Mean Annual Runoff in the Upper Ohio River Basin, 1941-70, and its Historical Variation

By ROBERT M. BEALL

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CONVERSION FACTORS AND SYMBOLS

Factors for converting English units to the International System of Units (SI) are given below to four significant figures. However, in the text the metric equivalents are shown only to the number of significant figures consistent with the values for the English units.

English	*Multiply by*	*Metric (SI)*
inches (in.)	25.40	millimeters (mm)
miles (mi)	1.609	kilometers (km)
square miles (mi^2)	2.590	square kilometers (km^2)
cubic feet per second (ft^3/s)	.02832	cubic meters per second (m^3/s)
cubic feet per second per square mile [$(ft^3/s)mi^2$]	.01093	cubic meters per second per square kilometer [$(m^3/s)/km^2$]

Q_A	Mean annual discharge, in ft^3/s.
$Q_A(30)$	Mean annual discharge, in ft^3/s, for the 30-year reference period 1941–70 (October 1940 through September 1970).
$Q_A(PR)$	Mean annual discharge, in ft^3/s, for the period of record.
$Q_{med}(30)$	Median annual discharge, in ft^3/s, for the 30-year reference period 1941–70.
$R_A(30)$	Mean annual runoff, in inches, for the 30-year reference period 1941–70.

MEAN ANNUAL RUNOFF IN THE UPPER OHIO RIVER BASIN, 1941–70, AND ITS HISTORICAL VARIATION

By Robert M. Beall

ABSTRACT

A map of the Ohio River basin above the Muskingum River shows patterns of mean annual runoff for the new climatologic and hydrologic reference period, 1941–70, and provides an up-to-date, consistent basis for consideration of this streamflow characteristic. The primary data base consisted of 98 long-term gaging-station records collected within this 27,300-square-mile (70,700-square-kilometer) headwater area of the Ohio River basin. Supplemental information was derived from 83 short-term records.

Mean annual runoff is at a regional minimum of less than 12 inches (300 millimeters) in an area extending from the northern West Virginia panhandle to the headwaters of the Mahoning River in Ohio. Mean annual runoff of more than 32 inches (810 millimeters) occurs in parts of the upper Cheat River basin in West Virginia. The zone of high runoff trends northeastward along the western slopes of the Allegheny Mountains; magnitudes diminish to about 25 inches (630 millimeters) at the eastern basin boundary near Ebensburg, Pa. Runoff of this magnitude occurs also in a band across the upper Allegheny River basin in Pennsylvania.

Ratios of mean annual discharge to the 30-year reference-period average were computed for each year of record for all long-term gaging stations. Annual discharges have ranged from about 30 percent to 200 percent of the 30-year mean. Graphed summaries of the annual ratios document the relative duration and magnitude of wet and dry periods during the past 65 years in the upper Ohio River basin.

INTRODUCTION

Mean annual runoff is the average flow of a stream during a par-

Note.—Throughout this report, years should be understood to mean water years (October 1 through September 30), the annual period for which gaging-station records are customarily published.

ticular period of years; its long-term value closely approximates the amount of streamflow potentially available for development. As such, it is a useful quantitative measure of an indispensable, renewable resource. Unlike a static mineral resource, runoff is always in a state of flux, varying principally in response to temporal and areal changes in precipitation and temperature. Climatically induced variations are influenced by the effects of topography, geology, vegetation, and, to a lesser degree, man's modification of the land.

The mean annual runoff of an area is a common and fundamental numeric, descriptive element. Needed values are generally extrapolated from or referenced to published data for the period of record at some conveniently located gaging station; they may or may not include a specification of the period and the area of representation.

THE PROBLEM

Many streamflow records are available for the upper Ohio River basin, but their periods of record are largely noncoincident; furthermore, available information cannot always be applied readily to a particular site or area of interest. Existing maps showing patterns of runoff are too small in size and too large in runoff-value intervals to be of use except for determining gross estimates for large basins or areas.

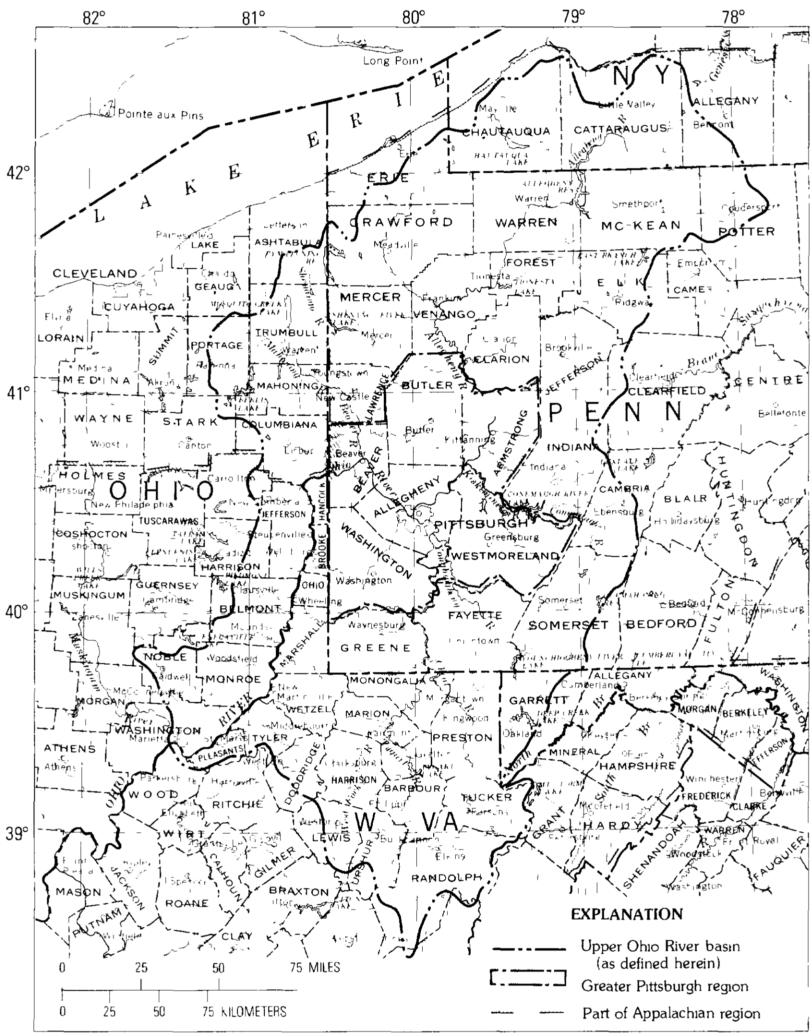
The credibility of the quantification in all resource appraisals increases with the number of data values used in the assessment, until some point of diminishing return is reached in terms of the value of or necessity for the improved information. The irregular, cyclic occurrence of wet and dry years is such that a specific time frame is desirable when considering this dynamic resource.

A PRELIMINARY SOLUTION

The principal purpose of this study is to produce a reasonably detailed but preliminary map of mean annual runoff for the upper Ohio River basin, representing conditions during an appropriate reference period—1941–70. This is the reference period presently used by the Environmental Data Service and National Weather Service, National Oceanic and Atmospheric Administration, for reporting of climatological-standard-normal temperature and precipitation data, and by the U.S. Geological Survey in its monthly analyses of nationwide streamflow and ground-water conditions. The 30-year reference period is a useful standard but has no particular hydrologic significance, as it is representative of recent experience but does not necessarily occupy a significant position in some climatic cycle.

AREA OF INTEREST AND LIMITS OF DEFINITION

The initial area of interest for definition of mean-runoff character-



Base from U S Geological Survey Appalachian Region 1967

FIGURE 1.—The upper Ohio River basin study area and the Greater Pittsburgh region within it.

istics was the Greater Pittsburgh region—for present purposes defined as including the six southwestern Pennsylvania counties of Allegheny, Armstrong, Beaver, Butler, Washington, and Westmoreland—an area of about 4,500 mi^2 (11,650 km^2). See figure 1.

The principal rivers of this region are Allegheny, Kiskiminetas, Monongahela, Youghiogheny, Beaver, and Ohio. All of these rivers have been gaged at sites within the region for many years, and documentation of the varying quantity of water available in these major arteries has been beneficial in innumerable ways. However, these large rivers are extraregional in origin, and their records do not define the pattern of runoff originating within the Greater Pittsburgh region. Continuous daily discharge records of streams whose drainage are wholly within the region have been collected at 14 gage sites, half of which are no longer in operation or which have been established in recent years.

Improved definition of runoff in the Greater Pittsburgh region can be achieved by using streamflow records for contiguous areas in the data analysis. To this end, the upper Ohio River basin was adopted as the study area. The upper Ohio River basin referred to here includes all of the basin area upstream from the Muskingum River basin in Ohio and the Little Kanawha River basin in West Virginia. This area is shown also in figure 1. This part of the Ohio River system comprises an area of about 27,300 mi^2 (70,700 km^2) in parts of Maryland, New York, Ohio, Pennsylvania, and West Virginia.

The extension of the study area was considerably greater than that required for examination of the six-county region. However, the map and data are expected to be useful for other studies. The extended study area approximates the area of responsibility of the Pittsburgh District, U.S. Army Corps of Engineers; and the Pittsburgh River Forecast Center, National Weather Service. The distribution of drainage areas among the several states and principal subbasins is as follows:

Drainage-area subdivision, in square miles

	Subbasin			Upper Ohio River basin [1]
	Allegheny	Monongahela	Ohio	
Pennsylvania	9,765	2,654	3,023	15,442
West Virginia	-----	[2] 4,305	[2] 1,620	[2] 5,925
Ohio	-----	-----	[2] 3,525	[2] 3,525
Maryland	-----	[2] 425	-----	[2] 425
New York	1,983	-----	-----	1,983
Total	11,748	7,384	[2] 8,168	[2] 27,300

[1] As defined in text above.
[2] Approximate.

The Ohio subbasin, as used herein, consists of all of the area tributary to the Ohio River from Pittsburgh, Pa., to Marietta, Ohio. The principal tributary within the subbasin is Beaver River.

