ORBES

PENNSYLVANIA BASELINE

Part 2 - Impact Assessment Data Base

Chapter 1 - Characteristics and Human Utilization Of Natural Ecosystems

Section 5 - Surface Hydrology

PHASE II

OHIO RIVER BASIN ENERGY STUDY

June, 1979

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Section 5 - Surface Hydrology

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2.1.5. SURFACE HYDROLOGY

2.1.5.1. HISTORICAL CONSIDERATIONS

A. Prehistoric Surface Hydrology

Prior to the first Pleistocene glaciation (Nebraskan), western Pennsylvania was drained by three northerly flowing rivers which emptied into an extension of the St. Lawrence River*. The western-most basin consisted of the Allegheny River south of Clarion, the Beaver, Monongahela, and Grand Rivers. The resulting waterway, often termed the Monongahela-Beaver or Pittsburgh River, emptied into the St. Lawrence at what is now the shore of Lake Erie between Ashtabula and Geneva-on-the-Lake. The central waterway, the Old Middle Allegheny, consisted of the Allegheny main stem from Emlenton to Franklin, Conneaut Creek, French Creek, and Crooked Creek; its direction of flow was northwest between the Ohio line and modern day Girard (1). The third preglacial waterway, the Old Upper Allegheny, flowed from south of Warren by way of the Chautauqua depression (2, 3, 4).

The arrival of glaciers in northern Pennsylvania brought ice and glacial debris which dammed the northward flowing streams and caused them to reverse their flow. The most significant break to the south occurred in the vicinity of New Martinsville, West Virginia. The divide in this area which formerly contained the headwaters of the ancestral Ohio River was cut through and the waters of western Pennsylvania were re-routed to the Mississippi Valley. Netting (2) believes that the modern day drainage pattern was established by pre-Illinoian or Illinoian glaciation rather than by the Wisconsin as some writers claim. It is known that during the last interglacial period (Sangamor), a great deepening occurred in the Upper Ohio valleys. Figure 2.1.5.1 illustrates the probable preglacial drainage pattern along with the present system.

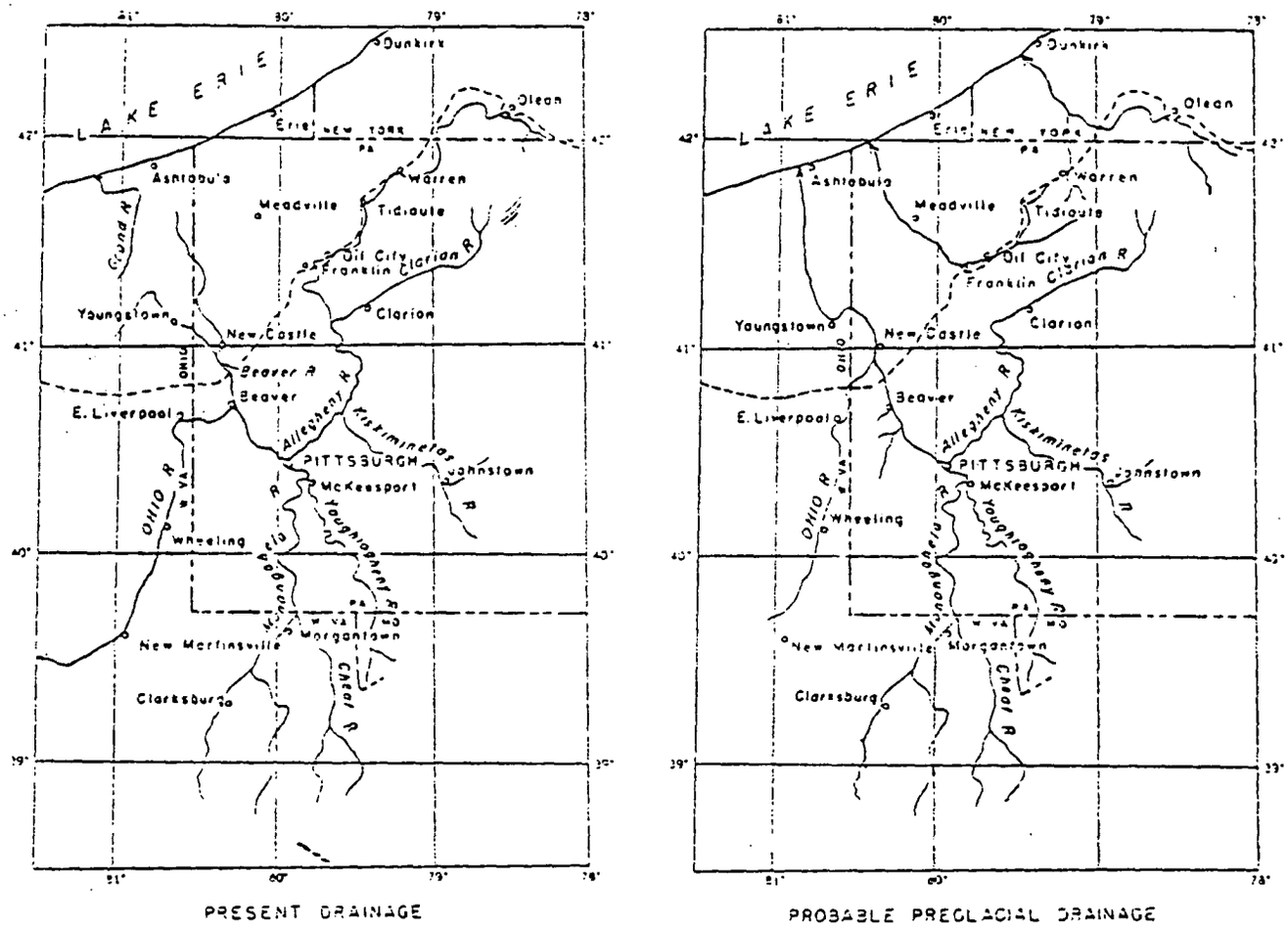
Noecker et al (3) note that these prehistoric changes in basin conformation

*At this time, the Great Lakes had not yet formed and the St. Lawrence flowed along its present day axis.

F I G U R E 2.1.5. - 1

PRESENT AND PROBABLE PREGLACIAL DRAINAGE

PATTERNS OF WESTERN PENNSYLVANIA



SOURCES: Noecker et al (3); Leverett (4).

are of great significance in the occurrence and present distribution of the highly productice alluvial deposits of the Pittsburgh vicinity. The aforementioned changes are largely responsible for the presence of valley fill materials in the Allegheny and Ohio River valleys which are conducive to the development of large ground water supplies.

B. General Historical Characteristics

The aesthetic appeal of a waterway, although difficult to qualify and impossible to quantify, is inextricably linked to hydrologic variables. Basic physical characteristics such as stream velocity, flow, meander pattern, gradient, and overall basin morphology enter into man's appraisal of beauty perhaps even more than the chemical quality and biological diversity of flowing waters. The earliest descriptions of the Upper Ohio consist chiefly of aesthetic appraisals.

The Frenchman LaSalle is credited with having been the first European to discover the Ohio River (circa 1670). The French, who considered the Allegheny and Ohio to be the same river, named the waterway "La Belle Riviere," or the beautiful river. Much controversy surrounds the origin of this name. American Indians referred to the river as "Oyo" a word which the French thought was derived from the Iroquois word "oyoneri," meaning beautiful. However, John Heckewelder, a Moravian missionary of the eighteen century, later theorized that the French had erred in their translation and that "Oyo" was actually a form of "Ohiopeekhanne," the Miami Indian word for "white foaming river" (5). Heckewelder noted that southwesterly winds were capable of producing "white caps" severe enough to prevent canoe travel. References to the wind occur in other historical pieces of literature. Douglas Southall Freeman, a biographer of George Washington, described Pittsburgh as "the windswept uninhabited point of land where the turbulent Allegheny received the waters of the slow, powerful and silent Monongahela..." (6).

Regardless of the etymology of the rivers' name, the waterways of western Pennsylvania were indeed appealing in pre-settlement and settlement times.

Celoron de Bienville, a chevalier commanding a military detachment in 1749, was the first European to sail on the Ohio. He described the area in the vicinity of the modern day "Point" as being the fairest spot along La Belle Riviere. George Washington was also enthralled with the waterways in this area, although chiefly from a strategic perspective (5).

Perhaps the most romantic description of the Ohio Basin can be found in the writings of the famous naturalist, John James Audubon, who made a float trip from Pittsburgh to Louisville in 1808. Twenty years later, Audubon reflected on his excursion and the changes occurring in the river valley since that time (6).

> Nature, in her varied arrangements, seems to have felt a partiality towards this portion of our country. As the traveler ascends or descends the Ohio he cannot help remarking that, alternately, nearly the whole length of the river on one side is bounded by lofty hills and a rolling surface; while on the other extensive plains of the richest alluvial land are seen as far as the eye can command the view. Islands of varied size and form rise here and there from the bosom of the water, and the winding course of the stream frequently brings you to places where the idea of being on a river of great length changes to that of floating on a lake of moderate extent...Purer pleasures I have never felt; nor have you, reader...
>
> When I think of these times, and call back to my mind, the grandeur and beauty of those almost uninhabited shores; when I picture to myself the dense and lofty summits of the forest, that everywhere spread along the hills and overhung the margins of the stream...When I reflect that all this...is now more or less covered with villages, farms, and towns...that steamboats are gliding to and fro over the whole length of the majestick river, forcing commerce to take root and to prosper at every spot...when I see the surplus population of Europe coming to assist...and transplanting civilization into its dark recesses...when I remember that these extraordinary changes have all taken place in a short period of twenty years I pause, I wonder, and although I know all to be the fact can scarcely believe its reality.

C. Historical Description - Channels and Hydraulics

Prior to the undertaking of slackwater navigation improvements by the U.S. Army Corps of Engineers, the Allegheny, Monongahela, and Ohio Rivers were known to have harbored numerous physical impediments to water based transportation.

Wiley (7) notes that numerous snags (i.e. fallen trees and boulders), in addition to many shallow areas resulting from sandbar or shoal formation, constituted major hazards to early navigation. In his classic work, The Navigator, riverman Zadock Cramer (8) emphasized the need to remove the abundant "rocks and ripples" in the reach of the Ohio River between Pittsburgh and Mingo Town (downstream of modern day Steubenville).

Along each of the "Three Rivers," depth and current velocity varied substantially. References indicate that the rivers consisted of alternating reaches of sluggish, deep pools and extremely shallow riffles or rapids with powerful currents (9, 10). The crews of early cargo boats employed long poles to move upstream in the deep reaches; however, crude winching techniques were often required to perform the same task in fast, shallow water. Historical evidence also suggests that all three rivers could be waded during normal flows, especially at areas downstream of major tributaries, where natural deltas formed at the mouth of tributary streams.

The Corps of Engineers (9, 10) describe the physical characteristics of the Allegheny and Monongahela Rivers prior to channelization as follows:

> One of the earliest, if not the first, recorded survey of the Allegheny Rivers was performed by Lieutenants C. Graham and J.M. Berrien (1828)(11). At that time, river widths varied from a maximum of about 1,200 feet towards the mouth, to an average of about 1,050 feet in the vicinity of the Kiskiminetas River, and eventually to about 550 to 900 feet towards the upstream limit of the present slackwater navigation improvements. Islands were present at normal intervals of 3 to 5 miles throughout most of the reach. Riffles and sandbars or shoals were not shown on the survey, but presumably they existed. The meander pattern was relatively gentle in the lower portion of the reach, becoming more pronounced in the upstream portion as is in evidence yet today.
>
> The first recorded survey of the Monongahela River was performed in 1833 under the direction of Dr. William Howard, U.S. Civil Engineer (12). At that time, the river rapidly narrowed in width from about 1,300 feet near the mouth to about 600 feet near the mouth of the Youghiogheny River (r.m.* 15.5). Between the mouth of the Youghiogheny River

*r.m. - river mile.

> and the upstream limit of the survey at Brownsville (r.m. 55), the river varied between 300 and 600 feet in width. Numerous ripples, shoals and bars were noted at intervals averaging slightly over 2 miles, but commonly varying in spacing from over 3 to less than 1 mile. The river survey bears out Wiley's contention (7), based on other historical observations, of the Monongahela's almost complete lack of islands compared with the upper Ohio and Allegheny Rivers. The river meander pattern was relatively gentle as is in evidence yet today.

J.K. Hoskins, sanitary engineer and contributing author to the well-known "Study of the Pollution and Natural Purification of the Ohio River " (13), rendered the following account of channel characteristics of the Ohio main stem in the early twentieth century.

> The Ohio is largely an alluvial stream in a fairly advanced stage of channel adjustment, as is evidenced by the fact that the velocities of flow are quite uniform throughout the length of the channel, and also by the fact that the meanders of the line of flow are gradual and wide-sweeping. The stiff clay soil has, however, brought about an adjustment to high rather than to low discharges, resulting in a channel floor that is relatively wide and flat... The river bed in the upper reaches consists of coarse gravel and boulders, but in passing downstream these are gradually replaced by sand and silt deposits. The channel is made up of a series of pools and riffles, alternating with stretches of rather smooth, uniform grade. The depth of the water in the pools at low stages ranges from less than 10 feet to over 50 feet, while in the riffles, especially in the upper part of the river, the depths are frequently less than 3 feet at low-water stages.
>
> The slope of the river, as measured by the elevation of the water surface, decreases gradually from 11.4 inches per mile between Pittsburgh and Wheeling to 3.7 inches per mile in the last 70 miles above its mouth...
>
> From Pittsburgh to Cincinnati, the channel is narrow and comparatively uniform in width, ranging from 1,200 feet to 1,500 feet at low water.

D. Historical Flow Variation

The Allegheny, Monongahela, and upper Ohio Rivers are all known to have exhibited large variation in flow prior to channelization. River traffic was often halted due to low flows that persisted for weeks and sometimes months, typically in the late summer and early fall (7). During low flow conditions in

the reach of the Ohio River upstream of Louisville, the worst shoals are known to have had minimum depths of one foot of water flowing over them. Even downstream of Louisville, such shoals had minimum depths of a mere two feet. The results of these conditions were disastrous to navigation since a minimum depth of three feet over bad shoals was deemed to be necessary for steamboats and river craft of cargo size (6).

Flooding, because of its devastating impacts upon civilization, has been especially well documented for the upper Ohio River Basin. The Pittsburgh area is known to have been traumatized by floods since the beginnings of its settlement. References to flooding extend back in time to 1756 in letters emanating from the French-occupied Fort Duquesne. The first recorded crest is from the January flood of 1762 and records exist for fifteen additional floods before 1885. Although the cutting of forests and draining of swamps are believed to have intensified the flooding problem in recent years, the available historical data indicates that flooding has always been a problem in this region. In 1763, before a single swamp was drained, the Ohio River crested at a modern height equivalent of 44 feet at "the Point" in Pittsburgh (6). The downstream results of this flood prompted the Shawnee Indians to relocate their main village from the mouth of the Scioto River to Chillicothe, Ohio.

Throughout the nineteenth century, even the ordinary high waters of late winter and early spring posed a significant threat to navigation since such flows often carried swiftly moving ice flows. Further discussion of the history of floods is included in Section 2.1.5.3, B.

E. Human Modification of the River System

By an Act of Congress approved on May 24, 1824, the U.S. Army Corps of Engineers was given the authority to remove the "planters, sawyers, and snags" from the channel of the Ohio River. Snagging and clearing operations were also

carried out on the Monongahela River at this time. The Allegheny River, however, did not receive any extensive attention until the latter portion of the 19th century.

The earliest attempts at improving navigation consisted of the construction of stone wingwalls in the rivers. These structures served to concentrate stream flow and thereby increase water depth in the rapids. Later, towards the middle of the 19th century (1839-1886), the Monongahela Navigation Company built Locks and Dams Nos. 1-7 on the Monongahela River. These structures, essentially the first slackwater locks and dams of the Pittsburgh area, generally provided a lift of less than ten feet.

