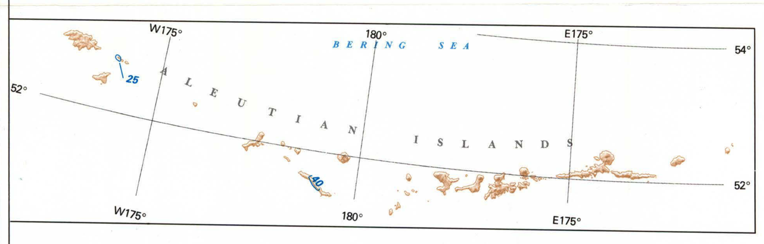


CONVERSION TABLE

For readers who prefer to use SI (metric) units rather than inch-pound units, conversion factors for terms used in this report are listed below.

Multiply	By	To obtain
inch (in.)	25.40	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
square mile (mi^2)	2.590	square kilometer (km^2)
acre	0.4047	hectare
foot per second (ft/s)	0.3048	meter per second (m/s)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
cubic foot per second per square mile [(ft^3/s)/mi^2]	0.01093	cubic meter per second per square kilometer [(m^3/s)/km^2]

INTRODUCTION

Runoff is the water in a river or stream that results from precipitation falling on the drainage basin. It is the net discharge into the stream from surface-water and ground-water sources with losses occurring from evapotranspiration and other consumptive uses. Runoff can be expressed by a variety of numerical values, but average depth of water over the drainage basin, in inches per year, probably is the most widely used unit of measurement.

The map of average annual runoff (fig. 1), in inches per year, shows the geographical distribution of runoff in tributary streams for the years 1951–80; it describes the magnitudes and variations of runoff nationwide. The map was prepared to reflect the runoff of tributary streams rather than in major rivers in order to represent more accurately the local or small scale variation in runoff with precipitation and other geographical characteristics. The 1951–80 period was selected to conform to the period chosen by the World Meteorological Organization for study of climatic variations. The map should not be used to estimate the streamflow for any specific site. More detailed information for a specific area can be obtained from streamflow data collected by the U.S. Geological Survey, other Federal agencies, and State agencies.

The map updates the one prepared by Busby (1966) that presented annual runoff for the period 1931–60. A similar map was prepared by Langbein (1949) for the period 1921–45.

The preparation of the map was greatly aided by Walter A. Lear, who prepared the runoff map for Texas; Iwao Matsuoka, who prepared the map for California; Roger P. Rumenik, who prepared the map for Florida; and the U.S. Geological Survey District offices for their reviews of the runoff maps for their respective States. The cartographic design and production was done by Christine M. BeBow.

MAP PREPARATION

Streamflow data were collected at 12,953 gaging stations during the 1951–80 period. Of this number, 5,951 stations were actually used for the study. Stations were omitted from the study because:

1. Many of the gaging stations are located on a major river that represents runoff contribution of a large drainage basin, and, therefore, the stations are not representative of the variation in tributary flow within the basin.

2. The annual runoff may have been affected by major storage reservoirs located upstream of a gaging station.

3. A substantial amount of diversion or return flow may have occurred upstream from a gaging station; this precluded use of the station unless the quantity of water diverted or returned to the stream could be estimated and used to adjust the recorded flow.

4. Some gaging stations were not operated for the entire 1951–80 period and could not be extended to the 30-year period by correlation with data from nearby gaging stations.

Figure 2 shows the number of gaging stations that had streamflow data for 1951–80; the number of gaging stations used to determine the runoff for each state; and the number of those gaging stations that had to have their record extended to the 30-year period by a correlation procedure. The number of stations used reflects a compromise between the total number available and the number required to define the runoff. In Wisconsin, for example, where the annual runoff is relatively uniform, ranging from 10 to 15 inches, only 89 of the 263 available stations were required to adequately define the runoff map. Although, in Washington where streamflow varies greatly, ranging from 0.1 to 160 inches, 300 of the 552 available stations were used.

