FLOODS IN PUERTO RICO, MAGNITUDE AND FREQUENCY

U.S. GEOLOGICAL SURVEY
Water Resources Investigations 78-141

Prepared in cooperation with the COMMONWEALTH OF PUERTO RICO

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UNITED STATES DEPARTMENT OF THE INTERIOR

CECIL D. ANDRUS, Secretary

GEOLOGICAL SURVEY

H. William Menard, Director

For additional information write to:

U.S. Geological Survey, WRD
Building 652; P.O. Box 34168
Ft. Buchanan, P.R. 00934

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by M. A. López, Eloy Colón-Dieppa and E. D. Cobb

ABSTRACT

Annual-peak discharge records at 50 sites with 5 or more years of record were used to determine individual site log-Pearson Type III frequency curves. The log-Pearson Type III frequency curve values for 2-, 10-, 25-, 50-, and 100-year recurrence intervals at 37 of these sites with 10 or more years of record were regressed against basin characteristics. Drainage area and mean annual rainfall proved to be the only independent variables significant at the 95 percent confidence level. The regression equations are:

$Q_2 = 0.033\ A^{.776}\ (\text{Ann P})^{2.11}$ $SE_R = +51, -34$ percent

$Q_{10} = 3.72\ A^{.822}\ (\text{Ann P})^{1.29}$ $SE_R = +45, -31$ percent

$Q_{25} = 25.7\ A^{.826}\ (\text{Ann P})^{.953}$ $SE_R = +50, -33$ percent

$Q_{50} = 89.9\ A^{.830}\ (\text{Ann P})^{.734}$ $SE_R = +55, -36$ percent

$Q_{100} = 286\ A^{.832}\ (\text{Ann P})^{.531}$ $SE_R = +61, -38$ percent

where Q is the T-year recurrence interval peak discharge,

A is the drainage area in square miles,

(Ann P) is the weighted mean annual precipitation in inches, and

SE is the standard error of estimate of the regression.

INTRODUCTION

Knowledge of flood experience and flood potential is important for the planning of use of flood plains and the development of all property adjacent to streams. It is an important criterion in the design of structures especially highway culverts and bridges. Improper design can lead to loss of life and property on one hand and to financial waste on the other. Proper design is both a human and economic necessity.

The concept of frequency of extreme values of a natural event is an elusive factor. Statistical evaluation requires the assumption that available data are representative of a much larger data group. The equations presented estimate floods of large recurrence intervals based on relatively short, finite-time samples at gaged sites. Whenever a significant amount of new data or a more effective method or technique of analysis becomes available, a new study may be warranted to improve definition of future floods.

A previous study of magnitude and frequency of floods in Puerto Rico was made in a U.S. Geological Survey open-file report entitled "A Proposed Streamflow-Data Program for Puerto Rico" prepared in cooperation with the Commonwealth of Puerto Rico by M. A. López and F. K. Fields (1970). This report used records through December 1969 and presented equations for the 5-, 10-, 25-, and 50-year recurrence-interval floods. Since the publication or release of this report, 6 more years of record and new techniques for frequency analysis are available.

Purpose and Scope

The purpose of this report is to document flood data for gaged sites, historical flood data, and to provide methods for estimating flood potential at ungaged sites on unregulated streams in Puerto Rico.

All flood data in Puerto Rico through December 1975 were analyzed. Short-term records were extended to include historic flood records. Frequency curves were computed by methods that tend to reduce time-sampling errors. A stepwise regression technique was used to relate flood frequency at the gaged sites to areal parameters.

Acknowledgments

This report was prepared as part of the cooperative program for water-resources investigations with the following agencies of the Commonwealth of Puerto Rico: Environmental Quality Board, Department of Natural Resources, Department of Transportation and Public Works, Water Resources Authority, and Aqueduct and Sewer Authority. Data contributed by the Commonwealth agencies, Federal agencies, and individuals are specifically acknowledged in the text or tables containing these data. A listing of all reports used appears in the Selected References.

FACTORS THAT INFLUENCE FLOODING

Flood magnitudes are affected by physiography, rainfall, and manmade regulation. In a homogeneous region, physiographic factors such as ground slopes, infiltration capacity of soils, stream patterns, and capacities of stream channels are considered to be relatively similar in their influence on floods. Climatic factors such as type, magnitude, and time distribution of flood-producing storms are subject to the variations of chance and are primarily responsible for the variation in flood magnitudes in an otherwise homogeneous region. Manmade storage may significantly affect the magnitude of flood-peak discharge, and channel improvements can affect peak stage as well as peak discharge. The effect of reservoirs on flood-frequency relationship is discussed in a later section.

Physiography

Puerto Rico is one of a long chain of mountainous islands that stretches from just south of Florida, North America, to Venezuela, South America. The principal topographic feature of the island is the Cordillera Central, which is the line of highest mountains running east-west and dividing the island into a northern two-thirds and a southern one-third. The Cordillera forms the principal drainage divide of the larger streams. River valleys are deeply incised into the mountain slopes, and the general characteristic is ruggedness.

Character and history of rocks and topographic characteristics of Puerto Rico are diversified and highly complex. Generalized physiographic regions for the island have been described by Picó (1950), and a hydrogeologic map by Briggs and Akers (1965) has defined hydrologic properties of the geologic formations. Each physiographic region or area contains a variety of landforms but these have been combined with the hydrogeologic divisions into three principal subdivisions: coastal lowlands, north coast limestone, and volcanic mountains and foothills. These subdivisions and major river systems are shown in figure 1.

Coastal Lowlands

Coastal lowlands are defined as the relatively flat areas at elevations less than 164 ft (50 m) above mean sea level. The flood runoff of the lowland areas is limited by the flat overland slopes and meandering channels. Flood-peak runoff originating in the higher elevations easily overflows the entrenched channel onto the flood plains. Consequently, flood-peak discharge is attenuated by channel and overbank storage as the flood moves through the valley to the ocean.

North Coast Limestone Area

A complete hydrologic description of the north coast limestone area is given by Giusti and Bennett (1976). The landforms developed on the north coast

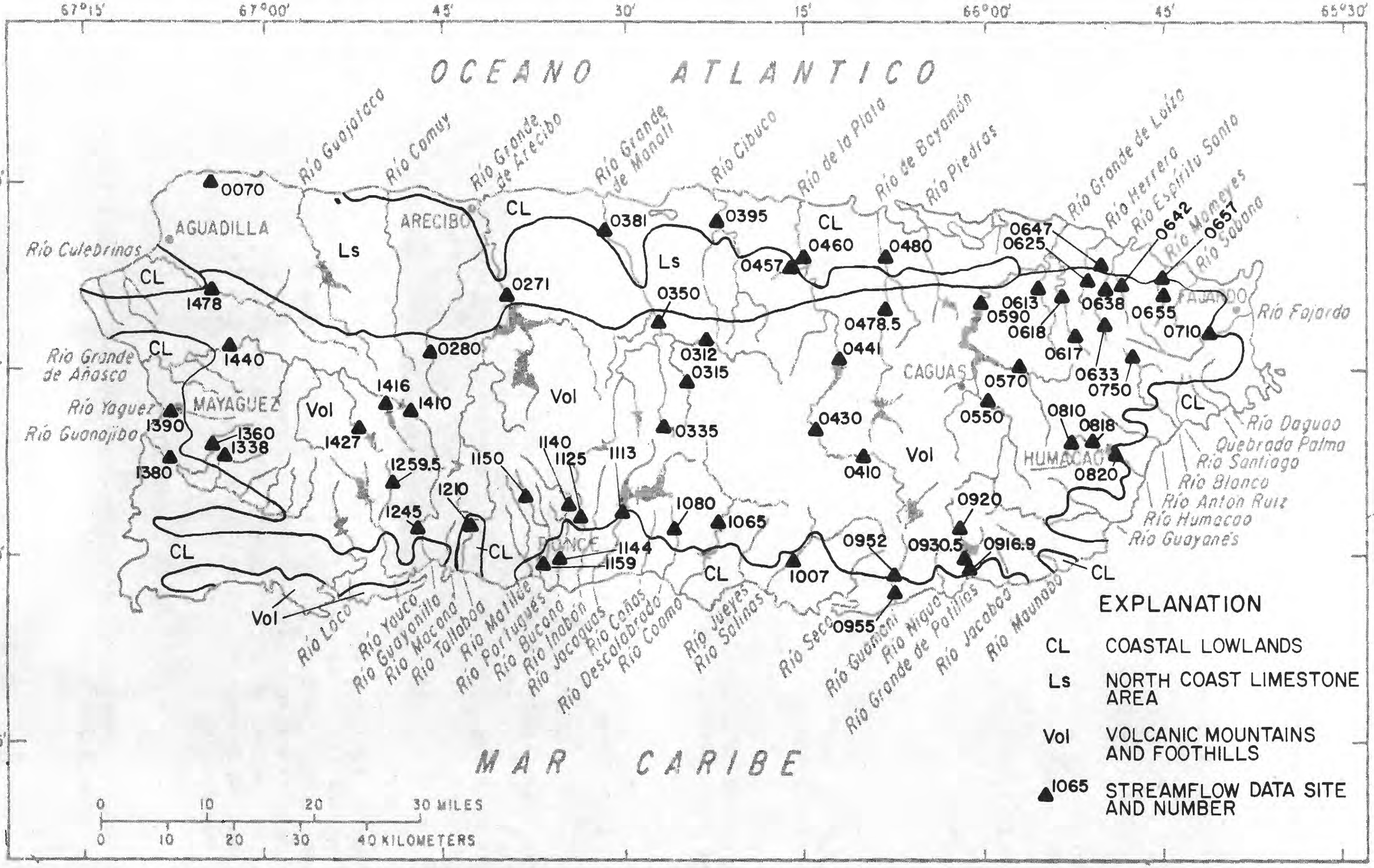

Figure 1.--Hydrologic subdivisions, major river systems, and locations of streamflow stations in Puerto Rico.

limestone area constitute one of the finest examples of tropical karst in the world: the main features are the mogotes (haystack hills), sinkholes, and the absence of major surface drainage. The north-flowing streams have cut through the limestone to form narrow gorges, and in the case of Ríos Camuy and Tanamá flow underground at several points. Flooding is confined to the narrow valleys which gradually widen as they reach the coastal lowlands.

The are areas that are not connected directly by surface drainage to the streams, and although runoff from these areas may appear in the river as streamflow shortly after a flood, it arrives too late to contribute to the peak. Only the area that has a defined surface-drainage connection with the stream is used in computing peak discharge.

Volcanic Mountains and Foothills

The interior mountain backbone of Puerto Rico, the Cordillera Central, is a topographically high, rugged, mountainous row of peaks ranging in elevation from 2,000 to 4,390 ft (610 to 1,340 m). Sierra de Luquillo, a group of high peaks in the northeast corner of the island, reach elevations of 3,450 to 3,520 ft (1,050 to 1,070 m). South-flowing streams fall steeply from the divide to the coast within 8 mi (13 km) near the east end of the Cordillera Central and within 12 to 15 mi (19 to 24 m) throughout the rest of the south coast. Fast-flowing streams have cut steep-síded valleys through the uplands and deposited boulders, gravel, sand, and silt along the south coast lowlands.

Larger streams flow northward and westward from the Cordillera Central. These streams, too, have cut steep-sided valleys through the upper reaches, but well developed flood plains are found in some interior valleys. Streams draining the Sierra de Luquillo are generally short and steep without any extensively developed valleys. The steep ground and channel slopes cause rapid runoff which causes "flash flood" type peaks.

Rainfall

Puerto Rico has a tropical marine climate, and is in a belt of prevailing northeasterly trade winds. As a result of orographic effects, a large amount of rainfall occurs on the windward (north and east) slopes of the mountains, and the mean-annual rainfall pattern is greatly affected by the topography. Areas of highest rainfall coincide with the higher elevations of Sierra de Luquillo and the Cordillera Central as shown in figure 2.

Flood-producing storms are more prevalent during the "hurricane season" of July through October. Rainfall during these months is normally caused by slow-moving low-pressure systems that cover large areas. These "tropical depressions" can develop enough circulation to be classified as hurricanes and cause serious wind damage as well as heavy rainfall. Severe flooding has been associated with hurricanes and tropical storms that have passed close to the island, such as Donna in 1960 (Barnes, 1961) and Eloise in 1975.