In 1875 a proposal emerged to provide a minimum channel depth of 6 feet in the Ohio main stem. The proposed task was to be accomplished by the construction of 68 movable dams. The first of these was constructed in the fall of 1885 at Davis Island (r.m. 4.7). Although this initial structure only maintained an upper pool elevation of 703.0 feet above mean sea level (msl), the City of Pittsburgh is reported to have had ample harbor space even during low flow conditions (6, 13).

It is a generally accepted fact that the expansion of railroads during the latter portion of the nineteenth century had a substantial impact on public opinion of river based transportation. People began to view the waterways as an inefficient and outmoded means of travel. Consequently, Santa (6) has labeled the period from 1885-1922 as a time of stagnation in the plans for channelization of the Ohio. Nonetheless, a real flurry of construction activity occurred in the Pittsburgh area during the turn of the century. Between 1874 and 1903, slackwater navigation was extended to the head of the Monongahela River by the construction of Locks and Dams Nos. 8-15; and in 1897, the U.S. Government acquired Locks and Dams Nos. 1-7 from the Monongahela Navigation Company. Between 1894 and 1902,

Lock and Dam No. 1 was constructed on the Allegheny River at mile 1.7. Construction of Allegheny L/D Nos. 2 and 3 followed between 1898 and 1908. In addition, the following locks and dams were constructed on the upper Ohio: Lock and Dam No. 2 (r.m. 9.0) from 1898-1906; L/D No. 3 (r.m. 10.9) from 1899-1907; L/D Nos. 4, 5 and 6 (r.m. 18.6, 23.9 and 28.8 respectively) from 1892-1908; and L/D Nos. 7, 8, and 9 (r.m. 36.9, 46.1 and 55.6 respectively) from 1904-1914.

Throughout the twentieth century various modifications of the slackwater navigation system have taken place. The general trend has been to reduce the number of separate structures, replacing several at a time with a single larger structure. The Emsworth Locks and Dams, constructed on the Ohio in 1921, replaced the Davis Island Lock and Dam and Ohio River L/D No. 2. In 1938, when Emsworth Pool was raised by 7 feet by dam reconstruction. Allegheny River L/D No. 1 and Monongahela River L/D No. 1 were also eliminated at that time. In addition, the Dashields Locks and Dams replaced Ohio River L/D No. 3 in 1929; the Montgomery Locks and Dams replaced Ohio River L/D Nos. 4, 5 and 6 in 1936; and the New Cumberland Locks and Dam replaced Ohio River L/D Nos. 7, 8, and 9 in 1960.

Various Allegheny and Monongahela structures were reconstructed and/or moved. Among these were the Monongahela L/D Nos. 2 and 3, built at new locations in 1934 and Allegheny L/D Nos. 2-6 (Nos. 2-5 were moved to new sites.) The original Allegheny L/D Nos. 7, 8 and 9 were replaced by new L/D Nos. 7 and 8 at new sites in 1925.

The series of locks and dams in use (see Tables 2.1.5.-3, 2.1.5.-7, and 2.1.5.-10) have significantly altered the channel and hydraulic characteristics of each river. The effect of these structures has been to create almost constant river stages within each pool in spite of wide range of river flows. Slight increases in river widths and substantial increases in river depths have resulted from empooling large reaches. The degree of water level fluctuation within a

navigation pool is largely the result of the type of dam utilized. Gated dams, which predominate in the Monongahela and Upper Ohio, maintain relatively stable pool elevations whereas fixed crest dams permit water level fluctuation.

Each of the "Three Rivers" are dredged as necessary in order to maintain the navigable channel at a minimum depth of 9 feet. The Corps of Engineers contracts the majority of this work to private companies.

2.1.5.2. THE "THREE RIVERS AND THEIR BASINS

A. The Monongahela River Basin

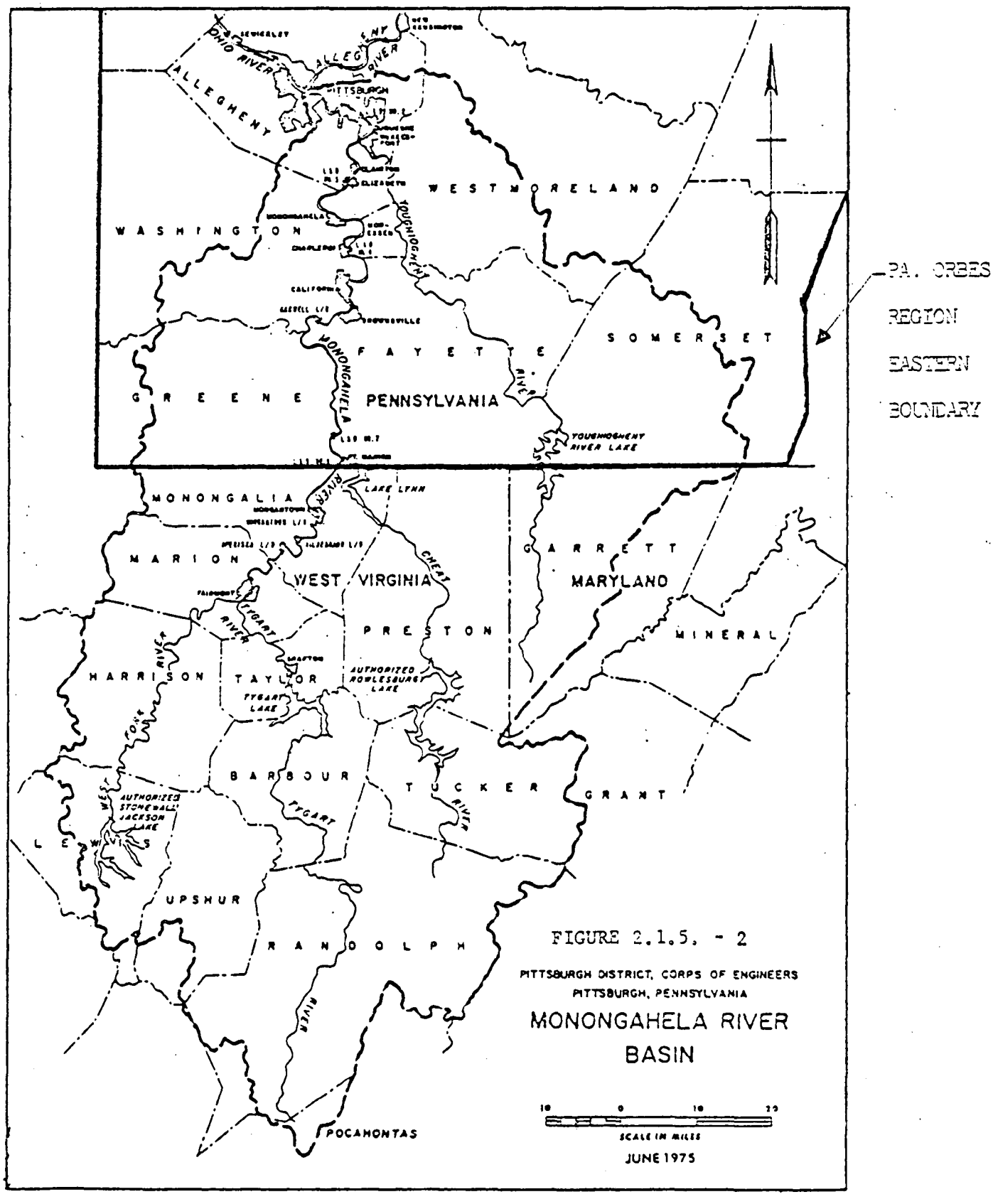
1. General Description

The Monongahela River, or "Mon" as it is colloquially known, is formed by the confluence of the West Fork River and Tygart Valley River at Fairmont, West Virginia. From its source, the Monongahela flows in a northerly direction of 128.7 miles to Pittsburgh, Pennsylvania where it meets the Allegheny to form the Ohio. Although 71% or 91.6 miles of the Monongahela's total length is contained within Pennsylvania, only 37% of the 7,384 square mile drainage area lies within the geographic confines of the state. West Virginia is home to the majority of the basin (4,228 sq. mi.), while Maryland accounts for a mere 420 square miles of drainage area. Figure 2.1.5.-2 maps the geography of the total basin.

2. Basin Configuration

Hydrologically, the Monongahela Basin is bordered by the Ohio River main stem drainage to the west, by the Little Kanawha and Kanawha River drainage to the south, by the Potomac River drainage to the east, and by the Allegheny River drainage to the north. The entire Monongahela Basin is approximately 130 miles long (north to south) and 75 miles wide (east to west).

Geopolitically, the Monongahela Basin within Pennsylvania (Pa. DER Sub-basin #19) is triangular in shape and contains the following ORBES counties: all of



SOURCE: U.S. Army Corps of Engineers (10).

Fayette; most of Greene, Washington, Westmoreland, and Somerset; and a small portion of Allegheny. In West Virginia, the basin includes all of Marion, Mongalia, Barbour, Harrison, Taylor, and Tucker counties; most of Preston, Randolph, Upshur and Lewis counties; and a small sector of northern Pocahontas County. The basin in Maryland is limited to more than half of Garrett County. Table 2.1.5.-1 presents the percentage of land in each county that is contained within the total Monongahela Basin.

3. Tributary Streams

Fifty-seven tributary streams enter the Monongahela River in Pennsylvania. The Youghiogheny River, Cheat River, and Ten Mile Creek are the largest and most hydrologically significant of these streams. The Youghiogheny drains a 1,763 square mile basin, 72% of which is contained in Pennsylvania. The upper portion of the "Yough" Basin lies in western Maryland and a small corner of eastern West Virginia. The Cheat River enters the Monongahela River at Point Marion, Pa., near the Mason-Dixon Line; consequently, less than 7% of its 1,422 square mile drainage basin is contained within Pennsylvania. Ten Mile Creek drains 338 square miles, all of which lie in western Pennsylvania. The physiographic characteristics of these three tributaries are presented in Table 2.1.5.-2.

4. Basin Physiography

The Monongahela River Basin is situated within the physiographic province known as the Appalachian Plateau, mostly in the Pittsburgh Plateaus Section, but partly in the Allegheny Mountains Section*. The portion of the basin in the Pittsburgh Section is characterized by moderate to strong relief. Erosion has imparted a slope to almost all of the land. Consequently, the area is well-drained and lacks natural lakes and extensive wetlands. Rounded hills and ridges reaching altitudes between 1,200 and 1,250 feet above mean sea level typify the region

*See Fig. 2.1.1.-1 of Geology Baseline

TABLE 2.1.5. - 1

COUNTIES OF THE
MONONGAHELA RIVER BASIN

State	County	Percent of County Land Area in Basin
Pennsylvania	Allegheny	30.7
" "	Fayette	100.0
" "	Greene	78.7
" "	Somerset	48.3
" "	Washington	36.8
" "	Westmoreland	42.0
West Virginia	Barbour	100.0
" "	Harrison	100.0
" "	Lewis	62.5
" "	Marion	100.0
" "	Monongahela	100.0
" "	Pocahontas	3.6
" "	Preston	99.0
" "	Randolph	91.3
" "	Taylor	100.0
" "	Tucker	100.0
" "	Upshur	83.0
*Maryland	Garrett	63.8

*Not part of the ORBES Study Area

SOURCE: Fed. Wtr. Poll. Cntrl. Admin. (14).

TABLE 2.1.5.-2

PHYSIOGRAPHIC CHARACTERISTICS OF MAJOR STREAMS OF THE MONONGAHELA RIVER BASIN

Stream	Miles Above Mouth of Monongahela River	Drainage Area (sq. mi.)	Length of Stream (miles)	Slope (Feet per Mile) Average	Headwater	Mouth
Monongahela River	0	7,384	128.7	1.15	1.6	0.6
Youghiogheny River	15.5	1,763	123	17.9	29.1	1.1
Ten Mile Creek	65.7	338	34.1	15.7	-	-
Cheat River	89.1	1,422	78	11.3	-	-
Tygart Valley River	128.7	1,375	131.8	19.6	32.6	9.2
West Fork River	128.7	880	99	7.5	20.6	0.96

SOURCE: U.S. Army Corps of Engineers (10).

between Pittsburgh and Washington, Pa. Southward and westward of Washington the topography is steeper with a maximum elevation of 1,600 feet in Greene County.

The upper Youghiogheny River and its tributaries drain a portion of the Allegheny Mountains Section in Fayette and Somerset Counties. This mature upland plateau of strong relief is home to three anti-clinal ridges (Chestnut Ridge, Laurel Hill and Negro Mountain) and the highest point in the state, Mt. Davis (3,213 feet above msl). The Youghiogheny River cuts through the Laurel Ridge and produces a spectacular gorge that is over 1,500 feet deep.

Stream elevations for the entire Monongahela Basin range from 4,842 feet above msl in the headwaters of the Cheat River to 6 feet above msl at the mouth of the Monongahela. The Monongahela main stem flows through a well defined river valley with steep sides rising 600-800 feet above the valley floor. In West Virginia, the valley width is narrow; however, it gradually widens to about 0.4-0.5 miles in Pennsylvania, downstream of Lock and Dam No. 7.

5. Channel Characteristics

The channel thalweg of the Monongahela main stem ranges in depth from approximately 15 to 35 feet (10). The shallower portions of the thalweg typically occur at sites immediately downstream of navigation dams, whereas thalweg depths of 25-35 feet may be found in areas directly upstream of these structures. Pool widths gradually increase in the downstream direction as follows:

	Approximate Pool Width (Feet)		
	Normal Maximum	Normal Minimum	Normal Average
Upper Monongahela	600	400	500
Lower Monongahela	1,000	700	850

Further characterization of specific pools is presented in Table 2.1.5.-3.

6. Impoundments

Within the confines of Sub-basin #19, 91 dams impound approximately 275,635

TABLE 2.1.5. - 3

CHARACTERISTICS OF MONONGAHELA RIVER NAVIGATION SYSTEM

Locks and Dams	River Mile	State	Dam Crest	Length of Pool (miles)	Upper Pool Elevation (msl)	Surface Area @ Normal Pool (acres)	Storage @ Normal Pool (acre-feet)	Mean Pool Depth (feet)	Commenced Operation
Emsworth L/D (Monongahela Arm)	6.2[1]	Pa.	Gated	11.2	710.0	1125	13,800	12.3	Sept. 1921
L/D 2	11.2	Pa.	Fixed	12.6*	718.7	1190	14,000	11.8	Aug. 1905
L/D 3	23.8	Pa.	Fixed	17.7	726.9	1595	15,800	9.9	May 1907
L/D 4	41.5	Pa.	Gated	19.7	743.5	1660	25,100	15.1	Aug. 1932
Maxwell L/D	61.2	Pa.	Gated	23.8	763.0	1875	31,000	16.5	Nov. 1964
L/D 7	85.0	Pa.	Fixed	5.8**	778.0	420	5,500	13.1	Nov. 1925
L/D 8	90.8	W. Va.	Gated	11.2	797.0	705	11,500	16.3	Oct. 1925
Morgantown L/D	102.0	W. Va.	Gated	6.0	814.0	365	6,200	17.0	Jul. 1950
Hildebrand L/D	108.0	W. Va.	Gated	7.4	835.0	405	7,600	18.8	Mar. 1960
Opekiska L/D	115.4	W. Va	Gated	13.3***	857.0	805	14,400[2]	17.9	Aug. 1964
				128.7		10,145	144,100		

1. Ohio River mileage for main channel dam.

2. Exclusive of West Fork & Tygart River Arms of the Opekiska Pool. Inclusive total storage = 17,300 acre-feet.

* Plus an additional 2.1 miles of slackwater on the Youghiogheny River.

** Plus an additional 1.5 miles of slackwater on the Cheat River.

*** Plus an additional 6.0 miles of slackwater on the West Fork and 7.6 miles on the Tygart River.

Adapted from U.S. Army Corps of Engineers (10,15).

acre-feet of water (16). Natural lakes are nonexistent in this region. In the Upper Monongahela Basin, four large reservoirs (Lake Lynn, Deep Creek Lake, Tygart Lake and Youghiogheny River Lake) drain approximately 3,100 square miles of land. Deep Creek Lake and Lake Lynn are owned by private power companies and are operated to produce peak load power of 51 and 19 megawatts, respectively. The Youghiogheny River Lake and Tygart River Lake are operated by the Corps of Engineers for flood control, recreation, low flow augmentation for water quality, and navigation. The four reservoirs contain 720,000 acre-feet of total storage. Allocated storage capacities are as follows: 250,000 acre-feet for summer flood control; 430,000 acre-feet for winter flood control; and 113,000 acre-feet of usable capacity for power generation. Table 2.1.5.-4 characterizes the individual reservoirs in greater detail.

