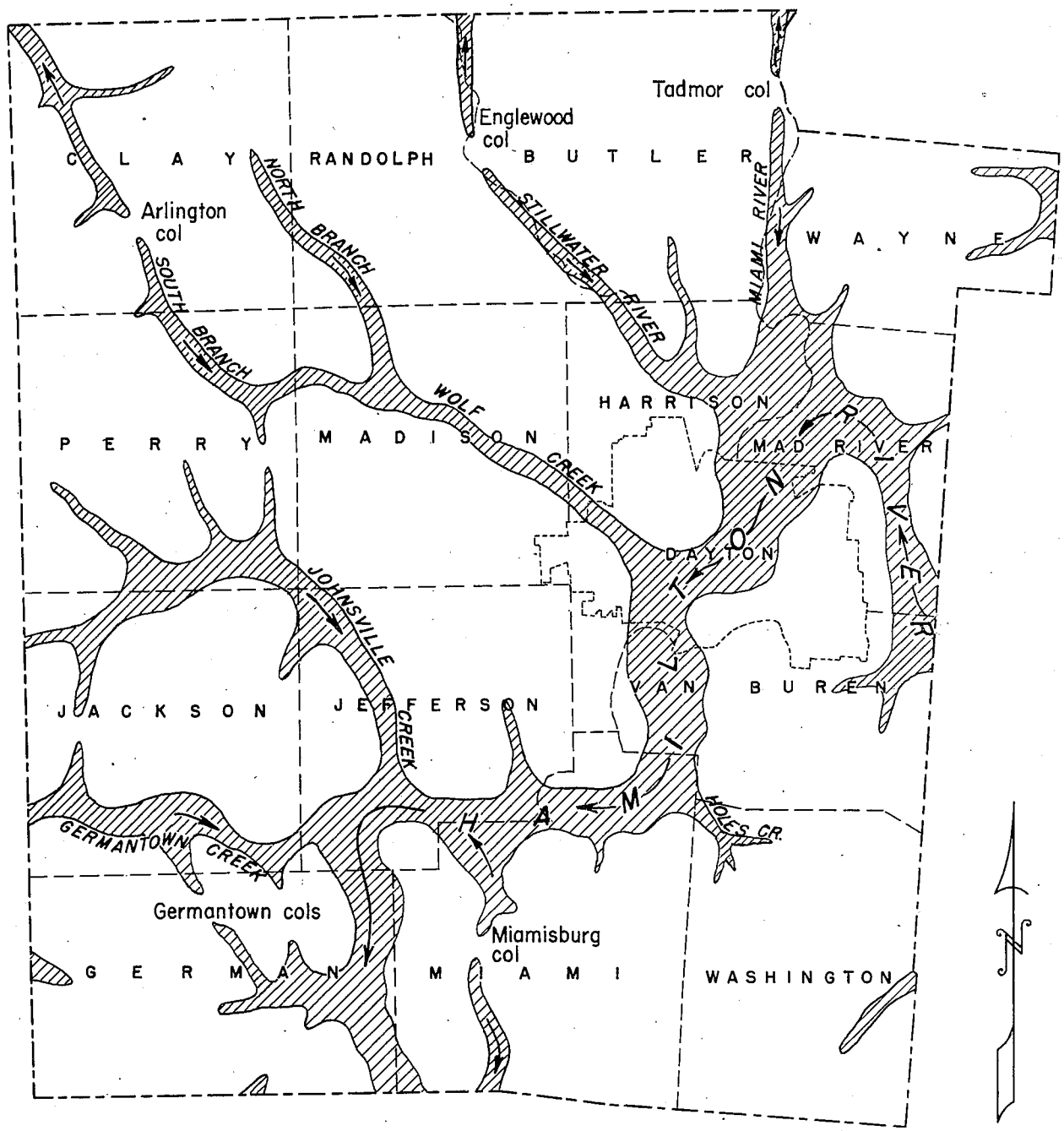
Not all the preglacial streams of Montgomery County drained into the Hamilton River. North-flowing tributaries from the master Teays River had cut back into the county from the north to terminate at the col areas at Tadmor, Englewood, and Arlington. These tributaries of the main Teays cut the northern parts of the courses of the present Miami and Stillwater Rivers and Wolf Creek.

In Montgomery County streams of later drainage stages greatly deepened the valleys originally developed in Teays time and only a few scattered remnants of the Teays valley floor are found. Remnants of the Teays valley floors occur as terraces along some of the more recent valleys. Such rock terraces are well-preserved along both sides of the present Stillwater River at elevations of 750 to 770 feet, and are seldom covered by more than 30 feet of glacial drift. Teays level terraces also occur at about the same elevation in patchy distribution along the Miami River from the southern border of Butler Township to the vicinity of Tadmor. The Teays level is found near Chatauqua, in the southern part of the county, at an elevation of about 650 feet.

The Teays system, according to Stout and others (2), was terminated by the advance of a very early, pre-Illinoian glacier, perhaps of the Kansan glacial stage. This early glacier, it is thought, never reached the area of Montgomery County, but it did advance to a point where it blocked the main Teays River to the north. This action caused major diversions of the drainage lines.

Interglacial (Deep Stage) drainage

The Deep Stage drainage system was begun by the advance of the pre-Illinoian glacier and was terminated by the later advance of the Illinoian ice sheet. It is called Deep Stage because during this time the streams cut deep, narrow valleys many feet below the levels established in Teays time.



PREGLACIAL VALLEYS

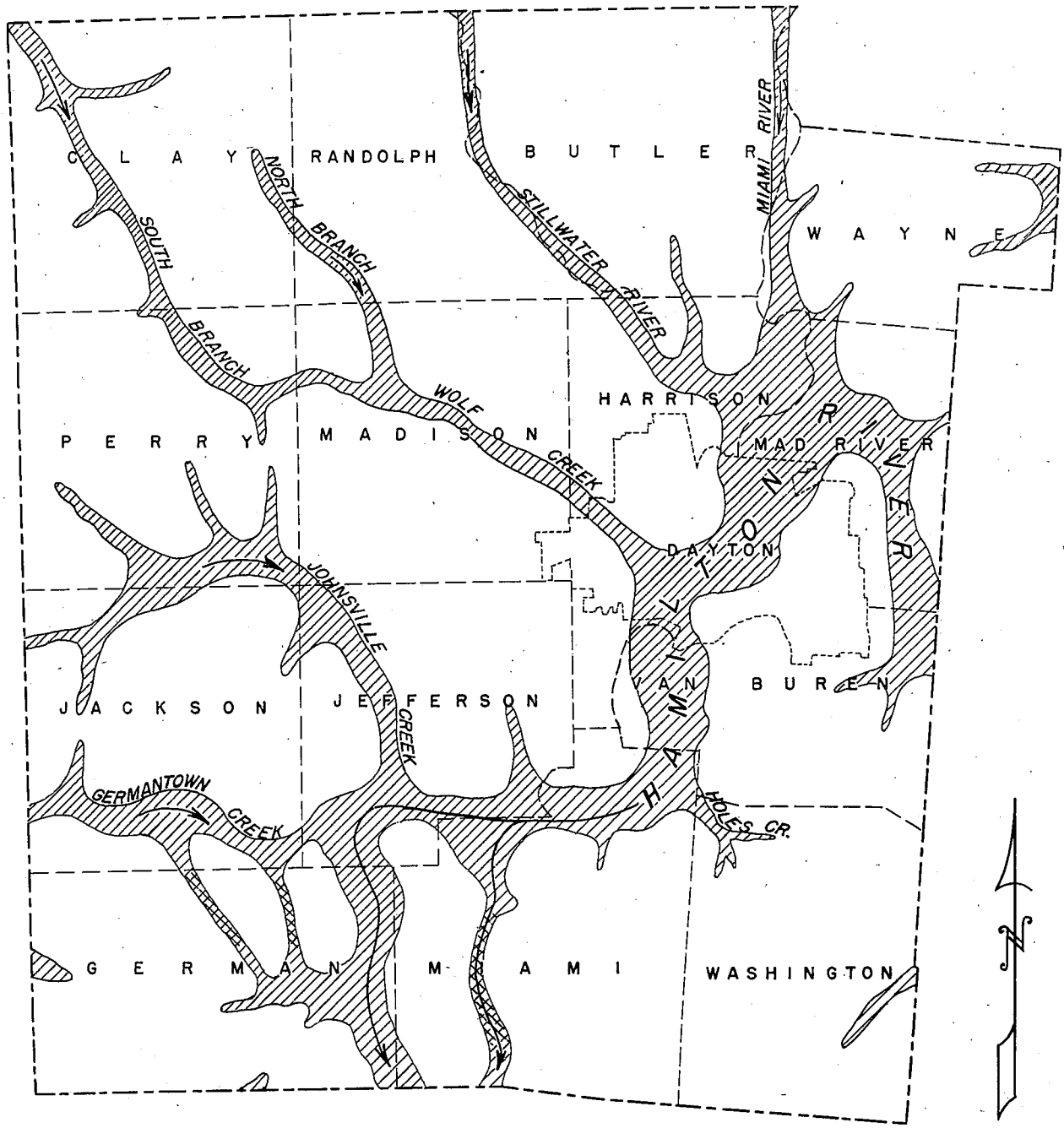
MONTGOMERY COUNTY

0 1 2 3 4 5 6

SCALE IN MILES

JK

Plate 14.



INTERGLACIAL VALLEYS

COURSE DURING DEEP STAGE TIME

COURSE IN POST-ILLINOIAN TIME

MONTGOMERY COUNTY

0 1 2 3 4 5 6

SCALE IN MILES

JK

Plate 15.

As indicated by the arrows on plate 15, it seems evident that the Hamilton River in Deep Stage time persisted in its original course in Montgomery County, as did its principal tributaries. Three of these tributaries, the Miami River, Stillwater River, and Wolf Creek, were extended northward beyond the county after the cols at Tadmor, Englewood, and Arlington were cut through. The Deep Stage valleys in Montgomery County are comparatively wide, perhaps as much as a mile in the Hamilton valley. The lowest elevation of the valley floor recorded at Dayton is about 513 feet, more than 200 feet lower than the Teays level. A well (log 639) thought to be near the axis of the Deep Stage channel a mile west of West Carrollton, struck bedrock at a depth of 212 feet, or at an elevation of about 500 feet. If this point and the one at Dayton are in the deepest parts of the valley, the gradient of the Deep Stage valley was about 1 foot per mile.

Effects of glaciation on the drainage in Montgomery County

The most important of the drainage diversions caused by the Illinoian glacier in Montgomery County was in the Miamisburg area, where the ice forced the main Hamilton drainage through a narrow col that in Teays and Deep Stage times had separated two short tributaries (see pl. 15). When the principal drainage became established through the Miamisburg col, that part of the Hamilton valley estending from the vicinity of Ellerton around to the southeast corner of German Township was abandoned and later buried by glacial drift. Other drainage diversions were created near Germantown where two narrow cols, one at the site of Germantown Dam about 2 miles northwest of town, and the other about 2 miles due north of town, were cut through. These col areas are now occupied by Little Twin Creek and Twin Creek, respectively.

The Wisconsin glacier may have caused some changes in the drainage lines of post-Illinoian time. Perhaps the Wisconsin ice caused some of the changes in the Deep Stage drainage system that are credited herein to the Illinoian glacier. It is believed, however, that the main effect of the Wisconsin ice sheet on the former drainage was in supplying the greater part of the unconsolidated materials that now fill these valleys.

Pre-Wisconsin glacial deposits

Older drift is found beneath deposits of the Wisconsin stage at the five localities indicated on plate 2. The age relationship of the Illinoian and the Wisconsin tills formerly was clearly shown at the base of the bluffs along Twin Creek, one mile east of Germantown in SE $\frac{1}{4}$ sec. 18 (15), where a buried soil zone was formerly exposed. This zone, containing the remains of trees and other vegetation, is

overlain by several feet of unweathered blue-gray Wisconsin till, providing evidence that the Wisconsin glacier overrode these old forests. In ten other localities in the county buried layers of yellow till have been reported in wells. A few of these yellow layers may represent soils formed on Illinoian till during the following interglacial stage, from which the vegetation was removed by the advancing Wisconsin ice before its drift was deposited. The pre-Wisconsin glacial deposits are not well enough known, nor are they believed to be of sufficient importance relative to the water resources of the county to warrant more complete discussion.

Wisconsin glacial deposits

There are two general types of glacial drift, that deposited directly by the ice sheet, and that deposited by melt water flowing from the ice. Melt-water materials, commonly called outwash, were deposited as kames, outwash plains, and valley trains. The ice-laid material consists of till, a mixture of unstratified rock materials ranging in size from minute particles to boulders. Till is generally called "hardpan" or "clay" by well drillers.

Ground moraine

The ground moraine consists chiefly of till which is high in clay content, compact, and largely impervious. Over large areas of the northern and western parts of Montgomery County the ground moraine obscures the underlying bedrock topography to produce the flat till plains especially characteristic of Clay and Perry Townships. Ground moraine, indicated as less than 20 feet thick on pl. 2, ranges from slightly more than this figure to less than 1 foot in areas of bedrock outcrops. On the same map, ground moraine indicated as being more than 20 feet thick may range from slightly less than 20 feet to as much as 150 feet thick where it covers buried valleys.

Most of the water supplies developed in the ground moraine are taken from large-diameter dug wells. These wells provide a large wall area for infiltration and a large storage space for accumulation of water between periods of pumping. The average depth of dug wells in Montgomery County is 25 feet, according to Works Progress Administration records of 807 wells. The average yield of these wells in the ground moraine is from 2 to 10 gallons per minute. Most of them are equipped with hand lift pumps, though a few are provided with small gasoline or electrically-powered pumps. In recent years many owners have installed large-capacity water systems on dug wells. Many of them find that, "for the first time since Grandad dug it, the well went dry." This has led to the

widespread belief in a constantly declining water table. However, it usually indicates only that the new pump withdraws water faster than it can seep from the till into the well.

Most water supplies in excess of about 10 gallons per minute that are obtained from wells in the ground-moraine areas come from outwash deposits in buried valleys covered by the till, or from lenses of gravel or sand within the till. The stratified deposits interbedded in the till are generally of limited thickness and extent and are termed "gravel streaks" or "pockets" by drillers. They were probably deposited by streams of melt water at the bottom of the ice sheet and were later covered by deposits from the ice above. They receive water from the till and make it more readily available to wells. Most of the drilled wells in the upland areas of the county that are not in buried valley areas, or do not penetrate the consolidated rocks, derive water from these interbedded stratified layers.

The water level in a typical dug well in the ground moraine in western Montgomery County has been measured, usually at weekly intervals, since April 1946. The hydrograph of this well (Mt 32) is shown on plate 13, in comparison with the hydrographs of other wells and the precipitation for the period. The water level in well Mt 32 responds rapidly to precipitation.

End moraine - Till phase

The areas of end-moraine glacial deposits in Montgomery County are shown on the map in plate 2. End moraines are deposits that accumulated along the ice front when the front remained relatively stationary for a long time. End moraines extend in irregular parallel bands across Illinois and Indiana into Ohio. They are hummocky ridges a few miles broad and as much as hundreds of miles long, rising 10 to 40 feet above the general level of the surrounding till plain. Plate 16 shows the different positions of the ice edge relative to the end-moraine system in Montgomery County.

The till of the end moraine is sandier in composition and contains more stony layers so that its water-bearing properties might be expected to be somewhat better than those of the clay-rich till of the ground moraine. More sand and gravel lenses are embedded in the till of the end moraine because of the shifting of the ice front. End-moraine till is thicker and probably furnishes more water to bedrock fissures or to interbedded sand and gravel layers. Dug wells in this area therefore might be expected to have a greater average capacity than those of the ground-moraine areas and a greater number of drilled wells should be successful.

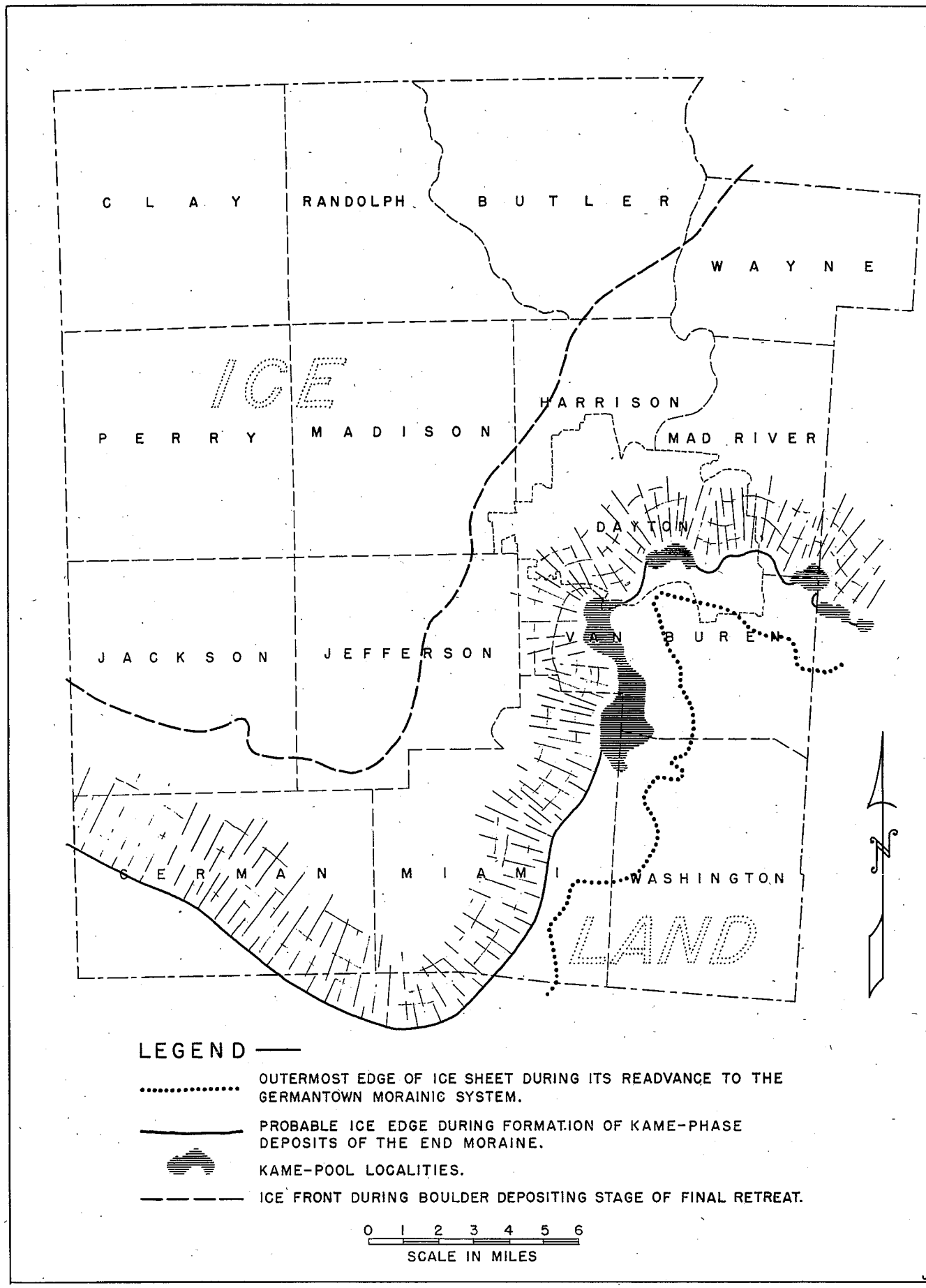


Plate 16. Map showing positions of the edge of the ice sheet in Montgomery County, Ohio.

End moraine - Boulder-strewn belt

An interesting combination of deposits in this area is the so-called boulder belt, which is principally associated with the ground moraine. The boulder belt is an accumulation of large rounded boulders stretching in a big loop across the county through Farmersville, Ellerton, Drexel Park, and Northridge, to Taylorsburg. As shown on plate 2, it passes over thin and thick till areas and over hills and valleys. It roughly parallels the ice-front position as it was when the so-called Germantown moraine was formed (see pl. 16). Over the normal ground moraine there is to be seen hardly one large boulder to a field. Within the boulder belt, however, from 5 to 500 boulders are sometimes strewn over each field or gathered and piled along fence rows. Apparently the boulder concentration extends at least a few feet below the surface, and numerous boulders might be encountered in these areas in drilling operations. The boulder belt probably has no significance relative to the water supplies of the deposits upon which it rests.

Ground moraine overlying sand and gravel

In the Miami River, Mad River, and Wolf Creek Valleys north of Dayton, and on the higher land south of Dayton, there are extensive areas of till over gravel. In these areas wells are drilled through the till into the gravel, where good water supplies are obtained in many places.

Kames and kame moraine

Kames are hummocky deposits of sand and gravel, and those in Montgomery County were formed along the edge of the melting ice sheet.

South and southeast of Dayton a remarkable kame moraine was formed as the northeastward continuation of the so-called Germantown moraine. (See pl.16) The high gravel hills at Southern Hills and Oakwood Heights described by Professor Foerste (5) were formed by melt waters trapped between the thinning ice edge and the steep eastern wall of the Miami Valley. Flooding melt water built these kame deposits as thick as 180 feet and as high as the 920-foot contour. These melt waters were discharged down the north branch of Sugar Creek Valley to the Little Miami River. The kame-moraine deposits of the Oakwood-Southern Hills area rest upon the outwash gravels that make up most of the fill in the Miami Valley. Bedrock over much of this area is probably as much as 300 or 350 feet below the surface. The materials of the kame deposits, as seen in numerous exposures, range from fine sands to very coarse gravels. The permeable gravels and sands of the kame deposits provide excellent ground-water supplies except where the deposits are above the regional water table.

The average depth of the drilled wells in the Oakwood-Southern Hills kame area is more than 150 feet. No large water supplies have been developed in this area. A 5 5/8-inch diameter well at the northwestern intersection of State Highway 25 and Dorothy Lane, in the NW ¼ sec. 11, Van Buren Township, had a capacity of at least 100 gallons per minute as estimated by Mr. R. B. Billman, representative of the Fairbanks-Morse Pump Co. The depth of this well was 159 feet and the static water level was 129 feet below the surface. It was not equipped with a well screen.

The base of these kame deposits, where the material rests on the valley-train deposits, is an important spring zone. This spring zone might result from a buried till layer at the base of the kame deposits, which deflects the water to the surface; otherwise it is difficult to explain its presence.

In the Little York area along the eastern bank of the Stillwater River, the Ordovician shale is overlain by kame deposits. The shale here occurs at depths as shallow as 20 feet in places. In this area no large water supplies are developed. Nearer the river and along its western bank the gravels are thicker and some supplies are obtained at depths ranging from 60 to 90 feet.

Kame deposits of limited extent overlying the Ordovician shale occur along northern Smithville Road in Mad River Township. As this area is served by city water, no wells are present and therefore little is known of the water-bearing properties of these deposits.

The valley-train deposits

The valley-train deposits originated as outwash from the melting glaciers. For a time after the ice disappeared from Montgomery County, it still lay thick over areas to the north. Floods of melt water swelled the flow down first one and then another of the valleys, bringing with them vast quantities of glacial debris. Periodic changes in velocity of flow caused deposition of layers of glacial materials ranging in size from coarse gravel to fine sand. Pore spaces in these outwash deposits are large and the openings are interconnected, producing highly permeable deposits through which water is readily transmitted to wells. Sections of outwash at matching levels on opposite sides of the present rivers show that the valley train originally formed a continuous surface extending across the valleys. Modern streams have cut into the deposits and covered them with alluvium in the narrow areas shown on plate 2.

Interbedded in the sands and gravels of the valley train are layers and irregular lenses of till. These impermeable till deposits have important effects on ground-water conditions in the valleys.

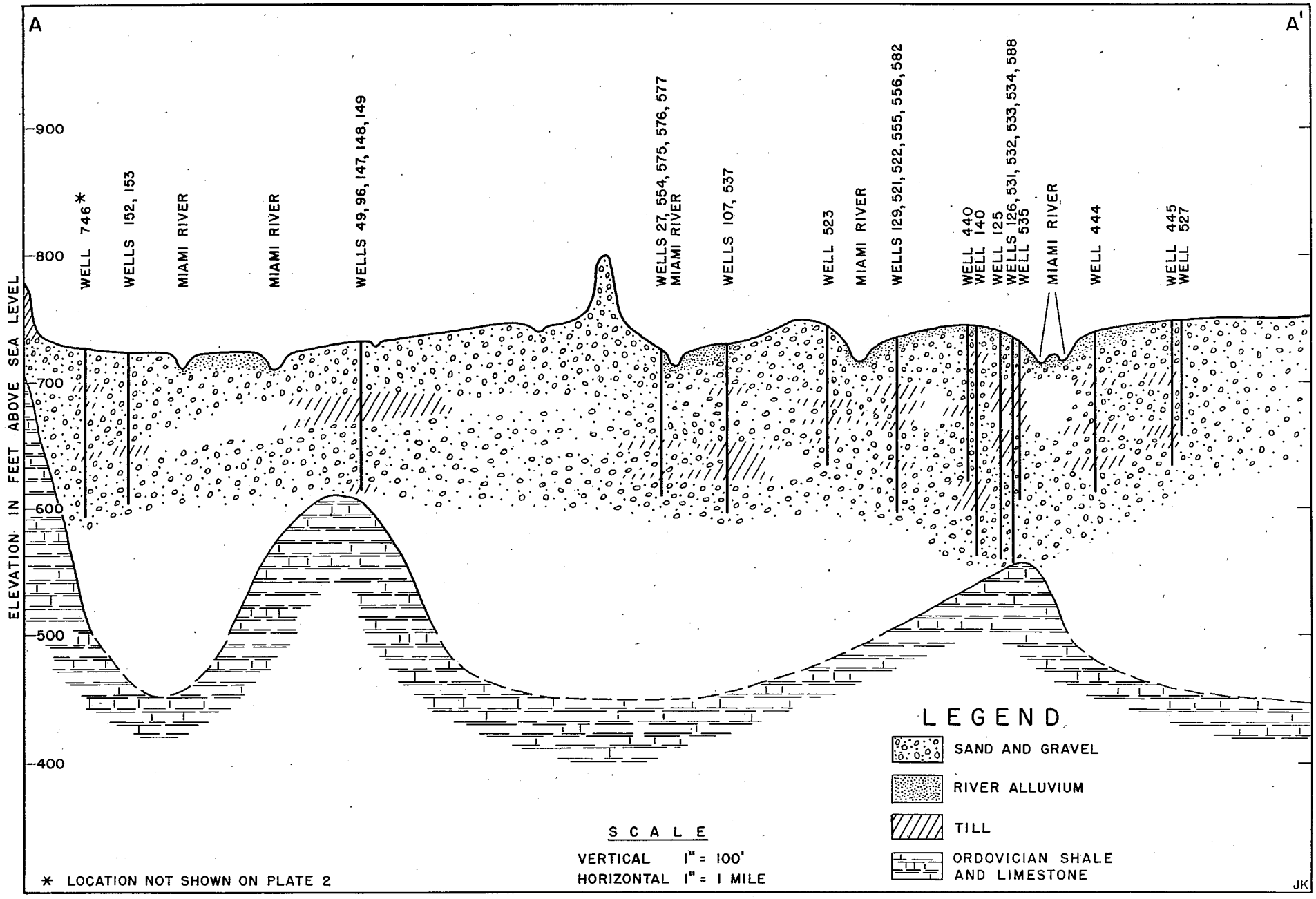


Plate 17. Cross section along line A–A' shown on map of glacial deposits (plate 2), Montgomery County, Ohio.

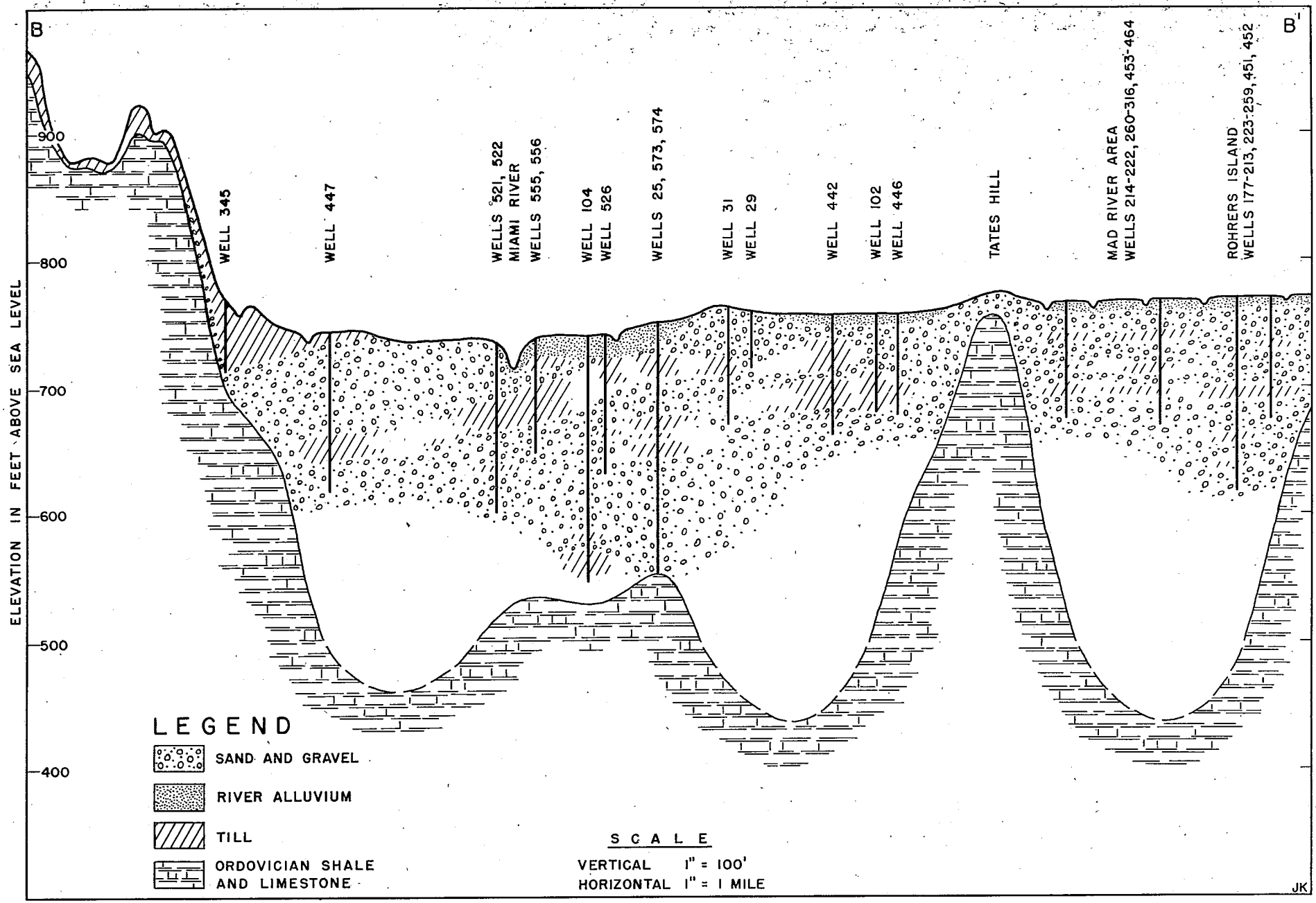


Plate 18. Cross section along line B–B' shown on map of glacial deposits (plate 2), Montgomery County, Ohio.

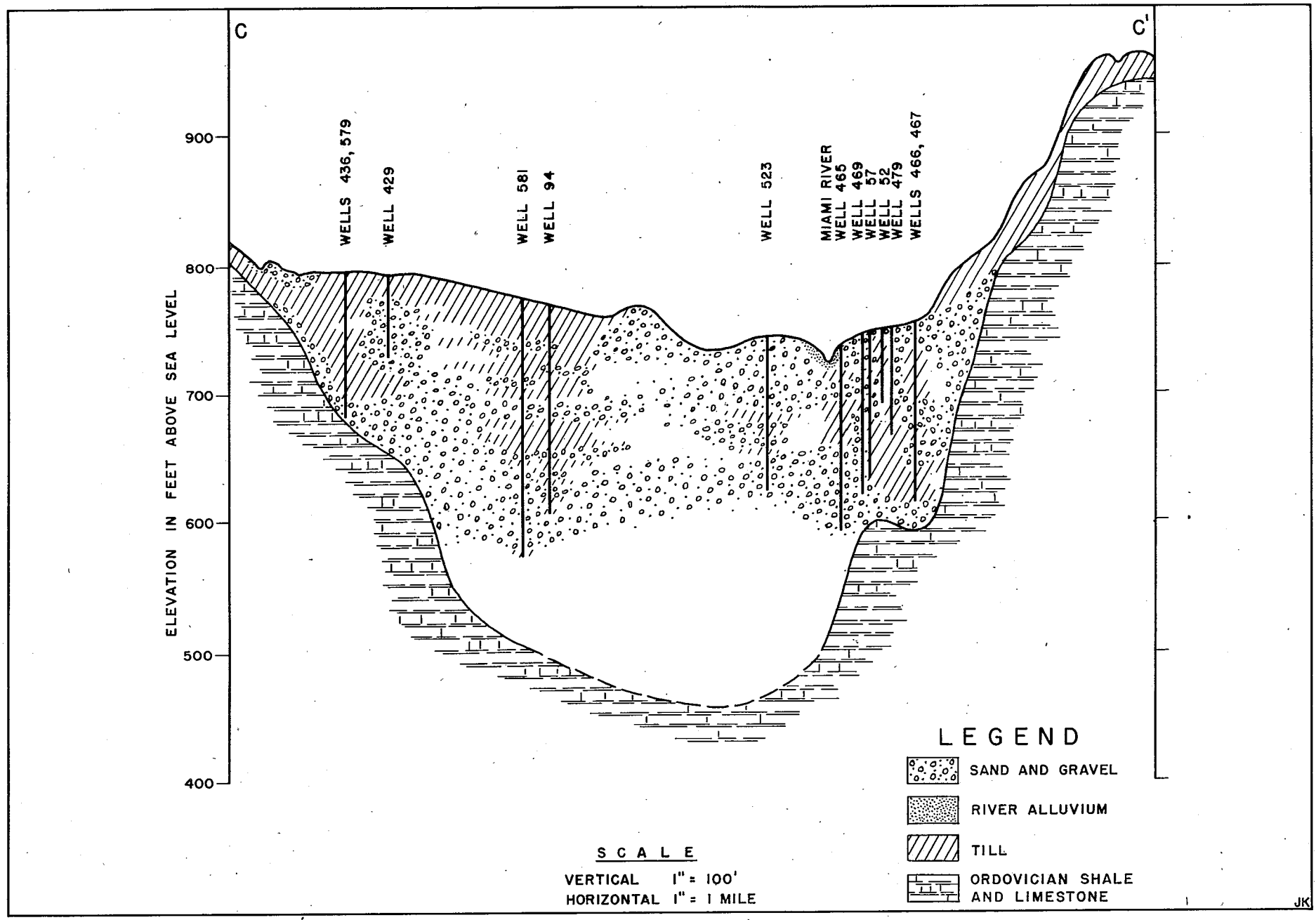


Plate 19. Cross section along line C – C' shown on map of glacial deposits (plate 2), Montgomery County, Ohio.

The relation of these interbedded till deposits to the outwash gravels is shown in three cross sections (pls. 17, 18, and 19) through the buried valleys along lines A-A', B-B', and C-C' shown on plate 2. An attempt has been made to correlate similar deposits from one well to another. Because of the complex nature of the deposits and the limited information available, these cross sections can be only approximate and local conditions cannot be inferred from them with certainty.

The total thickness of the glacial drift in the preglacial valleys of this county is as much as 200 to 300 feet in the deeper parts. This thickness of material is sufficient to fill most of the valleys, especially those lying roughly parallel to the direction of ice flow, to about two-thirds of their former depths. Other preglacial valleys, especially in the western part of the county, whose courses lay roughly transverse to the direction of ice flow, were buried so completely that their presence cannot be detected from surface features.

As shown on plate 11, practically all the large water supplies of Montgomery County are obtained from the gravels of the valley-train deposits. A general discussion of the types and yields of wells in these deposits is given in the section entitled, "Utilization of ground water in Montgomery County." Data on individual wells and water supplies are also given in that section. More detailed discussions of the character of the deposits and ground-water conditions in the buried valleys are presented in the section entitled, "Ground-water conditions in specific areas."

Recent river alluvium

Alluvium consists mostly of river silts and sands deposited by the present streams as they have cut their channels into the glacial deposits. The locations of alluvial deposits in Montgomery County are shown on plate 2. The alluvium is thin and consists primarily of fine, impermeable materials. They are not a good source of ground water but the glacial deposits underlying them often furnish large supplies of ground water.

GROUND-WATER CONDITIONS IN SPECIFIC AREAS

The maps on plates 1 and 2, contained in the cover pocket of this report, show respectively the kinds and relationship of the unconsolidated deposits covering the surface of Montgomery County, and define the bedrock systems that underlie these deposits. The locations of wells, for which records are given in the appendix of this report, are shown in the map on plate 2. These offer an indication of the types of deposits existing at various depths in different parts of the county.

Wolf Creek Valley, North Branch

The North Branch of the buried valley of Wolf Creek extends from Trotwood, in central Madison Township, to the eastern edge of Clay Township in the vicinity of Clayton. The surface material in this valley is till, as shown on plate 2.

In the upper part of this valley, log 135 shows the surface till to be about 40 feet thick, underlain by 90 feet of fine sand above the shale of Ordovician age. The sand found in this well is of interest chiefly because of its uniformly fine grain size. A sample furnished by the driller, Mr. D. J. Roe, of Vandalia, was examined microscopically by Prof. W. J. McCaughey of Ohio State University, who noted its characteristics as follows: The sample consisted of about 50 percent quartz grains with lesser amounts of several other minerals derived from igneous rocks. Seventy-five percent of the sample could be sieved through a screen having openings of about 1/100 inch. The individual grains of the material were fresh appearing and angular in shape, showing little evidence of weathering.

This seems to be the type of sand that offers much difficulty to well drillers because of the way it heaves up into wells. It is believed to exist at many places in other parts of the buried-valley systems in this part of the State.

Near the southern end of the North Branch of Wolf Creek Valley, log 138 shows the upper till to be 183 feet thick. Below this till 7 feet of fine sand was penetrated before drilling stopped. It is possible that, as in well 135, this sand continues to the bedrock surface, which is probably less than 50 feet below the bottom of the well.

The evidence afforded by these two well logs indicates that this valley is filled with predominantly fine material in its deeper parts, this material being overlain by a considerable thickness of till. The maximum thickness of the glacial material in this valley may approach 200 feet. Unless further drilling reveals coarser gravels below or interbedded in the till, only household or farm supplies are likely to be developed. The fine sand is not suitable for well development because it clogs pumping equipment and wells.

Wolf Creek Valley, southern branch

In the Teays interval of erosion the southern branch of Wolf Creek extended northwest from Trotwood to the col area near Arlington. In the Deep Stage interval of erosion the valley was extended beyond the county limits by junction with a north-flowing Teays tributary, after the col separating the two was cut through. The surface material in this valley consists of till, as shown on plate 2.

A well drilled in this valley in Darke County, 1 1/3 miles north of Verona, penetrated 150 feet of till and 100 feet of fine sand before striking bedrock. Log 650 of an unsuccessful well drilled just north of Providence Church in sec. 11, Perry Township, shows more than 250 feet of till and sand. These well logs indicate that conditions are similar to those found in the northern branch of this valley.

Brookville municipal water supply

The largest water-supply development in this valley area is at the Brookville waterworks, but it is not certain whether the water is derived from unconsolidated materials in the valley, or from the Silurian limestones that flank the valley. Brookville has four wells, ranging from 67 to 102 feet in depth. The average static water level is 71 feet below the surface and the average yield from each of these wells is 125 gallons per minute, with an average drawdown of about 12 feet. The average daily consumption amounts to 200,000 gallons. If the Brookville supply does come from unconsolidated deposits they must be coarser than the fine sand found in other parts of this valley, and further drilling might reveal other such potentially good areas.

Wolf Creek Valley, main branch

The buried valley of Wolf Creek extends northwest from the Miami Valley, in southwest Dayton, to a point near Trotwood where it divides into its northern and southern branches. The surface material in the main valley consists of gravel or of till which overlies gravel.

Trotwood municipal water supply

The wells of the Trotwood waterworks are in the NW $\frac{1}{4}$ sec. 16, Madison Township. There are five wells in this field, which is located on the Teays-level terrace of the buried valley about three-fourths of a mile south of the axis of the Deep Stage channel. Bedrock was reached in these wells about 35 feet below the surface and the water is taken, through screens 10 feet long, from coarse gravels that lie on the rock. The total capacity of the five wells ranges from about 200 gallons per minute in dry periods to a maximum of about 400 gallons per minute. The daily consumption averages about 125,000 gallons. Test wells drilled in the Deep Stage channel to the north to ascertain the character of the material, or test wells drilled southeast of town along the creek, would be a logical preliminary to locating a new supply. Depth to bedrock in the Deep Stage channel is from 150 to 200 feet below the surface, whereas the glacial materials a short distance southeast of town are only about half as thick. However, wells developed in the latter area would be more apt to receive recharge from Wolf Creek.

Dayton Rubber Co. water supply

In the area of the Dayton Rubber Co. in sec. 29, Harrison Township, logs of wells 23, 93, 94, 95, and 581 show alternating layers of gravel and till from the surface to a depth of about 130 feet, gravel extending below this depth to bedrock. Bedrock in this area is about 200 feet below the surface. Samples of the gravel from the lower part of well 581 ranged from "pea gravel" to stones the size of walnuts. The types of glacial deposits in this valley are in part shown on the cross section on plate 19, which includes the lower part of Wolf Creek Valley.

The Dayton Rubber Co. has three large-diameter wells, averaging about 200 feet in depth. These wells obtain water from coarse gravels above the bedrock. One well, provided with a screen 25 feet long, had an initial capacity of 744 gallons per minute. The capacities of the other two wells were somewhat greater. The normal static level is about 24 feet below the surface, and there has been no apparent decline in water levels in this area in the past few years despite heavy pumping amounting to nearly 4 million gallons a day.

At the area of the confluence of buried Wolf Creek Valley and the Miami Valley at the McCall Corp., log 447 shows a hard till layer between the depths of 80 and 100 feet, overlying several feet of sand. The sand in this well is so fine it often clogged the screen and the well was finally abandoned. The hard till layer above the sand acts as a confining layer. This is shown by fluctuations of the water level in observation well Mt 5, which is located about 1,500 feet southeast of the McCall well. Whenever a train passes this well, at a distance of about 50 feet, the water level rises abruptly as much as one-third of an inch, and it resumes its former static position as soon as the train has passed. The hydrograph of observation well Mt 5 is shown on plate 22, compared to river-stage fluctuations and to other hydrographs of wells in the valley area. The relatively subdued form of this hydrograph also suggests artesian conditions.

Other portions of Wolf Creek Valley, besides those already developed, may be suitable for additional water supplies but too few data are available to make definite predictions. It would probably be necessary to resort to test drilling to evaluate properly any other particular area in the valley.

Buried valley underlying Johnsville

A buried valley (called Johnsville Creek on pls. 14 and 15) extends from the vicinity of Ellerton northwest beyond New Lebanon and Johnsville, into Preble County. There is no trace of this buried valley on the surface and its location has been determined from well records.

Only one detailed deep-well log is available in what is thought to be the center of this valley. Well 568, located 1 mile west of Johnsville, was drilled to the depth of 273 feet without striking bedrock. The record of this well shows a till (ground moraine) deposit 140 feet thick overlying 130 feet of sand or, possibly, very sandy till. The well finished in gravel between the depths of 270 and 273 feet. Another well in this section of the valley, in the southwest corner of sec. 6, Jackson Township, was drilled 220 feet deep, mostly through what the driller called "blue mud," probably soft till. A well in the extreme southeast corner of sec. 22, Perry Township, in a short tributary of Johnsville Creek Valley, was drilled 140 feet deep, and fine sand was encountered in the lower part.

The indications are, therefore, that, at least in the section of this valley extending from near Johnsville to the Preble County line, a considerable thickness of till rests on fine sand. The coarser gravel found at 270 feet in well 568 may be fairly well distributed over the bottom of the valley near the bedrock floor. Wells at Johnsville commonly range in depth from about 60 feet to seldom more than 135 feet, which is indicative of the variable nature of the glacial drift, and the probability that several sand and gravel layers are interbedded in the till. (See log 609.)

The log of well 127 at New Lebanon on the southern flank of the valley, shows mostly till from the surface to the depth of 155 feet, interbedded with sand and gravel layers. This well ended in coarse gravel 167 feet below the surface. At Liberty, logs 338, 364, and others, of wells at the edge of the valley, show thick sand deposits alternating with the till. Bedrock was reached 148 feet below the surface in well 338, but this well is probably not in the deepest part of the valley.

New Lebanon municipal supply

The largest water-supply development from the gravels in this valley is at the New Lebanon waterworks, which has one well 161 feet deep, 8 inches in diameter, and equipped with 10 feet of screen. It is on the south side of the valley, in the SW $\frac{1}{4}$ sec. 36, Perry Township. On initial tests this well was pumped for 48 hours at the rate of about 70 gallons per minute with 12 feet of drawdown. The normal static water level at that time was only 3 feet below ground surface. At present the well is pumped at 125 gallons per minute and the daily pumpage averages 60,000 gallons. Another well (no. 127) was drilled in July 1946 but has not been put in operation at this writing. This well is 12 inches in diameter and 167 feet deep. The static water level was 25 feet below the surface when the well was drilled.