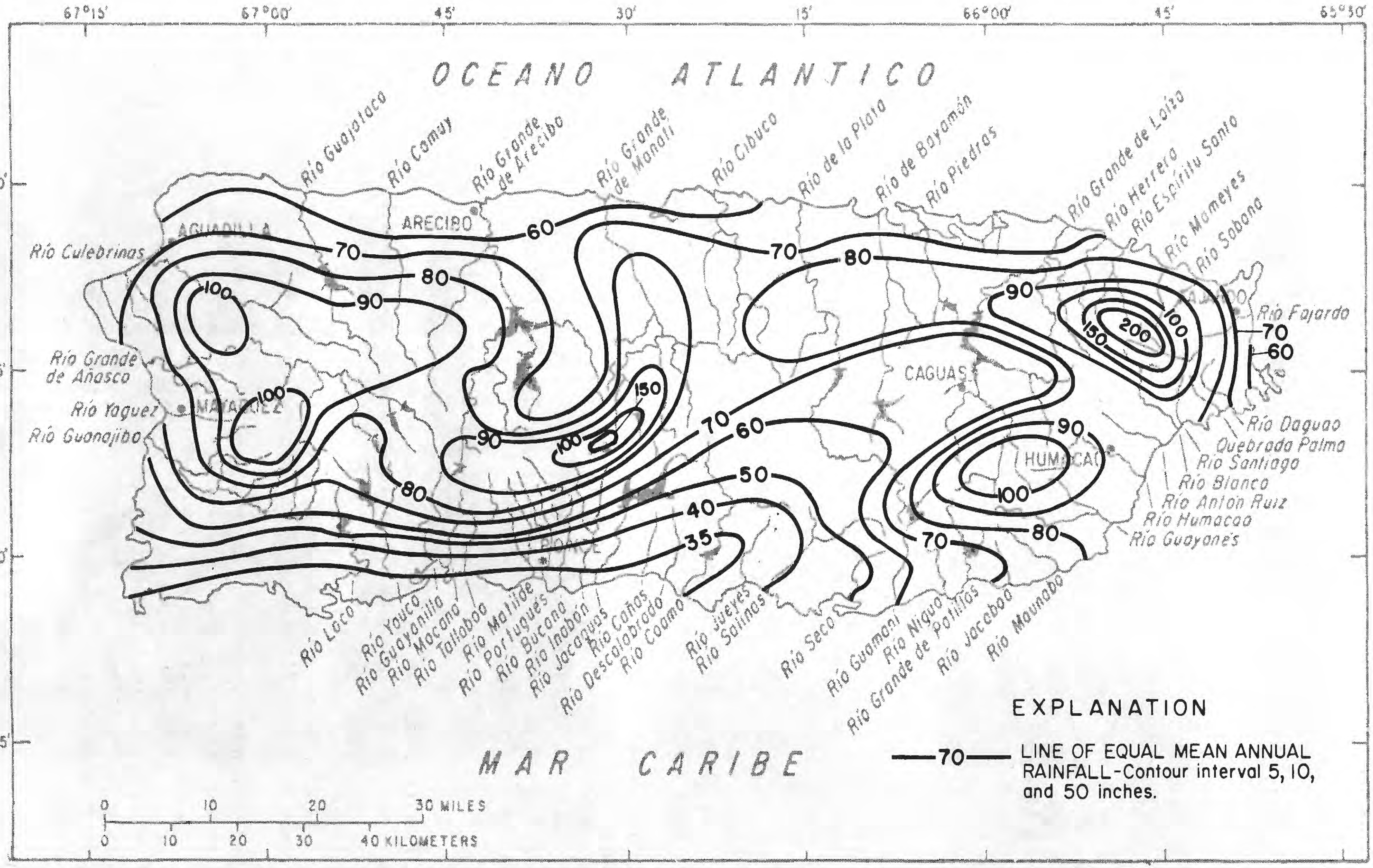

Figure 2.--Mean annual rainfall in inches, in Puerto Rico (from Calvesbert, R. J., 1970).

Other major rainfall-producing situations occur during the winter from about November to March. During this period the trailing edge of a cold front occasionally penetrates far enough south to affect Puerto Rico. A strong, active but slowly moving front is capable of bringing heavy and continuing rainfall, lasting for several days.

Convective-type rainfall of short duration but high intensity generally occurs during April, May, and June. These localized storms can cause serious flooding in small areas, but usually are too limited areally to cause major flooding on the large rivers.

The eastern two-thirds of the island has experienced significant flooding several times since 1959. The most severe floods occurred on September 6, 1960, during October 7-9, 1970, and in September 1975. The areas affected in 1960 and 1970 are shown in figures 3 and 4. The southwestern part of the island suffered severe flooding only once since 1959. The September 16, 1975, flooding affected the area shown in figure 5.

An early investigation of the occurrence of high-intensity rainfall and the resultant flood discharges was made by Quiñones (1952). A later study was published by the U.S. Weather Bureau in 1961, Technical Paper No. 42, "Generalized Estimates of Probable Maximum Precipitation and Rainfall-Frequency for Puerto Rico and Virgin Islands." These estimates were based on data from a single recording rainfall station in San Juan and a mathematical hurricane model. Lack of recording rainfall data prevented verification of the model. Since June 1971, the National Weather Service has been collecting continuous rainfall data at 13 sites throughout the island. Ten additional sites were added in June 1973. As these data are processed and analyzed, a better estimate of the rainfall intensity and frequency is expected.

A detailed description of the climate of Puerto Rico is available in the U.S. Department of Commerce publication "Climate of Puerto Rico and U.S. Virgin Islands, Climatography of the United States No. 60-52" (Calvesbert, 1970).

PEAK-DISCHARGE RECORDS

Flood-peak discharge data for this report were largely derived from streamflow records collected by the U.S. Geological Survey, Puerto Rico Water Resources Authority, and the Puerto Rico Aqueduct and Sewer Authority. The supplementary data table contains annual peak-discharge data used in flood-frequency regionalization.

The stations in the supplementary data table (p. 46-70) are listed in consecutive downstream order with numbers assigned by the Geological Survey. The stations are identified by these numbers in figure 1. The drainage area listed for each station is that which has a defined surface drainage system linking it to the stream channel. Some sites, especially along the north coast limestone area, have some depressions or closed basins in which storm

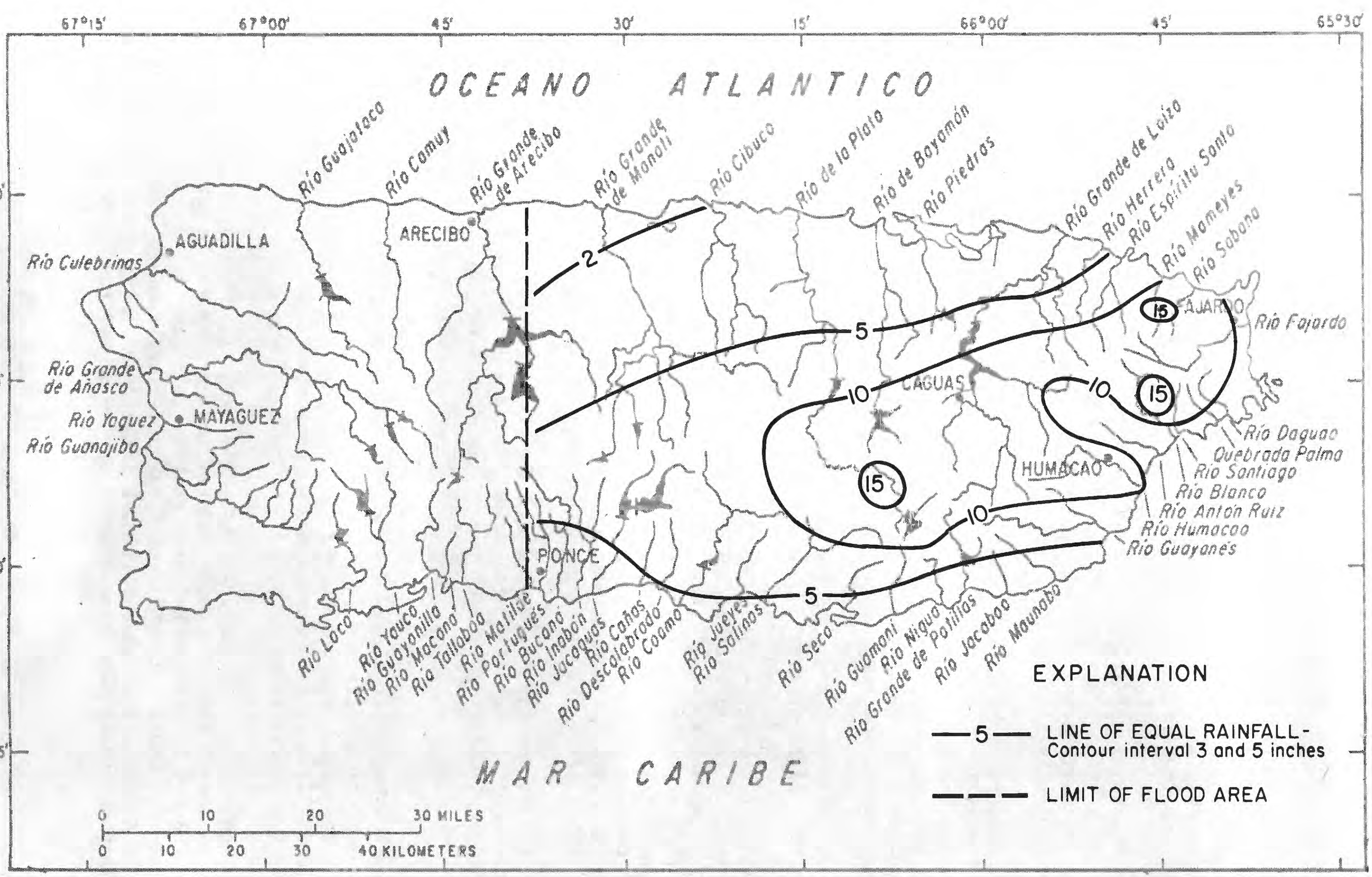

Figure 3.--Area experiencing outstanding flooding during September 5-7, 1960.

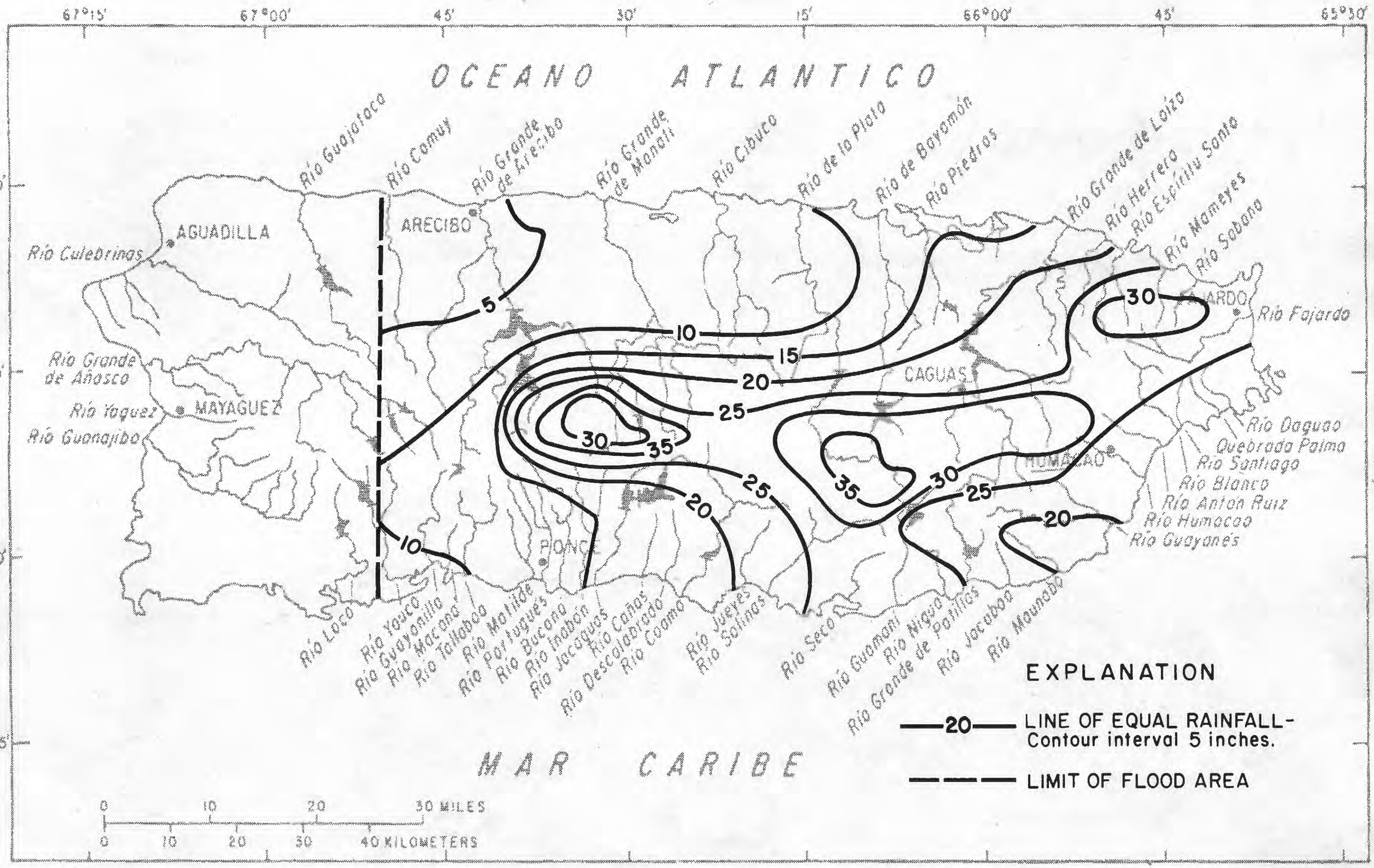

Figure 4.--Area experiencing outstanding flooding during October 5-10, 1970.