If annual runoff data were not available for the entire 1951–80 period of record, the average discharge for the 30-year period was estimated by a correlation procedure (Matalas and Jacobs, 1964). In general, the annual discharges at a station with a short record were correlated with the corresponding annual discharges at a nearby station with a complete 30-year record. This procedure is used to estimate only the average for the 30-year period and not the individual annual discharge. For this reason, the estimate of average annual runoff could be obtained with a lower correlation coefficient than would be required to estimate the individual annual values. For example, for a station with a 20-year record, an improved estimate of the long-term average could be obtained with a correlation coefficient as low as 0.24, and for a station with a 10-year record, a correlation coefficient of 0.35 was required. In most cases, a correlation coefficient greater than 0.8 was actually obtained. This procedure was used at 2,822 gaging stations in order to provide a uniform estimate of average annual runoff for the 30-year period. This was especially important because many of the gaging stations with small drainage areas did not have records for the entire 30-year period. The number of stations used to determine average annual runoff where the record was extended by correlation is shown in figure 2.

Streamflow data affected by diversions were adjusted if the affected station was the only one in an area. Adjustments were made based on an estimated amount of water diverted for crop irrigation. The estimates were based on water requirements for typical crops in a region and the number of acres irrigated by the diversions. In the central and western United States, adjustments for diversions out of basins were made according to data furnished by Harold E. Petsch (U.S. Geological Survey, written commun., 1984).

The average annual runoff for each station was plotted at the center of its drainage basin on a base map for each State and lines of equal average annual runoff were constructed using these points. Topography was used as a guide to the location of the lines in mountainous areas where the amount of runoff increases because of the orographic effect and increasing slopes. In some of the arid western United States, little or no runoff data are available, and runoff lines were estimated on the basis of precipitation and topographic maps. The runoff map is shown as figure 1. As illustrated, the average annual runoff ranges from 0.1 inch per year in many parts of several western States to more than 320 inches per year in Hawaii.

Average annual runoff also was determined for the 2,149 hydrologic cataloging units of the U.S. Geological Survey's Catalog of Information on Water Data (Seaber and others, 1984). This information, along with the average annual runoff for each station, a more detailed description of how the runoff values were computed, and an estimate of the accuracy associated with the runoff value for each cataloging unit are available from the U.S. Geological Survey (Krug, W.R., Gebert, W.A., and Graczyk, D.J., 1986, unpublished data on file in Madison, Wis., office of U.S. Geological Survey).

ACCURACY OF AVERAGE ANNUAL RUNOFF MAP

The accuracy of the map varies greatly depending on the number of streamflow-gaging stations in an area and the variability of flow within the area. The lines of equal average annual runoff are most accurate in the central and southern parts of the country; the least accurate are in parts of Nevada, Utah, Arizona, and New Mexico, where little or no data are available or where runoff may be strongly influenced by local differences in elevation.

AREAL AND TEMPORAL VARIATIONS IN RUNOFF

In many parts of the country, the annual runoff differs little from year to year. However, in some regions, such as the arid West, extreme differences may occur from year to year. For example, the annual runoff for Red River of the North ranged from a minimum of 49.7 ft^3/s in 1977 to a maximum of 6,780 ft^3/s in 1975 during the 1951–80 period. Generally the annual runoff of eastern streams had less variability as indicated by the French Broad River at Asheville, which ranged from a minimum of 1,170 ft^3/s to a maximum of 3,030 ft^3/s.

A coefficient of variation was calculated for all streamflow-gaging stations with drainage areas greater than 50 mi^2 and less than 2,000 mi^2, and with more than 20 years of record in the 1951–80 period to describe the annual variation in flow; the values were used to develop figure 3, which shows areas of large and small annual flow variations. The coefficient of variation is an index of changes in runoff from year to year and is determined by dividing the standard deviation by the average flow. where the standard deviation is the range of annual flows that two-thirds of the values should fall within. The areas of larger variability in annual flow shown in figure 3 are in the more arid central and southwestern States. The areas of smallest variability are the northwestern, upper midwestern, and northeastern States.