Germantown Creek Valley

Preglacial Germantown Creek entered Montgomery County in the southern part of Jackson Township and flowed approximately due east past Farmersville, to a junction with the former Hamilton River 3 miles west of Ellerton. In the Teays and Deep Stage intervals of erosion two southward-extending tributaries of Germantown Creek were separated from short Hamilton tributaries by narrow cols north and northwest of Germantown. These cols were cut through, probably when the Illinoian glacier caused drainage diversions. These breached col areas are now occupied by Twin Creek and Little Twin Creek.

The material covering and mostly filling this buried valley is till, which forms a relatively flat surface.

Only two well logs are available in the main valley. One is of a well (No. 151) located in the SE ¼ sec. 30, Jackson Township, where the valley enters Montgomery County. This well log shows 10 feet of surface till and 150 feet of very fine sand. Drilling stopped at about 150 feet in somewhat coarser sand, which Mr. J. D. Flory, the driller, described as "pin head" sand.

Farmersville municipal water supply

The other available record (log 137) is of a well 154 feet deep, at the Farmersville waterworks on the north side of the valley. It is about 3 miles down the valley from well 151. The Farmersville log shows about 146 feet of surface till, underlain by at least 8 feet of sand and gravel to the point where drilling stopped. The Farmersville water supply is pumped from two wells, one 6 inches and one 8 inches in diameter. Both obtain water from the sand and gravel below the till. The capacity of the individual wells is not known. However, both wells have been pumped together for 3-hour periods and yielded about 235-250 gallons per minute. The drawdown is not known but is believed to be small. The average static water level is about 30 feet below the surface. The daily pumpage averages about 20,000 gallons.

There is a significant change in the character of the material in this part of the valley, from thin till underlain by a thick deposit of fine sand at well 151, to thick surface till at Farmersville. Not enough well records are available to define the better ground-water areas.

Germantown municipal water supply

In the southern part of the col area occupied by Little Twin Creek, in sec. 12, German Township, logs are available, of the wells

drilled at the Germantown waterworks, about a mile north of the center of town. These logs (Nos. 150, 583, 584, 585, and 586) show alternating layers of gravel and till above the bedrock, which is reached at the shallow depth of about 50 feet. An average of 175,000 gallons per day is pumped from three of these wells (Nos. 150, 585, 586) from gravels lying from 15 to about 30 feet below the surface. On original tests each well yielded 400 gallons per minute when pumped separately. These wells probably receive recharge from nearby Little Twin Creek.

The buried Hamilton Valley from Ellerton to the county line

This section of the preglacial Hamilton Valley extends from the area of Ellerton southward through the eastern edge of German Township. One short tributary entered this valley section from the west, from the area now occupied by the village of Germantown. This portion of the Hamilton Valley became abandoned, it is believed, when the Illinoian glacier caused the drainage to be diverted through the narrow col area at Miamisburg. After the drainage became established in this shorter course the abandoned portion of the Hamilton channel was filled by glacial drift, which forms a fairly flat till plain.

Logs of only two wells are available in this valley section - well 508, located 2 miles southeast of Germantown, and well 510, about 2 miles northeast of that town. These logs show alternating layers of sand, gravel, and till in the upper part of the valley fill. Bedrock in this part of the Hamilton Valley is probably as much as 250 feet or more below the surface.

Germantown Rendering Co. water supply

The largest water-supply development in this valley section is at the Germantown Rendering Co. in the NE $\frac{1}{4}$ sec. 19, German Township. This company has a 6-inch well, 40 feet in depth, and an 8-inch well (No. 508), 70 feet in depth. Each well is equipped with a 12-foot screen at the bottom of the casing. The capacity of the 6-inch well was measured at 150 gallons per minute, and that of the 8-inch well at 250 gallons per minute. The average static water level in the 8-inch well is 5 feet below the surface, and the drawdown was less than 1 foot when the well was pumped at 250 gallons per minute. Recharge from nearby Twin Creek is indicated, for it is improbable that large-capacity wells could be developed in this valley section without an immediate source of stream recharge.

Holes Creek area

A short preglacial channel enters the Miami Valley from the southeast at a point about 1 mile east of Dwyer. The axis of this

tributary valley roughly parallels the course of Holes Creek, though it lies approximately half a mile northeast of this present stream. In the southeast corner of sec. 3, Washington Township, this valley splits into two branches, one heading into the upland in the direction of Woodbourne and Wittes Corners, the other extending south to end in the vicinity of sec. 11 or 12 in Miami Township. The surface material overlying the eastern part of this tributary valley is the till of the Germantown end moraine. Gravels overlie the western part of the valley. (See plate 2)

Logs of wells 317, 318, 319, and 144, drilled in this tributary valley, show about 100 to 200 feet of till resting on bedrock, or on gravel near the bedrock surface. These logs indicate that few gravel layers are interbedded in the till. The log of well 432 shows that the surface till in the northern branch of this valley is only about 50 feet thick and is underlain by 128 feet of fine sand. No water was available in the Ordovician shale below the sand, and this well was abandoned.

The evidence now available indicates that large ground-water supplies cannot be developed in this valley, although supplies large enough for household and farm purposes can generally be obtained.

Miami Valley

The Miamisburg col area

In the Teays and Deep Stage intervals of erosion, two short tributaries of the Hamilton River extended toward the Miamisburg area from opposite directions, forming a narrow col or drainage divide at Miamisburg. The Illinoian glacier, it is believed, forced the main Hamilton drainage through this col, causing the erosion of a deep, narrow gorge, which became established as the main drainage line. This col area is now occupied by the Miami River. Surface materials, as shown on plate 2, consist of gravel and river alluvium.

Several logs (Nos. 81 - 89, and 567) are available for wells in a small area on the northern side of the former col and on the north side of Miamisburg. These well logs, covering a relatively small area, show numerous till layers interbedded in the gravels. Bedrock was struck in the northern part of Miamisburg in an old oil well, 181 feet below the surface.

Miamisburg Paper Co. water supply

On the northern side of the col area the largest ground-water development is that of the Miamisburg Paper Co. (logs 81 - 89, and

567) on the north side of Miamisburg, between the old canal and the Miami River. This company has three wells averaging 75 feet in depth and pumping from the outwash materials that make up the valley fill. These wells are pumped at a rate of about 750 gallons per minute each. The static water level is about 23 feet below the surface. At the time it was drilled one well was tested at a rate of 1,000 gallons per minute and the drawdown amounted to 26 feet.

South of the col, at the southern edge of Miamisburg, the logs of wells 63-68, 78, and 80, drilled for the city waterworks, indicate that the surface gravels are at least 70 feet thick, only occasional interbedded till layers being reported by the drillers. This change from numerous layers of till in the gravels on the north side of the col to an almost unbroken thickness of gravels on the southern side might be due to a temporary retardation of the ice front by the narrow col. If this is true, till was laid down by the ice, along with the gravel outwash, on the north, while outwash material was built up in almost unbroken sequence immediately south of the col beyond the ice front.

Dayton Power and Light Co. wells, O. H. Hutchins Station

One mile north of the village of Chatauqua, on the south side of the Miamisburg col, in sec. 28, Miami Township, several test wells (Nos. 540 - 547) were drilled by the Dayton Power and Light Co. at the O. H. Hutchins Power Station now being built along the west side of the Miami River. This location is about halfway between Miamisburg and the Warren County line. Here the valleys which were cut during the Teays and Deep Stage intervals of erosion are about three-fourths of a mile wide. A gorge 500 feet wide and more than 150 feet deep was cut by the diverted Hamilton drainage in Illinoian time. Gravels in the wide part of the valley range from about 30 to 84 feet in thickness and rest on shale bedrock of the Ordovician system. These gravels may contain local till lenses. Wells 543, 544, 546, and 491 were drilled into the narrow gorge cut into this wide valley. Logs of these wells show that predominantly coarse gravel extends from the surface to a depth of at least 160 feet, and is interbedded with thin and probably discontinuous till layers. Of the 10 wells drilled at this site three wells (Nos. 544, 591, and 592) were developed. Well 544 is 135 feet deep, and the principal aquifer is coarse sand and gravel between the depths of 77 and 127 feet. This well was test-pumped for 8 hours at rates varying from 666 gallons per minute to 1,534 gallons per minute, with a drawdown of 33 feet at the end of the period. The static water level was 19.3 feet on March 31, 1947, and the water temperature was 55° F. The second of the three production wells (No. 591) was also pumped for 8 hours, at rates of 1,000 gallons per minute to 1,740 gallons per minute, with a

drawdown at the end of the period of only 3.8 feet. The static water level in this well was 15.8 feet below the surface on July 28, 1947. The water temperature was 53.5° F. The well is screened in coarse gravel between the depths of 111 and 150 feet. The third well in this field (No. 592) was developed in coarse gravel and sand between the depths of 89 and 150 feet. The well is 26 inches in diameter and has a 30-foot screen. On September 12, 1947, the static water level was 19 feet below the top of the casing. The well was pumped for 8 hours at rates varying from 1,000 to 1,800 gallons per minute, and the drawdown was 5.3 feet at the end of the period. These wells have the highest specific capacities of any known wells in Montgomery County.

Miamisburg municipal water supply

The City of Miamisburg pumps a daily average of about 700,000 gallons of ground water from a well field south of the town along the old Miami-Erie Canal, about 1,000 feet east of the Miami River. Three wells in this field are pumped regularly and five wells are kept in reserve. The three wells that are pumped regularly average 49 feet in depth, have 30-foot screens, and are 26 inches in diameter. Their average yield is from 700 to 1,200 gallons per minute and their drawdowns do not exceed 10 feet. The five reserve wells are 8 inches in diameter, about 50 feet deep, and have a total yield of about 1,000 gallons per minute. The static water level currently is about 21 feet below the surface.

No water-level records are available in the col area to indicate the water-level trends over a long period. Nowhere, however, does there seem to be a continual decline in water levels, despite a daily average withdrawal by the City of Miamisburg and its industries of about 2,000,000 gallons.

The West Carrollton area

In November 1947 the Ohio Water Resources Board drilled a test well in the buried Hamilton Valley at Whitfield, about 1½ miles west of West Carrollton. This site was chosen because it was thought to be near the middle of the buried valley at the point where the old Hamilton River diverged from the course now followed by the Miami River. This test well (log No. 639) was drilled to determine the character of the outwash deposits in the valley at this point, and to ascertain the depth to bedrock. An automatic water-stage recorder has been installed on the well and it will be maintained permanently as observation well Mt 49.

Bedrock (Ordovician shale) was struck in this well at a depth of 212 feet, or at an elevation of about 500 feet above sea level. The

elevation of the valley floor at Dayton is 513 feet, which indicates a southerly gradient of about 1 foot per mile. It must be borne in mind, however, that in neither location is it certain that the lowest place in the valley floor was reached. However, it seems probable that the valley floor is flat, and that these elevations are near the minimum. The outwash materials encountered in this test well are well-sorted and cleanly washed, and range in size from coarse sand to coarse gravel. Two till layers are present, one between the depths of 30 and 32 feet, and the other between the depths of 91 and 94 feet. These tills are hard and probably impermeable, for the static water level in the well rose to about 17 feet below the surface as soon as the upper till was penetrated. The coarser gravels are found immediately below these till layers. Although the well was not pumped, the driller, Mr. D. J. Roe, of Vandalia, said that the material was excellent for well development throughout the total depth of the drilling, except, of course, for the till layers. Samples of the material from the well are being retained by the Ohio Water Resources Board.

Logs of wells 62, 152, and 153, in the central part of the Hamilton Valley in the Alexandersville area, show mostly sand and gravel deposits from the surface to a depth of 122 feet, the maximum depth reached in these wells. There was some indication of a till layer between the depths of 74 and 82 feet. This till layer may be continuous with till deposits found farther up the valley near Dwyer, and this possibility is suggested on the cross section diagram A-A', on plate 17.

Miami-Oxford Paper Co. water supply

Nearly 7,000,000 gallons of water is pumped each day from a small area within the corporation limits of West Carrollton. This is one of the greatest concentrations of pumpage in the county. Of the total amount, more than 5,000,000 gallons per day is pumped by the Miami-Oxford Paper Co. from 18 wells located within the plant area. The well field is not far from the old canal and is about half a mile from the Miami River. The average depth of these wells is 65 feet and most of them are 8 inches in diameter. They were drilled shortly after 1900. The yields of the wells range from 400 gallons per minute to about 1,200 gallons per minute, the average yield of 14 wells being about 700 gallons per minute. Only one log is available in this well field and it is of the deepest well (No. 62). This well is 80 feet deep and is finished in about 20 feet of coarse gravel. The static water level in 1925, when it was drilled, was 23 feet below the surface. At that time the well was pumped at a rate of 1,500 gallons per minute with a drawdown of 24 feet. It is presently equipped with a 1,200-gallon-per-minute pump and its yield is the largest of the field. No long-term water level records are available from these wells, but there is believed to be no downward trend.

West Carrollton Parchment Co. water supply

The West Carrollton Parchment Co., another large consumer of ground water in this area, is located adjacent to the Miami-Oxford Co. This company pumps approximately 1,500,000 gallons of water a day from four wells. Two of these wells are 70 feet deep and two are 120 feet deep. They were originally equipped with screens but it is believed that these have since deteriorated. The combined yield of three of these wells is 1,250 gallons per minute, and the yield of the remaining well is 250 gallons per minute.

A log of a well recently completed at the West Carrollton Parchment Co. indicates the character of the material at that place. This log (No. 746) was received too late for the well to be shown on plate 2, but it is on the southeast side of the main square in West Carrollton. It was drilled 135 feet deep and coarse gravel and sand was encountered, broken by three till layers between the depths of 28 and 35 feet, 55 and 58 feet, and 83 and 88 feet. The upper and lower till layers appear to correlate roughly with the till layers found in the test well at Whitfield (log 639), but the large yield indicates the probability that the upper till layer is not continuous under the Miami River. Well 746 had not been test-pumped at the time the record was received. Its static level was reported as 14 feet below the surface.

West Carrollton municipal water supply

The municipal supply at West Carrollton is obtained from one 8-inch well 85 feet deep and one 12-inch well 110 feet deep, located adjacent to the well field of the West Carrollton Parchment Company. The yield of the 12-inch well is about 700 gallons per minute, and that of the 8-inch well is about 350 gallons per minute. The average daily consumption from the municipal system amounts to about 230,000 gallons.

Despite one of the largest concentrations of pumpage in the county (about 7,000,000 gallons per day), there seems to have been no downward trend in water levels in the West Carrollton area over the past few years. A continuous water-level recording gage has been recently installed on an unused well (observation well Mt 10) at the West Carrollton Parchment Co., to observe future trends of ground-water levels in this area.

The Dwyer area

There is a large concentration of pumpage in the Dwyer area, over 8,000,000 gallons per day being pumped by the Frigidaire Co.,

the largest private user in the county, and about 500,000 gallons per day by the Air Reduction Sales Co. Logs of wells 49, 96, 147, 148, and 149 in this area, show the presence of a till layer below the surface gravels. The top of this till stratum occurs at depths ranging from 33 to 64 feet, and the till is from 2 to 30 feet thick, averaging a about 18 feet. The fact that the till horizon is found in wells as much as three-fourths of a mile apart in this area indicates relatively large lateral continuity, although it probably does not extend under the Miami River. Below this till the sand and gravel deposits occur in unbroken sequence to a depth of at least 123 feet. Bedrock is known to be about 200 feet below the surface in part of this area.

Frigidaire Division, General Motors Corp. water supply

The Frigidaire Co. pumps mainly from six wells (Nos. 49, 96, 97, 147, 148, and 149), whose locations are shown on plate 2. These wells are about three-fourths of a mile from the Miami River. They average about 20 inches in diameter and are equipped with screens approximately 30 feet in length. Pumping tests were conducted when these wells were first drilled, and the results of the tests are given in table 9.

Table 9

Records of wells of the Frigidaire Co.

Well No.	Depth (feet)	Principal aquifer (ft. below surface)	Pumping rate (g.p.m.)	Duration of test (hours)	Draw-down (feet)	Date drilled	Static level (ft. below surface)	Normal pumpage (g.p.m.)
49	108	63 - 108	1,200	--	27	7/26/34	23	1,000
96	118	86 - 118	1,200	--	10	11/13/35	25	1,000
97	115	90 - 115	----	--	--	4/ 7/44	27	----
147	122	63 - 122	1,200	12	14	7/19/46	23	1,200
148	118	67 - 118	1,000	8	13	5/ 9/46	25	900
149	123	91 - 123	1,500	10	9	6/13/46	26	1,000

A study of this table indicates that there has been no continuous decline in ground-water levels in the area over the period from 1934, when the first well was drilled, to 1946, when the latest three wells were drilled.

The Dayton area

The buried Hamilton Valley underlies the main part of the city of Dayton, the axis trending northeast. The relationships of the glacial deposits in this section of the buried Hamilton Valley are complex, and correlation of deposits between wells is uncertain. As suggested on cross-section profile A-A', plate 17, it appears that discontinuous layers or lenses of till generally underlie from 40 to 100 feet of outwash gravels. The till is of variable thickness and may include one or several definite layers. It is not present in all areas, or at least it is not always detected or reported in wells. There is evidence of other till deposits below 100 feet, though little is known of the materials in the valley below about 120 feet.

The gravels in this section of the valley, except in limited areas, have generally been found to be coarse. The most notable of the areas in which normal well development is sometimes difficult, because of the fineness of the material, is in the northern part of Dayton, near the junction of the Mad and Miami Rivers. At the Delco Co. site in this area, fine sand was reported in most of the wells (Nos. 126, 531, 532, 533, 534, 588), and at least one well (No. 588) could not be developed because of the sand. Fine sand was also reported in a nearby well (No. 125) of Sears Roebuck and Co.

In this section of the valley, which is about 6 miles long, about 28,000,000 gallons of water per day is pumped for industrial use. Records are available for 57 wells in this area. Their average depth is 113 feet, and the principal aquifer occurs between the depths of 82 and 109 feet. The static water level in 39 wells averages 26 feet below the surface. The average yield of 30 wells is about 750 g.p.m.

The available data on certain of the wells in this section of the valley are given in table 10.

The hydrograph of observation well Mt 2, shown on plate 20, shows no downward water-level trend since 1942, when the record began. This well, as do all the observation wells in this valley, fluctuates in response to changes in the river stage, and also in response to nearby pumping. The hydrograph shows that the greatest recharge to the aquifer occurs in the spring of each year.

The Ohio Department of Highways in 1945 drilled a line of observation wells (Mt 3, Mt 40-47) along the east side of the Miami River, from Stewart Street to Monument Avenue, as an aid in planning highway construction. Plate 21 shows the locations of the observation wells in this area. Daily measurements were obtained in wells Mt 40-47 from 1945 to late 1947, as an aid in planning future highway construction. Well Mt 3 has been equipped with a continuous water-level recorder by the U. S. Geological Survey. A study of these water-level records by

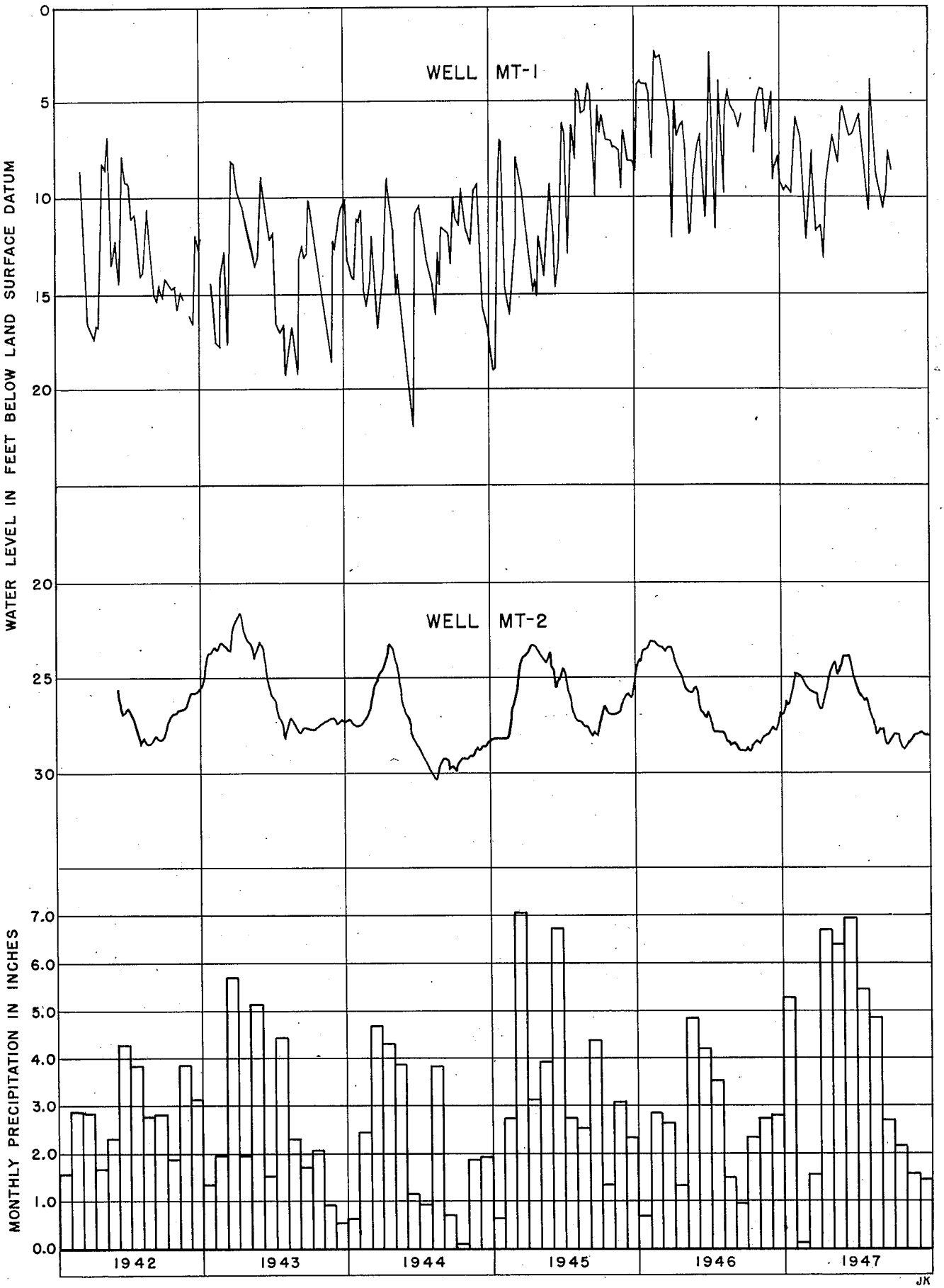


Plate 20. Hydrographs of wells in the heavily pumped areas of Rohrers Island (well MT-1) and the city of Dayton (well MT-2).

Table 10

Records of wells in the city of Dayton

Well log No.	Owner	Location (part of Dayton)	Depth (feet)	Principal aquifer (ft. below surface)	Pumping rate (g.p.m.)	Duration of test (hours)	Draw-down (feet)	Date drilled	Static water level (ft. below surface)
30	Baltimore and Ohio R. R.	Northeast-central	85	52 - 85	400	-	9	--	16
25	Dayton Power and Light Co.	East-central	152	107 - 152	800	-	30	10/23/36	27
556	do.	Central	87	53 - 71	875	-	31	1929	15
554	do.	South	65	43 - 65	425	-	5	1928	20
27	do.	South	67	38 - 67	1,000	-	12	6/ 4/36	16
575	do.	South	100	75 - 95	1,529	6	13	9/39	32
576	do.	South	120	92 - 117	1,987	6	32	9/41	30
577	do.	South	118	93 - 118	1,500	6	47	9/43	43
20	Dayton Steel Fdry.	Southwest	60	24 - 60	300	-	2	9/21/30	24
534	Delco Products Co.	North-central	117	95 - 117	440	72	6.8	9/12/34	25
437	Hewitt Soap Co.	East	72	38 - 49	300	-	6.3	3/31/45	21
447	McCall Corp.	Southwest	125	100 - 125	200	-	10	1936	60
102	Sheffield Gage Corp.	Northeast	75	55 - 75	395	-	8	3/ 7/41	4
107	Specialty Paper Co.	Southwest	134	115 - 134	1,100	-	23	8/15/41	32
129	Troy Pearl Laundry	South-central	130	110 - 123	300	-	2	9/13/45	29

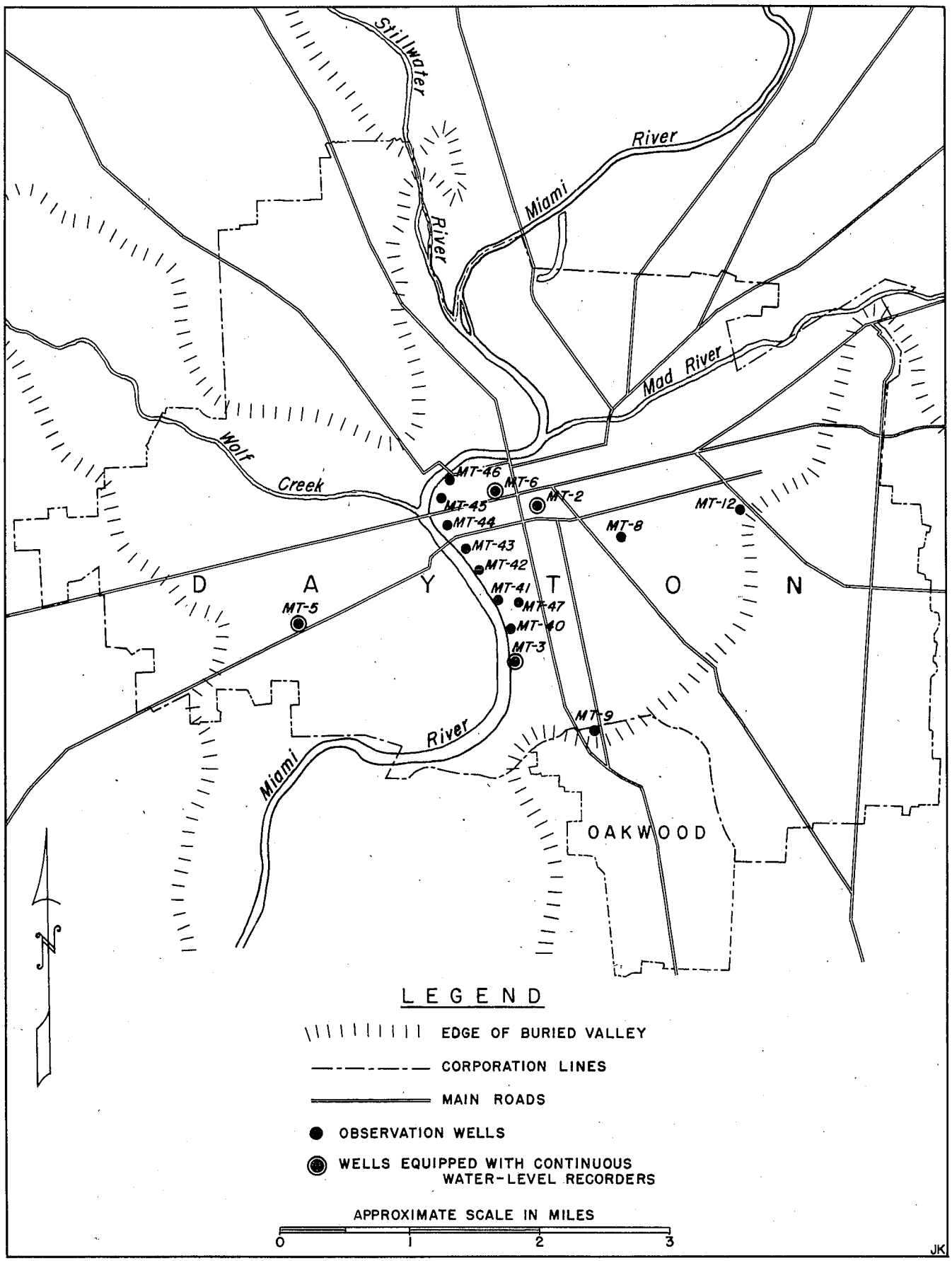


Plate 21. Map showing observation wells in Dayton and Oakwood.

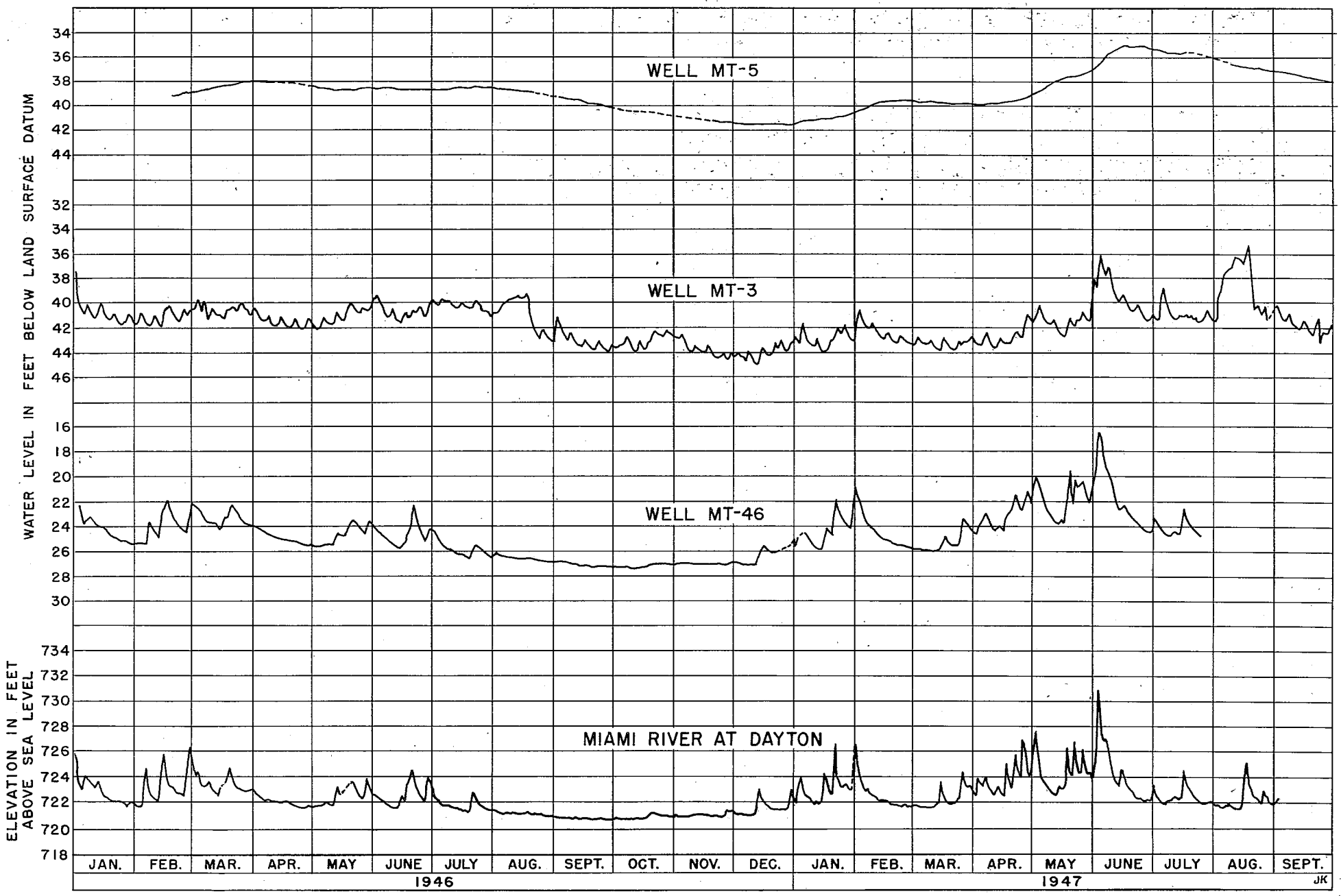


Plate 22. Hydrographs of wells in the Miami Valley at Dayton, compared to river-stage fluctuations.

Harry Marshall of the Highway Department has revealed the following: "The elevation of the water table in the wells has been consistently lower than the river, the amount varying from about 2.5 feet at low-river stage, to about 5.5 feet at high-river stage. The water table, within the area studied, is highest near the river and becomes lower away from the river." This is the reverse of the normal water-table gradient which, in humid areas, is toward the streams. It indicates that pumping within the valley has lowered the water table sufficiently to cause recharge by infiltration from the stream. Mr. Marshall also observes that the water table fluctuates with changes in river level, and this fact is readily apparent from a study of the hydrographs of the Miami River and of wells Mt 3 and Mt 47, shown on plate 22. The wells near the river, which are not greatly affected by pumping, fluctuate almost simultaneously with the river, whereas those farther from the river respond more slowly. The water table slopes at approximately the same rate as the river between Monument Avenue and Washington Street, or about 3.5 feet per mile. From Washington Street to Stewart Street, however, the slope of the water table is almost 17 feet per mile, which is believed to result from the pumpage in the vicinity of Stewart Street. This does not signify overpumping, but only the normal response of the regional water table in establishing gradients toward the wells.

Most wells drilled in this part of the valley encounter till from 40 to 100 feet below the surface. However, the rapid response of the wells to changes in the stage of the river and the large pumpage sustained in the area without continuously declining water levels indicates that the till is discontinuous enough to allow large amounts of recharge from the river to reach the underlying gravels.

National Cash Register Co. water supply

This company pumped over 5,000,000 gallons of water per day in 1946, making it the third largest private consumer of ground water in the county. Pumpage is from eight wells (Nos. 52, 54, 465, 469-472, and 480) located in the company area along the Miami River, in the vicinity of Stewart Street. The wells are 12 to 36 inches in diameter, are equipped with 14 to 20 feet of screen, and are provided with turbine type pumps. The company has measured water levels in these wells since 1933, and there is no downward trend. The hydrograph of well 480 shows that the water level varies from 46 to 69 feet below the ground surface, the fluctuations resulting most directly from the operation of the pump. The hydrograph of observation well Mt 3, shown on plate 22, along the river adjacent to the company grounds, likewise shows no downward trend, although the effects of nearby pumping are readily apparent.

Miami Valley north of Dayton

The buried valley underlying the Miami River north of Dayton extends due north through Taylorsville and Tadmor into Miami County. The thickness of the fill in this valley ranges from more than 200 feet at Dayton to less than 100 feet near Tadmor. The surface material in the central part of the valley consists of gravel and river alluvium, as shown on plate 2. Most of the available well records in this valley are near Dayton in the Northridge area.

A narrow area bordering the upland along the northwest side of the valley in eastern Harrison Township is designated on plate 2 as being till (ground moraine) overlying gravel. Well logs (Nos. 334, 335, 391, 400, 415, 424, 482, and others) show this till to be from 60 to 80 feet in thickness and to overlie coarse gravel. It seems probable that large-scale ground-water developments could be sustained in this part of the valley near the river, comparable to the present developments in the Miami Valley in central Dayton.

Vandalia municipal water supply

The largest ground-water development in this buried valley is at the Vandalia waterworks field, about a mile southeast of Tadmor in sec. 14, Butler Township. This well field consists of three 26-inch wells, one 57 feet in depth and two 67 feet in depth (log references 2 and 90), equipped with 25-foot well screens. These wells are spaced approximately 500 feet apart, roughly in the form of an equilateral triangle. Each well has a drawdown of about 12 feet at a pumping rate of 500 gallons per minute. The daily pumpage averages 700,000 gallons.

A record of water levels was obtained from July 1, 1944, to July 1947 in observation well Mt 48, located 20 feet north of water department well 3, the most southerly of the pumping wells. This record shows no downward trend of the water level, indicating that the pumping has not exceeded the rate of recharge. Large rises in water level occur in the observation well during periods of high stream flow in the Miami River, usually in the first 6 months of each year. During the period of record the water level fluctuated from 8 to 30 feet below the surface. The interference among the pumping wells seems to be slight. For example, on July 19, 1944, well 2, which had been pumped steadily for a period of 8 hours, was shut off for 1½ hours. The recovery in the observation well, about 600 feet away, amounted to only 0.4 foot in the period of the shutdown.

Because the water-level record indicates that recharge is derived in large part from stream flow, it seems highly probably that additional amounts of water can be obtained upstream or downstream from the present well field. It also seems probable that good water

supplies can be developed at many other sites along the Miami River above Dayton.

The Mad River Valley

The City of Dayton has drilled more than 150 wells and test holes (Nos. 177 to 316, and 453 to 464) along Mad River from a point about 1¼ miles west of Harshman to the upper part of Rohrers Island, in sec. 18, Mad River Township. The locations of these wells and well fields are shown on plate 23.

The well records show layers or lenses of till interbedded in the gravels of the valley train; the probable relationships of these deposits are shown on plate 18. There appears to be at least one fairly well defined till horizon, which is encountered at the average depth of about 70 feet at Rohrers Island, and at about 50 feet between the island and Tates Hill, in sec. 29, Mad River Township. The thickness of this till layer averages 12 feet. The till acts as a confining layer, as shown by differences in the static water levels in wells drilled into the gravels above and below it. Moreover, wells drilled into the gravels below the till have greater drawdowns per unit of discharge than those drilled into the gravels above the till. In addition, the water from the deeper wells contains more iron than that from the shallower wells. This is shown by the records of the analyses of wells 184 and 197 contained in the Quality of water section of this report. Other deposits of till also occur in this area about 40 feet below the surface, but they are discontinuous enough to allow large amounts of recharge to reach the underlying gravels.

Dayton municipal water supply

The Mad River Valley from the Keowee Street bridge to Rohrers Island yields to the city of Dayton one of the largest municipal groundwater supplies in the United States. An average of 37,630,000 gallons of water per day was used in 1946, and the daily average through July 1947 was 39,910,000 gallons. The all-time peak pumpage of the system was reached on Aug. 5, 1947, when 60,580,000 gallons was pumped.

Dayton water receives no treatment except chlorination. The water ranges from about 365 to 450 parts per million in total hardness. According to the consulting firm of Metcalf and Eddy (4), "No city in the United States with a population equal to or greater than that of Dayton has a public water supply with a higher degree of hardness than the Dayton supply." Plans are now under way for a softening and treatment plant to be constructed in the near future. The capacity of the system

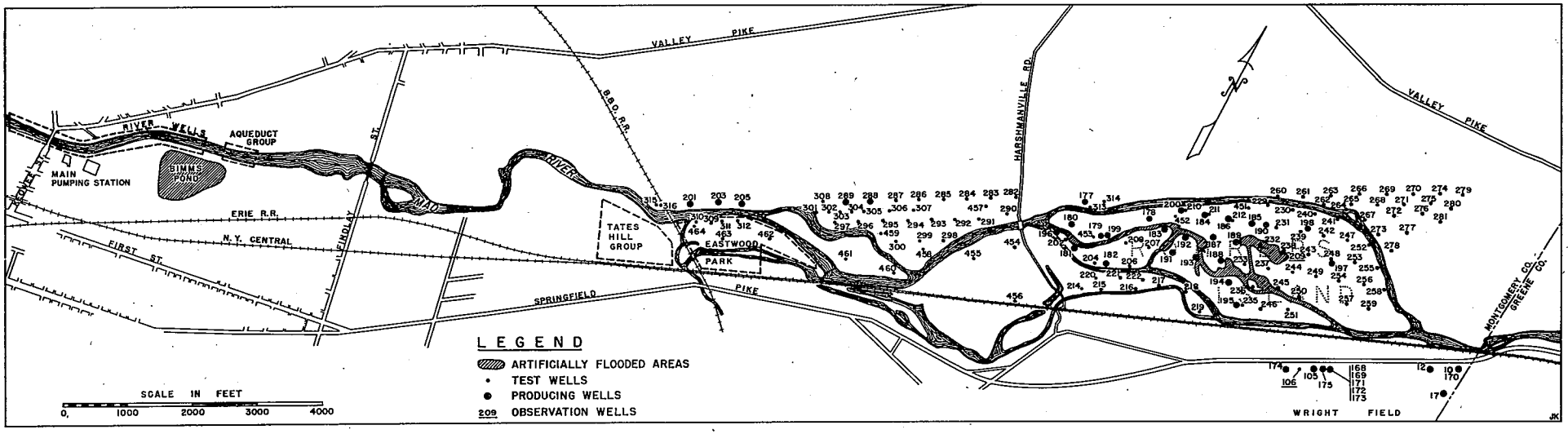


Plate 23. Map of Mad River area, showing the wells and well fields of the city of Dayton and Wright Field.

is also being enlarged by the drilling of additional wells. The temperature of the water in the present system varies during the year from 60° to 75°.

Rohrers Island

The greater part of the Dayton supply comes from 24 wells on Rohrers Island, a 180-acre tract in Mad River, located about half a mile downstream from Huffman Dam, mostly in the NE ¼ sec. 18, Mad River Township. (See pl. 23)

Twenty of the wells (Nos. 177-196) on Rohrers Island range in depth from 50 to 98 feet, and average 75 feet. The water is derived from the shallow gravel aquifer. These wells are from 17½ to 38 inches in diameter and are pumped by deep-well turbine pumps. Four wells in this field (Nos. 197-200) average 156 feet in depth and get their water from the gravels below the till horizon. The total available yield of the 24 wells on Rohrers Island is estimated at about 60,000,000 gallons per day. The individual yields of the wells, together with other data, are given in table 11.

The average yield of the shallow wells, as determined from table 11, is 2,298 gallons per minute and the average drawdown at this rate is 18½ feet. The four deeper wells show a somewhat larger yield, 2,388 gallons per minute, though with a drawdown of 35 feet, nearly twice that of the shallower wells.

Artificial recharge on Rohrers Island

Infiltration ditches and lagoons have been dredged on Rohrers Island and are flooded periodically to maintain high water levels in the wells. Flooding is accomplished by diverting water from the south channel of Mad River through a 48-inch intake pipe at the head of the island. (See pl. 23.) Flow through this diversion is maintained by a dam in the north (main) channel of Mad River near the head of the island, and by a dam in the south channel about one-fourth mile below the 48-inch intake pipe. The purpose of these dams is to raise the water sufficiently to cause flow through the 48-inch intake into the infiltration areas. These infiltration ditches constitute an area of more than 15 acres, or about one-tenth of the total island area. They are dredged from time to time to maintain the infiltration rate into the gravels.

On August 2, 1944, Robert Davies of the U. S. Geological Survey made nine current-meter discharge measurements in and around Rohrers Island in an attempt to determine the areas and quantities of the loss of water from Mad River. Mr. Davies found that recharge to

Table 11

Data pertaining to City of Dayton wells on Rohrers Island

Shallow wells

Log No.	City No.	Date drilled	Diam. (in.)	Depth (ft.)	Length screen (ft.)	Pumping test Date	Yield (g.p.m.)	Draw-down (ft.)	Spec. cap. (gals./foot drawdown)
*177	10	1926	38	75	40	2-28-44	1,760	24	73
178	11	1926	38	77	35	--	--	--	--
179	12	--	26	54	--	--	1,600	12	290
180	13	1930	--	--	20	3- 3-44	1,160	4	--
181	14	1931	26	74	40	1931	2,400	8	--
						3-24-42	2,860	6½	--
182	15	1931	30	85	30	1936	2,950	17	--
						3-16-42	2,550	18½	--
183	16	1931	26	65	30	2-27-42	2,219	17	--
						3- 1-44	1,800	15	--
184	19	1939	36	79	15	--	--	--	--
185	21	1941	26	68	16	4- 2-42	1,729	12	--
						3-23-45	2,135	15½	138
186	20	1939	30	78	25	12- 6-40	3,500	16	219
187	22	1941	26	73	15	4- 8-42	1,526	21	--
						3-10-45	1,942	34	57
188	23	1941	26	83	22	3- 9-45	1,637	41½	40
189	24	1941	26	64	11	3-13-45	838	24	35
190	25	1941	26	70	16	3-14-45	2,010	27	74
191	26	1941	26	75	22	3- 5-45	1,568	10	157
192	27	1941	26	69	16	3- 6-45	1,253	--	--
193	28	1941	26	76	16	1- 6-43	1,779	24½	73
194	29	1941	26	90	27	6-13-41	4,556	24	190
195	30	1941	26	98	32	10-16-41	4,341	25	--
						3-27-45	3,505	21½	163
196	31	1941	26	73	16	3-22-44	2,239	10½	--
						3-22-45	2,550	17	150

Deep wells

197	32	1942	17½	165	33	4-21-44	2,479	48	52
						10-25-42	2,159	32½	--
						7-13-42	2,219	32½	--
198	33	1942	17½	157	29	4-21-44	2,479	38½	--
						3-28-45	2,565	24	107
199	34	1942	17½	161	25	4-20-44	2,461	40½	--
						4-25-45	2,565	19	135
200	35	1942	17½	154	29	11- 4-42	2,239	34½	--
						4-20-44	2,332	47	50

* Located along Erie R. R. right of way adjacent to Rohrers Island

the well field directly from the river channel amounted to about 8,000,000 gallons on the day the measurements were made, and from the infiltration areas the recharge was about 21,000,000 gallons. As the total pumpage from the field on August 2, 1944 amounted to 36,283,000 gallons, the total amount of natural and artificial recharge from Mad River, totaling about 29,000,000 gallons, was equal to 80 percent of the quantity pumped. The hydrograph of well Mt-1 shows that the water level in the well field dropped in the period that the stream flow measurements were made indicating that the remainder was obtained from storage in the aquifer.