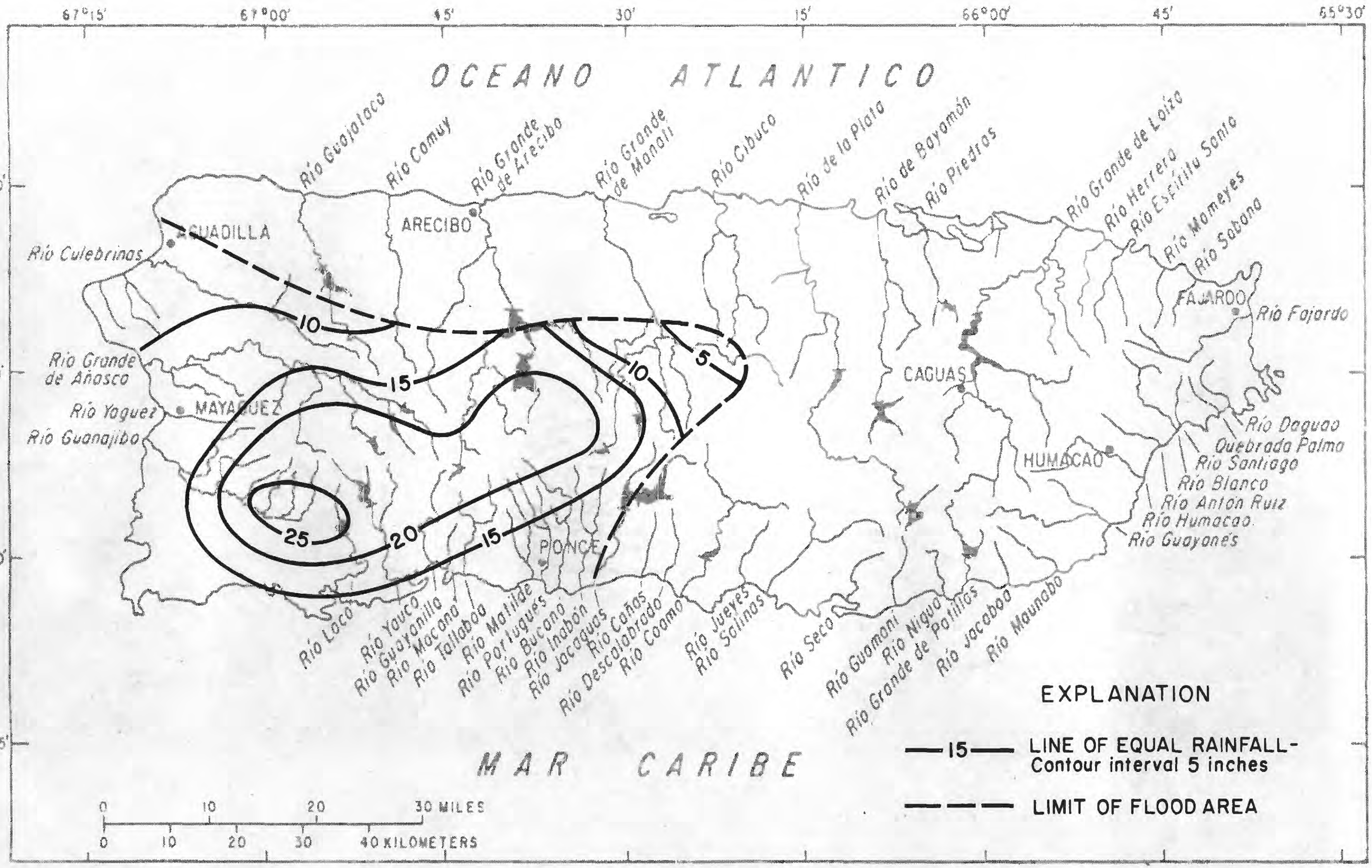

Figure 5.--Area experiencing outstanding flooding during September 15-17, 1975.

runoff collects and seldom reaches the stream as direct surface contribution. The contributing drainage area has been used as a correlative parameter in this report.

Much information about historical floods was taken from the U.S. Geological Survey Hydrologic Atlas series of flood inundation maps and bridge-site reports. The areas covered by flood studies and titles of the reports are shown in figure 6 and listed in table 1.

FLOOD-FREQUENCY ANALYSES

An analysis of flood frequency based on records collected at one gaging station is an indication of what has happened at that particular site during a specific period of time. Such a record is only a small sample of long-term flood characteristics, and therefore may not be a good basis for predicting what will happen in the future, even at that same site. A frequency curve based on regional characteristics of climate, topography, and other parameters is often believed to be more reliable than one solely based on flood experiences at a particular site. However, in order to derive a regional frequency curve, it is first necessary to define frequency curves for individual sites.

Frequency curves for individual stream sites were developed using the methods recommended and described in Water Resources Council Bulletin 17A (1977). The recommended method utilizes the log-Pearson Type III distribution. Methods are also described for checking for low data outliers and for utilizing historical peak flow data.

The skew coefficient in log-Pearson Type III analysis for short records is highly sensitive to extreme events. For this reason, it is sometimes recommended that a regional skew be used. There are inadequate data available to develop an accurate regional skew for Puerto Rico. However, a study of station skews indicated that a median skew for Puerto Rico was about 0.0 and there did not seem to be a trend in skew which could be related to geography or physiography. Therefore, to minimize the effects of the short record on the skew coefficient, a regional skew value of 0.0 was used in this analysis.

The supplemental data table lists the years and the peak flow data available for this study. Figure 7 shows in bar graph form, the years for which peak-flow data are available. Frequency curves were developed for 37 stream sites having 10 or more years of record.

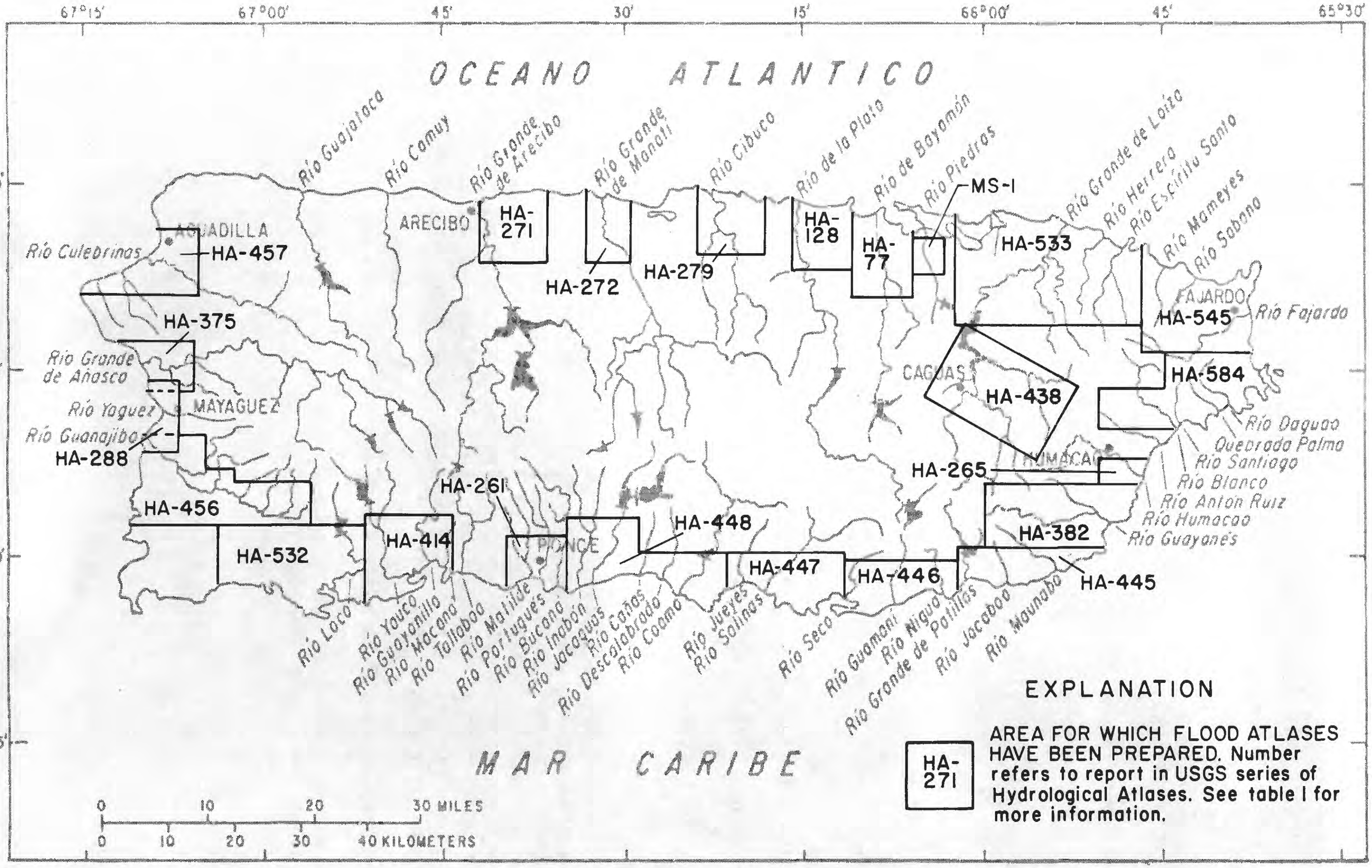

Figure 6.--Areas in Puerto Rico for which flood atlases have been prepared.

Station number	Drainage area in square miles
50027100	169
50028000	18.4
50031200	55.2
50031500	3.9
50033500	8.6
50035000	128
50038100	165
50039500	70.5
50043000	54.8
50045700	8.4
50046000	200
50048000	71.9
50055000	89.8
50057000	60.2
50059000	207
50061300	14.4
50061700	2.8
50061800	9.8
50062500	2.8
50063300	2.2
50063800	8.6
50064200	7.3
50065500	6.9
50065700	11.8
50071000	14.9
50075000	1.3
50082000	17.3
50092000	18.3
50093050	25.6
50095200	8.2
50095500	12.3
50100700	22.2
50106500	46
50108000	12.9
50111300	43.5
50112500	9.7
50114000	17.8
50114400	25.6
50115000	8.8
50115900	18.6
50121000	24.2
50124500	20.8
50125950	3.4
50133800	4.4
50136000	17.6
50141000	15.4
50141600	10.1
50142700	14.4
50144000	134
50147800	71.2

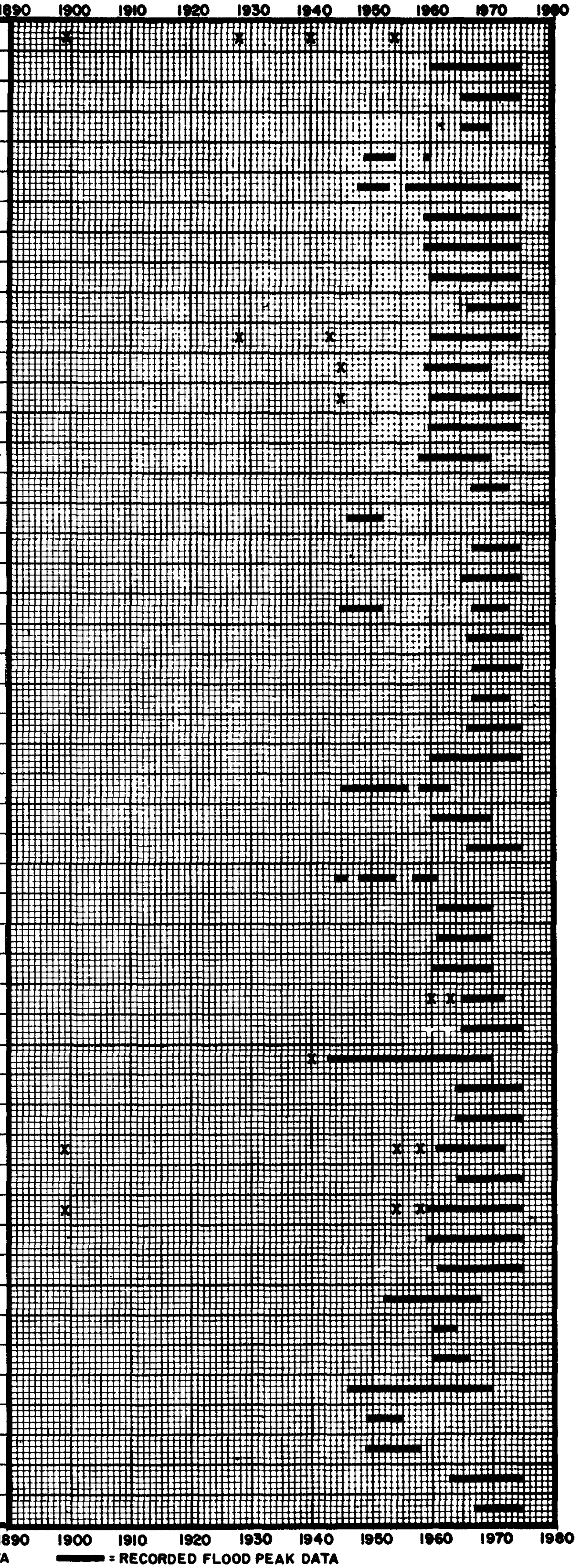

Figure 7.--List of annual peak discharge records in Puerto Rico for calendar years 1899 through 1975.