SOURCES OF DATA

Annual discharge records were obtained from the following reports:

U.S. Geological Survey, 1957, Compilation of records of surface waters of the United States through September 1950: part 3–A, Ohio River basin except Cumberland and Tennessee River basins: U.S. Geol. Survey Water-Supply Paper 1305, 652 p.

———, 1964, Compilation of records of surface waters of the United States, October 1950 to September 1960: part 3–A, Ohio River basin except Cumberland and Tennessee River basins: U.S. Geol. Survey Water-Supply Paper 1725, 560 p.

———, 1971, Surface water supply of the United States 1961–65: part 3, volume 1, Ohio River basin above Kanawha River: U.S. Geol. Survey Water-Supply Paper 1907, 621 p.

———, 1966–74, Water resources data for (state), part 1, Surface water records: annual reports published for year indicated by district offices of the Water Resources Division in Maryland, New York, Ohio, Pennsylvania, and West Virginia.

These reports should be consulted to obtain detailed information about the gaging stations for which data have been used in this study. Such information includes location, drainage area, period of record, type and history of gages, extremes of discharge, general remarks, and notations of revisions of previously published records.

Additional records of stage and(or) discharge are collected by the U.S. Army Corps of Engineers and by the National Weather Service at a few sites in the region. These unpublished records were not obtained for the study, because most document the discharge of principal streams at points intermediate to those published in the reports noted above. Most of these record sites have been catalogued by the U.S. Geological Survey, Office of Water Data Coordination (1973).

ACKNOWLEDGMENTS

A study such as this is founded on the efforts of generations of hydrographers and hydraulic engineers who measured the streams, maintained the gaging stations, and prepared the data for publication. Many records were collected before 1932 by the (then) Pennsylvania Department of Forests and Waters. Similarly, a number of records were obtained between 1921 and 1942 by the West Virginia

Power and Transmission Company. Most data-collection activity by the Geological Survey has been accomplished through financial cooperation with state and local agencies and in collaboration with the U.S. Army Corps of Engineers.

Reservoir records used to adjust annual-runoff data were provided by the Corps of Engineers, private companies, and public agencies that operate storage facilities.

The present study effort was made possible by the valued assistance of Pauline F. Silsley, U.S. Geological Survey, who performed or checked many of the data compilations and computations.

COMPUTATIONS AND ANALYSIS

LONG-TERM STATIONS

A few gaging stations in the upper Ohio region have been maintained continuously since the early 1900's. However, the 1930's and 1940's were periods of considerable expansion in the stream-gaging program here, as well as nationwide. Many of the stations established during that time are still in operation, because of the varied and continued use of the data. The resultant data accumulations are the primary source of information for preparation of the map of mean annual runoff for the 1941–70 reference period.

A sample compilation of annual discharge data for one station, taken from the reports previously listed, is shown in figure 2. Mean and median annual discharges for the 30-year reference period were computed from these data. The results of similar computations for 98 long-term stations are listed in table 1. To complete computations for the reference period, the mean annual discharge was divided by the drainage area above the gaging station (column headed $Q_A(30)$ $(ft^3/s)/mi^2$), and that unit discharge was multiplied by the factor 13.583 [1] to obtain the equivalent runoff (R_A30) in inches. The summary of station information in table 1 includes drainage area, period of record, and mean annual discharge for that period.

The natural flow regimen of many streams has been altered by construction and operation of storage reservoirs and by diversion of water for various purposes. The six principal rivers in the Greater Pittsburgh region, as well as many tributaries throughout the upper Ohio River basin, are so altered. Reservoir operations usually follow an annual cycle such that year-to-year difference in year-end storages

[1] Derivation of this factor is shown on the explanation for table 2.

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Mean annual discharges for period of record and annual ratios to the average for the 30-year reference period 1941-70: 03010500 Allegheny River at Eldred, Pa.+

Water Year	Q_A (ft^3/s) Obs.	Adj. for d.a.	Ratio to 1941-70 average	Water Year	Q_A (ft^3/s)	Ratio to 1941-70 average		Water Year	Q_A (ft^3/s)	Ratio to 1941-70 average		
				1941	634	0.70		1971	971	1.07		
					1159	1.28			1475	1.63		
					1361	1.50			1048	1.16		
					713	.79			1150	1.27		
				1945	1278	1.41		1975				
					1101	1.21						
					1089	1.20						
					957	1.06						
					703	.78						
				1950	905	1.00						
1921	678	705	0.78		1298	1.43						
	----	----	----		1104	1.22						
	----	----	----		878	.97						
	----	----	----		730	.80						
1925	----	----	----	1955	677	.75						
	732	761	.84		1284	1.42						
	1010	1050	1.16		822	.91						
	1100	1144	1.26		812	.90						
	918	955	1.05		906	1.00						
1930	894	930	1.03	1960	978	1.08						
	582	605	.67		789	.87						
	768	799	.88		631	.70						
	767	798	.88		683	.75						
	530	551	.61		852	.94						
1935	710	738	.81	1965	669	.74						
	806	838	.92		768	.85						
	1031	1072	1.18		851	.94						
	894	930	1.03		959	1.06						
	668	695	.77		704	.78						
1940	913		1.01	1970	916	1.01						
				ΣQ_A 41-70	27,211							
				$\bar{Q}_A$(30)	907							
				$Q_A$med(30)	865							

+ Combined with "at Larabee" (03010000) prior to 1940; Q_A adjusted by drainage area ratio of 1.04 (550/530).

FIGURE 2.—Sample station compilation of mean annual discharges and annual ratios.

TABLE 1.—*Summary of annual stream discharge and runoff data for the period of record and for the 30-year reference period, 1941–70, for long-term gaging stations in the upper Ohio River basin (Pennsylvania, New York, Maryland, northern West Virginia, and eastern Ohio)*

USGS station No. 03–	Gaging station name	Drainage area (mi²)	Period of record through 1973		Q_A(PR) (ft³/s)	Reference period 1941–70				Remarks
			From	Years		Q_{med}(30) (ft³/s)	Q_A(30) (ft³/s)	Q_A(30) ((ft³/s)/mi²)	R_A(30) (inches)	
010500	Allegheny River at Eldred, Pa.	550	July 1939	34	930	865	907	1.649	22.40	Combined[1] with "at Larabee" (03010000) prior to 1940; area, 530 mi². Q_A adjusted by 1.04 for annual ratios prior to 1940.
011020	Allegheny River at Salamanca, N.Y.	1,608	Sept. 1903	70	2,760	2,592	2,617	1.627	22.10	"At Red House" (03011500) prior to 1965; area, 1,690 mi². Q_A adjusted by 0.95 for annual ratios prior to 1965 and for Q_A(30). Q_A(PR) unadjusted.
012550	Allegheny River at Kinzua Dam, Pa.	2,180	Oct. 1935	38	3,758	3,545	3,687	1.691	22.97	"Near Kinzua" (03012500) prior to 1969 and "at Warren" 1969–72. Area, 2,179 mi² prior to 1965, 2,223 mi², 1965–72. Q_A adjusted by 0.98 for annual ratios 1965–72 and for Q_A(30). Q_A(PR) unadjusted for area but adjusted for storage since October 1965.
013000	Conewango Creek at Waterboro, N.Y.	290	Sept. 1938	35	510	491	503	1.734	23.55	None.
014500	Chadakoin River at Falconer, N.Y.	194	Nov. 1934	38	388	325	332	1.711	23.24	Q_A adjusted for storage 1951–66. Adjusted Q_A(30) = Unadjusted Q_A(30)
015000	Conewango Creek at Russell, Pa.	816	Oct. 1939	34	1,458	1,394	1,431	1.754	23.82	Q_A adjusted for storage
015500	Brokenstraw Creek at Youngsville, Pa.	321	Oct. 1909	64	575	556	584	1.819	24.71	None.

016000	Allegheny River at West Hickory, Pa.	3,660	Oct. 1941	32	6,429	6,118	6,270	1.713	23.27	Q_A adjusted for storage since 1941 est. for Q_A(30) from (03012550) + 03015000) and (03025500) — (03024000).
017500	Tionesta Creek at Lynch, Pa.	233	Oct. 1937	36	425	396	419	1.798	24.42	None.
020000	Tionesta Creek at Tionesta Dam, Pa.	479	June 1940	33	861	814	844	1.762	23.93	Q_A adjusted for storage since January 1941. Combined with "at Nebraska" (03019000) prior to 1941; area 469 mi². Q_A adjusted by 1.02 for annual ratios prior to 1941.
020500	Oil Creek at Rouseville, Pa.	300	June 1932	41	518	503	521	1.737	23.59	Combined with "near Rouseville" (03021000) prior to 1933: area, 315 mi² Q_A adjusted by 0.95 for annual ratios prior to 1933.
021520	French Creek near Union City, Pa.	221	Oct. 1909	64	418	428	428	1.937	26.31	"At Kimmeytown" prior to 1932," at Carters Corners" (03021500) 1933–71; area 208 mi². Q_A adjusted for storage and by 0.94 for area after 1971 for annual ratios. Q_A(PR) unadjusted for area.
024000	French Creek at Utica, Pa.	1,028	Aug. 1932	41	1,751	1,726	1,785	1.736	23.58	Combined with "at Carlton" (03023500) prior to 1933; area 998 mi². Q_A adjusted by 1.03 for annual ratios prior to 1933 and for storage after 1971.

See footnotes at end of table.