The response of water levels in the well field to the effects of this infiltration is rapid. The static water level in the well field is recorded by two indicating gages that are read hourly, and by a continuous water-level recorder installed by the U. S. Geological Survey on well 209. Water levels in this well (observation well Mt-1), as seen by the hydrograph on plate 20, vary from less than 4 to more than 30 feet below the surface. The record of this well for the week of April 21, 1942, offers a typical example of the results of the flooding. In the early morning of April 22, the water level in the well was 16.4 feet below ground level. The 48-inch intake pipe was opened at this time and within 2 hours the water level began to rise; by 4:15 a. m. on April 26, it was 4.2 feet below ground level. At this time the 48-inch intake was closed. For about 2 hours after this the water level continued to rise slowly and then began to drop rapidly; it had declined 3.4 feet by 11:45 a. m. on April 27, when the intake was again opened.

The water-level record obtained from observation well Mt-1,on Rohrers Island, indicates no downward trend since 1942, when the record began. The water level fluctuates from slightly less than 4 feet below the surface to more than 20 feet below the surface. (see pl. 20.) There are no indications that silting of the infiltration ditches and lagoons is causing the Rohrers Island area to become more difficult to recharge artificially.

The Rohrers Island well field is augmented by supplies from six other wells along Mad River between the island and the Tates Hill area, and from well groups between Tates Hill and the main pumping station on Keowee Street. These wells and well groups are shown on plate 23. They are described in the following paragraphs:

Segregated wells below Rohrers Island

There are six segregated wells along the old Erie Railroad right of way between Rohrers Island and the Tates Hill area. These are wells numbered 177, 201, 203, 205, 288, and 289. The first four of these wells are 38 inches in diameter, and the other two are 24-inch wells. Data on well No. 177 are included in the discussion of the Rohrers Island field. The other five wells average 61 feet in depth and have an average yield

of more than 1,700 gallons per minute per well, and a combined yield of about 13 million gallons per day.

River wells (old main group)

This group, just east of Keowee Street, was originally developed in 1887. It consists of 94 eight-inch wells from 30 to 88 feet in depth, equipped with bronze screens. The wells are located in the bed and along both sides of the Mad River in a total area of about 22 acres. They are pumped in two groups by vacuum pumps located in the main pumping station on Keowee Street. These are ordinarily used as reserve, although more active use is planned after a proposed water-treatment plant is installed. The estimated yield of these wells in combination is about 10,000,000 gallons per day.

Aqueduct wells

This group comprises six 8-inch wells 40 to 60 feet in depth, pumped by a single centrifugal pump witha capacity of 2,900,000 gallons per day. The estimated yield of these wells is about 1,000,000 gallons per day. They are used mostly for reserve. No well logs are available for this field, or for the river wells group, and little is known about the character of the aquifers.

Tates Hill wells

This group of wells, consisting of 28 eight-inch wells equipped with eight-foot screens, was developed about 1914. The wells range in depth from 50 to 72 feet and get their water from the shallower gravels. They are pumped by two centrifugal pumps, and the estimated yield is about 5,000,000 gallons per day. They are used as a reserve.

Eastwood Park wells

These wells are just northeast of Tates Hill and along the south side of the Mad River. The group consists of 10 eight-inch wells and one 24-inch well, ranging in depth from 50 to 63 feet and getting their water from the shallower gravels. The group is normally held in reserve and only one well is used seasonally to fill a swimming pool.

Bimms Pond

In addition to the flooded recharge areas on Rohrers Island, there is one other artificially flooded area along the lower course of Mad River

which is designed to furnish recharge to the River wells group and the Aqueduct group of wells. This flooded area, known as Bimms Pond, is an artificial basin comprising about 16 acres on the south bank of Mad River about half a mile above the main pumping station. It is flooded by a large-capacity centrifugal pump which pumps daily as much as 10,000,000 gallons of river water into the basin.

It seems probable that any increased demand for Dayton city water can be met by constructing additional wells in the gravels along Mad River. Available logs of wells along the river above Huffman Dam, in Greene County, indicate the probability that ground-water conditions are similar to those below the dam in Montgomery County. The prospects for large-scale well development above the dam, therefore, appear good.

The bedrock-contour map (pl. 1) indicates a considerable thickness of glacial fill in Mad River Valley between Tates Hill and the Aqueduct group of wells. If this glacial fill is composed of permeable water-bearing materials, such as underlie Rohrers Island, additional large amounts of water can be obtained in this area.

If the proposed softening and filtration plant is constructed by the City of Dayton, more water could probably be pumped from the deeper gravels underlying Rohrers Island. The present high iron content of the water from this deeper aquifer is undesirable. Greater development of this deeper aquifer would also increase the available storage capacity in the well fields that could be drawn upon during periods of low flow in the Mad River.

Wright Field water supply

The only other large water-supply development in the Mad River Valley is the supply serving area B, the Wright Field section, of the Air Materiel Command. As shown on plates 2 and 23, this well field is located in the NE $\frac{1}{4}$ sec. 18, Mad River Township, about 500 feet south of the northeastern end of Rohrers Island. The average daily pumpage in 1946 amounted to about 2,500,000 gallons. The supply is from 13 wells (Nos. 10, 12, 105, 106, 168-175) whose depths range from 43 to 109 feet and average 66 feet. The yields of some of the wells, when drilled, are summarized in table 12.

The materials in this area are generally similar to those encountered in the wells on Rohrers Island. There is a considerable thickness of gravel interbedded with scattered deposits of till.

Table 12

Data on wells at Wright Field

Well Log No.	AAF Well No.	Diam. (in.)	Depth (ft.)	Chief aquifer (ft. below land surface)			Yield (g.p.m.)	Drawdown (ft.)	Static water level (ft.)	Date drilled
168	1	12	109	86	to	109	200	---	12	1926
169	2	6	93	76	"	93	200	---	12	1927
170	3	5	55	47	"	53	252	---	12	1925
171	4	12	45	20	"	45	200	---	12	1927
172	5	12	49	17	"	49	200	---	12	1927
173	6	12	51	18	"	51	200	---	12	1927
17	7	38	61	26	"	61	640	8½	17	1938
12	8	26	71	58	"	73	1,900	18	11½	1940
105	9	14	52	31	"	51	1,300	5	18	1940
106	10	14	49	28	"	48	1,300	13	13½	1940
174	11	14	43	22	"	42	1,300	13	13	1940
10	12	26	57	34	"	54	2,000	2'4"	16'8"	1942
175	13	48	56	34	"	56	2,100	8	22	1944

The water level in observation well Mt 36 (log No. 106) shows fluctuations of about 2 feet in response to pumping. The water level in this well varies from about 17 to more than 20 feet below the surface.

Stillwater River Valley

This buried valley extends from Dayton northwest to the Miami County line. A short tributary valley joins the Stillwater Valley in sec. 9, Harrison Township, and extends north to the vicinity of Chambersburg (now called Merlin Heights). The surface materials in the Stillwater Valley, as shown on plate 2, consist of till, river alluvium, and, in some areas, gravel.

Englewood municipal water supply

The largest ground-water development in the Stillwater Valley is at the Englewood waterworks, which also serves the community of Union. This supply is from one 10-inch well 38 feet deep, equipped with an 8-foot screen. The well is located along the river in sec. 23, Randolph Township. The static level is about 10 feet below ground surface. When drilled, the well was tested at 400 gallons per minute for more than 4 hours, with a drawdown of 10 feet. At present the well is pumped at the rate of 100 gallons per minute, and average daily consumption amounts to approximately 30,000 gallons.

Stillwater Sanatorium water supply

This well field is located near the river in sec. 36, Randolph Township, on a rock terrace thinly covered by unconsolidated deposits. The terrace is a remnant of the Teays-level drainage. One pumping well about 35 feet deep, and within 30 feet of the river, yields 200 gallons per minute. Five test wells (Nos. 558 - 562) were drilled in the bottom land between this well and the upland, and from 200 to 1,000 feet from the river. Bedrock was struck in these test wells at the average depth of 32 feet. The material above the rock was mostly till, with thin and poorly sorted gravels near the bedrock. Well 561 was bailed for 1 hour at the rate of 40 gallons per minute, with a 3-foot drawdown. The static level was 8 feet below the surface. Test drilling in the Deep Stage gorge, which may be directly under the present river in this area, would probably reveal much better gravel aquifers. Wells at Little York have been drilled 90 feet in the Deep Stage gorge without encountering bedrock.

Farther down the valley, a well (No. 520) in sec. 5, Harrison Township, on the eastern side of the valley at the edge of the upland, shows 20 feet of till overlying at least 50 feet of gravel. The extent of this area in which the ground moraine overlaps the outwash gravels is shown on plate 2. The logs of wells 387 and 517, drilled into the buried tributary valley that joins the Stillwater in sec. 9, Harrison Township, show the surface till to be 50 and 85 feet thick respectively.

Near the mouth of the buried Stillwater Valley, several logs are available along the extreme eastern side, at the edge of the upland. These logs (wells 336, 413, 417, 570, 571, 572 and others) show varying thicknesses of till interbedded with sand and gravel deposits. The total thickness of the fill in this area is about 200 feet.

At the mouth of the Stillwater Valley, a narrow bedrock outlier in sec. 15 and 16, Harrison Township, is shown by logs of wells 402 and 412 to be overlain by as much as 90 feet of hard stony or gravelly till containing thin gravel layers near its base.

The width of Stillwater Valley is not as great as those of most of the other Hamilton tributaries, and the glacial drift is made up of a greater proportion of till than in the other valleys. In a large part of the Stillwater Valley the best gravel seems to be confined to the narrow Deep Stage gorge, whereas the Teays-level terraces are mostly covered by till.

Centerville area

Centerville municipal water supply

The water supply for the village of Centerville is taken from an abandoned quarry in the Brassfield limestone located about 1 mile northeast of the town. The water level in the quarry remains about 6 feet below the top of the ground and just above the top of the Brassfield. In areal extent the quarry covers 2.2 acres and pumpage amounts to an average of 75,000 gallons per day. The source of the water is probably in large part from former springs at or near the base of the Brassfield. Apparently some surface water contributes to the supply, as shown by the comparative softness (total hardness 161 p.p.m.) of the untreated water.

SURFACE-WATER RESOURCES

Montgomery County receives an abundance of surface water from the Miami River and its major tributaries, the Mad River, Stillwater River, Twin Creek, and Wolf Creek. Except for the southeastern corner, which drains into the Little Miami River basin, the entire county is drained by the Miami River. The present drainage system is shown on plate 5, and the entire Miami River drainage above Hamilton is shown on plate 24.

HISTORY OF SURFACE-WATER DEVELOPMENTS

Water was the key to the development of Dayton and Montgomery County from the time they were first settled (16). Streams were the only practicable means of transportation, and Dayton's site undoubtedly was chosen because of the junction there of three tributaries with the Miami River. The early economy was largely one of self-sufficiency, but growth beyond the pioneer stage required trade with the outside. For nearly 50 years grain, flour, whiskey, pork, timber, and other items were sent down the river to New Orleans. This trade was never entirely satisfactory, because the boats could not get back upstream and had to be sold or broken up at New Orleans. Manufactured goods were brought in over the mountains from the East, and the combination of low prices for exported goods at New Orleans and high prices for goods transported from the East kept the settlers in frugal straits. The answer to their problem appeared to be the construction of canals to transport goods to the East. The resulting Miami and Erie Canal completed in 1843 linked Dayton to the East by way of Lake Erie and the Erie Canal became the main artery of trade until the time of the Civil War when the canal could no longer compete with the railroads.

Local manufacturing and processing grew steadily. By 1820 there were so many mill dams on the Miami River and its tributaries that the New Orleans boat traffic was severely hampered. Hardly a trace of these mills remains today.

The first investigation of the surface-water resources of the Miami Valley was made by David S. Bates, an engineer for the Board of Canal Commissioners, in the early 1820's. His report was presented to the Board in 1825, and concerned particularly the available water supply for proposed canal routes in the central part of the State. Over 40 measurements of dry-weather stream flow were made, and these are of interest because at that time, according to the report, "not one half of the 40,000 square miles of our territory is yet settled; more than five sixths of it remains uncleared and uncultivated" (17). The accuracy of Bates' measurements undoubtedly was not comparable to that obtained in present stream gaging, but C. E. Sherman has concluded, from descriptions of methods used in those times, that the results were reasonably dependable (18).

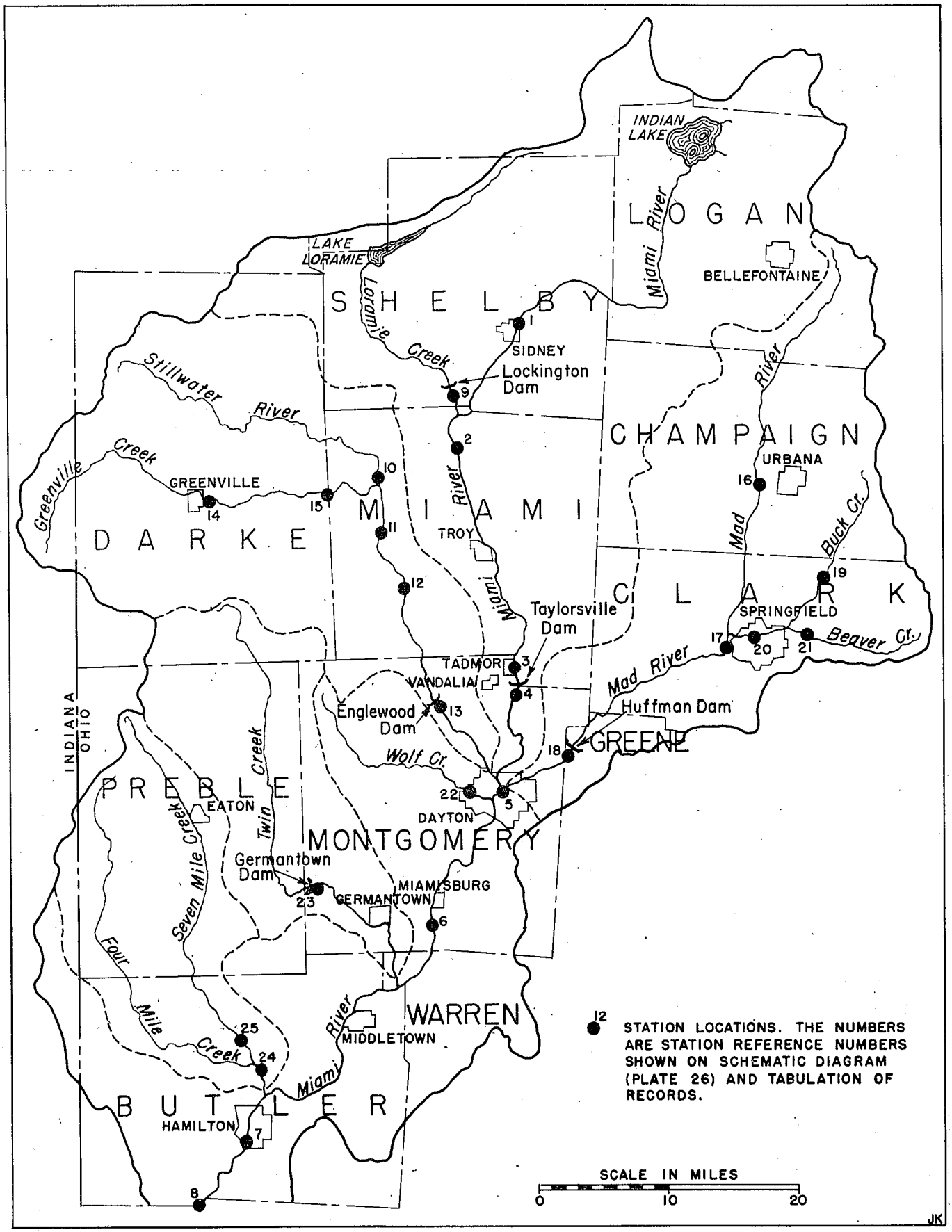


Plate 24. Map of Miami River Basin above Hamilton, showing locations of stream-gaging stations.

The 1824 measurements made in the Miami River Basin indicated extremely low stream flow, but not so low as recorded during more recent droughts. In the Scioto River Basin, however, several of the 1824 measurements indicated less flow than during the droughts of 1925 and 1930. Bates' measurements were computed in terms of cubic feet per minute. The following table lists his figures in cubic feet per second and second-feet per square mile for streams in the Miami River Basin.

Location	Flow in sec.-ft.	Area in sq. mi.	Flow in sec. ft. per sq. mile
Great Miami, 6 miles N. of Sidney (Port Jefferson)	29.0	450	0.064
Great Miami at Solomonstown (Reported dry 3 weeks prior to gaging)	0.70	50	0.014
Buckingelas Creek	48.3	-	-
Cherokee-mans Run	2.31	-	-
Mad River, near N. line of Clark County	167	250?	.667?
Honey, Lost, Millers, and Caldwells Creeks	8.33	?	-
Mosquito Creek	8.33	23	0.362

The flow of 167 second-feet for the Mad River seems open to question. Either it is in error, or Bates measured a medium-stage flow rather than low water. Largely on the basis of this flow, Bates recommended the location of the canal up the Mad River Valley, but later investigation showed that sufficient water was not always available, and this plan was abandoned in favor of the "Great Miami" Valley, using large reservoirs for storage to supply water to the summit level of the canal.

In 1839 Francis Cleveland, an engineer of the Canal Commission, measured the dry-weather flow of the Mad River "about 5 miles below West Liberty" and, allowing for mill operations, estimated the available flow as 23.3 second-feet. He obtained 36.7 second-feet "about four miles northwest of Urbana"; 70 second-feet "about 1 mile above the crossing of the National Road west of Springfield"; and 105 second-feet "2 miles above Dayton." Another measurement, in the 1840 report of the Board of Public Works, "... of the Great Miami River indicates that the minimum supply at Port Jefferson will not exceed twelve hundred cubic feet per minute (20 sec.-ft.). In three of the past ten years the flow at that point has been reduced even below that amount" (18). These early measurements indicate the fallacy of the popular notion that droughts are man-created, and that streams always carried an abundance of water before the country was settled.

The Miami Canal was built north from Cincinnati and the first boat arrived in Dayton in January 1829. The canal reached Piqua in 1836, but not until 1845 was it possible to reach Toledo from Dayton. Three reservoirs were built for supply, the largest one being Lake St. Marys or Grand Reservoir, formed by damming the upper reaches of the Wabash River and flooding the low divide between this and the St. Marys River drainage. The capacity of this reservoir is about 120,000 acre-feet. The other two reservoirs, both in the Miami River Basin, are Indian Lake, or Lewistown Reservoir, and Lake Loramie, or Loramie Reservoir. The first was formed by raising the level of Indian Lake, a much smaller pond, creating a reservoir with about 114,000 acre-feet of storage. Loramie Reservoir, on Loramie Creek, had a storage of about 11,000 acre-feet. All these reservoirs were completed about 1841. These reservoirs became State parks in 1894 and are now maintained for recreational use.

Traffic on the Miami Canal was large at first, but by 1851, 6 years after completion, the canal traffic began to decline. The economic depression of the late 1850's, and the era of railroad building of the 60's, hastened the decline of the canals. By 1900 all canals in the State had been virtually abandoned.

Despite the short life of the canals they had a profound influence on the economic growth of the Miami Valley. The change from the primitive means of travel of the pioneers to the relative ease of canal-boat transportation was greater than the modern change from horse-drawn to gasoline-driven vehicles. The canal increased the outlets for farm products and made more readily available the manufactured goods of the East. Dayton's situation on the canal, therefore, was important.

In addition to transportation, the canal furnished an easy means of obtaining power. From 1830 to 1880, 82 percent of the industry in Dayton was located on the canal for this reason. In 1880 215 mills were operating by water power in the Ohio portion of the Miami River Basin (18). By 1900 only 67 were left, of which 14 were on the canal system. In 1930 there were no more than a dozen hydro-power installations in the basin. At the present time there are only five plants of any importance. The two largest are at Hamilton and Middletown, of 3000 and 817 horsepower rated capacity, respectively. There is one on Greenville Creek at Covington, with a rated capacity of 790 horsepower, and one on the Stillwater River at West Milton with 234 horsepower. There are a few others, of small importance, on tributaries. Despite the small size of these plants they exceed in capacity the installations on any other Ohio river (19).

A more recent development of surface water in this area was the construction of the Miami Conservancy District's system of retarding basins. This subject is covered in the section entitled "Floods and the Miami Conservancy District."

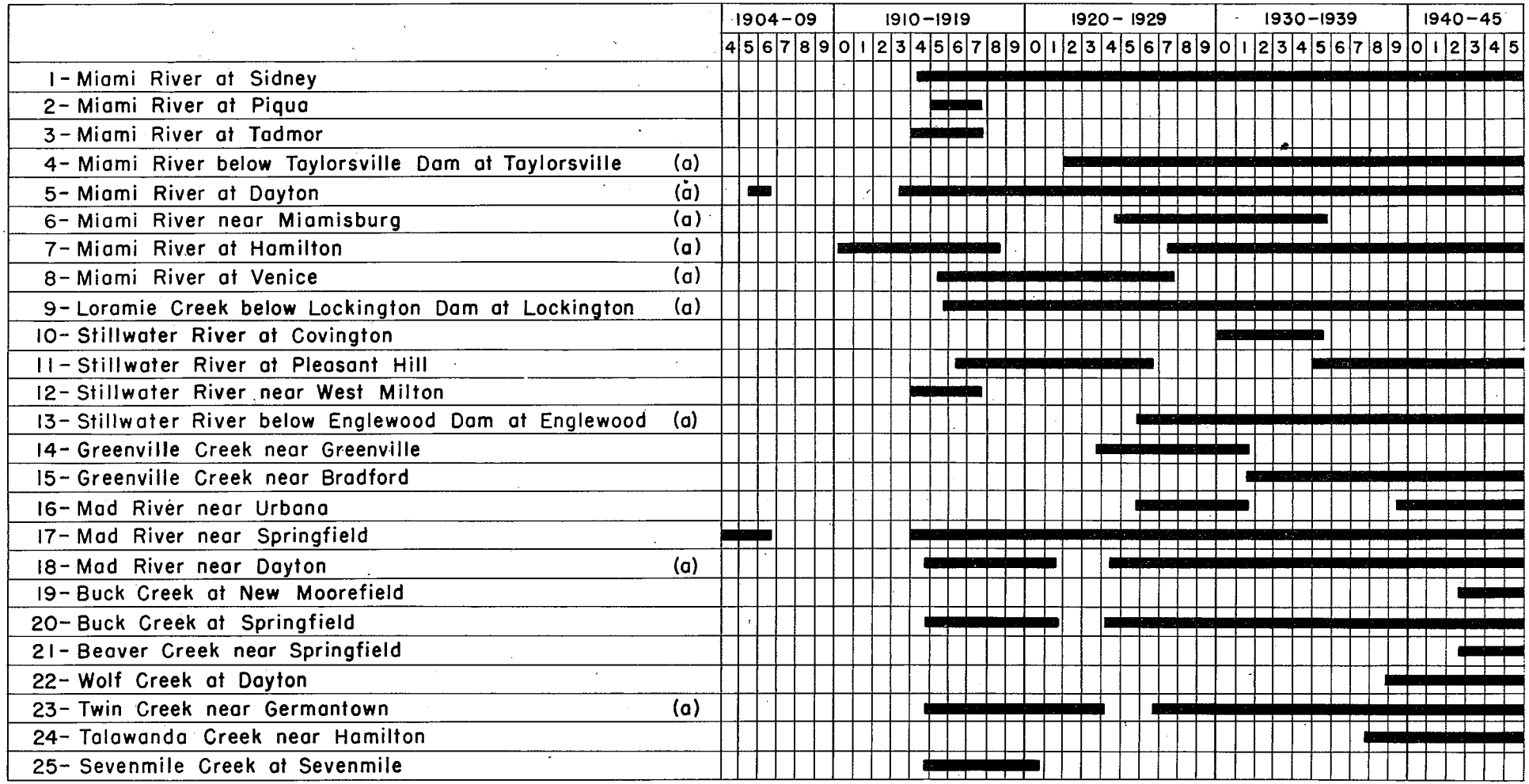
Surface water is not now an important source of water in Montgomery County for industrial or municipal use, except for power production and dilution of industrial waste and municipal sewage. The power plant of the Dayton Power and Light Co., which circulates about 250 million gallons per day of water from the Miami River for cooling condensers, is the largest user of surface water in the county. Because of the ease with which clear and cold water can be obtained from wells in the valley gravels, the use of surface water except as indicated is small. However, it should be noted that most of the ground water pumped in Dayton and vicinity is brought by the rivers, which recharge the ground-water reservoirs.

STREAM-FLOW RECORDS

Collection of stream-flow data on a continuing basis in Montgomery County began in 1913, when a gaging station was established on the Miami River at Dayton. A few stations were operated prior to that time, but the records are fragmentary and of limited value. The record at Hamilton, on the Miami River, began in 1910, but there is a 9-year break from 1918 to 1927, when no records were obtained. There are now nine stations in the Miami River Basin with 20 years or more of record without lapses. Stream gaging in the basin is carried on by the Miami Conservancy District, in cooperation with the U. S. Geological Survey.

Five gaging stations are now being operated in Montgomery County, and the gage on Mad River near Dayton is just outside the county. The locations of the gaging stations in the Miami River Basin are shown on plate 24. An index chart giving the years for which records in the basin are available is shown on plate 25. Plate 26 is a schematic diagram of the gaging-station locations, showing the drainage areas for each gage, and table 13 is a summary of the maximum, minimum and mean discharges for the important gaging-station records.

Hydrographs of the annual flow expressed as stream flow in inches are shown in plate 27 for the Miami River at Dayton, for the Miami River at Taylorsville, and the Mad River near Dayton. The data shown for the station at Dayton prior to 1913 are estimated by Houk (18) on the basis of gage-height record of the U. S. Weather Bureau at Dayton. These data are somewhat questionable, as no measurements are available to establish the stage-discharge relation. However, the diversion in the Miami and Erie Canal was estimated and included in the 1894-1913 figures. This diversion continued until 1929, and is not included in the U. S. Geological Survey daily records. The amount can be estimated from miscellaneous flow measurements made at intervals during each year. Diversion of water for municipal and industrial use also is not included. The



(a) Flood flows affected by Miami Conservancy District retarding basins after 1922.
Note – Fragmentary records for Miami River at Franklin, Mad River near Tremont City, and Fourmile Creek near Sevenmile are omitted.

Plate 25. Index chart of available stream-flow records in Miami River Basin.

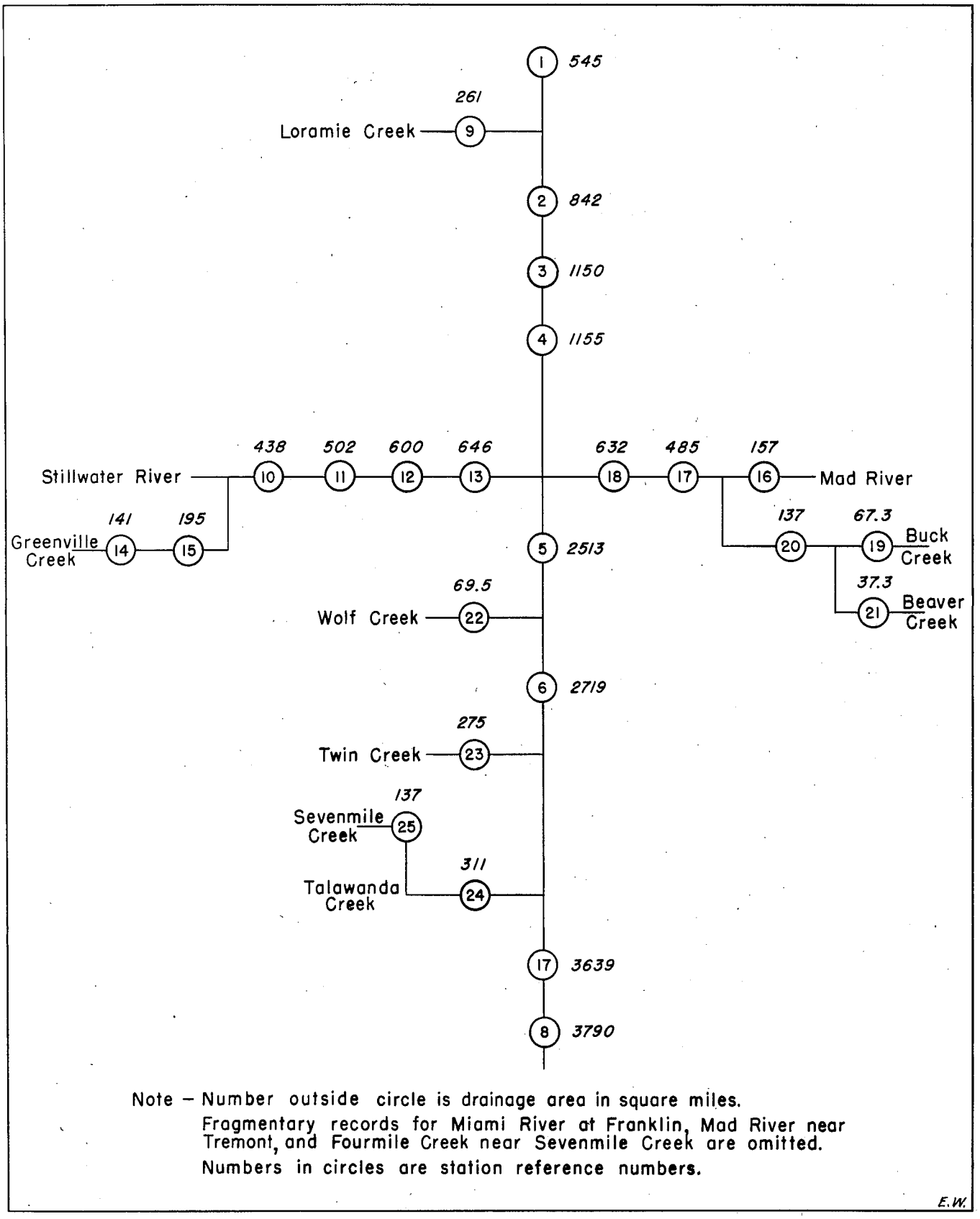


Plate 26. Schematic diagram of gaging-station locations in Miami River Basin.

effect of these diversions may have been equivalent annually to as much as $\frac{1}{2}$ to 1 inch of stream flow (stream flow in inches is the depth of the total volume of stream flow in the year spread over the drainage-basin area) at Dayton, and for this reason the hydrograph of the Miami River at Dayton is useful only in showing general trends. The records of the Miami River at Taylorsville and of the Mad River near Dayton are not affected by diversion. The hydrographs of these records could have been plotted in either second-feet or in second-feet per square mile, but the records have been converted to stream flow in inches for ease of comparison with rainfall.

Flow-duration tables and curves

An examination of table 13, the summary of selected stream-flow records in the Miami River Basin, is revealing. The mean flows for the periods of record, when converted to second-feet per square mile by dividing the mean flow by the appropriate drainage area, are about the same for all stations. On the other hand, the momentary maximum and minimum figures, when so converted for the purpose of comparison, show wide variations, particularly in the case of the minimum flows. For example, the minimum flow of the Miami River at Taylorsville is 0.026 second-feet per square mile, and the minimum flow of the Mad River near Dayton is 0.144 second-feet per square mile. This difference in flow may be attributed largely to a difference in the natural storage characteristics of the two drainage basins. A river flowing from a basin of bare, impermeable rock would experience a flood following every substantial rain, and would carry little or no flow a few hours later. Another river with the same mean flow, but flowing over an area of thick, permeable sands and gravels, might have but a slight increase in flow after a rain, and high sustained flows between rains. Natural lakes and artificial reservoirs would have the same effect, but in the Miami River Basin the storage is for the most part in the glacial deposits, and is ground-water storage.

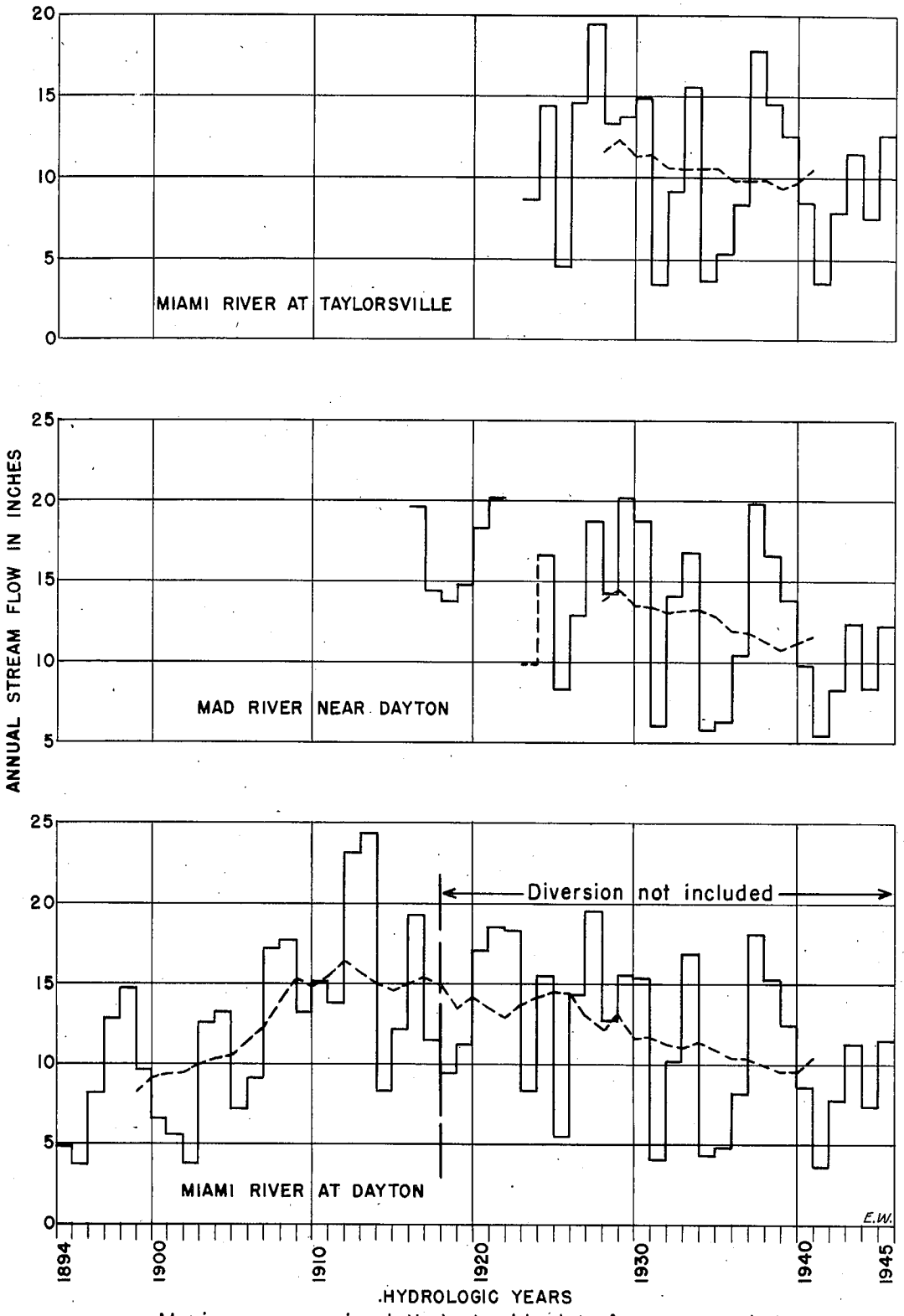
A convenient method of determining the distribution of high and low flows is the flow-duration curve. In this method the daily flows are arranged in order of magnitude and plotted against percentage of time. Flow-duration curves for the records at seven Miami River Basin gaging stations are shown on plates 28 and 29. The slope of the curve is a measure of the storage in the drainage basin; that is, the flatter the general slope of the curve, the lower the flood peaks and the higher the sustained dry-weather flow. The curves for the records other than those of the Mad River stations and the Miami River at Dayton, which includes the flow of the Mad River, are very similar. The Mad River curves are much flatter than the others, revealing the great natural storage in the glacial gravels in the Mad River drainage basin.

Table 13

Summary of selected stream-flow records - Miami River and Tributaries

Sta. No.	Station and location	Drainage area in sq. mi.	Period of record	Max. momentary Discharge		Mean discharge in cubic feet per second							Minimum momentary discharge (cfs)
				Flood of Mar. 1913 (cfs)	Period of record (cfs)	Highest day	Highest month	Highest water year	Period of record	Lowest year	Lowest month	Lowest day	
1	Miami River at Sidney	545	Feb. 1914-Sept. 1945	44,000	20,700 (3/20/27)	17,400 (3/21/27)	3,846 (Jan. 1930)	963 (1927)	471	141 (1931)	22.1 (Nov. 1914)	8.0 (9/23/35)	7.4 (9/23/35)
4	Miami River below Taylorsville Dam at Taylorsville (a)	1,155	Jan. 1922-Sept. 1945	127,000	25,500 (5/14/33 1/15/37)	24,400 (1/15/37)	8,024 (Jan. 1937)	1,680 (1927)	912	292 (1931)	55.1 (Sept. 1941)	36 (9/29/41)	30 (1/2/45)
5	Miami River at Dayton (a)	2,513	Apr. 1913-Sept. 1945	250,000		59,800 (4/21/20)	17,059 (Jan. 1937)	3,650 (1927)	2,161	662 (1941)	167 (Sept. 1941)	109 (8/8/34)	78 (9/26/41)
7	Miami River at Hamilton (a)	3,639	Jan. 1910-Sept. 1918 Apr. 1927-Sept. 1945	352,000	352,000 (3/26/13)	258,000 (3/26/13)	29,460 (Jan. 1937)	5,670 (1913)	3,261	978 (1941)	286 (Nov. 1935)	155 (9/27/41)	100 (9/26,27/41)
8	Miami River at Venice (a)	3,790	June 1915-Sept. 1927	370,000		55,600 (4/22/20)	16,900 (Jan. 1916)	5,880 (1927)	3,956	1,680 (1925)	480 (Oct. 1923)	232 (9/8/25)	225 (9/8/25)
9	Loramie Creek below Lockington Dam at Lockington (a)	261	Oct. 1915-Sept. 1945	25,600	10,400 (5/7/16)	6,590 (4/21/20 5/ 7/16)	1,728 (Jan. 1937)	367 (1916)	202	53.0 (1931)	3.37 (Aug. 1936)	2.4 (8/18/31) (9/19-21/36)	2.0 (8/19/31)
11	Stillwater River at Pleasant Hill	502	Oct. 1916-Sept. 1926 Dec. 1934-Sept. 1945	51,400	26,400 (1/14/37)	17,400 (1/15/37)	3,961 (Jan. 1937)	684 (1927)	432	99.3 (1941)	16.5 (Sept. 1941)	4 (1921)	
13	Stillwater River below Englewood Dam at Englewood (a)	646	Nov. 1925-Sept. 1945	85,400		9,910 (5/15/33)	5,129 (Jan. 1937)	893 (1937)	534	130 (1941)	21.0 (Sept. 1941)	4.8 (9/30/44)	3.7 (9/30/44) (10/1/44)
15	Greenville Creek near Bradford	195	Mar. 1931-Sept. 1945	---	9,320 (5/14/33 1/15/37)	7,920 (5/14/33 1/15/37)	1,430 (Jan. 1937)	293 (1933)	154	52.8 (1941)	10.7 (Sept. 1941)	6.9 (8/5/34)	6.7 (9/4,5/34)
16	Mad River near Urbana	157	Sept. 1925-Sept. 1931 Aug. 1939-Sept. 1945	---		7,740 (2/26/29)	450 (Feb. 1929)	221 (1927)	131	68.1 (1941)	35.4 (Sept. 1941)	24 (2/2,3/45)	
17	Mad River near Springfield	485	Feb. 1914-Sept. 1945	55,400	23,000 (2/26/29)	14,500 (2/26/29)	3,087 (Jan. 1937)	755 (1927)	480	210 (1941)	108 (Sept. 1941)	86 (7/30/34)	70 (2/9,26/34)
18	Mad River near Dayton (a)	632	Nov. 1914-Sept. 1921 Oct. 1924-Sept. 1945	75,700	18,400 (2/26/29)	17,400 (2/27/29)	3,862 (Jan. 1937)	934 (1929)	614	245 (1941)	119 (Sept. 1941)	94 (8/6/39)	91 (8/6,9/34)
19	Buck Creek at Springfield	137	July 1914-Sept. 1921 May 1924-Sept. 1928 Oct. 1928-Sept. 1945	11,100	13,000 (2/26/29)	7,670 (2/26/29)	798 (Jan. 1937)	202 (1929)	121	32.7 (1941)	8.05 (Sept. 1941)	4.0 (7/30/36)	2.1 (7/30/36)
22	Wolf Creek at Dayton	69.5	Sept. 1938-Sept. 1945	---	9,950 (3/19/43)	3,080 (3/19/43)	299 (June 1945)	73.5 (1945)	47.5	16.1 (1941)	1.98 (Dec. 1944)	1.1 (9/18,19/44)	1.0 (9/24,26/41)
23	Twin Creek near Germantown (a)	275	Apr. 1914-Dec. 1923 Dec. 1926-Sept. 1945	66,000	8,480 (4/21/20)	8,370 (7/8/15)	2,669 (Jan. 1937)	446 (1937)	264	66.5 (1931)	4.07 (Oct. 1945)	2.0 (9/25/41)	1.5 (9/25/41)

(a) Flood flows affected by retarding basins after 1922.



Moving average is plotted at midpoint of 10-year period.

Plate 27. Hydrographs of stream flow in inches, Miami River at Taylorsville, Mad River near Dayton, and Miami River at Dayton.

The flow-duration tables from which the curves were prepared are shown in table 14. They include the duration tables computed for the entire period of record, in second-feet and in second-feet per square mile. As the records for the stations are of unequal lengths, the results for the entire period of record are not strictly comparable. To aid in making comparisons between stations, and to show the difference in flow-duration characteristics for the same station for different periods and differing rainfall, the tables give the flow duration for each half decade (5-year period ending in 5 or 0) in the record. To show approximately the possible range of variations in flow-duration characteristics, tables for the years of maximum and minimum stream flow are also included. Plate 30 shows the flow-duration curves for one station, the Miami River at Taylorsville.

A major disadvantage of the duration-curve method of studying stream flow is that the time sequence is lost. Duration curves and tables therefore should be supplemented by studies of hydrographs of daily flows or, preferably, by the use of mass-curve analysis, which method is taken up in the next section. The duration curve indicates what flows may be expected, on the average, in a year, and the distribution of the flows in percentage of time, but gives no indication of the probable sequence of flows, or the probable flow for consecutive periods.

For comparative purposes the flow-duration tables may be converted into ratios to the mean flow, by dividing each discharge by the mean flow for the station. If this is done for the same period of record for all gaging-station records, the tables should be strictly comparable, thus revealing differences between drainage basins in flow-duration characteristics. Table 15 is a compilation of flow-duration tables, in abbreviated form, for the 5-year period ending in 1945, in terms of ratios to mean flow for this period, for the records at 13 stations in the Miami River Basin and 21 stations elsewhere in Ohio. For comparison, plate 31 shows the curves for four of the Miami River Basin records and plate 32 shows curves for five records outside the Miami River Basin.

Table 15 and the accompanying curves reveal strikingly the great natural storage that exists in the Mad River area. The curve of low flows of the Mad River at Urbana is far above the highest of the other curves, including the Mahoning River at Youngstown, whose low water flow is augmented by storage in several reservoirs of large capacity. The Cuyahoga River at Old Portage and the Muskingum River at McConnelsville also have large reservoirs in their upstream areas. The conclusion is definitely indicated that the Mad River area has more natural storage capacity in relation to its size than any other drainage area in the State. The character and water-bearing properties of the glacial materials making up the fill in Mad River Valley, which provides this storage, are discussed in the ground-water section of this report.