The Corps of Engineers' Stonewall Jackson Lake on the upper West Fork River is currently (1978) in the "construction phase" (real estate procurement). This multipurpose reservoir is to be operated for water supply, low flow augmentation for water quality maintenance, and flood control. The planned gross capacity is 74,650 acre-feet. The project is not expected to have a large impact on the hydrology of the Monongahela Basin due to its small storage capacity and drainage area (102 sq. mi.). The flood control summer and winter minima are projected to be 26,480 and 38,550 acre-feet respectively. Approximately 3,120 acre-feet are planned for permanent storage. The tentative year of completion for the project is 1984 (17).

Planning of the Rowlesburg Reservoir on the Cheat River is now inactive. The projected total storage capacity of this proposed reservoir was 750,000 acre-feet. If constructed, it would have a major influence on the hydrology of the region.

TABLE 2.1.5. - 4

MAJOR MULTIPURPOSE AND POWER GENERATION RESERVOIRS IN THE MONONGAHELA RIVER BASIN

Reservoir	Purpose[a]	Date In Operation	Drainage Area Sq. Mi.	Storage Capacity (1000 ac. ft)[b] Minimum	Conservation[c]	Flood Control[c]	Power	Total	Minimum Release (cfs) Winter	Summer	Operator
Tygart Valley River	FNR	1938	1184	9.7	0.0W 99.9S	278.0W 178.1S	-	287.7	100	100	Corps of Engineers
Youghiogheny	FLR	1948	434	5.2	97.8W 149.3S	151.0W 99.5S	-	254.0	100	100	Corps of Engineers
Deep Creek	P	1925	68.5	13.1	-	-	93.0	106.1	-	-	Pennsylvania Elec. Co.
Lake Lynn	P	1926	1413	45.0	-	-	19.7	72.3	-	-	West Penn. Power Co.

[a] Project Purposes: F = Flood Control
P = Power
N = Navigation
L = Low Flow Augmentation - Principally for Quality Control
R = Recreation

[b] Storage Capacity Allocations:
Minimum - Storage provided for various purposes, which is not drawn down except in unusual circumstances.
Conservation - Storage which is fluctuated as required for low flow augmentation, quality control, water supply, recreation and other purposes.
Power - Storage above the minimum pool which is drawn down for the production of hydroelectric power.
Flood Control - Storage reserved exclusively for reduction of floods.
Total - Total storage in the reservoir under a flat pool at ungated spillway crest elevation, or maximum pool elevation with spillway gates closed.

[c] W = Winter
S = Summer

SOURCE: U.S. Army Corps of Engineers (10).

At the present time, the proposed Davis Lake Pumped Storage Project on the Blackwater River in the Canaan Valley of West Virginia is under review by the Corps of Engineers, the FPC, the Ohio River Basin Commission and other environmental agencies. The proposed impoundment would inundate an area considered by numerous groups and individuals to contain unique biota, particularly wetland species. The project would provide 1,000 MW capacity of pumped storage peaking power; it would impound 162,500 acre-feet of water at an elevation of 3,182 feet above mean sea level. The resulting 7,000 acre reservoir would also serve as a recreational lake (18).

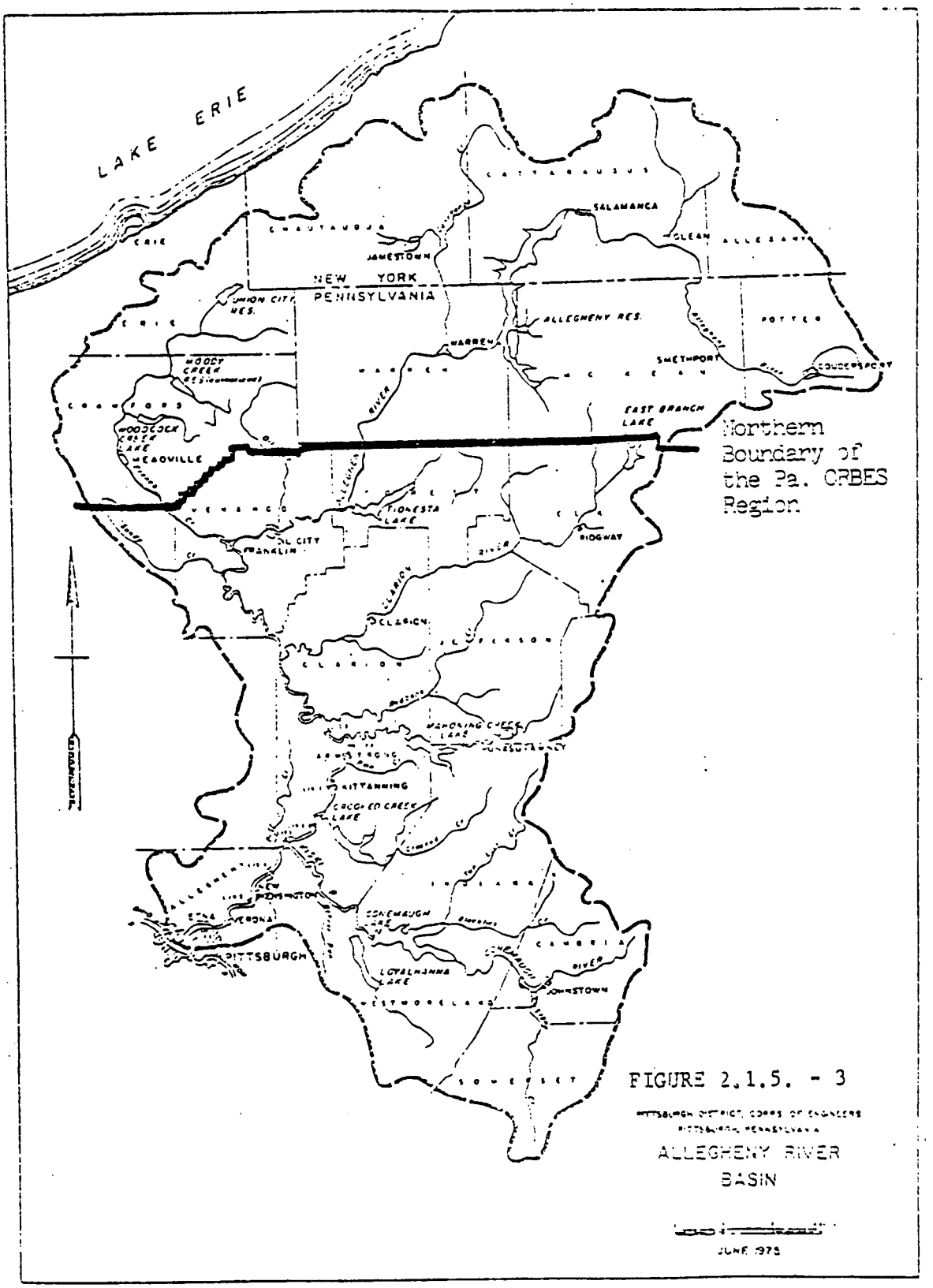
B. The Allegheny River Basin

1. General Description

The Allegheny River originates outside of the ORBES Study Area in Potter County near Coudersport, Pennsylvania. The river flows northwestward from its source into New York State where it bends, forming a loop 50 miles long before re-entering Pennsylvania in Warren County. The river first enters the ORBES region in northwestern Forest County, from which it meanders in a southerly direction to its confluence with the Monongahela at Pittsburgh. Approximately 50% of the Allegheny's 325 mile length and 54% of its 11,778 square mile drainage basin lies within the ORBES Study Area. The hydrologic boundaries of the entire Allegheny River Basin are shown in Figure 2.1.5.-3.

2. Basin Configuration

The Allegheny River Basin is bordered by the Great Lakes - St. Lawrence River Basin to the north; by the Susquehanna River Basin to the east; by the Monongahela River Basin to the south; and by the Beaver River Basin along with a segment of the Ohio main stem drainage to the west. The maximum dimensions of the entire Allegheny Basin are approximately 175 miles in length (north-south axis) and 130 miles in width (east-west axis).



SOURCE: U.S. Army Corps of Engineers (9).

Nineteen counties in Pennsylvania and three in New York are contained partly or entirely within the Allegheny Basin (see Table 2.1.5.-5). The Pennsylvania portion of the watershed covers approximately 9,813 square miles, whereas only 1,965 square miles of the basin occur in New York.

3. Tributary Streams

Numerous tributaries of various sizes empty their waters into the Allegheny River along its course. However, only nine tributary streams exert major influences on the hydrology of the river. Most of these tributaries approach the Allegheny from the east where the topography is rugged. Table 2.1.5.-6 lists the physiographic characteristics of the Allegheny River and these major tributaries. The drainage areas and map coordinates of all streams within the Commonwealth of Pennsylvania are available in the "Pennsylvania Gazetter of Streams" (19). Detailed mapping of state streams is available in Higbee's "Stream Map of Pennsylvania" (20).

4. Basin Physiography

The Allegheny River Basin has portions of its drainage area in four different Sections of the Appalachian Plateaus Physiographic Province.* All of Tionesta Creek, the upper Allegheny and Clarion Rivers, and lower Oil, French and Conewango Creeks are contained within the Allegheny High Plateaus Section, an unglaciated area characterized by highly dissected plateaus. Here, stream valleys are deep and have steep sides with only small tracts of flat land on some of the valley bottoms and stream divides.

Upper Oil Creek, as well as the majority of the French Creek Basin occurs within the Glaciated Section of the Appalachian Plateaus. This area consists of rounded hills with gentle slopes; valleys typically have broad and flat floodplains. Several natural lakes and swamps have been formed on the glacial deposits of this

*See Fig. 2.1.1-1 of Geology Baseline

TABLE 2.1.5-5

COUNTIES OF THE
ALLEGHENY RIVER BASIN

STATE	COUNTIES	PERCENT OF COUNTY LAND AREA IN BASIN
Pennsylvania	Allegheny	31.4
" "	Armstrong	100.0
" "	Butler	29.1
" "	Cambria	58.8
" "	Clarion	100.0
" "	Clearfield	9.9
" "	*Crawford	75.9
" "	Elk	67.2
" "	*Erie	49.2
" "	Forest	100.0
" "	Indiana	91.9
" "	Jefferson	100.0
" "	*McKean	97.4
" "	Mercer	15.8
" "	*Potter	28.6
" "	Somerset	37.7
" "	Venango	97.8
" "	Warren	100.0
" "	Westmoreland	58.0
New York	*Allegany	17.4
" "	*Cattaraugus	74.2
" "	*Chautauqua	71.6

*Not part of the ORRES Study Area

SOURCE: Fed. Wtr. Poll. Cntrl. Admin. (14)

TABLE 2.1.5. - 6

PHYSIOGRAPHIC CHARACTERISTICS OF MAJOR STREAMS OF THE ALLEGHENY RIVER BASIN

Stream	Miles above Mouth of Allegheny River	Drainage Area (sq.mi.)	Length of Stream (miles)	Slope (Feet per Mile) Average	Headwater	Mouth
Allegheny River	0	11,700	325	2.7	33.2	0.9
Kiskiminetas River	30.2	1,890	27	3.4	-	-
Conemaugh River	-	1,370	52.2	6.0	-	-
Mahoning Creek	55.5	425	62.8	8.0	-	-
Redbank Creek	64.0	605	47.5	8.4	-	-
Clarion River	86.1	1,235	96.3	6.0	-	-
French Creek	126.6	1,235	108	6.5	-	-
Oil Creek	134.0	340	45	-	-	-
Tionesta Creek	154.2	480	58	13.1	-	-
Conewango Creek	192.0	900	71.5	4.0	-	-

SOURCE: U.S. Army Corps of Engineers (9).

region. This is largely because the post-glacial drainage has not yet had the time required to develop any significant degree of integration.

Blacklick Creek, most of the Conemaugh River, and the headwaters of Loyalhanna Creek lie in the Allegheny Mountains Section of the Appalachian Plateaus. This is an area of strong relief with a series of high ridges. The greatest local relief is approximately 1,600 feet at the Conemaugh River gap through Laurel Hill.

All of Mahoning Creek, Crooked Creek and the Kiskiminetas River flow through the Pittsburgh Plateaus Section of the Appalachian Plateaus. Most of the Allegheny main stem, the Clarion River, and Redbank Creek are also contained in this section. The hill summits of this section are in general conformity with the local relief. The maximum relief between the Allegheny River Valley and the highest hills is approximately 775 feet.

Basin-wide elevations range from over 2,500 feet above msl in the eastern section to 710 feet above msl at the Allegheny's mouth in Pittsburgh. The Allegheny main stem flows through a well-defined river valley with a floor width averaging 0.5 miles in the lower reaches.

5. Channel Characteristics

The lower 72 miles of the Allegheny main stem are managed for commercial navigation. The channel thalweg in this reach, under normal flow, ranges from 10-20 feet directly downstream of dams to 25-30 feet (or somewhat greater) (9). Channel widths (exclusive of islands) of the normal slackwater pools range from approximately 600 feet to 1,500 feet with an average of 1,000 feet. A more detailed description of the navigation pools can be found in Table 2.1.5.-7.

6. Impoundments

In the Allegheny Basin, a network of ten large reservoirs are operated by the Corps of Engineers chiefly as structural measures for flood control. These impoundments have a pronounced effect on the hydrology of the region as they con-

TABLE 2.1.5. - 7

CHARACTERISTICS OF THE ALLEGHENY
RIVER NAVIGATION SYSTEM

Locks and Dams	River Mile	Dam Crest	Length of Pool (mile)	Upper Pool Elevation (ft. above msl)	Surface Area @ Normal Pool (Acres)	Storage @ Normal Pool (acre-feet)	Mean Pool Depth (feet)	Commenced Operation
Emsworth L/D (Allegheny Arm)	6.2[1]	Gated	6.7	710.0	725	10,000	13.8	Sept. 1921
L/D 2	6.7	Fixed	7.8	721.0	1120	14,500	12.9	Oct. 1934
L/D 3	14.5	Fixed	9.7	734.5	1220	16,800	13.8	Oct. 1934
L/D 4	24.2	Fixed	6.2*	745.0	710	9,000	12.7	Sept. 1927
L/D 5	30.4	Fixed	5.9	756.8	660	9,800	14.8	Oct. 1927
L/D 6	36.3	Fixed	9.4	769.0	1260	14,000	11.1	Oct. 1928
L/D 7	45.7	Fixed	6.9	782.1	640	8,400	13.1	Nov. 1930
L/D 8	52.6	Fixed	9.4	800.0	1010	15,200	15.0	May 1931
L/D 9	62.2	Fixed	11.8	822.0	1040	13,500	13.0	Oct. 1938

1. Ohio River Mileage for main channel dam

* Plus an additional 3.7 miles of slackwater on the Kiskiminetas River

SOURCE: U.S. Army Corps of Engineers (9).

trol the runoff from approximately 5,250 square miles of drainage area and provide a total storage capacity of about 2 million acre-feet. The allocated storage capacities for these reservoirs are as follows: 625,000 acre-feet for summer conservation, including low flow augmentation; 680,000 acre-feet for summer flood control; and 1.7 million acre-feet for winter flood control. Monthly releases of water from major reservoirs in the Allegheny Basin as well as the rest of Pennsylvania are published in the U.S. Geological Surveys "Water Resource Data for Pennsylvania" (21). These reservoirs are characterized in greater detail in Table 2.1.5.-8.