TABLE 1.—*Summary of annual stream discharge and runoff data for the period of record and for the 30-year reference period, 1941–70, for long-term gaging stations in the upper Ohio River basin (Pennsylvania, New York, Maryland, northern West Virginia, and eastern Ohio)*—Continued

USGS station No. 03–	Gaging station name	Drainage area (mi²)	Period of record through 1973: From	Period of record through 1973: Years	Q_A (PR) (ft³/s)	Reference period 1941–70: Q_{med}(30) (ft³/s)	Q_A(30) (ft³/s)	Q_A(30) ((ft³/s)/mi²)	R_A(30) (inches)	Remarks
025000	Sugar Creek at Sugarcreek, Pa.	166	Aug. 1932	41	266	252	267	1.608	21.84	None.
025500	Allegheny River at Franklin, Pa.	5,982	Oct. 1914	59	10,280	9,970	10,390	1.737	23.59	Q_A adjusted for storage after 1940.
028500	Clarion River at Johnsonburg, Pa.	204	Oct. 1945	28	371	351	364	1.784	24.23	Q_A adjusted for storage since 1952. 1941–45 est. for Q_A(30) from (03017500) and (03029000).
029500	Clarion River at Cooksburg, Pa.	807	Oct. 1938	35	1,414	1,362	1,397	1.731	23.51	Q_A adjusted for storage since 1952.
030500	Clarion River near Piney, Pa.	951	Oct. 1944	29	1,709	1,607	1,657	1.742	23.66	Q_A adjusted for storage. 1941–45 est. for Q_A(30) from (03029500) and (03031000).
031500	Allegheny River at Parker, Pa.	7,671	Oct. 1932	41	13,050	12,680	13,110	1.709	23.21	Q_A adjusted for storage since 1941.
032500	Redbank Creek at St. Charles, Pa.	528	Oct. 1918	55	847	798	833	1.578	21.43	None.
034000	Mahoning Creek at Punxsutawney, Pa.	158	Oct. 1938	35	265	254	261	1.652	22.44	None.
034500	Little Mahoning Creek at McCormick, Pa.	87.4	Oct. 1939	34	148	132	145	1.659	22.53	None.
036000	Mahoning Creek at Mahoning Creek Dam, Pa.	344	Aug. 1938	35	577	541	569	1.654	22.47	Q_A adjusted for storage since 1941.

036500	Allegheny River at Kittanning, Pa.	8,973	1904–28. Oct. 1934	63	15,460	14,650	14,970	1.668	22.66	Q_A adjusted for storage since 1941.
038000	Crooked Creek at Idaho, Pa.	191	Oct. 1937	36	282	244	275	1.440	19.56	Q_A adjusted for storage since 1968 but not for cooling-tower losses since 1967.
039000	Crooked Creek at Crooked Creek Dam, Pa.	278	Oct. 1909	64	418	360	404	1.453	19.74	Q_A (PR) adjusted for storage 1940–68. Q_A (med), Q_A (30) adjusted for storage since 1940 but not for cooling-tower losses since 1967.
040000	Stony Creek at Ferndale, Pa.	451	[a]1919–36. Oct. 1938	35	756	728	735	1.630	22.14	Q_A adjusted for storage and diversion since 1939. Q_A (PR) = 1938–73.
041000	Little Conemaugh River at East Conemaugh, Pa.	183	Apr. 1939	34	318	300	307	1.678	22.79	Q_A adjusted for storage and diversion.
041500	Conemaugh River at Seward, Pa.	715	May 1938	35	1,253	1,198	1,222	1.709	23.21	Q_A adjusted for storage.
043000	Blacklick Creek at Blacklick, Pa.	390	1905, 1908–51	45	671	----	642	1.646	22.36	1952–70 est. for Q_A (30) (03039000)
044000	Conemaugh River at Tunnelton, Pa.	1,358	Oct. 1939	34	2,320	2,200	2,263	1.666	22.63	Q_A adjusted for storage.
045000	Loyalhanna Creek at Kingston, Pa.	172	Oct. 1939	34	298	274	289	1.680	22.82	Q_A adjusted for storage and diversion.
047000	Loyalhanna Creek at Loyalhanna Dam, Pa.	292	Oct. 1939	34	474	432	456	1.562	21.22	Q_A adjusted for storage since 1942.

See footnotes at end of table.

TABLE 1.—*Summary of annual stream discharge and runoff data for the period of record and for the 30-year reference period, 1941–70, for long-term gaging stations in the upper Ohio River basin (Pennsylvania, New York, Maryland, northern West Virginia, and eastern Ohio)*—Continued

USGS station No. 03–	Gaging station name	Drainage area (mi^2)	Period of record through 1973		Q_A(PR) (ft^3/s)	Reference period 1941–70				Remarks
			From	Years		Q_{med}(30) (ft^3/s)	Q_A(30) (ft^3/s)	Q_A(30) ((ft^3/s)/mi^2)	R_A(30) (inches)	
048500	Kiskiminetas River at Vandergrift, Pa.	1,825	Aug. 1937	36	3,014	2,840	2,949	1.616	21.95	Q_A adjusted for storage and diversion but not for cooling-tower losses since 1969. Combined with "at Avonmore" (03047500) prior to 1938, area, 1,723 mi^2. Q_A adjusted by 1.05 for annual ratios 1908–37.
049000	Buffalo Creek near Freeport, Pa.	137	Oct. 1940	33	187	167	183	1.336	18.15	None.
049500	Allegheny River at Natrona, Pa.	11,410	Oct. 1938	35	19,030	18,120	18,820	1.649	22.40	Q_A adjusted for storage since 1940.
050000	Tygart River near Dailey, W. Va.	187	Apr. 1915	58	347	321	324	1.733	23.53	None.
050500	Tygart River near Elkins, W. Va.	272	Oct. 1944	29	536	480	476	1.750	23.77	1941–44 est. for Q_A(30) from (03051000).
051000	Tygart River at Belington, W. Va.	408	June 1907	66	800	749	756	1.853	25.17	None.
052000	Middle Fork at Audra, W. Va.	149	Feb. 1942	31	342	323	325	2.181	29.63	1941, 1942 est. for Q_A(30) from (03051500).
053500	Buckhannon River at Hall, W. Va.	277	Apr. 1915	58	591	546	569	2.054	27.90	None.
054500	Tygart River at Philippi, W. Va.	916	Apr. 1940	33	1,827	1,734	1,778	1.941	26.37	None.
056000	Tygart River at Tygart Dam near Grafton, W. Va.	1,184	June 1938	35	2,305	2,162	2,260	1.909	25.93	Q_A adjusted for storage.

057000	Tygart River at Colfax, W. Va.	1,366	May 1939	34	2,601	2,514	2,550	1.867	25.36	Q_A adjusted for storage.
058500	West Fork River at Butcherville, W. Va.	181	Apr. 1915	58	299	272	286	1.580	21.46	None.
059000	West Fork River at Clarksburg, W. Va.	384	Mar. 1923	50	585	564	569	1.482	20.13	Q_A adjusted for diversion.
061000	West Fork River at Enterprise, W. Va.	759	1907–16. Oct. 1932	49	1,139	1,104	1,117	1.472	19.99	None.
061500	Buffalo Creek at Barrackville, W. Va.	115	1908. 1916–23. Aug. 1932	50	163	152	158	1.374	18.66	None.
062000	Monongahela River at Lock 15, Hoult, W. Va.	2,388	1915–26. 1938–67	40	4,074	3,924	3,986	1.669	22.67	Q_A adjusted for storage from 1938. 1968–70 est. for $Q_A(30)$ from (03072500)–(0307000).
065000	Dry Fork at Hendricks, W. Va.	345	Oct. 1940	33	746	710	726	2.104	28.58	None.
066000	Blackwater River at Davis, W. Va.	86.2	Apr. 1921	52	195	194	191	2.216	30.10	None.
069000	Shavers Fork at Parsons, W. Va.	214	1910–26. Oct. 1940	49	550	506	517	2.416	32.82	None.
069500	Cheat River near Parsons, W. Va.	718	Jan. 1913	60	1,672	1,572	1,617	2.252	30.59	None.
070000	Cheat River at Rowlesburg, W. Va.	972	Oct. 1923	50	2,239	2,109	2,185	2.248	30.53	None.
070500	Big Sandy Creek at Rockville, W. Va.	200	1910–17. Apr. 1922	60	418	365	388	1.940	26.35	None.
072000	Dunkard Creek at Shannopin (Bobtown), Pa.	229	Oct. 1940	33	265	256	260	1.135	15.42	None.
072500	Monongahela River at Greensboro, Pa.	4,407	Oct. 1938	35	8,036	7,764	7,878	1.788	24.29	Q_A adjusted for storage.

See footnotes at end of table.

TABLE 1.—*Summary of annual stream discharge and runoff data for the period of record and for the 30-year reference period, 1941–70, for long-term gaging stations in the upper Ohio River basin (Pennsylvania, New York, Maryland, northern West Virginia, and eastern Ohio)*—Continued

USGS station No. 03–	Gaging station name	Drainage area (mi^2)	Period of record through 1973: From	Period of record through 1973: Years	Q_A(PR) (ft^3/s)	Reference period 1941–70: $Q_{med}(30)$ (ft^3/s)	Reference period 1941–70: $Q_A(30)$ (ft^3/s)	Reference period 1941–70: $Q_A(30)$ ((ft^3/s)/mi^2)	Reference period 1941–70: $R_A(30)$ (inches)	Remarks
073000	South Fork Tenmile Creek Jefferson, Pa.	180	Oct. 1931	42	196	174	190	1.056	14.34	None.
074500	Redstone Creek at Waltersburg, Pa.	73.7	Oct. 1942	31	97.2	88.2	94.3	1.280	17.39	1941, 1942 est. for $Q_A(30)$ from (03070500) and (03072000).
075000	Monongahela River at Charleroi, Pa.	5,213	Oct. 1933	40	8,914	8,484	8,722	1.673	22.72	Q_A adjusted for storage.
075500	Youghiogheny River near Oakland, Md.	134	Aug. 1941	32	289	282	281	2.097	28.48	1941 est. for $Q_A(30)$ from (03076500).
076500	Youghiogheny River at Friendsville, Md.	295	1898–1904. Oct. 1940	39	636	594	592	2.007	27.26	Q_A adjusted for storage since 1940.
077500	Youghiogheny River at Youghiogheny River Dam, Pa.	436	Oct. 1939	34	852	811	829	1.901	25.82	Q_A adjusted for storage.
078500	Big Piney Run near Salisbury, Pa.	24.5	June 1932–Sept. 1970	38	37.1	35.3	36.7	1.498	20.35	None.
079000	Casselman River at Markleton, Pa.	382	Oct. 1920	53	649	648	635	1.662	22.57	None.
080000	Laurel Hill Creek at Ursina, Pa.	121	Oct. 1918	55	264	260	259	2.140	29.07	None.
081000	Youghiogheny River below Confluence, Pa.	1,029	June 1940	33	1,949	1,807	1,892	1.839	24.98	Q_A adjusted for storage.
082500	Youghiogheny River at Connellsville, Pa.	1,326	July 1908	65	2,533	2,476	2,493	1.880	25.54	Q_A adjusted for storage since 1925.

