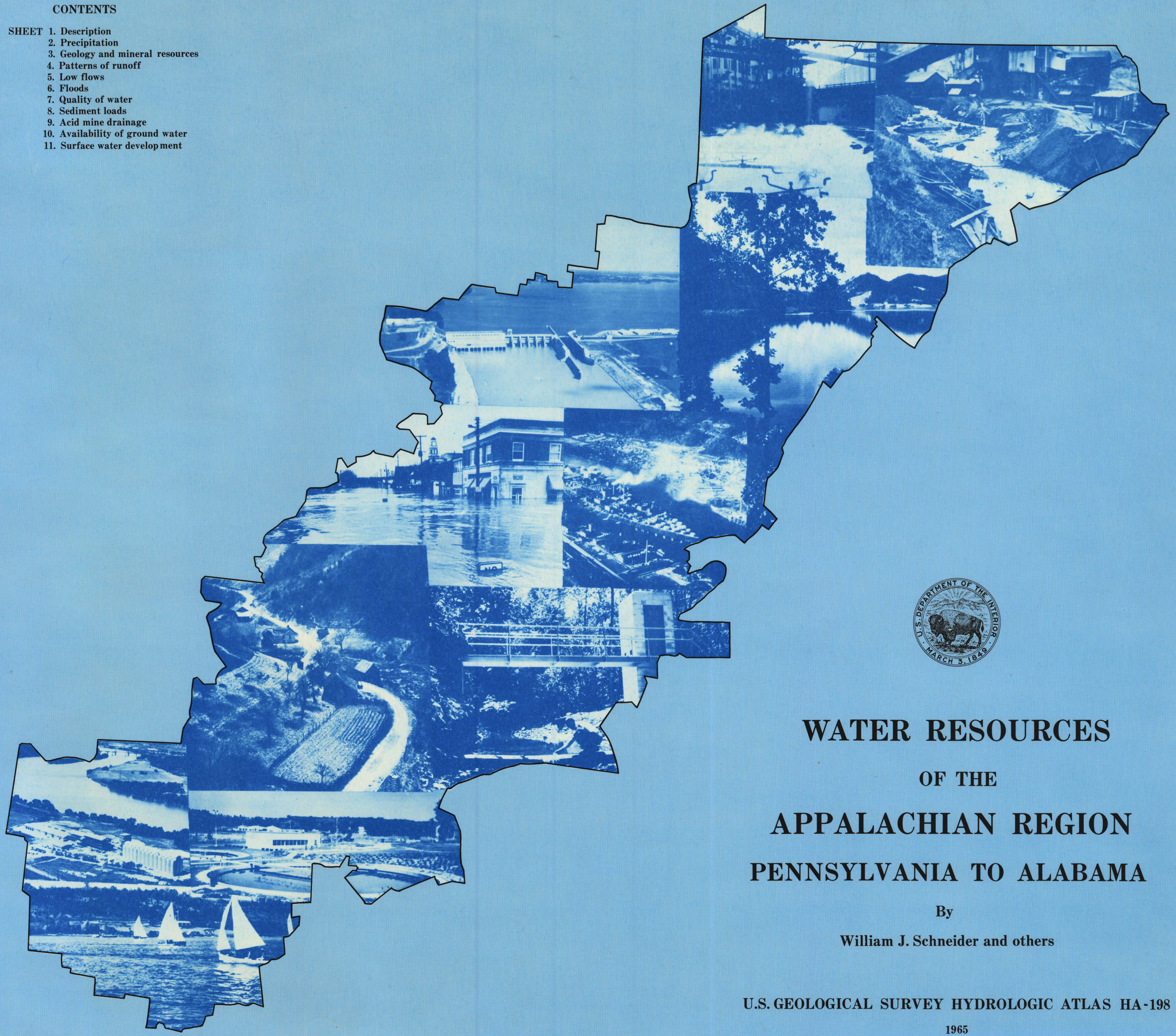
McGovern

CONTENTS



WATER RESOURCES
OF THE
APPALACHIAN REGION
PENNSYLVANIA TO ALABAMA

By

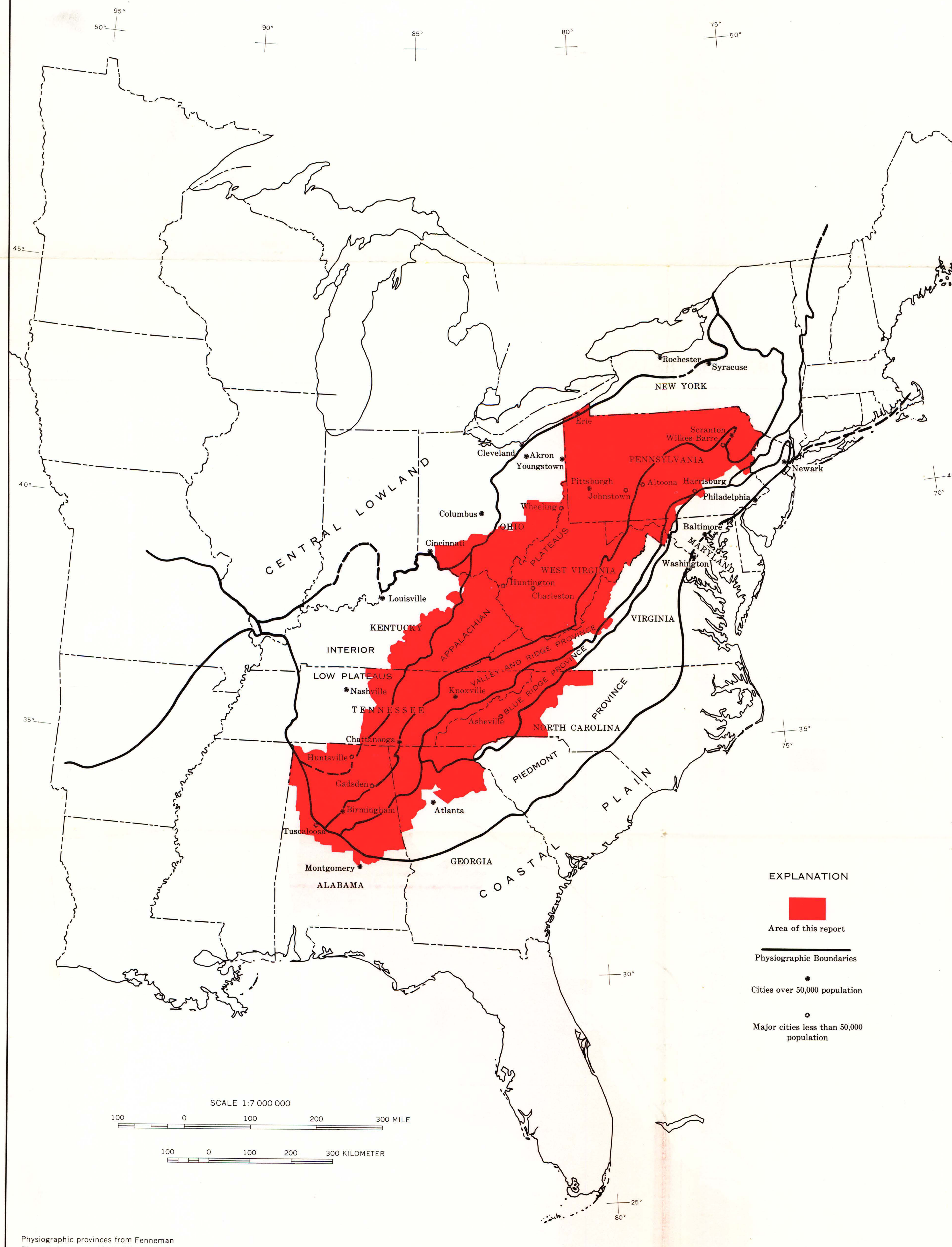
William J. Schneider and others

U.S. GEOLOGICAL SURVEY HYDROLOGIC ATLAS HA-198

1965

DESCRIPTION OF THE APPALACHIAN REGION

By
William J. Schneider and
Henry C. Barksdale



Physiographic provinces from Fenneman Physical Divisions of U.S. (Map, scale 1:7,000,000) U.S. Geological Survey, 1946

DESCRIPTION OF THE REGION

The Appalachian Region is at present a recognized problem area in the national economy. During the period following World War II, the Region has suffered from a declining economy based chiefly on mining, agriculture, and some industry. The problems confronting the many agencies - governmental and private - interested in accelerating the development of the Region are lack of adequate access to, and difficulty of travel within, the Region; inability to utilize fully the natural resources, including water; and chronic unemployment, resulting from changing technology in mining and industry.

On April 9, 1963, the President's Appalachian Regional Commission was established. This commission was charged with the development of a comprehensive plan for the economic recovery of the area through utilization of the natural resources of the Region.

This map report, consisting of 11 numbered sheets, discusses water as one of the more abundant resources of the Region. The report considers both the uniformity and variability of this resource, as well as its present benefits to and detrimental effects in the Region. It should be useful in formulating overall plans for development of the Region.

This report is based largely on hydrologic data previously collected by the U.S. Geological Survey in cooperation with State agencies. Acknowledgements are due many people for their assistance. Particular recognition is due the district chiefs of the Water Resources Division, U.S. Geological Survey, in the States within the Region for much of the data on the hydrology of their districts.

The Appalachian area, which has the highest peaks and most sharply-dissected plateaus east of the Rocky Mountains, lies in a long, narrow, curving band extending from northern New England to Central Alabama. It is an area of moderately high altitudes surrounded by the central and coastal lowlands of the Continent. Physiographically it consists of the Blue Ridge province, the Valley and Ridge province and the Appalachian Plateaus.

The Appalachian Region, as here considered (see map at left), differs from the physiographic interpretation, and is defined principally on the basis of topographic and economic factors. It is identical to the area designated in 1963 by the President's Appalachian Regional Commission as an area for economic development. This Region, consisting of 342 counties in Pennsylvania, Maryland, West Virginia, Ohio, Kentucky, Virginia, Tennessee, North Carolina, Georgia and Alabama, extends beyond the Appalachian Mountain area, and includes parts of the Piedmont province and the Interior Low Plateau and small sections of the Central Lowland for a total area of 164,113 square miles.

Table 1.— *Population and area of Region by States.*

State	No. of counties within Region	Population		Area	
		Number	Percent of State	Sq. mi.	Percent of State
Alabama	32	1,884,400	57.7	22,587	43.8
Georgia	35	674,700	17.1	10,934	18.6
Kentucky	44	853,500	28.1	15,565	38.5
Maryland	3	195,800	6.3	1,556	14.7
North Carolina	27	776,500	17.0	11,391	22.7
Ohio	20	743,900	7.7	9,929	24.1
Pennsylvania	56	6,565,600	58.0	39,193	86.5
Tennessee	49	1,599,000	44.8	19,383	45.9
Virginia	21	456,700	11.5	9,394	23.1
West Virginia	55	1,860,000	100.0	24,181	100.0
Total	342	15,610,100	8.7*	164,113	5.3*

*Percent of total United States.

The most rugged terrain in the Region occurs north and west of Asheville, N. C., in the Great Smokies and Black Mountains of the Blue Ridge province. Just northeast of Asheville, Mt. Mitchell rises to an elevation of 6,684 feet. Although not as high in altitude, parts of the Valley and Ridge province extending from eastern West Virginia northward into central Pennsylvania also have fairly rugged topography. The Valley and Ridge province is, however, a region of parallel and sub-parallel ridges and valleys that trend northeastward as contrasted to the less oriented arrangement of peaks in the Blue Ridge province. Also in the Valley and Ridge province, the crests of adjacent ridges, which are relatively narrow, are nearly concordant.

West of the Valley and Ridge province, the Appalachian Plateaus offer less rugged, but highly-dissected terrain which varies greatly in topographic relief. The area from northern Pennsylvania to east-central West Virginia is higher and more mountainous than the rest of this province, but less so than the adjacent Valley and Ridge province. Parts of the Plateaus in western Pennsylvania, western and central West Virginia and eastern Tennessee are extensively dissected; wide valleys do, however, occur along the Ohio and Kanawha Rivers.

The rock materials at the land surface throughout the Region are chiefly unconsolidated. These unconsolidated materials include residual soils and weathered products of the underlying rocks. Alluvial flood-plain deposits occur in most valleys, and bare rock is exposed on many mountain slopes, but less commonly where the topography is subdued. Bare rock also occurs commonly in stream channels even where flood-plain deposits and residual soils border the streams and to some extent in areas of moderate relief in limestone valleys.

Only a small part of the region was glaciated. All or parts of 6 counties in northwestern Pennsylvania, and all or parts of 13 counties in northeastern Pennsylvania were overrun by glaciers during the Illinoisian and again in the Wisconsin Ice ages. In this area, bedrock is generally covered by glacial drift, often less than 10 feet deep.

The Region is sparsely populated. According to the 1960 census, the population was 15,610,100. The rugged terrain has made the Region generally less attractive to extensive industrial development than the surrounding Coastal Plain and Interior Low Plateaus. Only 6 cities have populations of more than 100,000; of these only Pittsburgh exceeds 500,000. Within 100 miles of the boundary of the region, however, there are 30 cities of more than 100,000 population, including the metropolitan areas of Philadelphia, New York, Cleveland, Baltimore, Washington, and Atlanta.

Table 2.— *Population centers of 50,000 or more in the Region*

City	State	Population[1]	Major industry
Pittsburgh	Pa.	604,332	Primary and fabricated metals, machinery
Birmingham	Ala.	340,887	Primary and fabricated metals
Erie	Pa.	138,440	Electrical machinery, primary and fabricated metals
Chattanooga	Tenn.	130,009	Textiles, fabricated metals
Knoxville	Tenn.	111,827	Textiles and wearing apparel
Scranton	Pa.	111,443	Textiles and wearing apparel
Charleston	W. Va.	85,796	Chemicals and allied products.
Huntington	W. Va.	83,627	Stone, clay, and glass products.
Harrisburg	Pa.	79,697	Primary metals, food products.
Huntsville	Ala.	72,365	Food products.
Altoona	Pa.	69,407	Paper products, food products.
Wilkes-Barre	Pa.	63,551	Wearing apparel
Tuscaloosa	Ala.	63,370	Lumber, wood products
Asheville	N. C.	60,185	Textiles, lumber and wood products.
Gadsden	Ala.	58,088	Food products
Johnstown	Pa.	53,949	Wearing apparel, food products
Wheeling	W. Va.	53,400	Fabricated metals, food products

[1] 1960 Census figures.

The Region is rich in natural resources. Chief among these are coal, oil, gas, and timber. Coal mining has been a major industry of the area for many years. About two-thirds of the Nation's bituminous and all of its anthracite coal production comes from this Region. Automation and a declining demand for coal, however, have reduced employment in this industry by 64 percent between 1951 and 1961. Currently about 5 percent of the Region's total employment is engaged directly in mining.

Topography has strongly influenced the agriculture of the Region. Because of the hilly, steep terrain, the Appalachian Region has less farmland than any other area of comparable size in the conterminous United States. Much of the cropland consists of small fields in narrow valleys and on steep hillsides, and agriculture is based primarily on livestock. In 1960, farm population was 1,370,000, or 9 percent of the total population. Farm population declined 12 percent during the 1950-1960 decade. Almost two-thirds of the land is forested, with about 14 percent of the 67 million timbered acres in National Forest or other public ownership.

Excellent water is one of the factors favoring further development of the Appalachian Region. Water of good quality is generally sufficient for foreseeable expansion, although management will be necessary. Industrial growth, a prime factor in development of the Region, most likely will occur where adequate manpower, transportation facilities, and water are available. Although lack of an adequate highway network has been a deterrent to industrial development, completion of the new Interstate Highway System with connecting corridor roads as recommended by the President's Appalachian Regional Commission, will negate the inaccessibility of the Region created by the mountainous topography. The mountainous topography, however, will limit development to areas quite close to the major highways that link the Region to nearby industrial centers and markets. The combination of these factors—availability of water and accessibility by highways—will determine largely the locations of future industrial areas in the Region.

As surface streams generally will supply large future demands for industrial water, areas where major highways and streams coincide may offer best potential sites for industry.

Water problems are now present and will continue to arise with future development of the Region. Stream pollution is a major one, particularly in the lower reaches of streams where industries will tend to congregate. Increased occupancy of desirable flood-plain locations will result in greatly-increased flood damage unless adequate flood control and zoning measures precede development in the flood plain. Acid-mine drainage is a problem throughout much of the coal-bearing part of the Region; this problem will continue long after mines are abandoned. Other local problems in the Region include natural hardness of water from limestone areas and presence of other undesirable minerals.

Problems in water management in the Region undoubtedly will increase as further economic development occurs. With proper management, combining sound hydrologic knowledge and socio-economic needs, water can play a key role in the expanded development of the Appalachian Region.

Listed below are selected references on the water resources of the Region. The listing consists mostly of reports and publications of the U.S. Geological Survey and those of State agencies published either independently or cooperatively with the Geological Survey. Also included are other significant publications pertinent to discussions in these atlases on the Appalachian Region.

SELECTED REFERENCES

WATER RESOURCES-GENERAL

Doll, W. L., Meyer, Gerald, and Archer, R. J., 1963, Water Resources of West Virginia: West Virginia Dept. of Natural Resources, Div. of Water Resources, 134 p.

Doll, W. L., Wilmoth, B. M. Jr., and Whetstone, G. W., 1960, Water Resources Kanawha County, West Virginia: Bull. 20, West Virginia Geological and Economic Survey, 189 p.

Kirkpatrick, G. A., Price, W. E., Jr., and Madison, R. A., 1963, Water Resources of Eastern Kentucky-Progress Report: Kentucky Geological Survey, Report of Investigations no. 5, 65 p.

Nave, Edward, Editor, 1961, Tennessee's Water Resources: Tennessee Dept. of Conservation and Commerce, Div. of Water Resources, 128 p.

Ohio Dept., of Natural Resources, 1959, Water Resources of Southeastern Ohio: Division of Water, Ohio Dept. of Natural Resources, 35 p.

Robinson, W. H., Ivey, J. B., and Billingsley, G. A., 1953, Water Supply of the Birmingham area Alabama: U.S. Geol. Survey Cir. 254, 53 p.

Smith, R. C., Doll, W. L., and Stratton, Garland, 1955, Water Resources of the Wheeling-Steubenville area, West Virginia and Ohio: U.S. Geol. Survey Cir. 340, 31 p.

Swindel, G. W., Jr., Williams, M. R., and Geurin, J. W., 1963, Water in Alabama: U.S. Geol. Survey Water-Supply Paper 1765, 89 p.

GEOLOGY

Coe, Ann C., Conant, L. C., and Drakoulis, Sophia, 1955, Oil and gas fields of the United States: Map scale 1:2,500,000, U.S. Geol. Survey.

Cohee, G. V., Chairman, 1961, Tectonic map of the United States, exclusive of Alaska and Hawaii: Map, scale 1:2,500,000, U.S. Geol. Survey and Am. Assoc. Petroleum Geologists.

Colton, G. W., 1961, Geologic summary of the Appalachian Basin, with reference to the subsurface disposal of radioactive waste solutions: U.S. Geol. Survey Report TEI-791.

Lafferty, R. C., 1941, Central basin of the Appalachian geosyncline: Am. Assoc. Petroleum Geologists Bull. vol. 25, no. 5, p. 781-825.

Minerals Year (1962), U.S. Bureau of Mines, vol. III, Area reports.

Stose, G. W., and Ljungstedt, 1932, Geologic Map of the United States: Map, scale 1:2,500,00, U.S. Geol. Survey.

Trumbull, James, 1960, Coal fields of the United States: Map, scale 1:5,000,000, U.S. Geol. Survey.

VARIABILITY OF STREAMFLOW

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.

U.S. Geological Survey, issued annually until 1960, Surface Water Supply of the United States (in 14 numbered parts, determined mainly by drainage basins): U.S. Geol. Survey Water-Supply Papers [Beginning with 1961-65, a 5-year series will be used. To meet interim requirements, streamflow records are being published annually in reports entitled "Surface Water Records of ____________" (separate report for each State).]

LOW-FLOWS

Cross, W. P., 1963, Low-flow frequencies and storage requirements for selected Ohio streams: Division of Water, Ohio Dept. of Natural Resources, 66 p.

Goddard, G. C., Jr., 1963, Water-Supply characteristics of North Carolina streams: U.S. Geol. Survey Water-Supply Paper 1761, 223 p.

Hardison, C. H., and Martin, R. O. R., 1963, Low-flow frequency curves for selected long-term stream-gaging stations in the Eastern United States: U.S. Geol. Survey Water-Supply Paper 1669-G, 30 p.

Mangan, J. W., 1937, The drought of 1930 in Pennsylvania: Pennsylvania Dept. of Forests and Water, 22 p.

Thomson, M. T., and Carter, R. F., 1963, Effect of a severe drought (1954) on streamflow in Georgia: Bull. 73, Georgia Geol. Survey, Dept. of Mines, Mining and Geology, 97 p.

FLOODS

Bunch, C. M., and Price, M., 1962, Floods in Georgia—magnitude and frequency: U.S. Geol. Survey open-file report, 152 p.

Busch, W. F., and Shaw, L. C., 1960, Floods in Pennsylvania—frequency and magnitude: U.S. Geol. Survey open-file report, 231 p.

Cross, W. P., and Webber, E. E., 1959, Floods in Ohio, magnitude and frequency: Bull. 32, Division of Water, Ohio Dept. of Natural Resources, 325 p.

Forrest, W. E., and Speer, P. R., 1961, Floods in North Carolina—magnitude and frequency: U.S. Geol. Survey open-file report, 195 p.

Jenkins, C. T., 1960, Floods in Tennessee—magnitude and frequency: Tennessee Dept. of Highways, 68 p.

McCabe, J. A., 1962, Floods in Kentucky—frequency and magnitude: Kentucky Geol. Survey, 196 p.

Pierce, L. B., 1954, Floods in Alabama—magnitude and frequency: U.S. Geol. Survey Circ. 342, 105 p.

Speer, P. R., and Gamble, C. R., 1964, Magnitude and frequency of floods in the United States, Part 3-B, Cumberland and Tennessee River basins: U.S. Geol. Survey Water-Supply Paper 1676, 340 p.

Speer, P. R., and Gamble, C. R., Magnitude and frequency of floods in the United States, Part 3-A, Ohio River basin except Cumberland and Tennessee River basins (in press).

Steacy, R. E., and Heckmiller, I. A., 1961, Floods at Harrisburg, Pennsylvania: U.S. Geol. Survey Hydrol. Inv. Atlas HA-57.

Wiitala, S. W., Jetter, K. R., and Sommerville, A. J., 1961, Hydraulic and Hydrologic Aspects of Flood-Plain Planning: U.S. Geol. Survey Water-Supply Paper 1526, 69 p.

WATER QUALITY

Cherry, R. N., 1961, Chemical quality of water of Georgia streams, 1957-58, a reconnaissance study: Georgia Div. of Conservation, Bull. 69, 100 p.

Cherry, R. N., 1963, Chemical quality of water in Alabama streams, 1960, a reconnaissance study: Ala. Geol. Survey Inf. Series 27, 95 p.

Collier, C. R., and Krieger, R. A., 1958, Quality of Surface Water of Kentucky, 1953-55: Kentucky Dept. of Econ. Dev., 219 p.

Durfor, C. N., and Anderson, P. W., 1963, Chemical quality of surface waters in Pennsylvania: U.S. Geol. Survey Water Supply Paper 1619-W, 50 p.

Hubble, J. H., and Collier, C. R., 1960, Quality of surface water in Ohio, 1946-58: Ohio Water Plan Inv. Rept. no. 14, Ohio Dept. Natural Resources, 317 p.