Table 14
Flow-duration tables for selected stations in Miami River Basin

Miami River at Taylorsville (4)

Percentage of time discharge indicated was equalled or exceeded

Percent of time	Discharge in second-feet							Discharge in second-feet per sq. mi., 1922-45
	1926-30	1931-35	1936-40	1941-45	Max. year 1927	Min. year 1931	1922-45	
1	11,900	6,700	11,900	7,800	11,600	2,240	10,300	8.92
2	8,000	4,900	8,300	6,000	8,400	1,690	6,800	5.89
3	6,650	3,750	6,000	4,550	7,450	1,230	5,400	4.68
4	5,750	2,950	4,950	3,750	6,800	1,040	4,500	3.90
6	4,550	2,250	3,850	2,750	5,900	790	3,400	2.94
8	3,725	1,750	2,950	2,070	4,900	670	2,700	2.34
10	3,100	1,400	2,370	1,590	4,300	600	2,150	1.86
15	2,050	900	1,600	1,100	3,150	425	1,470	1.27
20	1,550	665	1,250	845	2,380	340	1,120	.970
25	1,260	530	990	665	1,760	282	900	.779
30	1,070	435	790	520	1,420	242	730	.632
40	830	310	530	345	1,030	185	480	.416
50	590	225	372	225	810	152	340	.294
60	440	168	264	157	645	135	240	.208
70	348	135	198	122	535	120	172	.149
75	300	118	168	109	490	114	145	.126
80	230	103	145	99	460	107	126	.109
85	202	86	120	93	415	101	108	.094
90	154	72	94	84.5	310	92	90	.078
92	135	68	85	80	197	89	84	.073
94	117	65	76	75	186	85.5	76	.066
96	103	61	70	68	176	82	69	.060
97	96.5	59	69	64	172	80	64.5	.056
98	89.5	55.5	67.5	58.5	165	78	59.5	.052
99	81	51.5	63.5	51.5	158	76	54	.047

Miami River at Dayton (5)

Percentage of time discharge indicated was equalled or exceeded

Percent of time	Discharge in second-feet								Discharge in second-feet per sq. mi., 1917-45
	1921-25	1926-30	1931-35	1936-40	1941-45	Max. year 1927	Min. year 1941	1917-45	
1	21,800	23,100	14,000	22,800	16,000	22,600	3,680	19,700	7.84
2	16,000	17,500	10,000	16,500	11,500	19,000	2,450	14,000	5.57
3	12,500	13,800	7,600	13,000	9,200	17,200	2,020	11,500	4.58
4	10,500	11,900	6,350	10,200	7,400	15,000	1,870	9,700	3.86
6	8,300	9,700	4,550	9,000	5,100	11,700	1,620	7,300	2.90
8	6,900	8,100	3,600	5,900	3,850	10,000	1,450	5,600	2.23
10	5,400	6,400	3,100	4,700	3,150	8,800	1,300	4,550	1.81
15	3,750	4,500	2,140	3,270	2,280	6,200	1,060	3,200	1.27
20	3,000	3,550	1,670	2,570	1,790	4,650	910	2,550	1.01
25	2,500	2,900	1,330	2,150	1,490	3,950	800	2,120	.844
30	2,120	2,580	1,180	1,880	1,270	3,400	705	1,830	.728
40	1,600	1,970	870	1,410	890	2,550	570	1,340	.533
50	1,150	1,590	670	1,040	630	2,000	500	980	.390
60	860	1,160	540	800	475	1,730	425	745	.296
70	685	835	430	625	375	1,390	355	560	.223
75	595	710	387	550	340	1,150	305	490	.195
80	515	605	353	485	315	890	273	437	.174
85	453	515	320	423	288	730	240	392	.156
90	408	435	272	358	253	610	208	344	.137
92	392	408	253	329	240	555	195	318	.127
94	371	380	234	292	225	510	180	288	.115
96	342	352	214	258	208	475	158	256	.102
97	320	339	202	242	199	460	145	239	.095
98	290	323	190	228	182	443	132	220	.088
99	238	300	168	213	158	424	129	197	.078

Table 14 (Cont.)

Miami River at Miamisburg (6)

Percentage of time discharge indicated was equalled or exceeded

Percent of time	Discharge in second-feet					Discharge in second-feet per sq. mi. 1925-35
	1926-30	1931-35	Max. year 1927	Min. year 1931	1925-35	
1	25,800	16,700	26,500	4,280	20,700	7.61
2	18,900	11,500	21,800	3,800	15,000	5.52
3	15,100	8,900	19,000	3,000	12,000	4.41
4	13,000	7,400	16,700	2,520	10,100	3.71
6	10,500	5,200	13,200	2,090	7,800	2.87
8	8,900	4,180	10,900	1,800	6,100	2.24
10	7,450	3,550	9,600	1,590	4,900	1.80
15	4,900	2,500	7,350	1,200	3,600	1.32
20	3,950	2,020	5,100	1,020	2,850	1.05
25	3,290	1,630	4,300	915	2,390	.879
30	2,810	1,350	3,790	823	2,050	.754
40	2,220	1,000	2,800	665	1,510	.555
50	1,850	780	2,310	572	1,110	.408
60	1,400	625	1,940	500	840	.309
70	1,030	505	1,620	457	653	.240
75	860	458	1,380	436	586	.216
80	730	410	1,200	412	523	.192
85	643	358	1,050	391	454	.167
90	572	304	915	371	400	.147
92	550	287	856	363	368	.135
94	508	269	800	355	330	.121
96	459	250	758	330	291	.107
97	429	239	737	317	271	.100
98	393	225	717	303	251	.092
99	354	203	700	287	223	.082

Stillwater River at Englewood (13)

Percentage of time discharge indicated was equalled or exceeded

Percent of time	Discharge in second-feet							Discharge in second-feet per sq. mi. 1926-45
	1926-30	1931-35	1936-40	1941-45	Max year 1937	Min. year 1941	1926-45	
1	6,450	4,450	7,500	5,700	9,000	1,120	6,200	9.60
2	5,200	3,330	5,950	4,200	9,000	780	4,800	7.43
3	4,700	2,210	4,430	3,190	8,500	515	3,800	5.88
4	4,130	1,750	3,600	2,530	5,380	389	3,070	4.75
6	3,000	1,250	2,650	1,520	3,330	300	2,050	3.17
8	2,340	965	1,860	1,180	2,300	272	1,570	2.43
10	1,850	790	1,400	930	1,800	248	1,180	1.83
15	1,080	480	920	535	1,300	205	780	1.21
20	840	350	690	380	980	168	565	.875
25	620	278	540	298	750	148	435	.673
30	525	228	435	249	605	132	355	.550
40	381	155	305	172	459	106	242	.375
50	295	111	210	122	361	84.5	164	.254
60	193	89.5	147	83.5	287	65	116	.180
70	120	69.5	100	59	195	51.5	81	.125
75	100	60	83	50.5	162	42.5	68.5	.106
80	89.5	50.5	68	44	140	35	58	.090
85	74.5	42	53.5	31.7	119	28.8	48.7	.075
90	56	34	43.5	26.8	102	21.5	38	.059
92	50	30.9	39.5	24.6	98	19	34	.053
94	46.5	27.6	34.9	21.7	88	18.3	29.6	.046
96	42.7	24	29.8	18.3	77.5	16.8	25.4	.039
97	40.5	22	26.7	15.7	73.8	15.4	22.8	.035
98	37.8	19.8	22.9	12.5	67	12.8	19.7	.030
99	34.2	16	18.8	9.3	60	8.55	15	.023

Table 14 (Cont.)

Mad River near Dayton (15)

Percentage of time discharge indicated was equalled or exceeded

Percent of time	Discharge in second-feet								Discharge in second-feet per sq. mi., 1915-45
	1916-20	1926-30	1931-35	1936-40	1941-45	Max. year 1929	Min. year 1941	1915-45	
1	4,350	5,600	3,450	4,400	2,900	8,700	685	4,230	6.69
2	3,050	4,100	2,230	3,100	1,900	4,700	610	2,870	4.54
3	2,390	3,230	1,710	2,150	1,500	4,000	535	2,230	3.53
4	1,930	2,630	1,500	1,850	1,250	3,450	460	1,850	2.93
6	1,600	1,830	1,190	1,500	1,000	2,550	410	1,460	2.31
8	1,420	1,530	970	1,300	860	2,010	388	1,230	1.95
10	1,290	1,360	840	1,160	760	1,710	364	1,110	1.76
15	1,000	1,040	630	950	630	1,290	315	905	1.43
20	880	880	500	820	540	1,040	282	765	1.21
25	810	780	425	720	480	900	267	670	1.06
30	750	710	370	640	420	800	258	595	.941
40	600	615	308	520	330	635	249	483	.764
50	500	525	269	426	260	510	230	403	.638
60	440	440	240	350	221	410	212	336	.532
70	397	363	216	300	200	340	190	281	.445
75	380	337	203	280	198	320	179	256	.405
80	360	310	190	260	192	302	166	234	.370
85	332	288	175	235	186	280	152	214	.339
90	295	259	160	206	175	220	139	197	.312
92	282	245	152	196	170	210	132	190	.301
94	270	230	144	185	160	204	125	180	.285
96	257	213	132	172	150	200	119	167	.264
97	250	204	123	166	144	200	114	160	.253
98	241	192	116	159	134	199	110	148	.234
99	226	176	107	150	120	194	104	131	.207

Wolf Creek at Dayton (22)

Percentage of time discharge indicated was equalled or exceeded

Percent of time	Discharge in second-feet				Discharge in second-feet per sq. mi., 1939-45
	1941-45	Max. year 1945	Min. year 1941	1939-45	
1	610	1590	170	690	9.93
2	345	840	105	385	5.54
3	270	470	72.0	300	4.32
4	192	380	59.0	235	3.38
6	120	270	48.0	145	2.09
8	90.0	180	42.0	105	1.51
10	72.0	132	35.0	84.0	1.21
15	49.0	72.0	23.5	55.5	.799
20	39.0	50.0	18.5	42.5	.612
25	31.0	38.0	16.0	35.0	.504
30	35.0	27.0	14.0	28.7	.413
40	16.50	16.8	11.0	19.5	.281
50	11.40	12.9	7.90	13.3	.191
60	8.00	11.0	6.00	9.40	.135
70	5.50	3.32	5.00	6.70	.096
75	4.90	3.05	4.50	5.60	.081
80	4.30	2.70	3.90	4.70	.068
85	3.50	2.30	3.50	3.90	.056
90	3.02	1.90	3.18	3.25	.047
92	2.75	1.75	3.00	3.00	.043
94	2.40	1.64	2.75	2.70	.039
96	2.00	1.56	2.40	2.30	.033
97	1.87	1.55	2.25	2.05	.029
98	1.71	1.54	2.06	1.84	.026
99	1.55	1.53	1.82	1.62	.023

Table 14 (Cont.)

Twin Creek near Germantown (23)

Percentage of time discharge indicated was equalled or exceeded

Percent of time	1916-20	1931-35	1936-40	1941-45	Max. year 1937	Min. year 1931	1914-45	Discharge in second-feet per sq. mi., 1914-45
1	3,300	2,920	4,100	2,480	6,550	755	3,400	12.4
2	2,300	1,600	2,800	1,500	5,600	470	2,300	8.36
3	1,720	1,130	1,890	1,200	3,300	350	1,670	6.07
4	1,410	950	1,370	950	2,650	286	1,300	4.73
6	1,000	700	1,000	600	1,380	218	930	3.38
8	770	520	800	475	1,090	170	720	2.62
10	620	400	630	375	900	122	590	2.15
15	440	235	420	253	550	92.0	410	1.49
20	355	162	320	192	407	74.0	305	1.11
25	275	119	250	152	322	61.0	230	.836
30	228	94.0	200	126	268	51.0	180	.655
40	162	61.0	133	85.0	193	35.2	118	.429
50	112	40.0	89.0	57.5	153	26.4	79.0	.287
60	84.0	26.8	63.0	34.0	123	20.7	50.0	.182
70	51.0	20.2	41.3	21.9	90.0	17.7	32.5	.118
75	42.0	17.9	31.0	18.3	74.0	16.2	26.5	.096
80	37.8	15.9	24.0	15.6	59.0	14.9	22.0	.080
85	33.4	13.8	19.5	11.8	43.0	13.4	18.0	.065
90	27.5	11.5	15.5	7.50	28.3	11.7	14.5	.053
92	25.0	10.5	13.8	6.50	24.0	10.9	12.9	.047
94	22.2	9.40	11.8	5.60	20.8	10.0	11.0	.040
96	19.7	8.20	9.90	4.80	18.3	9.00	8.80	.032
97	18.2	7.40	9.00	4.50	17.2	8.40	7.60	.028
98	16.5	6.60	8.00	4.00	16.1	7.70	6.40	.023
99	14.3	5.60	6.80	3.50	15.1	6.90	5.00	.018

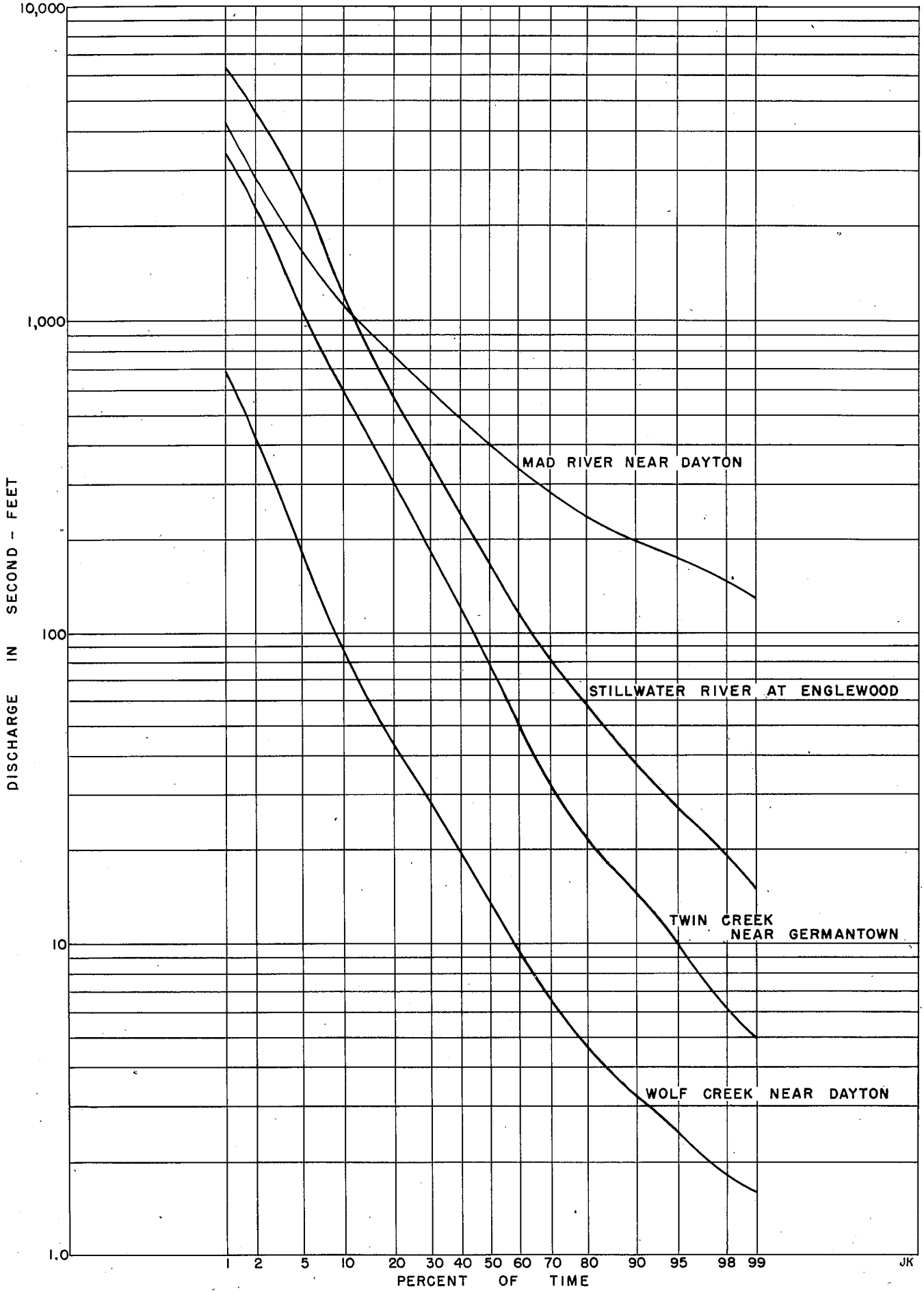


Plate 28. Flow-duration curves for stations in the Miami River Basin.

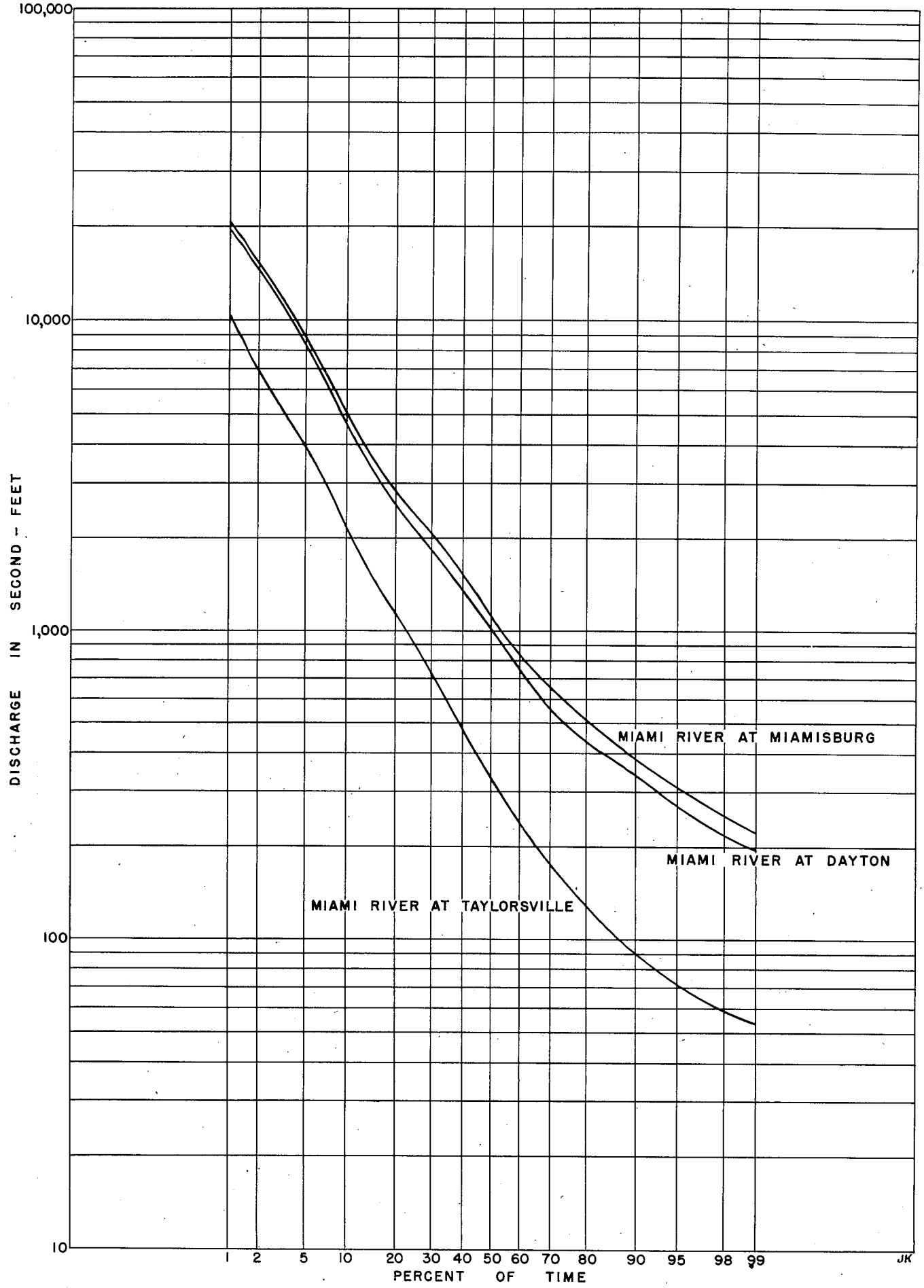


Plate 29. Flow-duration curves for stations in the Miami River Basin.

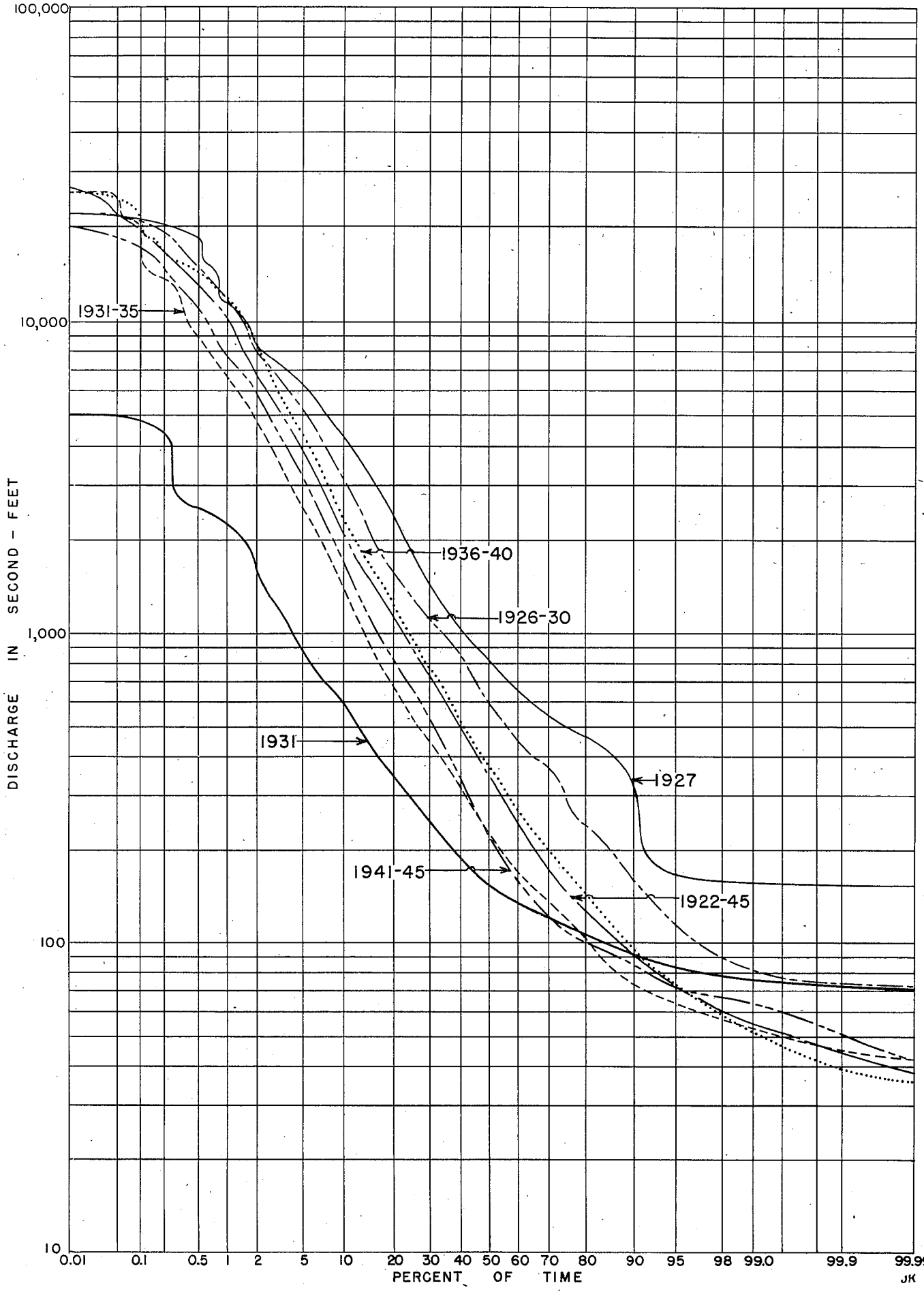


Plate 30. Flow-duration curves of the Miami River at Taylorsville.

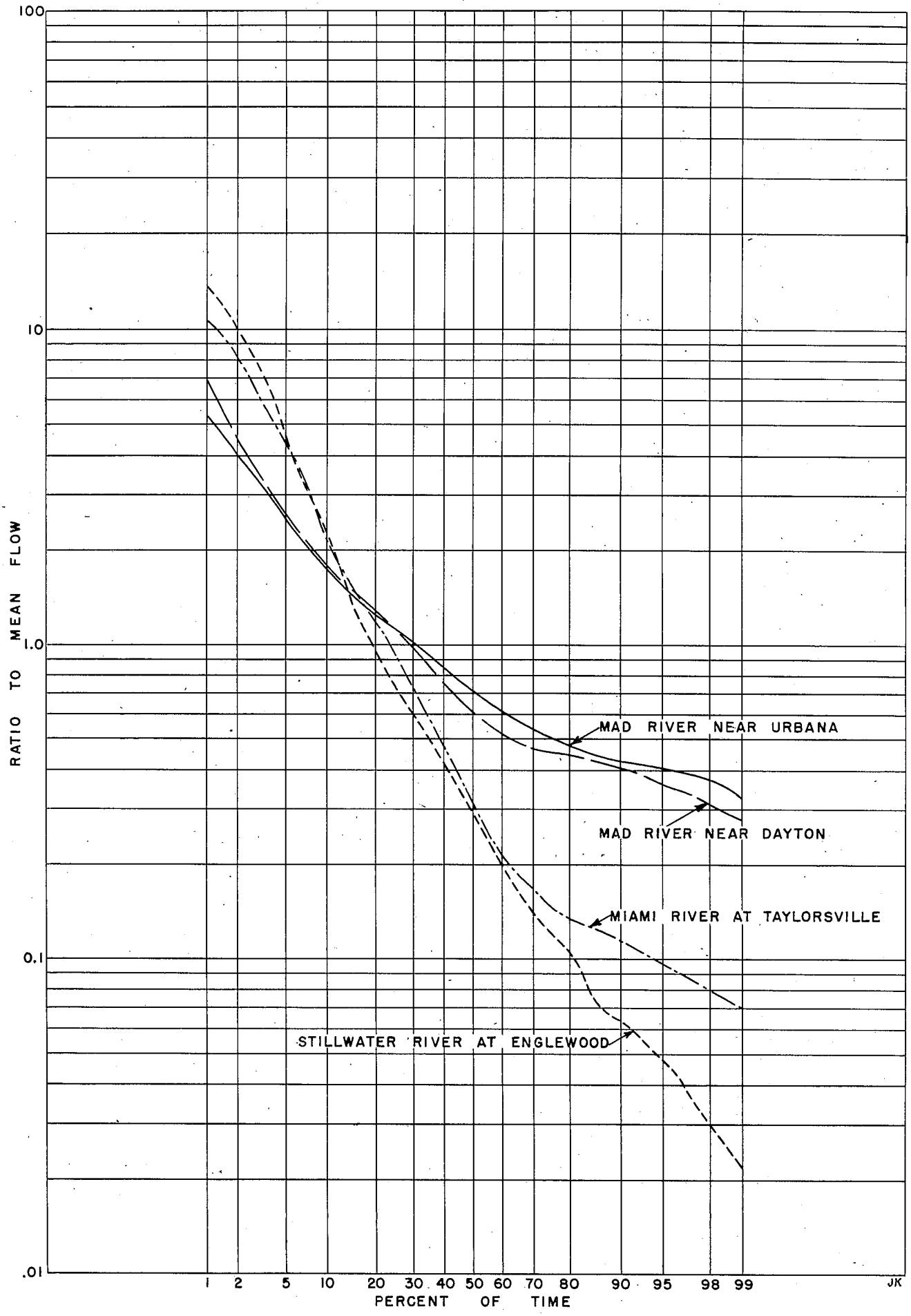


Plate 31. Flow-duration curves for stations in the Miami River Basin for period 1941-45.

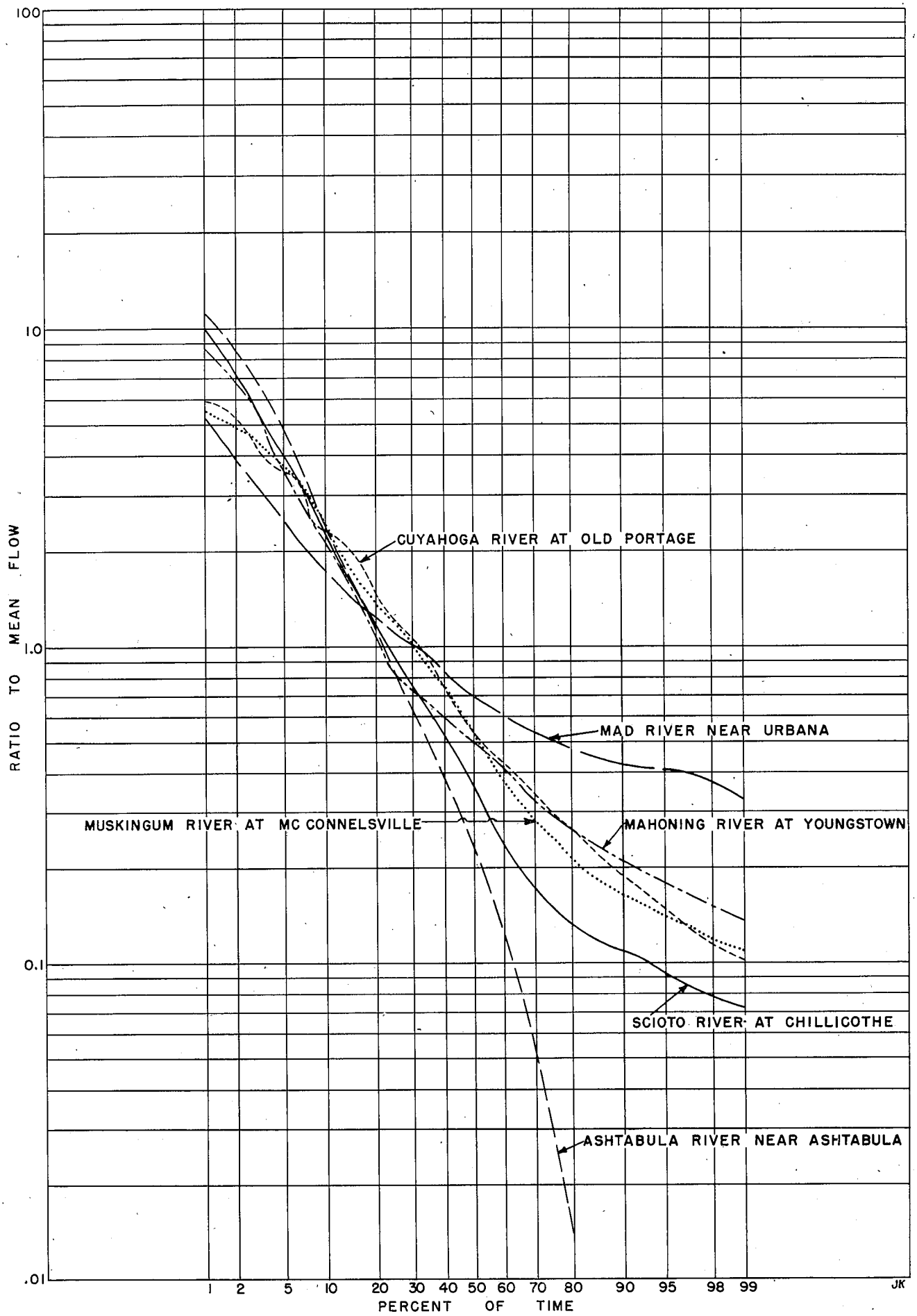


Plate 32. Flow-duration curves for selected gaging stations in Ohio, for period 1941-45.

Minimum flows and unit storage curves

As mentioned in the previous section, duration curves do not take into account the chronology or sequence of events. In the study of droughts, it is of interest to know the minimum flows which have occurred for consecutive periods of various lengths of time, and the minimum flows which may be expected, on the average, in any year. The minimum momentary discharges, and the minimum daily flows of record for certain stations are shown in table 13. The minimum flows recorded for consecutive periods ranging from 7 days to the total length of record for five stations in the Miami River Basin are plotted on plates 33, 34, 35, 36, and 37. The minimum flows occurring in each year for consecutive periods ranging in length from 7 days to 6 months were determined and plotted against percentage of time in a duration-type curve for each period. The 50-percent and 75-percent points from these curves were used in plotting the Q-50 and Q-75 curves shown on the figures. The Q-50 curve, therefore, shows the minimum flows which may be expected, on the average, each year, and the Q-75 curve indicates the minimum flows which may be expected, on the average, once in 4 years. The curves are plotted in terms of second-feet per square mile, for purposes of comparison.

Considering the range of drainage areas and the varying lengths of records, the curves for the three stations in the Miami River Basin, excluding the two in the Mad River Basin, are remarkably similar. These three curves are generally typical of all nonregulated streams in Ohio, but varying lengths of record make close comparisons impossible. Here, again, the large natural ground-water storage in the Mad River Basin is revealed. The minimum flows for short consecutive periods for the Mad River stations are about 10 times as great as minimum flows for the same lengths of time on other streams.

Another method of studying low-water flows, closely related to the above, is the computation of unit-storage or storage-required curves. This method amounts essentially to a mass-curve analysis, in which the amounts of storage required to build up the available volumes of flow to specific draft rates are computed. For purposes of comparison the regulated flows are in second-feet per square mile, and the required storage in millions of cubic feet per square mile, neglecting evaporation. This analysis is valuable in the design of storage reservoirs. However, it should be emphasized that the analyses presented here are but the preliminary steps toward the design analysis for a reservoir system. Many other factors of importance must be considered in addition to the minimum flow available at gaging stations. For the purposes of this report the studies are useful for showing the minimum-flow characteristics of the streams, and in a general way the relative amounts of storage necessary to maintain specific outflows from a reservoir.

A comparison of the unit-storage curves shown on plates 38, 39 and 40 indicates that the three stations outside the Mad River Basin that have been analyzed give similar results, which are generally typical of

all streams in Ohio. Although there are large differences in the values of minimum momentary and minimum daily flows among nonregulated streams in Ohio, the differences in the values of minimum discharges for longer consecutive periods are comparatively small. This is shown by the unit-storage graphs that have been prepared for a number of Ohio streams. There are some exceptions, of course, of which the Mad River curves are outstanding examples. The differences between the Mad River Basin curves and those for other streams show again the immense natural ground-water storage in the Mad River Basin. This storage above Urbana has about the same effect, at some flows, as 1½ billion cubic feet of artificial storage.

General relations of stream flow to climate and geology

Of the total rainfall in an area, only a part leaves the area as stream flow. The remainder is disposed of by evaporation from land and water surfaces and transpiration by plants, and possibly a minor amount (in Ohio) as ground-water underflow that leaves the basin without being measured. The evaporation and transpiration losses are often considered together as evapo-transpiration, and the difference between rainfall and stream flow, whatever the disposition, is called "water loss."

The relations among rainfall, stream flow, and water losses have been the subject of much study. The problem is a complex one, involving every phase of the movement of water in the hydrologic cycle from cloud to earth and, by various intricate paths, back to cloud. No entirely satisfactory solution can be reached without a great deal of detailed investigation. However, the general relations can be outlined.

Some of the factors that tend to produce low water losses are:

(1) Steep, barren slopes that drain rapidly into streams, thus reducing the opportunity for evaporation and transpiration.

(2) Permeable surface soils and other geologic conditions that allow water to percolate rapidly to considerable depth, beyond the reach of plants and evaporation.

Factors that tend to produce high water losses are:

(1) Hot, dry climates that cause excessive evaporation.

(2) Dense growth of vegetation that absorbs and transpires large quantities of water.

(3) Ground-water levels within capillary range of the ground surface.

Table 15

Flow-duration tables for selected gaging stations in Ohio, for period 1941-45, in terms of ratios to mean flow, in abbreviated form.

Station No.	Station and location	Percent of time								
		1%	10%	20%	30%	50%	70%	80%	90%	99%
1	Miami River at Sidney	11.9	2.40	1.21	.699	.299	.155	.123	.102	.059
4	Miami River at Taylorsville	10.6	2.15	1.14	.704	.304	.165	.134	.114	.070
5	Miami River at Dayton	10.4	2.04	1.16	.823	.408	.243	.204	.164	.102
9	Loramie Creek at Lockington	15.4	2.28	.799	.432	.145	.061	.053	.041	.021
11	Stillwater River at Pleasant Hill	13.3	2.08	.905	.587	.276	.137	.100	.072	.038
13	Stillwater River at Englewood	13.6	2.21	.905	.593	.290	.140	.105	.064	.022
15	Greenville Creek near Bradford	11.2	2.16	.992	.682	.342	.198	.160	.122	.077
16	Mad River near Urbana	5.34	1.74	1.24	1.02	.697	.534	.473	.422	.326
17	Mad River near Springfield	6.36	1.73	1.24	.954	.636	.514	.451	.393	.327
18	Mad River near Dayton	6.70	1.76	1.25	.970	.600	.462	.443	.404	.277
21	Buck Creek at Springfield	9.64	1.78	1.28	.991	.509	.376	.324	.238	.094
22	Wolf Creek at Dayton	14.3	1.68	.911	.584	.266	.129	.100	.071	.036
23	Twin Creek near Germantown	13.3	2.02	1.03	.677	.309	.118	.084	.040	.019
	Maumee River at Antwerp	9.57	2.47	1.31	.826	.338	.158	.118	.083	.043
	Bean Creek at Powers	9.00	2.52	1.32	.806	.331	.194	.146	.108	.049
	Blanchard River near Findlay	14.4	2.33	.972	.539	.189	.069	.045	.032	.012
	Sandusky River near Upper Sandusky	14.0	2.45	1.05	.582	.229	.095	.060	.037	.016
	Cuyahoga River at Old Portage	5.96	2.32	1.47	1.05	.534	.339	.266	.189	.100
	Chagrin River at Willoughby	12.6	2.20	1.16	.758	.404	.217	.159	.106	.065
	Ashtabula River near Ashtabula	11.3	2.39	1.12	.633	.233	.053	.014	.002	0
	Mahoning River at Youngstown	8.68	2.20	1.10	.738	.498	.327	.263	.211	.135
	Meander Creek at MineralRidge	19.4	2.28	.682	.094	.028	.020	.017	.014	.009
	Little Beaver Creek near East Liverpool	9.71	2.31	1.32	.889	.403	.214	.151	.099	.055
	Yellow Creek at Hammondsville	9.16	2.32	1.32	.871	.432	.177	.116	.059	.019
	Muskingum River at McConnelsville	5.54	2.39	1.38	1.00	.535	.279	.212	.164	.108
	Jerome Fork at Jeromesville	16.6	2.14	.989	.630	.241	.119	.089	.064	.037
	Licking River at Toboso	10.7	2.14	1.18	.757	.367	.204	.160	.122	.092
	Hocking River at Athens	10.1	2.39	1.21	.799	.373	.168	.118	.088	.066
	Symmes Creek at Getaway	11.3	2.94	1.31	.633	.209	.057	.025	.010	.004
	Scioto River at Chillicothe	10.1	2.29	1.16	.751	.362	.170	.132	.109	.072
	Alum Creek at Columbus	16.0	1.84	.941	.574	.224	.087	.054	.035	.010
	Darby Creek at Darbyville	12.5	2.20	1.14	.670	.249	.117	.083	.054	.021
	Deer Creek at Williamsport	12.4	2.06	1.05	.694	.290	.158	.081	.037	.014
	Little Miami River at Spring Valley	8.53	2.05	1.27	.853	.382	.246	.214	.168	.116

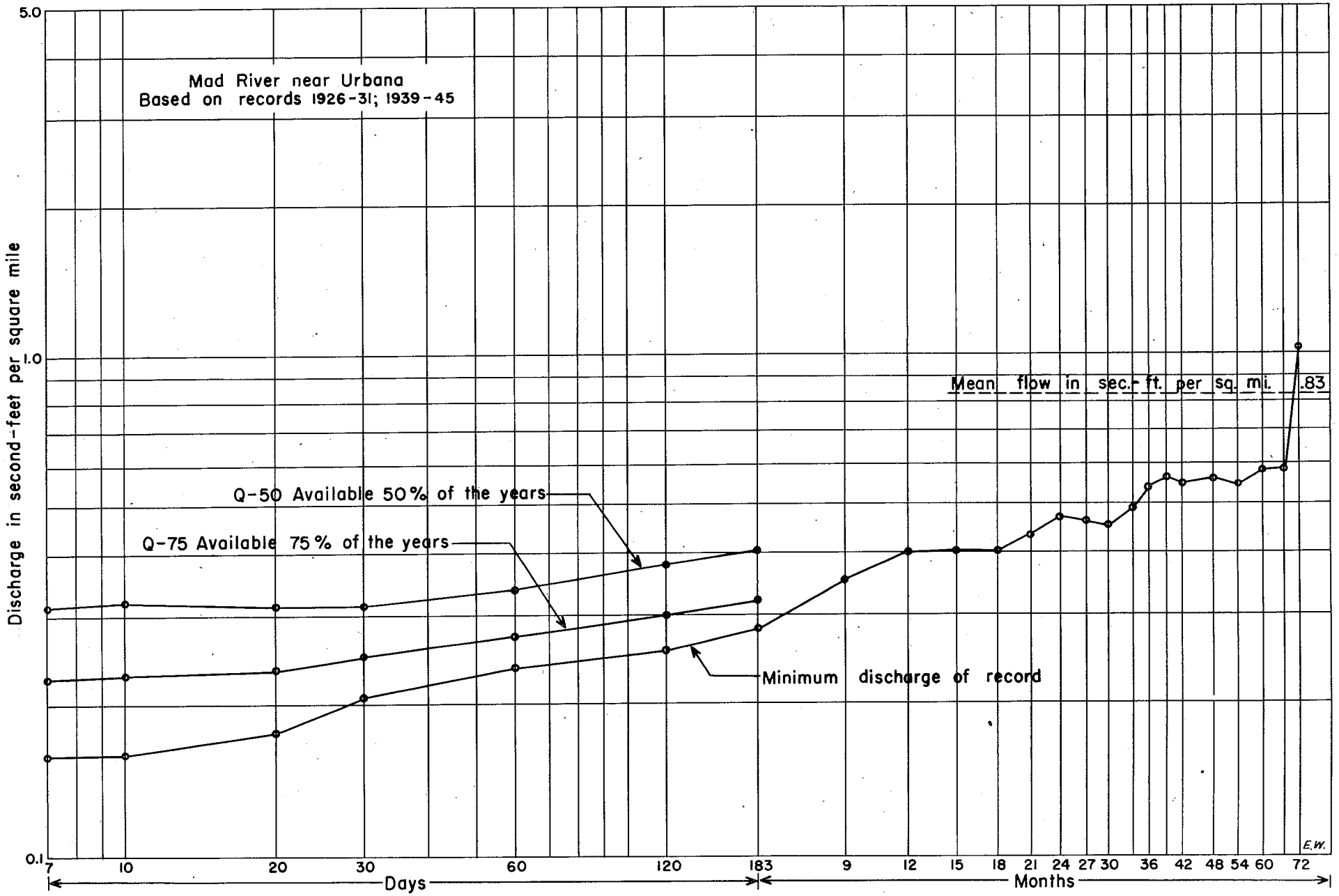


Plate 33. Discharge available without storage for Mad River near Urbana.

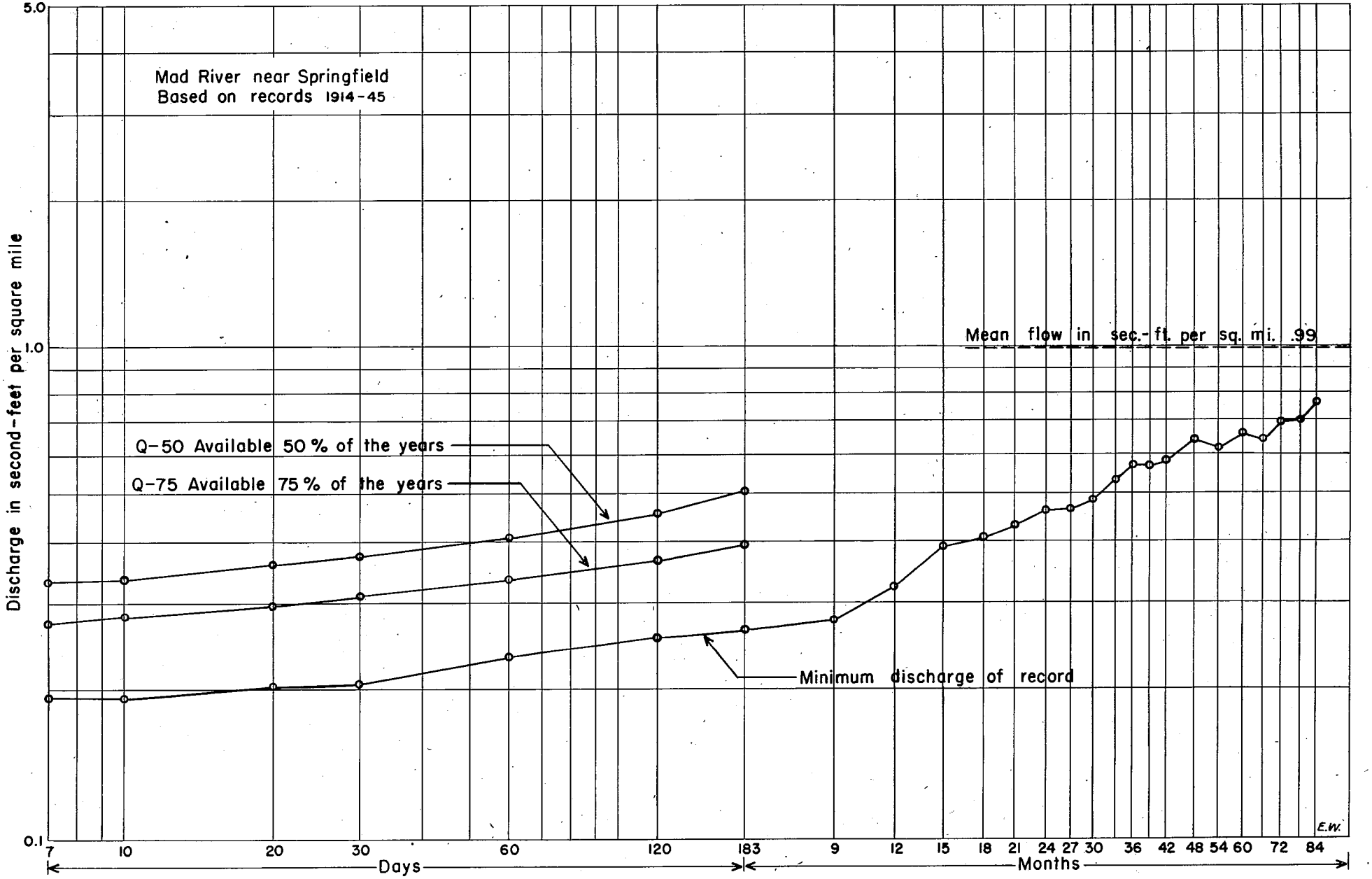


Plate 34. Discharge available without storage for Mad River near Springfield.