In addition to publically owned impoundments, several privately owned reservoirs associated with power generation are situated within the Allegheny Basin. The Pennsylvania Electric Company owns and operates the Piney Reservoir which drains 957 square miles above mile 13 of the Clarion River. Piney is operated for hydroelectric power generation (29 MW capacity) and has a maximum summer storage of approximately 28,900 acre-feet. The Keystone Station Dam impounds 830 acres of water on Crooked Creek and north Branch of Plum Creek in Armstrong County for use at the jointly owned, 1,640 MW coal-fired facility. The Kinzua (Seneca) Pump Storage Reservoir is a 106 acre impoundment in Warren County yielding approximately 246 MW.

One large natural lake, Lake Chatauqua, drains 189 square miles of New York State. Although the capacity of this lake has not been determined, its surface area is approximately 21 square miles. Numerous man-made recreational lakes and several other natural lakes are also distributed throughout the basin. Among the more popular of these are Conneaut Lake, Lake Somerset, the Quemahoning Reservoir, Yellow Creek Lake, North Park Lake, the Bear Run Reservoir, Cuba Lake and Edinboro Lake. Descriptive material on most of the impoundments in the Commonwealth of Pennsylvania as of 1970 is available in "Dams, Reservoirs, and Natural Lakes." (16).

Several potential sites for Corps of Engineers' reservoirs have been identi-

TABLE 2.1.5. - 8

MAJOR FLOOD CONTROL AND MULTI-PURPOSE RESERVOIRS
IN THE ALLEGHENY RIVER BASIN[a]

RESERVOIR	LOCATION PA. COUNTY	PURPOSE[b]	DATE IN OPERATION	DRAINAGE AREA SQ. MI.	STORAGE CAPACITY (1000 ac. ft)[c] MINIMUM	CONSERVATION	FLOOD CONTROL[d]	TOTAL	MINIMUM RELEASE (cfs) WINTER	SUMMER
Allegheny (Kinzua Dam)	Warren	FLRP	1967	2,180	24	216.0W 549.0S	940.0W 607.1S	1,180.0	500	500
Conemaugh	Indiana	FR	1953	1,351	4.0		270.0	274.0	100	100
Crooked Cr.	Armstrong	FR	1940	277	4.5		89.4	93.9	5	5
East Br. Clarion	Elk	FLR	1952	72.4	1.0	44.6W 64.3S	38.7W 19.0S	84.3	20	20
Loyalhanna	Westmoreland	FR	1942	290	2.0		93.3	95.3	10	10
Mahoning Cr.	Armstrong	FR	1941	340	4.5		69.7	74.2	10	10
Tionesta	Forest	FR	1940	473	7.8		125.6	133.4	5	5
Union City	Erie	FR	1970	222	0	1.4W 8.4S	46.3W 39.3S	47.7	-	-
Woodcock Cr.	Crawford	FRL	1974	45.7	0.9	0.4W 4.0S	18.7W 15.1S	20.0	5	5

a. All owned and operated by Corps of Engineers

b. Purposes: F = Flood Control, P = Power
L = Low Flow Augmentation - Principally for Quality Control
R = Recreation

SOURCE: U.S. Army Corps of Engineers (9)

c. Storage Capacity Allocations:
Minimum - Storage provided for various purposes, which is not drawn down except in unusual circumstances
Conservation - Storage which is fluctuated as required for low flow augmentation, quality control, water supply, recreation and other purposes.
Flood Control - Storage reserved exclusively for reduction of flo
Total - Total storage in the reservoir under a flat pool at ungated spillway crest elevation, or maximum pool elevation, or maximum pool elevation with spillway gates closed.

d. W = Winter, S = Summer

fied in the Allegheny River Basin. The St. Petersburg Reservoir on the Clarion River is one of the most significant of these proposed projects. A storage volume of 800 thousand acre-feet is the planned capacity at full pool.

C. The Upper Ohio River Sub-basin (Pa.)

1. General Description

The Ohio River is formed by the confluence of the Allegheny and Monongahela Rivers at Pittsburgh, Pennsylvania. At "The Point" in Pittsburgh, the Allegheny and Monongahela account for 61.5% and 38.5% respectively of the Ohio River's 19,164 square mile headwater drainage area. The Ohio flows southwesterly for 981 miles to Cairo, Illinois where its drainage area (exclusive of the Tennessee River Basin) covers approximately 163,000 square miles. The Ohio Basin in bordered on the north by the Great Lakes drainage area, on the east by the Appalachian divide, on the south by the Tennessee Valley, and on the west by the Mississippi River.

2. Sub-basin Configuration

The portion of the Ohio River Basin within the Commonwealth of Pennsylvania and exclusive of the Allegheny and Monongahela Basins is known as Pa. DER* Sub-basin #20. This sub-basin is triangular in shape with a drainage area of 3,080 square miles. The base of the "triangle" corresponds to the state boundary line; it is approximately 139 miles in length (north-south), extending from Pymatuning Reservoir to Ryerson Station State Park. The legs of the sub-basin "triangle" average about 78 miles in length from Pymatuning and Ryerson State Park to Butler, Pa. (see Figure 2.1.5.-4)

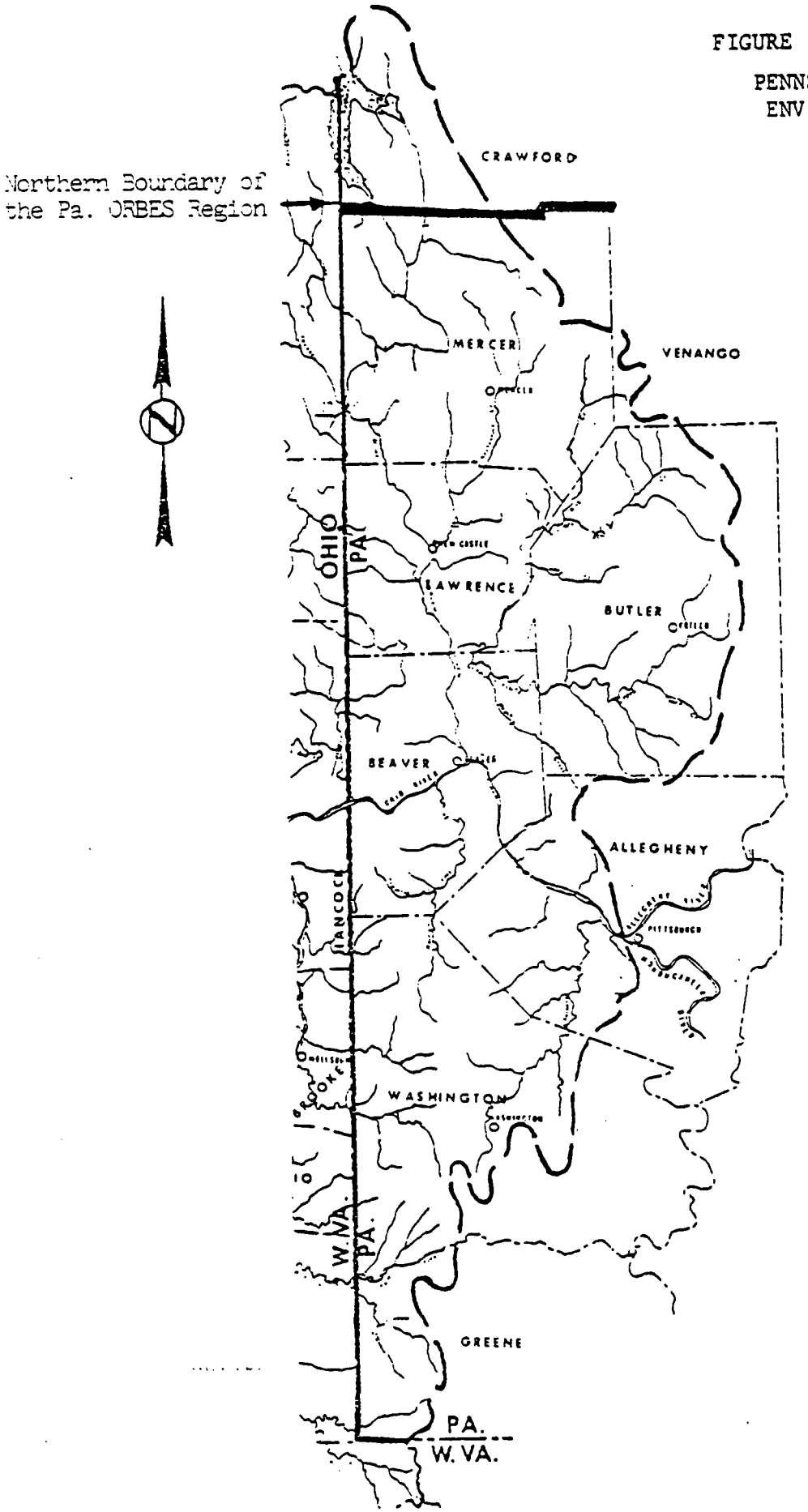
Geopolitically, Sub-basin #20 contains all of Beaver and Lawrence Counties, most of Mercer County, two-thirds of Butler County, approximately half of Allegheny and Washington Counties, and small sections of Crawford, Greene and Venango Counties. (see Table 2.1.5.-9).

*Pennsylvania Department of Environmental Resources

FIGURE 2.1.5. - 4

PENNSYLVANIA DEPT. OF ENVIRON. RESOURCES SUB-BASIN #20

(Upper Ohio Main Stem)



SOURCE: Adapted from Ohio River Basin Commission (22).

T A B L E 2.1.5. - 9

COUNTIES OF PA. DER
SUB-BASIN #20
(Upper Ohio - Beaver Basins within Pennsylvania)

State	County	Percent of County Land Area in Basin
Pennsylvania	Allegheny	37.9
" "	Beaver	100.0
" "	Butler	70.9
" "	*Crawford	15.0
" "	Greene	21.3
" "	Lawrence	100.0
" "	Mercer	84.2
" "	Venango	2.2
" "	Washington	63.2

SOURCE: Fed. Wtr. Poll. Cntrl. Admin. (14)

3. Tributary Streams

Forty miles of the Ohio River extend from Pittsburgh to the Pennsylvania State line. Along this reach of the river, 41 tributary streams enter the main stem. The hydrology of the region, however, is chiefly governed by only three of these tributaries - the Beaver River, Chartiers Creek and Raccoon Creek. These three streams collectively drain approximately 73% of the land area in Sub-basin #20.

The Beaver River is the largest and hydrologically most significant tributary of the Ohio River in Pennsylvania. The Beaver is formed by the confluence of the Mahoning and Shenango Rivers near New Castle, Pa. from which it flows in a southernly direction for 21 miles before joining the Ohio at Rochester, Pa. (Ohio River mile 25.4). The Beaver drains 1,368 square miles of northeastern Ohio and 1,785 square miles of northwestern Pennsylvania. The river's slope ranges from 1.6 feet per mile at its headwaters to 11.3 feet per mile near its mouth. The average slope for the entirety of the river is approximately 4.1 feet per mile (23).

4. Sub-basin Physiography

The northern third of Sub-basin #20 lies within the Glaciated Section of the Appalachian Plateaus. Rounded hills and rolling terrain dominate the landscape in this region. Most of the major waterways have broad, flat floodplains which may contain as much as 400 feet of unconsolidated glacial outwash deposits (24). Drainage patterns are generally not fully developed or integrated; consequently, wetlands are more common in this area than in the rest of the Pennsylvania ORBES region. In the past, glaciation overdeepened numerous valleys in this section, which are today occupied by small, slowly flowing streams. Crude radial and trellis drainage patterns are common in this section.

The hilly terrain of the Pittsburgh Plateaus Section contains the southern two-thirds of Sub-basin #20. In this region, stream valleys have cut into the upland surface and the drainage system is characterized as being well-developed and of a dendritic pattern. In Washington County, hilltops average 1,300 feet above

mean sea level (msl) with valley floors at 1,000 feet above msl.

5. Channel Characteristics

Three locks and dams are located in the Pennsylvania reach of the Ohio River. A fourth structure, the New Cumberland Locks and Dam is situated in West Virginia but has 8.3 miles of its pool within Pennsylvania. The navigation pools of the Upper Ohio are characterized in Table 2.1.5.-10. The river is dredged to provide a minimum navigable channel depth of 9 feet. The mid-channel depth in actuality, however, ranges between 20 and 35 feet. The channel widths (exclusive of islands) of the first four pools range from 1,340 - 1,400 feet. The average slope and thalweg slope of the river in this reach are 0.9 feet per mile and 1.5 feet per mile, respectively (23, 26). The average slope for the entire 981 miles of the Ohio is approximately 0.4 feet per mile.

6. Impoundments

The upper Beaver River Basin contains seven large reservoirs, most of which lie outside Sub-basin #20 in northeastern Ohio. These impoundments collectively drain 1,524 square miles and have a total usable storage capacity of approximately 713,000 acre-feet. Table 2.1.5.-11 characterizes the individual reservoirs in greater detail. Sub-basin #20 does not contain any natural lakes but approximately one hundred water supply and recreational impoundments exist throughout the area. Lake Arthur is the largest state-owned, man-made lake that is contained entirely within the state; it impounds approximately 37,000 acre-feet of water on Muddy Creek in Butler County.

2.1.5.3. STREAM FLOW

A. General Conditions

1. The Monongahela Basin

The four impoundments of the Monongahela Basin have a pronounced effect on the hydrology of the region. The storage of water in the Tygart and Youghiogheny reservoirs during peak runoff periods serves to reduce the frequency of flooding. Deep Creek Lake and Lake Lynn, although not operated to provide flood control,

TABLE 2.1.5. - 10

CHARACTERISTICS OF THE UPPER
OHIO RIVER NAVIGATION SYSTEM

Locks and Dams	River Mile	State	Dam Crest	Length of Pool (mile)	Upper Pool Elevation (ft. above msl)	Surface Area @ Normal Pool (Acres)	Storage @ Normal Pool (acre-feet)	Mean Pool Depth (feet)	Commenced Operation
Emsworth	6.2[1]	PA	Gated	6.2	710.0	1,220	18,900	15.5	Sept. 1921[2]
Dashields	13.3	PA	Fixed	7.1	692.0	1,200	17,000	14.2	Aug. 1929
Montgomery	31.7	PA	Gated	18.4*	682.0	2,990	57,500	19.2	June 1936
New Cumberland	54.4	WV	Gated	22.7	664.5	3,840	74,000	19.3	Oct. 1959

1. Mileage for main channel dam

2. Original Construction

* Plus 2.6 miles of slackwater on the Beaver River

SOURCE: U.S. Army Corps of Engineers (25)

TABLE 2.1.5. - 11

MAJOR RESERVOIRS OF THE BEAVER RIVER BASIN

RESERVOIR	LOCATION COUNTY, STATE	PURPOSE	DATE IN OPERATION	DRAINAGE AREA SQ. MI.	PERM MIN POOL AREA (ACRES)	STORAGE (ACRE-FEET) MAX. FLOOD CONTROL	WATER SUPPLY	MAXIMUM SUMMER	OPERATOR
Berlin	Portage, OH	FLW	1942	248	240	55,800	19,400	39,000	Corps. of Engineers
Milton	Mahoning, OH	L	1916	273	1,685			21,600	City of Youngstown, OH
Mosquito Cr.	Trumbull, OH	FLW	1943	97.5	700	33,000	11,000	71,400	Corps of Engineers
Meander Cr.	Trumbull, OH	W	1929	83.9	2,010		30,675		Mahoning Valley Sanitary L
Michael J. Kirwan	Portage, OH	FL	1966	80.5	580	33,200		56,700	Corps of Engineers
Pymatuning Lk.	Crawford, PA	FLR	1934	158	14,650	194,000		160,000	Pa. Dept. Environ. Resourc
Shenango	Mercer, PA	FLR	1967	583	1,910	180,900		41,400	Corps of Engineers

F - Flood Control
L - Low Flow Augmentation
W - Water Supply
R - Recreation

SOURCES: Fed. Wtr. Poll. Cntrl. Admin. (14) and U.S. Geologic Surv. (21).

do indeed provide this service on chance occasions.

The release of water from the Corps of Engineers' Reservoirs during low flow periods augments downstream flows. Tygart River Lake is operated to provide a minimum flow of 340 cfs in the Upper Monongahela whereas the release schedule for the Youghiogheny River Lake is designed to provide a minimum flow of 200 cfs in the Youghiogheny River at Connellsville.