McCarren, E. F., 1964, Chemical quality of surface water in the West Branch Susquehanna River basin, Pennsylvania: U.S. Geol. Survey Water-Supply Paper 1779-C, 40 p.

Rainwater, F. H., 1962, Stream composition of the conterminous United States: U.S. Geol. Survey Hydrol. Inv. Atlas HA-61.

U.S. Geological Survey, issued annually, Quality of surface waters of the United States (in 14 numbered parts determined by drainage basins): U.S. Geol. Survey Water-Supply Papers.

SEDIMENT

Interagency Committee on Water Resources, 1957, Summary of reservoir sedimentation studies made in the United States through 1953: Bull. 6, April 1957.

Wark, J. W., and Keller, F. J., 1963, Preliminary study of sediment sources and transport in the Potomac River basin: Interstate Commission on the Potomac River Basin, Tech. Bull. 1963-11, June 1963.

White, W. F., and Lindholm, C. F., 1950, Water Resources Investigations relating to the Schuylkill River restoration project, October 1957-December 1949: Pennsylvania Dept. of Forests and Waters.

ACID MINE DRAINAGE

Barnes, Ivan, and Clarke, F. E., 1964, Geochemistry of ground water in mine drainage problems: U.S. Geol. Survey Prof. Paper 473-A, 6 p.

Barnes, Ivan, Stuart, W. T., and Fisher, D. W., 1964, Field Investigation of mine waters in the Northern Anthracite Field, Pennsylvania: U.S. Geol. Survey Prof. Paper 473-B, 7 p.

Collier, C. R., and others, 1964, Influences of strip mining on the hydrologic environment of parts of Beaver Creek basin, Kentucky, 1955-1959: U.S. Geol. Survey Prof. Paper 427-B, 83 p.

Lorenz, W. C., 1962, Progress in controlling acid mine water—a literature review: U.S. Bur. of Mines Inf. Circ. 8080, 40 p.

Musser, J. J., 1963, Description of physical environment and of strip-mining operations in parts of the Beaver Creek basin, Kentucky: U.S. Geol. Survey Prof. Paper 427-A, 25 p.

Ohio River Valley Water Sanitary Commission, 1964, Principles and guide to practices in the control of acid mine drainage, supplemented by case histories: Ohio River Valley Water San. Comm. Cincinnati, Ohio, 30 p.

Pennsylvania Dept. of Health, 1962, Proceedings of the national symposium on the control of coal mine drainage: Div. San. Engr., Bur. Env. Health, Pub. no. 4, 113 p.

GROUND WATER

Carlston, C. W., and Graeff, G. D., Jr., 1955, Ground Water Resources of the Ohio River valley in West Virginia, in Geology and Economic Resources of the Ohio River Valley in West Virginia: West Virginia Geol. Survey, vol. 22, pt. 3, 131 p.

Johnston, W. D., Jr., 1933, Ground water in the Paleozoic rocks of northern Alabama: Alabama Geol. Survey Spec. Rept. 16, 414 p.

Leggette, R. M., 1936, Ground Water in northwestern Pennsylvania, with analyses by Margaret D. Foster, W. L. Lamar, and S. K. Love: Pennsylvania Geol. Survey, 4th ser., Bull. W-3, 215 p.

LeGrand, H. E., 1956, Ground water resources in North Carolina: North Carolina Dept. Conserv. and Devel., Div. Mineral Resources, Bull. 69, 20 p.

Lohman, S. W., 1938, Ground water in south-central Pennsylvania, with analyses by E. W. Lohr: Pennsylvania Geol. Survey, 4th ser., Bull. W-5, 315 p.

McGuinness, C. L., 1963, The role of ground water in the National water situation: U.S. Geol. Survey Water-Supply Paper 1800, 1121 p.

Piper, A. M., 1933, Ground Water in southwestern Pennsylvania, with analyses by Margaret D. Foster and C. S. Howard: Pennsylvania Geol. Survey, 4th ser., Bull. W-1, 406 p.

Price, W. E., Jr., Mull, D. S., and Kilburn, Chabot, 1962, Reconnaissance of ground water resources in the Eastern Coal Field region, Kentucky: U.S. Geol. Survey Water-Supply Paper 1607, 56 p.

Thomas, H. E., 1951, The conservation of ground water: McGraw-Hill Book Co., New York, 327 p.

U.S. Geological Survey, issued annually through 1955, Ground Water levels in the United States (in 6 parts, determined geographically): U.S. Geol. Survey Water-Supply Papers. (Beginning in 1956, 5 years of record will be published in 1 volume for each geographical section. During the transition period some volumes will contain less than 5 years of record. Prior to their publication, the data are made available for local use at the end of each calendar year).

DEVELOPMENT OF SURFACE WATER

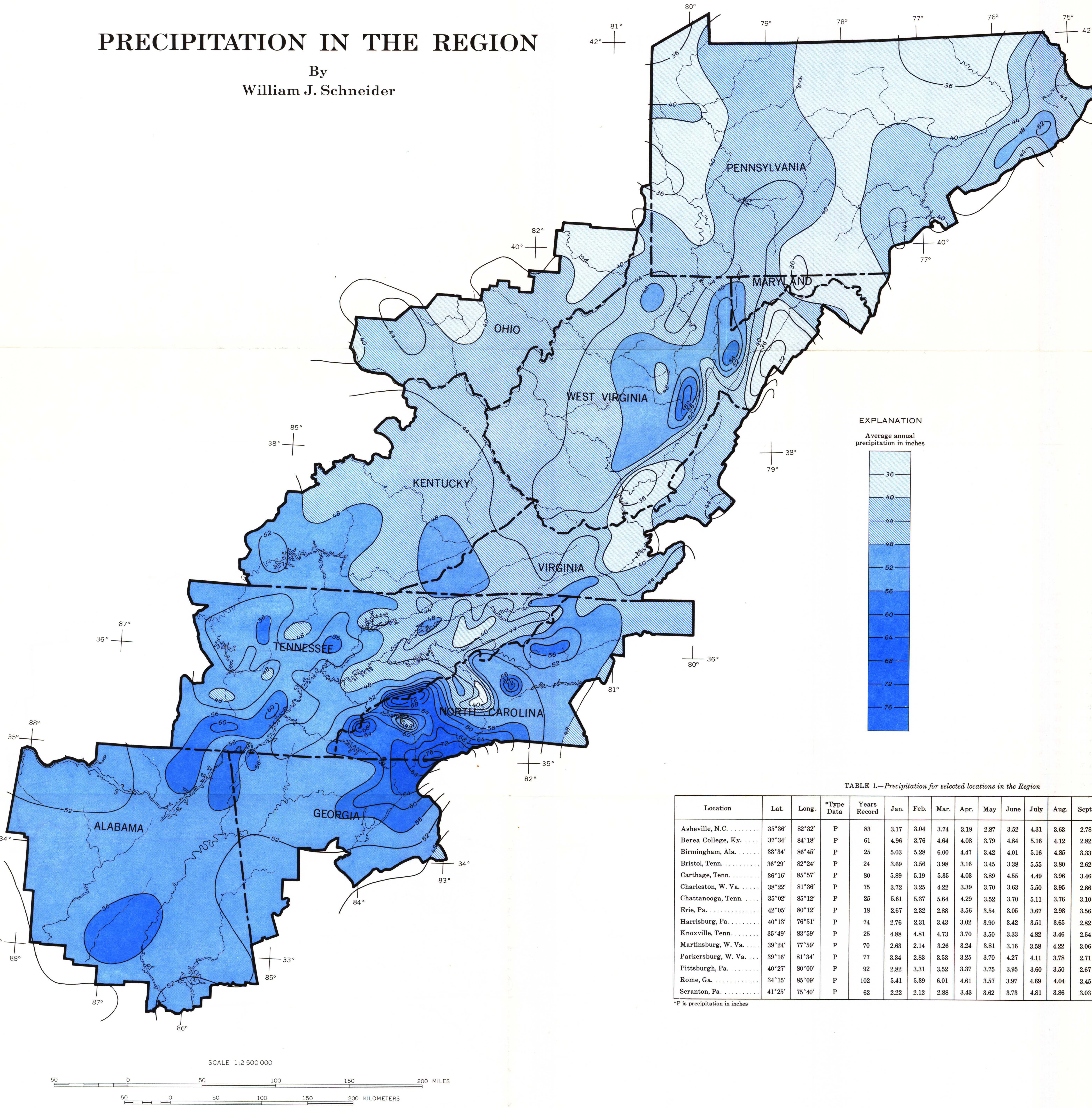
Thomas, N. O., and Harbeck, G. E., Jr., 1956, Reservoirs in the United States: U.S. Geol. Survey Water-Supply Paper 1360-A, 99 p.

INTERIOR—GEOLOGICAL SURVEY, WASHINGTON, D. C.—1965—W65108

For sale by U. S. Geological Survey, price $3.25 per set

PRECIPITATION IN THE REGION

By
William J. Schneider



Compiled from U.S. Weather Bureau data

PRECIPITATION

Precipitation averaging 47 inches annually is the source of an adequate supply of water for the Region. Reasonably well-distributed throughout the year, it sustains both nature's and man's activities. About one-half of this precipitation is consumed through evaporation and transpiration by plants, and about 5 percent supplies the needs of man for municipal and industrial uses.

The 47-inch average precipitation is much above the average for areas of comparable size. This is 18 inches more than the average of 29 inches for the conterminous United States and is exceeded only in two areas of the United States of similar size: (a) Florida and the southern part of the Gulf States, where precipitation averages more than 55 inches annually, and (b) along the Pacific Coast where local orographic cells of precipitation exceed 100 inches annually.

The average annual precipitation of the Region ranges from about 35 inches in the north to almost 80 inches in small areas in North Carolina. In general, though, precipitation over most of the Region averages between 35 and 55 inches annually.

The pattern of precipitation is influenced largely by the topography of the Region. Moisture-laden air masses moving generally eastward across the Region lose this moisture as they are forced upward over the mountainous areas. As a result, areas of high precipitation occur along the western side of the Blue Ridge, and distinct rain shadows occur to the lee or east of the mountains. This effect is particularly noticeable in North Carolina, where average annual precipitation varies from more than 80 inches to less than 40 inches within 50 miles. Other areas of high precipitation resulting from the topographic influences occur principally in West Virginia and along the Tennessee-North Carolina border.

In addition to the east-west orographic variation, there is also a general north-south orientation to the pattern of precipitation, with a steady pattern of increase from about 35 inches in Pennsylvania to more than 55 inches in Alabama. This orientation is especially evident in the Appalachian Plateaus where orographic effects are less pronounced than in the mountainous regions to the east.

Snowfall ranges from more than 100 inches annually in higher elevations in the northern part of the Region to less than 3 inches per year in Alabama. In Pennsylvania and West Virginia, snow exceeding 20 inches occurs occasionally in a single storm. Elevation again is a major factor. For example, annual snow-fall at Pickens, W. Va., averages about 115 inches whereas only 75 miles away at Charleston, W. Va., snowfall averages less than 20 inches. In 1930-31, 148 inches of snowfall was measured at Mount Mitchell, N.C., at elevation 6,684 feet. However, even in areas of heavy snowfall, transportation is seldom disrupted except for infrequent brief periods. Melting occurs throughout the season, and only occasionally do large accumulations of snow become serious flood threats. The floods of March 1936 in the Susquehanna and Potomac River basins are notable examples of a flood resulting from the combination of spring rainfall and snowmelt.

The precipitation is about equally distributed between growing and non-growing season. It is usually ample for crop production, although delays in planting and occasional serious droughts do occur over most of the Region because of maldistribution. Statistics for the southern part of the Region indicate that periods of 3 weeks or more with less than 0.01 inch of precipitation can be expected during May or June on an average of once in 10 years. Most summer precipitation occurs as thunderstorms. The number of thunderstorm-days per year ranges from 30 to 35 in Pennsylvania to about 60 in Alabama. Most of the Region experiences about 45 to 50 thunderstorm-days per year. Rainfall during these convective storms is often intense, causing both crop damage and severe local flooding.

Tropical storms are not a serious threat to the Region. These storms, moving inland from the Atlantic Ocean and Gulf of Mexico, lose much of their destructive energies before reaching the Region. Those storms that penetrate the area generally enter land along the Gulf Coast and move north or northeastward across the Appalachian Plateaus. Tropical storms that enter along the Atlantic Coast are frequently shunted northeastward by the mountains and generally have little serious effect on the Region. Heavy rains, however, occasionally accompany the passage of these tropical storms and cause flooding.

The relation between precipitation and potential evapotranspiration demands are shown in figure 1. The potential evapotranspiration is based on the Thornthwaite method of computation and assumes complete availability of water. Although these computations indicate a need for as much as 7 inches of water in addition to available precipitation during the growing season, the actual amount probably is closer to 3 or 4 inches because of soil-moisture deficiencies which prevent vegetation from achieving its full potential in transpiration.

Assuming evapotranspiration of full potential, the diagrams of figure 1 represent water budgets for the locations shown, and indicate the excess precipitation that becomes streamflow. Again, it should be noted that the excess precipitation is probably 3 or 4 inches greater than that shown because the actual soil moisture is often less than the potential. Although data on soil-moisture deficiency are not available, the estimate of 3 to 4 inches allows good agreement between the excess precipitation of figure 1 and the average runoff.

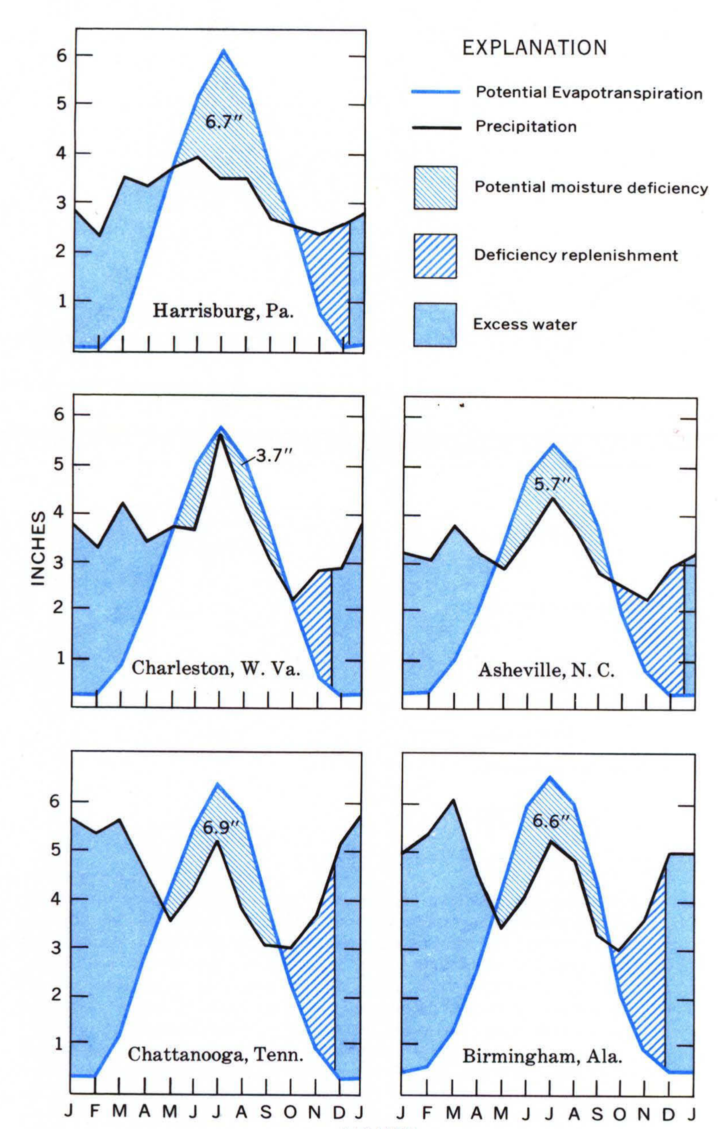


FIGURE 1.—*Water budget for selected sites in the Appalachian Region.*

TABLE 1.—*Precipitation for selected locations in the Region*

Location	Lat.	Long.	*Type Data	Years Record	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Asheville, N.C.	35°36′	82°32′	P	83	3.17	3.04	3.74	3.19	2.87	3.52	4.31	3.63	2.78	2.49	2.22	2.92	37.88
Berea College, Ky.	37°34′	84°18′	P	61	4.96	3.76	4.64	4.08	3.79	4.84	5.16	4.12	2.82	2.17	3.29	3.58	47.21
Birmingham, Ala.	33°34′	86°45′	P	25	5.03	5.28	6.00	4.47	3.42	4.01	5.16	4.85	3.33	2.95	3.53	5.02	53.05
Bristol, Tenn.	36°29′	82°24′	P	24	3.69	3.56	3.98	3.16	3.45	3.38	5.55	3.80	2.62	2.15	2.51	3.21	41.06
Carthage, Tenn.	36°16′	85°57′	P	80	5.89	5.19	5.35	4.03	3.89	4.55	4.49	3.96	3.46	2.49	4.05	4.76	52.11
Charleston, W. Va.	38°22′	81°36′	P	75	3.72	3.25	4.22	3.39	3.70	3.63	5.50	3.95	2.86	2.25	2.80	2.83	42.00
Chattanooga, Tenn.	35°02′	85°12′	P	25	5.61	5.37	5.64	4.29	3.52	3.70	5.11	3.76	3.10	3.02	3.65	5.19	51.96
Erie, Pa.	42°05′	80°12′	P	18	2.67	2.32	2.88	3.56	3.54	3.05	3.67	2.98	3.56	3.30	3.36	2.61	37.50
Harrisburg, Pa.	40°13′	76°51′	P	74	2.76	2.31	3.43	3.02	3.90	3.42	3.51	3.65	2.82	2.97	2.95	2.91	37.65
Knoxville, Tenn.	35°49′	83°59′	P	25	4.88	4.81	4.73	3.70	3.50	3.33	4.82	3.46	2.54	2.61	3.24	4.23	45.85
Martinsburg, W. Va.	39°24′	77°59′	P	70	2.63	2.14	3.26	3.24	3.81	3.16	3.58	4.22	3.06	3.28	2.53	2.74	37.65
Parkersburg, W. Va.	39°16′	81°34′	P	77	3.34	2.83	3.53	3.25	3.70	4.27	4.11	3.78	2.71	2.05	2.36	2.84	38.77
Pittsburgh, Pa.	40°27′	80°00′	P	92	2.82	3.31	3.52	3.37	3.75	3.95	3.60	3.50	2.67	2.50	2.34	2.54	36.87
Rome, Ga.	34°15′	85°09′	P	102	5.41	5.39	6.01	4.61	3.57	3.97	4.69	4.04	3.45	2.75	3.46	5.03	52.38
Scranton, Pa.	41°25′	75°40′	P	62	2.22	2.12	2.88	3.43	3.62	3.73	4.81	3.86	3.03	2.98	3.01	2.44	38.15

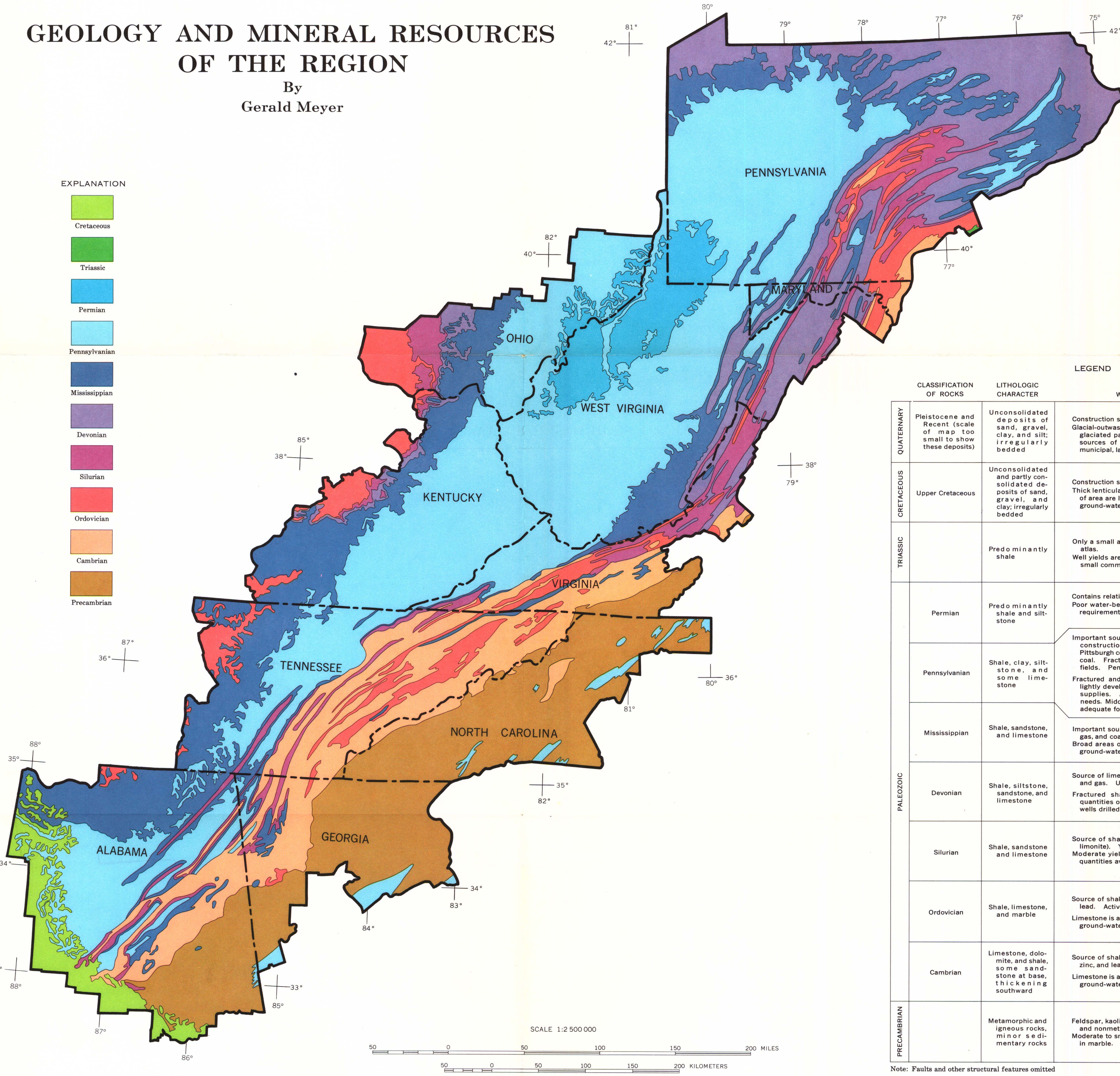
*P is precipitation in inches

Data from U.S. Weather Bureau

INTERIOR—GEOLOGICAL SURVEY, WASHINGTON, D. C.—1965—W65109

GEOLOGY AND MINERAL RESOURCES OF THE REGION

By
Gerald Meyer



Adapted from Geologic map of the United States by, Stose, G. W., and Ljungstedt, O. A., U.S. Geological Survey, 1932

LEGEND

	CLASSIFICATION OF ROCKS	LITHOLOGIC CHARACTER	MINERAL RESOURCES WATER-SUPPLY CHARACTERISTICS
QUATERNARY	Pleistocene and Recent (scale of map too small to show these deposits)	Unconsolidated deposits of sand, gravel, clay, and silt; irregularly bedded	Construction sand and gravel. Glacial-outwash deposits along Ohio River and in northern glaciated part of Pennsylvania are moderately developed sources of large ground-water supplies. Adequate for municipal, large commercial, industrial, and irrigation uses.
CRETACEOUS	Upper Cretaceous	Unconsolidated and partly consolidated deposits of sand, gravel, and clay; irregularly bedded	Construction sand and gravel. Clay. Thick lenticular beds of sand and gravel along southern edge of area are lightly to moderately developed sources of large ground-water supplies.
TRIASSIC		Predominantly shale	Only a small area lies within the boundaries adopted for this atlas. Well yields are small to moderate. Adequate for domestic or small commercial requirements.
PALEOZOIC	Permian	Predominantly shale and siltstone	Contains relatively minor coal beds. Poor water-bearing unit. Generally adequate for domestic requirements.
	Pennsylvanian	Shale, clay, siltstone, and some limestone	Important source of coal, petroleum and gas, refractory and construction clay, shale,limestone, and brine. Includes Pittsburgh coal seam, one of principal sources of bituminous coal. Fracturing techniques are reclaiming abandoned oil fields. Pennsylvanian rocks utilized for gas storage fields. Fractured and porous sandstone strata at the base are a lightly developed source of moderately large ground-water supplies. Adequate for limited industrial and municipal needs. Middle and upper beds yield ground water supplies adequate for domestic use.
	Mississippian	Shale, sandstone, and limestone	Important source of shale, limestone, gypsum, petroleum and gas, and coal. Underground gas storage fields. Broad areas of limestone are a source of moderately large ground-water supplies. Large springs common.
	Devonian	Shale, siltstone, sandstone, and limestone	Source of limestone and glass sand and, at depth, petroleum and gas. Underground gas storage fields. Fractured shale and porous sandstone yield moderate quantities of water to wells and through springs. Locally, wells drilled in limestone yield moderately large supplies.
	Silurian	Shale, sandstone and limestone	Source of shale and sandstone; iron ore ("Clinton ore" and limonite). Yields petroleum, gas, and salt at depth Moderate yield of water to wells and springs, locally large quantities available from limestone.
	Ordovician	Shale, limestone, and marble	Source of shale, limestone, and marble; barite, talc, zinc, and lead. Active prospecting for petroleum and gas. Limestone is a lightly to moderately developed source of large ground-water supplies. Large springs common.
	Cambrian	Limestone, dolomite, and shale, some sandstone at base, thickening southward	Source of shale, limestone, and dolomite; manganese, talc, zinc, and lead. Limestone is a lightly to moderately developed source of large ground-water supplies. Large springs common.
PRECAMBRIAN		Metamorphic and igneous rocks, minor sedimentary rocks	Feldspar, kaolin, mica, magnetite, and various other metallic and nonmetallic minerals. Moderate to small well and spring yields; locally, large springs in marble.