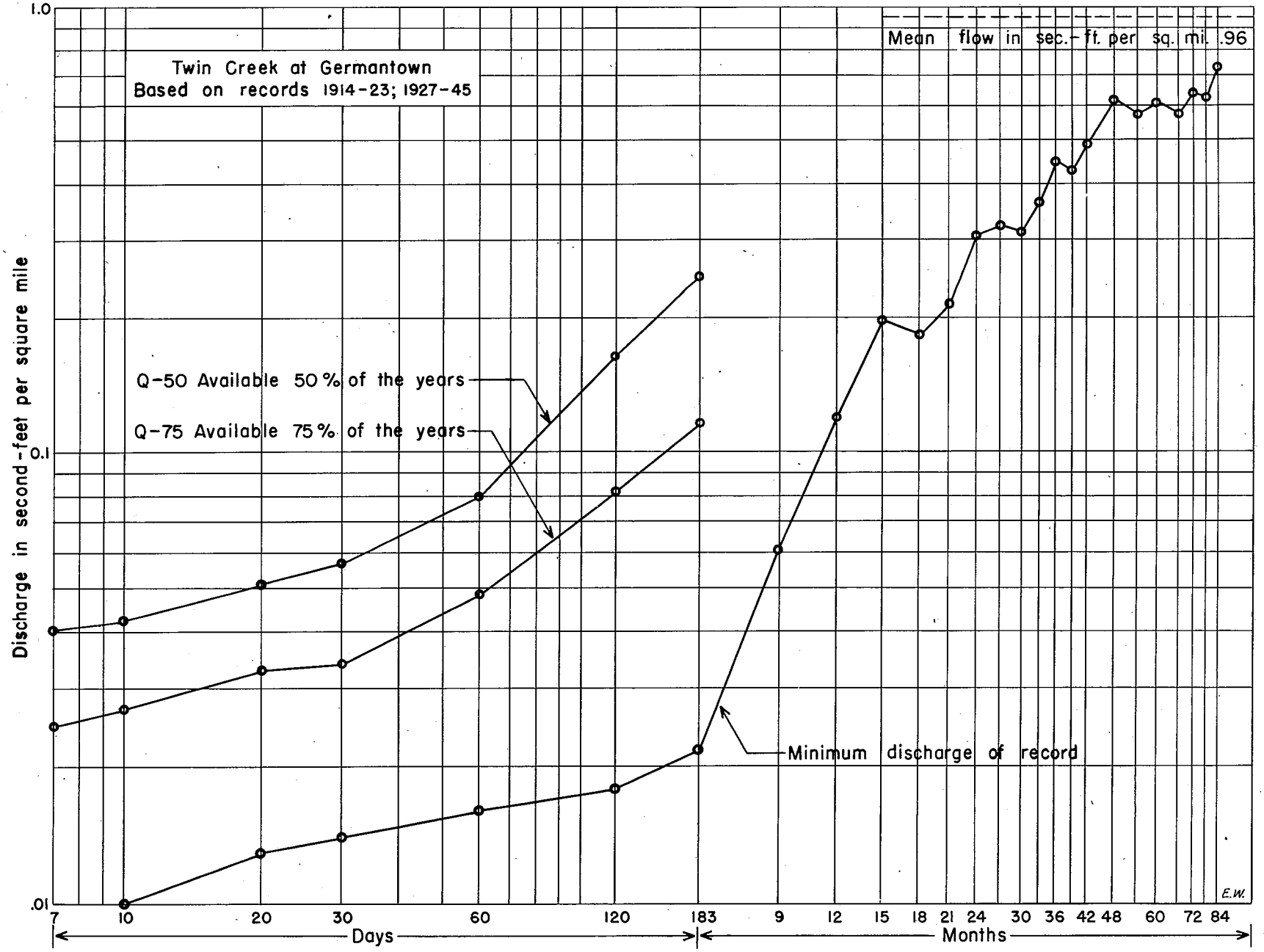


Plate 35. Discharge available without storage for Twin Creek at Germantown.

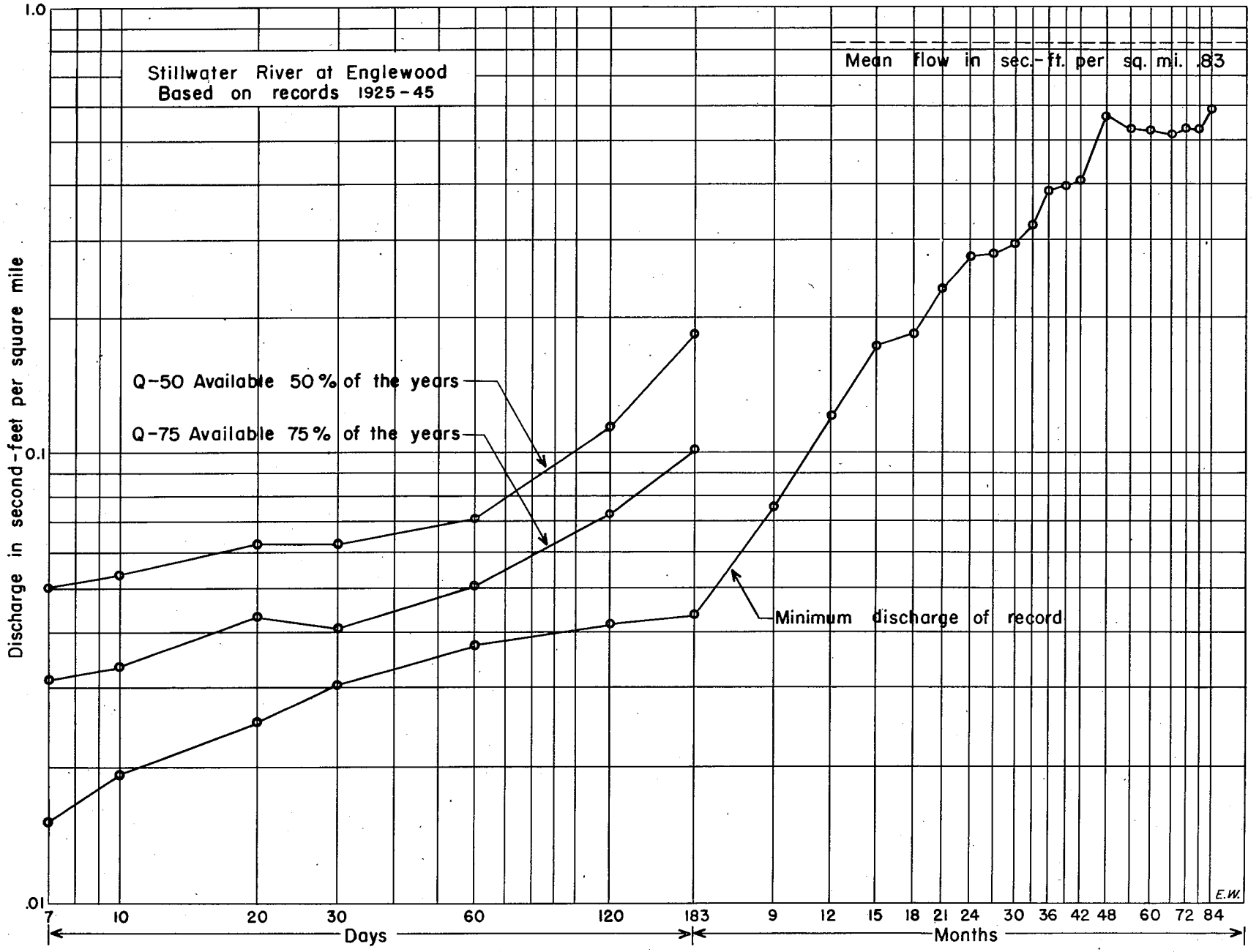


Plate 36. Discharge available without storage for Stillwater River at Englewood.

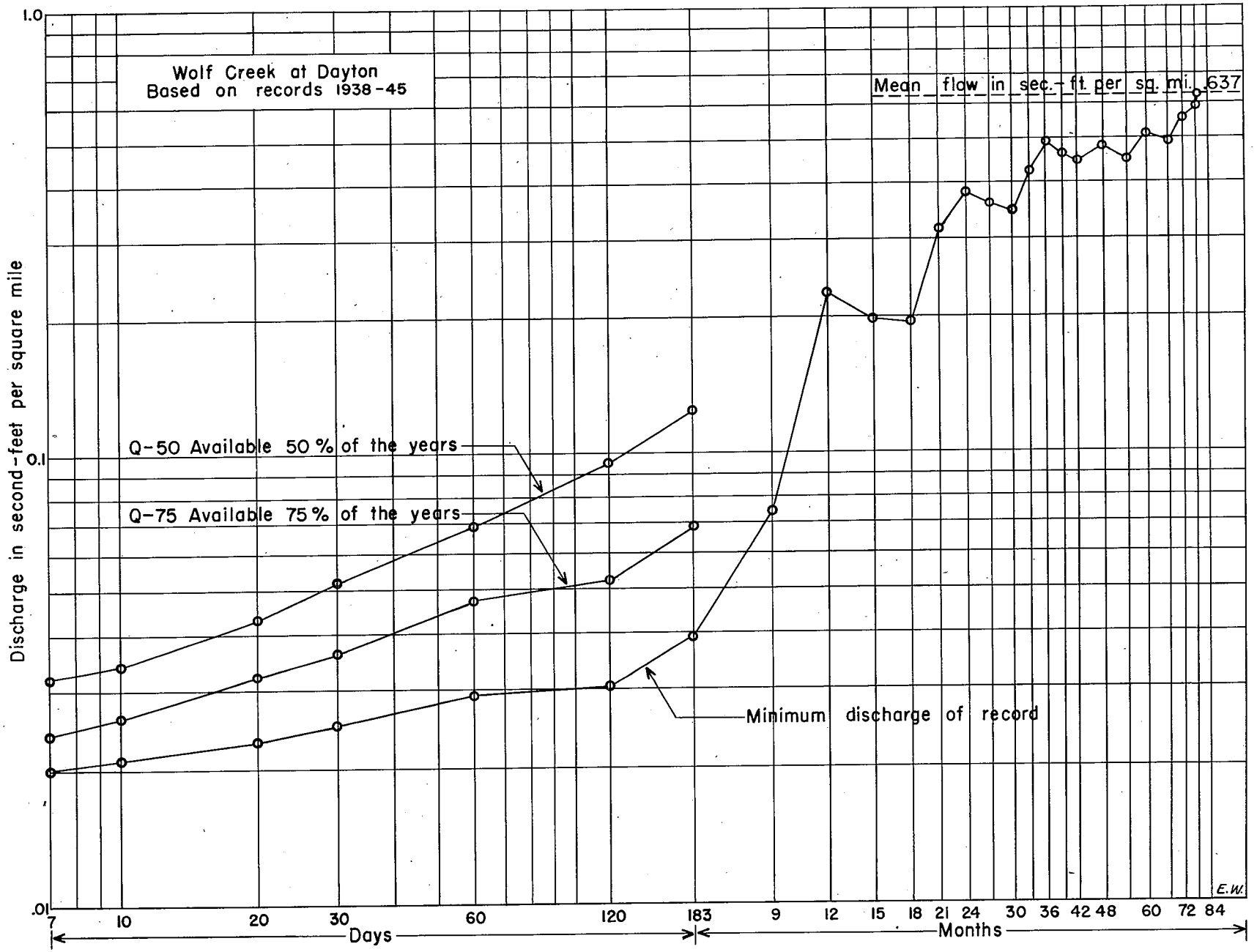


Plate 37. Discharge available without storage for Wolf Creek at Dayton.

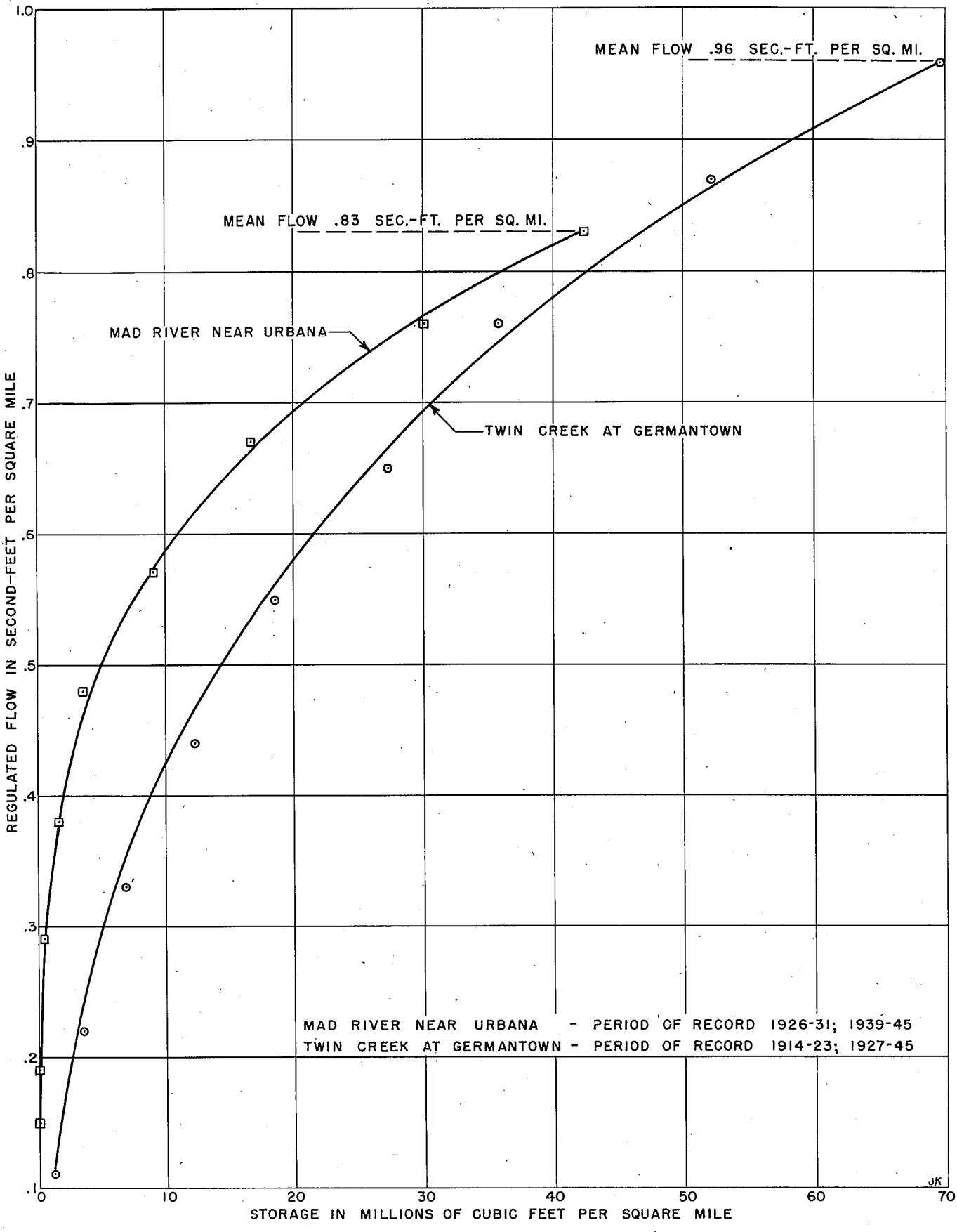


Plate 38. Unit storage graph for Mad River near Urbana and Twin Creek at Germantown.

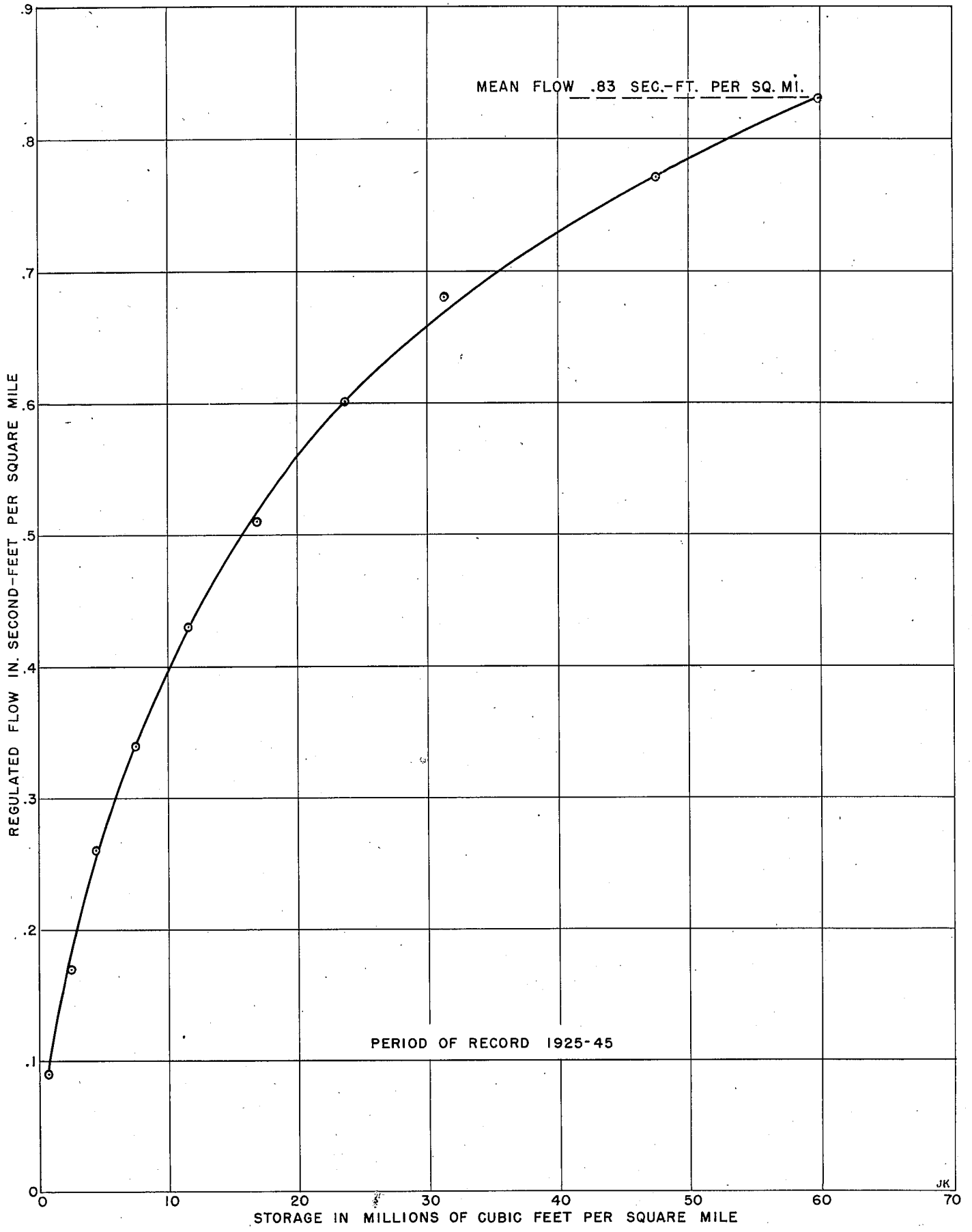


Plate 39. Unit storage graph for Stillwater River at Englewood.

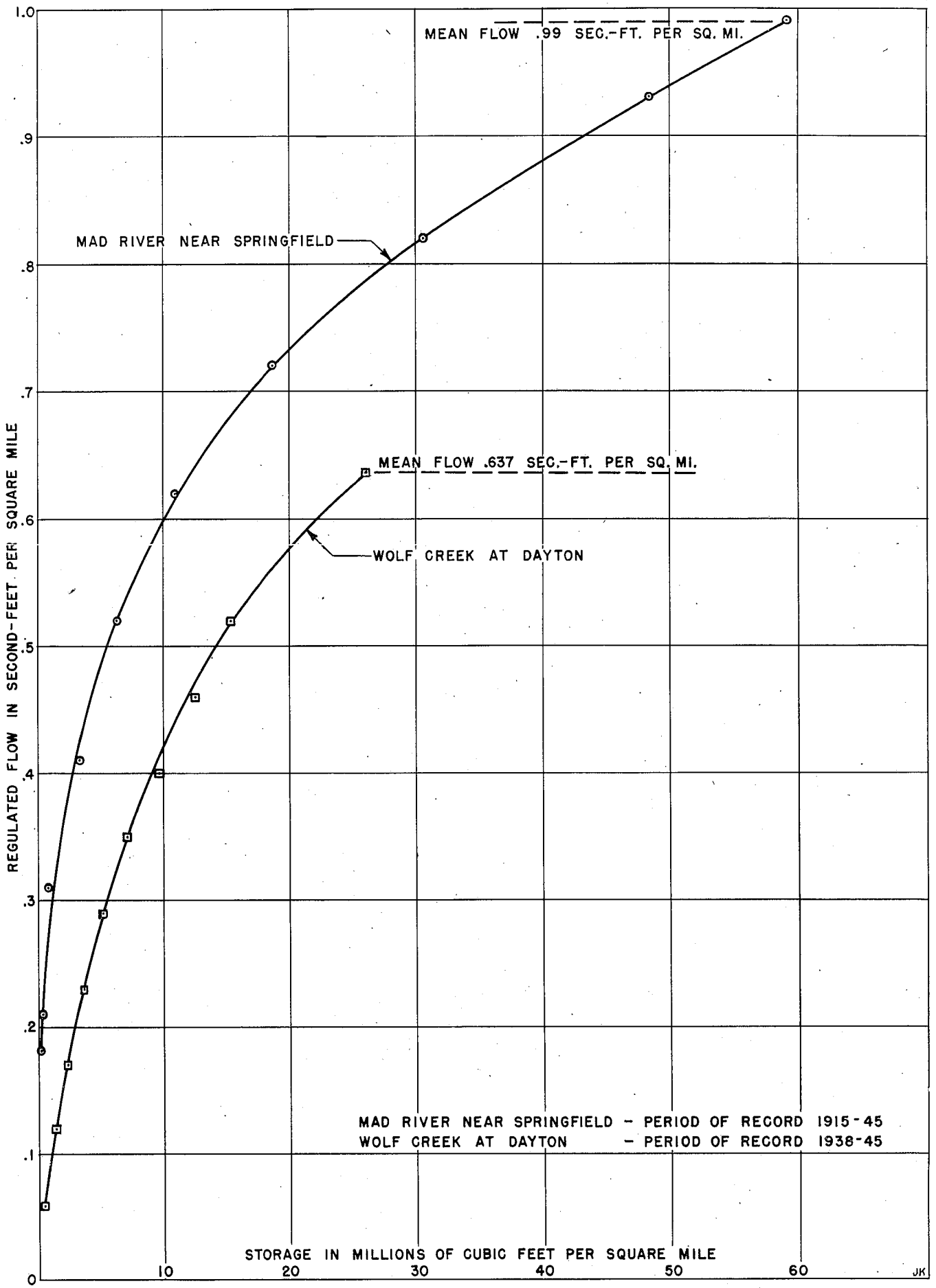


Plate 40. Unit storage graph for Mad River near Springfield and Wolf Creek at Dayton.

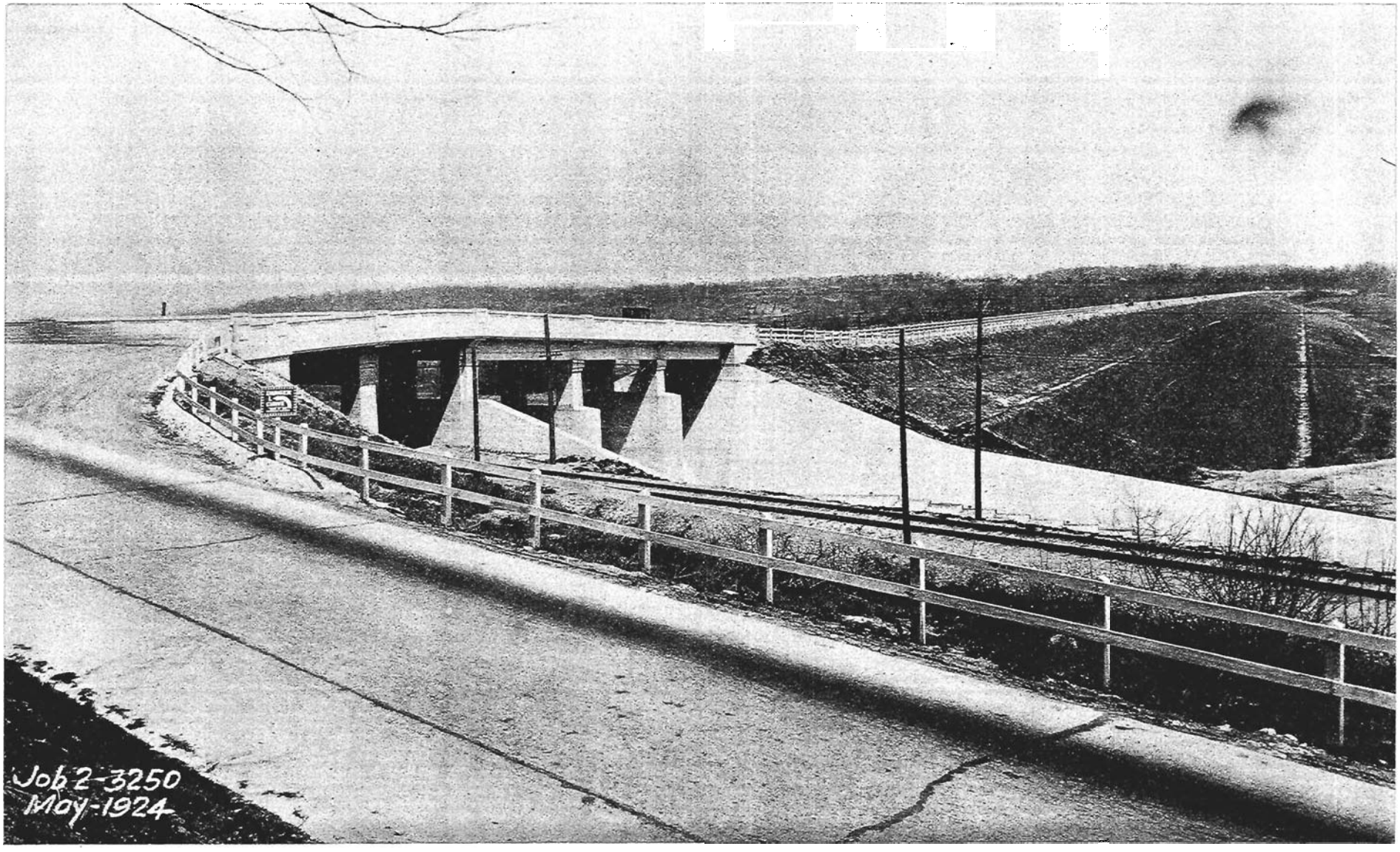


Plate 44. Photograph of Englewood Dam, one of five flood control dams built by the Miami Conservancy District. View looking eastward across Stillwater valley in section 23, Randolf Township. Dam spillway in foreground.

Photograph courtesy of the Miami Conservancy District

(4) Flat slopes and tight soils that increase the opportunity for evaporation from surface ponds.

(5) Large areas of lakes and swamps, increasing the evaporation opportunity.

(6) Geologic conditions that permit large quantities of ground water to leave the basin as underflow without being measured as stream flow.

Climate, particularly temperature and precipitation, is the major controlling factor that determines stream flow and water losses. Ohio has no large artesian basins, and the ground water that bypasses a gaging station by underflow is usually insignificant. Williams (20) has shown that water losses in the subhumid and humid parts of the United States, with mean annual precipitation in excess of 20 inches, are largely dependent on mean temperature. One of the difficulties in studies of this nature is that the available records are for different periods of time. Varying amounts of storage underground and in channels may seriously affect short-term studies, but has only a minor effect on long records. The 25-year period from 1921 through 1945 has been selected by the Ohio Water Resources Board as the standard period for comparative studies of this type, but unfortunately there are only seven continuous stream-flow records for this period in Ohio. Four of these, however, are in the Miami River Basin. Table 16 lists the average annual stream flow in inches, the average precipitation and water loss in inches, and the average annual temperature in degrees Fahrenheit, from the available records in Ohio for the standard period. The mean annual temperature has been plotted against mean annual water loss on plate 41. Also shown on this diagram is the mean trend line determined by Williams from a large number of basins in the humid area of the United States. Williams' data scatter more than do the plots for the Ohio stations, possibly because of unequal lengths of records and inadequate climatic records, but it is significant that the Ohio records follow closely the mean trend line. This would suggest that temperature is the controlling factor determining water losses over a long period of time.

From the foregoing it is evident that average stream flow in Ohio over a long period of time is determined by mean temperature and mean precipitation. These climatic factors undoubtedly act in various complex ways on other factors mentioned; for example, the type, density, and rate of growth of vegetation depends primarily on temperature and precipitation.

The annual temperatures for the Miami River drainage area above the Taylorsville stream-gaging station are plotted against the annual water losses for each year of record on plate 42. The wide scattering of the points is indicative of the large variations in amount of water in storage within the basin at the end of each year. Apparently several inches of

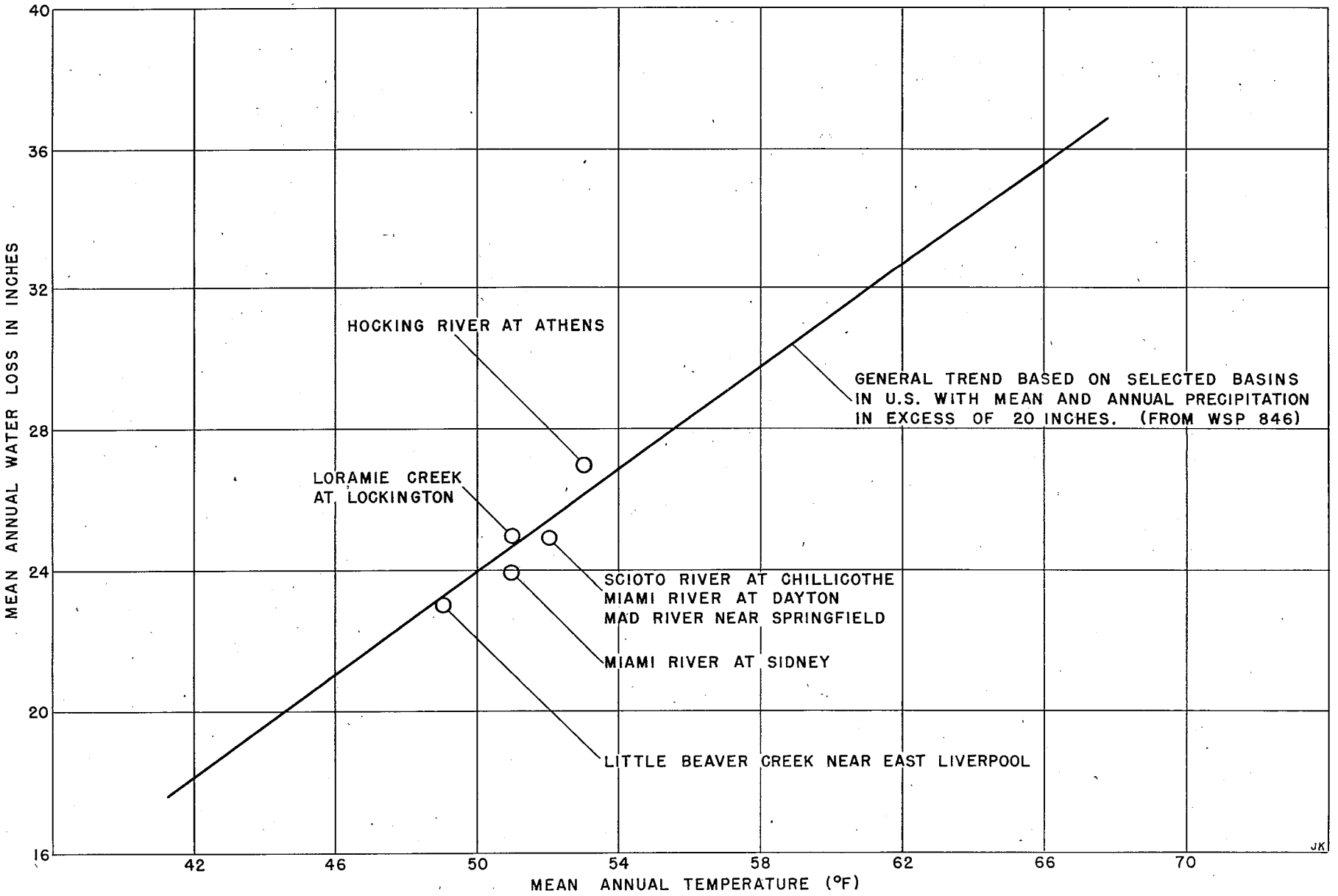


Plate 41. Comparison of mean annual water loss and mean annual temperature for selected basins in Ohio for 25-year period 1921-45.

water may be held over in ground-water storage at the end of a very wet year.

Many attempts have been made, particularly by early investigators, to obtain linear relationships between rainfall and stream flow. Such plots can show little more than general trends because of the effect of temperature and the differences in ground-water storage from year to year. Annual stream flow for the Miami River at Taylorsville is plotted against annual precipitation on the drainage area on plate 43. The diagram shows a general trend, but the correlation is poor.

The differences in stream-flow characteristics, as shown by the minimum flows, duration curves, and storage-required curves, may be explained by differences in the geologic conditions, particularly the thickness of glacial drift and its water-bearing properties. Other characteristics, such as the average slope of the land surface, stream gradients, degree of tillage and vegetative cover, are also important. These factors seem largely to influence ground water, resulting in differences in the distribution of the stream flow within the year rather than affecting the total annual stream flow.

FLOODS AND THE MIAMI CONSERVANCY DISTRICT

The Miami Valley in the past was subject to frequent floods. The dendritic pattern of the streams, with three large valleys coming together at Dayton, increased the flood danger at this city. The first flood of record occurred in 1805, the water reaching a depth of 8 feet in Dayton at Third and Main Streets (21). This was caused by a combination of heavy rains and the melting of deep snows on the headwaters of the streams. Damaging floods also occurred in 1814, 1828, 1832, and 1847. Over the years some small levees had been constructed, but they provided small protection. In September 1866 a 3-day rain produced a serious flood, and water was up on the floors of downtown hotels. The property loss was estimated at $250,000, a large amount for those times. Other serious floods were those of 1883, 1897, and 1898. These floods occurred in February or March.

By far the worst flood in the 150 years since the settlement of Ohio occurred in March 1913. Three days of heavy rains, with a cumulative total of more than 11 inches over a wide area, and with more than 8 inches everywhere in the Miami River Basin, was the immediate cause. Levees were topped in all the Miami Valley cities. Water was 12 feet deep on Main Street in Dayton. Over 400 lives were lost, and more than a hundred million dollars worth of property was destroyed. This tremendous disaster brought about a great determination to prevent the recurrence of floods in the Miami Valley. A State law was passed in 1914, providing for the formation of Conservancy Districts. The Miami Conservancy District was formed in 1915. Engineers studied and drew up

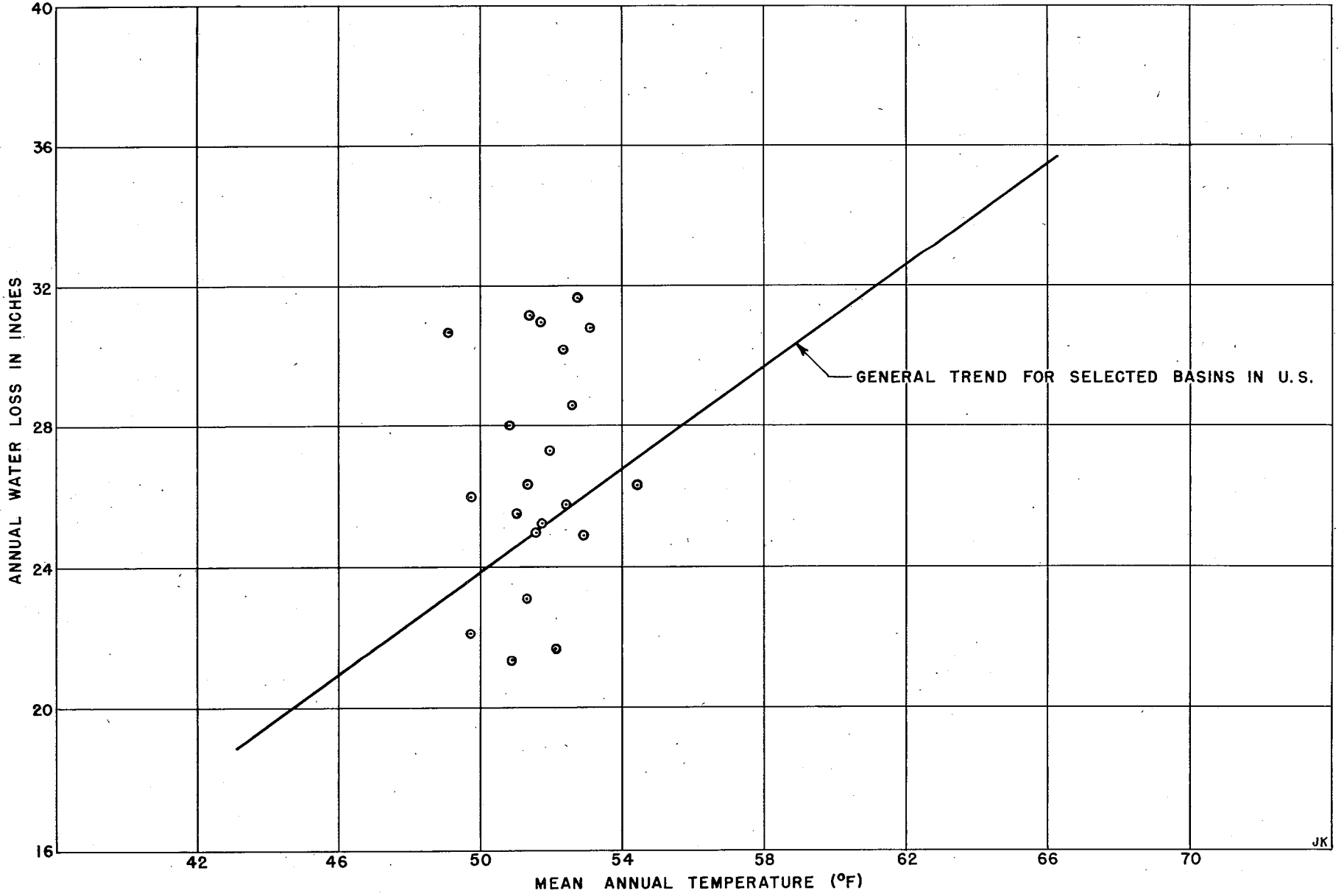


Plate 42. Annual water loss in inches and mean annual temperature, Miami River at Taylorsville.

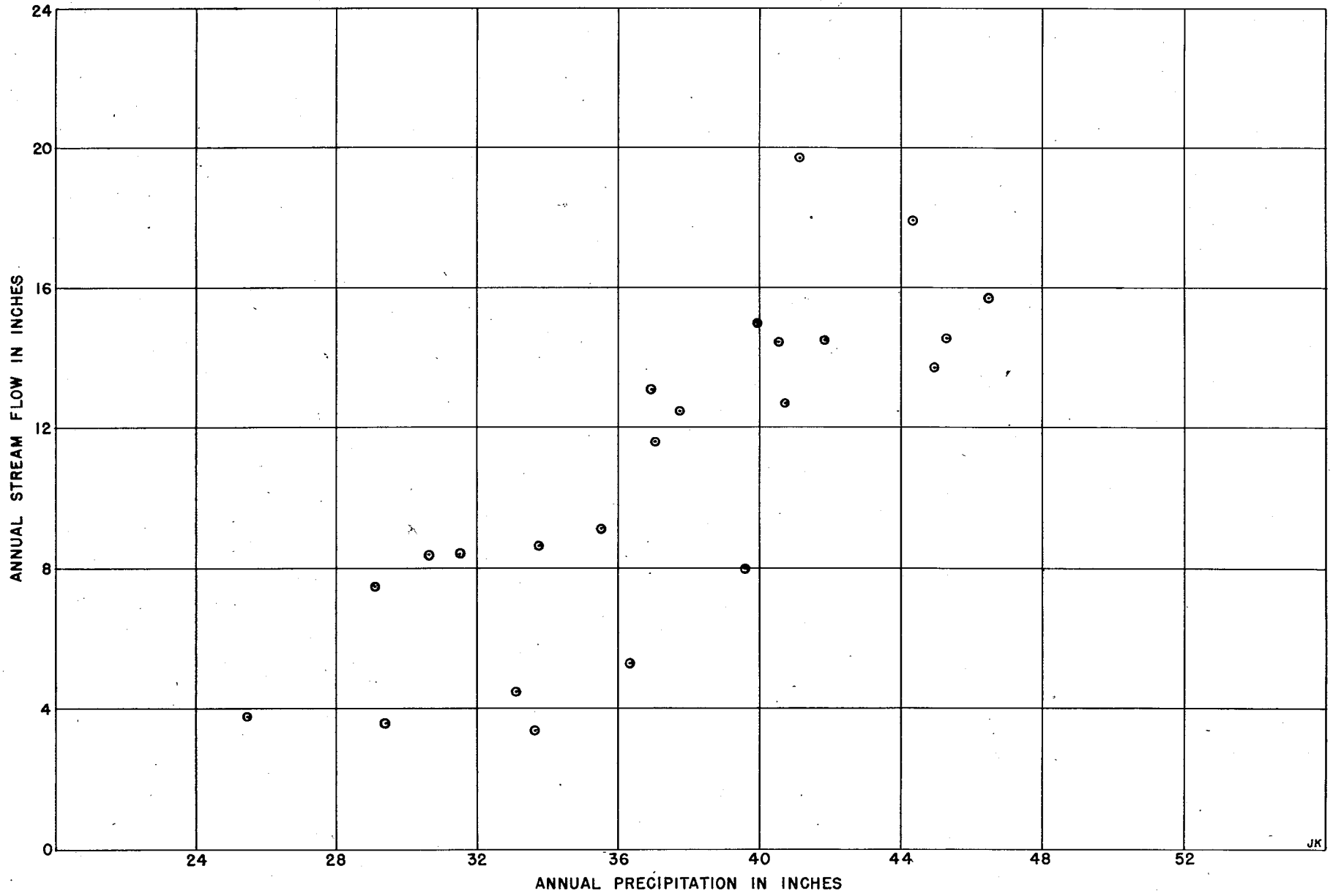


Plate 43. Annual precipitation and annual stream flow in inches, Miami River at Taylorsville.

Table 16

Precipitation, stream flow, water loss, and temperature for selected basins in Ohio
25-year average (1921-1945)

Station and Location	D. A.	Stream flow, in inches	Temperature, in degrees F.	Precipitation, in inches	Water loss, in inches
Miami River at Sidney	545	11.87	51	36	24
Miami River at Dayton	2513	11.53	52	37	25
Mad River near Springfield	485	13.32	52	38	25
Loramie Creek (below Lockington Dam at Lockington)	261	10.07	51	35	25
Scioto River at Chillicothe	3847	11.54	52	37	25
Hocking River at Athens	944	14.07	53	41	27
Little Beaver Creek (near East Liverpool)	505	14.01	49	37	23

Table 17

Effects of retarding basins on floods in Miami River Basin

Sta. No.	Stream and Location	Drainage Area sq. mi.	1913 FLOOD		1922 FLOOD		1929 FLOOD		1937 FLOOD	
			Sec. ft.	Sec. ft. Sq. mi.	Sec. ft.	Sec. ft. Sq. mi.	Sec. ft.	Sec. ft. Sq. mi.	Sec. ft.	Sq. mi.
1	Miami River at Sidney, Ohio. (a)	545	44,000	80.7	8,660	15.9	18,000	33.0	12,400	22.8
4	Miami River at Taylorsville, O. (a)	1,155	127,000	110.0	17,300	15.0	23,700	20.5	25,500	22.1
5	Miami River at Dayton, O. (a)	2,513	250,000	99.5	39,500	15.7	53,000	21.1	48,400	19.3
7	Miami River at Hamilton, O. (a)	3,639	352,000	96.7	49,300	13.5	70,300	19.3	73,900	20.3
8	Miami River at Venice, O.	3,790	370,000	97.6						
11	Stillwater River at Pleasant Hill (a)	502	51,400	102.4	13,000	25.9	16,500	32.9	26,400	52.6
13	Stillwater River at Englewood, O.	646	85,400	132.2			8,400	13.0	9,550	14.8
17	Mad River near Springfield O. (a)	485	55,400	114.2	7,500	15.5	18,000	37.1	15,900	32.8
18	Mad River near Dayton, O. (a)	632	75,700	119.8			18,400	29.1	15,400	24.4

plans for flood control, and an official plan was adopted by the District in 1916. The plan provided for five retarding basins, with automatic works which would release only sufficient volumes to cause bank-full stages below. Certain levees and channel improvements were also planned. Construction was begun in 1918, and the dams and other works were completed in 1922.

The work of the Miami Conservancy District is a pioneer achievement in flood control. It differs from most other more recent flood control projects in that those directly benefited paid the cost. The total cost of construction of the flood-control works was about $31,000,000. In addition, there are continuing maintenance costs of the dams and improved channels. It is estimated that the total benefits derived from the project so far are worth more than twice the cost. Bonds were issued to finance construction, and these bonds were completely retired in 1946, by paid assessments.