During periods of peak power demand, hydroelectric plants must release large volumes of water. Discharges from the Piney Reservoir in the Allegheny Basin and Deep Creek Lake in the Monongahela Basin can cause substantial flow variation in the Clarion and Upper Youghiogheny Rivers. Hydroelectric power-induced flow variation is perhaps best exemplified by the effects of Lake Lynn discharges when low flows occur in the Monongahela River above its confluence with the Cheat River. During such episodes, abrupt translatory waves are created in the Monongahela by Lake Lynn discharges and flows fluctuate widely by the hour (15).

Since almost two-thirds of the Monongahela Basin is located outside of Pennsylvania, the flow characteristics of the lower Monongahela are determined to a large degree by the hydrologic characteristics of northern West Virginia and to a lesser degree, Garrett County, Maryland. Indeed, a mere 30% of the Monongahela River flow at the mouth (Pittsburgh) originates from within Pennsylvania (27). Stream flow characteristics for the Monongahela Basin, determined at USGS gaging stations for the period of record prior to and including water year 1976, are presented in Table 2.1.5.-12. Table 2.1.5.-13 depicts flow-duration characteristics as determined for specified years at many of the USGS stations.

It is readily apparent from the aforementioned tables that, despite existing navigation and flood-control projects, the Monongahela and Youghiogheny are capable of wide flow variations. However, the seasonal flow variation of the smaller, uncontrolled tributaries is even more dramatic. Many of these tributaries are swollen, turbulent white-waters in the spring and mere trickles during the late

TABLE 2.1.5. - 12

HYDROLOGIC CHARACTERISTICS OF

MONONGAHELA BASIN STREAMS

USGS STATION NUMBER	STREAM	LOCATION*	DRAINAGE AREA @ GAGE (SQ.MI.)	PERIOD OF RECORD	AVERAGE ** DISCHARGE(cfs)	INSTANTANEOUS MAXIMUM (cfs) AND DATE (mo/yr)	MINIMUM DAILY (cfs) AND DATE (mo/yr)	INSTANTANEOUS MINIMUM (cfs) AND DATE (mo/yr)	AVERAGE ANNUAL RUNOFF (in.)
630	Monongahela R.	Point Marion	2,720	1929-55	4,494	90,400-3/36	235-2/40	---	---
720	Dunkard Cr.	Shannopin	229	1910-76	272	16,800-6/41	---	0.4-8/44	16.13
725	Monongahela R.	Greensboro	4,407	1938-76	8,089	134,000-3/67	204-9/46	---	24.93
725.9	Georges Cr.	Smithfield	16.3	1963-76	19.2	1,640-6/72	---	0-8/65,9/66	16.00
728.4	Tenmile Cr.	Clarksville	133	1968-76	149	20,200-9/75	---	1.4-9/73	15.21
730	South Fork Tenmile Cr.	Jefferson	180	1931-76	199	13,800-6/41	---	0.05-9/38	15.01
745	Redstone Cr.	Waltersburg	73.7	1942-76	98.5	8,660-6/72	---	4.2-8/62	18.15
750	Monongahela R.	Charleroi	5,213	1933-76	8,975	158,000-3/67	---	---	23.38
755	Youghiogheny R.	Oakland, Md.	134	1942-76	291	11,800-10/54	2.5-10/53	---	29.49
765	Youghiogheny R.	Friendsville, Md.	295	1899-1904 1941-76	637	13,000-10/54	8.2-9/66	---	29.32
775	Youghiogheny R.	Below dam	436	1939-76	859	13,700-5/48	---	~0-5,6/50[1]	26.76
780	Casselman R.	Grantsville, Md.	62.5	1948-76	117	8,400-10/54	---	0-8/62	25.42
790	Casselman R.	Markleton	382	1920-76	652	50,000-10/54	---	10-9/57	23.18
800	Laurel Hill Cr.	Ursina	121	1918-76	266	10,900-10/54	---	2.2-9/32	29.85
810	Youghiogheny R.	Confluence	1,029	1941-76	1,965	69,500-10/54	121-9/43	40-10/43	25.93
825	Youghiogheny R.	Connellsville	1,326	1909-76	2,548	103,000-10/54	---	11-9/08;10/10	26.09
835	Youghiogheny R.	Sutersville	1,715	1920-76	2,995	108,000-10/54	---	57-9/22	23.72
845	Turtle Cr.	Trafford	121	1920-52	76.8	5,200-5/46	---	0.1-10/22;9/39	---
850	Monongahela R.	Braddock	7,337	1938-76	12,300	201,000-6/41	703-9/46	559-9/46	22.77

* Pennsylvania locations unless otherwise noted
** Monongahela and Youghiogheny flows adjusted for storage
1. Reservoir gates closed

SOURCE: Adapted from U.S. Geol. Survey (21).

T A B L E 2.1.5. - 13

FLOW DURATION CHARACTERISTICS OF THE STREAMS IN THE MONONGAHELA RIVER BASIN

Discharge in cubic feet per second which was equaled or exceeded for indicated percentage of time.

STREAM	STATION	YEARS OF RECORD USED	2	5	10	20	30	40	50	60	70	80	90	95	98
Monongahela R.	L/D8, Point Marion	1929 -54	21,000	15,000	11,000	7,300	5,000	3,500	2,400	1,700	1,200	780	570	470	380
Monongahela R.	Greensboro	1940 - 60	35,000	26,000	20,000	13,000	9,200	6,600	4,600	3,300	2,300	1,500	900	640	480
Monongahela R.	Charleroi	1934 - 60	42,000	29,000	22,000	14,000	9,900	7,000	4,900	3,600	2,500	1,700	1,000	740	550
Monongahela R.	Braddock	1940 - 60	52,000	38,000	29,000	20,000	14,000	10,600	7,600	5,800	4,100	2,900	2,000	1,600	1,200
Youghiogheny R.	Dam	1939 - 60	3,500	2,400	1,700	1,200	890	730	630	540	450	330	220	160	120
Youghiogheny R.	below Confluence	1941 - 60	7,700	5,700	4,300	2,800	2,100	1,600	1,200	1,000	850	680	500	350	250
Youghiogheny R.	Connellsville	1910 - 60	12,000	8,000	5,700	3,800	2,700	2,000	1,500	1,200	850	590	350	220	130
Youghiogheny R.	Sutersville	1921 - 60	13,000	9,000	6,700	4,400	3,200	2,500	1,800	1,400	1,100	800	510	380	260
Casselman R.	Markleton	1921 - 60	3,600	2,300	1,500	940	660	470	330	230	150	94	50	32	21
Laurel Hill Creek	Ursina	1919 - 63	1,400	920	630	390	280	200	140	100	68	42	22	14	8.8
Dunkard Creek	Shannopin	1942 - 60	2,100	1,200	680	360	230	150	96	56	31	15	5.6	2.9	1.8
South Fork Tenmile	Jefferson	1932 - 60	1,500	830	480	260	160	100	64	35	19	8.3	2.5	1.2	0.7
Redstone Creek	Waltersburg	1943 - 60	480	300	210	140	110	82	62	47	35	28	23	19	16
Turtle Creek	Trafford	1920 - 52	510	300	180	100	70	48	32	21	13	7.4	3.8	2.3	1.3

SOURCE: Adapted from Busch and Shaw (28).

summer and early fall.

In terms of velocity, the Monongahela main channel maximum (100-year flood) is approximately 11 feet per second. Although published averages of velocity for the 7 day, 10-year low flow do not exist, they are estimated at 0.3 feet per second (10).

Approximately 25% of the Monongahela's mean discharge at Pittsburgh (12,500 cfs) originates from within the Youghiogheny Basin (29). This percentage becomes substantially greater during periods of low flow in the Monongahela main stem (15). At base flow, the Monongahela River is naturally a low-yielding stream. Youghiogheny River water is generally of better quality than that of the Monongahela. Consequently, flow contributions from the Youghiogheny tend to ameliorate the downstream-trend of water quality deterioration in the Monongahela.

Runoff from approximately 94% of the Upper Monongahela Basin (West Virginia and Maryland) enters ORBES Pennsylvania via the Monongahela main stem, the Cheat River, and the Youghiogheny River Lake (27). The average annual runoff within Sub-basin #19 varies from 14 inches in the west to 28 inches in the east with an area mean of about 19 inches. However, the mean annual runoff for the entire Monongahela Basin is 22.5 inches. Table 2.1.5.-12 includes annual runoff figures for specific sites (USGS gaging stations) in the Monongahela Basin.

2. The Allegheny Basin

The nine Corps of Engineers' reservoirs and to a lesser extent, the Piney Reservoir influence the hydrology of the basin by reducing flood flows by storage of water during periods of heavy rainfall and/or intense snowmelt. The Allegheny, Woodcock Creek, and East Branch Reservoirs are also operated to provide low flow augmentation by the release of stored water during periods of minimal surface run-off. The basin reservoirs (excepting the Allegheny Reservoir*), when considered individually, have little influence on the flow of the lower Allegheny River (9).

*The Allegheny Reservoir has large storage capacities for flood control and low flow augmentation.

Consequently, the Corps manages its facilities as an integrated system, thereby obtaining a substantial cumulative effect upon flows in the Allegheny main stem. Nonetheless, several individual reservoirs do indeed regulate flow appreciably in some of the Allegheny's tributaries.

The flow of the Allegheny main stem is determined largely by the hydrologic characteristics of the northern portion of the basin, including the effects of the Allegheny Reservoir. However, 12% of the average discharge at Pittsburgh originates within the Kiskiminetas watershed (29). This flow contribution is significant since acid mine drainage originating in the Kiskiminetas Basin has a detrimental effect on water quality and aquatic ecology in the lower Allegheny.

Decreases in stream gradient and changes in channel conformation hydraulically serve to reduce stream velocity in the lower reach of a river. The navigation dams in the lower Allegheny intensify this phenomenon. Under major flood conditions (100-year flood), the maximum velocity in the slackwater pools is approximately 8-9 feet per second, whereas the maximum velocity of the upper Allegheny is almost 15 feet per second (9). Under low flow conditions (7-day, 10-year low flow), the maximum velocity of the Allegheny in New York is approximately 7.8 miles per day (23). Low flow velocities for the lower Allegheny are estimated to be on the order of 5 miles per day or lower (9).

The hydrologic characteristics of streams in the Allegheny Basin as determined at USGS gaging stations are presented in Table 2.1.5.-14. Table 2.1.5.-15 depicts the flow-duration characteristics of selected basin waterways at many of these same USGS stations; changes in flow-duration are included for several stations before and after the construction of east Branch, Piney, and Crooked Creek Reservoirs. Table 2.1.5.-16 characterizes the flow-duration of the Allegheny main stem at the Natrona gage (river mile 24.3).

Average annual runoff within the Allegheny Basin ranges from approximately 18

TABLE 2.1.5. - 14

HYDROLOGIC CHARACTERISTICS OF
ALLEGHENY RIVER BASIN STREAMS

USGS STATION NUMBER	STREAM	LOCATION	DRAINAGE AREA @ GAGE (sq. mi.)	PERIOD OF RECORD (wtr. yr.)	AVERAGE[1] DISCHARGE(cfs)	INSTANTANEOUS MAXIMUM (cfs) AND DATE (mo/yr)	MINIMUM DAILY (cfs) AND DATE (mo/yr)	INSTANTANEOUS MINIMUM (cfs) AND DATE (mo/yr)	AVERAGE ANNUAL RUNOFF (in)
0105.	Allegheny R.	Eldred	550	1939-76	941	65,400-6/72	---	22-9/59	23.23
0110.2	Allegheny R.	Salamanca, NY	1,608	1903-76	2,777	73,000-6/72	79-9/71	---	23.45
0118	Kinzua Cr.	Guffey	46.4	1965-76	76.8	5,220-6/72	---	4.0-9/66	22.48
0125.5	Allegheny R.	Below Dam	2,180	1935-76	3,803	60,500-3/56	---	---	23.69
0150	Conewango Cr.	Russell	816	1939-76	1,475	14,400-4/47	57-10/60	---	24.54
0152.8	Jackson Run	North Warren	12.8	1962-76	23.4	1,020-3/72	---	0.4-10/63	24.87
0155	Brokenstraw Cr.	Youngsville	321	1909-76	579	18,000-3/13	---	19-10/34	24.50
0160	Allegheny R.	West Hickory	3,660	1941-76	6,519	101,000-3/56	---	---	24.19
0175	Tionesta Cr.	Lynch	233	1937-76	457	15,000-1/59	---	11-8/62	24.94
0200	Tionesta Cr.	Below Dam	479	1941-76	869	13,500-3/64	0.4-2,5,6/68	---	24.64
0205	Oil Cr.	Rouseville	300	1933-76	526	21,000-1/59	---	22-7,9/34	23.81
0215.2	French Cr.	Union City	220	1909-76	422	20,000-4/47	---	3.9-8/30	26.05
0240	French Cr.	Utica	1,028	1933-76	1,770	23,800-3/64	---	43-7/34	23.38
0250	Sugar Cr.	Sugarcreek	166	1933-76	270	10,000-5/46	---	9.2-10/35	22.09
0252	Patchel Run	Franklin	5.69	1965-76	8.91	1,650-7/72	---	0.42-10/66	21.26
0255	Allegheny R.	Franklin	5,982	1914-76	10,370	138,000-3/20	---	334-7/34	23.54
0275	East Br. Clarion R.	Below Dam	73.2	1948-76	133	2,590-5/57	0.40-7/69	0.20-7/69	25.04
0280	West Br. Clarion R.	Wilcox	63.0	1953-76	122	5,490-9/67	---	4.2-9/55	26.30
0285	Clarion R.	Johnsonburg	204	1945-76	377	11,700-5/46	20-10/48	6-9/52	25.10
0294	Toms Run	Cooksburg	12.6	1959-76	19.1	656-3/64	0.31-8/71	---	20.59
0295	Clarion R.	Cooksburg	807	1938-76	1,434	53,300-6/72	---	41-8/39	24.13
0305	Clarion R.	Piney	951	1944-76	1,745	74,500-6/72	---	---	24.92
0315	Allegheny R.	Parker	7,671	1932-76	13,220	175,000-1/59	---	409-7/34	23.40
0325	Redbank Cr.	St. Charles	528	1918-76	856	50,000-3/36	---	19-10/18	22.02
0340	Mahoning Cr.	Punxsutawney	158	1938-76	273	17,300-6/72	---	2.6-9/39	23.46
0345	Little Mahoning Cr.	McCormick	87.4	1939-76	150	6,200-6/72	---	0.3-9/59	23.31
0360	Mahoning Cr.	Below Dam	344	1939-76	589	10,400-3/42	---	8.8-9/59	23.25
0365	Allegheny R.	Kittanning	8,973	1905-28, 1934-76	15,570	269,000-3/13	---	570-9/13	23.56
0380	Crooked Cr.	Idaho	191	1937-76	287	13,200-6/72	1.0*-10/66	---	20.41
0390	Crooked Cr.	Below Dam	278	1909-76	421	21,000-3/36	---	0.1-9/32	20.57
0400	Stony Cr.	Ferndale	451	1938-76	765	59,000-3/36	---	5-9/29	23.03
0410	Little Conemaugh R.	East Conemaugh	183	1940-76	322	16,600-6/72	---	3.4-9,10/63	23.90
0415	Conemaugh R.	Seward	715	1939-76	1,265	54,000-10/54	105-12/38	---	24.03
0420	Blacklick Cr.	Josephine	192	1952-76	360	20,800-6/72	---	19-9/52,11/53	25.46
0422.8	Yellow Cr.	Homer City	57.4	1967-76	107	4,100-6/72	---	1.4-7/69	25.32
0425	Two Lick Cr.	Graceton	171	1952-76	276	19,600-6/72	8.7-9/52	2.0-9/52	21.92
0440	Conemaugh R.	Tunnelton	1,358	1939-76	2,349	59,200-3/45	1-9/54	1-9/54	23.49
0450	Loyalhanna Cr.	Kingston	172	1939-76	301	29,700-10/54	0.2-10/53	0.1-9/53	23.76
0470	Loyalhanna Cr.	Below Dam	292	1939-76	480	11,700-6/41	0.2-10/47	0.2-10/47,9/48	22.32
0485	Kiskiminetas R.	Vandergrift	1,825	1938-76	3,058	71,900-3/40	60-10/52	56-10/52	22.75
0490	Buffalo Cr.	Freeport	137	1940-76	190	14,000-10/54	---	1.3-10/60	18.83
0495	Allegheny R.	Natrona	11,410	1938-76	19,240	238,000-12/42	---	895-10/63	22.90

* Result of Abnormal Regulation

1. Stations downstream of impoundments regulated for storage

SOURCE: Adapted from U.S. Geol. Survey (21).