Note: Faults and other structural features omitted

GEOLOGY AND MINERAL RESOURCES

The Appalachian Region, with its varied geology, is an area of diverse mineral resources. Although coal has been the predominant resource developed to date, other important minerals are also found in the Region. These mineral and water resources are fundamental to the existing economy and development potential of the Region.

The optimum development of these resources is contingent upon an adequate knowledge of the geology. Interest in the geology and mineral potentialities of the Applachians has yielded at least general published information on every part of the region. Certain areas of intensive mineral development, such as part of the coal fields and the petroleum and natural gas belt, have been studied in detail, and detailed hydrologic investigations have been conducted in several small areas that have water resource problems.

Geologically the Appalachian Region is part of an enormous structural trough or basin. The basin contains a great mass of sedimentary rocks that fill an elongate depression in the crystalline basement complex. Predominantly crystalline rocks of the Piedmont and Blue Ridge provinces border the basin on the east. The basin extends westward to central Tennessee and Kentucky and western Ohio, beyond the western limit of the Region adopted for this map report. It terminates to the south in Alabama, where it is overlapped by sediments of the Coastal Plain province. It extends northward into New York and Canada.

The stratified rocks that occupy this enormous basin form a large, locally mineral-rich, wedge-shaped mass which is thickest near the east edge of the basin (about 35,000 to 40,000 feet) and becomes progressively thinner to the west. The deepest part of the basin—the area of greatest thickness—is in northern West Virginia and southern Pennsylvania. The stratigraphy may be described in general terms as follows: Precambrian rocks forming the basement include crystalline metamorphic and igneous rocks, with some volcanic and sedimentary rocks along the eastern edge of the basin. Cambrian clastic rocks, mostly siliceous detrital rocks, rest on the basement rocks, and in turn are overlain by a great thickness of Cambrian and Ordovician carbonate rocks, mostly limestone and dolomite. Ordovician and Silurian clastic rocks—shale, siltstone, and sandstone—occur next over the carbonate series, and these are overlain by still another sequence of carbonate rocks, of Silurian and Devonian age. Devonian clastic rocks consisting of shale, siltstone, and sandstone occur next, and above these are Mississippian rocks consisting of siliceous clastics in the north and carbonate rocks in the south. The overlying Pennsylvanian and Permian rocks are a series of clastics, coarse-grained in the lower part and shaly in the upper part.

Strata along the eastern margin of the Appalachian basin are strongly folded and broken by faults. Intensity of folding and faulting decreases to the west and in the western part of the basin strata are nearly horizontal. Because of these structural features, erosion has exposed all of the rock systems at the land surface in the eastern part of the area, but only the relatively young Pennsylvanian and Permian rocks underlie the land surface in the western part. (See map at left). The imposing Appalachian Mountains, potentially a large attraction to vacationers, is the topographic result of an intricate erosional history and of the great variety of geologic structures and rock types.

Unconsolidated and semiconsolidated sediments, including sand, gravel, and clay, compose the Cretaceous strata that terminate the Appalachian province in Alabama. These sediments thicken southward toward the Gulf Coast. Still younger deposits—sand, gravel, and clay of Quaternary age—form terraced alluvial deposits adjacent to many rivers and, in Pennsylvania, occur as outwash and drift of glacial origin. Outwash deposits occur also along the Ohio River in West Virginia and Kentucky. Quaternary deposits are not shown on the generalized geologic map.

The geologic map on this sheet shows the distribution of the systems of rocks in the Appalachian Region. The accompanying legend lists these rock systems, identifies the geologic eras in which they were formed, and describes their lithologic characteristics. It also lists the principal mineral resources derived from each rock unit and the general water-bearing properties. The occurrence and availability of ground water are described separately on Sheet 10.

Coal is the most valuable marketable mineral resource in the Region. It underlies a large part of the western half of the area. Practically all the coal occurs in rocks of three geologic systems: the Permian Pennsylvanian, and Mississippian. These bituminous fields are among the most important in the world; they yielded 73 percent of the United States production in 1961. Peak production was attained in 1947 and present production is approximately 30 percent less. Capacity of the major mines is considerably in excess of present production rates. Prospects for market expansion are considered to be favorable and appear to hinge on the year-to-year growth of electric-power generation, export markets, and on possible development of new uses for coal and its ingredients.

Mining operations in the coal industry—including surface mining, deep mining, and auger mining—have locally affected the quality of surface water and ground water in parts of the Appalachians.

Although no other minerals approach coal in value, many mineral industries are important to the economy of the Appalachian Region. In addition to the coal, the rocks of the Appalachians yield petroleum and natural gas and various metals and nonmetals.

Coal as an energy fuel is yielding somewhat to oil and gas for some uses. Being a large depositional basin with a great thickness of unmetamorphosed sedimentary rocks, the Appalachians are favorable for oil and gas accumulations. Presently, nearly all production is from rocks of the Pennsylvanian, Mississippian, Devonian, and Silurian systems. Deeper-lying rocks of the Ordovician and Cambrian systems yield oil and gas locally and are a potential source of supply. Oil-bearing rocks underlie a large part of the western half of the Region, (fig. 1). Petroleum and gas production is small, however, only several percent of the national total production.

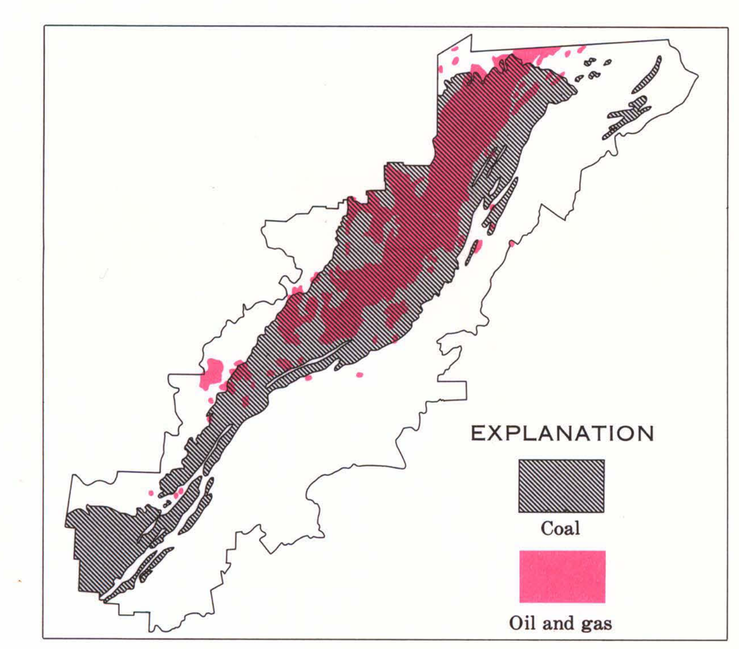


FIGURE 1.—*Locations of coal and oil and gas regions in the Appalachian Region.*

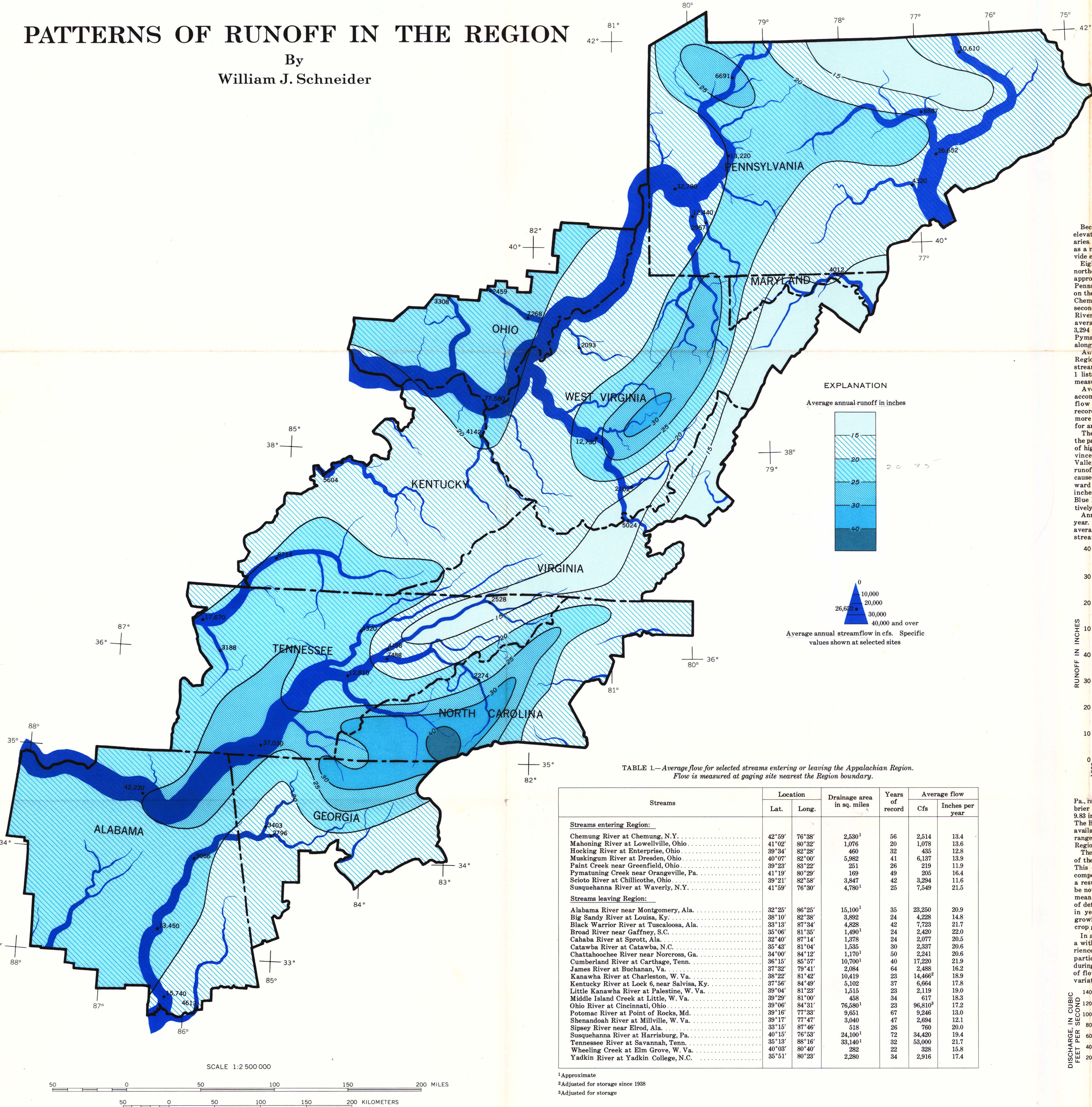
Pit mining and dredging of sand and gravel and quarry and deep mining of limestone are widespread. Much of the sand and gravel occurs as alluvial sand, streambed deposits, and glacial outwash. Great quantities of sand and gravel of glacial origin are dredged from the Ohio River; even river islands are being removed. These are used largely in concrete and for other construction purposes. Owing to the small scale of the geologic map, it is not possible to show the distribution of these deposits, all of which are of Pleistocene or Recent age. However, the location of the principal alluvial and outwash deposits that are important as aquifers are shown on another sheet in this report. These aquifers indicate in general the sand and gravel deposits.

Rocks of the Cambrian and Ordovician systems contain large volumes of commercially important limestone which is used as a component of cement and, in crushed form, for other construction purposes. They also yield lime for agriculture. Clay and shale of suitable quality for manufacture of construction or refractory bricks and other ceramics also occur in the Appalachian Region. Kaolin is mined in the crystalline-rock belt of western North Carolina. Other nonmetallic minerals of special significance include dolomite, marble, feldspar, mica, talc, gypsum, salt, and brine. Metal-ore deposits are worked in the eastern and southern parts of the region, the principal sources being the Cambrian and Ordovician carbonate rocks and certain Silurian strata. Zinc, lead, barium, iron, manganese are the most important metals obtained.

INTERIOR—GEOLOGICAL SURVEY, WASHINGTON, D. C.—1965— W65108

PATTERNS OF RUNOFF IN THE REGION

By
William J. Schneider



PATTERNS OF RUNOFF

Because the Appalachian Region is mainly a mountainous area of high elevations, most streams draining the Region originate within its boundaries. This is a distinct advantage in the management of these streams as a natural resource, since development of this resource will also provide economic stimulation within the Region.

Eight streams drain into the area. All enter the Region along its northern boundary. The largest of these, the Susquehanna River, drains approximately 7,300 square miles before entering the Region at the Pennsylvania-New York state line. The flow, as determined from data on the Susquehanna River at Waverly, N. Y., and the Chemung River at Chemung, N. Y., (see table 1) averages about 10,050 cubic feet per second (cfs). Other major streams entering the area are the Allegheny River averaging 2,793 cfs at Red House, N. Y., the Muskingum River, averaging 6,137 cfs at Dresden, Ohio, and the Scioto River, averaging 3,294 cfs at Chillicothe, Ohio. Four other streams, the Mahoning River, Pymatuning Creek, Hocking River, and Paint Creek, enter the Region along its northern boundary.

An average of 150 billion gallons of water—230,000 cfs—leaves the Region daily. About two-thirds of this flow is carried in four major streams: the Tennessee, Susquehanna, Ohio, and Alabama Rivers. Table 1 lists the average flow of all streams flowing from the Region, as measured at the gaging site nearest the boundary of the Region.

Average runoff for the various parts of the Region is shown on the accompanying map. Also shown are figures of average annual streamflow at selected gaging sites in the Region, based upon the period of record at the site. The Region, with an average runoff of 20 inches and more than 30 inches in places, ranks among the highest in the country for areas of comparable size.

The pattern of average annual runoff for the Region follows closely the pattern of average annual precipitation. There are two distinct areas of high runoff. One occurs in the southern part of the Blue Ridge province in North Carolina, and the other along the western face of the Valley and Ridge province in West Virginia and Pennsylvania. High runoff in both areas results from heavy precipitation (see Sheet 2) caused by the orographic effect of the mountainous terrain on the westward passage of frontal systems. Low runoff averaging less than 15 inches annually occurs along the leeward side of the mountains in the Blue Ridge province chiefly as a result of lesser precipitation and relatively high evapotranspiration demands in this area.

Annual runoff in the Appalachian Region varies widely from year to year. In many places, annual runoff ranges from nearly double the average to less than half the average. Annual runoff for three selected streams is shown in figure 1. The Susquehanna River at Harrisburg,

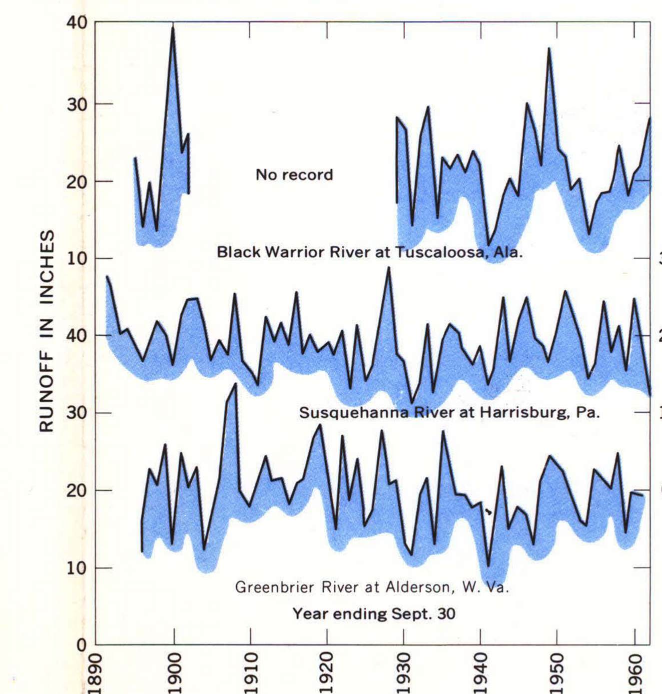


FIGURE 1.—*Variability of annual runoff.*

Pa., ranged from 11.35 inches in 1931 to 29.64 inches in 1891. The Greenbrier River at Alderson, W. Va., draining 1,357 square miles, ranged from 9.83 inches in 1941 to 33.83 inches in 1906, with an average of 20.0 inches. The Black Warrior River at Tuscaloosa, Ala., also for the period of record available, ranged from 11.59 inches in 1941 to 39.13 inches in 1900. These ranges in annual runoff are typical of those for other streams in the Region.

The 1931 water year is noted for large deficiencies in runoff over most of the Region. Runoff at most gaging sites was about half the average. This deficient streamflow resulted from below normal precipitation, compounded by below-normal ground-water storage and soil moisture as a result of below-normal precipitation in the preceding year. It should be noted, however, that years of deficient streamflow do not necessarily mean agricultural droughts, which occur as a result of extended periods of deficient precipitation during the growing season. Occasionally, even in years of extremely deficient streamflow, precipitation during the growing season will be ideally distributed to give maximum benefit to crop growth with little or no contribution to streamflow.

In addition to the year-to-year variations in total runoff, there is also a within-year cyclical variation. Streams throughout the Region experience high flows during spring and low flows during fall. Flooding, particularly on streams draining over 100 square miles, occurs mostly during the spring period of high runoff, followed by a general recession of flow to a minimum usually in September or October. Typical cyclical variation in daily flow is shown in figure 2.

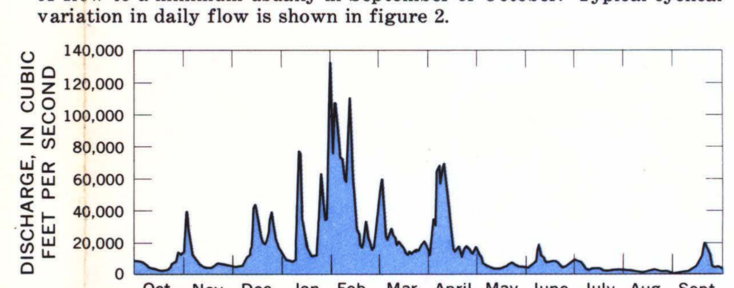


FIGURE 2.—*Daily streamflow, Kanawha River at Winfield, W. Va., 1956-7.*

TABLE 1.—*Average flow for selected streams entering or leaving the Appalachian Region. Flow is measured at gaging site nearest the Region boundary.*

Streams	Location		Drainage area in sq. miles	Years of record	Average flow	
	Lat.	Long.			Cfs	Inches per year
Streams entering Region:						
Chemung River at Chemung, N.Y.	42°59′	76°38′	2,530[1]	56	2,514	13.4
Mahoning River at Lowellville, Ohio	41°02′	80°32′	1,076	20	1,078	13.6
Hocking River at Enterprise, Ohio	39°34′	82°28′	460	32	435	12.8
Muskingum River at Dresden, Ohio	40°07′	82°00′	5,982	41	6,137	13.9
Paint Creek near Greenfield, Ohio	39°23′	83°22′	251	26	219	11.9
Pymatuning Creek near Orangeville, Pa.	41°19′	80°29′	169	49	205	16.4
Scioto River at Chillicothe, Ohio	39°21′	82°58′	3,847	42	3,294	11.6
Susquehanna River at Waverly, N.Y.	41°59′	76°30′	4,780[1]	25	7,549	21.5
Streams leaving Region:						
Alabama River near Montgomery, Ala.	32°25′	86°25′	15,100[1]	35	23,250	20.9
Big Sandy River at Louisa, Ky.	38°10′	82°38′	3,892	24	4,228	14.8
Black Warrior River at Tuscaloosa, Ala.	33°13′	87°34′	4,828	42	7,723	21.7
Broad River near Gaffney, S.C.	35°06′	81°35′	1,490[1]	24	2,420	22.0
Cahaba River at Sprott, Ala.	32°40′	87°14′	1,378	24	2,077	20.5
Catawba River at Catawba, N.C.	35°43′	81°04′	1,535	30	2,337	20.6
Chattahoochee River near Norcross, Ga.	34°00′	84°12′	1,170[1]	50	2,241	20.6
Cumberland River at Carthage, Tenn.	36°15′	85°57′	10,700[1]	40	17,220	21.9
James River at Buchanan, Va.	37°32′	79°41′	2,084	64	2,488	16.2
Kanawha River at Charleston, W. Va.	38°22′	81°42′	10,419	23	14,466[2]	18.9
Kentucky River at Lock 6, near Salvisa, Ky.	37°56′	84°49′	5,102	37	6,664	17.8
Little Kanawha River at Palestine, W. Va.	39°04′	81°23′	1,515	23	2,119	19.0
Middle Island Creek at Little, W. Va.	39°29′	81°00′	458	34	617	18.3
Ohio River at Cincinnati, Ohio	39°06′	84°31′	76,580[1]	23	96,810[3]	17.2
Potomac River at Point of Rocks, Md.	39°16′	77°33′	9,651	67	9,246	13.0
Shenandoah River at Millville, W. Va.	39°17′	77°47′	3,040	47	2,694	12.1
Sipsey River near Elrod, Ala.	33°15′	87°46′	518	26	760	20.0
Susquehanna River at Harrisburg, Pa.	40°15′	76°53′	24,100[1]	72	34,420	19.4
Tennessee River at Savannah, Tenn.	35°13′	88°16′	33,140[1]	32	53,000	21.7
Wheeling Creek at Elm Grove, W. Va.	40°03′	80°40′	282	22	328	15.8
Yadkin River at Yadkin College, N.C.	35°51′	80°23′	2,280	34	2,916	17.4

[1] Approximate
[2] Adjusted for storage since 1938
[3] Adjusted for storage

The ranges in daily flows of selected streams in the Region are shown in figure 3. Although the daily flows in this figure do not show chronological sequence, they do indicate strongly the extreme variability of

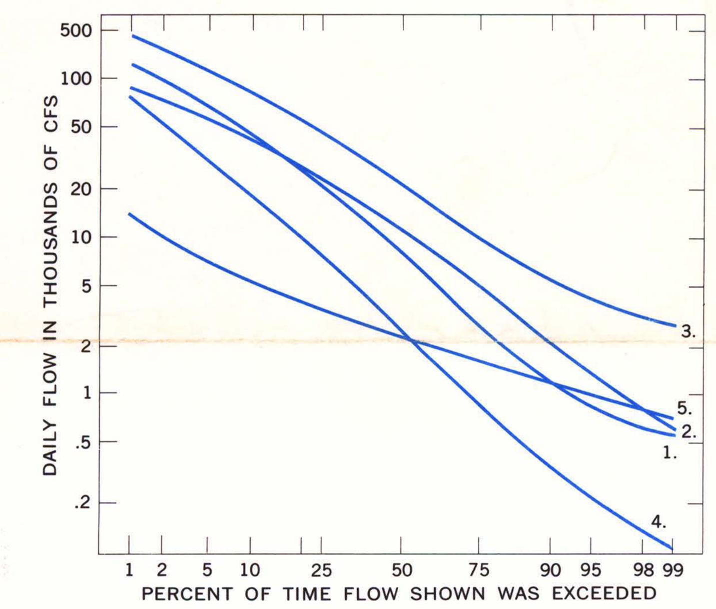


FIGURE 3.—*Variability of daily flows for selected streams in the Appalachian Region. 1. Cumberland River at Carthage, Tenn., 1923-43. 2. Cumberland River at Carthage, Tenn., 1944-62. 3. Susquehanna River at Harrisburg, Pa., 1891-1962. 4. Black Warrior River at Tuscaloosa, Ala., 1929-62. 5. Yadkin River at Yadkin College, N.C., 1929-62.*

daily flows. The overall effect on daily flows of regulation by reservoirs is shown in the comparison of the two curves for the Cumberland River at Carthage Tenn., for periods prior and subsequent to significant regulation of flow.