An analysis was made to compare runoff for the 1951–80 period with long-term runoff (1901–80) and with runoff for the periods used by Langbein (1921–45) and Busby (1931–60). A long-term streamflow-gaging station with continuous record from 1901 through 1980 was selected for each State. The gaging stations that were chosen reflected runoff from drainage areas that generally were from 500 to 1,000 mi^2. Table 1 compares average annual runoff for the period 1921–45, 1931–60, and 1951–80. In general, average annual runoff for the 1951–80 period was higher than that for the 1921–45 and 1931–60 periods and slightly lower than that for the long-term period (1901–80). A comparison of data from the 14 gaging stations that had data in all 4 periods is shown in table 2.

REFERENCES CITED

Busby, M. B., 1966, Annual runoff in the conterminous United States: U.S. Geological Survey Hydrologic Investigations Atlas HA–212, 1 p.
Langbein, W. B., 1949, Annual runoff in the United States: U.S. Geological Survey Circular 52, 14 p.
Matalas, N.C., and Jacobs, Barbara, 1964, A correlation procedure for augmenting hydrologic data: U.S. Geological Survey Professional Paper 434–E, 7 p.
Seaber, P. R., Kapinos, F. P., and Knapp, G. L., 1984, State hydrologic unit maps: U.S. Geological Survey Open-File Report 84–708.

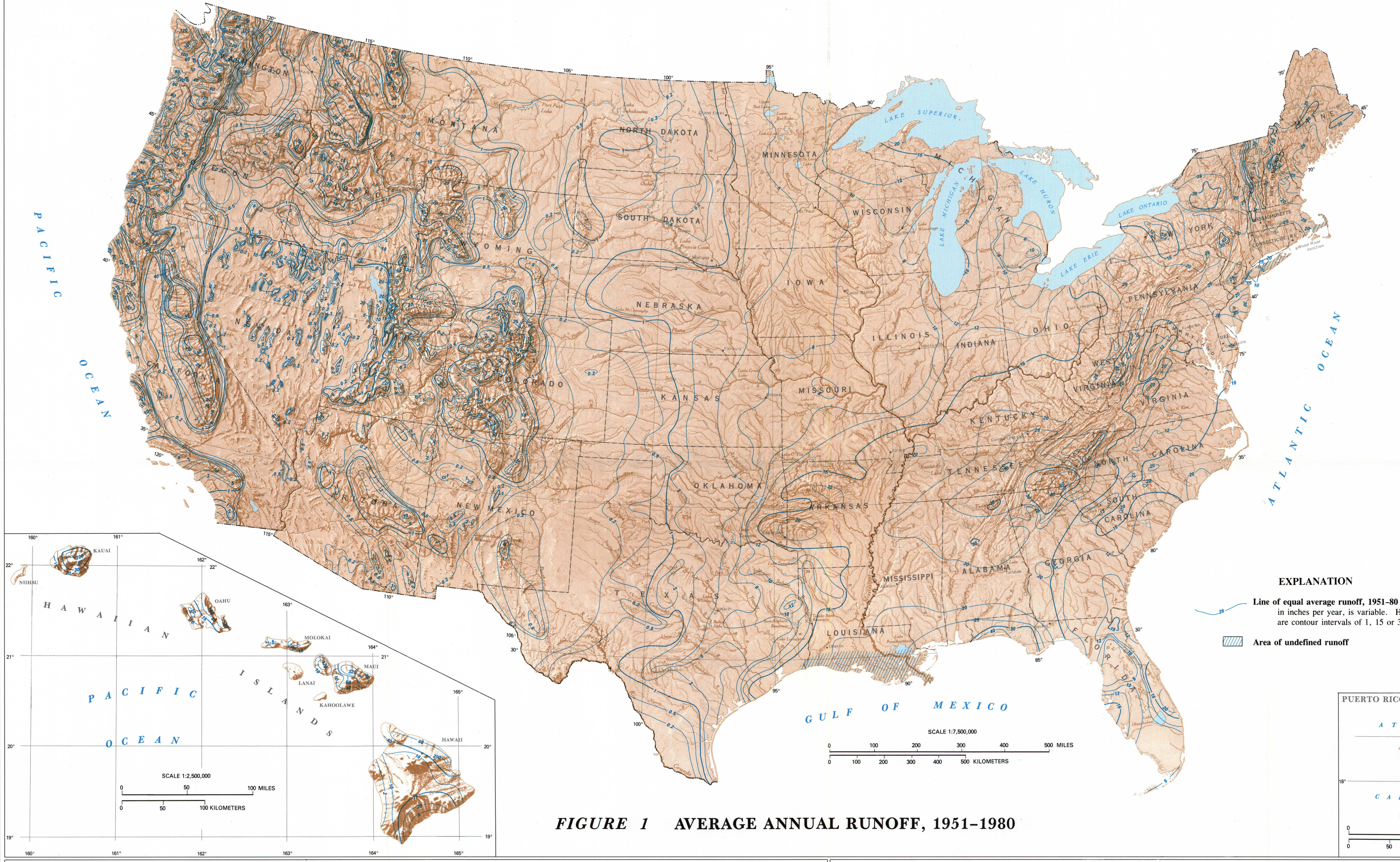
Table 1.—Comparison of runoff for the 1951-80 period with other periods