Table 1.--Hydrologic Investigations Atlases (Puerto Rico)

Number	Title and author	Published
HA-77	Floods at Bayamón and Cataño, Puerto Rico by M. A. López	1962
HA-128	Floods at Toa Alta, Toa Baja, and Dorado, Puerto Rico by M. A. López	1964
HA-261	Floods in the Ponce area, Puerto Rico by I. J. Hickenlooper and M. A. López	1967
HA-262	Floods at Barceloneta and Manatí, Puerto Rico by I. J. Hickenlooper	1967
HA-265	Floods at Humacao, Puerto Rico by M. A. López	1967
HA-271	Floods at Arecibo, Puerto Rico by I. J. Hickenlooper	1968
HA-288	Floods in the Mayaguez area of Puerto Rico by I. J. Hickenlooper	1968
HA-289	Floods in the area of Vega Alta and Vega Baja, Puerto Rico by I. J. Hickenlooper	1968
HA-375	Floods in the Añasco area, Puerto Rico by F. K. Fields	1971
HA-382	Floods in the Yabucoa area, Puerto Rico by F. K. Fields	1971
HA-414	Floods in the Guayanilla-Yauco area, Puerto Rico by F. K. Fields	1971
HA-430	Storm-wave swash along the north coast of Puerto Rico by F. K. Fields and D. G. Jordan	1972
HA-438	Floods at Caguas, Gurabo, Juncos, and San Lorenzo, Puerto Rico by F. K. Fields	1972
HA-445	Floods in Patillas-Maunabo area, Puerto Rico by W. J. Haire	1971
HA-446	Floods in Guayama area, Puerto Rico by W. J. Haire	1971
HA-447	Floods in Salinas area, Puerto Rico by W. J. Haire	1971
HA-448	Floods in Santa Isabel area, Puerto Rico by W. J. Haire	1971
HA-456	Floods in the Río Guanajibo valley, southwestern Puerto Rico by W. J. Haire	1972

Table 1.--Hydrologic Investigations Atlases (Puerto Rico)--Continued

Number	Title and Author	Published
HA-457	Floods in the Aguadilla-Aguada area, northwestern Puerto Rico by K. G. Johnson	1972
HA-532	Floods in the Lajas Valley, Puerto Rico by K. G. Johnson	1975
HA-533	Floods in the Carolina-Río Grande area, northeastern Puerto Rico by W. J. Haire	1975
HA-545	Floods in the Fajardo-Luquillo area, northeastern Puerto Rico by W. J. Haire	1975
HA-584	Floods in the Naguabo area, eastern Puerto Rico by W. J. Haire	1978
MS-1	Flooding along the Río Piedras in the San Juan area, Puerto Rico by W. J. Haire	1972

REGIONAL ANALYSIS

After individual station frequency curves were developed, results were regressed against basin parameters that can be measured from topographic and rainfall maps and soil data that can be retrieved from the Puerto Rico Department of Natural Resources' "Mapa de Inventario de Recursos Naturales, Culturales y Ambientales, 1974."

Records at stations downstream from certain reservoirs were used in the regional analysis for the period of record, even though some regulation was in effect. Generally, reservoir operation data during peaks was incomplete or missing altogether. Therefore, it is impossible to fully determine the effect of the reservoirs on downstream peak flows.

The effect on peak flows would definitely be significant in some instances if the reservoirs become nearly empty prior to a peak-flow producing storm. It is believed that the reservoirs usually are not allowed to be reduced to near-empty levels. Therefore, it was assumed that the storage had little effect on peak flows at the following stations and the unadjusted peak-flow analysis was used in the regional regression analysis.

Station number	River	Reservoir	Date regulation began	Usable storage (acre-ft)	Date of contents survey
50 0350 00	Río Grande de Manatí	Matrullas	1934	2,400	1934
		Guineo	1931	1,810	1931
0430 00	Río Grande de la Plata	Carite	1913	9,800	1913
0460 00	Río Grande de la Plata	Carite	1913	9,800	1913
		La Plata	1973	55,900	1974
1440 00	Río Grande de Añasco	Yahuecas	1956	1,800	1956
		Guayo	1956	17,400	1956
		Prieto	1955	1,800	1955

Regulation from reservoirs on the following streams was considered to be large enough to affect peak flows. Therefore, based on reservoir stage observations and records of reservoir outflows, determinations were made of peak inflows to the reservoirs. These determinations of peak inflow were then analyzed for flood frequencies and the results used in the regional regression analysis. Reservoir inflow data were used for the following stations:

50 0590 00 Río Grande de Loíza at Lago Loíza

0930 50 Río Grande de Patillas at Lago Patillas

1113 00 Río Jacaguas at Lago Guayabal

Because these reservoirs are not operated for flood control, they are allowed to fill before controlled releases are made. This method of operation generally results in reduced discharges downstream from the dam for the lesser frequency floods, but provides very little reduction in the larger floods which peak after the reservoir has filled. An analysis of inflow and outflow peak discharges at Lago Loíza Dam indicates the outflow peak discharge is not significantly reduced for floods of 50-year or greater recurrence intervals. Differences in the inflow and outflow frequency curves are shown in U.S. Geological Survey Hydrologic Investigations Atlas HA-533 (Haire, 1975).

The regression equations for less than the 50-year flood, generally do not apply below the larger reservoirs in Puerto Rico. However, since most reservoirs are fairly small relative to the volumes of flow occurring during major storm events, the equations should be applicable below most reservoirs. The degree of effect of regulation will be lessened as the flood magnitude increases. Therefore, while the peak-flow equation will perhaps not be applicable for a more frequent or smaller peak flow, the equation for a higher peak flow will more likely be applicable.

Basin Characteristics

Many basin characteristics were tested in the regression analyses with the gaged site T-year peaks, but only a few proved to be significant in the final equation. Those tested are described as follows:

1. Drainage area (a), in square miles: determined by outlining the basin on 1:20,000 U.S. Geological Survey topographic quadrangles and planimetering the area within the outline. Closed basins within the outline with no apparent surface drainage connection to the stream were not included.

2. Channel slope (S), in meters per kilometer: measured along the main channel from the first contour that crosses the channel downstream from the gage to the next contour that crosses the channel upstream from the gage. One was added to the result to avoid negative logs of numbers less than one.

3. Ground slope (GS), in percent: data retrieved from the Puerto Rico Department of Natural Resources "Mapa de Inventario de Recursos Naturales, Culturales y Ambientales (1974)." The average of the ground slope of all 1/4-km^2 cells within the basin boundary was computed from the retrieval program DATALIST.

4. Permeability (Perm), in inches per hour: data retrieved from the Puerto Rico Department of Natural Resources "Mapa de Inventario de Recursos Naturales, Culturales y Ambientales (1974)." The average of the permeability of all 1/4-km^2 cells within the basin boundary was computed from the retrieval program DATALIST. The reciprocal of this value was used in the multiple regression to avoid the negative logarithm of values less than one.

5. Depth to rock (D), in feet: data retrieved from the Puerto Rico Department of Natural Resources "Mapa de Inventario de Recursos Naturales, Culturales y Ambientales (1974)." The average depth to rock of all 1/4-km^2 cells within the basin boundary was computed from the retrieval program DATALIST.

6. Forest cover (F), in percent: data retrieved from the Puerto Rico Department of Natural Resources "Mapa de Inventario de Recursos Naturales, Culturales y Ambientales (1974)." The number of 1/4-km^2 cells that are over 50 percent forested was divided by the total number of cells within the basin boundary and the result multiplied by 100.

7. Annual precipitation (Ann P), in inches: weighted mean annual precipitation over the basin computed from figure 2 adapted from "Climatology of the United States" (U.S. Department of Commerce, 1965, revised May 1969).

8. Rainfall intensity, 24-hour, 25-year recurrence interval (I_{24-2}), in inches: weighted 24-hour, 2-year recurrence interval rainfall over the basin upstream from the gage was computed from figure 4-50 of the U.S. Weather Bureau Technical Paper no. 42 (U.S. Department of Commerce, 1961).

9. Rainfall intensity, 24-hour, 25-year recurrence interval (I_{24-25}), in inches: weighted 24-hour, 25-year recurrence interval rainfall over the basin upstream from the gage was computed from figure 4-53 of the U.S. Weather Bureau Technical Paper no. 42 (U.S. Department of Commerce, 1971).

Note: A high correlation exists between the 24-hour, 25-year recurrence interval rainfall and the 24-hour, 50- and 100-year recurrence interval rainfalls. Therefore, only the 2-year and 25-year recurrence interval rainfalls were used in the regressions.

Regression Analyses

A step-backward regression analysis using log transforms of the 2-, 10-, 25-, 50- and 100-year recurrence interval floods was regressed against log transforms of the basin characteristics. All the data for 50 gaging stations with 5 or more years of annual peak-discharge record were initially used. The ratio of (Q_{50} Observed)/(Q_{50} Regression) using drainage area as the independent variable was plotted at the center of each basin on a map of the island. No apparent regional pattern was evident. The significant basin characteristics were the drainage area and annual precipitation. All other basin characteristics tested did not reduce the error of estimate significantly at the 95-percent level.

Selected station records with 10 or more years of record were used in the next regression trial. Residuals of the 25-year flood at each basin using drainage area and annual precipitation as independent variables were again plotted on a map to identify any regional pattern. The ratio of (Q_{25} Observed)/(Q_{25} Regression) varied randomly throughout the island, ranging from 0.38 to 2.07.

Final regression equations determined from the analyses of 37 station records with 10 or more years are as follows:

$$Q_2 = 0.033\ A^{.776}\ (\text{Ann P})^{2.11} \qquad SE_R = +51, -34 \text{ percent}$$

$$Q_{10} = 3.72\ A^{.822}\ (\text{Ann P})^{1.29} \qquad SE_R = +45, -31 \text{ percent}$$

$$Q_{25} = 25.7\ A^{.826}\ (\text{Ann P})^{.953} \qquad SE_R = +50, -33 \text{ percent}$$

$$Q_{50} = 89.9\ A^{.830}\ (\text{Ann P})^{.734} \qquad SE_R = +55, -36 \text{ percent}$$

$$Q_{100} = 286\ A^{.832}\ (\text{Ann P})^{.531} \qquad SE_R = +61, -38 \text{ percent}$$

where

A is the drainage area in square miles,

Ann P is the weighted mean annual precipitation in inches, and

SE_R is the standard error of the regression equation.

These equations are for use with inch-pound units only.

The above equations may not be applicable on streams where large reservoirs exist. This was discussed in more detail earlier. Also, the equations do not take into consideration the storage of water on large overflow plains which may significantly reduce the peak flow. The equations are not appropriate where a significant part of the basin is urbanized. Use of the equations for drainage areas less than those used in this analysis may tend to give erroneous results.

Multiple-regression results using records through December 1969 (López and Fields, 1970) are compared in the following tabulation with multiple-regression equations using records through December 1975.

Data through 1969 Record ≥ 5 years		Data through 1975 Record ≥ 10 years	
Equation	SE_R (percent)	Equation	SE_R (percent)
$Q_2 = 43.9\ A^{.49}\ (\text{Ann P}-50)^{.28}$	35	$Q_2 = 0.033\ A^{.776}\ (\text{Ann P})^{2.11}$	+51, -34
$Q_{10} = 2230\ A^{.60}$	35	$Q_{10} = 3.72\ A^{.822}\ (\text{Ann P})^{1.29}$	+45, -31
$Q_{25} = 2840\ A^{.66}$	34	$Q_{25} = 25.7\ A^{.826}\ (\text{Ann P})^{.953}$	+50, -33
$Q_{50} = 3230\ A^{.71}$	34	$Q_{50} = 89.9\ A^{.830}\ (\text{Ann P})^{.734}$	+55, -36
		$Q_{100} = 268\ A^{.832}\ (\text{Ann P})^{.531}$	+61, -38

Accuracy of Regionalized T-Year Flood Event

Although the standard error of estimate of the regression gives an approximation of the standard error of the flow characteristic, the standard error of prediction is a better parameter for evaluating accuracy of the regression equation. As shown by Matalas and Gilroy (1968), the accuracy of a prediction depends in part on how much of the standard error of estimate is due to time-sampling error (error in the characteristic at the stations used in the regression) and how much is due to error in the underlying relation between the true values of the flow characteristics. Hardison (1971) evaluated the equations proposed by Matalas and Gilroy (1968) and presented a method of converting the standard error of estimate of the regression to a standard error of prediction at ungaged sites.

As the standard error of prediction of a streamflow characteristic depends largely on the variability of the annual events, it tends to vary widely from one region to another. One way to remove the bias in evaluating the accuracy of a prediction equation is to express it in terms of the equivalent years of record that would be required to give results of equal accuracy at an individual site. This concept of equivalent-year accuracy was used in the design of streamflow data programs (Carter and Benson, 1969). Equations for converting standard error of prediction to accuracy in equivalent years of record for the regression equation selected were computed using the method proposed by Hardison (1971). An average interstation correlation coefficient of 0.25 was assumed for the computation of the standard error of prediction and of the equivalent years of record.

The standard error of prediction, SE_p, and the equivalent length of record for the regression equations are as follows:

Equation	T-year flood equation	SE_p (percent)	Equivalent years of record
1	$Q_2 = 0.033\ A^{.776}\ (\text{Ann P})^{.211}$	+48, -32	5
2	$Q_{10} = 3.72\ A^{.882}\ (\text{Ann P})^{1.29}$	+36, -27	15
3	$Q_{25} = 25.7\ A^{.826}\ (\text{Ann P})^{.953}$	+38, -28	19
4	$Q_{50} = 89.9\ A^{.830}\ (\text{Ann P})^{.734}$	+42, -29	20
5	$Q_{100} = 286\ A^{.832}\ (\text{Ann P})^{.531}$	+46, -32	20

DETERMINATION OF FLOOD MAGNITUDE AND FREQUENCY

Ungaged Sites

The expected magnitude of selected frequency floods can be computed, using equations 1-5 as defined in the previous section. Since the solution to these equations involves only two independent variables, drainage area (A) and mean annual precipitation (Ann P), a set of diagrams can be used to determine the peak discharge. These diagrams are in figures 8-12.

An example of the use of these diagrams follows for Río Valenciano at Highway 30 at Juncos. Assume a 50-year recurrence interval flood-peak discharge is required for the design of a new bridge on Highway 30. The pertinent basin characteristics needed are:

drainage area (A) = 18.6 mi^2 (48.2 km^2)

weighted mean annual precipitation (Ann P) = 92 in (2,337 mm)

Enter the diagram in figure 11 at 18.6 mi^2 on the horizontal scale, draw a line vertically to six-tenths the distance between the 80- and 100-in (Ann P) diagonal lines and then draw a line horizontally to the peak discharge scale. Read the peak discharge of 28,100 ft^3/s.