Geology and topography exert strong influences on the variability of daily flows of streams in the Region. Areas of deep, permeable soils and rocks permit greater infiltration of rainfall during the spring period of high rainfall. The subsequent release of this ground-water storage to streamflow extends into the fall period of minimum streamflows. On the other hand, areas of tight, clayey soils or those of shallow soil underlain by relatively impermeable shales permit little infiltration of high precipitation, resulting in rapid runoff and high flows in the spring, with little or no streamflow sustained by the ground-water reservoir during the fall. The comparisons, shown in figure 4, are typical of the range in daily variations in streamflow for the Region. Figure 4 shows daily

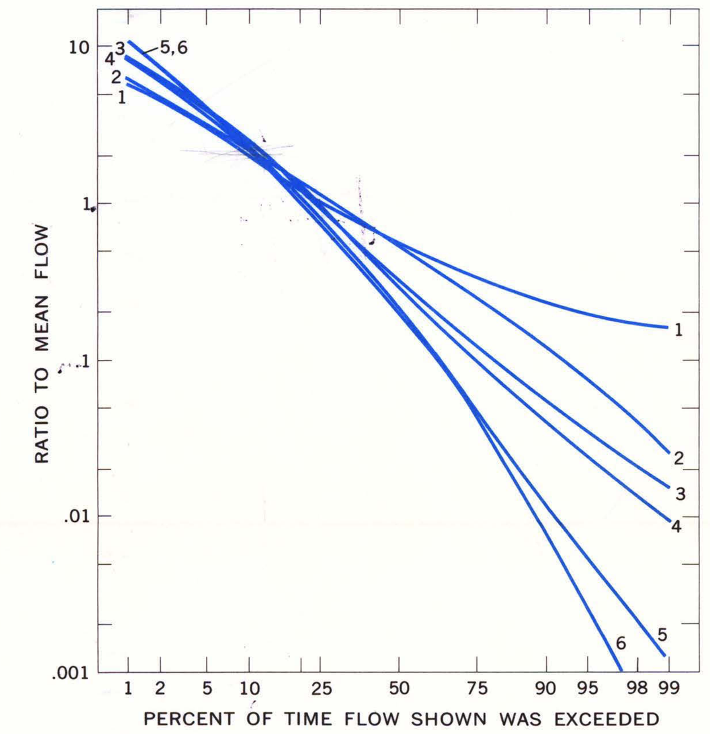


FIGURE 4.—*Variability of flows for streams in different geologic environments. 1. Opequan Creek near Martinsburg, W. Va. 2. Shavers Fork at Parsons, W. Va. 3. Guyandotte River at Branchland, W. Va. 4. Coal River at Ashford, W. Va. 5. Mud River near Milton, W. Va. 6. Pocatalico River at Sissonville, W. Va.*

streamflow as a ratio to the mean daily flow so that differences in total runoff are eliminated to facilitate comparison of the variability of daily flows.

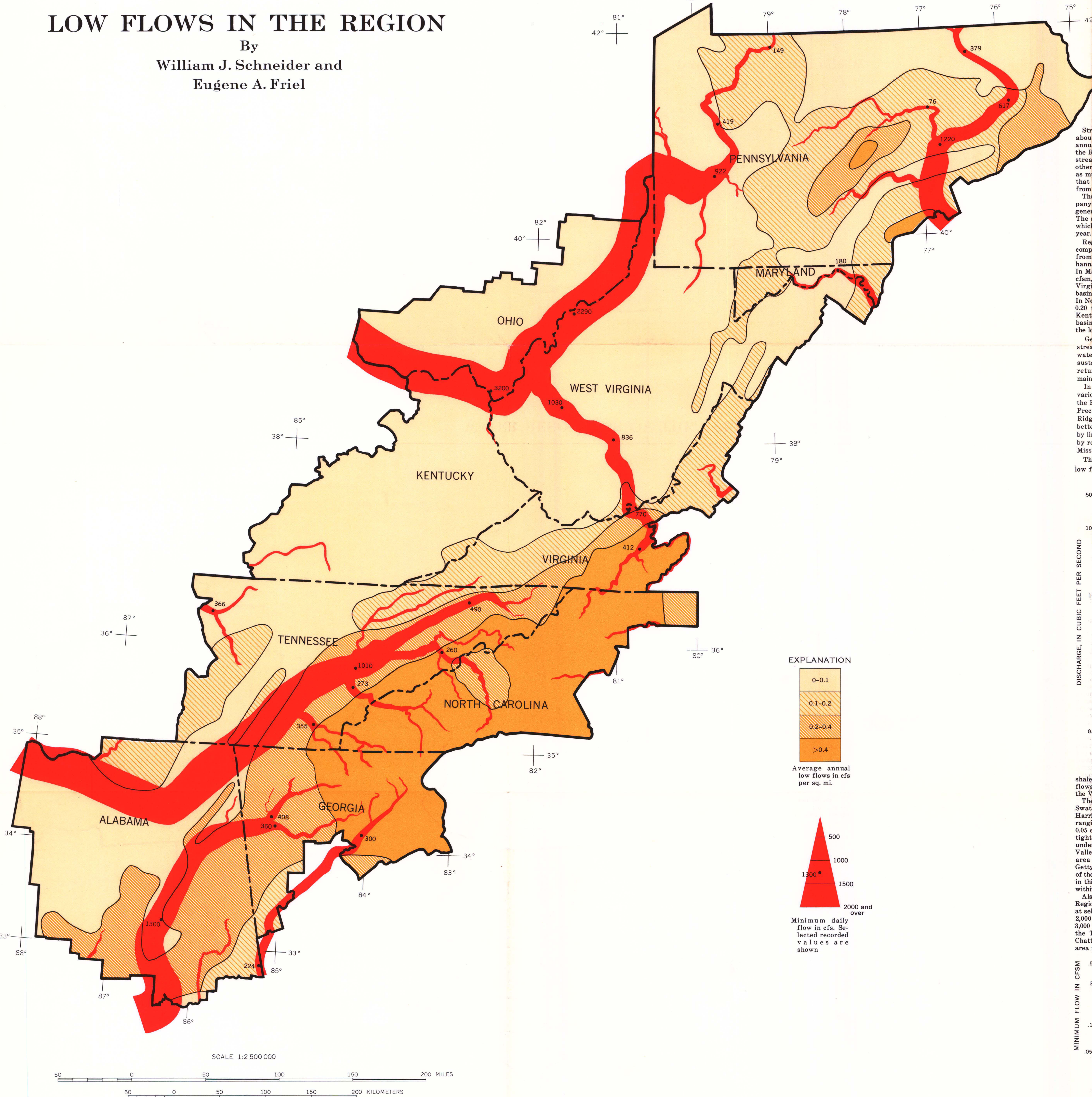
Differences in the variability of daily flows as reflected in the duration curves of figure 4 are related primarily to geologic influences. The limestones underlying the Opequan Creek basin are fractured, solution ridden, and capable of storing ground water. Part of the water precipitated over the basin enters the fractures and solution voids in the limestone, thereby reducing storm runoff. This stored water continues to drain to the stream channels during low-flow periods and maintains relatively high streamflow. In contrast, the shales and sandstone underlying the Mud River basin have low permeabilities and storage capacities. As a result, the stream is flashy and flow quickly recedes during dry periods.

More detailed information on low-flows can be found in Sheet 5 and on flood flows in Sheet 6.

INTERIOR—GEOLOGICAL SURVEY, WASHINGTON, D. C.—1965—W65108

LOW FLOWS IN THE REGION

By
William J. Schneider and
Eugene A. Friel



LOW FLOWS

Streamflow in the Appalachian Region is generally abundant, averaging about 350 million gallons per year for each square mile of area. The annual cyclical variation in streamflow, however, causes streamflow in the Region to recede during late summer and fall. During this period, streams draining areas as large as 900 square miles may go dry, while others draining as little as 70 square miles may have sustained flows of as much as 25 cubic feet per second (cfs). The variation in low flows that may occur in the Region on an average of once in 2 years ranges from near zero to more than 1.2 cfs per square mile.

The regional pattern of average annual low flows is shown on the accompanying map. This pattern of average annual low flows is extremely generalized, and large-scale departures from the ranges shown do occur. The average annual low flow as shown on this map is the flow below which a stream can be expected to recede on an average of every other year.

Regional variations in low flow yields are illustrated by the following comparisons. The range in average annual low flows in Pennsylvania is from 0.56 cubic feet per second per square mile, (cfsm) in the Susquehanna basin to about 0.005 cfsm in the southwestern part of the State. In Maryland, the range is from about 0.13 cfsm to slightly less than 0.03 cfsm, both extremes occuring in the Potomac basin. Low flows in West Virginia range from about 0.17 cfsm in the Potomac and Monongahela basins to less than 0.005 cfsm in basins in the western part of the State. In North Carolina, low flows in the French Broad River basin range from 0.20 to 1.21 cfsm, the highest yields within the Region, whereas in Kentucky, the range of from 0.12 cfsm in the Upper Cumberland River basin to near zero in parts of the Kentucky and Green River basins is the lowest of the Region.

Geology is a major influence on the low flow characteristics of the streams. High sustained flows indicate good capacity for natural groundwater storage and high rate of ground water return to the stream. Low sustained flows indicate little ground water storage and a low rate of return of ground water to streams. These low sustained flows occur mainly in areas underlain by relatively impermeable shales and sandstones.

In general, the low flows of streams in the Region are related to the various geologic units (see Sheet 3). Highest sustained yields occur in the Piedmont and Blue Ridge provinces underlain by crystalline rocks of Precambrian period. Moderate sustained yields occur in the Valley and Ridge province underlain by rocks of the early Paleozoic era, with the better flows in this province generally coming from the areas underlain by limestones. Areas of poorest sustained flows are generally underlain by rocks of the middle and late Paleozoic era, particularly those of the Mississippian, Pennsylvanian, and Permian systems.

This geologic effect is shown markedly in figure 1 which compares the low flows of the Tygart Valley River, which drains poorly permeable

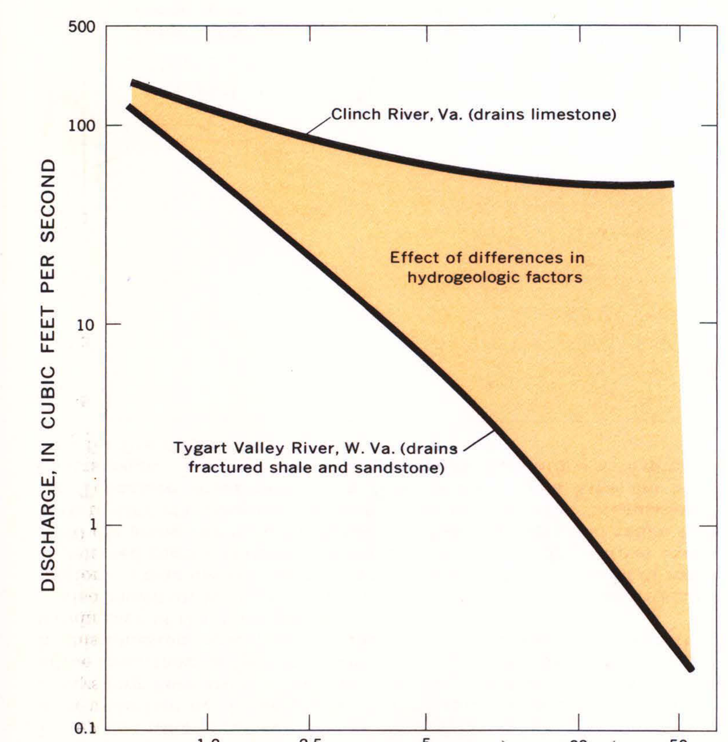


FIGURE 1.—*Magnitude and frequency of annual low flow for two streams in the Appalachian region.*

shales and sandstones of the Appalachian Plateaus province, with low flows of the Clinch River, which drains permeable calcareous rocks of the Valley and Ridge province.

The magnitude of the geologic influence can also be seen in the Swatara Creek basin in Pennsylvania. This 576-square mile area east of Harrisburg shows variation in average annual low flows from subareas ranging from zero to more than 1.0 cfsm. The lowest yields of 0.01 to 0.05 cfsm occur in an area underlain by the Martinsburg Formation of tight, impermeable shales; yields of 0.10 to 0.20 cfsm occur in an area underlain by interbedded sandstones, shales, and conglomerates in the Valley and Ridge province; and yields of 0.20 and 0.40 cfsm occur in an area underlain by the deeply weathered sandstones and shales of the Gettysburg Formation. The low flows vary most in the limestone area of the basin, ranging from zero to more than 1.0 cfsm. However, even within this limestone area there is reasonable consistency in the low flows within each of the limestone formations.

Also shown on the map are the minimum flows of streams within the Region. These are minimum flows as recorded for the period of record at selected gaging stations. Minimum flows of the Ohio River exceed 2,000 cfs along the western border of West Virginia and range from 3,000 to 4,000 cfs along the northern border of Kentucky. Regulation on the Tennessee River provides a flow of more than 3,000 cfs below Chattanooga. The variation of the minimum streamflow with drainage area for five major streams is shown in figure 2.

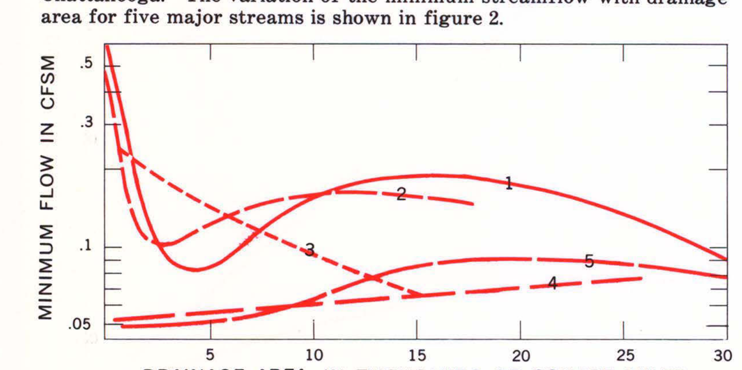


FIGURE 2.—*Minimum flows of major rivers in the Appalachian Region;* 1. *French Broad-Tennessee;* 2. *Cartecay-Coosa-Alabama;* 3. *Kanawha;* 4. *Susquehanna;* 5. *Allegheny-Ohio.*

The minimum flow of streams also varies from year to year. In general, the minimum observed flow is about one-third to one-fourth of the average low flow at a site. Probability of occurrence of specific low-flow magnitudes can be determined from statistical interpretation as shown in figure 3. Shown in this figure are frequency curves for selected streams in the Region, including those gaged streams of highest and lowest sustained flows (French Broad River at Asheville, N.C., and Levisa Fork at Paintsville, Ky.). All large streams in the area lie between these extremes, with frequency curves having slopes also within the range of the curves shown in figure 3. These curves are for the lowest average flow for a 7 consecutive-day period in each year.

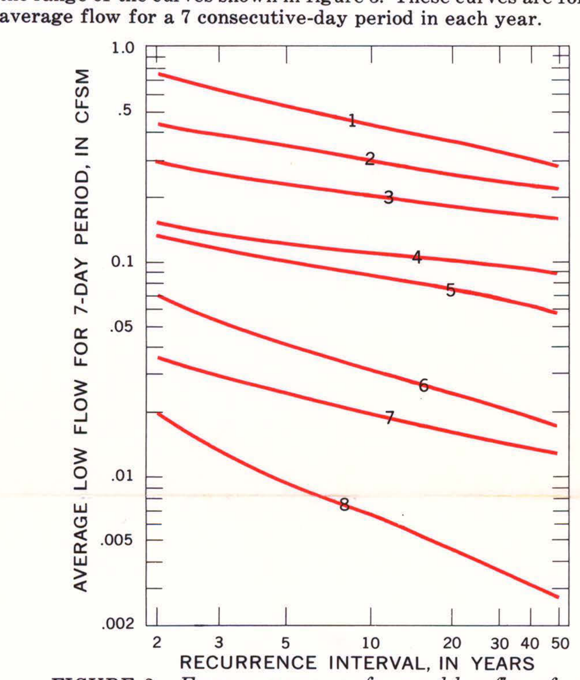


FIGURE 3.—*Frequency curves of annual low flows for selected streams in the Appalachian Region;* 1. *French Broad River at Asheville, N.C.;* 2. *New River at Allisonia, Va.;* 3. *Oostanaula River at Resaca, Ga.;* 4. *Powell River near Arthur, Tenn.;* 5. *Susquehanna River at Wilkes-Barre, Pa.;* 6. *Greenbrier River at Alderson, W. Va.;* 7. *Locust Fork at Trafford, Ala.;* 8. *Levisa Fork at Paintsville, Ky.*

The average flow for a 7-day period is customarily used for low-flow studies because of its greater stability than the flow for a minimum day. During the early years of record for many gaged streams, diurnal fluctuations in streamflow were caused by operation of mill dams. The use of a 7-day period minimizes the effect of this diurnal fluctuation and change in storage. The 7-day period also eliminates the disproportionate influence of a daily flow affect by temporary storage or diversion caused by an unusual or rare event. For most streams, however, the difference between the minimum average 7-day flow and the minimum daily flow is only a few percent.

As the time periods are increased, however, the average flow for the minimum period also increases. Low-flow frequency curves for six lengths of period illustrate this in figure 4. Again, the two streams

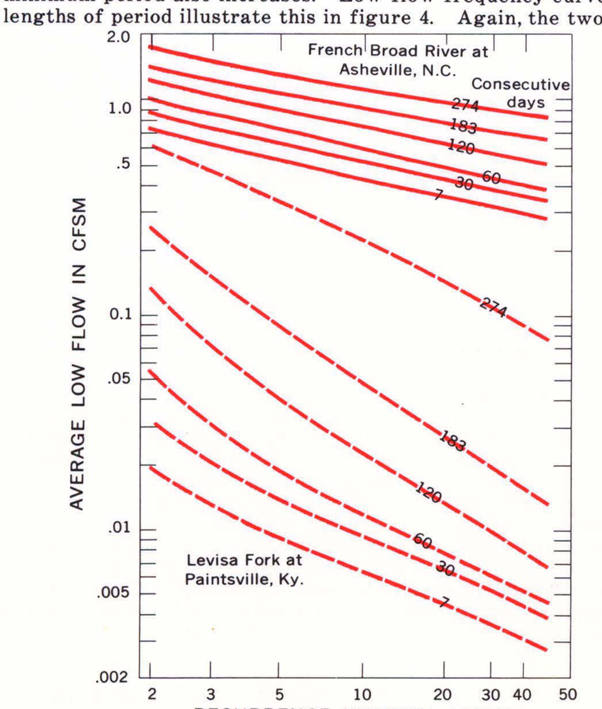


FIGURE 4.—*Frequency curves of annual low flows for selected periods of time.*

shown represent the range of variability for gaged streams in the Region. As shown in figure 4, the increase in flow with increase in length of period is greater for streams with the more variable low flows than for those with well-sustained flow.

The ranges in low-flow frequency curves shown in figures 3 and 4 represent natural unregulated streamflow. Artificial regulation of stream-flow for low-flow augmentation greatly increases the sustained yield of many streams. The Cumberland River at Celina, Tenn. is an excellent example of the effect of storage on low flows. Under natural flow conditions, the annual low flow averaged 263 cfs. Since completion of the Dale Hollow Reservoir in Tennessee and Kentucky, and Lake Cumberland in Kentucky, the annual minimum daily flow has averaged 535 cfs.

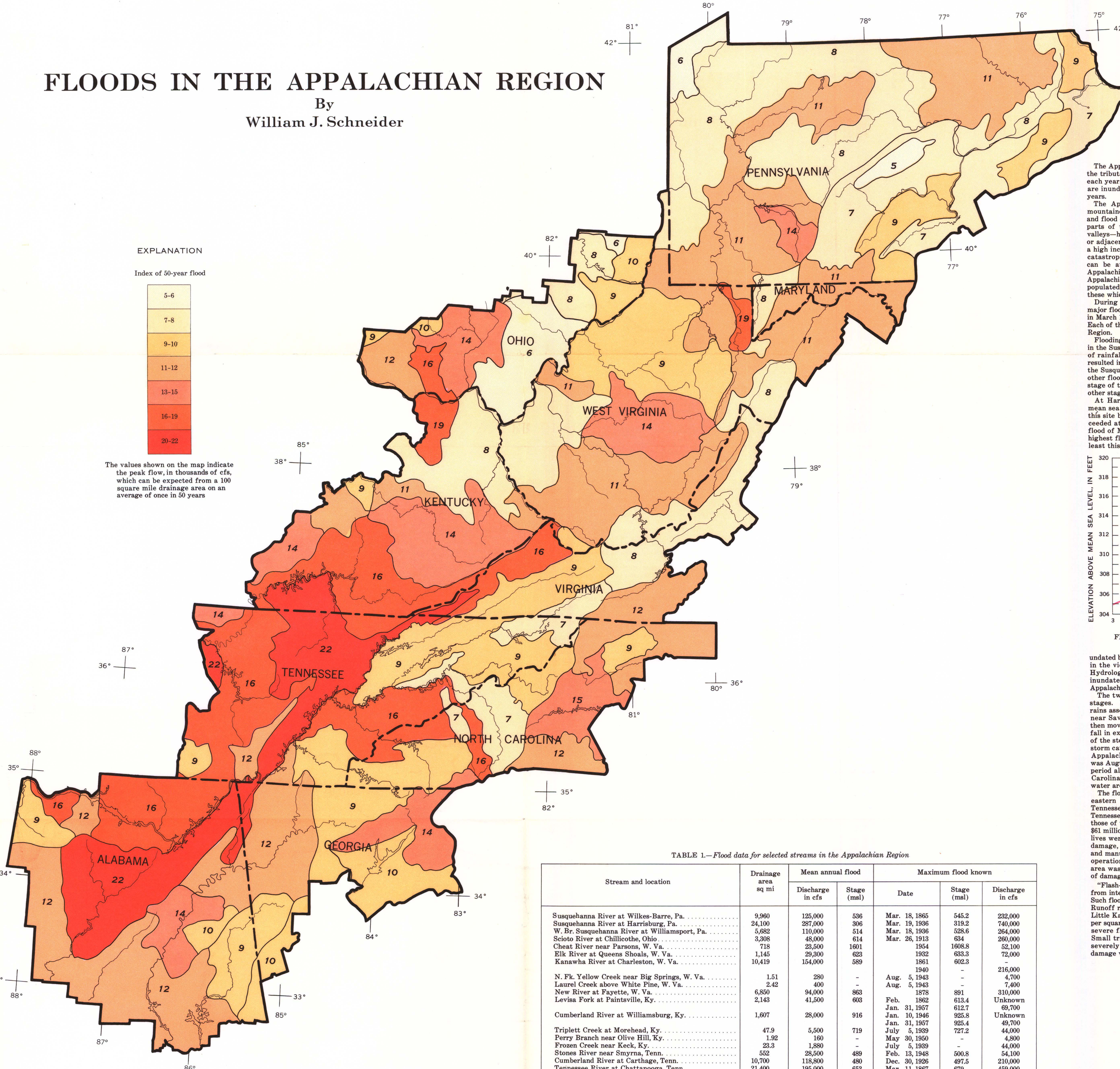
During 1953, when streamflow was unusually deficient, average daily flow at Celina for the 6-month period of June through November was 6,100 cfs. Of this flow, 82 percent was drawn from storage and 18 percent, averaging only 1,100 cfs, was natural flow. Assuming storage available was equal to the 2.56 million cfs-days of usable reservoir capacity (including flood control), an average flow of more than 15,000 cfs could have been maintained during this same 6-month period by completely depleting the storage.