083000	Greenlick Run at Greenlick Reservoir, Pa.	3.07	Aug. 1941	32	5.52	5.02	5.31	1.730	23.50	1941 est. for $Q_A(30)$ from (03045000) and (03078500).
083500	Youghiogheny River at Sutersville, Pa.	1,715	Oct. 1920	53	2,969	2,892	2,947	1.718	23.34	Q_A adjusted for storage since 1925.
084000	Abers Creek near Murrysville, Pa.	4.39	Oct. 1948	25	5.14	5.00	5.26	1.198	16.27	1941–48 est. for $Q_A(30)$ from (03045000) and (03049000).
085000	Monongahela River at Braddock, Pa.	7,337	Oct. 1938	35	12,200	11,720	11,950	1.629	22.12	Q_A adjusted for storage and diversion.
085500	Chartiers Creek at Carnegie, Pa.	257	1919–33. 1940–71	45	281	244	264	1.027	13.95	None.
086000	Ohio River at Sewickley, Pa.	19,500	Oct. 1933	40	32,090	30,760	31,800	1.631	22.15	Q_A adjusted for storage since 1938.
086500	Mahoning River Alliance, Ohio	89.2	Aug. 1941	32	80 .9	78.1	81.8	0.917	12.46	$Q_{med}(30)$ and $Q_A(30)$ adjusted for diversion prior to Dec. 1954; $Q_A(PR)$ unadjusted. 1941 est. for $Q_A(30)$ from (03117500).
089500	Mill Creek near Berlin Center, Ohio.	19.1	Sept. 1941–Sept. 1971	30	17.2	14.8	16.4	.832	11.31	1941 est. for $Q_A(30)$ from (03117500).
090500	Mahoning River below Berlin Dam, near Berlin Ctr., Ohio.	248	Oct. 1930	43	221	202	220	.887	12.05	Flow regulated and diverted; $Q_A(30)$ provisionally adjusted.[2] $Q_A(PR)$ unadjusted.
091500	Mahoning River at Pricetown, Ohio.	273	July 1929	44	243	211	237	.868	11.79	Flow regulated and diverted but Q_A not adjusted.
092000	Kale Creek near Pricetown, Ohio	21.9	Oct. 1940	33	21.1	19.0	20.5	.936	12.71	None.

See footnotes at end of table.

TABLE 1.—*Summary of annual stream discharge and runoff data for the period of record and for the 30-year reference period, 1941–70, for long-term gaging stations in the upper Ohio River basin (Pennsylvania, New York, Maryland, northern West Virginia, and eastern Ohio)*—Continued

USGS station No. 03–	Gaging station name	Drainage area (mi^2)	Period of record through 1973: From	Period of record through 1973: Years	Q_A(PR) (ft^3/s)	Reference period 1941–70: Q_{med}(30) (ft^3/s)	Reference period 1941–70: Q_A(30) (ft^3/s)	Reference period 1941–70: Q_A(30) ((ft^3/s)/mi^2)	Reference period 1941–70: R_A(30) (inches)	Remarks
092500	West Branch Mahoning River near Newton Falls, Ohio.	96.3	June 1926	47	95.2	88.8	96.8	1.005	13.65	Flow regulated since Dec. 1966; Q_A(PR) not adjusted Q_A(30) provisionally adjusted.[2]
093000	Eagle Creek at Phalanx Station, Ohio.	97.6	1926–34. Oct. 1937	44	104	97.1	104	1.066	14.47	None.
094000	Mahoning River at Leavittsburg, Ohio.	575	Oct. 1940	33	538	485	527	.916	12.45	Flow regulated and diverted but Q_A not adjusted.
095500	Mosquito Creek below Mosquito Creek Dam near Cortland, Ohio.	97.5	1926–29. May 1943	33	86.2	83.2	94.9	.973	13.22	1941–43 est. for Q_A(30) from (03103000). Flow regulated and diverted; Q_A(30) provisionally adjusted.[2]
098000	Mahoning River at Youngstown, Ohio.	898	Oct. 1921	52	829	746	814	.906	12.31	Flow regulated and diverted but Q_A not adjusted.
099500	Mahoning River at Lowellville, Ohio.	1,073	Oct. 1942	31	1,026	883	994	.926	12.58	Flow regulated; Q_A not adjusted. 1941–1942 est for Q_A(30) from (03098000)
101500	Shenango River at Pymatuming Dam, Pa.	167	June 1934	39	197	184	199	1.192	16.19	Q_A adjusted for storage.
102500	Little Shenango River at Greenville, Pa.	104	Oct. 1913	60	139	134	140	1.346	18.28	None.
103000	Pymatuming Creek at Orangeville, Pa.	169	1913–63	50	203	185	197	1.166	15.84	1964–70 est. for Q_A(30) from (03101500) and (03102500).

103500	Shenango River at Sharpsville, Pa.	584	Mar. 1938	35	713	661	710	1.216	16.52	Q_A adjusted for storage.
105500	Beaver River at Wampum, Pa.	2,235	1914–18 Aug. 1932	45	2,335	2,184	2,374	1.062	14.43	Q_A adjusted for storage since 1932.
106000	Connoquenessing Creek near Zelienople, Pa.	356	Oct. 1919	54	463	406	442	1.242	16.87	None.
106500	Slippery Rock Creek at Wurtemburg, Pa.	398	Oct. 1911	62	559	502	538	1.352	18.36	Q_A adjusted for storage since 1969.
108000	Raccoon Creek at Moffatts Mill, Pa.	178	Sept. 1941	32	185	171	181	1.017	13.81	1941 est. for $Q_A(30)$ from (03085500). Q_A not adjusted for regulation and diversion.
109500	Little Beaver Creek at East Liverpool, Ohio.	496	Mar. 1915	58	506	433	484	.976	13.26	None.
110000	Yellow Creek near Hammondsville, Ohio.	147	Oct. 1940	33	154	144	152	1.034	14.04	None.
111500	Short Creek near Dillonvale, Ohio.	123	Oct. 1941	32	120	110	117	.951	12.92	1941 est. for $Q_A(30)$ from (03110000).
112000	Wheeling Creek at Elm Grove, W. Va.	282	Oct. 1940	33	319	290	310	1.099	14.93	None.
114500	Middle Island Creek at Little, W. Va.	458	1915–16. Oct. 1928	46	617	586	606	1.323	17.97	None.

[1] Records combined only for computation of annual ratios shown in table 3. Prior periods of record are evident from that tabulation.
[2] Adjusted discharge not published; computed only for this report.

are small in comparison with total annual flows. Monthly and annual streamflow-data summaries for most stations significantly affected by storage or diversion are adjusted for those effects. Adjusted rather than observed annual data were used where available and have been noted under Remarks in table 1. No adjustments were made for evaporation from reservoirs or other losses.

Reference-period data were complete for 80 of the 98 listed stations. The remainder had records beginning in the 1940's or were discontinued prior to 1970 after a long period of operation. Annual discharges for the missing years were estimated from logarithmic regressions with concurrent annual data from nearby stations. The estimated periods, most of which were less than 5 years, are noted in station remarks.

The long-term stations are identified on plate 1. Detailed location descriptions are in the reports previously listed in the section on "Sources of Data." For illustrative convenience and for conformation with a subbasion designation system adopted by the Commonwealth of Pennsylvania, subdivisions of the Allegheny River basin are shown on plate 1 and limits of the Pennsylvania subbasins are noted.

Parts of plate 1 of Water-Supply Paper 1907 were used, after some modification, as the base for location of gaging stations. A few erroneously drawn stream segments and mislocated station symbols were corrected, and some station symbols were added. The map scale of 1:1,000,000 appears to be appropriate in relation to the density of data available for analysis.

Many of the larger streams of the area are gaged at two or more sites. The primary data selected for map preparation were the runoff values calculated for the gaged sites farthest upstream. A total of 53 of the 98 long-term records met this requirement. Because the basins represented occupy 40 percent of the study area, this data base was considered more than adequate for defining lines of equal annual runoff.

Data summaries for the remaining 45 long-term stations provided a secondary data base. After subtracting the flow at one or more upstream stations from that at a downstream station, runoff for intervening areas was computed. These data are subject to considerable error because they commonly represent a difference between comparatively large quantities that inherently are subject to some errors of measurement; consequently, they were not included in this report. However, the information was useful in developing or confirming the runoff patterns in ungaged tributary areas, particularly in the mainstream valleys.

SHORT-TERM STATIONS

Streamflow records have been collected at many sites for relatively short periods where stations are no longer operated. Many other stations have been established relatively recently. Records for a total of 83 such stations were used in this study. They are identified on plate 1 and are considered to be a tertiary data source. Because many of these records are for gages on small drainages, they are useful in defining the areal variation in runoff within the long-term-station basins, most of which are of comparatively large areas. A few records of significant length, not coincident with the present reference period, were analysed in the same manner as short-term stations.

Runoff values for the period of record at the short-term stations were adjusted to represent the 1941–70 reference period by means of a factor expressing the ratio of reference-period discharge to short-term-period discharge at a nearby long-term station. The computation procedure is detailed at the head of table 2, which shows the summary results of calculations for the 83 short-term stations. This adjustment to the 30-year reference period should not be confused with the adjustment for storage or diversion described earlier.