Gaged Sites

Log-Pearson Type III flood-frequency curve discharge values were determined at 50 sites with 5 or more years of annual peak record. The computed peak discharges for 2-, 10-, 25-, 50- and 100-year recurrence-interval floods at each of these sites are given in table 2. Also listed are the drainage area (A) and weighted mean annual precipitation (Ann P) for each site. These two basin characteristics can be used to determine the selected recurrence interval flood-peak discharge using figures 8-12. The peak discharge computed at the site using the basin parameters can be compared with the peak discharge derived from the individual station record.

For example, assume a flood-control channel is proposed for Río Grande de Manatí from Highway 2 to the ocean. The design flood capacity of the channel should carry at least the 100-year recurrence interval peak discharge. A record of annual peak discharges for 17 years is available at station 50 0381 00, Río Grande de Manatí at Highway 2 near Manatí. The log-Pearson Type III frequency curve magnitude for 100 years at this site is found in table 2 and is equal to 255,000 ft^3/s (7,220 m^3/s).

To compare this estimate of the 100-year flood determined from the record at the site with the regression estimate, use figure 12 with the area (A) = 165 mi^2 (427 km^2) and the weighted mean annual precipitation (Ann P) = 84 in (2,134 mm). The regression result is 210,000 ft^3/s (5,950 m^3/s).

The U.S. Water Resources Council (Appendix 8, 1977) recommends that the logarithms of the discharge be weighted by the appropriate equivalent years of record to estimate the frequency characteristics at a site where both regionalized and site information are available. The equation that is used to determine the best estimate of the T-year flood is:

$$\text{Log } Q_T = \frac{N_1 \log Q_S + N_2 \log Q_R}{N_1 + N_2}$$

where Q_T is the discharge of the T-year flood peak

Q_S is the T-year discharge determined by site data

Q_R is the T-year discharge determined by regionalized data

N_1 is the years of record at the site and

N_2 is the equivalent years of record represented by the regional equation.

The data for station 50 0381 00 on the Río Grande de Manatí are used as an example. The 100-year flood determined from site data is 255,000 ft^3/s (7,220 m^3/s) and that by the regionalized data is 210,000 ft^3/s (5,950 m^3/s).

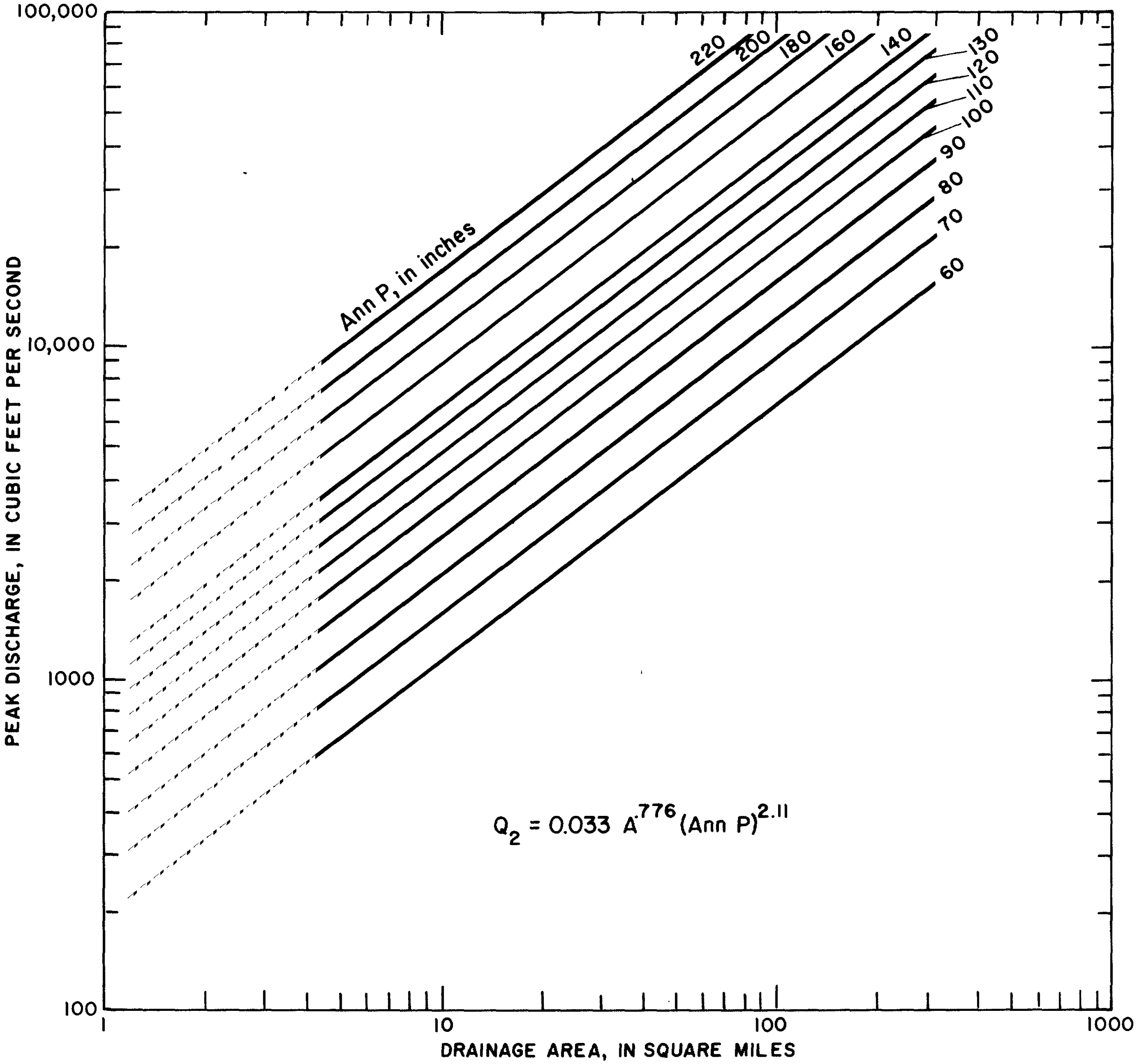

Figure 8.--Diagram for determining the 2-year flood-peak discharge at ungaged sites in Puerto Rico.

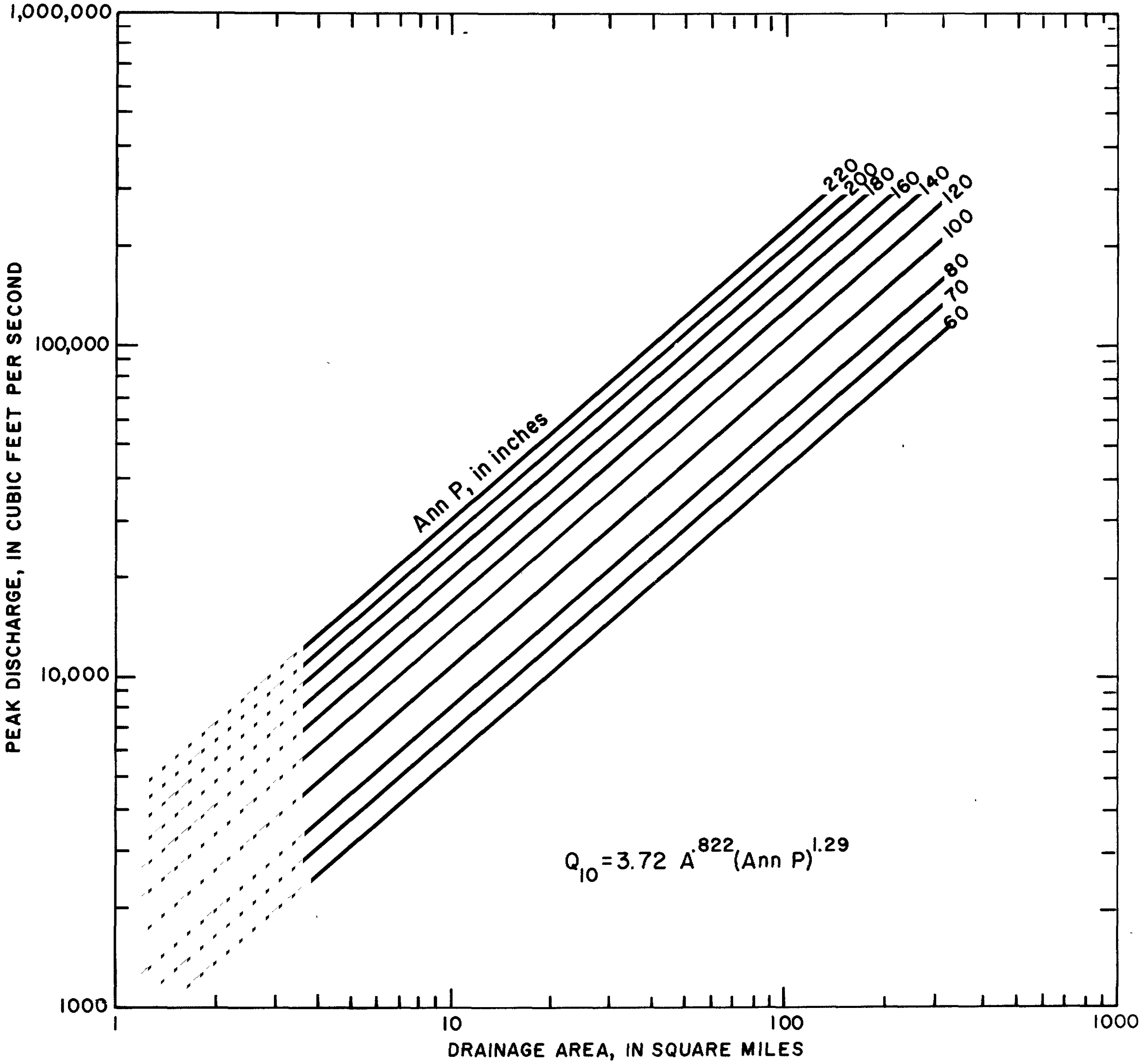

Figure 9.--Diagram for determining the 10-year flood-peak discharge at ungaged sites in Puerto Rico.

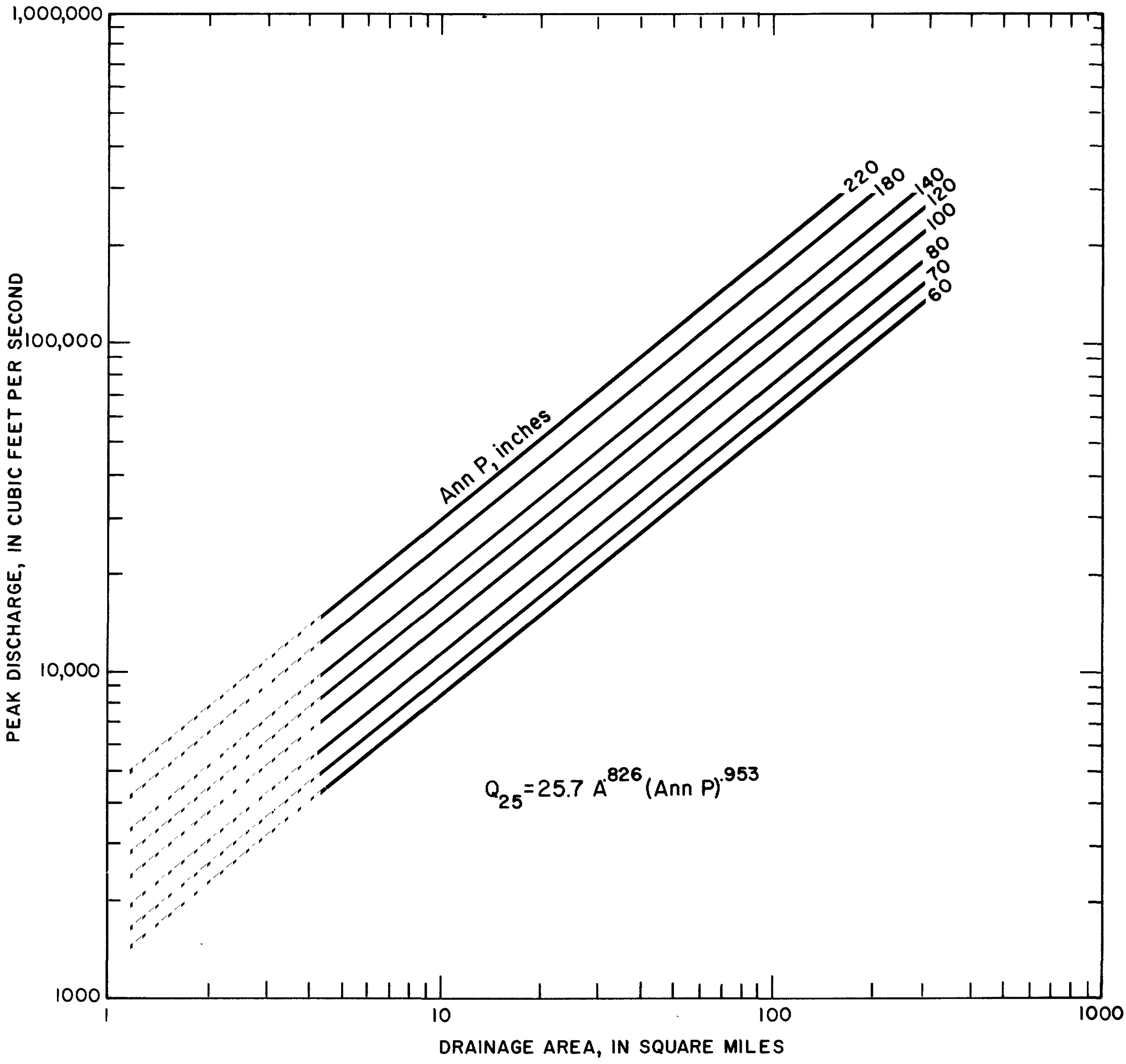

Figure 10.--Diagram for determining the 25-year flood-peak discharge at ungaged sites in Puerto Rico.