Flows of major streams in the Region are sufficient to meet increased demands without additional storage. Throughout the entire Region, sufficient surface water for most foreseeable needs can be made available by storage used to augment low flow. In general, throughout most of the area, low-flow augmentation can increase minimum flows to at least 0.2 to 0.3 of the average flow.

INTERIOR—GEOLOGICAL SURVEY, WASHINGTON, D. C.—1965—W65108

FLOODS IN THE APPALACHIAN REGION

By
William J. Schneider



FLOODS IN THE REGION

The Appalachian Region has always been plagued by floods. Many of the tributary streams in the Region overflow their banks several times each year. Almost all of the more than 6 million acres of flood plains are inundated by floods having an average recurrence interval of 10 years.

The Appalachian Region is predisposed to severe flooding. The mountainous terrain induces both high precipitation and rapid runoff, and flood experiences in the Region are as great as those in many other parts of the country. The same terrain—steep hillside and narrow valleys—have also concentrated the industrial and urban development on or adjacent to the flood plains. This combination of factors results in a high incidence of flood damage. That flood damage has not been as catastrophic as in surrounding areas, particularly the urbanized East, can be attributed only to the relative lack of development in the Appalachian Region. Severe urban damage has been infrequent in the Appalachian Region because of a combination of relatively few heavily—populated areas and a moderate amount of flood-control protection for these which do exist.

During the current century, all parts of the Region have experienced major flooding. Some of the more notable of the recent floods occurred in March 1936, August 1940, January and February 1957, and March 1963. Each of these floods caused record stages on streams in some part af the Region.

Flooding during the period March 9-22, 1936, was exceptionally severe in the Susquehanna River basin. A combination of as much as 12 inches of rainfall on a snow pack having a water content of up to 10 inches resulted in record-breaking flood stages at many places. Flood stage of the Susquehanna River at Harrisburg, Pa., was 3.5 feet higher than any other flood stage at Harrisburg in the previous 200 years, and the flood stage of the Ohio River at Pittsburgh, Pa., was 6.1 feet higher than any other stage there since 1762.

At Harrisburg, the 1936 flood reached a stage of 319.2 feet above mean sea level at the gaging station at Nagle Street. Flood stage at this site begins at 307.0 feet. The elevation of 307.0 feet has been exceeded at least once in each of 24 years of the 177-year record. The flood of March 1963 reached a stage of 311.5 feet which is the seventh highest flood of record. Average recurrence interval for a flood of at least this magnitude is once in 30 years (see figure 1). The area inundated by the 1936 flood along a 15-mile reach of the Susquehanna River in the vicinity of Harrisburg is shown in the U.S. Geological Survey Hydrologic Atlas 57. At present this is the only delineation of flood-inundated areas prepared by the U.S. Geological Survey in the Appalachian Region.

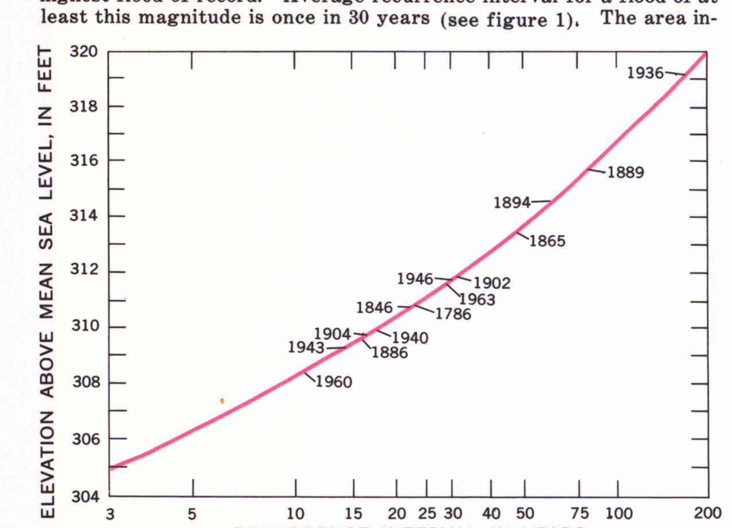


FIGURE 1.—*Frequency of floods at Nagle Street on Susquehanna River at Harrisburg, Penn.*

The two flood periods in August 1940 also produced record-breaking stages. During the period August 10-17, flooding resulted from heavy rains associated with the passage of a hurricane that entered the coast near Savannah, Ga., moved inland to the Appalachian Mountains, and then moved northward along the eastern front of the mountains. Rainfall in excess of 15 inches was measured at many points along the path of the storm, with as much as 8 inches being recorded in one day. This storm caused about 20 deaths and more than $3 million in damage in the Appalachian Region and surrounding areas. The second flood period was August 28-31, when 8 to 13 inches of rain fell during a 20- to 30-hour period along the western slopes of the Blue Ridge Mountains in North Carolina. Particularly hardhit by this second storm were the headwater areas of the French Broad and the Little Tennessee basins.

The floods of January and February 1957 affected large areas of southeastern Kentucky, southwestern West Virginia, and northeastern Tennessee drained by the Big Sandy, Kentucky, Cumberland, and Tennessee Rivers. Some flood stages on the Cumberland River equaled those of the historic floods of 1918 and 1946. Damage was estimated at $61 million, of which about $39 million was in the Big Sandy basin. Nine lives were lost, 597 homes were destroyed, 2,293 homes sustained major damage, and 8,740 sustained minor damage. About 900 coal mines and manufacturing plants were forced to shut down or seriously curtail operations in a 12-county area hardest hit by the flood. Much of this area was again hit by the floods of March 1963, when $40 million worth of damage was sustained.

"Flash-floods"—high, sudden runoff from small drainage areas resulting from intense localized thunderstorm activity—are also a severe problem. Such floods occur during the summer months and cause localized damage. Runoff rates are exceptionally high; for example, small streams in the Little Kanawha River basin in West Virginia peaked as high as 3,100 cfs per square mile during the flood of August 5, 1943. Another exceptionally severe flash-flood occurred in east-central Kentucky on July 5, 1939. Small tributaries in the Kentucky and the Licking River basins were severely affected, 98 persons lost their lives, and more than $2 million damage was sustained in a four-county area.

Major flood peaks at selected locations in the Appalachian Region are shown in the accompanying table. The list includes both floods on major rivers at large cities and flash-floods on small areas. For comparison, estimates of mean annual flood and its approximate stage are given for those sites where data are available.

The pattern of flooding in the Region is shown on the accompanying map. This pattern is based upon a study of annual floods determined at more than 800 sites. It has been generalized for this report from similar, more detailed studies by the U.S. Geological Survey published in its water-supply paper series, and in reports prepared cooperatively with State agencies in Alabama, Georgia, Kentucky, North Carolina, Pennsylvania, and Tennessee. Because of its general treatment, it is not intended here for use in design of engineering projects.

The 50-year flood—that flood exceeded on an average of once in 50-years—is used here as an index of the variability of flooding in the Appalachian Region. It is obtained from a statistical array of annual floods interpreted to estimate the average recurrence interval of a flood of a given magnitude. The annual floods used in this array are the highest discharge in each water year (October 1 to September 30).

The values shown on the map indicate the peak flow, in thousands of cfs, which can be expected from a 100 square mile drainage area on an average of once in 50 years. Floods of other recurrence intervals, ranging downward to the mean annual flood, show a similar pattern for the Region.

The effect of drainage area on flooding in the Appalachian Region is shown in figure 2. The ratios obtained from the graph apply to the unit discharges—that is, the peak flow in cfs per square mile. Although the unit discharge decreases markedly in the downstream direction, the absolute magnitude of the peak discharge of the 50-year flood increases in the down-stream direction proportional to about the seven-tenths power of the drainage area. That is, for an area of uniform flood index, the 50-year flood can be expressed as the equation $Q \propto A^{0.7}$.

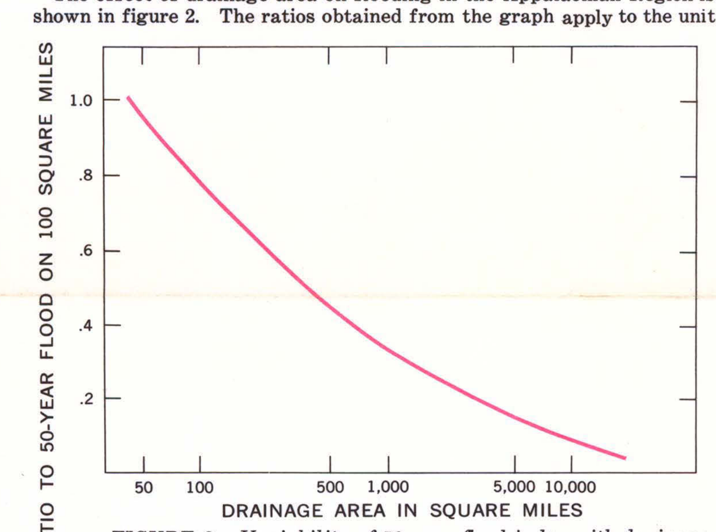


FIGURE 2.—*Variability of 50-year flood index with drainage area*

There are two distinct patterns to the variability in the 50-year floods. First, there is a distinct physiographic division separating the Appalachian Plateaus (see Sheet 1) from the more mountainous Valley and Ridge and Blue Ridge provinces. Floods are larger in the Appalachian Plateaus, as a result of orographic influence of the mountains on the westward movement of moisture over the Region. Another possible factor is the more dendritic-type drainage of the Appalachian Plateaus which tends to concentrate runoff in stream channels more rapidly than in the long, narrow valleys of the Valley and Ridge province.

The second pattern to the variability is a distinct increase in the magnitude of the 50-year flood in a southward direction. This increase is more pronounced in the Appalachian Plateaus, where the index increases almost threefold from Pennsylvania to Alabama. This southward increase in flood index seems generally related to the southward increase in average annual precipitation, since indices of 8 to 11 occur in Pennsylvania in areas of about 40 to 44 inches of precipitation, whereas indices of 16 to 22 occur in Alabama in areas of about 52 to 56 inches of precipitation.

The fact that the southern part of the Appalachian Plateaus has the highest flood peaks does not necessarily mean that the flood plains are inundated either more frequently or to greater depths than those in the rest of the Region. Topographic and geologic controls exert strong influences on the size and shape of valleys, and frequently the flood-plain area in a valley bottom will change considerably both in width and slope within a few miles as a result of these influences. Any changes in width of the flood plain or slope of the stream can effect the depth and frequency of flooding. The differences in magnitudes of the flood peaks do indicate the relative sizes of openings necessary for bridges, culverts, or other engineering features across stream channels. For basins of equal area, the one with the higher peak flows generally will need larger openings.

Future development in the Appalachian Region undoubtedly will require further utilization of flood-plain areas. Industrial expansion, in particular, will find the valley bottoms attractive, where prime factors such as water and transportation facilities are readily accessible. The valley floors, even with their flooding hazards, are also more amenable to cultivation than the steeper, often rocky, hillsides. Such future developments will, of course, aggravate flood problems and increase flood damages if flood-protection measures are not considered.

Strict zoning of flood plains in the Appalachian Region, aimed at preventing additional flood damage, would contravene proposed development of the Region. Although such restrictions on flood plain occupancy are feasible for some areas of less rugged relief, they would exclude in the Appalachian Region practically all of the desirable land from high investment use and therefore inhibit severely any industrial or urban expansion. In this Region, zoning should rather define those areas having adequate control against flooding, and prevent serious channel encroachment which would impede the normal passage of floodflows. Flood protection should be so designed to permit orderly conversion of flood plains for occupancy in those parts of the Region offering the best combinations of all needed facilities for economic growth.

Methods for such planning are available, based upon hydraulic and hydrologic data. The approach involves the study of flood magnitudes as recorded or computed, flood frequencies based on many years of record, and the use of existing stage-discharge relations and flood profiles. A pilot study of this type has been made by the U.S. Geological Survey in Allegheny County, Pa., delineating areas along Chartiers Creek flooded at various frequencies. Such studies for other parts of the Appalachian Region as needs develop, would be valuable in preliminary planning.

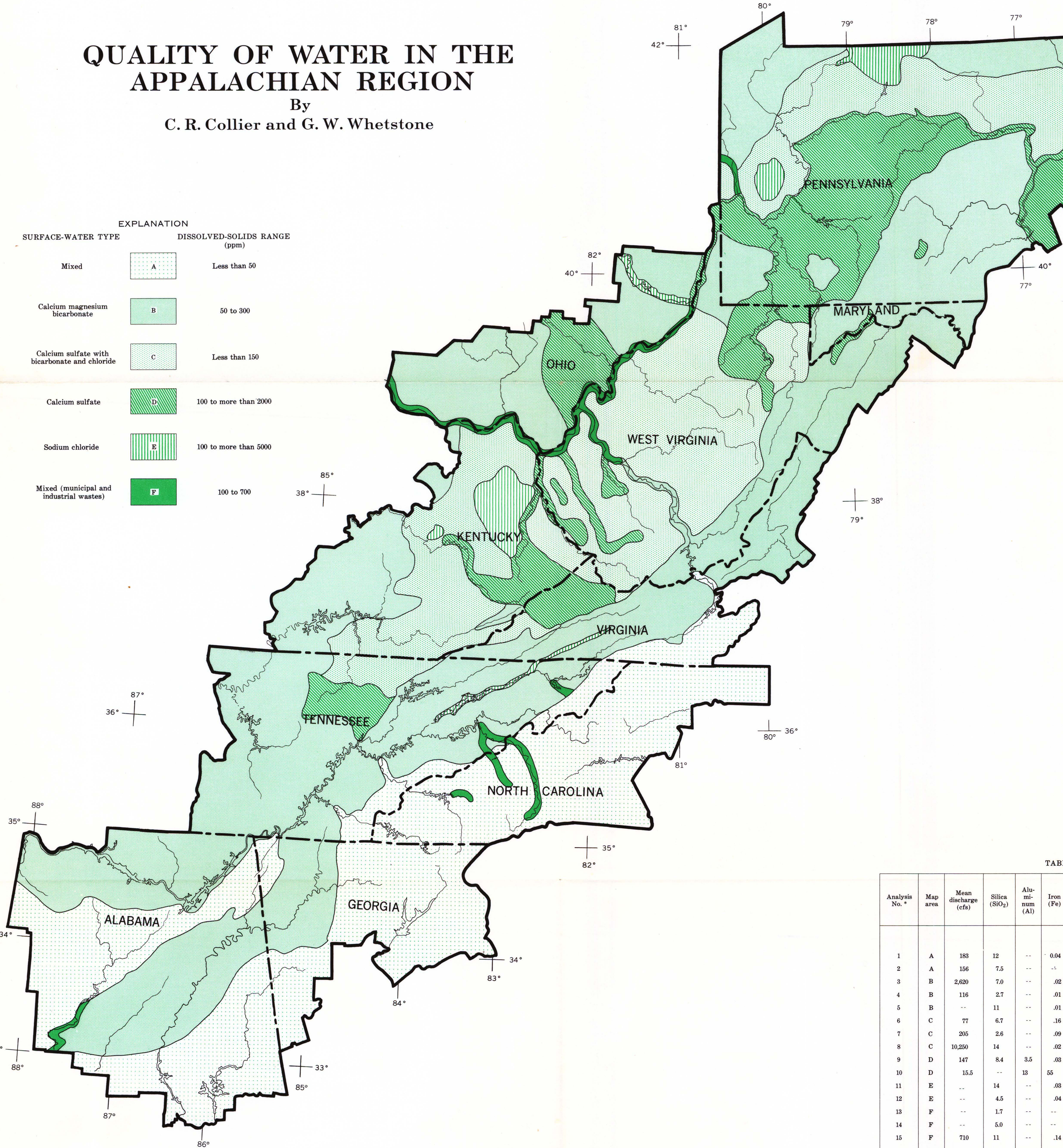
TABLE 1.—*Flood data for selected streams in the Appalachian Region*

Stream and location	Drainage area sq mi	Mean annual flood		Maximum flood known		
		Discharge in cfs	Stage (msl)	Date	Stage (msl)	Discharge in cfs
Susquehanna River at Wilkes-Barre, Pa.	9,960	125,000	536	Mar. 18, 1865	545.2	232,000
Susquehanna River at Harrisburg, Pa.	24,100	287,000	306	Mar. 19, 1936	319.2	740,000
W. Br. Susquehanna River at Williamsport, Pa.	5,682	110,000	514	Mar. 18, 1936	528.6	264,000
Scioto River at Chillicothe, Ohio	3,308	48,000	614	Mar. 26, 1913	634	260,000
Cheat River near Parsons, W. Va.	718	23,500	1601	1954	1608.8	52,100
Elk River at Queens Shoals, W. Va.	1,145	29,300	623	1932	633.3	72,000
Kanawha River at Charleston, W. Va.	10,419	154,000	589	1861	602.3	-
				1940	-	216,000
N. Fk. Yellow Creek near Big Springs, W. Va.	1.51	280	-	Aug. 5, 1943	-	4,700
Laurel Creek above White Pine, W. Va.	2.42	400	-	Aug. 5, 1943	-	7,400
New River at Fayette, W. Va.	6,850	94,000	863	1878	891	310,000
Levisa Fork at Paintsville, Ky.	2,143	41,500	603	Feb. 1862	613.4	Unknown
				Jan. 31, 1957	612.7	69,700
Cumberland River at Williamsburg, Ky.	1,607	28,000	916	Jan. 10, 1946	925.8	Unknown
				Jan. 31, 1957	925.4	49,700
Triplett Creek at Morehead, Ky.	47.9	5,500	719	July 5, 1939	727.2	44,000
Perry Branch near Olive Hill, Ky.	1.92	160	-	May 30, 1950	-	4,800
Frozen Creek near Keck, Ky.	23.3	1,880	-	July 5, 1939	-	44,000
Stones River near Smyrna, Tenn.	552	28,500	489	Feb. 13, 1948	500.8	54,100
Cumberland River at Carthage, Tenn.	10,700	118,800	480	Dec. 30, 1926	497.5	210,000
Tennessee River at Chattanooga, Tenn.	21,400	195,000	653	Mar. 11, 1867	679	459,000
Tennessee River at Knoxville, Tenn.	8,934	100,000	823	Mar. 10, 1867	842.7	290,000
Charles Creek at Faulkner Springs, Tenn.	32	2,110	-	June 13, 1952	-	23,000
Reedy Creek at Kingsport, Tenn.	57	2,120	-	May 30, 1927	-	15,900
French Broad River at Asheville, N.C.	937	9,400	1955	July 16, 1916	1973.4	110,000
Swannanoa River at Biltmore, N.C.	130	3,150	1984	April 1791	2002	40,000
Nantahala River at Almond, N.C.	174	5,650	1604	Feb. 4, 1936	1606.7	11,000
Panther Creek near Toccoa, Ga.	32.5	2,500	680	June 16, 1949	691.5	15,100
Coosa River near Rome, Ga.	4,040	51,000	510	Apr. 6, 1886	523.9	115,000
Black Warrior River at Tuscaloosa, Ala.	4,830	-	-	Apr. 18, 1900	151.1	215,000

INTERIOR—GEOLOGICAL SURVEY, WASHINGTON, D.C.—1965—W65108

QUALITY OF WATER IN THE APPALACHIAN REGION

By
C. R. Collier and G. W. Whetstone



QUALITY OF WATER

The prevalent dissolved-solids concentrations and chemical type of waters in the Appalachian Region are shown on the map at the left. These data provide a general evaluation of the quality of water in the Region, indicate areas where acceptable supplies might be found, and delineate some of the principal problem areas throughout the Region. The delineation is based on analyses of streamflow, but locally it may also represent the general quality of ground water.

The quality of a water determines its utility, or worth, for a particular purpose. Water for nearly every use requires a certain minimum quality and often some degree of treatment. The degree and type of treatment depend on the quality and the intended use of the available water. Water used by industry for cooling purposes generally has liberal quality tolerances. For other industrial uses and for municipal supplies, the quality requirements are more stringent. The quality traits selected for presentation in this sheet—dissolved solids and chemical type—are most commonly used to evaluate the quality of water.

The chemical type of a stream is determined from the principal dissolved constituents in the water. The chemical type, shown by the color code on the map, is prevalent in the areas most of the time and generally represents periods of dry-weather streamflow. During these periods, water that reaches the streams has seeped through the soil and subsurface rocks to the ground-water reservoir. This water has been in contact with soil and rock material for long periods of time and has had the opportunity to dissolve significant quantities of the rocks. The dissolved-solids concentration of the streams is generally highest during the low or dry-weather flow periods. Therefore, the concentration of dissolved solids generally occurring during the periods of low streamflow is given by the upper value of the range in concentration for each area. These concentrations, therefore, may also indicate the chemical quality of ground water in the vicinity of the stream.

In contrast to low-flow conditions, the streams generally have the lower concentration of dissolved solids during periods of high flows. Immediate runoff from the storms moves overland to the streams and is in contact only with the well-leached soils and rocks on the surface of the land for relately short periods of time. The expected dissolved-solids concentation during high-flow periods is the lower value shown for each area.

Although the chemical quality of water is constantly changed by its environment, changes due to climate are generally small. Rainfall in the Appalachian Region is abundant and is distributed fairly evenly throughout the year. As a result, the maximum dissolved-solids concentrations throughout most of the Region are generally less than six times the minimum concentrations.

Rock types and their degree of weathering have important influence on the quality of the water in the streams. Bicarbonate-type waters result from chemical reactions between precipitation and limestones, dolomites, and glacial drift. Sulfate-type waters result from chemical reactions between precipitation and sandstones, shales, and evaporite deposits containing sulfide and sulfate minerals.