A few intervening-area runoff computations were made from the adjusted short-term-station data or from a combination of long- and short-term data. Including those mentioned previously, a total of 48 such computations were made, providing supplemental information for a total area of about 11,700 mi² (30,300 km²), or 43 percent of the upper Ohio River basin.

DATA DISTRIBUTION

A summary of the numbers of available records by drainage-area category and by major subbasins of the study area is given in the following table:

Distribution of records

	Subbasin			Upper Ohio River basin
	Allegheny	Monongahela	Ohio	
Long term > 1000 mi² (2590 km²)	10	9	3	22
Long term 500–1000 mi²	6	4	3	13
Long term < 500 mi² (1295 km²)	20	23	20	63
Total long term	36	36	26	98
Short term > 1000 mi²	2	1	0	3
Short term 500–1000 mi²	1	0	1	2
Short term < 500 mi²	28	29	21	78
Total short term	31	30	22	83
Total records	67	66	48	181

Considering only those records for stations having drainage areas of less than 500 mi^2, the overall data density is 1 record per 194 mi^2 (502 km^2).

PREPARATION OF THE MAP

Plate 1 shows the mean annual runoff for the upper Ohio River basin for the 30-year reference period, 1941–70.

The base for plate 1 is a part of the station-location map base used in U.S. Geological Survey Water-Supply Paper 1907.

Three overlays to this base map were prepared showing areas of:
1. Drainage basins above long-term, upstream gaged sites.
2. Intervening drainage between gaged sites.
3. Drainage basins above short-term gaged sites.

Values of average runoff for the reference period were entered near the centroid of the described basins. Three overlays were used so that different weights could be given, subjectively, to the three data sources while drawing the lines of equal runoff. The objective was to draw the lines so that the average runoff in each basin or inter-

TABLE 2.—*Summary of runoff estimates for the 30-year reference period, 1941–70, for short-term gaging stations in the upper Ohio River basin*

	Explanation of computation procedure
STS	Short-term station.
LTS	Long-term station used in ratio computation.
N	Number of water years of short-term record used in computation
$Q_A(N)$S or $Q_A(N)$L	Mean annual discharge in cubic feet per second, for indicated period of N concurrent years at the STS or the LTS.
$Q_A(30)$L	Mean annual discharge, in cubic feet per second, for the period 1941–70 at the LTS.
$Q_A(30)$S	Computed mean annual discharge, in cubic feet per second, for the period 1941–70 at the STS; averaged if two or more computations made; an estimate.
cfsm(30)S	Computed mean annual discharge, in cubic feet per second per square mile, for the period 1941–70 at the STS; an estimate.
$R_A(30)$S	Computed mean annual runoff, in inches, for the period 1941–70 at the STS; an estimate.
$Q_A(30)$S	$Q_A(N)\text{S} \times \frac{Q_A(30)\text{L}}{Q_A(N)\text{L}}$

$$1\ \text{ft}^3/\text{s for 1 day} = \frac{86{,}400\ \text{ft}^3 \times 12\ \text{in./ft}}{27{,}878{,}400\ \text{ft}^2/\text{mi}^2} = 0.03719\ \text{inch depth on 1 mi}^2$$

Reference period 1941–70 = 7 years at 366 days + 23 years at 365 days = 10957 days = average of 365.233 days per year.

$R_A(30)$S in inches per year = cfsm(30)S X 365.233 X 0.03719 = cfsm(30)S X 13.583.

TABLE 2.—*Summary of runoff estimates for the 30-year reference period, 1941–70, for short-term gaging stations in the upper Ohio River basin*—Continued

USGS Station No. 03–	Drainage area (mi²)	Number of years record	R_A(30) (inches)	USGS Station No. 03–	Drainage area (mi²)	Number of years record	R_A(30) (inches)
Allegheny				Monongahela			
008000	7.79	8	21.3	050800	29.2	5	26.8
011000	137	17	23.2	050900	2.86	5	37.7
011800	46.4	8	20.8	051500	122	27	30.4
012000	171	7	25.7	052500	14.5	27	23.6
015280	12.8	11	24.1	054000	6.19	4	19.4
016500	128	5	24.4	057500	25.7	15	20.9
017000	85.3	5	23.1	058000	102	27	21.2
021700	3.60	13	28.4	059500	84.6	27	18.8
022000	597	8	25.6	060000	.29	7	18.5
023000	90.2	28	21.0	060100	.92	5	21.1
025200	5.69	9	19.9	060500	8.32	18	18.6
026500	7.84	22	24.3	062400	10.9	8	20.9
027500	73.2	25	24.5	062500	63.2	23	21.5
028000	63.0	20	26.2	063500	36	2	25.5
029400	12.6	14	20.5	063600	6.57	4	18.1
031000	1,246	12	24.3	064000	46.3	2	25.0
031950	7.38	10	21.1	064500	41	2	28.8
032000	458	2	20.8	065500	58.7	2	29.4
033000	8,389	7	23.0	066500	17.9	2	39.9
033500	22.1	4	28.2	067000	140	3	31.2
037000	67.6	4	20.3	069880	12.2	6	30.8
037500	30.0	5	20.0	071000	1,354	31	29.6
039200	3.68	9	21.2	072590	16.3	10	14.7
039500	244	3	19.9	072840	133	5	12.3
042000	192	21	24.1	074000	33.1	9	15.3
042200	7.36	13	23.4	074300	3.80	7	22.3
042250	50.4	4	23.6	076600	48.9	9	21.7
042280	59.5	6	21.5	078000	62.5	23	24.4
042500	171	22	21.3	082200	9.27	12	26.9
044500	13.0	2	26.2	084500	55.9	32	16.8
049800	5.78	11	15.1				
Ohio							
086100	15.6	6	14.0	104500	792	22	14.7
087000	17.4	9	13.3	104580	13.0	7	18.2
088000	33.2	10	12.2	104760	2.26	5	18.8
088500	175	8	12.3	105000	228	5	17.4
092090	21.8	8	14.8				
				106300	51.2	10	17.9
093500	32.3	8	10.8	109000	6.19	16	11.6
096000	138	14	11.5	111150	10.3	13	11.9
097500	84.3	19	11.6	113700	4.97	4	14.9
098500	66.3	28	11.8	114000	134	15	15.2
101000	9.34	21	14.9				
				114650	4.21	4	16.2
102950	96.7	8	15.7	115400	210	15	16.0

vening area would conform to the plotted value. Full weight was given to data for the long-term sites. In some cases, little or no weight could be given to anomalous values for intervening areas or for runoff estimates for very short-term stations. These amounted to about 25 percent of the data points of these two source classes.

Major topographic features of the region were given some weight in shaping the general pattern of runoff interpreted from the plotted values. Runoff patterns are tenuously defined at the boundary of the upper Ohio River basin, because records beyond that boundary were not used in the analysis.

A map of a dynamic resource is subject to revision. The present map for the 1941–70 reference period should be expected to be different in detail, if not in general pattern, from maps for earlier reference periods, such as 1921–45 (Langbein and others, 1949) or 1931–60 (Busby, 1966). However, the present definition did not exist for earlier periods when significantly fewer long-term records were available for analysis. Mean annual runoff for the 1941–70 reference period, as defined by plate 1, conforms to recorded or computed runoff data within 1 inch (25 mm) at more than 80 percent of the data points used.

This map is considered a preliminary version owing to the fact that it is subject to modification when additional factors are considered. A more detailed method of analysis was used by Rantz (1974) in constructing a map of mean annual runoff in the San Francisco Bay region.

MEAN ANNUAL RUNOFF

UPPER OHIO RIVER BASIN

The distribution of runoff depicted on plate 1 is primarily a function of the pattern of long-term precipitation distribution, although that is but one of several influential factors. The effects of climate, geology, topography, size of area, and vegetation were discussed by Langbein and others (1949) in a report accompanying a map of annual runoff in the United States for the 1921–45 reference period. Langbein's map was updated by Busby (1966) to the reference period 1931–60.

The combined effects of topography and prevailing storm direction are evident in the runoff gradients found along the southeastern side of the basin, which includes the upper reaches of the Kiskiminetas, Youghiogheny, Cheat, and Tygart Rivers. Here both the mean and variability of annual runoff are at their regional maxima. Mean annual runoff exceeds 32 inches (810 mm) in parts of the upper Cheat River basin, but it decreases to about 18 inches (460 mm) in lower tributary basins.

The effects of topography are reflected also by a gradual increase in mean annual runoff in a northeastward direction across the northwest side of the basin. From a regional minimum of less than 12 inches (300 mm) in an area extending from the northern West Virginia panhandle to the headwaters of the Mahoning River basin, runoff increases in a northeasterly direction, to about 25 inches (630 mm) across the upper Allegheny River basin from French Creek to East Branch Clarion River. The character of bedrock and regolith changes also in this direction; the changes in properties may have a significant bearing on the distribution of runoff.

Mean annual runoff at sites on the larger rivers can be determined best by reference to data in table 1 if the site or reach where information is required is reasonably close to a gage location. If interpolation or extrapolation is required, appropriate weighted allowance must be made for the effect of intervening areas where runoff may differ markedly from that of the basin upstream. For example, mean annual runoff at the mouth of the Allegheny River at Pittsburgh might be estimated at about 0.2 inch (5 mm) less than that at Natrona (22.4 inches, 569 mm) on the basis of about 16 inches (410 mm) of runoff produced from 338 mi^2 (875 km^2) of tributary area downstream from Natrona.

The cumulative and progressive effect of changes caused by the relative influence of tributary runoff is illustrated in figure 3, which shows an average annual runoff at successive long-term gaged sites on the Allegheny and Monongahela Rivers.

To estimate the mean annual runoff from smaller rivers or streams, sketch the basin in question on plate 1. If coincident long-term runoff data are available, use the information from table 1, modified as described above for disparity in areas between the gaged basin and the basin in question. If short-term runoff data or no information are available for a basin of interest, sketch the basin on plate 1 and approximate the runoff value by areal weighting with respect to the lines of equal mean annual runoff.

County boundaries or geographic locations can be sketched on plate 1 by light-table transfer of that information from the 1:1,000,000 version of the U.S. Geological Survey state base map.