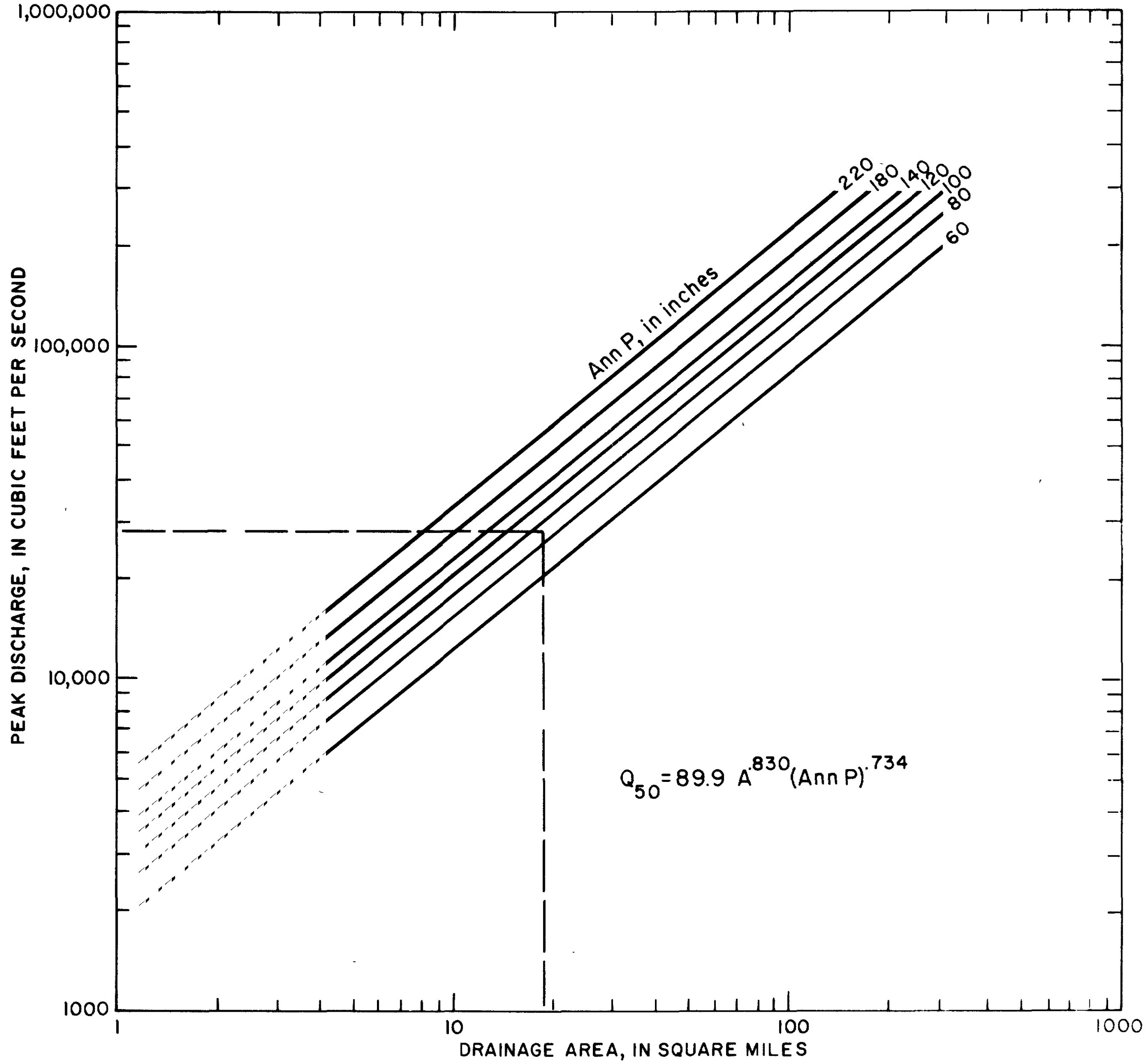

Figure 11.--Diagram for determining the 50-year flood-peak discharge at ungaged sites in Puerto Rico.

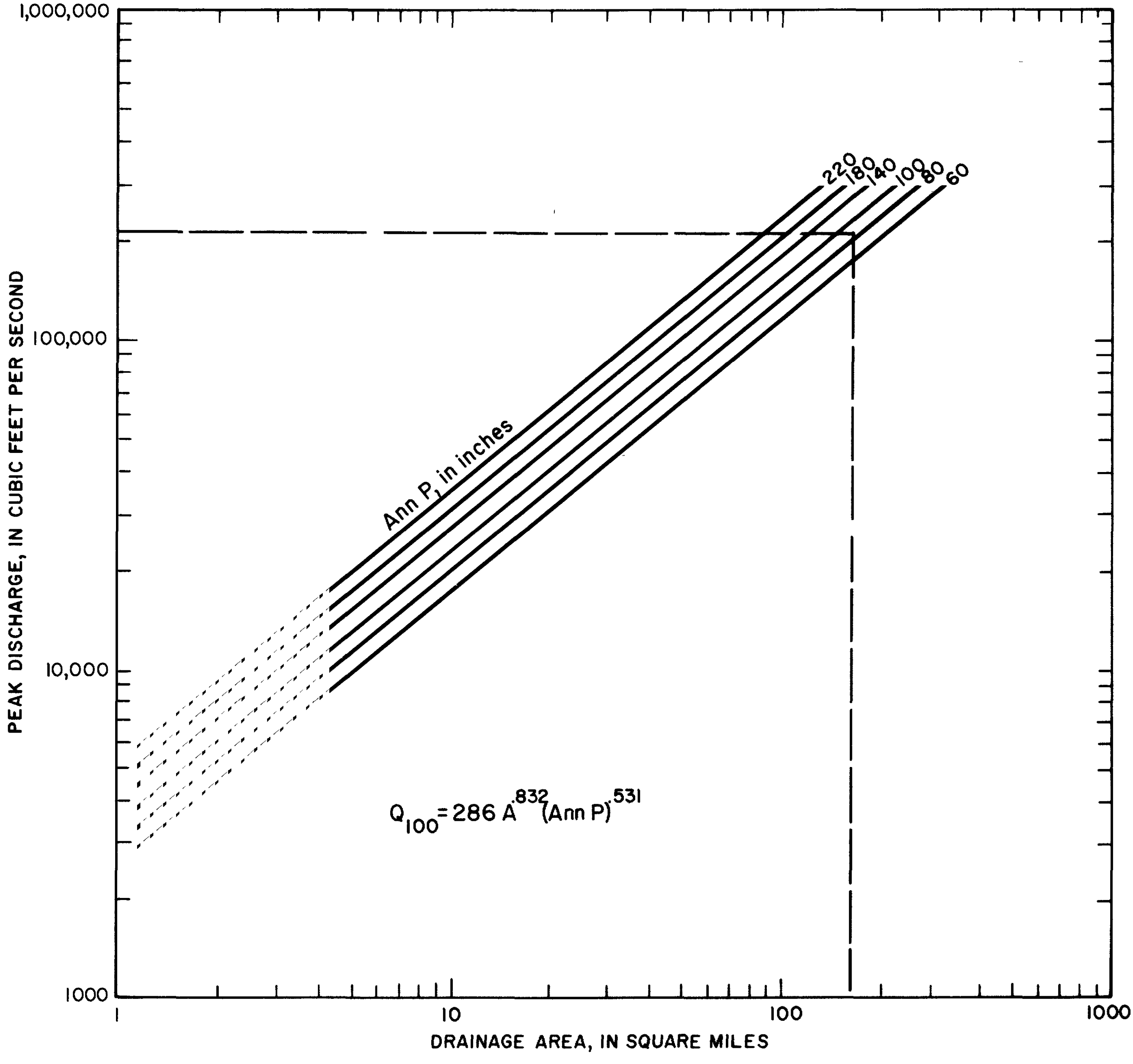

Figure 12.--Diagram for determining the 100-year flood-peak discharge at ungaged sites in Puerto Rico

The site data are based on 17 years of record and we have determined that the regional data for the 100-year flood are equivalent to 20 years of record. The estimated of the 100-year flood for this site is then computed as follows:

$$\text{Log } Q_{100} = \frac{17 \log 255{,}000 + 20 \log 210{,}000}{17 + 20} = 5.3610$$

$$Q_{100} = 230{,}000 \text{ ft}^3/\text{s } (6{,}510 \text{ m}^3/\text{s}).$$

For sites near gaged sites and on the same stream, flood-frequency data can be estimated by transferring the nearby station data to the ungaged site and weighting with the regression data for the ungaged site.

The following procedure can be used if the site has a drainage area within 50 percent of the gaged site. The station value can be transferred upstream or downstream by the equation.

$$Qu = \left(\frac{Au}{Ag}\right)^n Q_T$$

where

Qu is the transferred discharge at the ungaged site

Au is the drainage area of the ungaged site

Ag is the drainage area of the gaged site

n is the exponent for the drainage area for the appropriate T-year regional regression equation and

Q_T is the weighted T-year flood discharge at the nearby gaged site

and a weighted value can be computed by the equation

$$Q_W = \left(\frac{2\Delta A}{Ag}\right) Q_R + \left(1 - \frac{2\Delta A}{Ag}\right) Q_u$$

where

Q_W is the weighted T-year flood discharge at the ungaged site

ΔA is the difference between the drainage areas of the gaged and ungaged site

Ag is the drainage area of the gaged site

Q_R is the T-year discharge determined by regionalized data

Q_u is the transferred discharge at the ungaged site.

Table 2.--Log-Pearson Type III flood-frequency discharge at selected sites in Puerto Rico.

Station number	Length of record (years)	Area (mi^2)	Weighted mean annual precipitation (inches)	Peak discharge for indicated recurrence intervals (ft^3/s)				
				2	10	25	50	100
50 0280 00	16	18.4	91	5,400	8,920	10,700	12,100	13,400
0312	11	55.2	85	9,960	27,800	40,600	51,700	64,400
0315	6	3.68	91	4,240	15,300	24,500	33,200	43,600
0335	8	8.59	92	4,800	9,880	12,900	15,300	17,800
0350	25	134	88	15,600	64,100	107,000	150,000	203,000
0381	17	165	84	21,500	84,100	139,000	191,000	255,000
0395	16	70.5	80	6,600	19,200	28,300	36,500	45,800
0430	16	63.0	86	13,200	52,200	86,100	119,000	159,000
0457	10	8.4	85	2,170	6,680	10,100	13,200	16,700
0460	16	208	82	13,500	58,300	101,000	145,000	202,000
0478 50	6	41.8	87	7,040	29,900	50,700	71,300	97,000
0480	12	71.9	85	12,500	53,400	88,000	120,000	159,000
0550	16	89.8	91	20,000	58,500	84,000	106,000	131,000 (a)
0570	16	60.2	88	11,800	62,000	114,000	168,000	240,000
0590	13	207	87	51,000	170,000	215,000	262,000	300,000 (a)
0613	7	14.4	97	4,110	19,500	34,500	49,900	69,500
0617	7	2.80	151	1,450	2,670	3,340	3,860	4,390

(a) From graphical analysis.

Table 2.--Log-Pearson Type III flood-frequency discharge at selected sites in Puerto Rico--Continued.

Station number	Length of record (years)	Area (mi^2)	Weighted mean annual precipitation (inches)	Peak discharge for indicated recurrence intervals (ft^3/s) 2	10	25	50	100
50 0618 00	9	9.84	121	3,580	18,400	33,500	49,300	69,800
0625	11	2.75	122	2,440	3,790	4,460	4,950	5,430
0633	15	2.23	192	4,830	8,510	10,500	12,000	13,500
0638	10	8.62	155	6,330	12,700	16,400	19,300	22,400
0642	9	7.31	160	7,430	19,400	27,500	34,500	42,200
0655	7	6.88	154	6,010	22,100	35,500	48,200	63,600
0657	10	11.8	140	11,700	32,800	47,900	61,200	76,200
0710	16	14.9	118	6,430	18,900	28,000	36,100	45,400
0750	17	1.26	204	1,390	2,120	2,480	2,740	2,990
0820	11	17.3	121	6,460	21,100	32,500	42,900	55,200
0920	10	18.3	98	5,860	17,000	25,100	32,300	40,500
0930 50	15	25.6	97	5,030	21,900	37,500	53,100	72,600
0952	10	8.22	75	881	5,730	11,400	17,700	26,300
0955	10	12.3	70	579	5,340	12,000	20,400	32,700
1007	9	22.2	86	5,970	11,500	14,700	17,200	19,800
1065	8	46.0	81	5,410	19,900	32,000	43,500	57,300
1080	11	12.9	74	3,130	8,260	11,800	14,800	18,200

Table 2.--Log-Pearson Type III flood-frequency discharge at selected sites in Puerto Rico--Continued.