Changes in water- and land-use patterns materially influence the water quality of streams and often completely change the character and flow of a stream. Large sudden variations in dissolved-solids content and composition may occur in streams receiving municipal and industrial wastes. The type of wastes, degree of waste treatment, and volume of waste in relation to streamflow control the water quality of these streams. The acid water draining from coal mines and brines associated with petroleum development often produce erratic and extreme changes in dissolved-solids concentration and chemical type of the receiving streams. At some locations, the maximum concentration of dissolved-solids may exceed the minimum by a factor of 50 or more.

In about 90 percent of the Appalachian Region, the prevalent concentrations of dissolved-solids are less than 300 ppm (parts per million). This is an important consideration in developing new municipal and and industrial water supplies, for waters of these concentrations generally require little treatment for use. In the Region, the dissolved-solids content of surface waters is an indication of the hardness, which is caused primarily by calcium and magnesium. Waters with a dissolved-solids content of less than 100 ppm are soft; from 100 to 300 ppm of dissolved solids are moderately hard to hard; and those greater than 300 ppm are very hard.

Areas A on the map have streams with very low dissolved-solids content, often less than 50 ppm. They are a mixed type of water, generally a calcium-magnesium bicarbonate type, but sodium, sulfate, and chloride sometimes predominate. These waters are extremely soft, as shown by analyses 1 and 2 in table 1. These streams drain about 23 percent of the Appalachian Region and include the Blue Ridge and Piedmont provinces of Virginia, North Carolina, Georgia, and Alabama, and the Southern Appalachian Mountains of Alabama and northeastern Pennsylvania.

Areas B have streams with a calcium-magnesium-bicarbonate type water. The dissolved-solids content of these waters generally ranges from 50 to 300 ppm. These streams comprise about 42 percent of the Region and include the limestone and dolomite areas of the Appalachian Plateau and the Appalachian Mountains. The softer and less mineralized waters of the bicarbonate type are generally found in central Kentucky, Tennessee, and northern Alabama.

Areas C have primarily calcium sulfate water containing less than 150 ppm dissolved-solids. Although some streams have significant bicarbonate and chloride, and in extreme eastern Kentucky and southern West Virginia the dissolved-solids content sometimes exceeds 150 ppm, most streams in these areas generally have soft water and, like those in areas A and B, require little treatment other than chlorination, coagulation, and filtration before use as municipal supplies. The streams drain the Appalachian Plateau and the area includes 20 percent of the Appalachian Region.

Areas D are affected by mine drainage. The streams contain calcium sulfate type waters which are usually hard to very hard and require softening to remove the permanent hardness. These waters range in dissolved-solids concentrations from 100 to 500 ppm or more in the larger streams and sometimes exceed 2,000 ppm in the smaller streams. These streams drain 13 percent of the Region and are in the coal mining areas of Pennsylvania, West Virginia, Kentucky, Ohio, and Tennessee. Waste water from coal mines is often acid and contains high concentrations of calcium and sulfate. Acid mine drainage is discussed more fully in Sheet 9.

Areas E have streams affected by brines from petroleum production or salt manufacturing. The streams contain sodium chloride type waters. Dissolved-solids concentrations generally range from 100 to 1,300 ppm in the major streams, although concentrations of dissolved solids in excess of 5,000 ppm have been measured in many of the small streams in these areas. The Muskingum River in Ohio and North Fork Holston River in Virginia and Tennessee are major rivers affected by chloride brines.

Throughout the Appalachian Region, the chemical type of a few streams does not agree with the classification given for a particular area. Areas F are principal exceptions to the areal classification. They are segments of rivers that drain areas of diverse geology or centers of population and industry. In the latter areas, industrial and domestic water use is high and, consequently, considerable amounts of treated and untreated wastes are discharged to the streams. Water in these rivers require additional treatment besides chlorination, coagulation, and filtration for most uses. The waters generally are hard and may contain a wide variety of organic and inorganic substances, with the dissolved-solids concentration as high 700 ppm.

TABLE 1. —*Selected chemical analyses of streams in the Appalachian Region. (Chemical analyses in parts per million)*

Analysis No. *	Map area	Mean discharge (cfs)	Silica (SiO_2)	Aluminum (Al)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Lithium (Li)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Phosphate (PO_4)	Dissolved solids (residue at 180°C)	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Total acidity as H_2SO_4	Specific conductance (micromhos at 25°C)	pH	Color	ABS
1	A	183	12	--	0.04	--	3.2	1.1	5.3	1.0	--	21	2.4	4.4	0.0	1.4	--	41	12	0	--	50	6.7	5	--
2	A	156	7.5	--	--	--	1.0	.2	.9	.5	--	8	.2	.8	.1	.0	--	18	4	0	--	13	6.6	3	--
3	B	2,620	7.0	--	.02	--	13	3.3	6.0	.9	--	56	9.6	4.0	.1	.1	--	72	46	0	--	115	6.7	7	--
4	B	116	2.7	--	.01	--	39	11	4.1	1.9	--	163	12	2.5	.0	1.7	--	151	143	9	--	278	8.2	5	--
5	B	--	11	--	.01	0.00	62	20	7.7	3.2	--	220	53	10	.2	4.8	--	296	237	56	--	475	7.6	13	--
6	C	77	6.7	--	.16	--	12	5.8	8.8	2.1	--	33	37	7.5	.2	.5	--	106	54	27	--	168	6.9	5	--
7	C	205	2.6	--	.09	.00	5.8	2.2	1.7	1.0	--	13	15	2.5	.1	.1	--	39	24	13	--	66	6.4	5	--
8	C	10,250	14	--	.02	--	21	4.9	7.9	1.5	--	32	50	12	--	.9	--	127	73	47	--	200	7.0	12	--
9	D	147	8.4	3.5	.03	.89	42	13	23	1.8	--	0	208	2.5	.1	.6	--	314	159	159	24	478	4.2	1	--
10	D	15.5	--	13	55	4.1	--	--	--	--	--	0	820	8.0	--	--	--	1,200	700	700	150	1,570	3.2	--	--
11	E	--	14	--	.03	--	206	38	434	4.2	--	99	5.0	1,080	.2	.9	--	1,990	671	590	--	3,520	7.0	5	--
12	E	--	4.5	--	.04	.35	153	22	122	7.1	--	113	192	322	.7	3.5	--	1,010	472	380	--	1,550	7.2	6	--
13	F	--	1.7	--	--	--	71	16	70	5.1	--	26	229	101	.6	6.3	0.2	545	243	222	--	848	--	3	0.1
14	F	--	5.0	--	--	--	49	7.8	40	2.5	--	78	54	95	.2	5.7	.49	326	154	90	--	574	--	7	.1
15	F	710	11	--	.14	--	5.9	1.6	33	2.3	--	37	45	12	.2	3.5	--	140	22	0	--	210	6.3	33	--

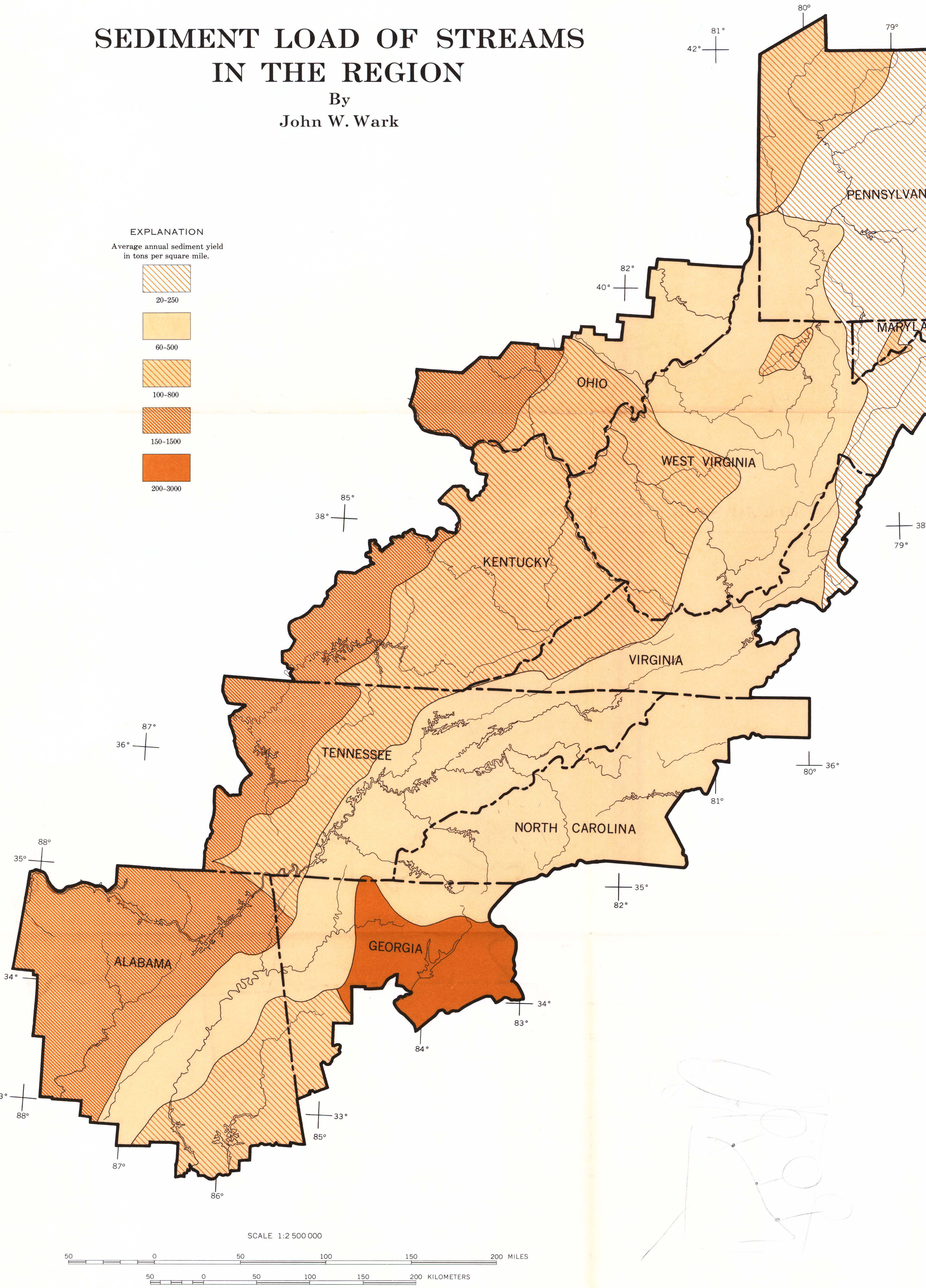
*Nos. correspond to stream names below.

1. Catawba River near Marion, N.C.
2. Hiwassee River at Presley, Ga.
3. Coosa River at Gadsden, Ala.
4. Clinch River at Cleveland, Va.
5. Scioto River at Lucasville, Ohio
6. South Fork Kentucky River at Oneida, Ky.
7. Gauley River above Beech Glen, W. Va.
8. Allegheny River at Kittanning, Pa.
9. West Branch Susquehanna River near Curwensville, Pa.
10. Browns Creek near Clarksburg, W. Va.
11. Big Sinking Creek near Crystal, Ky.
12. Muskingum River at McConnelsville, Ohio
13. Ohio River at Dam 22 near Ravenswood, W. Va.
14. Kanawha River at Winfield Dam at Winfield, W. Va.
15. French Broad River at Asheville, N.C.

INTERIOR—GEOLOGICAL SURVEY, WASHINGTON, D. C.—1965—W65108

SEDIMENT LOAD OF STREAMS IN THE REGION

By
John W. Wark



SEDIMENT LOAD OF STREAMS

Suspended material in surface water and the sediment loads transported by streams in the Appalachian Region have a direct effect on the cost and feasibility of water resources development. Water from streams having significantly high sediment concentrations requires treatment before use for most purposes and can damage the recreation potential of streams and lakes. High sediment loads must be considered in reservoir design, particularly for reservoirs that have a small capacity-inflow ratio. Sediment deposits in stream channels may interfere with navigation and can reduce channel capacity, thus increasing the flood potential. Also, during floods the deposition of mud on flood plains and the cost of clean up often represent the major damage by floods.

The map of average annual sediment loads (at left) was derived from samples of suspended sediment loads in streams and from sedimentation surveys of reservoirs. Most sediment stations are located on the larger rivers and therefore the measured sediment yields are from areas comprised of mixed land use and other environmental factors that influence sediment loads. The given ranges in annual load for each area may not include the extremes found in some smaller tributaries in the Region. For example, streams draining completely forested areas may have annual loads less than 20 tons per square mile; conversely, small streams receiving large quantities of suspended wastes from industry or mining may have annual loads that exceed the upper limits of the ranges given.

The boundaries of the different areas on the map were located somewhat arbitrarily because of the limited number of sites where either measured loads or reservoir surveys were available. Measured loads do not include bedload (sediment transported in contact with the streambed); however, bedload is believed to represent only a rather small portion of the total load in most streams in the Region. Reservoir sedimentation surveys would normally include bedload but do not account for any sediment passed through the reservoir. Reservoir survey measure a volume of sediment accumulated between surveys rather than the total weight of sediment. In preparing the map an average density of 60 pounds per cubic foot was used to convert sediment volume to tons, because actual densities were not determined in many of the surveys.

Within the Region, average annual sediment loads range from about 20 tons per square mile to as high as 3,000 tons per square mile. This wide range can be partly explained by differences in climatic factors, such as quantity and intensity of precipitation and length of growing season. On the basis of the limited data available, annual loads appear to increase in a westerly and southerly direction. In areas having nearly uniform climate, variations in loads are related closely to land use, such as cropland, forest, mining or urban and industrial use.

Studies of sediment sources in the Potomac River basin show that the sediment loads of streams are closely related to the amount of forest cover and cropland, (fig. 1). Areas having only 40 percent forest cover

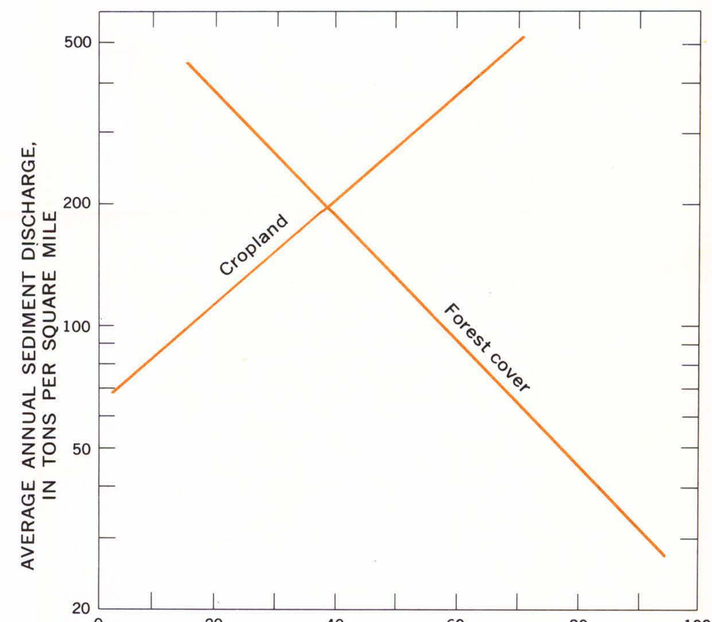


FIGURE 1.—*Relation between sediment discharge and land use in 32 sub-basins in the Potomac River basin (Adapted from Wark and Keller, 1963).*

have sediment yields of about 200 tons per square mile annually whereas basins with 80 percent in forest have annual loads of less than 50 tons per square mile. Conversely, areas having little cropland have low loads and those having high percentage of cropland have high loads. A major sediment source in the Appalachian Region is excessive erosion in areas where strip mining is dominant. Exposed areas in watersheds undergoing urban development constitute another significant source of sediment. These areas are generally adjacent to large cities where urban growth is greatest and where large tracts of land are opened for development. During the construction it is not uncommon to have annual sediment yields 50 to 100 times the yield from nearby rural areas.

The quantity of sediment transported by some tributaries has been reduced by improved land treatment and by reduction of wastes being discharged to streams. Soil conservation practices and the construction of flood retarding structures in the Salem Fork basin, W. Va., have reduced the annual sediment load from 240 tons per square mile in 1956 to only 24 tons per square mile in 1960. Storage reservoirs in the Region are trapping inflowing sediment and thus reduce the loads transported downstream. In the Schuylkill River basin, Pa., sediment loads have been reduced markedly by a concentrated program to eliminate wastes and erosion associated with coal mining.

Although most sediment records available in the Region are less than 10 years in length, the measured maximum annual load, as given in table 1, is about 5 times the minimum annual load of record. For any given

TABLE 1. —*Variability of annual sediment loads of nine streams in or adjacent to the Appalachian Region.*

Stream and location	Length of record (years)	Drainage area (sq mi)	Annual sediment load: tons per sq mi, Maximum	Annual sediment load: tons per sq mi, Minimum	Max./Min.
Scioto River at Higby, Ohio	7	5,129	381	74.9	5.1
Green River at Munfordville, Ky. . .	9	1,673	640	176	3.6
Kentucky River at Lock 4 at Frankfort, Ky.	8	5,412	703	58.6	12
Plum Creek at Waterford, Ky.	6	31.9	2,400	787	3.1
Muskingum River at Dresden, Ohio .	8	5,982	196	47	4.2
Cumberland River at Williamsburg, Ky.	7	1,607	425	101	4.2
Juniata River at Newport, Pa.	7	3,354	152	55.4	2.7
Yadkin River at Yadkin College, N.C.	8	2,280	611	205	3.0
Delaware River at Trenton, N.J. . . .	10	6,780	342	50	6.8

stream, sediment concentrations and loads generally change rapidly with changes in water discharge. Except for the few rivers in the Region that derive their sediment largely from channel material, the bulk of the sediment is delivered to the stream system during rain storms or snowmelt. Figure 2 illustrates the typical relationship of sediment load to concurrent water discharge.

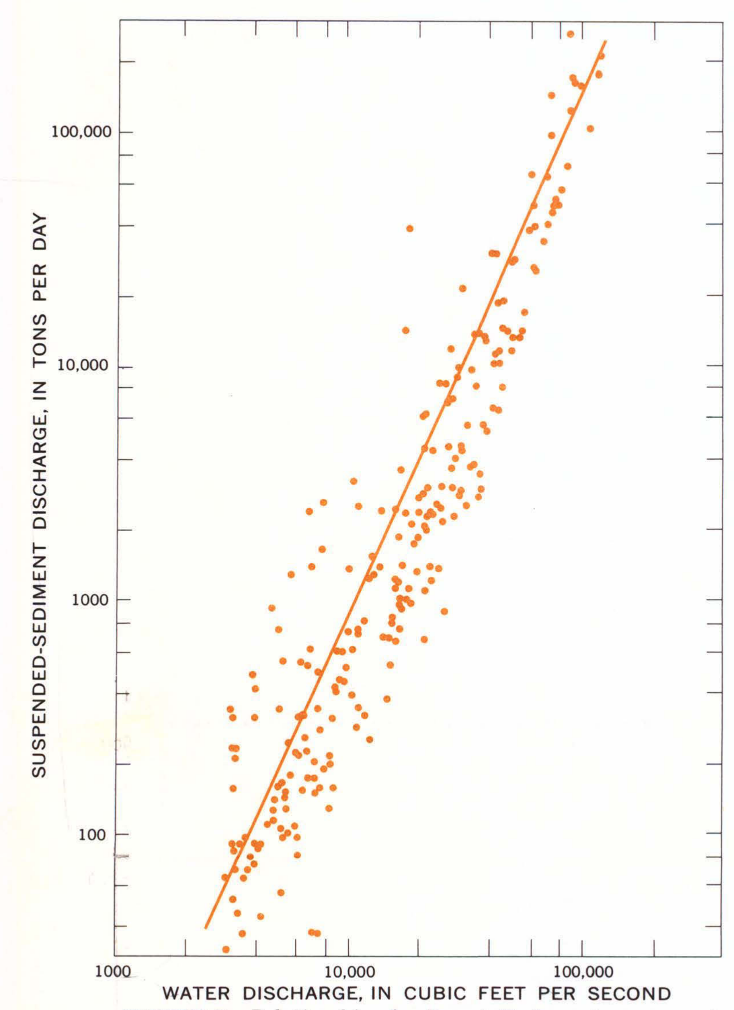


FIGURE 2.—*Relationship of sediment discharge to concurrent water discharge, Potomac River at Point of Rocks, Md.*

TABLE 2. —*Sediment accumulation rates of reservoirs in the Appalachian Region.*

Reservoir	Net drainage area (sq mi)	Period between surveys (years)	Storage capacity (acre-ft)	Average annual sediment accumulation per sq mi: acre-ft	Average annual sediment accumulation per sq mi: tons	Projected life of reservoir[1] (years)
Tygart River near Grafton, W. Va.	1,178	7.0	289,000	0.46	101	4,500
Loyalhanna Creek near Saltsburg, Pa.	286	6.3	94,700	.376	819	750
Nolichucky near Greeneville, Tenn. . .	1,182	12.5	14,000	.252	274	40
Cheoah near Tapoco, N.C.	1,607	11.8	44,000	.264	316	90
Town Creek near Wheeler, Ala.	5,033	6.0	1,071,000	.437	523	390

[1] Useful life of reservoir based upon 85 percent depletion of storage capacity.

A large percentage of the annual sediment load is characteristically transported in one month or in a single day each year. Analysis of 20 years of record at four stations in the Region show that, on the average, 39 percent of the annual load is transported during the maximum month each year. Also, an average of 14 percent of the yearly load is transported on the maximum day. A further example of the high variability in the sediment load of rivers is the observations made on the Little Miami River at Oldtown, Ohio, in June 1954. Runoff from a heavy local storm carried a sediment load of 105 tons per square mile during a seven hour period. This load was 90 percent of the total load for the year and exceeded the annual load for 4 of the 6 years of record.