The protection given Dayton and the lower Miami Valley is nearly complete because the dams were designed to provide for a flood 40 percent greater than the 1913 flood. The action of the dams is simple. Ordinary river flows pass without detention through concrete outlets extending through the base of the dam. As the river rises to flood stages the tunnels permit a rate of flow to pass that does not exceed channel capacities. The excess flood waters are stored behind the dam. Thus the operation of the dams is entirely automatic. The greater part of the land in the reservoir area is not subject to frequent flooding and most of it is under cultivation.

The locations of the five retarding basins are shown on the map, plate 9. A photograph of the Englewood Dam across the Stillwater Valley is shown on plate 44. The capacities of the "dry" reservoirs in acre-feet are as follows:

Englewood	312,000
Germantown	106,000
Huffman	167,000
Lockington	70,000
Taylorsville	186,000

The value of the flood-control works has been demonstrated many times. For example, excess water has been stored behind Germantown Dam 117 times in the first 22 years of operation. The effect of one of the dams during the 1937 flood is shown on plate 45, which shows the hydrographs of daily flow at Pleasant Hill, above the dam, and at Englewood, just below the dam on Stillwater River. The peaks are "knocked off" and the outflow graph is a broad, flat peak.

No later floods have approached in magnitude that of 1913 in the Miami Valley, or elsewhere in Ohio. However, fairly large floods occurred

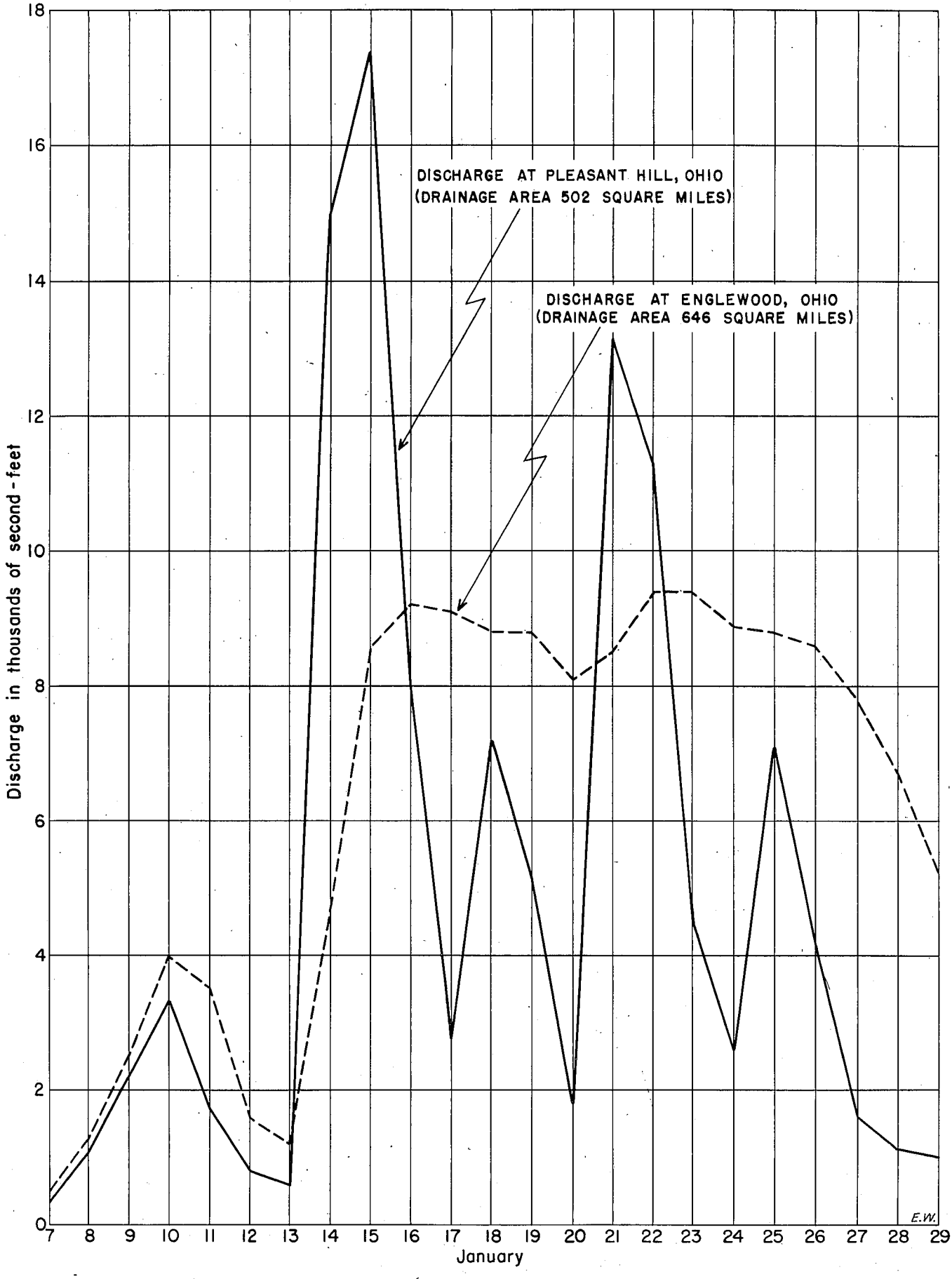


Plate 45. Hydrographs of discharge of the Stillwater River at Pleasant Hill and Englewood, Ohio, January, 1937.

in 1922, 1929, and 1937. During the 1929 and 1937 floods serious damage would have occurred in Dayton and the other cities in the lower valley if the dams had not existed. Table 17 is a tabulation of peak discharges in second-feet and second-feet per square mile, for the 1913, 1922, 1929, and 1937 floods for a number of Miami River Basin stations. These data show clearly how the dams have reduced peak flows below or within bank flows.

It is impossible to estimate the probable recurrence interval for the 1913 flood; undoubtedly it is of the order of hundreds, if not thousands, of years. No other recorded flood in Ohio has approached it in magnitude. The modified Myers formula, $Q = 10{,}000\ P\ M$, in which Q is the flow in cubic feet per second, M is the drainage area in square miles, and P is a coefficient usually expressed in percent, is often used for comparison of the intensities of floods on streams in different drainage areas. The Myers "rating" for the 1913 flood on the Miami River at Venice is 60 percent. All other floods in Ohio, for comparable drainage areas, are less than half this rating. Higher Myers figures have been recorded, however, in adjacent States.

It is interesting to note that the only other flood of record in Ohio comparable to 1913, in Myers rating, was on the East Fork of Honey Creek near New Carlisle. The flow here on 6.7 square miles, following a cloudburst in July 1918, was estimated by Miami Conservancy District engineers as 14,800 cubic feet per second, or 57 percent on the Myers scale. Such cloudburst floods are infrequent in Ohio, but they cause considerable damage to limited areas. Floods other than this local type are now impossible in the lower Miami Valley.

DROUGHTS

Ohio is subject not only to infrequent floods but also to occasional serious droughts. Generally these occur near the end of the growing seasons, in August and September. Infrequently high temperatures and lack of rainfall in these months give the State a temporary subhumid climate.

It is not entirely accidental that Bates, in 1822, found higher flows in second-feet per square mile in the Miami area than in the Scioto River Basin. The Miami River at Dayton and downstream, on the average, is not affected as often by extremely low stream flow as are some other streams in the State. The large ground-water storage in the Mad River Basin is the chief regulating influence. The average rainfall in the Miami area is slightly greater than in the upper Scioto basin area. However, the Miami Valley has had occasional severe droughts and will have similar droughts in the future.

The lowest annual rainfall recorded at Dayton occurred in 1895, and the mean annual flow estimated by Houk (pl. 27) is about as low as for any other year. The minimum flows for this period are not known. Other drought years, indicated by the annual precipitation, were 1914, 1931, 1934-36, and 1940-41.

Records of mean annual precipitation give only a general indication of droughts. The seasonal distribution of the precipitation is important, as are the temperature and its distribution, and the wind velocities. For example, a severe drought may occur in a year with normal annual precipitation, if the seasonal distribution is such that most of the rainfall comes within a few months. Conversely, favorable seasonal distribution of rainfall may prevent a drought in a year of subnormal precipitation.

An examination of the minimum flows in table 13 shows that stream flow was as deficient in the Miami River in 1941 as during any time yet recorded. This was caused by below-normal precipitation in 1940 and again in 1941. The temperature was subnormal in 1940, but above normal in 1941. The seasonal distribution of rainfall in 1941 was uneven, that for June being exceptionally high and that for September exceptionally low. The rainfall of 1.50 inches in September 1941 is exceeded in 9 years out of 10. The average wind velocity in this month was above average. The evaporation from a standard pan at Vandalia was far above average. All of these climatic factors combined to cause low flows in all the streams.

CHEMICAL QUALITY OF THE WATER

The chemical character of a water is often of extreme importance in water utilization. For example, in planning a municipal water supply the hardness of the water is an important consideration. The use of a hard water without softening means that each individual must use a water softener, or use additional soap. It has been estimated that one cent's worth of lime in a municipal softening plant will soften more water than four dollars worth of soap at the consumers tap. This assumes that all the water is softened with soap; actually, only a fraction of the water is softened with soap by the average consumer. Nevertheless, on this basis alone the consumer can afford to pay several times as much for softened as for unsoftened water.

The quantity and kinds of dissolved mineral matter affect the usefulness of water in many other ways. Many industrial users require water having special characteristics. Railroads, rubber factories, bottling plants, breweries, distilleries, canneries, ice plants, laundries, paper mills, and textile plants are examples of industries requiring water of special character. In many instances the natural water must be treated to obtain the required characteristics and the chemical analysis of the untreated water furnishes a guide to the kind of treatment and its cost.

Source and significance of mineral constituents in natural waters

The characteristics and mineral constituents of natural waters here considered include those found in quantities sufficient to have a practical effect on the value of the waters for ordinary uses.

Color.--In water analysis the term "color" refers to the appearance of water that is free from suspended solids. Water for domestic use and some industrial uses should be free from perceptible color. Natural color in surface waters is caused almost entirely by organic matter extracted from plants and by minerals. A color less than 20 usually passes unnoticed. Some swamp waters have natural color of 200 or 300. At many places high color in water results from industrial wastes.

pH.--The acidity or alkalinity of a water, as indicated by the hydrogen-ion concentration, is of importance with reference to the corrosiveness of water, and to proper regulation of coagulation at water-treatment plants. The symbol pH is commonly used to indicate the hydrogen-ion concentration. It represents the negative logarithm of the number of moles of ionized hydrogen per liter of water. For practical purposes, the pH scale may be used with reference to acidity and alkalinity, as a temperature scale is used with reference to heat conditions. A neutral water has

a pH of 7.0. The pH of most natural waters ranges between 6.0 and 8.0. Some alkaline waters have pH values greater than 8.0 and waters containing free mineral acid usually have values less than 4.5.

Specific conductance.--The specific conductance of a water is a measure of its ability to conduct a current of electricity. It varies with the concentration and degree of ionization of the different minerals in solution.

When considered in conjunction with results of determinations for other constituents, specific conductance is a useful determination and in view of the simplicity and low cost of the determination, plays an important part in following changes in concentration of the total quantity of dissolved minerals in surface waters.

Silica (SiO_2).--Silica is dissolved from practically all rocks. A few natural waters contain less than 3 parts per million of silica and some contain more than 50 parts, but most of them contain from 10 to 30 parts per million. Silica affects the usefulness of a water because it contributes to the formation of boiler scale.

Aluminum and manganese (Al and Mn).--Aluminum and manganese are not regularly determined in the practical analysis of water. However, acid waters may have relatively large quantities of these constituents which can be troublesome to certain users of the waters. Manganese is especially objectionable in laundry work and in textile processing that involves washing.

Iron (Fe).--Iron is dissolved from many rocks and soils. On exposure to the air water that contains more than a few tenths of a part per million of iron soon becomes turbid with the insoluble compound produced by oxidation; surface waters therefore seldom contain as much as 1 part per million of dissolved iron. Some acid waters carry large quantities of iron in solution. Excessive iron causes stains on white porcelain or enameled ware and fixtures and on clothing or other fabrics washed in the water.

Calcium (Ca).--Calcium is dissolved from practically all rocks, but particularly from limestone, dolomite, and gypsum. Calcium and magnesium make water hard and are the active agents in forming boiler scale. Most waters from granite contain less than 10 parts per million of calcium; many waters from limestone contain from 30 to 70 parts; and waters that leach deposits of gypsum may contain even larger quantities.

Magnesium (Mg).--Magnesium is dissolved from many rocks but particularly from dolomite and magnesian limestone. Its effects are similar to those of calcium, but waters that contain much magnesium and chloride are likely to be corrosive, especially in steam boilers. The magnesium in soft waters may amount to only 1 or 2 parts per million, but water in areas of dolomite or magnesian limestone may contain 20 to 50 parts per million, or more, of magnesium.

Sodium and potassium (Na and K).--Sodium and potassium are dissolved from practically all rocks, but they make up only a small part of the dissolved mineral matter in most waters in humid regions. Natural waters that contain only 3 or 4 parts per million of the two together are likely to carry about equal quantities of each. As the total quantity of these constituents increases the proportion of sodium becomes greater. Moderate quantities of these constituents have little effect, but waters that carry more than 50 or 100 parts per million of the two may require careful operation of steam boilers to prevent foaming. Waters that contain large quantities of sodium salts may be injurious to crops, and some waters contain so much sodium that they are unfit for nearly all uses.

Carbonate and bicarbonate (CO_3 and HCO_3).--Carbonate and bicarbonate occur in waters largely through the action of carbon dioxide, which enables the water to dissolve carbonates of calcium and magnesium. Carbonate is not present in appreciable quantities in most natural waters. The bicarbonate in waters that come from insoluble rocks may amount to less than 10 parts per million; many waters from limestone contain from 200 to 400 parts per million; and certain waters that contain sodium bicarbonate may carry 1,000 or more parts of bicarbonate per million. Water containing large quantities of bicarbonates are unsatisfactory for use in boilers or in condensers without treatment, because upon heating the soluble bicarbonates of calcium and magnesium are converted to insoluble carbonates, which are deposited as a hard scale in the boiler tubes or condensing system. A large quantity may make water unsatisfactory for drinking and other domestic uses.

Sulfate (SO_4).--Sulfate is dissolved in large quantities from gypsum and from deposits of sodium sulfate. It is also formed by the oxidation of sulfides of iron and is generally present in considerable quantities in waters from mines and from many beds of shale. Sulfate in waters that contain much calcium and magnesium contributes to the formation of hard scale in steam boilers and may increase the cost of softening the water.

Chloride (Cl).--Chloride is dissolved in small quantities from soil materials in most parts of the country. The chloride in waters normally has little effect on their use unless it is present in excessive quantities, as in brines. Chloride in excess of 250 to 300 parts per million can generally be detected by taste, but it is not too distasteful for domestic use even when in the range of 300 to 500 parts per million. Because of the highly corrosive nature of waters containing excessive amounts of chloride salts in combination of calcium or magnesium, industries necessarily require water relatively free of these salts.

Fluoride (F).--Fluoride has been reported as present in the rocks of the earth's crust to about the same extent as chloride. However, the quantity present in natural waters is usually much less than that of chloride. Fluoride in water is associated with the dental defect known as mottled enamel, if the water is used for drinking by young children during calcification or formation of the teeth. This condition becomes more noticeable as the quantity of fluoride in water increases above 1 part per million. It is reported that the incidence of dental caries (decay of teeth) is decreased or prevented by quantities of fluoride that are not sufficient to cause permanent disfigurement from mottled enamel.

Nitrate (NO_3).--Nitrate in water is considered a final oxidation product of nitrogenous organic material. The quantities usually present have little effect on the value of water for ordinary use.

Dissolved solids.--The quantity reported as dissolved solids (the residue on evaporation) consists mainly of the dissolved mineral constituents in the water. It may also contain some organic matter and water of crystallization. Waters with less than 500 parts per million of dissolved solids are usually satisfactory for domestic and most industrial uses. Waters with more than 1,000 parts per million of dissolved solids are likely to be unsuitable for most domestic and industrial uses.

Hardness.--Hardness is usually expressed as the quantity of calcium carbonate ($CaCO_3$) equivalent to the calcium and magnesium present. Water that has less than 50 parts per million of hardness is usually rated as soft and its treatment for removal of hardness is seldom justified. Hardness between 50 and 150 parts per million does not seriously interfere with the use of water for many purposes, but its removal by softening processes may be profitable for laundries and other industries. Water with hardness beyond 150 parts per million usually can be profitably softened.

Parts per million (ppm) is a measure of the concentration of a dissolved constituent by weight in a million parts of the water by weight. Thus, a water may contain one part per million of calcium by weight in one million parts of the water by weight. To convert parts per million to grains per gallon, divide parts per million by 17.1.

An equivalent per million (epm) is a unit chemical equivalent weight of a constituent in a million unit weights of water. A unit chemical equivalent weight may be calculated by dividing the concentration of a constituent in parts per million by the chemical combining weight of the constituent.

In order to compare analyses it is desirable to express them in equivalents per million. In this form the concentrations of the constituents are directly comparable, whereas in parts per million they are not.

This is because elements or radicals of different atomic weights unite to form compounds. For example, 23 grams of sodium (Na) is equivalent chemically to 35.5 grams of chlorine (Cl). They combine to form the compound sodium chloride, or common salt.

Interpretation of water analyses

The water analyses given in this bulletin are stated in the ionic form. The parts per million (p.p.m.) and equivalents per million (e.p.m.) of each significant cation (positive ion) and anion (negative ion) are determined with no attempt to state the manner in which the positive and negative ions may be associated. Methods have been devised for combining the ions into hypothetical combinations, and to the laymen such hypothetical combinations often make the analysis more intelligible. In general use is the method of Hale, as described by Montgomery (22), for computing hypothetical combinations, in which the positive and negative ions, converted to equivalents per million, are combined in the following order:

Calcium	Bicarbonate
Magnesium	Sulfate
Sodium	Chloride
Potassium	Nitrate

According to Montgomery's description, the method of combining is as follows: "Calcium is first combined with bicarbonate. If there is excess calcium above that required for bicarbonate, it is combined with sulphate, chloride, and nitrate, until exhausted. If there is excess bicarbonate above that required for calcium, it is combined with magnesium, sodium, and potassium, until exhausted. As each positive and negative radical is used up, the next following radical is combined until the radicals on both sides are exhausted."

Diagraming a water analysis consists in plotting to scale the cations, expressed in equivalents per million, alongside the anions expressed similarly. Cations are plotted from bottom to top in the order, calcium, magnesium, sodium, and potassium; anions in the order, bicarbonate, sulfate, chloride, fluoride, and nitrate as described in U. S. Geological Survey water-supply paper 596.

Hypothetical combinations are made from bottom to top, combining the calcium with bicarbonate until the calcium is exhausted, etc. as previously explained. By scaling the diagram the amounts of the hypothetical compounds can be determined in equivalents per million which can then be converted to parts per million by multiplying the e.p.m. of each compound so scaled by its appropriate chemical factor (combination factor) as follows:

Conversion of p.p.m. to e.p.m.

$$\text{e.p.m.} = \text{p.p.m.} \times \frac{\text{valence}}{\text{atomic weight}}$$

$$\text{p.p.m.} = \text{e.p.m.} \times \frac{\text{atomic weight}}{\text{valence}}$$

Plate 46 shows the diagraming of several representative waters in Montgomery County. These diagrams are constructed so that hypothetical combinations can be readily made.

Table 18 shows, in relation to the aquifers, the average amounts of iron, the hardness, and the hydrogen-ion concentration in several samples of water collected from private sources in the county. Table 19 shows the analyses of 15 samples of water collected from the different aquifers and analyzed by the U. S. Geological Survey. In table 20 are given the analyses of samples of water from each of the municipal systems of the county, made by the Ohio Department of Health.

Table 21 summarizes the analyses of surface-water samples collected from streams in the county or those flowing into the county. These analyses were made by the U. S. Geological Survey, The locations of the sampling stations are shown on plate 47. Tables 22A and 22B show the analyses of 10-day composite water samples collected at intervals from the Miami River at Dayton between October 1946 and September 1947.

Table 18

Average constituents in ground water from the different aquifers in Montgomery County
(Parts per million except pH)

Aquifer	Iron (Fe)	No. of samples	Total hardness	No. of samples	pH	No. of samples
Valley train and alluvial deposits	0.85	13	362	26	7.4	22
Upland glacial deposits	2.40	41	409	46	7.3	45
Silurian limestone	0.34	5	507	7	7.1	7
Ordovician shale	0.90	7	425	14	7.2	14

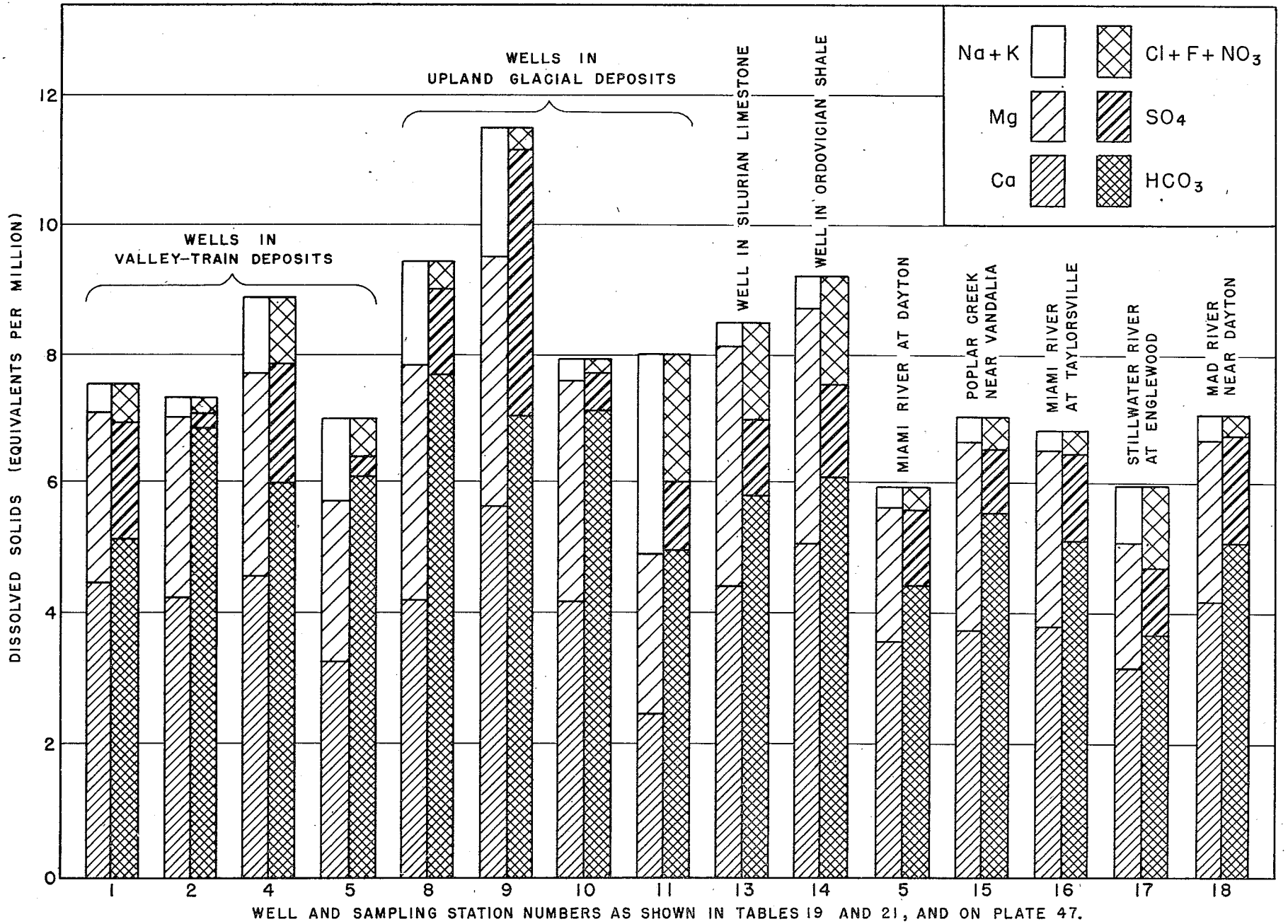


Plate 46. Chemical analyses of ground and surface waters of Montgomery County, Ohio.

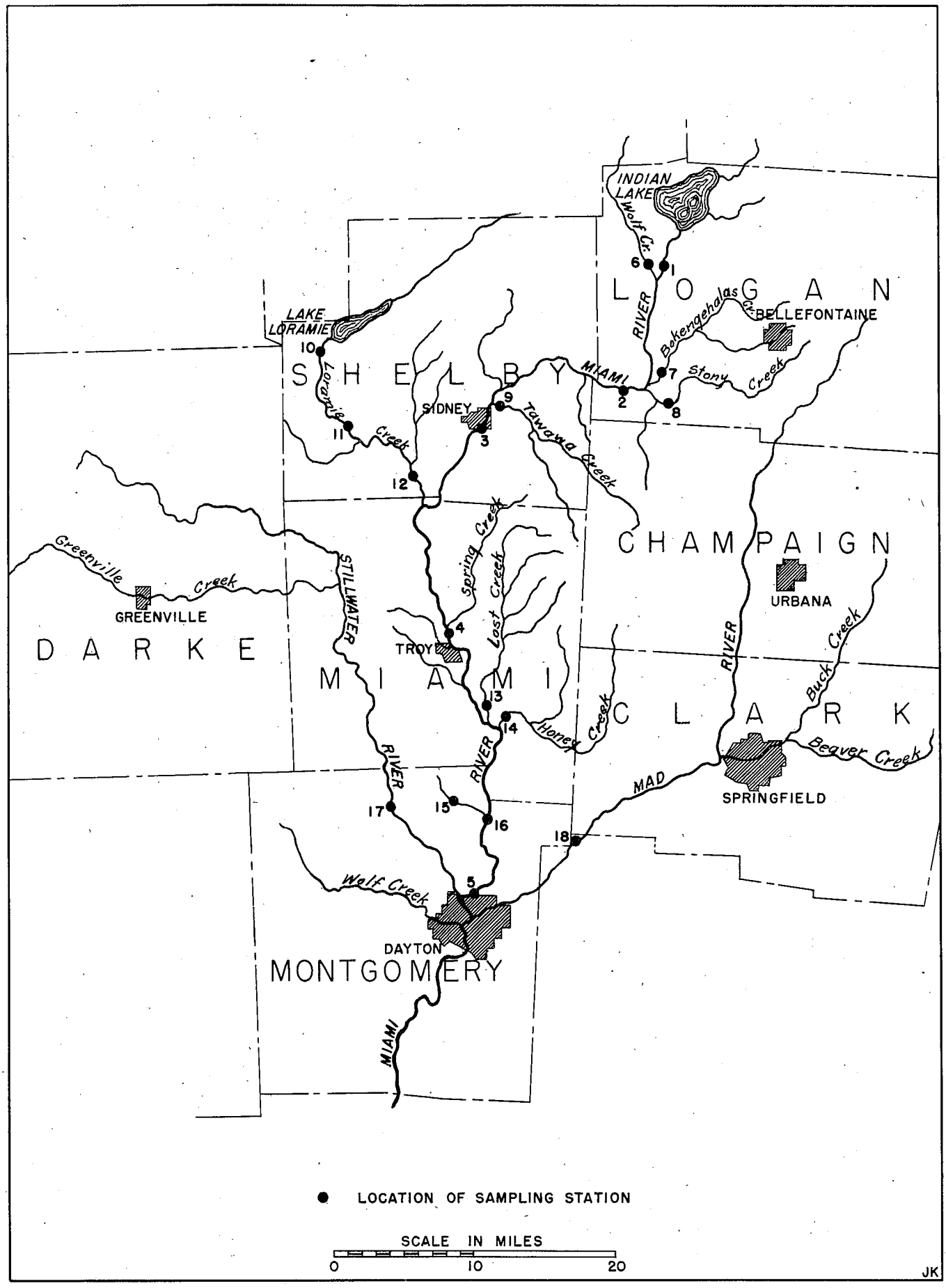


Plate 47. Map of Miami River Basin above Dayton, showing locations of stations at which samples of water were taken for analysis.

Table 19

Analyses of water from representative wells in different aquifers in Montgomery County
(Quality of Water Division, U. S. Geological Survey)

Chemical constituents given in parts per million

NO.	OWNER	LOCATION	DEPTH	WELL LOG	DATE	SILICA (SiO_2)	IRON (Fe)	CALCIUM (Ca)	MAGNESIUM (Mg)	SODIUM (Na)	POTASSIUM (K)	CARBONATE (CO_3)	BICARBONATE (HCO_3)	SULFATE (SO_4)	CHLORIDE (Cl)	FLUORIDE (F)	NITRATE (NO_3)	DISSOLVED SOLIDS	TOTAL HARDNESS AS $CaCO_3$	SPECIFIC CONDUCTANCE ($K \times 10^5$ 25° C)	COLOR	pH	AQUIFER
1*	City of Dayton	Mad River Twp., NW¼ sec. 18	74	184	4/ 3/47	4.8	0.30	90	32	8.4	1.8	14	287	87	8.9	0.1	7.3	406	358	66.0	1	7.9	Valley train "shallow well"
2*	City of Dayton	Mad River Twp., NW¼ sec. 18	163	197	4/ 3/47	13	1.5	85	34	7.8	1.4	—	355	60	8.8	.3	.0	379	352	65.4	2	7.8	Valley train "deep well"
4*	National Cash Register Company	South Dayton	131	470	4/ 3/47	11	.05	92	38	27	2.2	8	350	88	34	.2	.5	475	386	79.4	1	7.8	Valley train
5*	Farm Bureau Cooperative Ass'n	Madison Twp., SE¼ sec. 25	102	436	3/27/46	15	2.2	66	30	28	1.7	—	373	16	15	1.1	1.9	361	288	63.1	6	7.6	do.
6	Village of Germantown	German Twp., NE¼ sec. 12	35	586	5/23/47	7.5	.55	79	31	3.5	1.9	—	311	54	7.2	.2	17	362	325	59.5	1	7.4	do.
7	Johnsville Church	Jackson Twp., NW¼ sec. 3	124	—	5/ 9/47	3.6	.41	54	25	58	5.9	—	123	250	3.2	2.6	.1	485	238	72.2	3	7.4	Upland glacial deposits
8*	Village of Farmersville	Jackson Twp., NE¼ sec. 28	150	137	5/16/47	18	1.6	85	44	35	2.7	—	470	63	18	2.0	3.0	532	393	83.6	0	7.4	do.
9*	Mr. Carl Dunn	Butler Twp., NE¼ sec. 33	140	387	4/ 3/47	14	.88	114	47	44	2.9	—	430	198	4.2	2.6	.2	675	478	98.6	5	7.5	do.
10*	Mr. Charles Reynolds	Clay Twp., SE¼ sec. 24	28	139	3/27/47	16	12.0	84	41	8.6	1.7	—	434	28	2.4	1.0	.4	396	378	67.3	5	7.5	do.
11*	Mr. John Brockman	Washington Twp., NW¼ sec. 6	48	326	3/27/47	11	1.0	50	30	71	2.2	11	280	50	64	2.6	6.0	444	248	77.4	6	8.2	do.
12	Mr. R. E. Miller	Jefferson Twp., NW¼ sec. 2	64	---	5/19/47	18	.76	81	44	15	5.5	—	460	25	10	1.0	2.0	433	383	73.6	0	7.1	Silurian limestone
13*	Mr. A. A. Walker	Clay Twp., SW¼ sec. 1	55	---	5/ 7/47	9.2	.48	89	45	6.9	3.0	—	356	58	18	.0	63	492	407	76.6	2	7.3	do.
14*	United Fireworks Company	Jefferson Twp., SW¼ sec. 3	80	---	5/19/47	12	.14	102	44	9.7	3.3	—	371	71	39	.3	36	522	435	84.1	0	7.3	Ordovician shale
15	Mr. Frank Miller	Jefferson Twp., NE¼ sec. 14	112	511	3/26/47	4.9	.47	157	73	445	25	—	163	8.2	1100	.7	1.0	1990	692	370	1	7.6	do.

*Analysis shown in graphic form on plate 46.

Table 20

Analyses of water from the municipal water works in Montgomery County
(State of Ohio, Department of Health)

Chemical constituents given in parts per million

MUNICIPALITY	LOCATION	METHOD OF TREATMENT	SOURCE	DATE	TOTAL SOLIDS	TOTAL ALKALINITY	PHENOL ALKALINITY	ALKALI BICARBONATES	HARDNESS AS $CaCO_3$ NONCARB.	HARDNESS AS $CaCO_3$ TOTAL	pH	FREE CO_2	pH AFTER $CaCO_3$	TOTAL IRON (Fe)	MANGANESE (Mg)	CHLORIDE (Cl)	FLUORIDE (F)	SILICA (SiO_2)	AQUIFER
City of Dayton	———	Chlorine disinfection only	Dist. system	4/14/44	392	250	0	0	62	312	7.4	18	7.25	0.05	0.01	9	0.3	9	Valley train
City of Oakwood	Van Buren Twp.	do.	Works tap	12/16/42	530	338	0	0	81	419	7.2	41	7.0	0	.01	43	.1	13	do.
City of Miamisburg	Miami Twp.	do.	do.	12/11/42	446	279	0	0	46	325	7.2	33	7.3	2.0	.02	14	.2	9	do.
Village of Englewood	Randolph Twp.	No treatment	do.	7/ 2/42	490	335	0	0	74	409	7.5	20	7.3	.2	.05	6	.10	8	do.
Village of Germantown	German Twp.	do.	do.	9/17/42	306	240	0	0	43	283	7.4	18	7.4	0	0	6	.1	6	do.
Village of Trotwood	Madison Twp.	do.	do.	7/13/42	498	350	0	0	73	423	7.1	55	7.1	.02	.01	7	.7	10	do.
Village of West Carrollton	Miami Twp.	Chlorine disinfection only	Dist. system	9/24/42	360	258	0	0	49	307	7.4	19	7.4	.10	.05	9	.10	10	do.
Village of Vandalia	Butler Twp.	do.	do.	2/16/44	398	300	0	0	42	342	7.35	27	7.3	0	0	10	.10	7	Upland glacial deposits
Village of Brookville	Clay Twp.	do.	Works tap	10/--/46	452	402	0	18	0	384	7.2	60	---	6.1	.08	5	1.3	15	do.
Village of Farmersville	Jackson Twp.	No treatment	do.	4/13/44	548	388	0	0	1	389	7.4	27	7.35	1.0	.01	18	1.8	17	do.
Village of New Lebanon	do.	do.	do.	1/ 8/43	566	370	0	20	0	350	7.4	28	7.4	1.9	.04	53	1.1	12	do.
Village of Centerville	Washington Twp.	Softened (lime-soda process)	Raw	2/24/47	220	113	0	0	48	161	7.6	6	7.7	.05	0	5	.1	0	Silurian limestone
do.	do.	do.	Treated	2/24/47	132	42	22	0	45	87	10.5	0	10.4	.05	0	5	.1	1	do.

Table 21

Chemical analyses of surface waters from Miami River Basin, Ohio

Parts per million

No.	Date of collection (1947)	Discharge (sec. ft.)	Temperature (°F.)	Color	pH	Specific conductance (Kx10 at 25°C.)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$	
																			Total	Noncarb. hardness
1	June 26	116	70	8	7.5	43.7	3.2	0.06	60	20	4.1	1.9	195	63	3.6	0.3	3.4	269	323	72
2	June 26	278	68	14	7.7	56.0	5.4	.07	78	27	3.0	---	272	73	6.1	.3	4.8	356	306	83
3	June 26	366	69	12	8.0	57.0	5.4	.07	80	28	3.0	---	283	72	6.0	.6	5.2	362	315	83
4	June 26	446	72	11	7.8	59.0	5.0	.05	80	28	6.5	---	290	69	8.4	.5	7.6	368	315	77
*5	June 11-20	---	--	18	7.8	54.6	6.8	.02	72	25	5.4	3.4	272	55	7.1	.5	10	331	282	60
6	June 26	22	68	9	7.9	63.3	4.4	.06	93	30	5.2	1.4	293	101	4.2	.3	6.2	409	355	115
7	June 26	39	65	17	7.9	73.0	4.8	.06	95	36	18	2.4	343	95	18	.3	8.0	473	385	104
8	June 17	--	64	--	8.1	65.0	---	---	--	--	---	---	344	70	1	---	6.9	---	---	---
9	June 26	22	71	8	7.9	53.4	4.2	.04	71	28	4.4	1.4	290	47	4.2	.2	3.8	316	292	54
10	June 26	5.9	--	35	7.3	30.1	6.4	.19	40	12	4.2	1.8	140	32	3.2	.3	2.4	192	149	34
11	June 17	---	62	--	7.6	32.2	---	---	--	--	---	---	146	39	2	---	5.6	---	---	---
12	June 26	44	--	7	7.9	59.7	8.6	.04	79	31	7.6	1.6	302	72	4.8	.3	4.3	376	325	77
13	June 17	---	63	--	8.1	53.8	---	---	--	--	---	---	292	46	4	---	7.0	---	---	---
14	June 26	72	64	6	8.0	59.3	5.4	.06	79	33	4.1	1.6	330	45	5.1	.3	8.4	359	333	62
*15	July 21	1.1	--	3	8.1	61.3	7.0	.06	75	35	9.4	1.4	340	48	9.4	.2	1.8	363	331	74
*16	May 10	290	61	20	7.7	62.0	.8	.05	76	33	7.6		306	70	10	.3	4.0	372	325	75
*17	May 14	567	57	40	7.7	49.0	7.2	.11	64	23	2.2		226	50	6.1	.1	16	307	254	69
*18	May 14	506	59	20	7.8	64.6	7.6	.04	84	31	10		312	79	9.8	.2	8.2	406	337	81
											Equivalents per million									
1	June 26	---	--	--	---	-----	---	---	2.994	1.645	0.178	0.049	3.196	1.312	0.102	0.016	0.055	---	---	---
2	June 26	---	--	---	---	-----	---	---	3.892	2.220	.132	---	4.459	1.520	.172	.016	.077	---	---	---
3	June 26	---	--	--	---	-----	---	---	3.992	2.303	.131	---	4.642	1.499	.169	.032	.084	---	---	---
4	June 26	---	--	--	---	-----	---	---	3.992	2.303	.284	---	4.756	1.437	.237	.026	.123	---	---	---
5	June 11-20	---	--	--	---	-----	---	---	3.593	2.056	.235	.087	4.458	1.145	.200	.026	.161	---	---	---
6	June 26	---	--	--	---	-----	---	---	4.641	2.467	.226	.036	4.807	2.103	.118	.016	.100	---	---	---
7	June 26	---	--	--	---	-----	---	---	4.741	2.961	.783	.061	5.625	1.978	.508	.016	.129	---	---	---
8	June 17	---	--	--	---	-----	---	---	----	----	---	---	5.638	1.457	.028	---	.111	---	---	---
9	June 26	---	--	--	---	-----	---	---	3.543	2.303	.191	.036	4.756	.979	.118	.011	.061	---	---	---
10	June 26	---	--	--	---	-----	---	---	1.996	.987	.183	.046	2.294	.666	.090	.016	.039	---	---	---
11	June 17	---	--	--	---	-----	---	---	----	----	---	---	2.393	.812	.056	---	.090	---	---	---
12	June 26	---	--	--	---	-----	---	---	3.942	2.549	.330	.041	4.951	1.499	.135	.016	.069	---	---	---
13	June 17	---	--	--	---	-----	---	---	----	----	---	---	4.785	.958	.113	---	.113	---	---	---
14	June 26	---	--	--	---	-----	---	---	3.942	2.714	.178	.041	5.412	.937	.144	.016	.135	---	---	---
15	July 21	---	--	--	---	-----	---	---	3.743	2.878	.409	.036	5.572	.999	.265	.011	.029	---	---	---
16	May 10	---	--	--	---	-----	---	---	3.792	2.714	.329	---	5.146	1.332	.649	.021	.087	---	---	---
17	May 14	---	--	--	---	-----	---	---	3.194	1.891	.095	---	3.704	1.041	.172	.005	.258	---	---	---
18	May 14	---	--	--	---	-----	---	---	4.192	2.549	.437	---	5.114	1.645	.276	.011	.132	---	---	---

Number	Location
1	Miami River near Russells Point
2	Miami River at Quincy
3	Miami River at Sidney
4	Miami River near Troy
*5	Miami River at Dayton
6	Wolf Creek near Russells Point
7	Bokengehalas Creek at Degraff
8	Stony Creek near Degraff
9	Tawawa Creek at Sidney

Number	Location
10	Loramie Creek near Ft. Loramie
11	Loramie Creek near Newport
12	Loramie Creek at Lockington
13	Lost Creek near Tipp City
14	Honey Creek near Tipp City
*15	Poplar Creek near Vandalia
*16	Miami River at Taylorsville
*17	Stillwater River at Englewood
*18	Mad River near Dayton

*Analysis shown in graphic form on plate 46

SUMMARY AND CONCLUSIONS

Ground-water conditions

The survey of ground-water conditions in Montgomery County shows that an average of about 90 million gallons a day is pumped from wells in the county. This is the greatest concentration of pumpage of ground water in any comparable area in Ohio.

The largest ground-water supplies in Montgomery County are obtained from the glacial aquifers in the Mad River and Miami Valleys. The largest ground-water development in the county is the well field of the Dayton Water Department on Rohrers Island in the Mad River Valley. The pumpage from this well field currently averages about 40 million gallons a day and peak pumpage sometimes reaches 60 million gallons a day.

Most of the recharge to the glacial aquifer at Rohrers Island is accomplished by diversion of water from the Mad River into infiltration ditches and ponds on the island. The effectiveness of the recharge facilities is demonstrated by records of water levels from observation wells on the island which show that there has not been a continuing downward trend of ground-water levels, despite the heavy pumping.

If more water is required by the City of Dayton, geologic evidence indicates that large additional supplies of ground water might be obtained along the Mad River between Tates Hill and the Aqueduct group of wells above Huffman Dam in the Mad River Valley in Greene County. Test drilling and pumping tests would be necessary to evaluate properly either area. The evidence also indicates that, by lowering water levels in the upper stratum, recharge from Mad River would probably be induced.

At the present time most of the water pumped from wells on Rohrers Island is from the shallow gravel stratum which supplies water lower in iron content than that from the deeper stratum in that area. If present plans for treatment of the municipal supply are accomplished, it would be possible to construct additional wells in the deep stratum and to use the water after treatment. A larger amount of the water in storage in the deep stratum would thus be available in drought periods.

In the Miami Valley between Dayton and West Carrollton there are six areas of heavy pumping, each of which yields more than 5 million gallons a day for industrial purposes, with no downward trend of the water levels. At the National Cash Register Company in south Dayton, for example, more than 5 million gallons a day is pumped, and records of ground-water levels at this plant obtained since 1933 show that no continual decline in water levels is taking place. The rapid response of ground water levels in this area to changes in the stage of the Miami River suggests that most of the recharge is obtained from stream flow. The available information indicates that similar conditions exist in the other heavily

pumped areas. If the assumption is true that recharge is received largely from stream flow, it seems probable that additional large ground-water supplies can be obtained at other sites where deep gravels underlie the river.

Geologic evidence also indicates that large ground-water supplies can be obtained from gravels in the Miami River Valley north of Dayton, in the lower Wolf Creek Valley, and in parts of Stillwater Valley, to mention the better areas.

In all the areas of heavy pumping, an observation well program should be maintained and periodic water-level measurements should be made in as many places as possible as a guide to future water-level trends. These records will indicate whether a given area is being overpumped or is capable of additional development.

The consolidated rock strata underlying Montgomery County consist of limestones and dolomites of the Silurian system and the shales of the Ordovician system. The Silurian rocks can generally be depended on to yield adequate farm and domestic water supplies and a few wells in those rocks yield as much as 200 gallons per minute. The Ordovician shales are very poor sources of water and most wells drilled into these strata are dry or yield water high in salt and iron compounds. Where wells do encounter fresh water in the Ordovician shales the yield is generally about 1 gallon per minute, though exceptional wells yielding up to 50 gallons a minute have been drilled.

The upland glacial deposits, consisting mostly of the till of the ground moraine, yield adequate farm and domestic supplies where interbedded sand or gravel deposits are encountered. Where the till is thin, and overlies the Ordovician shale, most rural supplies are taken from large-diameter dug wells.

Surface-water conditions

The use of surface water by industries is small in Montgomery County, though the county is favorably situated with respect to its availability. Dayton is especially well situated at the confluence of the Mad River, Stillwater River, and Wolf Creek with the Miami River. The combined drainage areas of these streams above Dayton amounts to 2,710 square miles.

Because of the large storage of ground water in gravels in the buried valleys in the Miami River Basin, the flow of these streams is well-sustained even in drought periods. The storage capacity of the gravels in the Mad River Valley is the largest in any valley in the State.

The work of the Miami Conservancy District is a pioneer achievement in flood control. The flood-control works consist of five retarding basins capable of storing a total of 841,000 acre-feet of water in an extreme flood period. The protection given Dayton and the lower Miami Valley is nearly complete, as the dams and channel improvement works were designed to provide for a flood 40 percent greater than the 1913 flood, the worst flood on record.

Quality of water

Ground water in Montgomery County, as determined by available analyses, is hard and in many places is high in iron. As shown on table 18, the hardest water comes from wells in the Silurian limestones, and the softest comes from valley-train deposits that receive stream infiltration. Water from all aquifers generally contains more than 0.3 ppm of iron, in excess of which iron staining and precipitation occur on exposure to the air though the limestone waters average only slightly more than the critical concentration. Water from the upland glacial deposits generally contains a very high concentration of iron. Water from all the aquifers is high in the scale-forming ingredients calcium, magnesium, and bicarbonate. The chloride, the constituent most generally responsible for corrosiveness, is probably highest in the water from the consolidated rocks.