Station name	Mean annual runoff, in inches for selected stations, and variation from 1901–80 runoff, in percent			
	1951–80	1931–60	1921–45	1901–80
Tallapoosa River below Tallasee, Ala.	20.1	18.5		
Susitna River at Gold Creek, Alaska	21.4			
San Pedro River at Charleston, Ariz.	.56	.64	0.73	
Petit Jean River near Danville, Ark.	13.3	15.5		
Arroyo Seco River near Soledad, Calif.[2]	9.14	8.50	9.16	9.23
	(−1.0%)	(−7.9%)	(−0.8%)	
White River near Meeker, Colo.	10.7	10.6	11.4	
Housatonic River at Falls Village, Conn.	23.6	23.0	22.8	
Nanticoke River near Bridgeville, Del.	17.1			
Ochlockonee River near Havana, Fla.	12.5	11.0		
Oostanaula River at Resaca, Ga.[2]	24.7	22.6	23.2	24.3
	(+1.6%)	(−6.9%)	(−4.5%)	
Kalihi Stream near Honolulu, Hawaii	30.7	32.7	40.6	
Boise River near Twin Springs, Idaho	21.1	19.4	17.5	
Sangamon River at Monticello, Ill.	9.43	8.77	10.5	
East Fork White River at Seymour, Ind.	14.3	13.6		
Cedar River at Cedar Rapids, Iowa	7.59	6.02	5.19	
Marais Des Cygnes River near Ottawa, Kans.	6.90	6.39	5.99	
Cumberland River at Cumberland Falls, Ky.	22.8	20.2	20.3	
Calcasieu River near Oberlin, La.	18.9			
Piscataquis River near Dover-Foxcroft, Maine	29.9	26.6	25.6	
Monocacy River at Jug Bridge near Frederick, Md.	15.8	15.1		
Westfield River at Knightville, Mass.	28.9	27.9	27.4	
Huron River at Ann Arbor, Mich.	8.61	7.87	6.70	
Mississippi River at St. Paul, Minn.[2]	4.56	3.53	2.64	3.84
	(+18.8%)	(−8.1%)	(−31.2%)	
Pearl River at Jackson, Miss.	18.5	16.2		
Castor River at Zalma, Mo.	15.5	14.8	14.8	
Missouri River at Fort Benton, Mont.[2]	4.37	3.51	3.54	4.17
	(+4.8%)	(−15.8%)	(−15.1%)	
Little Blue River near Fairbury, Nebr.	2.20	2.14		
Humbolt River at Palisade, Nev.	1.06	.94	.96	
Pemigewasset River at Plymouth, N.H.	23.0	29.5	29.2	
Raritan River at Manville, N.J.	21.6	20.8	19.9	
Rio Grande at Embudo, N. Mex.[2]	.89	1.25	1.30	1.26
	(−29.4%)	(−0.7%)	(+3.2%)	
Genesee River at Portageville, N.Y.	18.0	16.9	16.3	
French Broad River at Asheville, N.C.[2]	29.7	27.2	27.0	30.2
	(−1.6%)	(−9.9%)	(−10.6%)	
Red River of the North at Grandforks, N. Dak.[2]	1.41	.88	.58	1.14
	(+23.7%)	(−22.8%)	(−49.1%)	
Little Beaver Creek near East Liverpool, Ohio	14.7	14.2	14.2	
Mountain Fork near Eagletown, Okla.	19.5	23.6		
Willamette River at Albany, Oreg.[2]	43.0	41.1	36.2	39.9
	(+7.8)%	(+3.0%)	(−9.3%)	
West Branch Susquehanna River at Williamsport, Pa[2]	22.0	20.6	20.1	21.5
	(+2.3%)	(−4.2%)	(−6.5%)	
Pawcatuck River at Wood River Junction, R.I.	27.6			
Saluda River at Chappels, S.C.	19.8	21.7		
James River near Scotland, S. Dak.	.26	.21		
Tennessee River at Chattanooga, Tenn.[2]	23.4	21.3	21.5	23.3
	(+0.4%)	(−8.5%)	(−7.7%)	
Brazos River at Waco, Tex.[2]	.92	1.16	1.25	1.05
	(−12.4%)	(+10.5%)	(+19.0%)	
White Rocks River near Whiterocks, Utah	13.5	12.9		
White River at West Hartford, Vt.	23.0	23.2	23.0	
Rappahannock River near Fredericksburg, Va.	14.0	13.8	14.0	
Spokane River at Spokane, Wash.[2]	22.3	21.6	18.9	21.0
	(+6.2%)	(+2.9%)	(−10.0%)	
Greenbrier River at Alderson, W.Va.[2]	19.8	18.6	18.6	20.0
	(−1.0%)	(−7.0%)	(−7.0%)	
Fox River near Berlin, Wis.[2]	10.9	10.4	11.2	11.2
	(−2.7%)	(−7.1%)	(0%)	
Bull Lake Creek near Lenore, Wy.	17.4	16.6	18.2	
Rio Grande de Loiza at Caguas, P.R.[1]	33.0			