Concentrations of sediment in streams in the Region vary according to source, streamflow characteristics and season of the year. Most streams have concentrations below 20 parts per million about half the time. Figure 3 illustrates the range and variability of sediment con-

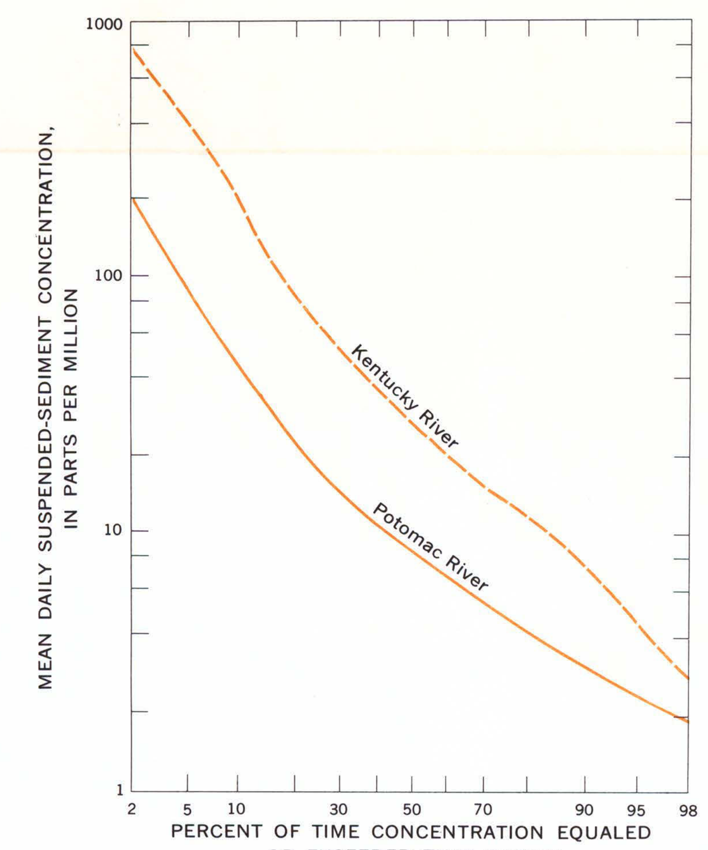


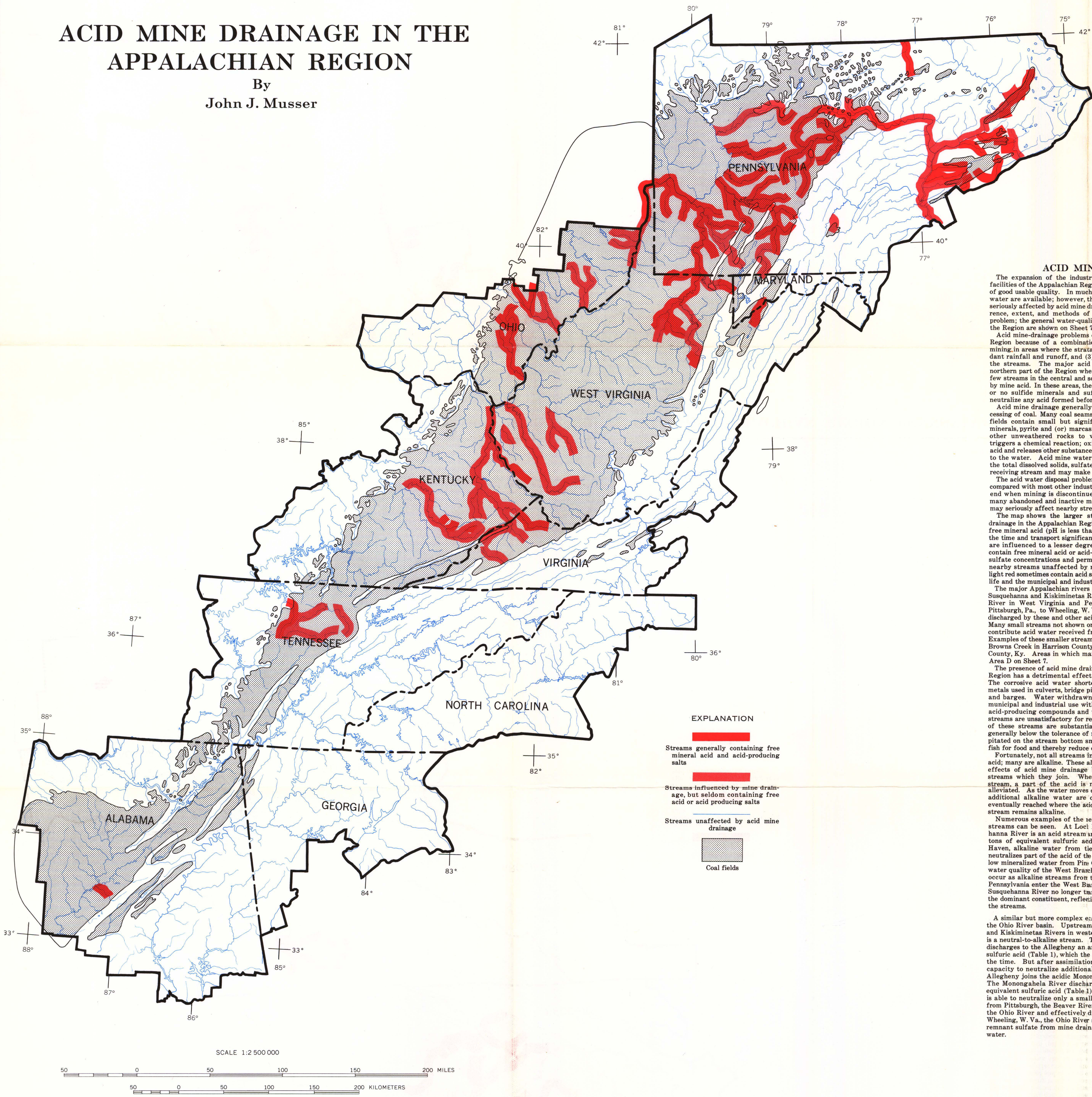
FIGURE 3.—*Cumulative frequency curves of daily suspended-sediment concentration; Kentucky River at Lock 4, at Frankfort, Ky., 1953-55 and Potomac River at Point of Rocks, Md., 1961-63.*

centration of two large rivers in the Region. Reservoir life, as measured by loss of storage capacity from sediment deposition, is a function of the rate of sediment inflow, size of sediment particles, trap efficiency of the structure, and the mode of reservoir operation. Large reservoirs are usually necessary in the Region for flood control or to obtain maximum development of the available water supply because of the high runoff. Their large capacities (in relation to the area drained) and the sediment inflow rates generally require a long time before useful reservoir life is depleted. Smaller reservoirs constructed on relatively large streams, on the other hand, may fill rapidly with sediment. Table 2 gives sedimentation data for 5 reservoirs in the Region. It can be seen that, although annual accumulation rates are generally of the same magnitude (101 to 819 tons per square mile), the projected life of these structures varies by a hundredfold. The chief cause for the variations in reservoir life is that some reservoirs are small in comparison to their drainage area, and thus have less capacity to accomodate the inflowing sediment.

INTERIOR—GEOLOGICAL SURVEY, WASHINGTON, D. C.—1965—W65106

ACID MINE DRAINAGE IN THE APPALACHIAN REGION

By
John J. Musser



ACID MINE DRAINAGE

The expansion of the industrial, municipal, and outdoor recreational facilities of the Appalachian Region requires an adequate supply of water of good usable quality. In much of the Region, good potential sources of water are available; however, the streams and rivers in some areas are seriously affected by acid mine drainage. This sheet describes the occurrence, extent, and methods of alleviation of the acid mine-drainage problem; the general water-quality characteristics of streams throughout the Region are shown on Sheet 7.

Acid mine-drainage problems occur in many parts of the Appalachian Region because of a combination of three factors: (1) extensive coal mining in areas where the strata contain iron sulfide minerals, (2) abundant rainfall and runoff, and (3) low natural alkalinity of the water in the streams. The major acid mine-drainage problems occur in the northern part of the Region where all three factors are operative. Very few streams in the central and southern parts of the Region are affected by mine acid. In these areas, the coals and associated rocks contain little or no sulfide minerals and sufficient alkaline water is available to neutralize any acid formed before it is transported very far.

Acid mine drainage generally is associated with the mining and processing of coal. Many coal seams and adjacent rocks in the northern coal fields contain small but significant quantities of the iron disulfide minerals, pyrite and (or) marcasite. Mining exposes these minerals and other unweathered rocks to weathering processes. This exposure triggers a chemical reaction; oxidation of these minerals forms sulfuric acid and releases other substances such as iron, manganese, and aluminum to the water. Acid mine water, when discharged to streams, increases the total dissolved solids, sulfate, iron, and hardness of the water of the receiving stream and may make it acid.

The acid water disposal problem of the mining industry is unique when compared with most other industries, in that the water pollution does not end when mining is discontinued. Sulfuric acid continues to form at many abandoned and inactive mines and, if not controlled, this drainage may seriously affect nearby streams for many years.

The map shows the larger streams that are affected by acid mine drainage in the Appalachian Region. Streams shown in dark red contain free mineral acid (pH is less than 4.5) and acid-producing salts much of the time and transport significant acid loads. Streams shown in light red are influenced to a lesser degree by acid mine drainage; they seldom contain free mineral acid or acid-producing salts, but they generally have sulfate concentrations and permanent hardness far in excess of that in nearby streams unaffected by mine drainage. The streams shown in light red sometimes contain acid slugs that will seriously affect the aquatic life and the municipal and industrial use of the water.

The major Appalachian rivers affected by acid mine drainage are the Susquehanna and Kiskiminetas Rivers in Pennsylvania; the Monongahela River in West Virginia and Pennsylvania; and the Ohio River from Pittsburgh, Pa., to Wheeling, W. Va. The tons of acidity as sulfuric acid discharged by these and other acid streams annually are given in Table 1. Many small streams not shown on the map or in Table 1 are also acid and contribute acid water received from mining areas to the larger streams. Examples of these smaller streams are Elk Creek in Cambria County, Pa.; Browns Creek in Harrison County, W. Va.; and Cane Branch in McCreary County, Ky. Areas in which many small streams are acid are shown in Area D on Sheet 7.

The presence of acid mine drainage in the streams of the Appalachian Region has a detrimental effect on the general welfare of the Region. The corrosive acid water shortens the life of ordinary concrete and metals used in culverts, bridge piers, dams, pumps, pipes, turbines, boats, and barges. Water withdrawn from acid streams is not suitable for municipal and industrial use without extensive treatment to neutralize acid-producing compounds and to remove iron and manganese. Acid streams are unsatisfactory for recreational use because the normal biota of these streams are substantially altered. The pH of the water is generally below the tolerance of most species of fish. Iron salts precipipitated on the stream bottom smother bottom flora and fauna used by fish for food and thereby reduce or kill many forms of aquatic life.

Fortunately, not all streams in the northern Appalachian Region are acid; many are alkaline. These alkaline streams decrease the deleterious effects of acid mine drainage by diluting and neutralizing the acid streams which they join. When acid mine water enters an alkaline stream, a part of the acid is neutralized and the problem is partly alleviated. As the water moves downstream and sufficient quantities of additional alkaline water are contributed by tributaries, a point is eventually reached where the acid load is completely assimilated and the stream remains alkaline.

Numerous examples of the neutralization of acid water by alkaline streams can be seen. At Lock Haven, Pa., the West Branch Susquehanna River is an acid stream and transports an annual load of 66,000 tons of equivalent sulfuric acid (Table 1). Downstream from Lock Haven, alkaline water from the limestones along Bald Eagle Creek neutralizes part of the acid of the West Branch. Near Jersey Shore, Pa., low mineralized water from Pine Creek dilutes and thereby improves the water quality of the West Branch. Further neutralization and dilution occur as alkaline streams from the Appalachian Mountains of central Pennsylvania enter the West Branch. Near its mouth, the West Branch Susquehanna River no longer transports an acid load, but sulfate is still the dominant constituent, reflecting the effect of acid mine drainage on the streams.

A similar but more complex example of neutralization can be seen in the Ohio River basin. Upstream from the confluence of the Allegheny and Kiskiminetas Rivers in western Pennsylvania, the Allegheny River is a neutral-to-alkaline stream. The Kiskiminetas River, an acid stream, discharges to the Allegheny an annual load of 120,000 tons of equivalent sulfuric acid (Table 1), which the Allegheny is able to neutralize most of the time. But after assimilation of this load, the Allegheny has little capacity to neutralize additional acid water. At Pittsburgh, Pa., the Allegheny joins the acidic Monongahela River to form the Ohio River. The Monongahela River discharges an annual load of 200,000 tons of equivalent sulfuric acid (Table 1) to the Ohio River, but the Ohio River is able to neutralize only a small part of this acid load. Downstream from Pittsburgh, the Beaver River and numerous small tributaries enter the Ohio River and effectively dilute and neutralize its acid load. At Wheeling, W. Va., the Ohio River seldom transports an acid load, but the remnant sulfate from mine drainage is the dominant constituent in the water.

Some parts of the northern Appalachian Region do not have sufficient alkaline water to neutralize the quantities of acid mine drainage added to the streams. This condition exists along the Monongahela River in West Virginia and Pennsylvania. Along its upper reach near Hoult, W. Va., the Monongahela transports 45,000 tons of equivalent sulfuric acid annually. The load of acid increases in a downstream direction, as is shown by the five stations along the Monongahela River in Table 1, because the Monongahela River receives more acid water than alkaline water from its tributaries.

In th field of acid-mine-drainage control, no single procedure has been developed to date that can be considered a cure-all for acid mine drainage. The total elimination of acid mine drainage from the streams of the Appalachian Region is hydrologically complex and often economically impractical. However, a variety of corrective measures which are partly effective are being applied by the mining industry and by State and Federal agencies to reduce the effects of mine drainage on the streams. These measures generally fall into the following categories: (1) minimizing the contact between water and acid-producing materials; (2) regulating the flow of mine waste water to nearby streams; (3) neutralizing acid water with alkaline compounds; (4) protecting acid-producing materials from weathering and erosion at the end of mining operations; and (5) regulating the flow of the receiving stream.

Many economic and aesthetic benefits would be derived from a control program aimed at reducing the amount of acid mine drainage discharges to the streams in the Appalachian Region. Controlling acid mine drainage at or near mining areas would provide water of better quality for downstream public and industrial uses and would, in some cases, reduce water-treatment costs. In mining areas, mine drainage control would result in restored and improved fish habitats in streams now made unproductive by mine wastes. With a plentiful supply of good water, the citizens of the mining areas of the Appalachian Region would have an opportunity to strengthen their general economy through the attraction of new industrial and recreational facilities.

TABLE 1.— *Acid discharge by streams in the Appalachian Region*

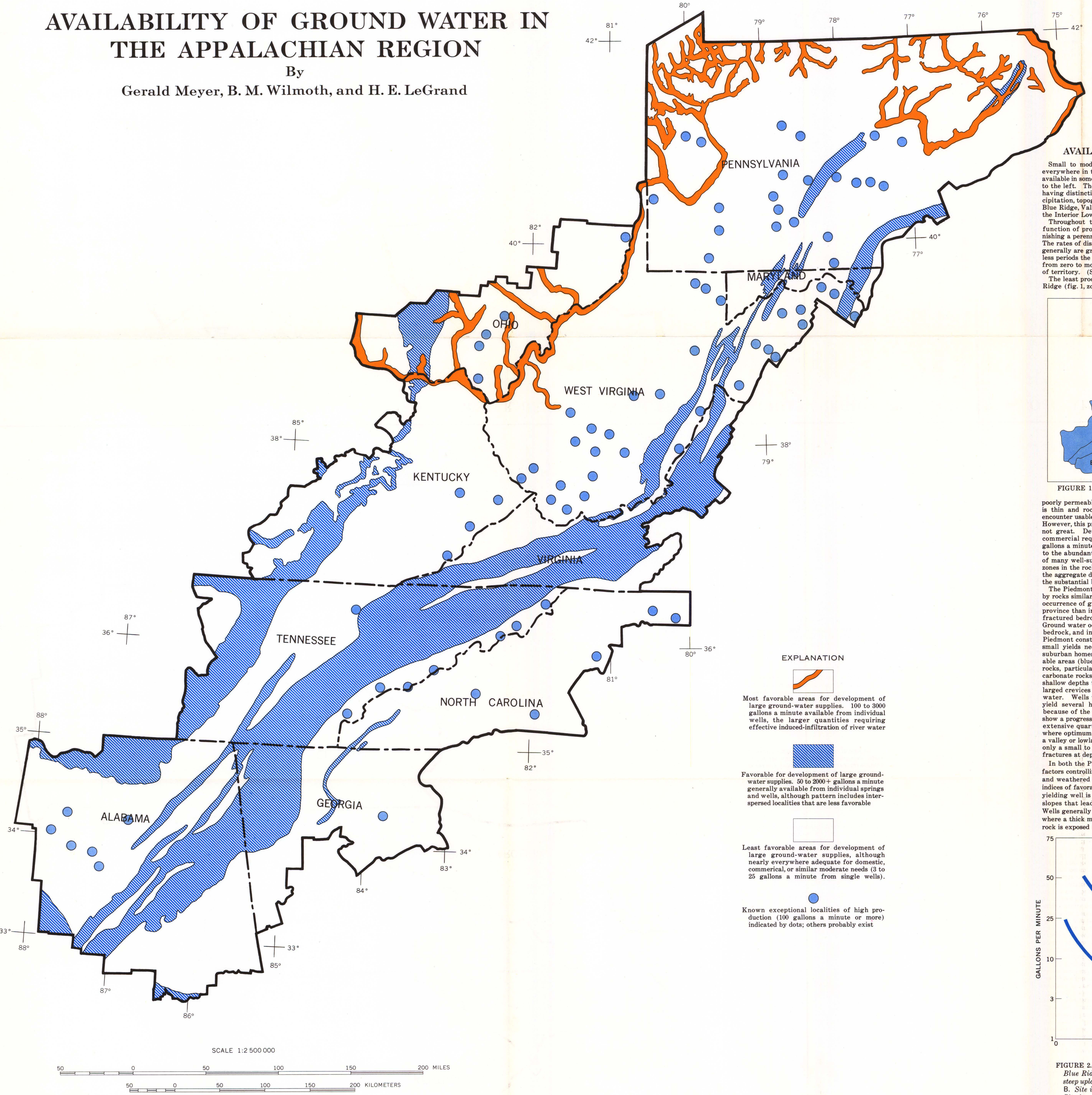
(From U.S. Geological Survey National Water Resources Data Network)

River and station	Tons of acidity as H_2SO_4 discharged per year
OHIO RIVER BASIN	
Allegheny River at Kittanning, Pa.	0
Kiskiminetas River at Vandergrift, Pa.	120,000
Allegheny River at Natrona, Pa.	2,500
Tygart Valley River at Colfax, W. Va.	6,000
West Fork River at Enterprise, W. Va.	40,000
Monongahela River at Hoult, W. Va.	45,000
Monongahela River at Morgantown, W. Va.	48,000
Monongahela River at Point Marion, Pa.	80,000
Monongahela River at Charleroi, Pa.	150,000
Youghiogheny River at McKeesport, Pa.	12,000
Monongahela River at Braddock, Pa.	200,000
Ohio River at Ambridge, Pa.	150,000
Beaver River at Beaver Falls, Pa.	0
Ohio River at Newell, W. Va.	130,000
Muskingum River at Marietta, Ohio	0
Ohio River at Parkersburg, W. Va.	0
Little Kanawha River at Parkersburg, W. Va.	0
Hocking River at Athens, Ohio	100
Ohio River at Ravenswood, W. Va.	0
Kanawha River at Point Pleasant, W. Va.	0
Raccoon Creek at Adamsville, Ohio	2,000
Guyandot River at Huntington, W. Va.	0
Levisa Fork near Grundy, Va.	4,000
Tug Fork at Louisa, Ky.	0
Big Sandy River at Catlettsburg, Ky.	0
SUSQUEHANNA RIVER BASIN	
Susquehanna River at Falls, Pa.	0
Lackawanna River at Old Forge, Pa.	27,000
Nescopeck Creek at Nescopeck, Pa.	4,000
Catawissa Creek at Catawissa, Pa.	1,800
Susquehanna River at Danville, Pa.	3,000
W. Br. Susquehanna River at Lock Haven, Pa.	66,000
W. Br. Susquehanna River at Lewisburg, Pa.	0
Susquehanna River at Sunbury, Pa.	0
Shamokin Creek at Weigh Scale, Pa.	20,000
Mahoney Creek at Dornsife, Pa.	15,000
Juniata River at Newport, Pa.	0
Susquehanna River at Harrisburg, Pa.	0
SCHUYLKILL RIVER BASIN	
Schuylkill River at Pottsville, Pa.	8,100
W. Branch Schuylkill River at Cressona, Pa.	800
Schuylkill River at Landingville, Pa.	11,000
Schuylkill River at Auburn, Pa.	11,600
Little Schuylkill River at Tamaqua, Pa.	1,400
Panther Creek at Tamaqua, Pa.	8,000
Little Schuylkill River at Drehersville, Pa.	13,700
Schuylkill River at Berne, Pa.	16,000
Schuylkill River at Reading, Pa.	0

INTERIOR—GEOLOGICAL SURVEY, WASHINGTON, D. C.—1965—W65106

AVAILABILITY OF GROUND WATER IN THE APPALACHIAN REGION

By
Gerald Meyer, B. M. Wilmoth, and H. E. LeGrand



EXPLANATION

Most favorable areas for development of large ground-water supplies. 100 to 3000 gallons a minute available from individual wells, the larger quantities requiring effective induced-infiltration of river water

Favorable for development of large ground-water supplies. 50 to 2000+ gallons a minute generally available from individual springs and wells, although pattern includes interspersed localities that are less favorable

Least favorable areas for development of large ground-water supplies, although nearly everywhere adequate for domestic, commerical, or similar moderate needs (3 to 25 gallons a minute from single wells).

Known exceptional localities of high production (100 gallons a minute or more) indicated by dots; others probably exist

AVAILABILITY OF GROUND WATER

Small to moderate quantities of ground water are available nearly everywhere in the Appalachian Region, and abundant ground water is available in some areas, as shown on the map of ground-water availability to the left. The map covers parts of six physiographic provinces, each having distinctive features of ground water occurrence related to precipitation, topography, and geology. The provinces are the Piedmont, Blue Ridge, Valley and Ridge, Appalachian Plateaus, and small parts of the Interior Low Plateaus and Central Lowland.

Throughout the Region the ground-water aquifers serve the dual function of providing water supply via wells and springs and of furnishing a perennial base of streamflow by seepage and spring discharge. The rates of discharge from the ground-water reservoirs to the streams generally are greatest immediately after rainfall. During lengthy rainless periods the discharge from ground-water reservoirs is least, ranging from zero to more than 1.0 cubic foot per second from each square mile of territory. (See Sheet 5).

The least productive ground water province in the Region is the Blue Ridge (fig. 1, zone A) which is underlain by dense, sparsely fractured,

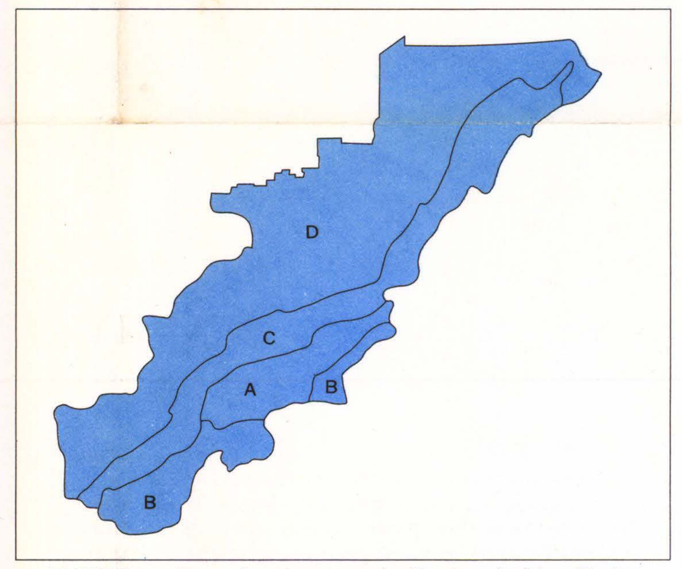


FIGURE 1.—*Ground water zones in the Appalachian Region.*

poorly permeable crystalline rocks that yield little water to wells. Soil is thin and rock weathering is shallow, and wells generally do not encounter usable quantities of water below depths of a few hundred feet. However, this province has a sparse population and the water demand is not great. Development of supplies in excess of domestic or small commercial requirements is unlikely; well yields in excess of about 15 gallons a minute generally are not to be expected. Nevertheless, owing to the abundant and regular precipitation, the Blue Ridge is a province of many well-sustained springs that issue from weathered or fractured zones in the rocks. Though the discharge of individual springs is small, the aggregate discharge, in conjunction with seepage discharge, provides the substantial base flow of streams in the Blue Ridge province.

The Piedmont province within the Region (fig. 1, zone B) is underlain by rocks similar to those of the Blue Ridge but is more favorable to the occurrence of ground water. There has been less erosion of soil in this province than in others—a thick mantle of weathered rock overlies the fractured bedrock, and topography and elevations are more moderate. Ground water occurs in the lower part of the soil zone, in the weathered bedrock, and in fractures in the underlying firm rock. Rocks of the Piedmont constitute one of the Nation's most reliable aquifers for the small yields needed for domestic supplies of thousands of rural and suburban homes. Large yields are uncommon except in certain favorable areas (blue dots on map at left). Highly calcareous metamorphic rocks, particularly the narrow belts of marble, limestone, and other carbonate rocks, are the best aquifers, but they are not widespread. At shallow depths these rocks yield readily to solutional attack and the enlarged crevices provide space for the storage and movement of ground water. Wells that penetrate cavernous water-filled carbonate rocks yield several hundred to several thousand gallons per minute, but, because of the narrowness and shallowness of the aquifers, they may show a progressive decrease of yield with continued heavy pumping. The extensive quartzite rocks of the Piedmont also contain good aquifers where optimum conditions such as deep weathering, open fractures, and a valley or lowland topographic situation exist, but as a whole they yield only a small to moderate supply. Few wells encounter water-bearing fractures at depths greater than two or three hundred feet.