TABLE 2.1.5.-15

FLOW DURATION CHARACTERISTICS
OF THE STREAMS IN THE
ALLEGHENY RIVER BASIN

STREAM	STATION	YEARS OF RECORD USED	Discharge in cubic feet per second which was equaled or exceeded for indicated percentage of time. 2	5	10	20	30	40	50	60	70	80	90	95	98
Tionesta Cr.	Below Dam	1941-60	4,900	3,300	2,300	1,400	930	710	440	240	200	120	76	58	42
Oil Cr.	Rouseville	1933-60	3,000	1,900	1,200	740	510	360	270	190	140	90	54	44	36
French Cr.	Utica	1933-60	8,800	6,200	4,400	2,800	1,900	1,300	910	620	410	240	140	110	84
Sugar Cr.	Sugarcreek	1933-60	1,500	950	610	380	270	190	140	100	72	48	32	25	21
Allegheny R.	Franklin	1931-63	49,000	35,000	26,000	16,000	11,000	7,900	5,400	3,800	2,600	1,600	1,000	770	640
E. Br. Clarion	Below Dam	1949-52	720	490	360	240	180	130	90	56	29	18	12	9.5	8.0
		1953-60	500	290	240	210	170	130	83	45	28	22	18	16	14
W. Br. Clarion	Wilcox	1954-60	610	400	280	180	130	96	77	57	41	25	14	10	6.4
Clarion R.	Johnsonburg	1946-52	2,100	1,400	980	630	470	340	220	160	95	57	35	29	26
		1953-60	1,600	1,000	720	470	380	310	250	230	200	160	100	45	32
Clarion R.	Ridgway	1941-53	3,000	2,000	1,400	900	620	440	310	230	160	92	54	42	35
Clarion R.	Cooksburg	1939-52	7,500	4,900	3,500	2,300	1,600	1,100	800	540	360	220	130	100	78
		1953-60	6,100	4,200	3,100	2,100	1,600	1,200	920	690	520	380	270	150	97
Clarion R.	Piney	1949-52	9,600	6,800	4,900	3,200	2,300	1,600	1,100	680	350	170	64	30	26
		1953-60	7,500	5,300	3,900	2,600	1,900	1,400	1,100	800	560	370	130	27	24
Clarion R.	St. Petersburg	1942-53	11,000	7,500	5,500	3,600	2,600	1,800	1,200	840	540	330	170	97	66
Redbank Cr.	St. Charles	1919,1922-57	4,600	3,100	2,100	1,300	840	580	400	270	180	110	72	53	41
Mahoning Cr.	Punxsutawney	1939-60	1,400	910	620	400	280	200	140	100	68	44	29	24	20
Little Mahoning	McCormick	1940-60	900	560	360	220	150	100	70	47	30	15	6.6	3.9	2.4
Mahoning Cr.	Below Dam	1939-60	3,100	2,000	1,500	890	600	420	290	200	140	85	46	31	22
Crooked Cr.	Idaho	1938-60	1,800	1,100	710	410	270	190	130	84	53	31	16	11	7.7
Crooked Cr.	Below Dam	1919-40	2,800	1,600	1,000	530	340	230	150	94	58	33	17	9.0	4.3
		1941-60	2,600	1,700	1,100	720	440	260	190	120	76	44	24	17	12
Stony Cr.	Ferndale	1914-35,40-60	3,700	2,400	1,600	970	650	450	310	220	150	94	50	31	21
Little Conemaugh R.	East Conemaugh	1940-60	1,500	930	640	420	290	200	140	96	66	42	20	13	8.8
Conemaugh R.	Seward	1939-60	5,900	4,000	2,800	1,800	1,300	920	670	530	420	330	250	210	190
Blacklick Cr.	Josephine	1953-60	1,800	1,100	850	540	370	260	180	130	95	68	43	34	29
Two Lick Cr.	Graceton	1951-60	1,500	960	650	400	280	200	140	90	59	38	22	17	14
Blacklick Cr.	Blacklick	1905,08-51	3,800	2,400	1,600	990	660	470	340	240	160	100	62	44	31
Loyalhanna Cr.	Kingston	1941-60	1,600	1,000	750	440	310	220	160	110	72	41	19	10	3.5
Kiskiminetas R.	Vandergrift	1938-60	14,000	10,000	7,200	4,700	3,300	2,400	1,700	1,300	900	650	440	360	290
Buffalo Cr.	Freeport	1941-60	1,200	730	470	280	190	130	90	59	35	19	9.2	6.6	4.9

SOURCE: Adapted from Busch and Shaw (28).

TABLE 2.1.5. - 16

FLOW - DURATION CHARACTERISTICS[a] OF THE ALLEGHENY RIVER AT NATRONA, PA.[b]

Discharge (cfs)	Percent of Time Flow Equaled or Exceeded
1,000	100.0
2,000	100.0
3,000	99.0
4,000	85.8
5,000	75.9
6,000	66.2
7,000	60.8
8,000	56.5
9,000	53.1
10,000	50.0
11,000	47.1
12,000	44.7
13,000	42.6
14,000	40.6
15,000	38.7
16,000	37.0
17,000	35.5
18,000	34.0
19,000	32.6
20,000	31.3

[a]For present conditions of development (April 1975)

[b]River Mile 24.3

SOURCE: U.S. Army Corps of Engineers (9).

inches in areas near Pittsburgh to sites yielding 26 inches at French Creek and the West Branch of the Clarion River (21,30). Table 2.1.5.-14 includes annual runoff figures for USGS stations within the basin. Runoff is more or less homogeneous in the upper portion of the basin; however, runoff tends to decrease from east to west in the middle and lower sections; reflecting changes in the distribution of precipitation (30, 31, 32).

3. The Upper Ohio Basin (Pa.)

Approximately 60% of the Ohio River's mean discharge at Pittsburgh is contributed by the Allegheny River, the remaining 40% is contributed by the Monongahela (29). The flow of the Ohio for its first 25 miles is chiefly governed by the contributions of these two streams since Chartiers Creek is the only other significant tributary to this reach.

At Rochester, the Beaver River makes a significant contribution (mean discharge = 3,250 cfs) to the flow of the Ohio River. The Beaver Basin is an intensively regulated area; it contains 713,000 acre-feet of storage space in a land area of 3,150 square miles. Flood control and low flow augmentation are dual purposes in the operation of five of the basin's seven major reservoirs. Milton Reservoir is operated for low flow augmentation alone (see Table 2.1.5.-11).

Table 2.1.-17 depicts the hydrologic characteristics of streams at the major USGS gaging stations in the Ohio and Beaver Basins. Table 2.1.-18 presents the flow-duration characteristics at many of these same stations. Flow-duration of the Ohio main stem at the Sewickley gage is graphed in Figure 2.1.5.-5.

Annual runoff within Sub-basin #20 ranges from 14 inches in the west to areas yielding approximately 20 inches in the east (24). However, individual sites, such as the Ohio River at Sewickley may yield annual runoffs as high as 22.5 inches. Table 2.1.5.-17 includes annual runoff data for this sub-basin.

TABLE 2.1.5. - 17

HYDROLOGIC CHARACTERISTICS OF
OHIO RIVER MAIN STEM AND TRIBUTARIES

USGS STATION NUMBER	STREAM	LOCATION*	DRAINAGE AREA @ GAGE (sq. mi.)	PERIOD OF RECORD (wtr yr.)	AVERAGE ** DISCHARGE(cfs)	INSTANTANEOUS MAXIMUM (cfs) AND DATE (mo/yr)	MINIMUM DAILY (cfs) AND DATE (mo/yr)	INSTANTANEOUS MINIMUM (cfs) AND DATE (mo/yr)	AVERAGE ANNUAL RUNOFF (in)
855	Chartiers Cr.	Carnegie	257	1919-33, 1940-76	287	13,500-8/56	---	16-8/26,9/32	15.17
860	Ohio R.	Sewickley	19,500	1933-76	32,370	574,000-3/36	---	1,800-9/57	22.54
861	Big Sewickley Cr.	Ambridge	15.6	1967-76	17.7	2,540-7/75	---	0-often	15.41
1015	Shenango R.	Pymatuning Dam	167	1935-76	199	1,540-9/37	---	0.1-6/34	16.18
1025	Little Shenango R.	Greenville	104	1913-76	140	8,540-1/59	---	2.9-7/34	18.28
1028.5	Shenango R.	Transfer	337	1965-76	455	5,200-2/76	---	33-7/68	18.34
1035	Shenango R.	Sharpsville	584	1938-76	726	15,700-1/59	43-9/41	---	16.88
1055	Beaver R.	Wampum	2,235	1915-18, 1933-76	2,394	50,100-5/46	97-7,8/33	74-7/33	14.55
1060	Connoquenessing Cr.	Zelienople	356	1919-76	467	23,000-6/24	---	6-7/36	17.81
1065	Slippery Rock Cr.	Wurtemburg	398	1911-76	563	19,000-1/37	---	16-9/32	19.21
1075	Beaver R.	Beaver Falls	3,106	1935-76	3,545	69,900-1/59	---	---	15.50
1080	Raccoon Cr.	Moffatts Mill	178	1942-76	190	8,590-1/52	---	4.5-8/65	14.50
1111.5	Brush Run	Buffalo	10.3	1961-76	9.26	1,180-2/66	---	0-often	12.21
1300	Conneaut Cr.	Conneaut, OH	175	1923-34, 1950-61	257	17,000-1/59	---	0.2-7,8/33,8/34	19.95

* Pennsylvania locations unless otherwise designated
** Adjusted for storage where applicable

SOURCE: Adapted from U.S. Geological Survey (21).

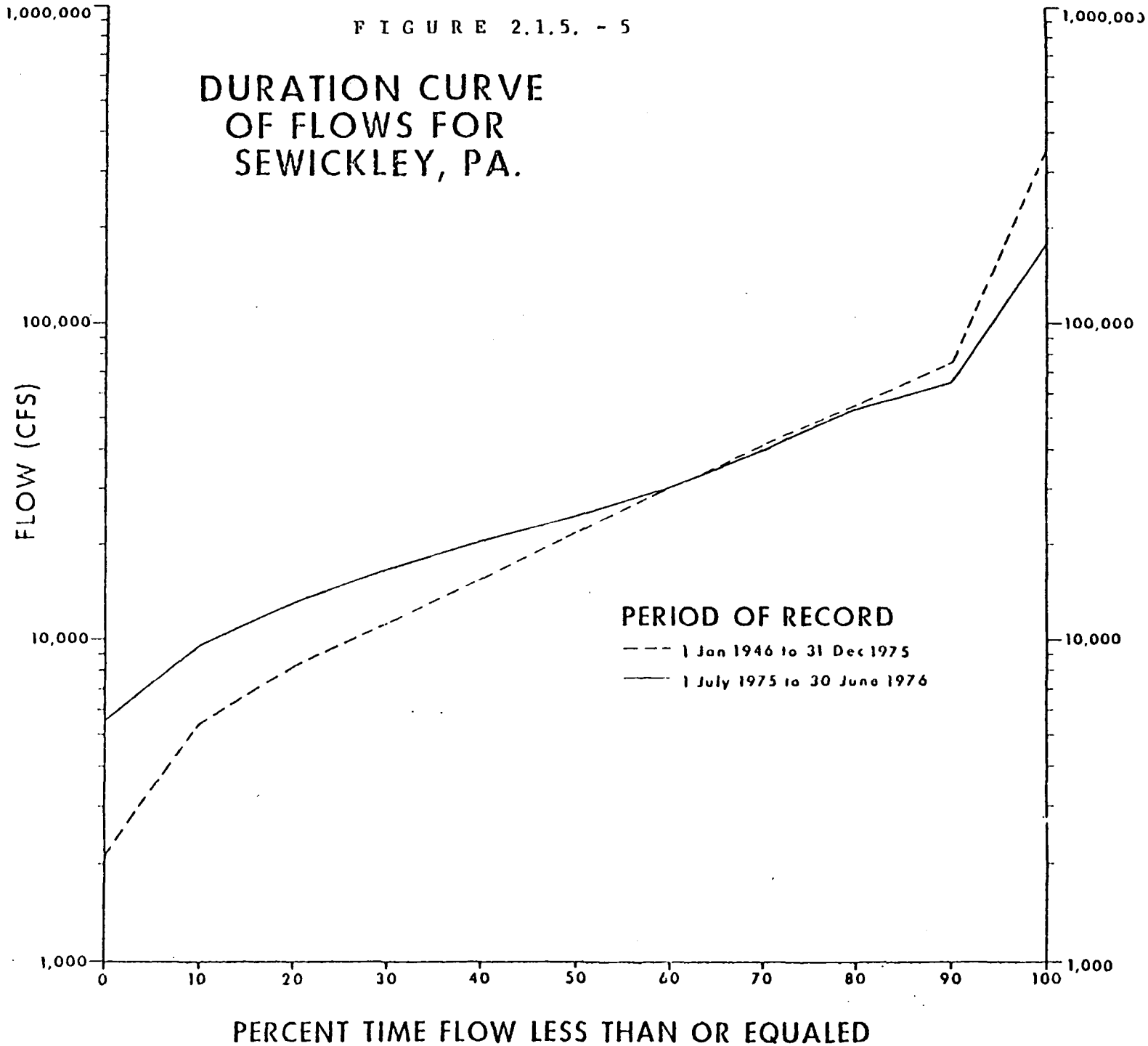
TABLE 2,1,5. - 18

FLOW DURATION CHARACTERISTICS
OF THE STREAMS IN THE
UPPER OHIO BASIN (PA.)

STREAM	STATION	YEARS OF RECORD USED	Discharge in cubic feet per second which was equaled or exceeded for indicated percentage of time.												
			2	5	10	20	30	40	50	60	70	80	90	90	98
Shenango River	Turnerville	1913-22	1,300	730	470	280	170	110	77	53	30	16	8.7	6.7	5.1
Sugar Run	Pymatuning Dam	1941-60	92	46	25	12	7.0	4.3	2.5	1.3	0.6	0.3	0.08	0.02	0
Shenango R.	Pymatuning Dam	1935-60	850	680	500	280	220	190	150	110	75	36	10	3.8	2.0
Shenango R.	Jamestown	1920-33	1,200	840	600	370	230	140	96	58	32	16	8.2	5.4	4.0
Little Shenango	Greenville	1915-60	880	550	330	190	120	86	61	42	28	18	11	8.3	6.5
Shenango R.	Sharpsville	1939-60	3,600	2,400	1,800	1,100	770	510	360	290	250	210	170	130	110
Shenango R.	New Castle	1939-60	5,100	3,300	2,200	1,400	900	560	380	240	140	83	44	30	22
Beaver R.	Wampum	1933-60	13,000	8,300	5,700	3,300	2,200	1,600	1,200	980	820	630	450	340	220
Connoquenessing	Zelienople	1920-60	3,000	1,800	1,200	680	450	300	200	130	80	47	26	18	13
Slippery Rock	Wurtemburg	1912-63	3,100	2,000	1,400	840	540	370	260	170	120	84	59	47	38
Raccoon Cr.	Moffatts Mill	1942-60	1,100	700	460	290	200	140	98	68	47	31	19	14	10

SOURCE: Adapted from Busch and Shaw (28).

FIGURE 2.1.5. - 5



SOURCE: ORSANCO (33).

Travel times during various flow regimes in four reaches of the upper Ohio River upstream of Cincinnati, Ohio have been calculated by the U.S. Geological Survey (34). Figure 2.1.5.-6 graphs the average times of travel as a function of flow at Cincinnati for each of these reaches. During low flow conditions, however, such calculations may be inaccurate due to the effects of wind action, diffusion, and lock operation.