[1] Data only for 1961–80.
[2] Used in table 2 for comparison of long-term runoff.

Table 2.—Comparison of average annual runoff from 14 long-term stations and percent difference from 1901–80

	1951–80	1931–60	1921–45	1901–80
Average annual runoff for 14 long-term stations	15.5	14.4	13.9	15.2
Percent difference from 1901–80	+1.9	−5.3	−8.6	



EXPLANATION

Line of equal average runoff, 1951–80 Interval in inches per year, is variable. Heavier lines are contour intervals of 1, 15 or 30

Area of undefined runoff

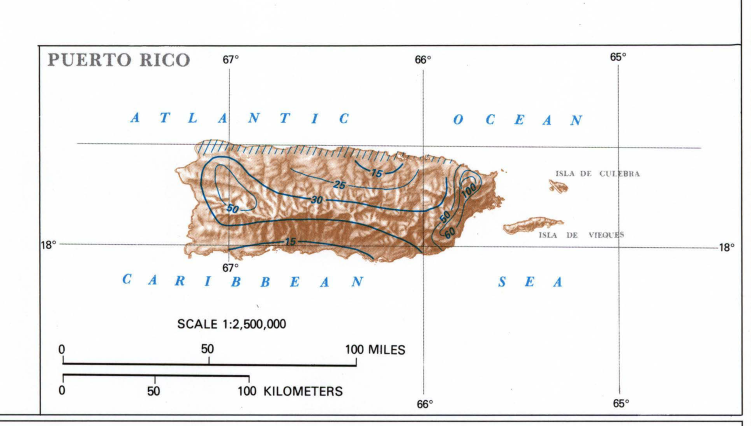


FIGURE 1 AVERAGE ANNUAL RUNOFF, 1951–1980

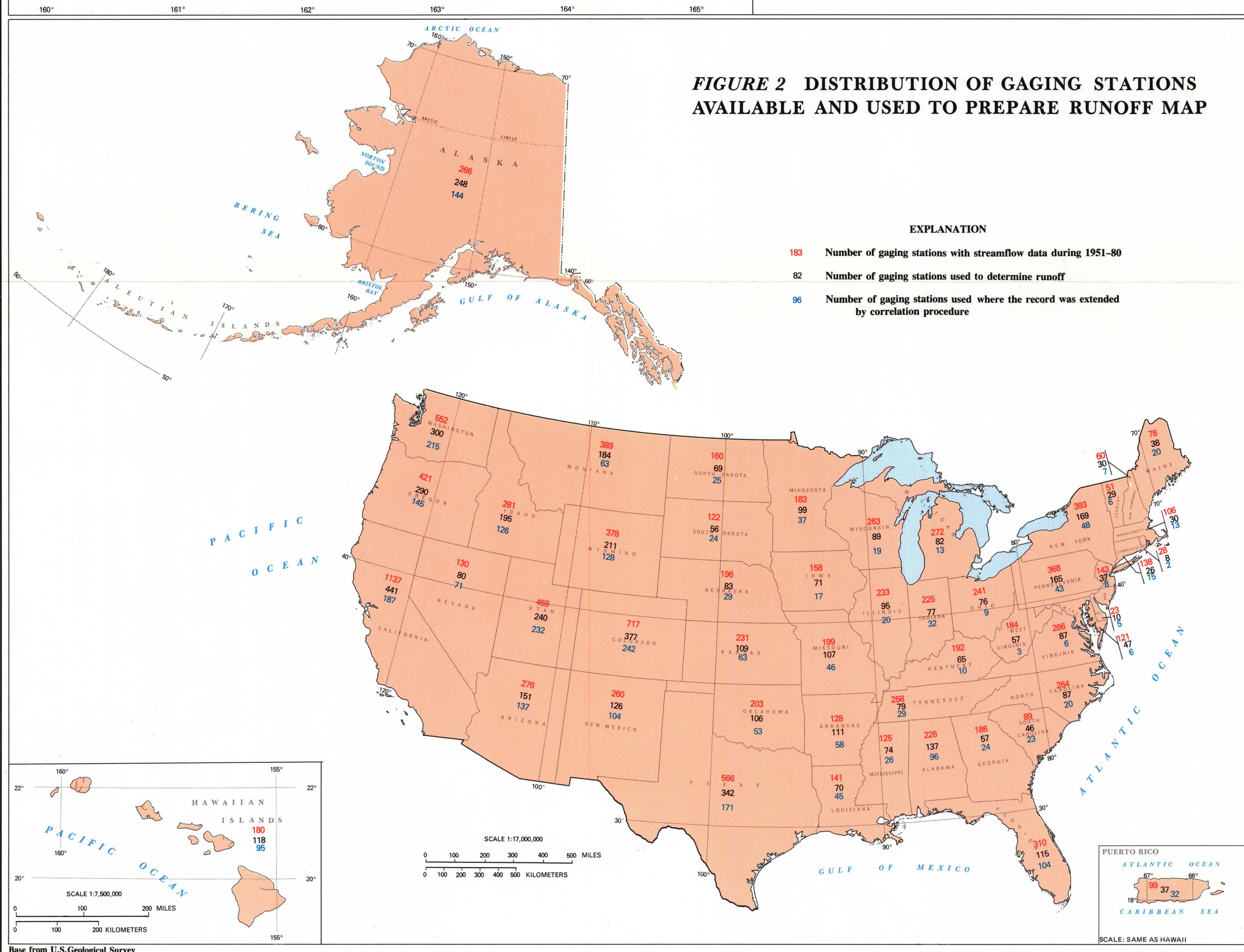