An estimate of the annual runoff for a particular geographic area, when determined from a generalized map such as that presented in plate 1, should not be used with greater precision than the nearest inch (25 mm). The nearest 2 inches (50 mm) probably is a more realistic limit in the southeastern part of the basin, where areal variability is greatest. As will be shown later, the runoff during individual years in any long period for which a mean is determined may range from as little as 30 percent of the mean to as much as 200 percent of the mean.

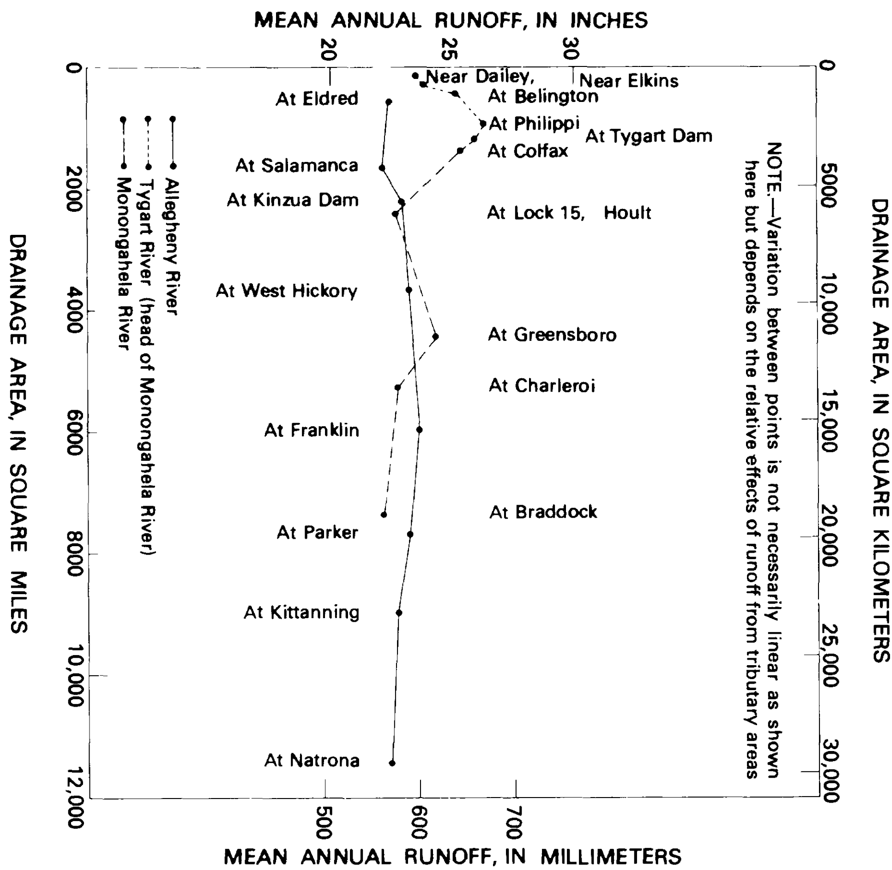

FIGURE 3.—Progressive variation in mean annual runoff at main stream sites on the Allegheny and Tygart-Monongahela Rivers.

GREATER PITTSBURGH REGION

Within the confines of the six-county Greater Pittsburgh region, mean annual runoff for the 1941–70 reference period ranges from a low of about 12 inches (300 mm) in northwestern Washington County, to a high of about 25 inches (630 mm) along Laurel Hill, on the eastern boundary of Westmoreland County.

County runoff approximations derived from plate 1 are as follows:

County	Mean annual runoff, in inches: Range	Average
Allegheny	14–18	15.5
Armstrong	17.5–20.5	19
Beaver	12.5–16.5	14
Butler	15.5–19.5	17.5
Washington	12–15	13.5
Westmoreland	15–28	19.5

Runoff from the Greater Pittsburgh region averages 17 inches (430 mm) annually and is produced by an average annual precipitation of about 39 inches (990 mm). The latter value is an arithmetic average of normal (1941–70 average) annual precipitation for 22 stations in or immediately adjacent to the Greater Pittsburgh region as computed from data reported by the National Oceanic and Atmospheric Administration (1975).

The runoff produced *within* the region, on the average is considerably less than that available *to* the region, which enters by way of the Monongahela, Youghiogheny, Conemaugh, Clarion, Allegheny, and Beaver Rivers, and other smaller extraregional tributaries. Mean annual runoff of the Monongahela River at Braddock (11 miles upstream from the mouth) is calculated as 22.12 inches (562 mm, table 1), whereas the mean annual runoff of small streams in the vicinity of the gage site (as shown on plate 1) is only 15 to 16 inches (380 to 410 mm).

Comparison of runoff estimates for the Greater Pittsburgh region to mean annual precipitation for the 1941–70 reference period, suggests that mean annual evapotranspiration losses are in the range of 22 to 26 inches (560 to 660 mm). Evapotranspiration losses are a function of temperature, wind, pressure, vegetal cover, availability of moisture, and other factors, and have less annual variability than precipitation or runoff. One aspect of the geographic variation in evapotranspiration across the Greater Pittsburgh region is shown in a map of mean-annual lake evaporation by Rahn (1973), wherein the highest values are shown for Washington County and the lowest are for Butler, Armstrong, and Westmoreland Counties.

YEARLY VARIATIONS

There is a propensity to place extremes of natural phenomena in some frame of reference. To some, the drought period of the 1930's is a climatological landmark. To a succeeding generation, and in some areas, the dry mid-1960's is a more clearly remembered time. Wet years generally result from the accumulated effect of many individual storm events that are less well remembered.

To place each water year in perspective for the upper Ohio River basin, ratios of annual mean discharge to the average for the 30-year reference period (1941–70) were computed as illustrated in figure 2. These ratios have been compiled in table 3 (in pocket) for each year of record for all long-term stations. They might be termed modular or normalized values of discharge or annual runoff, for they are percentages of average divided by 100. For example, the 1.19 ratio for the 1973 water year at station 1145 means that the discharge for that year was 119 percent of the 1941–70 average.

In order to extend the series of annual ratios, annual mean discharges for former gage sites on some streams were adjusted by a drainage-area ratio to approximate discharge of the drainage area at the current site. Records thus combined were noted in remarks on table 1.

The ratios for many individual years, particularly the drier years, are remarkably consistent over a considerable part of the basin, which gives evidence to the relative climatic homogeneity of the region.

Observations of stage and discharge were made at a few sites in the basin before the turn of the century. Systematic and continuous collection of records having some semblance of basinwide coverage began in about 1910. Figure 4*A* shows the historic variation in number of stations in operation, considering only those stations which were continued in operation for more than about 25 years.

The basinwide average of the annual ratios for all stations in operation after 1910 is shown in figure 4*B*. The sequence of average yearly ratios for the four principal subdivisions of the upper Ohio River basin is illustrated in figure 5 by plotting data given in table 4. Busby (1963) showed similar graphs of yearly variations in runoff for nine regions of the conterminous United States for the period 1931–60.

Two drought periods are evident in the record since 1910, that of the early 1930's and that of the mid-1960's. The duration and intensity of the deviation from average during those periods is demonstrated in figure 4*C* by 3- and 5-year moving averages of the data shown in figure 4*B*. The early 1910's, late 1920's, and early 1950's show up here as sustained wet periods. The 1950's would have been a prominent wet period were it not for much-below-average runoff in 1954. After beginning near average, the 1970's have been years of

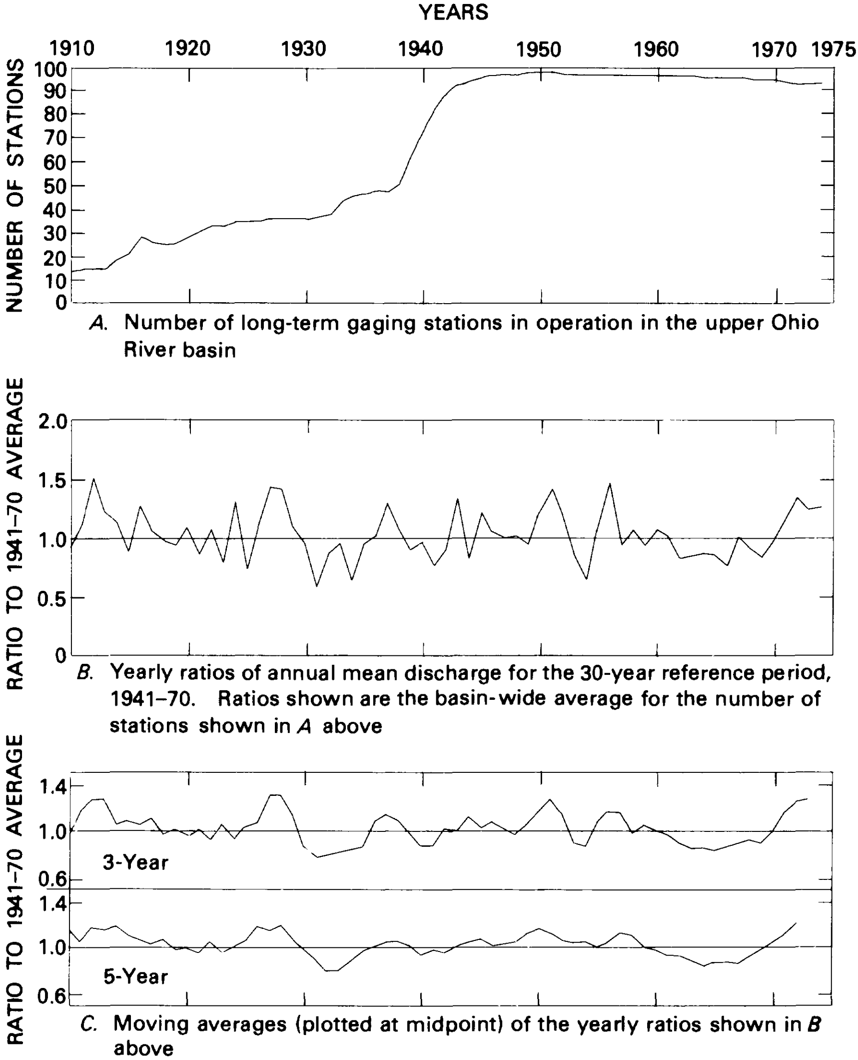

FIGURE 4.—Historical variation in basinwide average yearly discharge as indicated by long-term streamflow records for the period 1910–74.