One sample of water from the Ordovician shale showed 1,100 ppm of chloride, which condition is not uncommon in wells drilled several feet into these shales. In this particular well, however, the water is derived from the very top of the shale.

The total quantity of dissolved solids in water from all aquifers averages less than 500 ppm and exceeds this amount in few wells. This factor, therefore, is not generally of much consequence relative to the use of the water. The pH factor, or hydrogen-ion concentration, is within the common range for natural waters.

For most industrial uses there is no notable difference among the waters from the different aquifers, except possibly for the lower iron content of the limestone water. Softening and removal of the iron are necessary to make suitable for most industrial uses the ground water from all sources in this county.

BIBLIOGRAPHY

1. Fuller, M. L. and Clapp, F. G., The underground waters of southwestern Ohio: U. S. Geol. Survey Water-Supply Paper 259, 1912.

2. Stout, Wilber, and others, Geology of water in Ohio: Ohio Geol. Survey, 4th Ser., Bull. 44, 1943.

3. Bernhagen, R. J. Record of wells in Montgomery County: Ohio Water Resources Board Bull. 1, Nov. 1945.

4. Anonymous. Additional water supply and waterworks improvements, Dayton, Ohio, Metcalf and Eddy, Boston, Mass., 1924.

5. Foerste, A. F., Geology of Dayton and vicinity, Dayton, Ohio, 1915.

6. Meinzer, O. E., Wenzel, L. K., and others, Water levels and artesian pressure in observation wells in the United States in 1942, Part 1. Northeastern States: U. S. Geol. Survey Water-Supply Paper 944, 1944.

7. Meinzer, O. E., Wenzel, L. K, and others, Water levels and artesian pressure in observation wells in the United States in 1943, Part 1, Northeastern States: U. S. Geol. Survey Water-Supply Paper 986, 1946.

8. Youngquist, C. V., Ohio Stream Flow - Part II: Ohio State Univ., Eng. Exper. Sta. Bull. 127, 1947.

9. Horton, A. H., and Jackson, H. J., The Ohio Valley flood of March - April 1913: U. S. Geol. Survey Water-Supply Paper 334, 1913.

10. Morgan, Arthur E., The Miami Valley and the 1913 flood: Miami Conservancy District Tech. Repts., Part I, 1917.

11. Miami Conservancy District Tech. Repts., Parts I - X, 1917-36.

12. Wenzel, L. K., and Fishel, V. C. Methods for determining permeability of water-bearing materials: U. S. Geol. Survey Water-Supply Paper 887, 1942.

13. Orton, Edward, Economic Geology, Geological Survey of Ohio, vol. 6, p. 286, 1888.

14. Fenneman, N. M.,Physiography of eastern United States, McGraw-Hill Book Co., Inc., 1938.

15. Leverett, Frank, Glacial formations and drainage features of the Erie and Ohio Basins: U. S. Geol. Survey Monograph 41, p. 363, 1902.

16. Wittke, Carl (Editor), History of the State of Ohio, Ohio Archeological and Historical Soc., 6 vols., 1941.

17. Ohio Board of Canal Commissioners, 3rd Ann. Rept., p. 41, Jan. 1825.

18. Sherman, C. E., Ohio Stream Flow - Part I: Ohio State Univ., Eng. Exper. Sta. Bull. 73, 1932.

19. Report of the Chief of Engineers on the Miami River, Ohio: 71st Cong., H. Doc. 681, 1930.

20. Williams, G. R., and others, Natural water losses in selected drainage basins: U. S. Geol. Survey Water-Supply Paper 846, 1940.

21. The story of the Miami Conservancy District, Booklet prepared by the Miami Conservancy District, Dayton, Ohio, 1945.

22. Montgomery, James M., of Hoover and Montgomery, Consulting Engineers, Interpretation of chemical analysis of water: Water and Sewage Works, vol. 93, no. 4, Apr. 1946.

GENERAL REFERENCES

Flint, Richard Foster, Glacial geology and the Pleistocene epoch, John Wiley and Sons, Inc., New York, 1947.

Meinzer, O. E., The occurrence of ground water in the United States,with a discussion of principles: U. S. Geol. Survey Water-Supply Paper 489, 1923.

Meinzer, O. E., Outline of ground-water hydrology with definitions: U. S. Geol. Survey Water-Supply Paper 494, 1923.

Bennison, E. W., Ground water, its development, uses and conservation, 1st ed., Edward E. Johnson, Inc., St. Paul, 1947.

Mitchelson, A. T., and Muckel, Dean C., Spreading water for storage underground: U. S. Dept. Agri. Tech. Bull. 578, Dec. 1937.

Table 22A
Miami River above Stillwater River at Dayton, Ohio

Chemical analyses, in parts per million, water year October 1946 to September 30, 1947

Date of collection	Mean discharge (second feet)	Temperature (°F.)	Color	pH	Specific conductance (Kx10⁵ at 25°C.)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$	
																		Total	Non-carbonate
Oct. 1-10, 1946	66.5	61	11	7.7	65.6	6.0	0.02	74	36	17	4.7	329	61	17	0.6	6.2	390	333	63
Oct. 11-20	98.2	60	16	7.7	65.2	4.2	.02	73	35	17	5.2	327	61	17	.5	6.0	383	326	58
Oct. 21-31	117	59	20	7.7	63.9	6.5	.02	74	33	16	4.5	311	64	16	.6	4.9	383	320	60
Nov. 1-10	105	57	12	7.8	66.8	7.4	.02	77	34	17	4.0	330	65	18	.5	5.8	403	332	61
Nov. 11-20	137	46	15	7.8	66.4	7.8	.04	80	34	15	3.7	330	70	14	.5	6.4	405	339	69
Nov. 21-30	156	42	16	7.8	66.9	4.2	.02	80	35	14	3.5	322	77	15	.4	4.4	410	344	80
Dec. 1-10	138	41	7	8.0	68.5	2.0	.03	84	35	14	3.8	318	87	15	.4	7.6	417	354	93
Dec. 11-20	713	31	17	8.0	64.2	8.4	.02	85	30	8.3	3.2	264	97	11	.4	17	409	335	119
Dec. 21-29	413	32	7	7.7	63.5	5.6	.02	82	31	9.8	3.0	286	86	11	.4	8.6	394	332	93
Jan. 1-10, 1947	1,180	35	8	7.7	65.0	6.2	.02	83	30	9.2	3.4	294	87	9.5	.4	12	402	330	90
Jan. 11-20	1,350	32	15	7.8	54.2	6.0	.04	71	25	6.0	3.0	236	72	7.2	.3	12	335	280	87
Jan. 22, 26-28, 30-31	4,040	33	15	7.8	50.0	7.8	.09	67	23	4.2	3.3	210	68	6.6	.3	19	321	262	90
Feb. 1-10	1,870	-	-	-	-	Samples frozen in shipment				-	-	-	-	-	-	-	-	-	-
Feb. 11-14, 16-20	543	32	7	7.5	60.8	6.6	.01	83	30	8.4	2.9	285	77	9.2	.3	11	379	330	86
Feb. 21-28	391	32	8	7.7	62.2	5.6	.02	82	31	9.4	2.7	290	78	10	.3	10	387	332	94
Mar. 1-10	350	37	7	7.7	61.0	6.4	.12	81	28	9.3	2.6	288	77	10	.5	22	380	317	81
Mar. 11-20	755	42	8	7.7	50.2	6.0	.04	64	22	6.8	3.3	218	64	8.1	.4	29	312	250	72
Mar. 21-31	1,790	44	8	7.7	50.7	6.8	.10	67	22	5.7	3.0	221	65	7.2	.3	32	316	258	82
Apr. 1-10	2,210	54	7	7.8	46.2	7.1	.09	70	23	4.8	1.7	236	68	8.0	.4	27	333	269	76
Apr. 11-20	1,840	58	18	7.5	48.9	7.2	.05	66	22	5.1	1.9	219	60	6.5	.2	13	307	255	76
Apr. 21-30	4,080	58	17	7.6	48.2	6.1	.04	66	22	4.3	2.3	221	59	5.4	.2	12	302	255	74
May 1-10	3,550	58	15	7.8	55.9	5.8	.05	74	25	8.1	3.0	257	60	9.5	.2	15	337	287	77
May 11-20	1,990	65	17	7.9	51.2	6.2	.09	67	24	6.1	2.7	245	54	6.8	.2	8.5	308	266	65
May 21-31	3,460	64	20	7.6	47.5	7.5	.06	65	22	4.6	2.0	234	50	5.5	.4	13	301	253	61
June 1-10	7,780	69	17	7.8	52.5	7.6	.04	72	26	6.0	2.3	272	54	7.6	.5	9.6	332	287	64
June 11-20	1,810	70	18	7.8	54.6	6.8	.02	72	25	5.4	3.4	272	55	7.1	.5	10	331	282	60
June 21-30	995	-	-	-	-	Samples lost in shipment				-	-	-	-	-	-	-	-	-	-
July 1-10	880	75	10	7.9	57.9	7.2	.05	80	29	6.6	2.6	312	56	7.4	.4	12	360	319	63
July 11-20	1,290	74	7	8.0	60.2	5.9	.03	80	31	7.4	2.7	316	58	9.0	.4	8.5	368	327	68
July 21-31	453	75	7	8.0	62.3	4.9	.03	83	33	8.4	2.5	326	61	10	.4	6.8	380	343	76
Aug. 1-10	276	81	6	8.0	60.9	6.1	.02	78	32	8.6	2.6	316	61	10	.4	6.7	372	326	67
Aug. 11-20	1,040	83	17	7.8	51.9	8.5	.06	69	27	7.2	3.0	273	50	8.1	.4	4.5	311	283	59
Aug. 21-30	622	81	17	7.6	50.2	8.6	.02	69	24	6.3	4.6	248	53	7.4	.3	6.2	303	271	68
Sept. 1-10	648	80	8	7.7	54.5	7.0	.02	71	27	7.3	3.0	270	59	8.1	.3	6.0	328	288	67
Sept. 11-10	365	78	8	7.7	55.6	6.3	.01	71	28	7.6	3.2	273	60	9.4	.3	6.3	335	292	69
Sept. 21-30	411	63	7	7.7	55.9	6.5	.02	72	27	7.0	3.2	275	60	9.0	.3	5.9	334	291	65
Average	1,330	56	12	7.8	57.6	6.4	0.04	74	28	8.8	3.1	277	66	9.9	0.4	11	353	300	73

Table 22B
Miami River above Stillwater River at Dayton, Ohio

Chemical analyses, in equivalents per million, water year October 1946 to September 30, 1947

Date of collection	Mean discharge (second feet)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)
Oct. 1-10, 1946	66.5	3.693	2.961	0.739	0.120	5.392	1.270	0.479	0.032	0.100
Oct. 11-20	98.2	3.643	2.878	.739	.133	5.359	1.270	.479	.026	.097
Oct. 21-31	117	3.693	2.714	.696	.115	5.100	1.332	.451	.032	.079
Nov. 1-10	105	3.842	2.796	.739	.102	5.410	1.353	.508	.026	.094
Nov. 11-20	137	3.992	2.796	.652	.095	5.408	1.457	.395	.026	.103
Nov. 21-30	156	3.992	2.878	.609	.090	5.279	1.603	.423	.021	.071
Dec. 1-10	138	4.192	2.878	.609	.097	5.213	1.811	.423	.021	.123
Dec. 11-20	713	4.242	2.467	.361	.082	4.327	2.020	.310	.021	.274
Dec. 21-29	413	4.092	2.549	.426	.077	4.687	1.791	.310	.021	.139
Jan. 1-10, 1947	1,180	4.142	2.467	.400	.087	4.818	1.811	.268	.021	.194
Jan. 11-20	1,350	3.543	2.056	.261	.077	3.868	1.499	.203	.016	.194
Jan. 22, 26-28, 30-31	4,040	3.343	1.891	.183	.084	3.442	1.416	.186	.016	.306
Feb. 1-10	1,870	Samples frozen in shipment								
Feb. 11-14, 16-20	543	4.142	2.467	.365	.074	4.674	1.608	.259	.016	.177
Feb. 21-28	391	4.092	2.549	.409	.069	4.756	1.624	.282	.016	.161
Mar. 1-10	350	4.042	2.303	.404	.067	4.720	1.603	.282	.026	.355
Mar. 11-20	755	3.194	1.809	.296	.084	3.573	1.332	.228	.021	.468
Mar. 21-31	1,790	3.343	1.809	.248	.077	3.622	1.353	.203	.016	.516
Apr. 1-10	2,210	3.493	1.891	.209	.043	3.868	1.416	.226	.021	.435
Apr. 11-20	1,840	3.293	1.809	.222	.049	3.589	1.249	.183	.011	.210
Apr. 21-30	4,080	3.293	1.809	.187	.059	3.622	1.228	.152	.011	.194
May 1-10	3,550	3.693	2.056	.352	.077	4.212	1.249	.268	.011	.242
May 11-20	1,990	3.343	1.974	.265	.069	4.015	1.124	.192	.011	.137
May 21-31	3,460	3.244	1.809	.200	.051	3.835	1.041	.155	.021	.210
June 1-10	7,780	3.593	2.138	.261	.059	4.458	1.124	.214	.026	.155
June 11-20	1,810	3.593	2.056	.235	.087	4.458	1.145	.200	.026	.161
June 21-30	995	Samples lost in shipment								
July 1-10	880	3.992	2.385	.287	.067	5.113	1.166	.209	.021	.194
July 11-20	1,290	3.992	2.549	.322	.069	5.179	1.208	.254	.021	.137
July 21-31	453	4.142	2.714	.365	.064	5.343	1.270	.282	.021	.110
Aug. 1-10	276	3.892	2.632	.374	.067	5.179	1.270	.282	.021	.108
Aug. 11-20	1,040	3.443	2.220	.313	.077	4.474	1.041	.228	.021	.073
Aug. 21-30	622	3.443	1.974	.274	.118	4.064	1.103	.209	.016	.100
Sept. 1-10	648	3.543	2.220	.317	.077	4.425	1.228	.228	.016	.097
Sept. 11-20	365	3.543	2.303	.330	.082	4.474	1.249	.265	.016	.102
Sept. 21-30	411	3.593	2.220	.304	.082	4.507	1.249	.254	.016	.095
Average	1,330	3.693	2.303	0.383	0.079	4.507	1.374	0.279	0.021	0.177

Monthly and annual precipitation at Dayton, Dayton Airport (Vandalia), and Germantown, Ohio

Table 23 A

Monthly and annual precipitation in inches at Dayton, Ohio

Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1844-45	3.17	2.58	1.52	2.65	1.90		2.70	0.91		3.27			
1845-46				4.87	3.68	3.24	5.37	8.87	7.49	4.69	7.44	3.34	
1846-47	2.13	4.30	7.54	5.44	5.07	3.73	2.44	5.27	7.02	5.65	2.43	3.14	54.16
1847-48	7.05	6.30	6.39	5.36	1.28	4.99	1.31	4.73	1.89	5.02	5.02	1.34	50.68
1848-49	3.15	2.64	8.85	6.13	1.31	4.53	5.90	3.07	5.02	9.77	4.21	2.60	57.18
1849-50	5.97	2.84	5.02	4.39	3.20	3.81	5.51	1.30	4.65	2.00			
1855-56				1.49	1.15	1.15	1.09	2.64	2.33	3.16	1.71	2.09	
1856-57	0.70												
1857-58								7.56	4.82	3.18	3.96	1.14	
1858-59	3.25	3.75											
1873					2.74	2.75							
1882-83		1.70	1.78	2.67	6.24	3.25	2.28	5.09	5.69	4.31	1.95	2.38	
1883-84	4.92	3.29	4.90	2.21	5.67	3.17	2.90	4.56	2.23	2.63	1.21	3.85	41.54
1884-85	1.17	0.75	3.79	3.37	2.41	0.36	2.81	3.47	5.03	3.42	6.23	2.11	34.92
1885-86	2.27	2.23	1.61	2.96	1.27	1.82	4.15	6.68	4.92	3.27	4.76	3.98	39.92
1886-87	1.61	3.32	2.58	2.05	5.30	3.39	4.15	2.54	4.23	3.27	2.08	1.37	35.89
1887-88	0.52	3.53	2.51	3.52	1.25	4.40	1.67	3.95	1.92	3.44	5.53	1.34	33.58
1888-89	5.14	5.52	1.13	3.28	0.51	0.98	0.55	4.35	3.35	3.11	0.34	2.06	30.32
1889-90	1.51	4.05	2.69	4.83	5.09	4.34	2.70	3.54	3.28	0.28	5.27	7.37	44.95
1890-91	2.42	2.27	1.18	3.17	4.41	4.90	2.89	0.99	5.16	2.43	3.20	1.75	34.77
1891-92	2.36	5.29	2.30	1.20	3.09	1.86	3.76	4.54	6.58	1.36	1.92	3.28	37.54
1892-93	0.37	1.92	1.57	2.77	4.87	1.98	6.80	5.48	4.08	1.86	0.89	2.59	35.18
1893-94	3.81	1.63	2.17	2.27	3.31	2.15	1.51	4.17	3.75	0.75	1.85	1.54	28.91
1894-95	1.43	1.77	3.07	4.87	0.48	1.78	1.71	1.78	3.48	0.65	3.05	0.66	24.73
1895-96	0.90	5.32	3.40	1.82	1.62	3.12	2.17	3.34	4.34	8.13	4.93	6.02	45.11
1896-97	0.80	3.12	1.44	2.07	3.35	6.61	4.26	3.51	2.20	3.49	2.89	0.15	33.89
1897-98	1.26	8.40	3.24	5.95	2.12	8.00	1.89	3.49	3.24	4.31	2.92	4.13	48.95
1898-99	4.05	4.30	3.05	3.51	2.01	4.10	1.07	3.64	1.49	4.10	1.30	1.22	33.84
1899-00	2.06	1.34	3.34	3.16	2.66	1.97	1.23	2.79	3.96	3.81	4.56	0.99	31.87
1900-01	3.35	3.60	1.78	2.00	1.33	2.42	1.87	3.45	4.04	1.33	0.91	2.32	28.40
1901-02	1.12	1.43	3.83	1.13	0.61	2.55	2.13	2.39	7.32	3.42	0.71	4.95	31.59
1902-03	3.25	3.56	3.95	2.39	4.79	3.69	3.66	4.66	9.09	1.43	1.17	0.65	42.29
1903-04	2.72	2.44	2.00	4.61	2.53	7.90	3.18	4.05	2.47	3.04	1.87	2.00	38.81
1904-05	1.23	0.63	4.16	1.63	1.90	2.05	4.20	6.53	2.46	3.23	8.98	4.45	41.45
1905-06	3.89	2.12	2.20	2.96	1.11	5.49	1.40	2.00	3.22	6.07	5.56	2.89	38.91
1906-07	1.51	3.81	3.62	8.16	0.42	6.00	2.94	3.17	3.98	7.01	3.08	4.22	47.92
1907-08	2.90	2.56	3.08	1.64	6.44	5.78	3.80	5.40	2.67	4.93	2.81	0.25	42.26
1908-09	0.36	0.86	1.32	2.95	6.77	2.23	5.13	6.25	5.60	4.84	3.41	0.84	40.56
1909-10	4.19	2.00	2.59	3.15	4.66	0.05	1.85	4.59	2.11	3.62	0.47	3.35	32.63
1910-11	7.08	0.96	1.95	3.91	1.57	2.67	5.87	2.01	2.45	1.36	3.25	4.19	37.27
1911-12	4.34	2.26	3.13	2.25	2.14	5.21	4.94	2.27	2.15	3.35	6.64	2.16	40.84
1912-13	2.13	0.81	1.96	6.66	1.32	8.89	4.78	3.41	2.67	2.90	1.81	2.31	39.65
1913-14	2.15	3.98	0.72	2.19	3.33	1.80	2.87	0.94	2.17	1.72	3.74	0.71	26.32
1914-15	3.48	1.11	2.86	3.88	0.78	1.19	0.83	4.76	4.35	4.34	4.76	5.44	37.78
1915-16	2.92	2.22	3.30	5.67	1.42	3.51	2.38	3.21	5.06	0.33	3.07	5.90	38.99

Table 23 A (Cont.)

Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1916-17	1.42	1.67	2.16	4.04	1.09	3.95	3.68	3.81	4.20	3.34	3.74	0.85	33.95
1917-18	3.51	0.34	1.15	3.46	2.53	2.17	3.40	4.35	2.87	2.62	3.44	4.13	33.97
1918-19	1.64	1.67	2.92	0.97	1.11	5.16	3.57	4.33	2.59	4.20	3.12	1.26	32.54
1919-20	7.08	3.23	1.66	1.80	1.13	2.78	5.28	2.71	3.75	3.76	2.64	2.62	38.44
1920-21	1.61	3.46	1.54	2.59	2.25	7.41	3.42	2.26	1.13	1.34	3.30	4.75	35.06
1921-22	1.79	4.88	3.48	1.43	1.47	5.81	5.38	4.16	1.54	4.49	2.51	2.46	39.40
1922-23	1.10	1.79	3.62	3.83	1.60	2.42	1.56	2.56	3.69	1.50	3.23	3.45	30.35
1923-24	1.86	2.26	6.84	3.71	1.79	4.31	2.20	3.63	7.59	2.78	1.27	2.92	41.16
1924-25	0.33	1.45	3.57	0.95	1.98	2.37	3.57	2.10	3.56	2.91	2.49	6.47	31.75
1925-26	3.93	4.95	0.72	2.25	2.51	2.71	2.21	2.15	2.09	5.03	6.59	6.26	41.40
1926-27	5.46	1.41	2.30	4.14	1.66	4.05	5.43	3.81	2.51	3.37	1.71	2.82	38.67
1927-28	3.24	6.50	2.49	1.37	2.73	2.04	3.62	1.48	7.13	2.24	3.00	0.73	36.57
1928-29	2.89	3.50	2.09	4.34	3.43	2.45	4.01	7.41	5.30	5.32	1.21	3.04	44.99
1929-30	3.64	2.97	3.21	5.27	2.31	1.97	1.54	2.64	2.38	1.57	4.98	2.76	35.24
1930-31	1.17	1.37	0.97	0.97	1.77	2.51	4.43	2.11	2.90	6.74	2.27	2.36	29.57
1931-32	4.66	3.41	4.29	6.14	1.42	3.02	1.47	2.47	7.22	3.41	0.94	3.78	42.23
1932-33	3.62	2.64	4.87	2.16	2.04	5.98	4.24	7.96	1.00	3.68	3.36	4.74	46.29
1933-34	1.98	0.89	3.04	1.39	1.07	2.98	0.95	0.90	3.45	2.14	3.47	4.09	26.35
1934-35	0.15	1.83	1.32	2.63	0.96	3.21	2.27	5.47	3.57	4.28	2.26	3.31	31.26
1935-36	2.20	3.58	2.22	1.25	2.87	2.98	3.52	1.15	0.45	1.34	4.44	3.15	29.15
1936-37	4.60	3.53	2.01	11.74	1.75	1.75	4.78	3.80	4.82	3.58	4.90	3.31	50.57
1937-38	4.19	1.82	2.99	1.44	2.77	6.52	2.73	9.06	4.89	5.05	2.54	4.22	48.22
1938-39	0.91	4.76	1.25	2.81	4.02	3.20	4.64	2.56	6.37	4.58	1.57	1.67	38.34
1939-40	2.47	1.25	1.68	1.59	2.80	2.71	6.18	6.61	2.12	1.13	2.63	1.45	32.62
1940-41	2.31	4.39	3.01	1.72	0.78	0.60	1.73	1.35	7.34	1.43	4.33	1.76	30.75
1941-42	5.84	2.34	3.49	1.89	3.34	2.92	2.15	2.72	4.79	3.78	3.30	2.86	39.42
1942-43	1.57	4.13	3.67	1.31	2.09	5.83	2.25	4.56	1.96	5.23	2.41	1.22	36.23
1943-44	2.02	1.02	0.98	0.70	2.77	5.41	5.10	3.13	1.16	1.04	4.04	1.93	29.30
1944-45	0.26	2.42	2.34	1.43	4.00	8.67	4.49	3.53	6.08	2.62	3.54	4.99	44.37
25 year average 1921-45	2.55	2.90	2.72	2.76	2.25	3.75	3.35	3.58	3.80	3.22	3.05	3.22	37.17
Average entire record -	2.70	2.84	2.84	3.15	2.52	3.60	3.21	3.75	3.89	3.36	3.20	2.85	37.72
Max.	7.08	8.40	8.85	11.74	6.77	8.89	6.80	9.06	9.09	9.77	8.98	7.37	57.18
Min.	0.15	0.34	0.72	0.70	0.42	0.05	0.55	0.90	0.45	0.28	0.34	0.25	24.73

Records from Station 1, October 1844-Oct. 1882;
Station 2 and 3, Nov. 1882-July 1911;
Station 4, Aug. 1911-June 1933;
Station 7, July 1933-Dec. 1935;
Station 8, Jan. 1936-Sept. 1945.

Table 23 B

Dayton Airport - Precipitation in inches

Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1943-44	2.08	0.92	0.56	0.62	2.45	4.70	4.31	3.85	1.18	0.79	3.85	0.72	26.03
1944-45	0.10	1.89	1.94	0.64	2.71	7.05	3.17	3.87	6.78	2.77	2.53	4.40	37.85
1945-46	1.37	3.09	2.33	0.70	2.86	2.62	1.35	4.85	4.20	3.54	1.50	0.99	29.40

Table 23 C

Monthly and annual precipitation in inches at Germantown, Ohio

Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1850-51			2.70	0.69	6.13	2.60	2.49	2.69	2.81	5.86	2.77	1.18	
1851-52	2.48	3.35	3.23	2.57	3.80	2.64	4.70	3.05	2.33	1.55	1.43	2.79	33.92
1852-53	2.49	3.95	9.88	1.07	3.02	1.65	3.13	1.43	1.55	3.54	4.39	2.49	38.59
1853-54	2.32	2.56	1.39	3.71	4.68	5.97	4.57	10.46	1.95	3.37	1.37	1.09	43.44
1854-55	2.80	3.42	1.33	4.19	1.44	3.55	2.28	2.54	6.93	5.19	5.04	4.64	43.35
1855-56	1.29	6.26	3.65	0.99	1.63	0.72	0.88	1.94	1.81	4.11	0.76	3.26	27.30
1856-57	1.35	3.57	3.13	1.01									
1913-14								1.43	2.68	2.51	6.21	0.87	
1914-15	3.24	2.03	2.71	2.95	1.75	1.34	1.54	5.58	3.01	5.48	7.40	5.62	42.65
1915-16	2.12	2.34	3.52	6.34	1.41	3.20	2.13	3.58	5.22	1.76	3.06	2.78	37.46
1916-17	1.91	1.89	2.78	4.14	1.56	4.31	3.27	4.11	4.37	3.43	3.56	1.82	37.15
1917-18	3.77	0.50	1.95	4.07	2.14	1.71	3.51	4.18	3.51	1.94	6.31	4.60	38.19
1918-19	1.85	1.66	3.32	1.08	0.68	4.85	4.16	4.53	1.50	4.34	3.73	1.02	32.72
1919-20	7.93	3.97	2.30	1.44	1.81	3.48	7.57	2.95	5.43	3.47	3.15	3.01	46.51
1920-21	1.38	3.19	2.05	2.79	2.41	8.06	4.01	1.69	1.25	1.84	4.77	4.48	37.92
1921-22	2.66	6.77	4.04	1.46	1.74	6.39	5.03	5.94	1.32	2.84	4.74	2.71	45.64
1922-23	1.92	1.94	4.49	4.00	2.26	3.18	2.43	3.26	3.09	1.88	3.72	2.70	34.87
1923-24	1.42	2.27	6.12	4.12	1.50	4.27	2.17	3.72	5.92	4.18	2.09	2.45	40.23
1924-25	0.23	1.48	3.78	1.02	1.78	2.56	3.29	1.40	3.28	3.43	3.52	8.71	34.48
1925-26	7.90	6.04	0.67	2.23	3.27	2.71	3.45	3.21	1.94	2.90	7.96	5.16	47.44
1926-27	5.83	1.33	2.18	4.16	1.45	4.48	5.75	4.13	2.97	3.59	2.29	2.16	40.32
1927-28	3.68	5.85	2.90	1.56	2.57	1.99	3.43	1.15	6.11	3.61	2.41	1.24	36.50
1928-29	2.78	3.62	2.46	6.15	4.00	2.76	3.64	7.66	5.17	4.90	1.53	3.19	47.86
1929-30	3.67	3.58	3.08	6.45	3.48	2.41	1.75	2.34	1.85	1.55	3.17	2.53	35.86
1930-31	0.99	1.57	1.05	1.55	1.78	2.54	3.74	2.44	5.26	2.99	5.21	3.44	32.56
1931-32	3.21	3.21	4.52	6.53	1.54	2.97	1.41	1.72	8.06	4.48	0.75	4.67	43.07
1932-33	3.57	2.99	5.32	2.43	2.30	6.47	3.90	8.45	0.40	2.02	2.47	4.39	44.71
1933-34	2.18	1.00	2.58	1.28	0.87	2.71	0.86	0.92	1.54	3.24	2.03	4.13	23.34
1934-35	0.17	1.92	1.58	2.93	0.58	3.59	2.15	4.83	3.40	3.08	5.17	4.57	33.97
1935-36	1.60	3.48	2.03	1.36	2.63	2.66	3.93	1.21	0.81	0.67	3.23	3.78	27.39
1936-37	4.58	2.92	2.31	10.15	1.39	1.32	3.57	3.91	3.05	3.23	4.36	3.38	44.17
1937-38	4.55	1.54	3.77	1.26	2.11	5.30	2.00	7.36	4.83	7.73	2.33	2.60	45.38
1938-39	0.76	3.33	1.14	4.27	2.87	3.18	4.17	0.85	7.11	4.48	1.36	1.17	34.69
1939-40	2.95	0.99	1.48	1.55	2.88	2.26	6.20	4.82	2.45	0.74	1.72	1.42	29.46
1940-41	1.15	3.88	2.62	1.55	0.63	0.59	1.54	2.33	6.70	1.57	3.25	1.50	27.31
1941-42	6.71	1.59	3.47	1.91	2.43	2.57	1.55	3.17	5.27	5.33	2.04	3.84	39.88
1942-43	1.30	4.48	2.75	0.91	1.91	6.13	2.05	6.09	3.01	3.57	2.94	1.96	37.10
1943-44	1.84	0.86	1.07	0.75	2.61	4.43	4.44	2.08	1.44	0.80	2.73	1.43	24.48
1944-45	0.31	2.27	2.30	0.61	3.44	8.49	4.04	3.48	5.62	5.35	2.22	5.32	43.45

Table 23 C (Cont.)

Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
25 year average 1921-45	2.69	2.88	2.79	2.92	2.18	3.76	3.22	3.53	3.67	3.20	3.12	3.32	37.28
Average entire record -	2.73	2.91	2.94	2.82	2.28	3.51	3.26	3.60	3.55	3.33	3.35	3.11	37.59
Max.	7.93	6.77	9.88	10.15	6.13	8.49	7.57	10.46	8.06	7.73	7.96	8.71	47.86
Min.	0.17	0.50	0.67	0.61	0.58	0.59	0.86	0.85	0.40	0.67	0.75	0.87	23.34

Table 24

Average and extremes of monthly precipitation in inches at Dayton, Ohio

Period of record used, 1921-45

Month	Aver.	Max. Monthly	Min. Monthly	Average precipitation equaled or exceeded 10% of the time	25%	50%	75%	90%
Jan.	2.76	11.74	0.70	5.27	3.71	1.89	1.39	0.97
Feb.	2.25	4.02	0.78	3.43	2.77	2.09	1.66	1.07
Mar.	3.75	8.67	0.60	6.52	5.41	2.98	2.45	1.97
Apr.	3.35	6.18	0.95	5.38	4.49	3.52	2.20	1.54
May	3.58	9.06	0.90	7.41	4.16	2.72	2.15	1.35
June	3.80	7.59	0.45	7.22	5.30	3.56	2.09	1.13
July	3.22	6.74	1.04	5.23	4.49	3.37	1.57	1.34
Aug.	3.05	6.59	0.94	4.90	3.54	3.00	2.27	1.27
Sept.	3.22	6.47	0.73	4.99	4.09	3.04	2.36	1.45
Oct.	2.55	5.84	0.15	4.66	3.64	2.20	1.57	0.33
Nov.	2.90	6.50	0.89	4.88	3.58	2.64	1.79	1.25
Dec.	2.72	6.84	0.72	4.29	3.49	2.49	1.68	0.98
Annual	37.17	11.74	0.15	46.29	41.40	36.57	31.26	29.30

*Maximum annual precipitation = 50.57 inches in 1936-37
*Minimum annual precipitation = 26.35 inches in 1933-34
Minimum consecutive 12-month period Jan. to Dec. 1934 = 23.74 inches
Maximum consecutive 12-month period Oct. 1936 to Sept. 1937 = 50.57 inches

*Hydrologic year - October to September

Table 25

Monthly and annual snowfall in inches at Dayton, Ohio

Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Annual
1882-83				5.1	0.5	5.5	0.2		
1883-84			17.0	20.0	1.4	2.1	2.5		
1884-85			17.9	9.2	12.4	1.8			
1885-86		T	11.0	19.3	4.2	1.8			36.3
1886-87		4.4	10.3	3.6	4.5	11.0			33.8

Table 25 (Cont.)

Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Annual
1887-88		5.8	0.5	7.8	T	8.3			22.4
1888-89		3.2	T	7.9	2.2	2.0			15.3
1889-90		T		2.0	0.4	3.3	T		
1890-91			9.5	3.0	1.0	8.8	1.1		
1891-92		2.5		12.5	4.0	2.7	T		
1892-93		6.2	3.6	17.3	6.0	T	2.0		35.1
1893-94			1.0	3.5	7.7	4.0			
1894-95	T	4.5	2.0	23.6	4.8	2.5	T		37.4
1895-96		T	4.5	1.0	8.3	12.0	T		25.8
1896-97	T	T	0.7	9.9	5.5	T			16.1
1897-98			6.5	2.0	4.0	3.5			16.0
1898-99		2.2	10.5	4.1	6.0	4.0			26.8
1899-1900			5.2	1.3	3.5	2.0			12.0
1900-01		2.5	2.5	5.3	4.2	0.5	3.5		18.5
1901-02		0.5	2.5	6.6	3.6	0.7			13.9
1902-03		T	4.9	9.1	4.0	T			18.0
1903-04		2.1	3.6	15.9	7.2	0.7	2.8		32.3
1904-05		0.5	6.8	9.5	7.1	1.2	1.8		26.9
1905-06		T	0.3	7.9	5.5	26.9			40.6
1906-07	T	0.4	7.5	5.6	1.8	0.4	3.7		19.4
1907-08		0.1	2.4	0.9	6.3	2.7	T		12.4
1908-09		T	T	16.0	3.8	0.7	T	T	20.5
1909-10		0.1	8.7	10.0	31.6	T	T		50.4
1910-11	T	0.2	3.6	13.5	6.4	T	1.6		25.3
1911-12		2.3	0.4	10.1	12.3	8.5	3.0		36.6
1912-13		0.2	3.0	2.9	3.6	3.5	0		13.2
1913-14	T	3.2	0.7	5.7	15.2	0.7	T		25.5
1914-15		T	5.6	22.0	0.5	1.0	T		29.1
1915-16	T	0.4	4.5	0.4	6.5	6.1	2.6		20.5
1916-17	T	0.8	6.9	9.0	3.2	6.1	0.5	T	26.5
1917-18	0.4	0.6	13.7	24.4	0.4	T	3.0		42.5
1918-19		0	0.9	0.7	1.5	0.1	0		3.2
1919-20		T	2.3	7.3	3.3	0.3	4.3		17.5
1920-21	T	8.6	2.5	4.1	4.1	0	0.2	0	19.5
1921-22	T	1.0	4.3	3.7	0.5	3.1	0	0	12.6
1922-23	0	1.3	4.0	0.2	4.9	2.0	T	0.5	12.9
1923-24	0	T	2.9	3.0	2.6	7.0	3.0	0	18.5
1924-25	0	1.9	2.0	8.9	0.2	0.4	0	0	13.4
1925-26	2.8	0.4	1.4	12.1	5.4	4.3	0.6	0	27.0
1926-27	T	0.4	5.3	6.9	4.1	T	T	0	16.7
1927-28	0	1.3	1.2	1.0	4.7	1.9	0.1	0	10.2
1928-29	0	0.5	T	11.1	10.1	0.5	T	T	22.2
1929-30	T	0.7	7.4	4.9	0.7	3.5	T	0	17.2
1930-31	T	0.7	4.4	2.0	0.4	4.5	T	0	12.0
1931-32	0	5.3	T	T	0.6	1.6	T	0	7.5
1932-33	0	2.6	6.3	T	3.2	3.2	T	0	15.3
1933-34	0	0.2	3.0	1.4	10.7	5.9	0.1	0	21.3
1934-35	0	T	2.0	4.5	0.2	0	0.2	0	6.9
1935-36	0	0.2	12.0	9.9	7.1	1.9	0.2	0	31.3
1936-37	0	6.9	3.2	4.4	0.3	4.2	0	0	19.0

Table 25 (Cont.)

Year		Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May		Annual
1937-38		0	3.5	7.5	2.0	4.0	0.5	T	0		17.5
1938-39		0	2.2	2.0	7.7	13.0	T	T	0		24.9
1939-40		0	0	5.4	9.3	6.9	2.8	0.5	0		24.9
1940-41		0	T	0	6.0	2.3	T	0	0		8.3
1941-42		0	T	T	2.8	0.6	3.0	0.4	0		6.8
1942-43		0	0.5	13.4	4.3	0.6	4.0	0.1	0		22.9
1943-44		T	1.0	1.0	T	9.1	2.0	0.4	0		13.5
1944-45		0	0.2	6.2	10.9	1.3	T	T	0		18.6
25 year average (1921-45)			1.58	3.90	4.84	3.90	2.25	0.23			16.84
Average entire record			1.47	4.64	7.25	4.79	3.04	0.77			21.26
1921-1945	Max.	2.8	8.6	13.4	12.1	13.0	7.0	3.0	0.5	(1935-36)	31.3
	Min.	0	0	0	T	0.2	0	0	0	(1941-42)	6.8
1883-1945	Max.	2.8	8.6	17.9	24.4	31.6	26.9	4.3	0.5	(1909-10)	50.4
	Min.	0	0	0	T	T	0	0	0	(1918-19)	3.2

Table 26 A

Monthly and annual temperature in °F. at Dayton, Dayton Airport (Vandalia) and Germantown, Ohio

Monthly and annual temperature in ° F. at Dayton, Ohio

Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Average Annual
1844-45	47.3	42.0	35.6	35.4	36.4		56.0	59.2		70.4			
1845-46				31.9	28.8	41.8	54.3	63.7	70.4	71.3	72.0	67.5	
1846-47	51.2	43.5	35.9	28.0	33.4	37.9	54.7	60.5	67.1	72.9	69.6	63.2	51.5
1847-48	52.0	45.5	33.1	36.4	35.8	41.0	51.9	64.7	68.4	72.1	71.0	60.8	52.7
1848-49	51.7	37.2	38.9	30.0	29.7	44.8	50.2	62.2	72.2	71.4	71.2	63.6	51.9
1849-50	52.0	48.7	31.0	35.7	34.6	39.6	47.7	57.9	70.6	77.4			
1855-56		47.3		19.2	24.5	29.5	54.0	60.0	73.3	76.8	68.7	63.4	
1856-57	52.7							58.6	72.2	75.9	72.7	64.8	
1857	57.3	38.1											
1873					33.0	38.6							
1882-83		40.5	29.4	23.8	32.9	34.6	50.4	60.1	70.4	74.3	69.7	62.7	
1883-84	54.4	43.3	32.9	19.0	34.6	38.8	48.5	61.5	72.9	73.8	72.3	71.3	51.9
1884-85	57.3	39.9	30.0	22.1	19.7	31.0	50.7	62.3	69.9	77.6	70.7	64.2	49.6
1885-86	50.8	41.0	32.5	24.4	27.8	39.7	54.2	64.3	69.9	74.2	72.1	66.9	51.5
1886-87	53.5	39.6	26.6	26.9	36.8	38.0	51.7	68.2	74.7	83.6	73.1	65.6	53.2
1887-88	50.3	40.3	32.3	26.5	32.4	36.8	52.9	62.2	74.3	76.4	72.9	62.5	51.6
1888-89	49.2	44.0	35.0	34.9	28.4	42.3	52.6	62.9	69.9	76.2	71.7	65.0	52.7
1889-90	48.3	41.5	46.2	40.5	41.0	36.9	53.8	62.3	77.6	77.9	72.3	63.4	55.1
1890-91	54.4	45.3	32.7	34.0	38.0	37.0	55.0	60.0	73.0	73.6	72.5	69.1	53.7
1891-92	52.6	41.4	40.7	26.6	37.2	37.6	51.5	62.0	76.3	77.1	75.4	65.7	53.6
1892-93	54.0	38.5	31.3	21.0	32.3	42.9	52.7	61.6	72.6	78.2	73.8	68.2	52.3
1893-94	54.4	40.9	35.6	35.8	30.7	47.4	53.3	62.5	74.4	76.7	74.3	70.3	54.7
1894-95	56.1	40.7	34.2			33.8	53.9	63.5	75.1	75.4	76.5	72.2	
1895-96	48.8	42.6	37.0	32.0	33.8	35.6	60.0	71.2	72.0	76.5	74.4	64.4	54.0
1896-97	51.0	46.8	36.2	27.7	35.2	44.8	51.0	58.4	71.1	78.5	71.9	69.0	53.5

Table 26 A (Cont.)

Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Average Annual
1897-98	60.4	44.2	34.0	34.0	33.0	47.1	49.4	64.0	73.7	74.2	75.2	70.6	55.0
1898-99	56.4	40.9	29.6	31.2	23.2	39.5	56.9	65.4	74.2	76.0	76.6	67.2	53.1
1899-1900	59.4	45.7	31.2	33.8	26.5	35.6	52.4	65.2	72.4	76.4	79.2	72.8	54.4
1900-01	63.0	43.0	33.0	30.2	24.4	41.9	48.0	60.4	73.8	80.7	75.8	66.7	53.4
1901-02	54.8	38.4	27.7	28.9	22.2	43.0	49.3	65.4	69.8	75.8	71.9	65.4	51.0
1902-03	56.4	49.8	30.6	28.2	32.0	47.6	51.2	65.2	66.0	75.2	74.3	67.4	53.7
1903-04	55.6	38.2	25.8	21.3	25.4	41.8	45.4	61.6	70.2	73.6	71.6	66.6	49.8
1904-05	53.6	41.8	29.3	24.4	22.1	45.8	51.2	62.3	71.8	74.8	74.0	66.8	51.5
1905-06	53.8	41.2	33.6	36.0	28.4	32.3	53.8	63.2	71.3	74.0	76.6	70.8	52.9
1906-07	53.8	41.9	33.5	34.7	29.0	49.4	42.8	56.2	67.9	75.0	71.6	67.2	51.9
1907-08	50.6	39.8	34.3	31.0	30.2	44.8	52.2	64.2	70.8	75.8	73.8	69.2	53.1
1908-09	54.9	43.3	35.2	33.0	37.7	39.8	50.7	60.3	72.6	72.2	74.4	64.3	53.2
1909-10	50.0	51.0	26.4	29.7	27.0	50.4	52.6	57.2	68.2	75.0	73.0	67.7	52.4
1910-11	57.6	37.6	27.4	35.1	36.8	40.0	49.3	67.6	72.9	76.4	73.8	69.8	53.7
1911-12	54.7	38.0	37.8	18.4	23.2	34.4	53.6	64.4	68.4	74.9	71.0	68.2	50.6
1912-13	56.6	43.2	34.4	36.9	27.6	40.9	50.6	62.8	72.5	76.6	75.7	65.8	53.6
1913-14	54.8	46.8	36.2	34.4	23.1	37.2	51.4	64.4	73.0	76.4	73.8	65.7	53.1
1914-15	58.4	43.8	26.6	27.6	37.0	34.7	57.2	58.8	68.6	72.8	67.4	68.0	51.7
1915-16	57.1	45.3	31.6	36.4	27.6	36.7	50.2	62.8	66.2	79.4	75.4	64.4	52.8
1916-17	54.8	43.6	29.9	29.9	26.0	41.3	49.7	55.0	68.2	73.2	72.6	56.8	50.1
1917-18	47.4	41.4	21.8	15.0	32.1	46.3	49.4	68.2	70.2	72.1	78.0	59.1	50.1
1918-19	58.5	43.2	41.3	34.4	33.8	42.8	51.4	59.0	75.6	77.0	71.5	68.8	54.8
1919-20	60.8	41.9	26.7	23.4	29.8	42.6	46.9	60.6	70.3	72.3	71.1	67.9	51.2
1920-21	60.7	41.4	34.0	34.7	35.8	50.4	55.6	64.0	75.4	80.0	72.5	71.2	56.3
1921-22	54.2	44.2	34.8	27.8	34.4	43.6	54.2	66.4	72.8	74.2	72.4	70.2	54.1
1922-23	57.7	45.4	34.3	34.5	26.6	38.4	50.1	60.4	72.4	75.8	72.8	67.0	53.0
1923-24	52.7	42.8	42.2	25.4	30.4	36.6	52.2	56.2	70.0	72.0	73.5	62.0	51.3
1924-25	59.0	41.8	29.0	28.9	38.4	43.1	56.4	58.0	74.6	73.9	73.4	72.6	54.1
1925-26	47.0	40.9	29.6	28.8	33.7	33.9	45.6	62.8	67.5	74.8	75.4	67.8	50.6
1926-27	54.9	40.9	30.6	29.9	39.0	44.8	52.0	61.5	66.5	74.8	68.0	70.4	52.8
1927-28	59.0	47.1	32.8	29.9	32.5	39.1	48.2	61.0	65.8	75.4	75.4	63.4	52.5
1928-29	58.7	43.7	36.3	27.4	26.4	47.7	55.4	60.0	68.9	74.6	70.7	66.3	53.0
1929-30	53.2	39.4	32.6	28.4	41.7	39.6	54.8	64.8	71.8	77.6	73.6	69.0	53.9
1930-31	53.6	43.7	31.6	33.8	37.6	37.1	52.4	59.6	74.0	78.9	73.6	72.0	54.0
1931-32	58.8	52.0	41.3	40.4	40.5	34.3	51.0	63.1	72.9	76.0	74.4	67.4	56.0
1932-33	55.0	40.2	33.0	39.0	32.4	40.0	51.6	65.1	77.5	76.6	72.4	70.3	54.4
1933-34	51.9	39.4	36.0	34.1	21.4	35.0	51.2	65.8	78.4	81.4	73.8	67.4	53.0
1934-35	54.9	45.2	31.2	31.2	32.2	46.4	49.0	58.3	68.7	78.0	74.6	64.7	52.9
1935-36	53.8	41.8	26.0	23.4	22.5	44.0	47.1	65.8	71.8	80.7	78.4	69.8	52.1
1936-37	54.2	37.8	35.2	36.2	31.5	36.0	51.4	62.6	71.6	74.8	75.6	63.4	52.5
1937-38	52.1	39.7	29.4	30.4	37.8	46.4	54.6	63.1	70.4	75.4	75.8	67.5	53.6
1938-39	55.6	44.1	34.2	35.0	33.2	40.6	48.6	65.2	74.2	74.8	73.7	71.0	54.2
1939-40	56.0	41.4	35.8	16.5	30.8	37.1	47.6	62.4	73.3	76.2	75.3	63.8	51.4
1940-41	56.2	41.8	37.6	30.2	27.6	34.6	57.8	65.2	73.3	78.0	74.4	70.4	53.9
1941-42	59.4	44.3	38.0	29.0	28.3	43.2	55.6	64.7	73.7	78.0	72.7	65.5	54.4
1942-43	55.6	45.2	28.7	32.3	35.0	40.0	47.5	63.6	78.3	77.0	75.0	63.6	53.5
1943-44	53.6	40.0	30.0	34.0	35.5	38.4	51.9	70.2	77.4	78.2	75.8	67.2	54.4
1944-45			28.0	24.4	32.6	52.4	54.8	59.0	70.4	74.4	73.5	69.9	
25 year average 1921-45	55.3	42.7	33.3	30.6	32.7	40.9	51.9	62.8	72.5	76.5	73.9	67.8	53.4

Table 26 A (Cont.)

Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Average Annual
Average entire record													
	54.6	42.6	32.9	29.9	31.4	40.4	51.8	62.4	71.8	75.8	73.4	66.9	52.8
Max.	63.0	52.0	46.2	40.5	41.7	52.4	60.0	71.2	78.4	83.6	79.4	72.8	56.3
Min.	47.0	37.2	21.8	15.0	19.7	29.5	42.8	55.0	65.8	70.4	67.4	56.8	49.6

Records from Station 1, Oct. 1844-Oct. 1882
Station 2 and 3, Nov. 1882-July 1911; Station 4,
Aug. 1911-June 1933; Station 7, July 1933-Dec. 1935;
Station 8, Jan. 1936-Sept. 1945.

Table 26 B

Monthly and annual temperature in °F. at Dayton Airport

Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Average Annual
1943-44			28.7	32.2	33.1	36.2	49.2	67.7	75.1	76.7	74.6	66.6	
1944-45	54.5	42.2	25.8	21.6	30.1	50.6	52.9	56.4	68.6	72.8	72.4	68.2	
1945-46	51.8	42.6	23.9	29.4	33.0	51.1	51.4	58.5	69.7	73.6	68.2	67.2	
1946-47	58.6	46.1	34.8	33.6	22.0	32.3	49.7	57.6					

Table 26 C

Monthly and annual temperature in ° F. at Germantown, Ohio

Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Average Annual
1850-51			30.7	31.5	38.5	43.2	48.9	63.0	67.5	71.8	69.8	65.3	
1851-52	50.2	37.6	26.1	23.0	33.6	42.6	46.6	60.8	65.5	73.4	68.9	61.7	49.2
1852-53	56.3	37.6	36.3	31.5	30.9	38.5	51.8	61.2	76.1	72.7	71.8	63.5	52.3
1853-54	46.6	44.6	29.1	28.0	35.2	42.9	51.2	61.5	70.9	77.2	75.7	70.8	52.8
1854-55	55.9	38.2	31.6	30.3	22.6	34.1	56.2	62.5	67.2	75.2	71.4	68.4	51.1
1855-56	48.3	44.2	29.3	15.6	21.0	30.4	53.0	60.3	72.6	76.2	68.6	62.0	48.5
1856-57	52.5	38.9	23.8	15.8									
1913-14								61.0		75.8	73.6	65.6	
1914-15	57.8	44.8	28.2	26.6	38.2	34.8	56.6	59.8	68.4	72.8	68.0	68.0	52.0
1915-16	56.7	46.0	31.8	36.4	28.6	37.2	51.0	63.5	65.8	78.2	75.4	65.0	53.0
1916-17	54.0	43.8	30.7	29.4	29.4	41.8	50.8	55.3	67.3	72.1	71.8	62.9	50.8
1917-18	47.6	41.0	21.3	15.2	32.2	44.3	50.0	66.4	69.6	71.6	77.6	58.6	49.6
1918-19	58.6	43.0	41.6	34.2	34.1	42.6	51.2	58.4	74.5	75.8	72.0	68.3	54.5
1919-20	60.5	42.6	26.7	24.6	29.7	42.8	46.8	59.8	69.3	71.4	70.4	67.0	51.0
1920-21	59.6	41.6	34.7	34.1	36.2	51.2	55.4	63.7	75.6	79.8	72.1	70.6	56.2
1921-22	54.2	44.7	35.4	28.2	35.0	44.6	54.6	65.2	72.8	74.7	71.9	70.8	54.3
1922-23	57.7		33.9	34.5	28.8	40.8	49.8	59.8	71.7	74.8	72.7	66.6	
1923-24	52.2	43.0	42.1	26.2	30.9	37.2	52.8	55.4	69.8	70.8	72.6	61.9	51.2
1924-25	58.3	43.0	29.6	29.3	39.2	44.0	56.6	56.9	74.2	73.4	72.7	72.0	54.1
1925-26	47.2	40.8	30.0	28.6	34.3	34.5	46.2	62.2	67.0	74.4	74.6	68.0	50.6
1926-27	56.0	40.6	31.0	29.6	39.4	44.0	52.2	61.6	65.6	73.4	67.0	69.6	52.5
1927-28	58.6	47.7	33.0	30.4	32.4	40.2	48.2	60.4	65.7	74.4	74.8	63.1	52.4
1928-29	58.8	43.9	35.8	27.7	25.2	48.3	55.0	59.3	68.2	73.6	69.8	66.4	52.7
1929-30	52.9	40.3	33.2	30.0	41.5	40.6	55.0	64.6	72.1	77.9	74.4	68.7	54.3
1930-31	52.8	43.6	31.7	33.8	38.4	37.3	52.8	59.9	73.4	78.6	73.2	71.0	53.9
1931-32	58.2	51.6	41.3	40.4	40.4	36.3	51.2	62.6	73.2	76.5	73.6	66.9	56.0
1932-33	54.9	40.4	32.4	38.6	33.4	40.6	51.1	64.8	76.2	75.8	73.0	71.0	54.3
1933-34	53.6	40.4	36.4	35.0	23.5	37.3	51.4	65.0	77.6	81.6	74.0	68.1	53.7
1934-35	55.5	46.6	31.4	31.5	33.6	48.4	49.6	58.2	68.8	78.0	74.4	66.2	53.5
1935-36	55.6	43.3	25.8	23.4	25.2	46.3	47.6	65.3	72.9	81.7	79.6	70.7	53.1

Table 26 C (Cont.)

Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Average Annual
1936-37	55.0	38.5	36.4	37.0	33.2	37.2	52.0	60.9	70.8	73.2	75.8	63.8	52.8
1937-38	52.3	40.6	29.9	31.9	39.7	47.3	54.0	63.1	69.4	75.0	76.2	68.1	53.9
1938-39	57.2	45.3	35.8	35.4	34.3	42.8	48.5	64.9	73.2	74.4	73.2	73.2	54.8
1939-40	57.8	40.9	36.2	16.4	31.5	38.1	48.5	58.7	72.1	74.7	75.6	64.5	51.2
1940-41	57.4	42.0	39.0	30.6	28.8	36.0	56.6	65.4	72.0	76.0	73.5	70.2	53.9
1941-42	59.7	44.0	38.0	29.0	29.0	44.8	55.6	63.4	72.2	75.4	71.7	66.0	54.1
1942-43	56.4	45.6	29.6	32.1	34.7	38.6	48.5	62.5	75.3	75.4	74.0	63.8	53.0
1043-44	53.8	40.8	30.2	33.9	36.0	39.4	51.6	68.0	75.8	77.1	77.4	66.8	54.2
1944-45	55.2	44.3	27.8	23.6	32.2	52.5	54.0	57.8	69.0	72.8	72.6	69.0	52.6
25 year average 1921-45	55.6	43.2	33.6	30.8	33.5	41.9	52.0	62.0	71.8	75.7	73.6	67.9	53.5
Average entire record -	55.0	42.7	32.3	29.3	32.7	41.2	51.7	61.7	71.1	75.2	73.0	67.0	52.8
Max.	60.5	51.6	42.1	40.4	41.5	52.5	56.6	68.0	77.6	81.7	79.6	73.2	56.2
Min.	46.6	37.6	21.3	15.2	21.0	30.4	46.2	55.3	65.5	70.8	67.0	58.6	48.5

Table 27

Average temperature at Dayton, Ohio

Period of record used, 1921-25

	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
Average	55.3	42.7	33.3	30.6	32.7	40.9	51.9	62.8	72.5	76.5	73.9	67.8	53.4
Av. Max.	65.4	50.4	40.0	37.8	40.2	49.7	61.4	72.3	81.9	86.4	83.6	78.0	62.3
Av. Min.	45.9	35.1	26.6	23.4	25.2	32.3	41.9	52.2	62.1	65.9	63.9	57.9	44.4
Highest	88	77	67	71	72	84	90	94	101	105	100	98	105
Lowest	21	0	6	16	9	0	18	28	40	49	45	33	16

Table 28

Average monthly wind velocity at Dayton, Ohio, in miles per hour

Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Average Annual
1920-21	8.4	10.3	14.0	11.9	11.4	12.6	11.3	9.6	8.6	7.9	7.6	8.1	10.1
1921-22	10.6	12.0	12.4	11.5	13.2	12.9	12.4	8.2	8.7	8.6	7.4	7.7	10.5
1922-23	8.7	11.3	11.1	12.4	12.4	14.9	13.0	11.9	8.3	7.0	6.6	6.7	10.4
1923-24	7.8	8.9	9.9	11.8	11.4	10.6	10.4	9.5	7.6	6.9	7.2	8.9	9.2
1924-25	6.5	11.3	11.1	9.7	11.0	11.2	9.6	8.9	8.8	7.7	5.9	7.5	9.1
1925-26	8.0	10.0	11.0	11.1	11.5	12.2	12.0	8.7	9.0	7.8	6.4	7.2	9.6
1926-27	8.1	12.0	10.1	9.7	10.9	10.0	10.6	10.8	8.2	7.5	6.1	6.9	9.2
1927-28	8.7	12.0	11.6	10.8	9.4	10.0	11.4	7.4	8.1	5.8	6.2	7.4	9.1
1928-29	7.5	9.6	7.2	10.0	7.1	10.1	10.8	7.8	7.0	6.6	5.6	6.0	7.9
1929-30	8.3	8.2	9.4	9.3	8.9	10.8	8.1	7.9	7.2	6.4	5.0	6.2	8.0
1930-31	6.0	6.0	8.2		6.7	8.5	7.7	7.7	5.6	5.6	5.6	6.4	
1931-32	6.6	7.9	7.4	10.1	9.9	11.2	9.6	8.7	7.3	8.0	6.9	7.8	8.4
1932-33	9.5	9.0	9.9	10.3	10.8	10.3	9.6	9.0	8.1				
1933-34													
1934-35						11.0	8.5	8.2	8.2	6.7	7.3	6.4	
1935-36	6.6	8.6	9.1	9.8	10.1	10.4	9.4	7.7	8.2	7.8	7.4	8.0	8.6
1936-37	7.8	9.6	8.6	9.7	11.5	9.1	10.0	7.4	7.3	6.8	6.0	6.8	8.4

Table 28 (Cont.)

Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Average Annual
1937-38	8.7	9.4	9.1	10.2	10.1	10.9	10.9	9.9	9.3	7.0	7.2	8.5	9.3
1938-39	7.8	12.2	10.8	11.7	12.6	12.1	12.2	8.7	9.2	7.1	7.5	9.1	10.1
1939-40	10.8	9.0	12.0	10.7	10.5	10.8	11.9	10.6	9.7	8.0	8.1	7.1	9.9
1940-41	7.8	12.3	10.1	10.0	11.3	10.8	9.6	9.4	8.4	7.6	7.6	9.6	9.5
1941-42	9.5	11.4	10.8	11.8	10.4	12.6	10.4	10.3	7.9	8.3	7.5	9.0	10.0
1942-43	9.5	12.0	10.2	11.1	12.7	11.7	11.8	10.8	9.5	8.3	7.8	8.8	10.3
1943-44	10.3	11.6	10.9	10.4	11.9	14.0	12.4	9.6	10.1	9.2	9.2	8.3	10.7
1944-45	9.4	10.9	11.0	11.1	11.5	12.4	12.9	11.8	9.9	7.9	8.1	9.9	10.6
Average	8.4	10.2	10.3	10.7	10.7	11.3	10.7	9.2	8.3	7.4	7.0	7.8	9.5
Max. Aver.	10.8	12.3	14.0	12.4	13.2	14.9	13.0	11.9	10.1	9.2	9.2	9.9	10.7
Min. Aver.	6.0	6.0	7.2	9.3	6.7	8.5	7.7	7.4	5.6	5.6	5.0	6.0	7.9
Max. any day	50	48	52	48	58	66	52	47	54	60	42	54	66

Table 29

Mean relative humidity at Dayton, Ohio in percent

Year	Oct.		Nov.		Dec.		Jan.		Feb.		Mar.		Apr.		May		June		July		Aug.		Sept.		Average Annual	
	Morn	Eve	M	E	M	E	M	E	M	E	M	E	M	E	M	E	M	E	M	E	M	E	M	E	M	E
1920-21	78	55	82	74	82	77	80	73	80	74	80	66	79	62	76	61	72	58	73	52	79	59	87	70	79	65
1921-22	81	64	86	77	82	76	80	68	83	74	81	71	79	65	76	62	74	57	75	56	75	55	78	59	79	65
1922-23	78	57	79	68	84	77	83	78	82	74	74	64	75	57	69	56	76	62	74	56	79	63	84	67	78	65
1923-24	81	60	81	68	86	80	75	72	77	72	79	74	68	52	78	64	79	67	74	55	78	58	80	63	78	65
1924-25	79	51	75	64	80	72	79	73	79	69	74	60	69	53	71	53	72	57	76	58	82	59	80	63	76	61
1925-26	83	76	81	66	79	69	79	74	79	75	77	69	70	61	67	49	70	53	71	57	85	69	88	76	77	66
1926-27	86	73	74	64	83	79	82	79	84	72	78	65	74	62	78	65	75	58	74	56	80	58	78	56	79	66
1927-28	80	57	81	74	80	74	80	72	79	75	77	64	71	52	69	49	79	70	79	62	84	62	79	51	78	63
1928-29	82	63	79	72	76	70	76	74	79	72	78	61	74	59	77	67	76	59	78	60	78	56	83	68	78	65
1929-30	85	70	86	75	89	83	88	75	79	70	80	63	71	52	70	55	68	48	64	39	76	52	81	60	78	62
1930-31	80	59	82	68	85	78	80	75	83	69	82	73	71	54	72	58	71	55	74	52	82	62	82	66	79	64
1931-32	82	66	82	71	87	76	82	78	77	64	79	69	71	54	66	53	76	59	74	52	76	48	79	58	78	62
1932-33	80	64	79	69	85	75	81	70	80	62	80	69	74	61	82	68	64	46								
1933-34																										
1934-35											75		74		70		76		78		82		83			
1935-36	81		83		84		85		81		74		71		66		63		62		72		76		75	
1936-37	88		80		80		84		78		87		73		76		80		80		86		82		81	
1937-38	80		77		82		78		80		80		73		79	61	76	54	80	57	84	59	84	60	79	
1938-39	80	50	78	59	77	66	81	72	83	67	74	56	72	59	71	46	82	65	81	60	83	55	76	45	78	58
1939-40	76	52	76	64	79	69	86	76	80	72	76	64	73	59	78	61	78	58	78	46	80	61	84	59	79	62
1940-41	84	63	87	72	88	81	91	83	88	76	82	66	78	58	70	49	79	64	77	63	77	55	80	62	82	66
1941-42	86	77	85	75	88	80	86	80	87	80	83	69	75	60	81	69	84	69	85	60	89	72	86	69	85	72
1942-43	86	69	85	73	88	86	88	87	86	76	81	69	83	65	83	71	82	65	85	63	84	61	83	62	84	71
1943-44	85	66	80	69	84	70	88	76	86	80	83	71	83	57	84	62	77	54	69	41	80	60	85	59	82	64
1944-45	81	56	86	74	89	81	88	84	85	79	83	68	78	64	78	62	83	64	83	59	84	63	87	70	84	69
Average	82	62	81	70	83	76	83	76	82	73	79	67	74	58	74	59	76	59	76	55	81	59	82	62	79	65
Max.	88	77	87	77	89	86	91	87	88	80	87	74	83	65	84	71	84	70	85	63	89	72	88	76	85	72
Min.	76	50	74	59	76	66	75	68	77	62	74	56	68	52	66	46	63	46	62	39	72	48	76	45	75	58

Table 30

Percentage of possible sunshine at Dayton, Ohio

Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Average Annual
1920-21	70	36	28	39	32	47	63	74	75		74	67	
1921-22	65	40	25	54	41	37	59	66	74	81	80	87	59
1922-23	68	55	41	27	38	58	63	66	75	80	75	69	60
1923-24	68	46	34	50	42	34	61	47	65	80	80	61	56
1924-25	86	47	36	44	52	64	67	72	70	66	72	65	62
1925-26	24	50	43	45	29	45	54	72	70	71	54	51	51
1926-27	41	29	23	31	34	40	50	48	68	69	62	68	47
1927-28	66	25	32	48	32	45	45	61	39	66	61	65	49
1928-29	58	25	49	33	43	52	45	51	66	71	70	70	53
1929-30	47	36	28	34	40	56	62	68	77	82	63	67	55
1930-31	63	49	26	35	43	24	61	54	62	73	60	73	52
1931-32	58	44	31	34	48	42	62	74	71	79	75	67	57
1932-33	47	41	33	45	62	29	47	51	83				
1933-34													
1934-35							47	56	72	70	63	75	
1935-36	54	28	32	41	54	63	50	80	83	82	74	75	60
1936-37	49	43	50	33	52	55	59	63	58	71	68	77	56
1937-38	47	42	29	42	27	49	62	61	69	66	70	52	51
1938-39	77	58	41	30	47	60	49	79	63	66	80	79	61
1939-40	69	52	35	42	31	46	49	52	65	84	67	70	55
1940-41	71	40	29	18	33	48	66	79	68	82	79	74	57
1941-42	45	55	29	51	38	47	72	58	68	73	68	66	56
1942-43	52	32	17	21	52	60	49	45	74	69	74	67	51
1943-44	63	28	43	45	36	24	34	51	65	69	63	65	49
1944-45	68	25	33	32	33	51	50	50	50	67	67	63	49
Average	59	40	33	38	41	47	55	62	68	74	70	68	55
Max.	86	58	50	54	62	64	72	80	83	84	80	87	62
Min.	24	25	17	18	27	24	34	45	39	66	54	51	47

Table 31

Monthly evaporation in inches and wind movement in miles at Dayton Airport

Year		April		May		June		July		Aug.		Sept.		Oct.		Total Apr.-Oct.	
1937	E	3.616		4.698		5.717		6.132		5.673		3.996		2.197		32.029	
	W		1,550		1,175		942		887		851		878				
1938	E	4.388		5.907		6.333		6.278		6.338		3.899		2.448		35.591	
	W		1,411		1,295		1,012		823		760		690		710		6,701
1939	E	3.095		6.585		5.827		6.320		6.323		5.900		3.355		37.405	
	W		1,693		1,030		970		855				770		990		
1940	E	3.742		5.129		6.025		7.826		6.472		4.357		2.592		36.143	
	W		1,292		1,010		755		715		1,030		580		715		6,097
1941	E	4.492		7.132		6.288		7.692		6.686		5.525		2.674		40.489	
	W								785		660		890		955		
1942	E	4.440		5.151		6.149		6.877		5.054		4.216		2.445		34.332	
	W				1,185		895		895		740		895		665		
1943	E	3.520		4.549		6.722		6.383		6.014		3.845		2.491		33.524	
	W		1,900		1,395		990		845		810		815		1,035		7,790
1944	E	3.491		5.508		8.465		8.381		6.998		3.684		2.120		38.647	
	W				860		1,210		960		920		660		790		
1945	E	3.871		5.335		5.972		7.172		6.193		4.743		2.640		35.926	
	W		1,540		1,790		1,100		1,060		1,001		1,145		1,079		8,715
1946	E	4.504		4.021		7.088		7.048		5.410		4.082		2.383		34.536	
	W		1,777		1,375		1,181		763		901		899		835		7,731

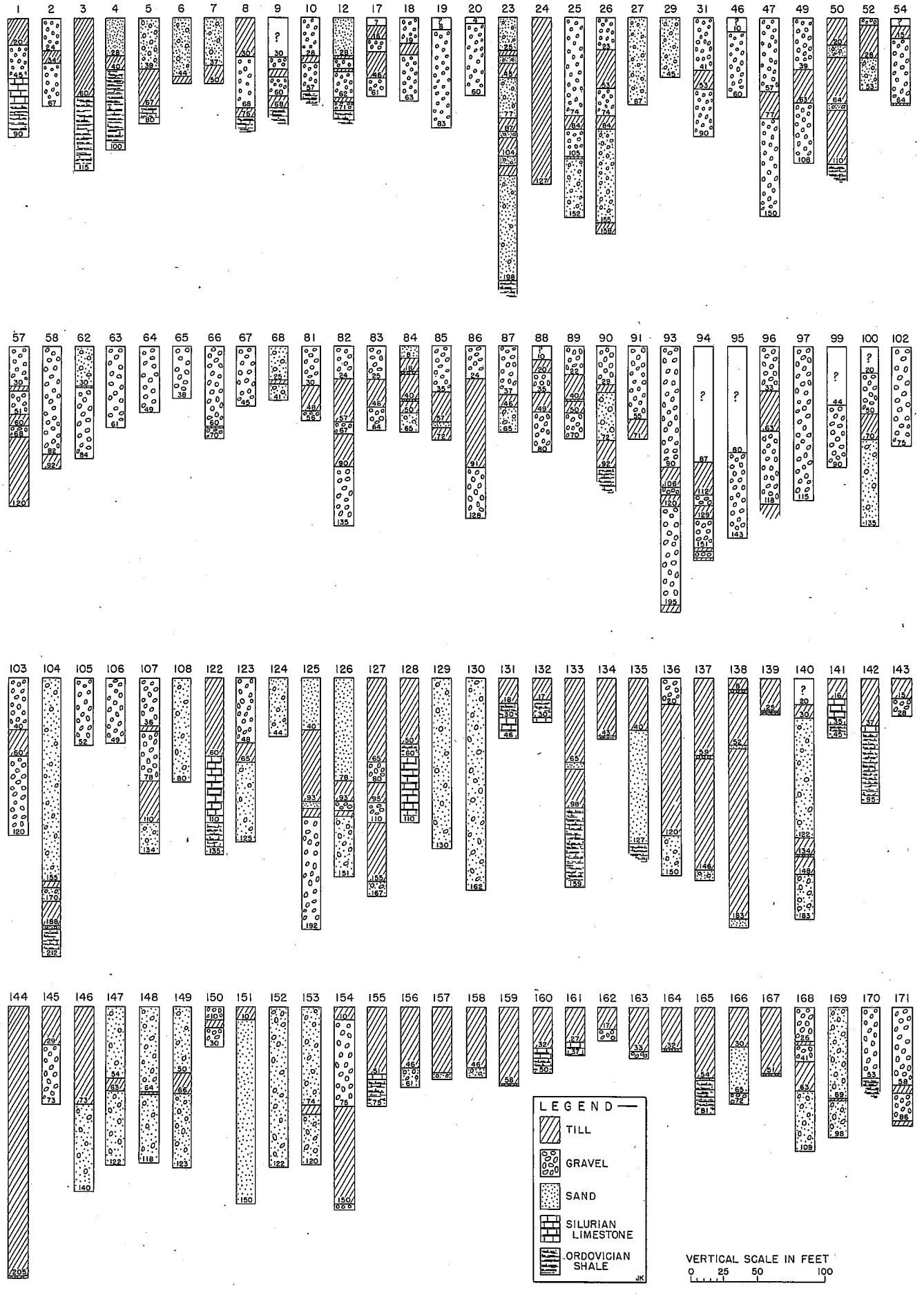


Plate 48-A. Logs of wells in Montgomery County, Ohio. Well numbers refer to locations shown on plate 2.

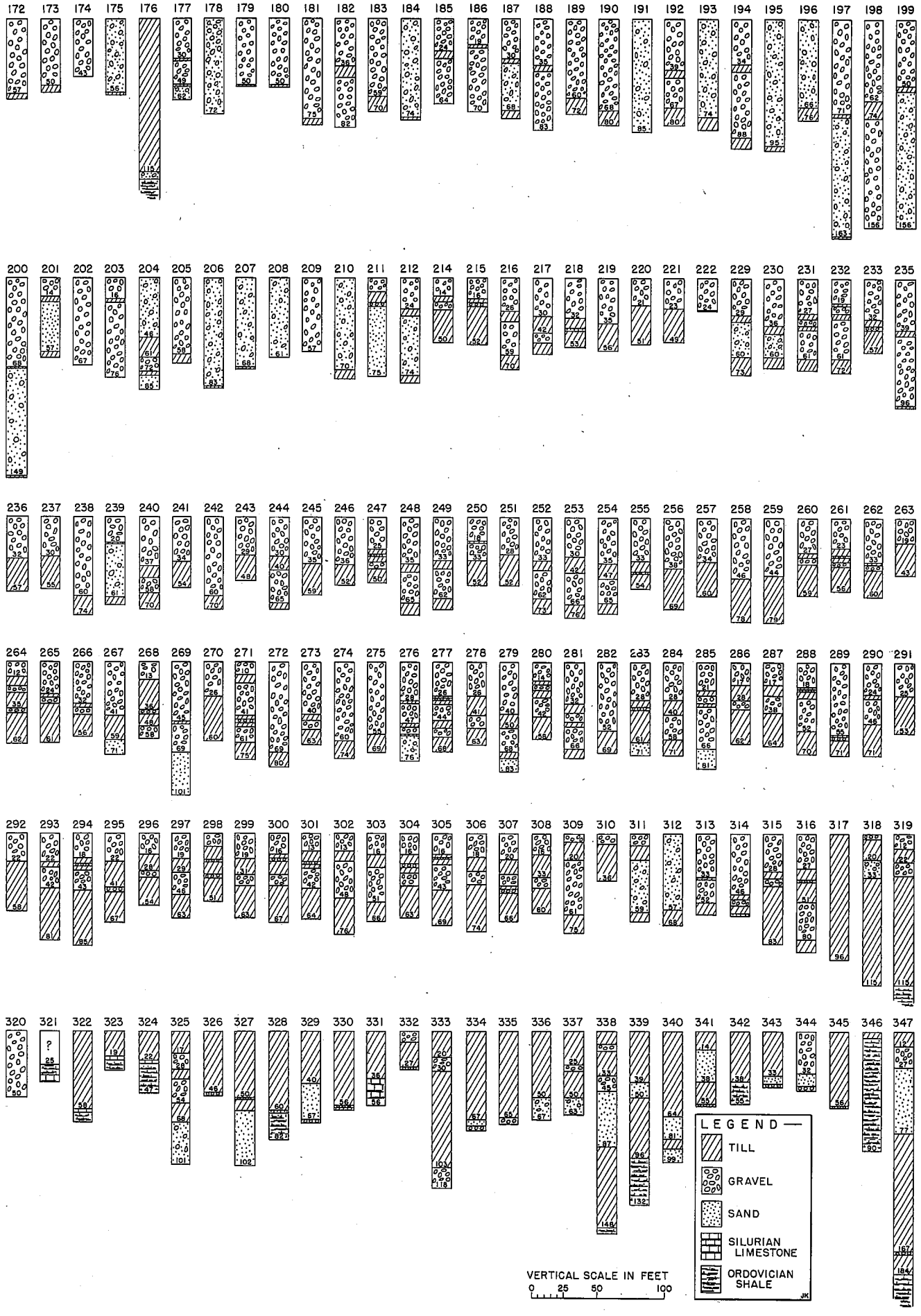


Plate 48-B. Logs of wells in Montgomery County, Ohio. Well numbers refer to locations shown on plate 2.

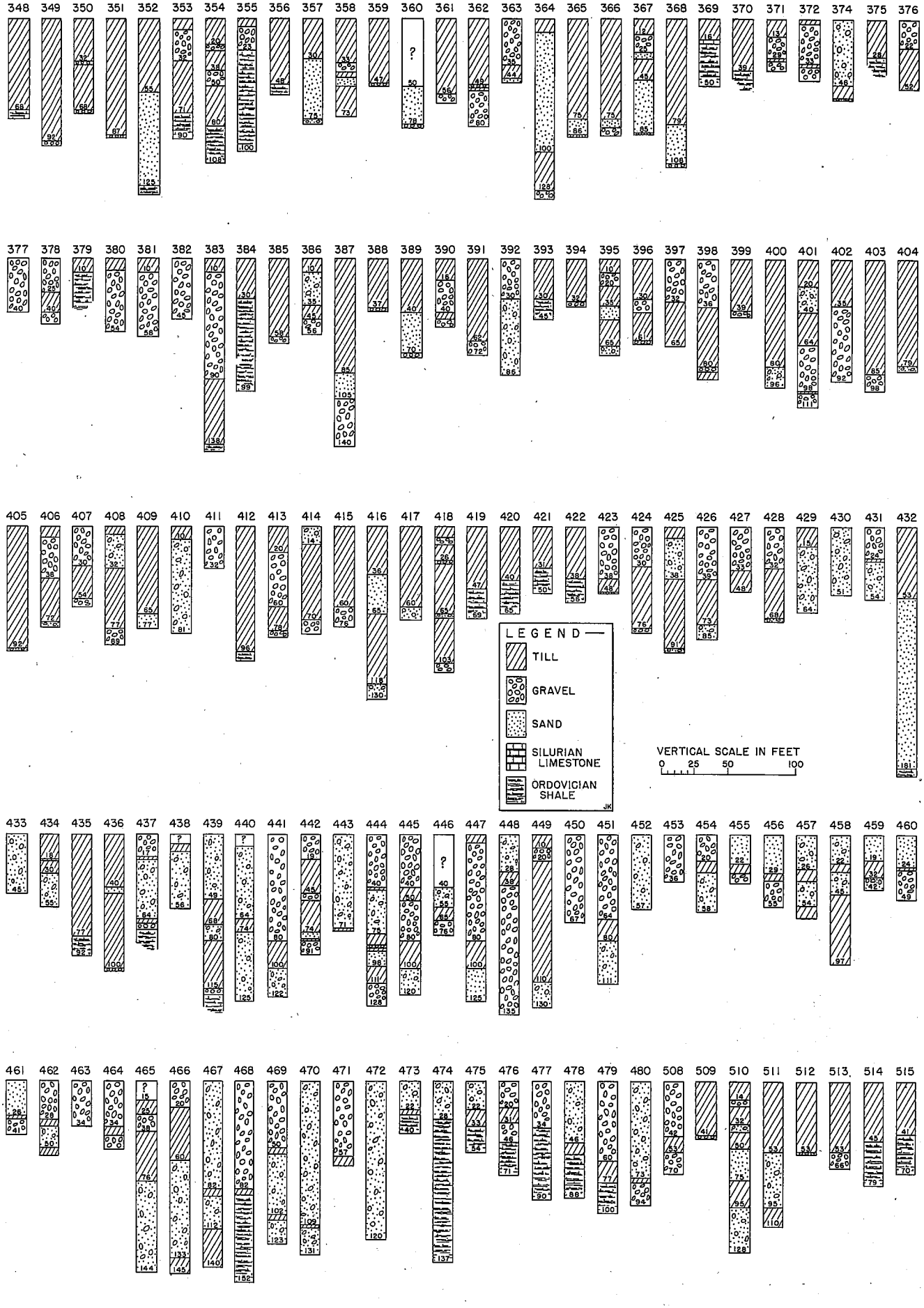


Plate 48-C. Logs of wells in Montgomery County, Ohio. Well numbers refer to locations shown on plate 2.

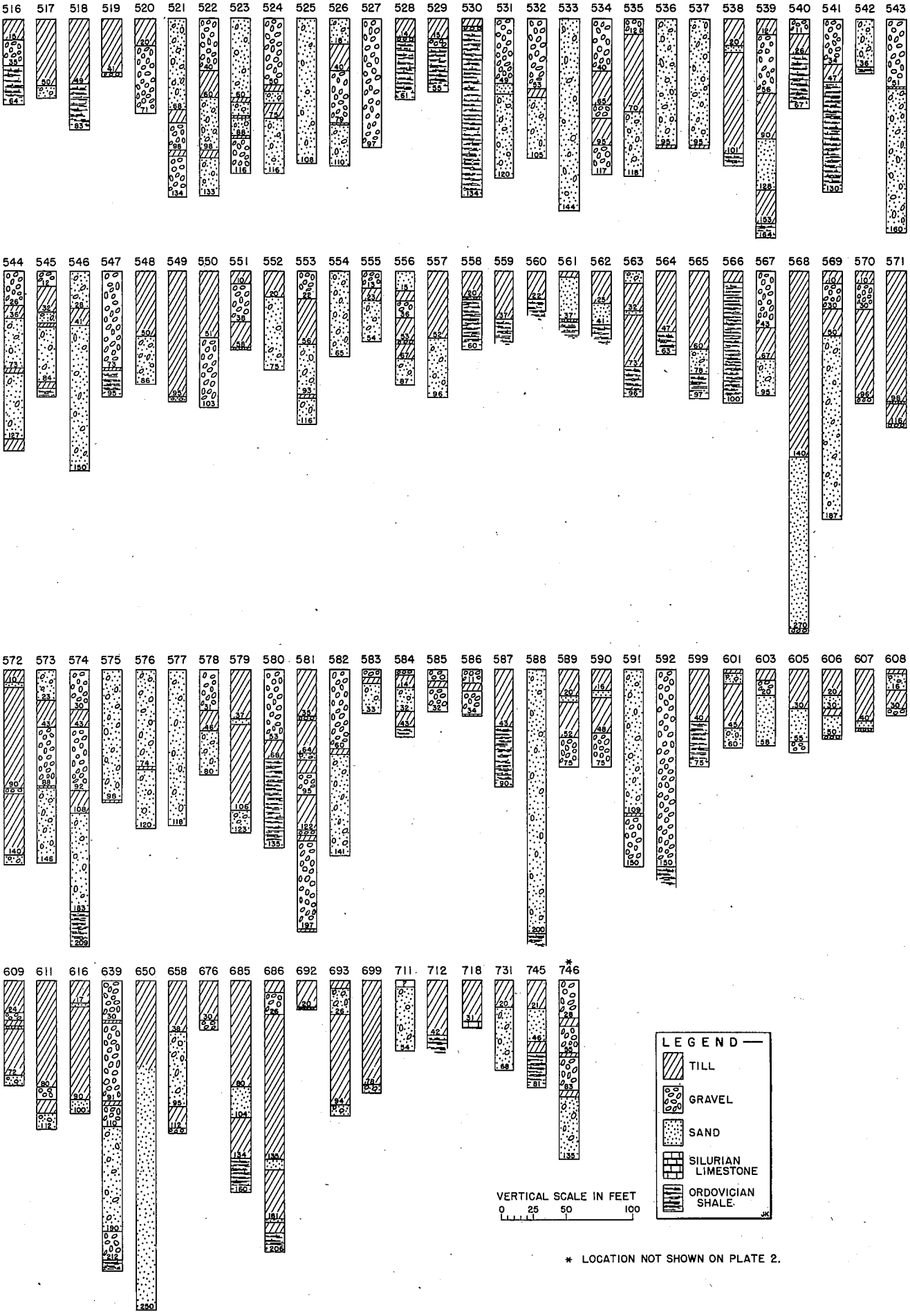


Plate 48-D. Logs of wells in Montgomery County, Ohio. Well numbers refer to locations shown on plate 2.

GEOLOGIC MAP OF
MONTGOMERY COUNTY, OHIO
SHOWING CONTOURS ON BEDROCK SURFACE

ELEVATIONS IN FEET ABOVE SEA LEVEL

CONTOUR INTERVAL 50 FEET

EXPLANATION

SILURIAN

NIAGARA AND CLINTON AGE

(LIMESTONES AND DOLOMITES PREDOMINATE. GENERALLY GOOD WATER SUPPLIES FOR FARM AND DOMESTIC REQUIREMENTS. WELLS ORDINARILY YIELD FROM 5 TO 15 GPM. A FEW WELLS YIELD FROM 100 TO 200 GPM. WATER VERY HARD. IMPORTANT SPRING HORIZON AT BASE OF SYSTEM.)

ORDOVICIAN

RICHMOND AND MAYSVILLE GROUPS

(INTERBEDDED PLASTIC SHALES AND THIN ARGILLACEOUS LIMESTONES. WELLS GENERALLY YIELD LESS THAN 10 GPM. MANY WELLS GO DRY. WATER IS SOMETIMES HIGHLY CHARGED WITH IRON SULFIDE OR SALT COMPOUNDS. WHERE WATER IS PRESENT IT GENERALLY OCCURS IN TOP FEW FEET OF STRATA.)

73 (4)

LOCATION OF WELLS MEASURED IN SURVEY.
NUMBER WITHOUT PARENTHESES SHOWS DEPTH TO BEDROCK. NUMBER IN PARENTHESES SHOWS DEPTH TO WATER AT TIME OF MEASUREMENT.

△ OUTCROP OF SILURIAN ROCKS.

▲ OUTCROP OF ORDOVICIAN ROCKS.

NOTE:
TOPOGRAPHY (PRINTED IN BROWN) FROM U.S. GEOLOGICAL SURVEY TOPOGRAPHIC MAPS OF THE BROOKVILLE, DAYTON, MIAMISBURG, AND WAYNESVILLE QUADRANGLES.
CONTOUR INTERVAL 20 FEET.

SCALE IN MILES
1 ½ 0 1 2 3 4

GEOLOGY BY S.E. NORRIS

MAP ARRANGED AND DRAFTED BY J.C. KROLCZYK

PUBLISHED BY
OHIO WATER RESOURCES BOARD
IN COOPERATION WITH
U.S. GEOLOGICAL SURVEY
NOVEMBER 1947

MAP OF THE ALLUVIAL AND GLACIAL DEPOSITS OF MONTGOMERY COUNTY, OHIO

GEOLOGY BY R.P. GOLDTHWAIT

MAP ARRANGED AND DRAFTED BY J.C. KROLCZYK

PUBLISHED BY
OHIO WATER RESOURCES BOARD
IN COOPERATION WITH
U.S. GEOLOGICAL SURVEY
NOVEMBER 1947

EXPLANATION

QUATERNARY — RECENT

ALLUVIAL DEPOSITS IN RIVER BOTTOM LANDS
(THIN FLOOD-PLAIN DEPOSITS OF RIVER-LAID GRAVELS AND SILTS ON CUT SURFACES OF OUTWASH GRAVELS OF WISCONSIN STAGE. WATER SUPPLIES MEAGER IN THIS MATERIAL AND WELLS GENERALLY PENETRATE THROUGH TO THE UNDERLYING GLACIAL DEPOSITS.)

QUATERNARY — PLEISTOCENE (WISCONSIN STAGE)

VALLEY TRAIN
(OUTWASH DEPOSITS OF SAND AND GRAVEL LAID DOWN BY FLOODING MELT WATER FROM THE ICE. MOST LARGE WATER SUPPLIES OF COUNTY ARE DERIVED FROM THESE DEPOSITS. YIELDS AS MUCH AS 1,500 GPM TO WELLS RECEIVING INFILTRATION FROM STREAMS. WATER HARD AND HIGH IN IRON. WATER TABLE NEAR SURFACE.)

QUATERNARY — PLEISTOCENE (WISCONSIN STAGE)

KAMES AND KAME MORAINE
(SANDS AND GRAVELS OF VARIABLE COARSENESS AND THICKNESS DEPOSITED AT EDGE OF MELTING ICE SHEET, GENERALLY IN THE FORM OF HILLS THAT REST ON OTHER GLACIAL DEPOSITS OR ON BEDROCK. KAME MATERIALS ARE GENERALLY HIGHLY PERMEABLE BUT THE WATER TABLE IS IN MANY PLACES BELOW THE LEVEL OF THESE DEPOSITS AND WATER SUPPLIES ARE GENERALLY DERIVED FROM THE UNDERLYING MATERIALS.)

GROUND MORAINE – THIN PHASE
(TILL, COMMONLY CALLED "CLAY AND GRAVEL" OR "HARDPAN", DEPOSITED BY THE ICE. GENERALLY NOT OVER 20 FEET THICK. BEDROCK EXPOSED IN MANY PLACES. BROAD HILL SLOPES DOMINATE. WATER SUPPLIES MEAGER AND GENERALLY TAKEN FROM DUG WELLS. YIELDS ORDINARILY 2 TO 10 GPM. MANY SUPPLIES OBTAINED FROM UNDERLYING BEDROCK.)

GROUND MORAINE – THICK PHASE
(TILL MORE THAN 20 FEET THICK AND CONTAINING BURIED SAND OR GRAVEL BEDS IN SOME PLACES. CREEK VALLEYS OR TILL PLAINS DOMINATE. MEAGER WATER SUPPLIES IN THE TILL (SEE GROUND MORAINE – THIN PHASE) BUT GENERALLY GOOD SUPPLIES FOR FARM OR DOMESTIC REQUIREMENTS IN INTERBEDDED SAND OR GRAVEL LENSES.)

QUATERNARY

GROUND MORAINE OVERLYING SAND AND GRAVEL
(TILL 5 TO 70 FEET THICK RESTING ON THICK AND EXTENSIVE OUTWASH DEPOSITS. THIS SEQUENCE INDICATES A READVANCE OF THE ICE SHEET. ABUNDANT WATER SUPPLY IN UNDERLYING SANDS AND GRAVELS.)

END MORAINE – TILL PHASE
(THICK STONY OR SANDY TILL WITH NUMEROUS INTERBEDDED SAND OR GRAVEL LAYERS. DEPOSITED NEAR ICE EDGE. HUMMOCKY LAND SURFACE DOMINATES. WATER SUPPLIES IN INTERBEDDED SAND OR GRAVEL LAYERS IN SOME PLACES.)

END MORAINE – BOULDER-STREWN BELT
(ABUNDANT ERRATIC BOULDERS IN BELT MARKING FORMER ICE EDGE. FOUND IN AREAS OF BOTH THIN AND THICK GROUND MORAINE. BOULDERS NOT SIGNIFICANT IN REGARD TO WATER SUPPLY.)

509-43+
WELLS OF WHICH LOGS ARE AVAILABLE SHOWING THE MATERIALS PENETRATED. FIRST NUMBER SHOWN IS THE WELL-LOG NUMBER AND IDENTIFIES THE LOG IN APPENDIX OF REPORT. SECOND NUMBER SHOWS DEPTH OF UNCONSOLIDATED MATERIALS PENETRATED. DEPTHS NOT REACHING BEDROCK ARE SHOWN WITH A PLUS.

LOCATION WHERE MORE THAN ONE WELL LOG IS AVAILABLE.

WELLS OR EXPOSURES IN WHICH IT IS BELIEVED BURIED ILLINOIAN-STAGE GLACIAL TILL WAS ENCOUNTERED.

GLACIAL STRIAE GROOVES OR SCRATCHES ENGRAVED IN BEDROCK SHOWING THE DIRECTION OF ICE MOTION.

NOTE:
TOPOGRAPHY (PRINTED IN BROWN) FROM U.S. GEOLOGICAL SURVEY TOPOGRAPHIC MAPS OF THE BROOKVILLE, DAYTON, MIAMISBURG, AND WAYNESVILLE QUADRANGLES. CONTOUR INTERVAL 20 FEET.

SCALE IN MILES
1 ½ 0 1 2 3 4