B. Extreme Conditions

1. Floods

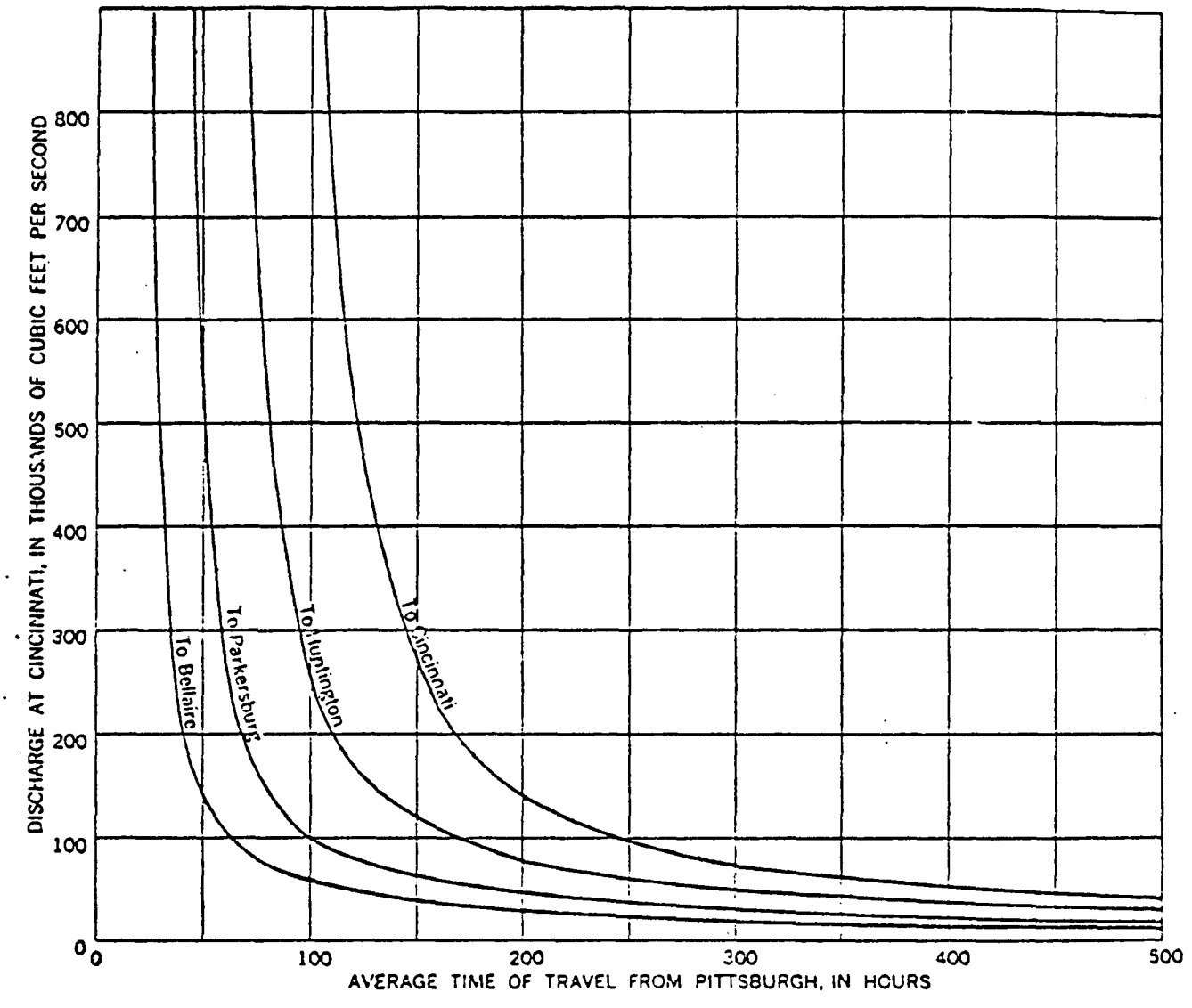
In the 46 years from 1900 to 1945, 64 floods occurred at Pittsburgh, an average of 1.4 floods* per year (35). Approximately 70% of these floods were experienced from January to March. Another analysis (3), extending back in time to 1885 has indicated that prior to the construction of flood-control reservoirs, Pittsburgh could anticipate high waters, which would cause at least minor flooding on an average of 1.3 times per year. Table 2.1.5.-19 lists the great floods of the major ORBES-Pennsylvania waterways from 1763 to 1963. Numerous floods of slightly less than maximum gage height have been purposely omitted to focus attention on the most severe episodes.

As early as 1912 the Pittsburgh Flood Commission had recommended construction of 17 flood-control reservoirs in the upper reaches of the Monongahela and Allegheny. However, no such projects were in operation in March of 1936 when the devastating and memorable "St. Patrick's Day Flood" hit Pittsburgh. Caused by a combination of river ice james, melting snow and rain, this flood remains the worst on record for the Pittsburgh metropolitan area. The flood crested at 46.0 feet, exceeding by 4.9 feet the previous record set in 1763. Although the upper reaches of the Monongahela and Allegheny rivers did not reach maximum flood stage, their tributaries near Pittsburgh (Red Bank Creek, Kiskiminetas River and Youghiogheny River were at record high levels concurrently (36).

*"Flood stage" is 25 feet at the Pittsburgh gage. No one knows exactly why this particular elevation was chosen; and it is meaningless today since no real damage occurs until the water level exceeds 27 feet, a level reached 43 times in the 46 year study period.

F I G U R E 2.1.5. -6

RELATION OF DISCHARGE AT CINCINNATI TO
AVERAGE TRAVEL TIME OF WATER FROM PITTSBURGH



SOURCE: U.S. Geological Survey (34).

TABLE 2.1.5. - 19

GREAT FLOODS ON MAJOR RIVERS
OF WESTERN PENNSYLVANIA

RIVER	STATION	DATES	GAGE HEIGHT (ft.)	COMMENTS
Monongahela	Charleroi	July 11, 1888 , 1887 March 18, 1936 October 16, 1954	26.1 24.5 22.47 21.07	Bankfull stage, 24' gage
Youghiogheny	Connellsville	August 21-22, 1888 March 14, 1907 March 29, 1924 March 18, 1936 October 16, 1954	17.8 18.4 20.5 20.28 21.96	Bankfull stage, 16' gage
Allegheny	Kittaning	April 10, 1806 March 18, 1865 February 5, 1883 March 20, 1905 March 26, 1913	30.0 29.5 29.0 28.8 30.7	Bankfull stage, 23' gage
Kiskiminetas	Avonmore	August 21, 1888 June 1, 1889 February 17, 1891 March 14, 1907 March 18, 1936	31.8 29.8 30.4 33.8 47.2	Floodstage, about, 27' gage
Ohio	Pittsburgh	March 9, 1763 February 10, 1832 February 6, 1884 March 15, 1907 March 18, 1936	41.1 38.0 36.3 38.5 46.0	Floodstage, about 25' gage

SOURCE: Adapted from Shank (36).

Total damages wrought by the 1936 flood were greater than any previous or subsequent water disasters in the Pennsylvania-ORBES region. The Duquesne Light Company's power generating system, although designed to operate under flood conditions greater than those of past records, was unable to provide normal service to the City of Pittsburgh for eight days (37).

Flood-control reservoirs in the Monongahela and Allegheny Basins reduce flood crests by 2-4 feet and 4-10 feet respectively in each of the main stems from what would be normally expected without such flood control measures (9, 10). It has been estimated that the St. Patrick's Day Flood would have had its crest reduced by 10.1 feet at Pittsburgh, if only the first eight flood control reservoirs to be constructed were in operation in 1936 (3). This analysis does not even consider the additional reduction that would be afforded today by the presence of the large Allegheny Reservoir. Nonetheless, despite structural flood control measures, flood damages have exhibited a tendency to increase along with urbanization. This trend has been ascribed mainly to inadequate enforcement of flood plain regulations (38).

Information on flood discharges from several floods in the Allegheny and Monongahela Basins is presented in Tables 2.1.5.-20 and 2.1.5.-21. Tables 2.1.5.-22 and 2.1.5.-23 relate flood flows to surface elevation in these two rivers.

An examination of recorded high flow maxima reveals that floods can occur at virtually any time of the year. However, studies of the relationships between factors influencing flood occurrence (storm duration, intensity, affected area, and seasonality) indicate that the large streams tend to flood in the winter whereas small tributaries have a propensity to produce summer floods. Reich (39) demonstrated by analysis that Pennsylvania watersheds greater than 100 square miles had up to one-third of their annual floods in March. Regional storms bring abundant precipitation to the area in late winter and early spring. Furthermore, runoff

T A B L E 2.1.5. - 20

ALLEGHENY RIVER
DISCHARGES FOR VARIOUS FLOODS

Station	Actual Discharge in 1,000 cfs			
	Jun. 1972	Jan. 1959	Mar. 1964	Mar. 1936
Lock and Dam No. 4 (Natrona Gage)	225.0	245.0	240.0	360.5
Lock and Dam No. 7 (Kittanning Gage)	189.3	207.7	213.8	201.9
Parker, Pa.	161.1	182.0	163.0	---
Franklin, Pa.	86.2	126.3	106.6	---

Source: U. S. Army Corps of Engineers (9).

T A B L E 2.1.5. - 21

MONONGAHELA RIVER
DISCHARGES FOR VARIOUS FLOODS

Station	Actual Discharge in 1000 cfs		
	June 1972	March 1967	March 1963
Lock & Dam No. 2 Braddock Gage	180.0	178.0	163.0
Lock & Dam No. 4 Charleroi Gage	130.9	158.0	154.0
Maxwell Lock & Dam	120.0	158.0	154.0
Lock & Dam No. 7 Greensboro Gage	107.0	145.0	134.5
Morgantown Lock & Dam	31.1	85.0	77.0

Source: U. S. Army Corps of Engineers (10)

TABLE 2.1.5. - 22

FLOOD FLOWS AND ELEVATIONS[a]
ALLEGHENY RIVER

Flood Frequency	Stations: Lock & Dam No. 4 Natrona Gage	Lock & Dam No. 7 Kittanning Gage	Parker, Pa. Gage	Franklin, Pa. Gage
1 year flow (cfs)	93,000	90,000	70,000	50,400
Upper pool elevation (ft. above msl)	753.6	790.9	858.3	968.1
5 year flow (cfs)	139,000	132,500	107,000	72,000
Upper pool elevation (ft. above msl)	756.8	793.6	862.3	970.7
50 year flow (cfs)	210,000	196,000	157,000	110,000
Upper pool elevation (ft. above msl)	762.1	797.0	867.1	974.5
100 year flow (cfs)	233,000	215,500	173,000	121,500
Upper pool elevation (ft. above elevation)	763.4	798.2	868.3	975.8

[a]Flows and elevations based on existing basin development and existing river conditions (April 1975).

SOURCE: Adapted from U. S. Army Corps of Engineers (9).

TABLE 2.1.5. - 23

FLOOD FLOWS AND ELEVATIONS[a]
MONONGAHELA RIVER

Flood Frequency	Stations: Lock & Dam No. 2 Braddock Gage	Lock & Dam No. 4 Charleroi Gage	Lock & Dam No. 7 Greensboro Gage	Maxwell L/D	Morgantown L/D
1 year flow (cfs)	104,900	82,000	73,000	79,300	33,000
Upper pool elevation (ft. above msl)	730.0	745.4	788.2	---	---
Lower pool elevation (ft. above msl)	---	---	---	758.6	802.5
5 year flow (cfs)	145,000	119,300	107,500	115,800	55,000
Upper pool elevation (ft. above msl)	733.0	751.2	791.8	---	---
Lower pool elevation (ft. above msl)	---	---	---	765.4	806.7
50 year flow (cfs)	205,000	167,000	157,000	164,000	92,000
Upper pool elevation (ft. above msl)	738.4	757.8	798.2	---	---
Lower pool elevation (ft. above msl)	---	---	---	773.2	812.5
100 year flow (cfs)	220,800	182,500	168,000	178,100	104,000
Upper pool elevation (ft. above msl)	740.1	759.6	799.4	---	---
Lower pool elevation (ft. above msl)	---	---	---	775.3	814.0

[a]Flows and elevations based on existing basin development and existing river conditions (April 1975)

SOURCE: U.S. Army Corps of Engineers (10)

(snowmelt often included) is high due to the impervious state of the soil (saturated or frozen). Conversely, small watersheds were shown to have their highest probability of flooding in August. Such findings support the notion that small tributary basins are susceptible to flash-flooding from local summer thundershowers.

Flash-floods are often partially attributed to steep topography. However, land use can substantially modify this tendency. Although the Allegheny Mountain Section of the Monongahela Basin is steeper than the Pittsburgh Plateau Section, a study comparing equivalent drainage areas in each section revealed insignificant differences in flood response (40). The higher degree of forestation in the more mountainous area is believed to be the equalizing factor. The effects of forest cover on hydrology are discussed in greater detail in Section 2.1.4. (Terrestrial Ecology).

2. Low Flow

Stream flow in the Appalachian Region is generally quite plentiful, averaging about 350 million gallons per year per square mile of drainage basin (41). Although low flow augmentation is a consideration in the release schedules of ten reservoirs that regulate stream flow in the Pennsylvania ORBES region, area waterways are nevertheless capable of developing flow deficiencies during periods of drought. An analysis of the annual cyclical variations in stream flow reveals that low flow conditions are most likely to occur in the late summer and early fall (August, September, October). Most USGS stations have their record minima logged for these months (see Tables 2.1.5.-12, 2.1.5.-14, 2.1.5.-17). When drought conditions persist, surface runoff is virtually nonexistant and small unaugmented streams rely almost totally on ground water for their flow. Unfortunately, the level of ground water storage is typically also at its lowest level during this time of the year.

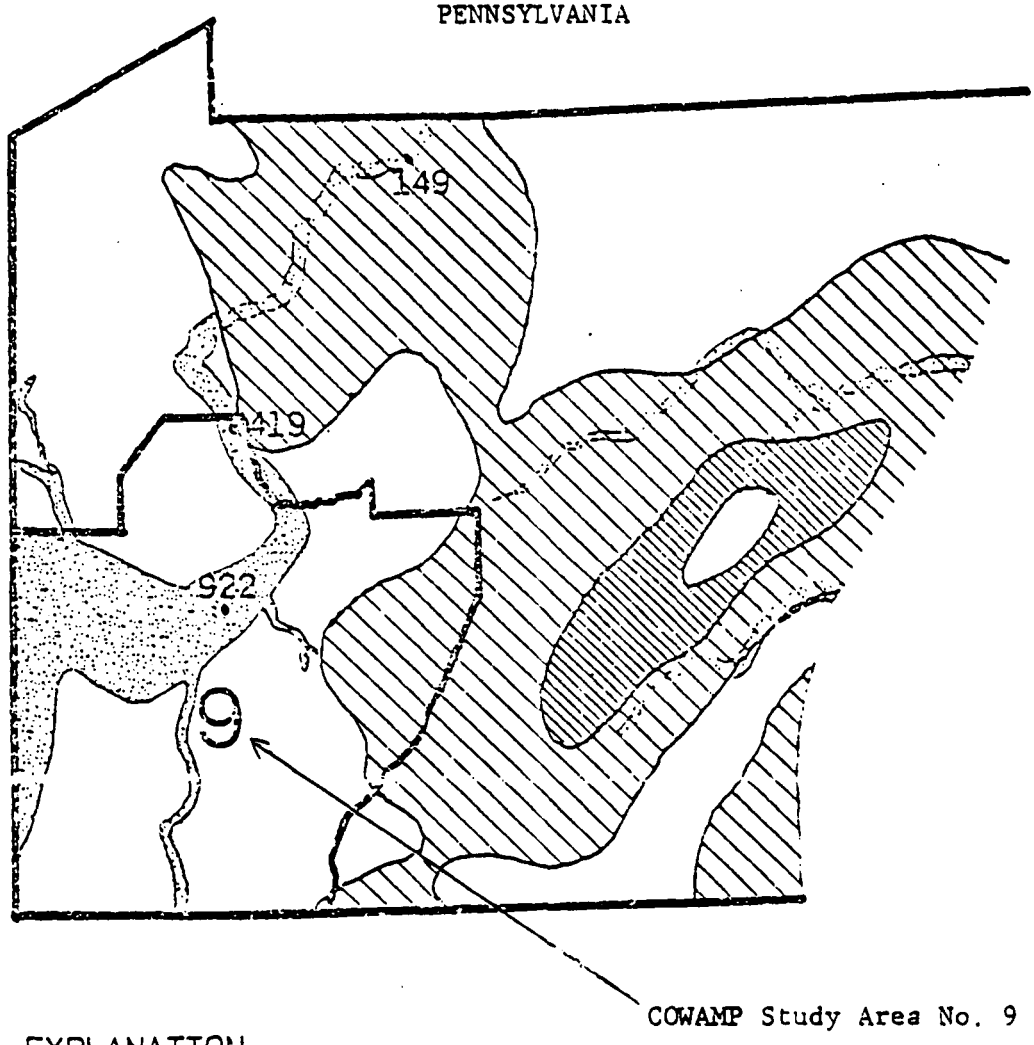
Minimum stream flows may vary substantially from one year to the next. Variations in low flow usually range from zero to about 1.2 cfs/sq. mi. within a two year period. A generalized geographic distribution pattern of average annual low flows is presented in Figure 2.1.5.-7.