TABLE 4.—*Subbasin and basin averages of the ratios of mean annual discharge to the average for the 30-year reference period 1941–70 for long-term stream-gaging stations in the upper Ohio River basin (Pennsylvania, New York, Maryland, northern West Virginia, and eastern Ohio)*

[Numbers set in italic indicate number of records used to derive the subbasin average (Av). UA: Upper Allegheny River subbasin; CLA: Central and Lower Allegheny River subbasins; Mon.: Monongahela River subbasin; Ohio: Ohio River tributary area from Pittsburgh to Marietta; Basin: The 27,300 mi² upper Ohio River basin upstream from Muskingum River]

		1899, 1900, 1901	1902	1903	1904	1905	1906	1907	1908	1909	1910	1911	1912	1913	1914	1915	1916	1917	1918	1919
UA	#	-------	----	----	1	1	1	1	1	2	6	6	5	5	5	6	6	6	6	6
	Av	-------	----	----	1.28	0.86	0.82	1.09	1.30	1.01	0.92	1.16	1.33	1.31	1.04	0.87	1.23	1.06	0.93	0.92
CLA	#	-------	----	----	----	2	1	1	3	3	4	4	4	4	5	5	5	5	5	6
	Av	-------	----	----	----	1.00	.88	1.12	1.39	.92	.86	1.01	1.60	1.22	1.11	.88	1.35	1.00	.93	.96
Mon	#	1, 1, 1	1	1	1	----	----	----	3	3	4	5	5	5	6	6	11	10	9	10
	Av	1.55, .97, 1.35	1.35	1.78	.96	----	----	----	1.39	.74	.93	1.13	1.55	1.06	1.14	.82	1.26	1.11	1.04	.90
Ohio	#	-------	----	----	----	----	----	----	----	----	----		1	1	3	4	6	5	5	4
	Av	-------	----	----	----	----	----	----	----	----	----	----	1.64	1.36	1.22	.94	1.24	.92	.98	.89
Basin	#	-------	1	1	2	3	2	2	7	8	14	15	15	15	19	21	28	26	25	26
	Av	1.55, .97, 1.35	1.35	1.78	1.12	.95	.85	1.10	1.38	.87	.91	1.11	1.50	1.20	1.12	.87	1.27	1.04	.98	.92

		1920	1921	1922	1923	1924	1925	1926	1927	1928	1929	1930	1931	1932	1933	1934	1935	1936	1937	1938
UA		6	7	6	6	7	7	7	7	7	7	7	7	7	9	9	9	11	11	12
	Av	0.78	0.84	0.89	0.69	0.94	0.70	0.96	1.25	1.28	1.14	0.96	0.61	0.86	0.73	0.63	0.75	0.91	1.23	1.06
CLA	#	6	6	6	6	6	6	6	6	6	5	5	5	5	6	6	7	6	6	7
	Av	1.16	.92	1.03	.79	1.34	.64	.99	1.38	1.57	.93	.83	.58	.76	.96	.69	.98	1.06	1.41	1.06
Mon.	#	10	12	14	14	15	15	15	13	13	13	13	13	14	16	18	18	18	18	18
	Av	1.27	.84	1.18	.87	1.38	.72	1.18	1.45	1.23	.92	.78	.69	.92	1.14	.74	1.12	1.13	1.19	1.08
Ohio	#	6	6	7	7	7	7	7	10	10	11	11	12	12	13	13	13	13	13	14
	Av	1.03	.94	1.07	.70	1.45	.76	1.20	1.50	1.58	1.32	1.05	.46	.88	.90	.45	.83	.97	1.44	1.16
Basin	#	28	31	33	33	35	35	35	36	36	36	36	37	38	44	46	47	48	48	51
	Av	1.09	.87	1.08	.79	1.30	.71	1.10	1.41	1.40	1.09	.93	.58	.87	.96	.63	.95	1.02	1.30	1.09

	1939	1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957
UA #	*13*	*14*	*14*	*15*	*15*	*15*	*15*	*15*	*15*	*15*	*15*	*15*	*15*	*15*	*15*	*15*	*15*	*15*	*15*
Av	0.82	1.02	0.74	0.98	1.42	0.83	1.13	1.07	1.25	0.97	0.81	1.14	1.32	1.15	0.90	0.79	0.95	1.46	0.94
CLA #	*13*	*18*	*19*	*19*	*19*	*19*	*20*	*21*	*21*	*21*	*21*	*21*	*21*	*20*	*20*	*20*	*20*	*20*	*20*
Av	.79	.93	.79	.88	1.32	.82	1.25	1.09	.97	1.02	.90	1.12	1.48	1.20	.95	.70	1.14	1.50	.89
Mon. #	*22*	*24*	*30*	*32*	*34*	*34*	*35*	*35*	*35*	*35*	*36*	*36*	*36*	*36*	*36*	*36*	*36*	*36*	*36*
Av	.98	.99	.82	.86	1.29	.88	1.32	.96	.76	1.12	1.09	1.29	1.31	1.05	.84	.63	1.19	1.33	.95
Ohio #	*15*	*15*	*20*	*24*	*25*	*26*	*26*	*26*	*26*	*26*	*26*	*26*	*26*	*26*	*26*	*26*	*26*	*26*	*26*
Av	.94	.98	.76	.94	1.36	.71	1.07	1.08	1.19	.88	.90	1.26	1.50	1.38	.74	.62	1.20	1.67	.96
Basin #	*63*	*71*	*83*	*90*	*93*	*94*	*96*	*97*	*97*	*97*	*98*	*98*	*98*	*97*	*97*	*97*	*97*	*97*	*97*
Av	.90	.98	.78	.90	1.34	.81	1.21	1.04	1.00	1.01	.96	1.22	1.40	1.19	.85	.67	1.14	1.48	.94

	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975
UA #	*15*	*15*	*15*	*15*	*15*	*15*	*15*	*15*	*15*	*15*	*15*	*15*	*15*	*15*	*15*	*15*	*15*	----
Av	0.92	1.07	1.13	0.83	0.69	0.73	0.89	0.90	0.93	1.02	1.02	1.08	0.98	1.12	1.36	1.13	1.10	----
CLA #	*20*	*20*	*20*	*20*	*20*	*20*	*20*	*20*	*20*	*20*	*20*	*20*	*20*	*20*	*20*	*20*	*20*	----
Av	.98	.92	1.11	.98	.83	.78	.94	.85	.86	.98	.90	.76	1.10	1.26	1.43	1.22	1.26	----
Mon. #	*36*	*36*	*36*	*36*	*36*	*36*	*36*	*36*	*36*	*36*	*35*	*35*	*35*	*34*	*34*	*34*	*34*	----
Av	1.19	.75	1.01	1.18	.99	1.05	.88	.87	.67	1.08	.90	.74	1.00	1.20	1.40	1.26	1.28	----
Ohio #	*26*	*26*	*26*	*26*	*26*	*26*	*25*	*25*	*25*	*25*	*25*	*25*	*25*	*25*	*24*	*24*	*24*	----
Av	1.08	1.19	1.14	.90	.70	.68	.85	.84	.77	.92	.88	.88	.92	1.11	1.21	1.36	1.35	----
Basin #	*97*	*97*	*97*	*97*	*97*	*97*	*96*	*96*	*96*	*96*	*95*	*95*	*95*	*94*	*93*	*93*	*93*	----
Av	1.08	.95	1.08	1.01	.83	.85	.88	.86	.78	1.01	.91	.84	.99	1.18	1.35	1.25	1.26	----

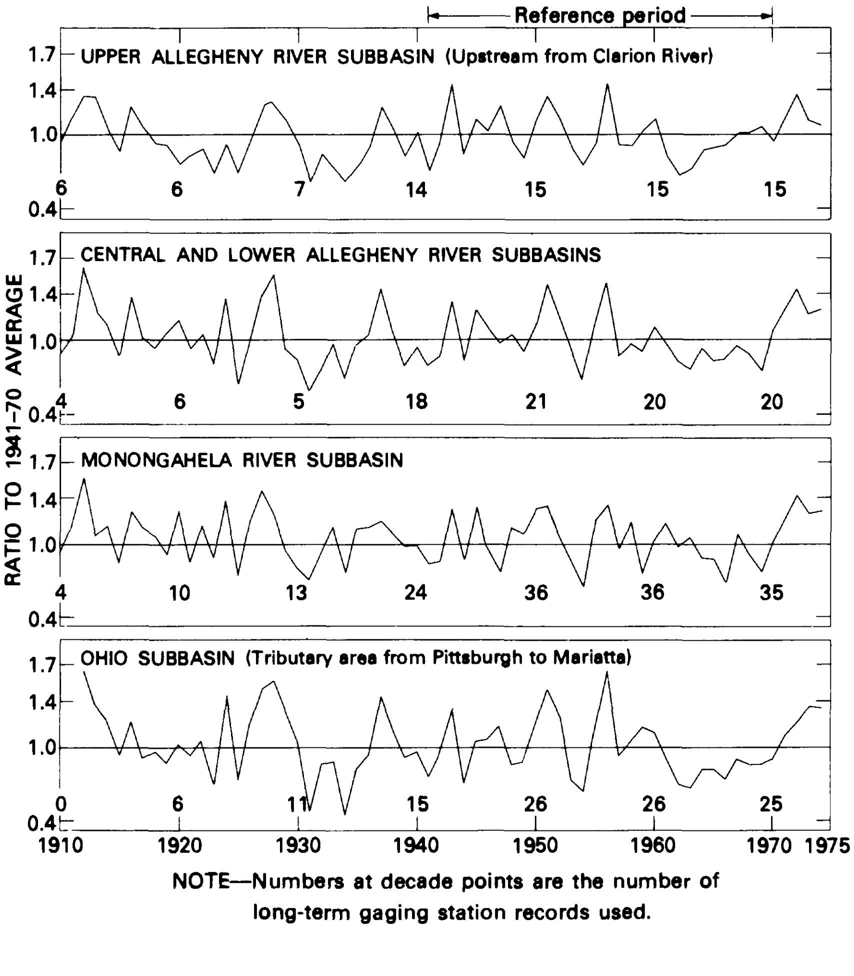

FIGURE 5.—Subbasin variations in yearly discharge.