Station number	Length of record (years)	Area (mi^2)	Weighted mean annual precipitation (inches)	Peak discharge for indicated recurrence intervals (ft^3/s)				
				2	10	25	50	100
50 1113 00	28	43.5	87	9,570	29,100	44,800	59,600	77,400
1125	12	9.70	93	2,950	7,250	10,100	12,400	15,100
1140	12	17.8	98	3,840	10,100	14,400	18,000	22,200
1144	12	25.6	87	5,630	12,000	16,000	21,200	26,400
1150	12	8.82	96	2,900	8,810	13,200	17,200	21,800
1159	18	18.6	84	2,720	8,580	13,400	18,000	23,500
1210	16	24.2	89	5,820	17,300	25,700	33,300	42,000
1245	14	20.8	79	3,110	10,600	17,700	25,100	34,700
1259 50	17	3.40	93	3,210	7,300	9,860	12,000	14,300
1338	5	4.42	98	3,130	5,170	6,210	6,990	7,780
1360	10	17.6	108	6,720	15,900	21,900	26,800	32,200
1410	25	15.4	89	5,770	11,900	15,500	18,300	21,400
1416	7	10.1	84	3,340	9,310	13,600	17,300	21,500
1427	10	14.4	87	3,260	15,100	26,500	38,100	52,800
1440	13	134	96	12,700	35,900	52,400	67,000	83,600
1478	9	71.2	103	20,700	52,200	73,200	91,100	111,000

MAXIMUM KNOWN FLOODS

Maximum peak discharges known in Puerto Rico prior to January 1, 1976, are given in table 3. The list includes the maximum recorded peak discharge at some gaging stations used in the flood-frequency analysis, some sites where complete records for flood-frequency computations were not available, and historical flood data at sites investigated during flood-map surveys or bridge-site investigations.

Station numbers in the first column of table 3 correspond to those used to show the location of the sites in figure 1. Contributing drainage area is listed in the column following the stream name. Period of known floods indicates the calendar years for which flood data are available. Discharges shown represent unregulated flow, unless noted otherwise. The source of the peak discharge data is identified by footnoted symbols in the last column.

The maximum known peak discharges are plotted versus drainage area in figure 13 (data shown in table 3). For comparison, selected maximum known peak discharges in the United States were also plotted. An approximate upper limit curve was drawn roughly parallel to the plotted points and can be used as an estimator for the maximum floods in recent history in Puerto Rico.

ASSESSMENT OF RESULTS

Adequacy of Flood Frequency Curves

Considerable uncertainty in the definition of individual station flood-frequency curves exists because of the relatively short records available for analysis. The average length of annual peak record used in the final regression equations was 14.3 years.

Adequacy of Basin Characteristics Used

Of all the basin characteristics used, only drainage area and mean annual precipitation proved to be significant in the final equations. An attempt was made to substitute the 24-hour 2-year recurrence interval and the 24-hour 25-year recurrence interval rainfall for the mean annual rainfall in the regression. One of the two proved to be significant when tested at the 95 percent confidence level, but in all cases the standard error of estimate was higher than when using mean annual precipitation.

The mean annual precipitation based on the U.S. Weather Bureau records from 1931 to 1960 should be fairly accurate. A more recent attempt to relate the variation of mean annual precipitation with elevation was made by Black and Veatch (1971) and seems to show the same pattern, but with more localized detail. Possibly the mean annual rainfall map may be modified upon further study.

Table 3.--Maximum known floods in Puerto Rico prior to January 1, 1976.

Station number	Station name	Latitude	Longitude	Drainage area (mi^2)
50 0070 00	Quebrada de los Cedros near Isabela	18°30'46"	67°05'47"	6.9
0271	Río Grande de Arecibo at Dos Bocas Dam	18°20'16"	66°40'05"	169
0350	Río Grande de Manatí at Ciales	18°19'26"	66°27'36"	134
0410	Río de la Plata near Cayey	18°08'24"	66°09'49"	42.2
0440	Río de la Plata at Comerío Dam	18°15'49"	66°12'24"	140
0457	Río Lajas at Toa Alta	18°23'28"	66°15'28"	8.4
0460	Río de la Plata at Toa Alta	18°23'50"	66°15'17"	208
0480	Río de Bayamón at Bayamón	18°23'53"	66°08'25"	71.9
0530	Río Turabo at Hwy 765 near La Plaza	18°09'27"	66°02'24"	6.82
0540	Quebrada de las Quebradillas near Caguas	18°11'36"	66°03'48"	6.25
0550	Río Grande de Loíza at Caguas	18°14'35"	66°00'35"	89.8
0560	Río Valenciano near Las Piedras	18°10'37"	65°54'21"	6.85
0570	Río Gurabo at Gurabo	18°15'30"	65°58'05"	60.2
0590	Río Grande de Loíza at Lago Loíza	18°19'49"	66°01'00"	207
0610	Río Grande de Loíza at Carolina	18°22'39"	65°57'08"	243
0647	Quebrada Boneta at Río Grande	18°22'42"	65°49'48"	.77

Table 3.--Maximum known floods in Puerto Rico prior to January 1, 1976--Continued

Station number	Period of known floods	Maximum known flood Date	Discharge (ft^3/s)	Source of data (1)
50 0070 00	1969-75	05-07-70	7,480	WRD
0271	1899, 1928, 1940, 1954	08-08-99	242,000	Quiñones
0350	1948-53, 1956-75	10-09-70	125,000	WRD
0410	1960-75	09-06-60	51,000	Cir. 451
0441	1914-75	09-14-28	116,000	Quiñones
		09-06-60	101,000	Cir. 451
0457	1966-75	04-20-73	14,000	WRD
0460	1899, 1928, 1943, 1960-75	1899	157,000	WRD
		09-13-28	120,000	WRD
		09-06-60	95,500	WRD
0480	1945, 1959-70	08-04-45	72,000	HA-77
0530	1960	09-06-60	24,000	Cir. 451
0540	1960-75	09-06-60	8,150	Cir. 451
0550	1945, 1960-75	08-04-45	85,000	HA-438
		09-06-60	71,500	Cir. 451
0560	1960-75	09-06-60	28,800	Cir. 451
0570	1960-75	09-06-60	74,600	WRD
0590	1958-70	09-06-60	182,000	Cir. 451
0610	1958-75	09-06-60	197,000	Cir. 451
0647	1965, 1967-75	01-13-65	2,270	WRD

Table 3.--Maximum known floods in Puerto Rico prior to January 1, 1976--Continued

Station number	Station name	Latitude	Longitude	Drainage area (mi^2)
50 0810 00	Río Humacao at Las Piedras	18°10'27"	65°52'11"	6.65
0818	Río Humacao at Hwy 30 at Humacao	18°09'45"	65°50'23"	10.0
0916 90	Río de Apeadero at Patillas	17°59'45"	66°00'30"	4.62
1113	Río Jacaguas at Lago Guayabal	18°05'16"	66°30'08"	43.5
1144	Río Bucaná near Ponce	18°02'18"	66°35'12"	25.6
1159	Río Portugués at Hwy 14 at Ponce	18°01'09"	66°36'26"	18.6
1245	Río Guayanilla at Guayanilla	18°02'01"	66°47'57"	20.8
1280	Río Yauco near Yauco	17°59'19"	66°49'55"	45.5
1360	Río Rosario at Rosario	18°10'24"	67°04'27"	17.6
1380	Río Guanajibo near Hormigueros	18°08'29"	67°08'46"	120
1390	Río Yaguez at Mayaguez	18°12'27"	67°08'27"	13.2
1440	Río Grande de Añasco near San Sebastián	18°17'00"	67°03'02"	134
1478	Río Culebrinas at Hwy 404 near Moca	18°21'42"	67°05'33"	71.2

(1) Source of data: WRD Water Resources Data for Puerto Rico, Part 1. Surface Water Records published by U.S. Geological Survey

Quiñones High intensity rainfall and major floods in Puerto Rico. Published in 1952.

Cir. 451 U.S. Geological Survey Circular 451, Floods of Sept. 6, 1960, in eastern Puerto Rico.

Table 3.--Maximum known floods in Puerto Rico prior to January 1, 1976--Continued

Station number	Period of known floods	Maximum known flood Date	Discharge (ft^3/s)	Source of data (1)
50 0810 00	1960-75	09-06-60	20,800	Cir. 451
0818	1960-75	09-06-60	27,600	Cir. 451
0916 90	1970	10-07-70	14,000	Bull. 12
1113	1940	05-19-40	78,000	Quiñones
1144	1899, 1954, 1958, 1961-72	08-08-99	47,000	HA-261
1159	1899, 1954, 1958-75	08-08-99	35,000	HA-261
1245	1899, 1961-72, 1974-75	08-08-99	39,000	HA-414
1280	1899-1975	08-08-99	42,000	HA-414
1360	1960-68, 1975	09-16-75	33,600	WRD
1380	1945, 1952, 1954, 1975	09-16-75	128,000	WRD
1390	1933-75	03-03-33	25,000	HA-128
1440	1963-75	09-16-75	140,000	WRD
1478	1967-75	09-16-75	69,000	WRD

(1) Source of data--Continued:

Bull. 12 Water-resources Bulletin 12, flood of Oct. 5-10, 1970 in Puerto Rico.

HA- Hydrologic Investigations Atlas series published by the U.S. Geological Survey. See table 1.

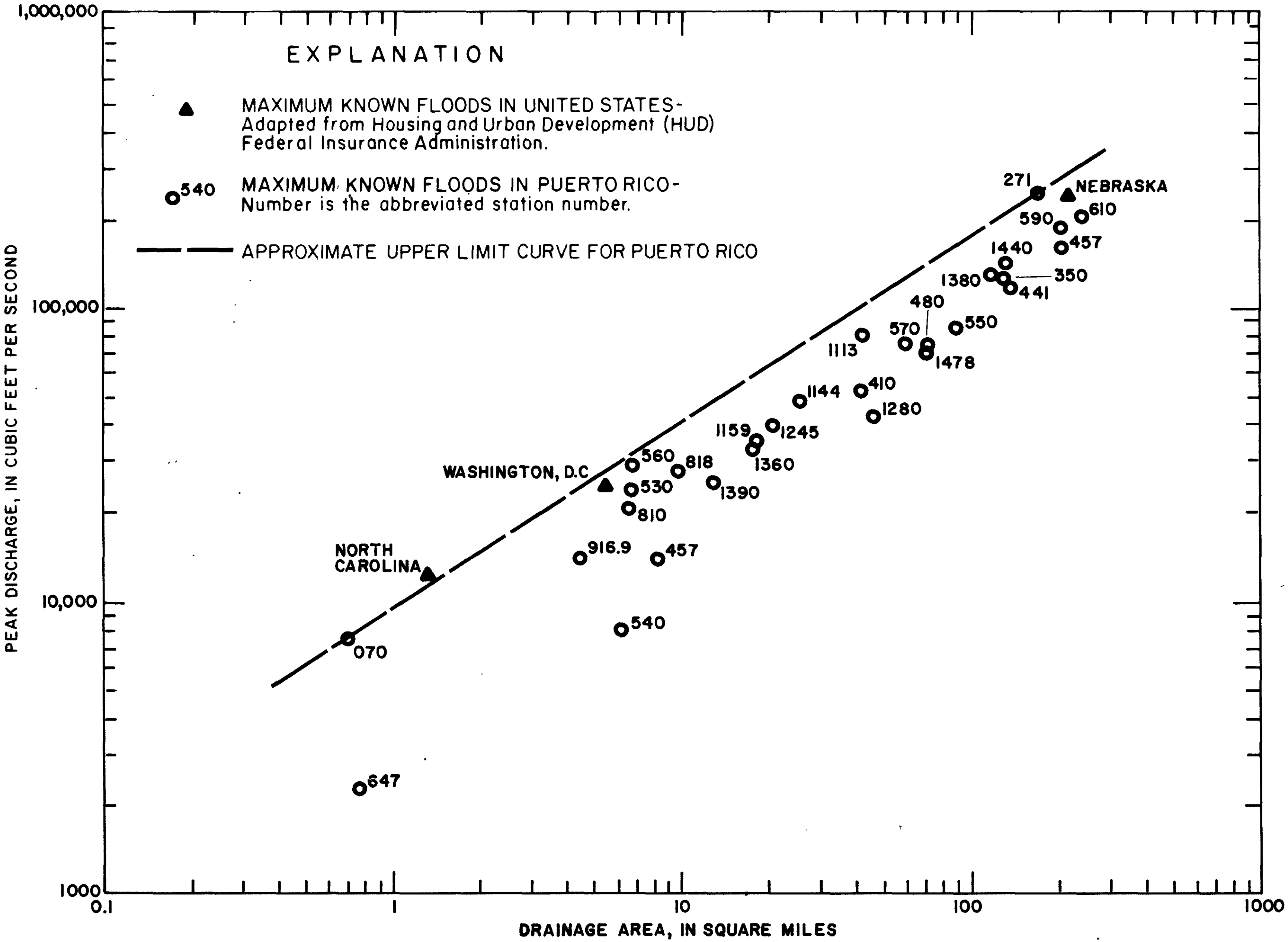

Figure 13.--Maximum known floods in Puerto Rico prior to January 1, 1976.

Other basin characteristics which would logically influence peak discharge rates did not prove statistically significant. Range in permeability was from 0.68 to 0.99 in/hr (17.3 to 25.1 mm/hr) with the most common rates between 0.80 and 0.85 in/hr (20.3 and 21.6 mm/hr). Average ground slope ranged between 29 and 50 percent with most values between 40 and 50. Accuracy of average permeability and average ground slope varies throughout the island, depending on the method used by the U.S. Soil Conservation Service in mapping different areas.

Recommendations for Future Investigations

It is recommended that collection of annual flood peak data be continued especially at those sites where 10 or more years of record exist. Only after 20 or 30 stations have 25 years or more of annual peak record will the identification of regional flood-frequency characteristics be adequately defined.

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SUPPLEMENTARY DATA

Table of annual maximum discharge records at gaging stations.