FIGURE 2 DISTRIBUTION OF GAGING STATIONS AVAILABLE AND USED TO PREPARE RUNOFF MAP

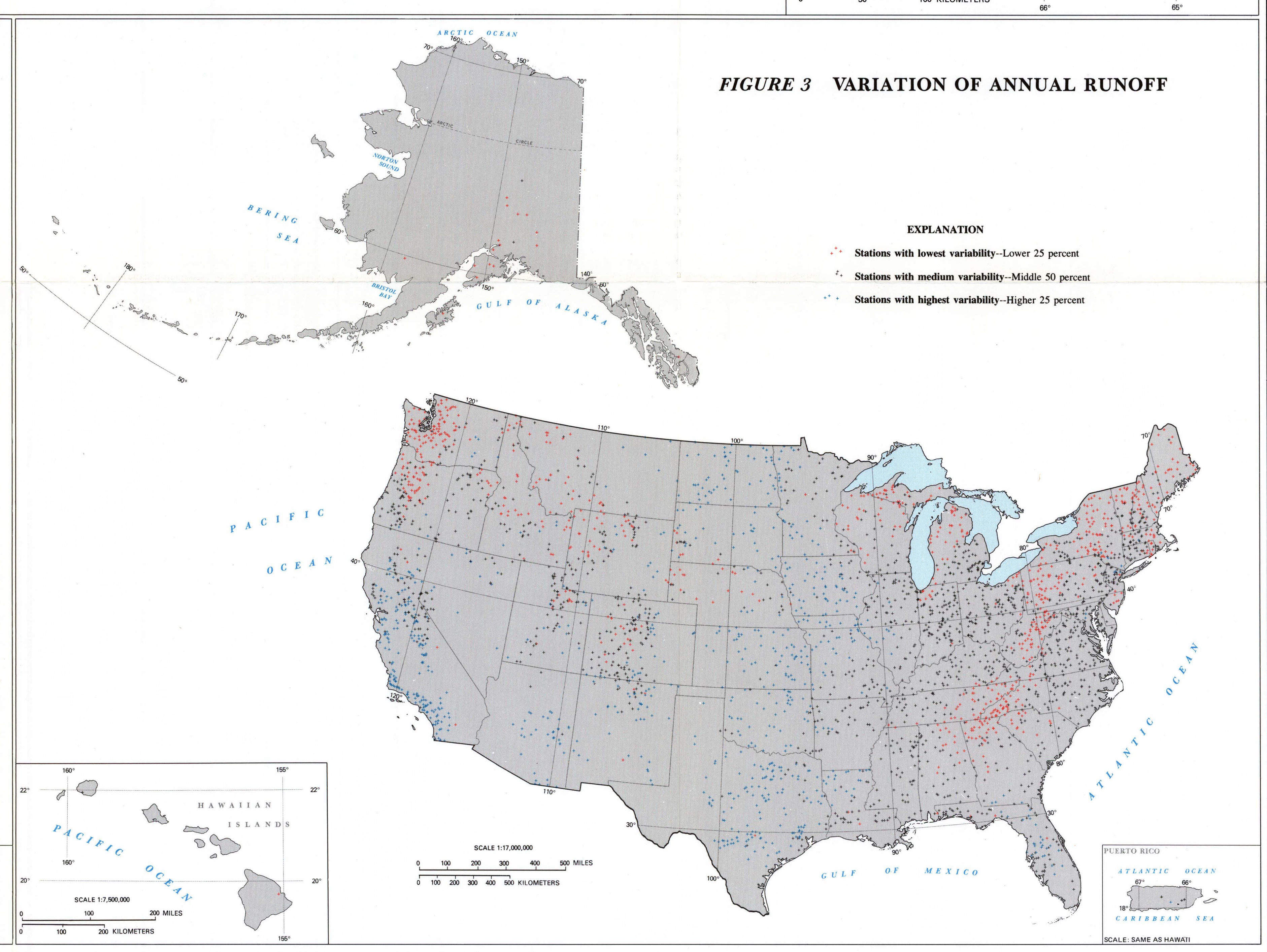


FIGURE 3 VARIATION OF ANNUAL RUNOFF

Base from U.S.Geological Survey National Atlas, 1970

AVERAGE ANNUAL RUNOFF IN THE UNITED STATES, 1951–80

BY
WARREN A. GEBERT, DAVID J. GRACZYK, AND WILLIAM R. KRUG

INTERIOR—GEOLOGICAL SURVEY, RESTON, VIRGINIA—1988