In both the Piedmont and Blue Ridge provinces the most significant factors controlling the yield to wells are topography and thickness of soil and weathered mantle over bedrock. These features may be used as indices of favorable locations for wells. The chance of obtaining a higher-yielding well is greater in valleys and lowlands and along the concave slopes that lead upward from valleys than on hills and upland slopes. Wells generally are more productive and tend to have more stable yield where a thick mantle of soil and weathered rock occurs than where bare rock is exposed (fig. 2).

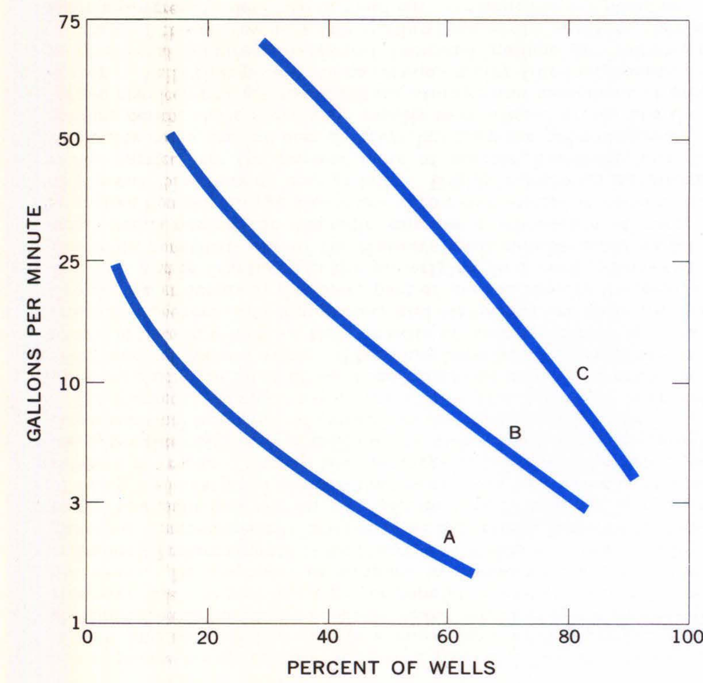


FIGURE 2.—*Well-yield probability chart for Piedmont and Blue Ridge crystalline silicate rocks;* A. *Drilling site is a steep upland slope with thin soil and numerous rock outcrops;* B. *Site is a moderate slope with moderately thick soil;* C. *Site is a gentle topographic sag, soil is thick, and rock outcrops are absent.*

Folded sandstone and shale beds of only moderate water-bearing capacity and highly productive cavernous limestone characterize the ground water hydrology of the Valley and Ridge province (fig. 1, zone C). Shale and limestone underlie the valleys of the province, and sandstone forms the crests of the ridges. In the central and northern parts of the province, the western sides of the valleys are sheltered from the generally eastward moving storms, and rain shadows decrease appreciably the total annual moisture to these areas. During drought, water shortages in such localities are commonly very severe. The carbonate-rock areas provide large water supplies to many drilled wells and to numerous tubular springs. Springs discharging several thousand gallons per minute are common, and limestone springs are the source of many municipal and industrial water supplies. Some geologic and hydrologic conditions that affect the yield of water wells in limestone or dolomite are shown diagrammatically in figure 3. Cavernous water-bearing zones occur erratically, and not all holes drilled will penetrate them. Discovery of good drilling sites is largely a matter of chance, but geologic study and exploratory drilling decrease the risk. Sink holes and ponds and gently rolling hills are characteristic of limestone areas underlain by cavernous rock.

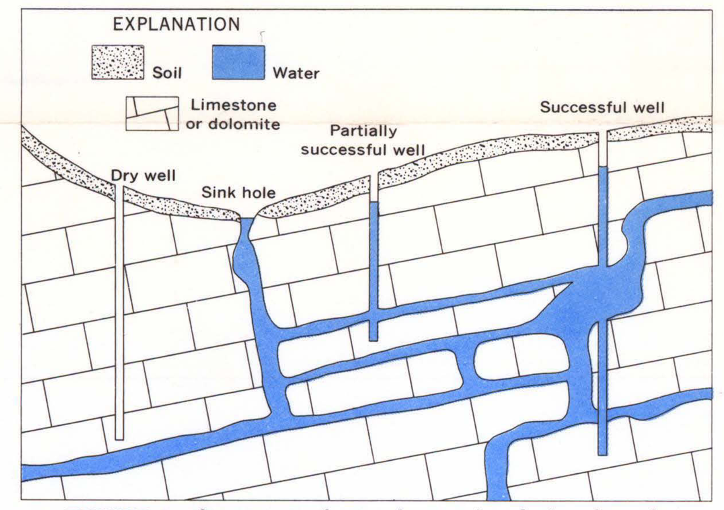


FIGURE 3.—*Occurrence of ground water in solution channels in limestone or dolomite.*

The Appalachian Plateaus province generally includes the western half of the Appalachian Region (fig. 1, zone D). For convenience, small segments of the Interior Low Plateaus and Central Lowland in central Tennessee and Kentucky and eastern Ohio are treated as a part of this province because of similar ground water conditions. Though ground water is sufficient nearly everywhere for domestic, commercial, and farm needs, the Appalachian Plateaus province is an area of only moderate well and spring supplies—with two important exceptions.

Locally, large well yields of several hundred gallons per minute, adequate for industrial and municipal needs, are obtainable. Known areas of higher-than-normal production are indicated on the map by blue dots. Many of these are in the belt of coarse clastic rocks of Pennsylvanian age in the eastern part of the province. It is reasonable to expect that other areas of above-average water-bearing capacity exist in untested parts of this belt of rocks.

Glacial outwash deposits in the valleys in northern Pennsylvania and along the Allegheny and Ohio Rivers provide large supplies of ground water to municipalities and industries. These important water-bearing deposits are depicted on the water-availability map by a thin, sinuous yellow pattern. Present withdrawals are only a small fraction of the supply available. Only one or two localities have serious problems from overpumpage. The glacial outwash is recharged mainly from precipitation and from adjacent streams. Heavy pumping of wells lowers the water level in the outwash below river level and river water is induced to move through the stream bed, into the outwash deposits, and to the pumping wells. Inasmuch as the river stage of the Ohio River is upheld by navigation dams and by flow augmentation from surface reservoirs, the ground-water supply available by induced infiltration is limited only by the permeability of the river bed and of the outwash deposits. In the stretch of outwash along the Ohio River in West Virginia the quantity of ground water available per mile of river length ranges from as much as 42 million gallons per day to as little as 6 mgd. New, higher dams being installed will raise the river level and, in turn, may be expected to increase ground-water supplies in the adjacent and subjacent outwash appreciably.

Gravel, sand, and clay deposits of the Coastal Plain province occur within the Region in Alabama. Although the great mass of unconsolidated deposits of the Coastal Plain constitute a source of major water supplies, the thin northern edge of these deposits within the boundaries of the Appalachian Region yields only moderate quantities of water. The deposits form low, well-drained hills or occur as a thin, partly dissected cover over the older consolidated rocks. Locally, under favorable conditions such as a permeable stratum extending over a moderately large area, yields of several hundred gallons per minute have been obtained from drilled wells, but most yields are adequate for only domestic, farm, or small commercial requirements.

Ground water may be expected to continue its role in meeting domestic, agricultural, municipal, and industrial needs in the Appalachian Region. The trend toward urbanization and resultant decrease in rural populations may reduce the amount of ground water used for rural domestic purposes, but the stimulation of industrial diversification, wilderness recreation, and growth in irrigation practices, may be expected to increase the demand for ground water.

Areas of heavy pumpage are relatively few and the density of settlement is thin in the Region as a whole. Present ground-water development is only a small part of the supply available. Depletion of shallow ground water in parts of the coal belt (Sheet 9) by accelerated drainage through mines has caused local shortages. Although large tracts of territory are limited to moderate production by the geohydrologic conditions, certain areas outlined above are sources of additional major ground-water supplies. This is especially true of the glacial outwash along the Ohio River, where abundant supplies are readily obtainable by induced infiltration techniques.

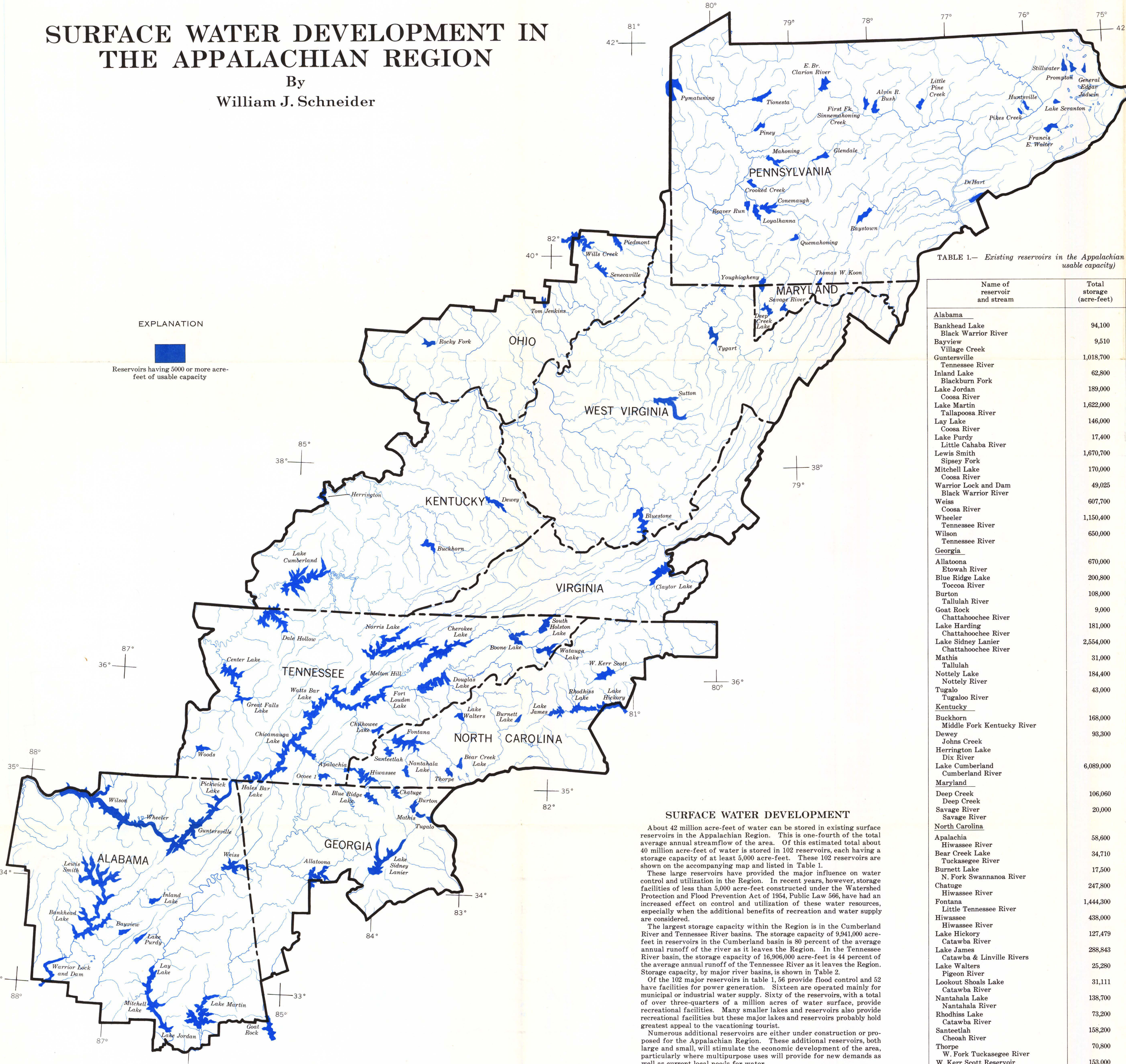
The chemical quality and physical characteristics of the ground water are generally satisfactory for domestic and most other uses, but there are some problems. Throughout much of the region, the iron content of the water may be troublesome, and hardness must be reckoned with in areas underlain by limestone and marble. However, modern water-treatment techniques alleviate these objectionable features and new advances in water-treatment technology promise additional aid. Saline ground water occurring naturally at depths of several hundred feet throughout much of the western Appalachian Plateaus tends to limit the availability of fresh water to shallow depths.

Man's activities and pollution add problems of water quality. Leaking oil- and gas-well casings; drillers' brine disposal pits; and the discharge of oil-separator wastes at the land surface contaminate the shallow ground water in some oil fields. Liquid and solid chemical wastes and mine gob deposited on the land surface yield contaminants that infiltrate to the ground-water reservoirs. Some ground-water pollution is associated with acid-mine water generated in active and abandoned coal mines, both surface and deep mines. Corrective action at both the State and Federal levels includes strengthening and enforcement of pollution laws and further field and laboratory research into methods for waste disposal and pollution abatement.

INTERIOR—GEOLOGICAL SURVEY, WASHINGTON, D. C.—1965—W65108

SURFACE WATER DEVELOPMENT IN THE APPALACHIAN REGION

By
William J. Schneider



SCALE 1:2 500 000

50 0 50 100 150 200 MILES

50 0 50 100 150 200 KILOMETERS

SURFACE WATER DEVELOPMENT

About 42 million acre-feet of water can be stored in existing surface reservoirs in the Appalachian Region. This is one-fourth of the total average annual streamflow of the area. Of this estimated total about 40 million acre-feet of water is stored in 102 reservoirs, each having a storage capacity of at least 5,000 acre-feet. These 102 reservoirs are shown on the accompanying map and listed in Table 1.

These large reservoirs have provided the major influence on water control and utilization in the Region. In recent years, however, storage facilities of less than 5,000 acre-feet constructed under the Watershed Protection and Flood Prevention Act of 1954, Public Law 566, have had an increased effect on control and utilization of these water resources, especially when the additional benefits of recreation and water supply are considered.

The largest storage capacity within the Region is in the Cumberland River and Tennessee River basins. The storage capacity of 9,941,000 acre-feet in reservoirs in the Cumberland basin is 80 percent of the average annual runoff of the river as it leaves the Region. In the Tennessee River basin, the storage capacity of 16,906,000 acre-feet is 44 percent of the average annual runoff of the Tennessee River as it leaves the Region. Storage capacity, by major river basins, is shown in Table 2.

Of the 102 major reservoirs in table 1, 56 provide flood control and 52 have facilities for power generation. Sixteen are operated mainly for municipal or industrial water supply. Sixty of the reservoirs, with a total of over three-quarters of a million acres of water surface, provide recreational facilities. Many smaller lakes and reservoirs also provide recreational facilities but these major lakes and reservoirs probably hold greatest appeal to the vacationing tourist.

Numerous additional reservoirs are either under construction or proposed for the Appalachian Region. These additional reservoirs, both large and small, will stimulate the economic development of the area, particularly where multipurpose uses will provide for new demands as well as current local needs for water.

Although the construction of these proposed reservoirs will raise the storage in the Region to more than one-third of the average annual runoff of the Region, additional surface storage will probably be needed as economic development creates water shortages in areas not having access to the current or proposed sources of storage. Long-range planning often can foresee potential water shortages and provide for the necessary development of the water resources concurrent with the economic and social growth of the area.

Navigation facilities also have been developed on several major streams in the Region, particularly the Ohio, Monongahela, Kanawha, and Tennessee Rivers. In many places, surface water is diverted for municipal and industrial supply without storage. These developments, however, do not affect the normal patterns of flow as much as reservoir operations.

TABLE 1.—*Existing reservoirs in the Appalachian Region (5,000 acre-feet or more usable capacity)*

Name of reservoir and stream	Total storage (acre-feet)	Usable storage (acre-feet)	Use
Alabama			
Bankhead Lake Black Warrior River	94,100	55,100	NR
Bayview Village Creek	9,510	5,100	W
Guntersville Tennessee River	1,018,700	162,900	FNPR
Inland Lake Blackburn Fork	62,800	61,600	W
Lake Jordan Coosa River	189,000	49,000	P
Lake Martin Tallapoosa River	1,622,000	1,375,000	P
Lay Lake Coosa River	146,000	72,000	P
Lake Purdy Little Cahaba River	17,400	15,300	M
Lewis Smith Sipsey Fork	1,670,700	675,000	FMPR
Mitchell Lake Coosa River	170,000	77,000	P
Warrior Lock and Dam Black Warrior River	49,025	44,775	N
Weiss Coosa River	607,700	599,200	PR
Wheeler Tennessee River	1,150,400	347,500	FNPR
Wilson Tennessee River	650,000	53,000	FNPR
Georgia			
Allatoona Etowah River	670,000	587,200	FPR
Blue Ridge Lake Toccoa River	200,800	186,300	PR
Burton Tallulah River	108,000	87,000	PR
Goat Rock Chattahoochee River	9,000	5,000	P
Lake Harding Chattahoochee River	181,000	57,000	MNPRW
Lake Sidney Lanier Chattahoochee River	2,554,000	1,686,400	FMPR
Mathis Tallulah	31,000		PR
Nottely Lake Nottely River	184,400	171,200	FNPR
Tugalo Tugaloo River	43,000	11,500	PR
Kentucky			
Buckhorn Middle Fork Kentucky River	168,000	157,720	FR
Dewey Johns Creek	93,300	81,000	CF
Herrington Lake Dix River		123,200	P
Lake Cumberland Cumberland River	6,089,000	4,236,000	FP
Maryland			
Deep Creek Deep Creek	106,060	92,975	PR
Savage River Savage River	20,000	20,000	FRM
North Carolina			
Apalachia Hiwassee River	58,600	50,000	FNP
Bear Creek Lake Tuckasegee River	34,710	4,540	P
Burnett Lake N. Fork Swannanoa River	17,500	17,500	M
Chatuge Hiwassee River	247,800	229,200	FNPR
Fontana Little Tennessee River	1,444,300	1,157,300	FNPR
Hiwassee Hiwassee River	438,000	364,600	FNPR
Lake Hickory Catawba River	127,479	77,557	P
Lake James Catawba & Linville Rivers	288,843	241,194	P
Lake Walters Pigeon River	25,280	20,500	P
Lookout Shoals Lake Catawba River	31,111	8,914	P
Nantahala Lake Nantahala River	138,700	126,000	P
Rhodhiss Lake Catawba River	73,200	39,417	P
Santeetlah Cheoah River	158,200	133,300	PR
Thorpe W. Fork Tuckasegee River	70,800	67,100	FP
W. Kerr Scott Reservoir Yadkin River	153,000	145,000	F
Ohio			
Piedmont Stillwater Creek	65,000	64,900	CFR
Rocky Fork Rocky Fork	34,100	34,100	R
Senecaville Seneca Fork	88,500	86,300	CFR
Tom Jenkins E. Br. Sunday Creek	26,900	26,900	CFR
Wills Creek Wills Creek	196,000	194,000	CF
Pennsylvania			
Alvin R. Bush Kettle Creek	75,000	73,410	FR
Beaver Run Beaver Run	28,600	28,600	M
Conemaugh River Conemaugh River	274,000	273,600	FR
Crooked Creek Crooked Creek	93,900	93,900	FR
DeHart Clark Creek	18,480	18,480	M
E. Br. Clarion River E. Br. Clarion River	84,300	84,300	FRW
First Fk. Sinnemahoning Creek First Fk. Sinnemahoning Creek	75,800	73,800	F
Francis E. Walter Lehigh River	110,700	108,700	F
General Edgar Jadwin Dyberry Creek	24,500	23,500	F
Glendale Beaverdam Run	41,000	41,000	FR
Huntsville W. Br. Tobys Creek	5,898	5,898	M
Lake Scranton Stafford Meadow Brook	8,036	8,036	M
Lake Wallenpaupack Wallenpaupack Creek	209,300	157,800	P
Little Pine Creek Little Pine Creek	24,800	24,800	FMR
Loyalhanna Loyalhanna Creek	95,300	95,300	F
Mahoning Mahoning Creek	74,200	74,100	FNR
Penn Forest Wild Creek	19,980	19,000	M
Pikes Creek Pikes Creek	9,026	9,026	M
Piney Clarion River	28,900	13,000	P
Prompton W. Br. Lackawaxen River	51,700	48,280	F
Pymatuning Shenango River	198,200	159,900	FMR
Quemahoning Quemahoning Creek	32,766	32,766	MW
Raystown Raystown Branch	9,000	9,000	P
Shawnee Shawnee Branch	16,750	16,750	FR
Still Creek Still Creek	8,290	8,290	M
Stillwater Lackawana River	12,000	11,800	FM
Thomas W. Koon Evitts Creek	7,090	7,049	M
Tionesta Creek Tionesta Creek	133,400	133,400	FR
Watres Spring Brook	5,963	5,963	M
Wild Creek Wild Creek	12,500	12,000	M
Youghiogheny Youghiogheny River	254,000	254,000	FRW
Tennessee			
Boone Lake S. Fork Holston River	196,700	150,000	FNPR
Center Hill Caney Fork	2,092,000	1,254,000	FPR
Cherokee Lake Holston River	1,565,400	1,473,100	FNPR
Chickamauga Lake Tennessee River	705,300	329,400	FNPR
Chilhowee Lake Little Tennessee River	49,250	6,800	FNP
Dale Hollow Obey River	1,706,000	849,000	FPR
Douglas Lake French Broad River	1,514,100	1,419,700	FNPR
Fort Loudoun Lake Tennessee River	386,500	109,300	FNPR
Great Falls Lake Caney Fork River	54,500	49,400	PR
Hales Bar Lake Tennessee River	147,700	12,400	FNPR
Melton Hill Clinch River	118,500	26,000	NP
Norris Lake Clinch River	2,567,000	2,281,000	FNPR
Ocoee No. 1 Ocoee River	91,300	33,100	PR
Pickwick Lake Tennessee River	1,091,400	418,400	FNPR
South Holston Lake South Fork Holston River	744,000	625,200	FNPR
Watauga Lake Watauga River	678,800	627,200	FNPR
Watts Bar Lake Tennessee River	1,132,000	377,600	FNPR
Woods Elk River	79,870	19,540	FRW
Virginia			
Claytor Lake New River	232,000	100,000	PR
West Virginia			
Bluestone New River	631,000	621,000	F
Sutton Elk River	265,300	261,200	FMR
Tygart Lake Tygart River	287,700	287,700	FNR

C-Conservation, F-Flood control, M-Municipal, N-Navigation, P-Power, R-Recreation, W-Industrial

TABLE 2.—*Existing reservoir storage capacity in major basins in the Appalachian Region (reservoirs over 5,000 acre-feet usable capacity).*

Major basins	No. of Reservoirs	Acre-feet total storage
Allegheny	8	771,200
Beaver	1	198,200
Big Sandy	1	93,300
Chattahoochee	3	2,744,000
Cumberland	4	9,941,500
Delaware	7	436,900
Hocking	1	26,900
Kanawha	3	1,128,300
Kentucky	2	291,000
Mobile	12	5,308,200
Monongahela	3	647,800
Muskingum	3	349,500
Pee Dee	1	153,000
Potomac	2	27,100
Santee	4	520,600
Savannah	3	182,000
Scioto	1	34,100
Susquehanna	12	301,800
Tennessee	30	16,906,000
Totals	102	40,135,600

INTERIOR—GEOLOGICAL SURVEY, WASHINGTON, D. C.—1965—W65108