The 7-day, 10-year low flow is a widely used basis for allocating waste loadings to a stream; it represents the flow expected to occur annually with a ten percent probability. Estimations of such flows for sites in each of the basins are given in Tables 2.1.5.-24, 2.1.5.-25 and 2.1.5.-26. More detailed statistical manipulations of low flow data including low flow frequency curves, yield-storage-frequency relationship curves, and low flows for various durations and recurrence intervals are available in two publications (28, 44) of the Pennsylvania Department of Environmental Resources.

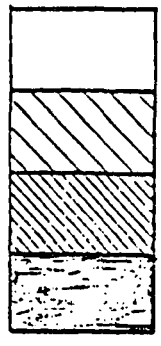
The Ohio River Valley Water Sanitation Commission (ORSANCO) has noted that the activities of the Corps of Engineers have increased the 7-day, ten-year low flow of the Ohio River. Likewise, the minimum 7-day running averages of flow at Sewickley, Pennsylvania (r.m. 11.8) have been increased since 1967 due to the operation of the Allegheny Reservoir (see Fig. 2.1.5.-8). However, the 7-day running averages of flow at Sewickley have remained unaffected by releases from this large impoundment (see Fig. 2.1.5.-9). Moreover, trend analysis extending from 1953 to 1975 indicates no net change in flow.

F I G U R E 2.1.5. - 7

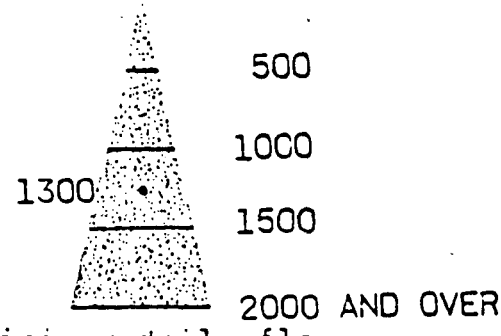
LOW FLOW VARIABILITY IN WESTERN PENNSYLVANIA



EXPLANATION



Average annual low flows* in cfs per sq. mi.



Minimum daily flow in cfs. Selected recorded values are shown.

* The flow below which a stream can be expected to recede on an average of every other year.

SOURCE: Green International, Inc. (41).

TABLE 2.1.5. - 24

7-DAY, 10-YEAR LOW FLOWS
IN THE MONONGAHELA RIVER BASIN

USGS Station Number	Stream	Location*	7 Day, 10 Year Low Flow
---	Monongahela R.	Pa.-W.Va. State Line	330
720	Dunkard Cr.	Shannopin	0.6
---	Cheat R.	Below Lake Lynn	38
725	Monongahela R.	Greensboro	400
730	South Fork Ten Mile Cr.	Jefferson	0.2
745	Redstone Cr.	Waltersburg	13
750	Monongahela R.	Charleroi	420
765	Youghiogheny R.	Friendsville, Md.	47
---	Youghiogheny R.	Above Reservoir	50
780	Casselman R.	Grantsville, Md.	1.0
790	Casselman R.	Markleton	14
800	Laurel Hill Cr.	Ursina	4.6
810	Youghiogheny R.	Confluence	220
825	Youghiogheny R.	Connellsville	240
---	Youghiogheny R.	Above Jacobs Cr.	245
835	Youghiogheny R.	Sutersville	310
---	Monongahela R.	Above Yough. R.	310
845	Turtle Cr.	Trafford	0.6
850	Monongahela R.	Braddock	1,000
---	Monongahela R.	Near Mouth	1,010

*Pa. location unless specified otherwise

---Extrapolations from existing USGS stations

SOURCE: Busch and Shaw (28) and Ohio River Basin Commission (42).

TABLE 2.1.5. - 25

7 DAY, 10 YEAR LOW FLOWS
IN THE
ALLEGHENY RIVER BASIN

USGS Station Number	Stream	Location*	7 Day, 10 Year Low Flows[a]	7 Day, 10 Year Low Flows[b]	Natural 7 Day, 10 Year Low Flows[c]
105	Allegheny R.	Eldred	23		
205	Oil Cr.	Rouseville	28		
240	French Cr.	Utica	60		
250	Sugar Cr.	Sugarcreek	15		
255	Allegheny R.	Franklin		2,500	470
280	West Br. Clarion R.	Wilcox	4.2		
	Clarion R.	Ridgway	26		
	Clarion R.	St. Petersburg	53		
325	Redbank Cr.	St. Charles	30		
340	Mahoning Cr.	Punxsutawney	15		
365	Allegheny R.	Kittanning		2,700	750 - 778
390	Crooked Cr.	Below Dam	4.3		
415	Conemaugh R.	Seward	165		
420	Blacklick Cr.	Josephine	25		
	Blacklick Cr.	Blacklick	23		
	Loyalhanna Cr.	New Alexandria	14		
490	Buffalo Cr.	Freeport	3.1		
495	Allegheny R.	Natrona		2,900	900 - 1,096

*Pennsylvania

SOURCES: a.) Busch and Shaw (28), periods of analysis specified therein; b.) U.S. Army Corps of Engineers (9); c.) Fed. Wtr. Poll. Cntrl. Admin.(14) and the U.S. Army Corps of Engineers (9), represents low flows without augmentation from reservoirs.

TABLE 2.1.5. - 26

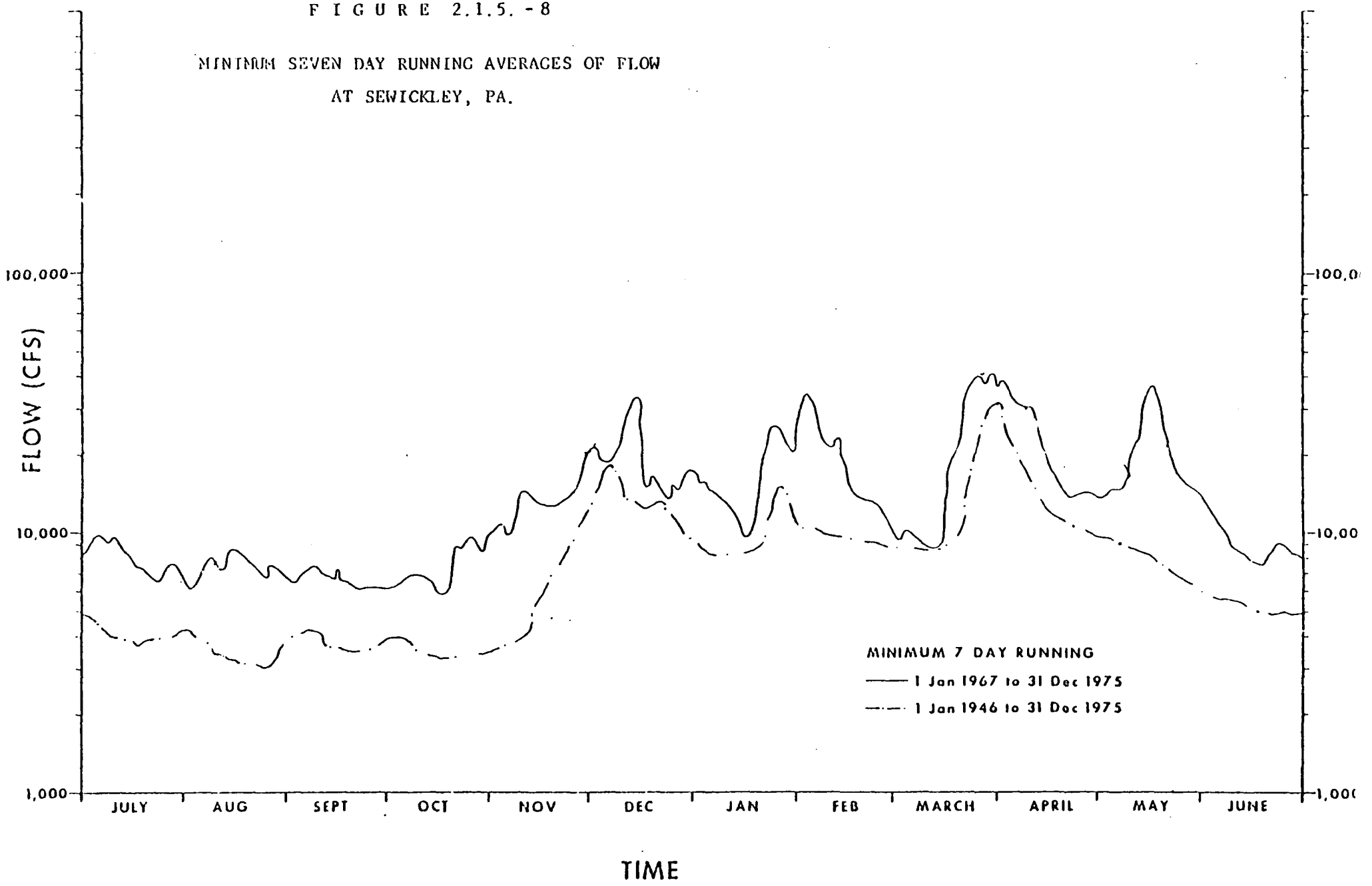
7 DAY, 10 YEAR LOW FLOWS
IN THE UPPER OHIO AND BEAVER BASINS

USGS Station Number	Stream	Location	7 Day, 10 Year Low Flow[a]	7 Day, 10 Year Low Flow[b]	Natural 7 Day, 10 Year Low Flow[c]
---	Ohio R.	Pittsburgh	5,050	6,555	
855	Chartiers Cr.	Carnegie	25		
860	Ohio R.	Sewickley		6,600	1,800
861	Big Sewickley Cr.	Ambridge	0.0		
995	Mahoning R.	Lowellville, OH	290		
1015	Shenango R.	Pymantuning Dam	14		
1025	Little Shenango R.	Greenville	5.4		
1028.5	Shenango R.	Transfer	29		
1035	Shenango R.	Sharpsville	81		
1055	Beaver R.	Wampum	270		
1060	Connoquenessing Cr.	Zelienople	10		
1065	Slippery Rock Cr.	Wurtemburg	30		
1075	Beaver R.	Beaver Falls	560		
1080	Raccoon Cr.	Moffatts Mill	7.4		
1111.5	Brush Run	Buffalo	0.0		

*Pa. location unless otherwise specified.
---Extrapolation from existing USGS stations.
a. The existing 7 day, 10 year low flow is that provided by the Army and represents the flow which would result from the 1968 A Reservoir System minus Rowlesburg Lake. SOURCE: Ohio River Basin Commission (22).
b., c. SOURCES: Brill (43) and the Ohio River Valley Water Sanitation Commission (33).

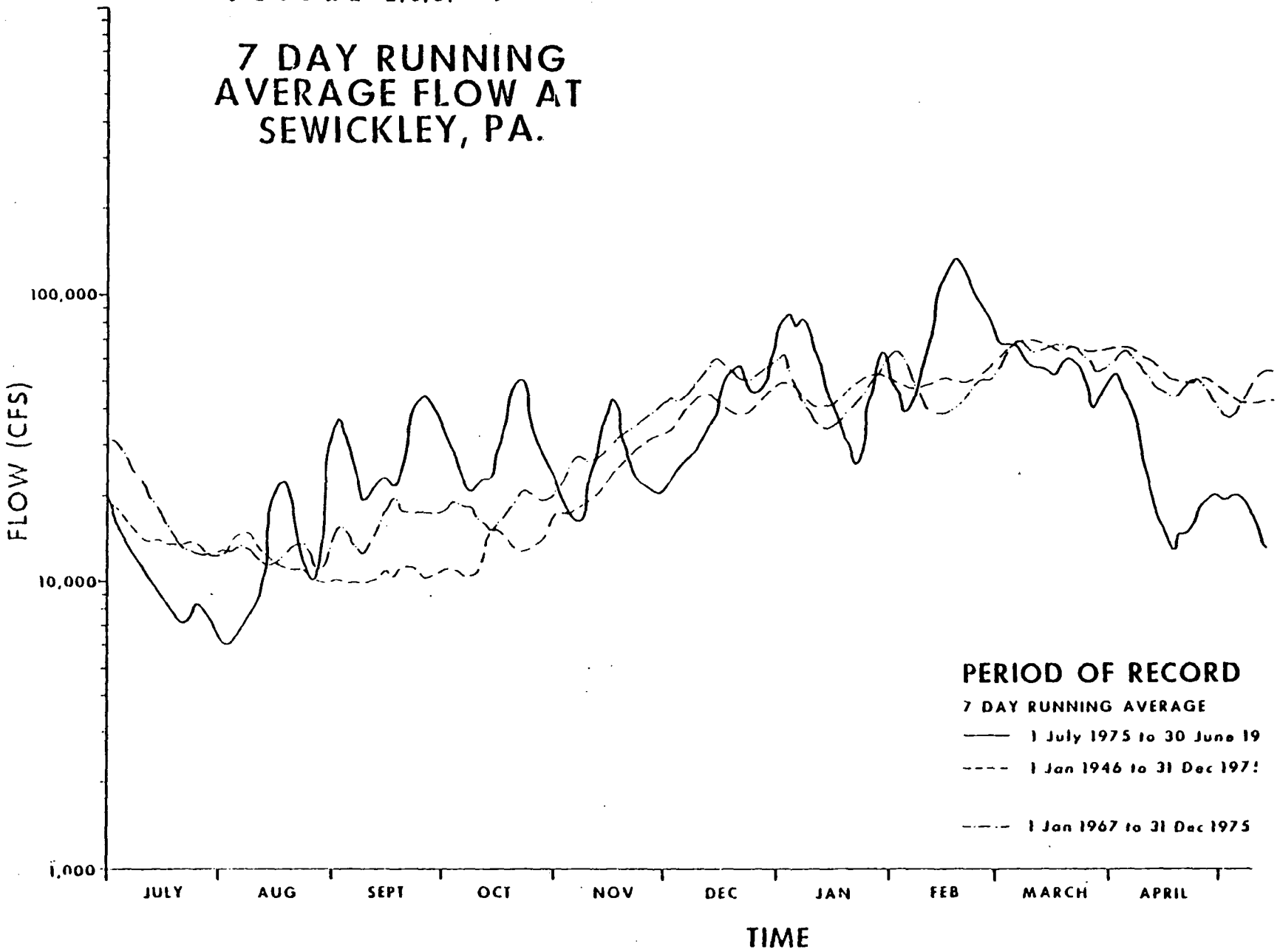
F I G U R E 2.1.5.-8

MINIMUM SEVEN DAY RUNNING AVERAGES OF FLOW
AT SEWICKLEY, PA.



SOURCE: ORSANCO (33)

FIGURE 2.1.5. - 9



SOURCE: ORSANCO (33).

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