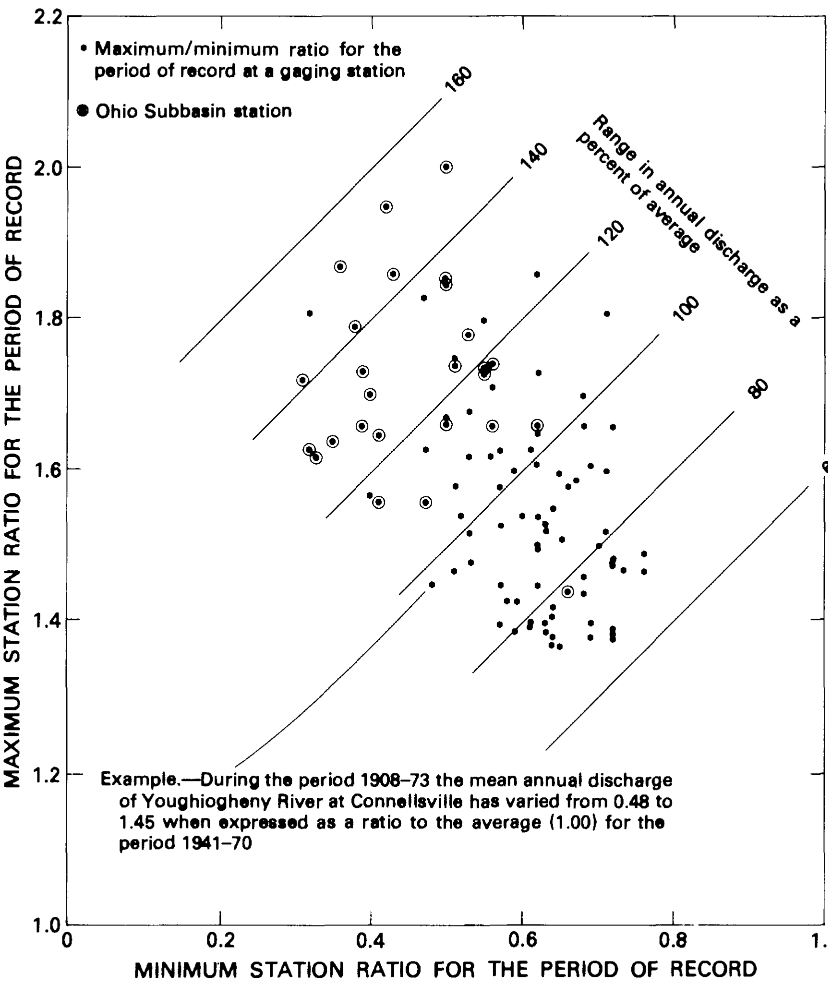

FIGURE 6.—Range of ratios of annual mean discharge to the average for the 1941–70 reference period for 98 long-term gaging stations in the upper Ohio River basin.

above-normal runoff in the upper Ohio River basin (fig. 4*B*). The sequence of basinwide averages shows that 1972 was a moderately high runoff year; partly the result of "extra" runoff generated by Tropical Storm Agnes in June. Records for selected index stations indicate that above-normal runoff has persisted through the 1975 water year (U.S. Geological Survey and others, 1975, p. 20).

The cyclic trends of moving averages (fig. 4*C*) are interesting, but they should not be considered as a forecasting mechanism.

Annual mean discharge differs considerably from year to year, as amply demonstrated by data for individual stations. Within table 3, ratios indicate a total range from about 30 percent of average (station 0980 in 1934) to 200 percent of average (station 0855 in 1928). Distribution of the range in ratios for individual stations is summarized in figure 6.

In general, total annual variability is greatest in Ohio River tributary basins below Pittsburgh, but there is no evident correlative characteristic. The range in ratios is least among some sites that seem to reflect attenuating effects of reservoir storage or large drainage area, but this observation is not consistently demonstrable.

REFERENCES

Busby, M. W., 1963 Yearly variations in runoff for the conterminous United States, 1931–60: U.S. Geol. Survey Water-Supply Paper 1669–S, 49 p.

———, 1966, Annual runoff in the conterminous United States: U.S. Geol. Survey Hydrol. Inv. Atlas HA–212.

Langbein, W. B. and other, 1949, Annual runoff in the United States: U.S. Geol. Survey Circ. 52, 14 p.

Rahn, J. J., 1973, Pan and lake evaporation in Pennsylvania: Institute for Research on Land and Water Resources Inf. Rept. 69, The Pennsylvania State University, 23 p.

Rantz, S. E., 1974, Mean annual runoff in the San Francisco Bay region, California, 1931–70: U.S. Geol. Survey Misc. Field Studies Map MF–613, 2 sheets, 24 p.

U.S. Geological Survey, 1973, Catalog of information on water data, Water Resources Region 05 (Ohio), edition 1972: Office of Water Data Coordination rept., 213 p.

U.S. Geological Survey, and Canada Dept. of the Environment, 1975, Water resources review, September 1975: U.S. Geol. Survey monthly release, 20 p.

(U.S.) National Oceanic and Atmospheric Administration, 1975, Climatological data, Pennsylvania, annual summary 1974: Environmental Data Service, Asheville, N.C., v. 79, no. 13, 15 p.

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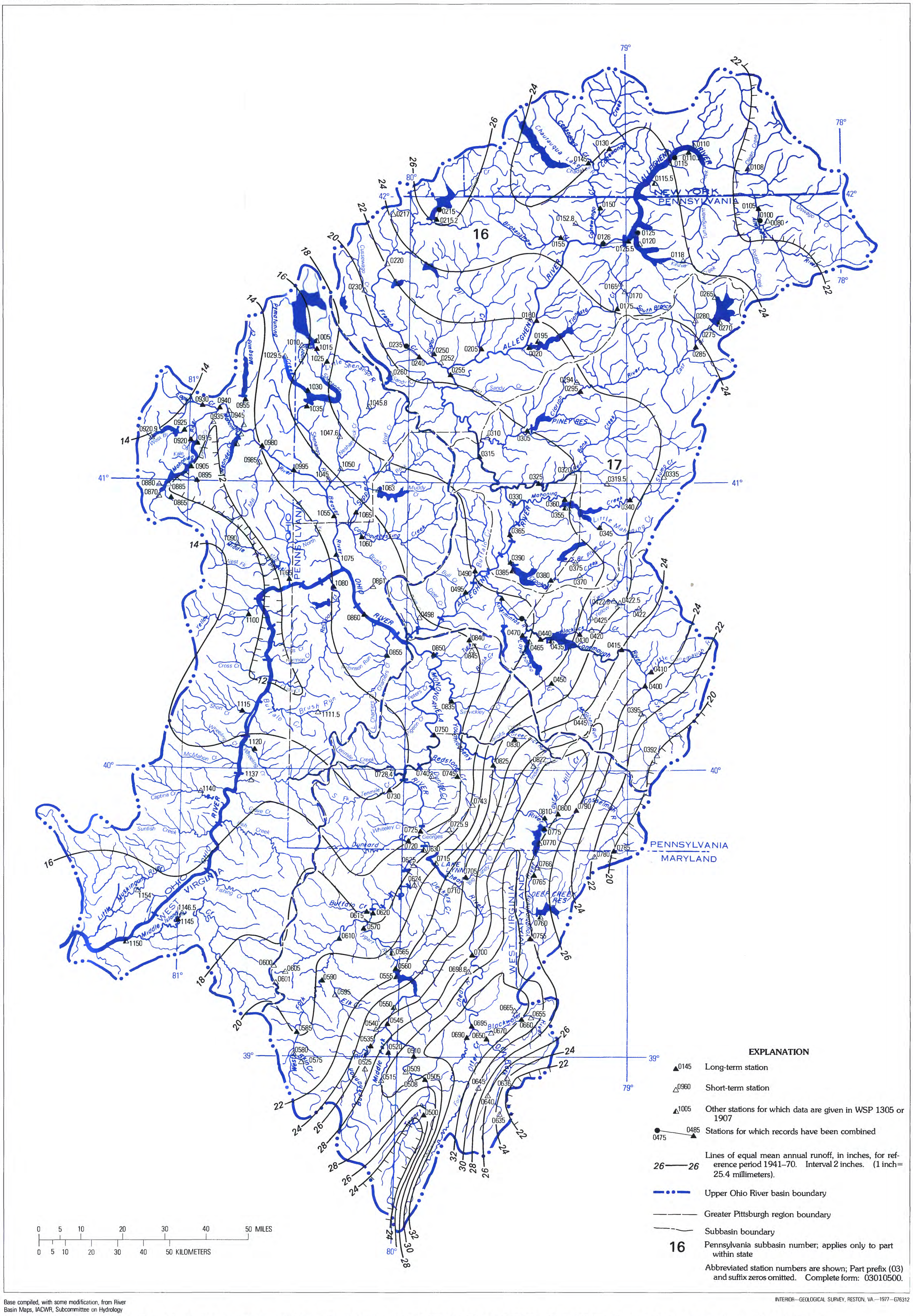

Base compiled, with some modification, from River Basin Maps, IACWR, Subcommittee on Hydrology

INTERIOR—GEOLOGICAL SURVEY, RESTON, VA.—1977—G76312

MAP OF OHIO RIVER BASIN ABOVE MUSKINGUM RIVER SHOWING MEAN ANNUAL RUNOFF AND LOCATION OF GAGING STATIONS