Annual peak discharge data used in flood-frequency regionalization

Station number	Station name	Latitude	Longitude	Drainage area (mi^2)	Period of record	Annual maximum Date	Gage height (ft)	Discharge (ft^3/s)
50 0271 00	Río Grande de Arecibo at Dos Bocas Dam	18°20'16"	66°40'05"	169	1899,	08-08-99	--	242,000
					1928,	09-13-28	--	103,500
					1940,	05-19-40	--	90,000
					1954	10-13-54	--	76,000
0280	Río Tanamá near Utuado	18°18'02"	66°46'58"	18.4	1960-75	09-29-60	10.12	5,420
						09-16-61	11.95	7,340
						11-07-62	8.33	3,760
						05-17-63	13.29	8,950
						04-05-64	5.62	1,930
						05-13-65	8.70	4,060
						09-17-66	9.40	4,700
						11-20-67	8.75	4,100
						11-27-68	11.55	6,860
						04-21-69	9.92	5,220
						05-09-70	10.24	5,540
						10-26-71	12.45	7,940
						03-25-72	8.89	4,210
						11-13-73	11.37	6,670
						10-23-74	11.53	6,840
						09-16-75	12.99	8,590
0312	Río Grande de Manatí near Morovis	18°17'45"	66°24'47"	55.2	1965-75	12-09-65	18.3	30,000
						04-20-66	5.0	3,650
						10-24-67	5.68	4,670
						11-26-68	7.50	7,300
						11-09-69	17.3	28,000
						10-09-70	20.3	35,000
						04-17-71	6.22	5,180
						03-30-72	7.50	7,300
						04-20-73	6.92	6,270
						10-23-74	10.88	13,800
						09-16-75	7.90	8,020

Annual peak discharge data used in flood-frequency regionalization--Continued

Station number	Station name	Latitude	Longitude	Drainage area (mi^2)	Period of record	Annual maximum Date	Gage height (ft)	Discharge (ft^3/s)
50 0315 00	Río Sana Muerto near Orocovis	18°16'14"	66°24'47"	3.68	1965-70	12-09-65	13.0	9,000
						04-20-66	10.60	5,620
						10-26-67	4.60	750
						11-02-68	7.15	2,200
						11-09-69	13.0	9,000
						05-08-70	12.2	7,780
0335	Río Bauta near Divisoria	18°11'45"	66°26'30"	8.59	1949-54, 1959, 1960	09-22-49	7.20	3,800
						08-27-50	7.60	4,200
						10-30-51	8.80	5,600
Record collected by P.R. Water Resources Authority.						05-05-52	11.22	8,500
						09-15-53	5.20	2,030
						10-12-54	14.00	12,500
						11-18-59	6.70	3,300
						02-09-60	7.80	4,400
0350	Río Grande de Manatí at Ciales	18°19'26"	66°27'36"	134	1948-53, 1956-73, 1975	11-06-48	4.10	3,000
						09-22-49	5.90	7,250
						02-04-50	5.75	6,880
Record of 1948-59 collected by P.R. Water Resources Authority. Drainage area includes 6.0 mi^2 (15.5 km^2) above Matrullas and El Guineo reservoirs; usable storage 4,200 acre-ft (5.18 hm^3).						09-30-51	5.25	5,620
						05-09-52	6.80	9,900
						06-06-53	3.98	2,760
						08-12-56	10.3	22,400
						11-03-57	4.55	3,900
						01-10-58	3.45	6,120
						05-03-59	15.00	48,200
						09-06-60	19.0	77,300
						08-27-61	--	(e) 46,000
						05-20-62	8.50	14,600
						05-17-63	11.30	27,500

Annual peak discharge data used in flood-frequency regionalization--Continued

Station number	Station name	Latitude	Longitude	Drainage area (mi^2)	Period of record	Annual maximum		
						Date	Gage height (ft)	Discharge (ft^3/s)
50 0350 00	Río Grande de Manatí at Ciales--Continued					10-15-64	5.37	5,580
						12-09-65	14.01	42,100
						04-20-66	12.48	33,400
						10-24-67	5.74	5,900
						11-26-68	9.98	21,000
						11-09-69	16.22	56,500
						10-09-70	24.0	125,000
						10-15-71	11.32	8,360
						03-30-72	14.08	19,900
						04-20-73	11.81	10,200
						09-16-75	18.39	72,100
0381	Río Grande de Manatí at Hwy 2 near Manatí	18°25'52"	66°31'37"	171	1959-75	05-03-59	32.3	76,000
						09-06-60	31.9	62,000
						08-27-61	31.6	53,000
						05-20-62	28.95	15,800
Drainage area includes 6.0 mi^2 (15.5 km^2) above Matrullas and El Guineo reservoirs; usable storage, 4,200 acre-ft (5.18 hm^3).						05-17-63	27.77	11,300
						1964	<25.62	(e) 5,000
						12-11-65	32.17	70,800
						04-20-66	29.42	18,200
						1967	<25.62	(e) 6,000
						11-28-68	29.2	17,000
						11-09-69	32.4	80,000
						10-09-70	33.30	119,000
						01-22-71	25.55	6,320
						03-30-72	25.74	6,610
						04-21-73	26.05	7,100
						10-23-74	29.92	23,200
						09-16-75	29.99	24,000

Annual peak discharge data used in flood-frequency regionalization--Continued

Station number	Station name	Latitude	Longitude	Drainage area (mi^2)	Period of record	Annual maximum: Date	Annual maximum: Gage height (ft)	Annual maximum: Discharge (ft^3/s)
50 0395 00	Río Cibuco at Vega Baja	18°26'53"	66°22'29"	70.5	1959-74	05-04-59	24.28	6,800
						09-06-60	23.82	4,600
						12-06-61	24.67	9,100
						10-18-62	<22.66	(e) 2,500
						05-23-63	24.25	6,000
						1964	<22.66	(e) 2,600
						12-11-65	26.21	28,000
						04-20-66	25.68	19,000
						10-28-67	20.59	2,160
						12-03-68	24.78	9,700
						11-09-69	--	(e) 15,000
						11-09-70	26.1	25,000
						02-20-71	--	(e) 3,500
						10-25-72	--	(e) 3,000
						04-20-73	17.78	6,740
						10-24-74	17.25	3,900
0430	Río de la Plata at Proyecto La Plata	18°09'37"	66°13'44"	63.0	1960-75	09-06-60	30.5	54,500
	Drainage area includes 8.2 mi^2 (21.2 km^2) above Caribe reservoir; usable storage, 9,800 acre-ft (12.1 hm^3).					08-27-61	32.2	59,600
						08-22-62	14.69	12,400
						05-19-63	12.00	6,250
						07-12-64	10.77	2,680
						08-10-65	20.9	27,000
						05-28-66	13.48	8,960
						10-29-67	8.93	1,150
						11-27-68	11.67	6,190
						11-22-69	15.78	14,700
						10-09-70	28.32	48,000
						04-19-71	14.57	12,100
						10-07-72	14.17	11,300

Annual peak discharge data used in flood-frequency regionalization--Continued

Station number	Station name	Latitude	Longitude	Drainage area (mi^2)	Period of record	Annual maximum: Date	Annual maximum: Gage height (ft)	Annual maximum: Discharge (ft^3/s)
50 0430 00	Río de la Plata at Proyecto La Plata--Continued					08-15-73	15.25	13,600
						10-23-74	22.30	30,800
						09-15-75	17.73	19,200
0457	Río Lajas at Toa Alta	18°23'28"	66°15'28"	8.4	1966-75	12-23-66	6.47	1,620
						10-28-67	6.61	1,710
						06-26-68	6.63	1,720
						11-22-69	8.45	3,060
						10-09-70	11.2	5,780
						02-20-71	4.36	638
						12-08-72	5.56	1,130
						04-20-73	17.8	14,000
						10-23-74	7.20	2,060
						09-26-75	5.88	1,300
0460	Río de la Plata at Toa Alta	18°23'50"	66°15'17"	208	1899, 1928, 1943, 1960-75	1899	--	157,000
						09-13-28	37.4	120,000
						06-16-43	34.4	82,000
Drainage area includes 8.2 mi^2 (21.2 km^2) above Carite reservoir; usable storage, 9,800 acre-ft (12.1 hm^3). Peak of 1899 is the highest peak in the 77-year period, 1899-1975. Peaks of 1928 and 1960 are, respectively, the highest and second highest in the 48-year period, 1928-75.						09-06-60	36.35	95,500
						08-27-61	33.08	53,700
						05-02-62	22.45	12,100
						05-18-63	19.97	8,140
						08-28-64	23.20	13,400
						08-10-65	24.56	16,100
						04-20-66	22.05	11,500
						10-28-67	10.33	1,390
						11-27-68	20.01	8,190
						11-09-69	30.8	38,000
						10-09-70	34.0	62,000
						04-19-71	16.48	4,790
						03-30-72	15.84	4,340

Annual peak discharge data used in flood-frequency regionalization--Continued

Station number	Station name	Latitude	Longitude	Drainage area (mi^2)	Period of record	Annual maximum Date	Gage height (ft)	Discharge (ft^3/s)
50 0460 00	Río de la Plata at Toa Alta--Continued					04-23-73	15.63	4,190
						10-23-74	25.21	17,500
						09-16-75	25.73	18,800
0478 50	Río de Bayamón near Bayamón	18°20'08"	66°08'13"	41.8	1965-70	12-10-65	13.10	11,400
						05-27-66	11.56	7,920
						08-06-67	6.07	1,090
						07-23-68	8.90	3,640
						11-09-69	13.36	12,100
						10-09-70	20.2	28,000
0480	Río de Bayamón at Hwy 2 at Bayamón	18°23'53"	66°08'25"	71.9	1945, 1959-70	08-04-45	39.2	72,000
						05-03-59	37.4	27,000
						09-06-60	37.7	29,000
						08-27-61	38.11	35,000
Drainage area includes 8.6 mi^2 (22.3 km^2) above Cidra reservoir; usable storage, 5,220 acre-ft (6.44 hm^3). Peaks of 1945 and 1970 are, respectively, the highest and second highest in the 26-year period, 1945-70.						06-12-62	30.7	3,860
						05-18-63	30.55	3,680
						07-01-64	32.19	6,010
						12-10-65	34.33	11,000
						10-14-66	34.80	13,300
						08-06-67	--	(e) 1,000
						08-03-68	32.83	7,300
						11-09-69	--	(e) 12,000
						10-09-70	35.27	58,000

Annual peak discharge data used in flood-frequency regionalization--Continued

Station number	Station name	Latitude	Longitude	Drainage area (mi^2)	Period of record	Annual maximum Date	Annual maximum Gage height (ft)	Annual maximum Discharge (ft^3/s)
50 0550 00	Río Grande	18°14'35"	66°00'35"	89.8	1945,	08-04-45	33.2	85,000
	de Loíza				1960-75	09-06-60	31.17	71,500
	at Caguas					08-21-61	26.07	48,300
Peaks of 1945, 1960,						07-13-62	18.66	20,500
and 1970 are respectively						09-27-63	13.35	6,900
the first, second, and						07-13-64	18.54	20,100
third highest in the						08-10-65	22.58	34,700
31-year period, 1945-75.						05-27-66	13.41	7,600
						06-20-67	9.42	1,720
						11-27-68	11.70	4,600
						11-22-69	19.64	23,700
						10-09-70	29.3	62,800
						08-24-71	18.51	20,000
						10-21-72	14.86	10,500
						08-15-73	18.58	20,000
						10-23-74	20.02	25,100
						09-16-75	18.3	19,400
0570	Río Gurabo at	18°15'30"	65°58'05"	60.2	1960-75	09-06-60	27.7	74,600
	Gurabo					08-27-61	16.59	12,200
Peaks of 1960 and 1970						06-12-62	10.64	3,290
are, respectively, the						05-26-63	7.77	1,620
first and third highest						10-11-64	14.32	7,880
in the 31-year period,						08-10-65	20.69	25,300
1945-75.						10-17-66	12.41	5,350
						11-10-67	8.25	1,920
						08-02-68	11.45	4,450
						05-21-69	23.48	41,600
						10-09-70	26.64	64,100
						08-24-71	16.53	12,100

Annual peak discharge data used in flood-frequency regionalization--Continued

Station number	Station name	Latitude	Longitude	Drainage area (mi^2)	Period of record	Annual maximum Date	Annual maximum Gage height (ft)	Annual maximum Discharge (ft^3/s)
50 0570 00	Río Gurabo at Gurabo--Continued					11-11-72	8.37	2,000
						08-15-73	22.60	34,800
						11-12-74	16.75	12,700
						09-16-75	23.85	42,100
0590	Río Grande de Loíza at Lago Loíza	18°19'49"	66°01'00"	207	1958-70	07-21-58	--	85,600
Record collected by P.R. Aqueduct and Sewer Authority. Peak flow computed by U.S.G.S. The peaks of 1960 and 1970 are, respectively, the second and third highest in the 26-year period, 1945-70.						05-03-59	--	59,500
						09-06-60	--	182,000
						08-27-61	--	98,000
						05-02-62	--	51,800
						09-27-63	--	7,900
						09-23-64	--	23,600
						08-10-65	--	79,000
						10-17-66	--	30,600
						1967	--	(e) 2,000
						06-17-68	--	15,800
						10-07-69	--	62,000
						10-09-70	--	161,000
0613	Río Canovanillas near Loíza	18°21'13"	65°55'00"	14.4	1967-73	01-09-67	2.35	340
						07-15-68	6.33	4,320
						11-09-69	8.40	8,820
						10-09-70	10.03	13,100
						02-20-71	5.77	3,460
						10-21-72	5.86	3,590
						08-15-73	8.62	9,390

Annual peak discharge data used in flood-frequency regionalization--Continued

Station number	Station name	Latitude	Longitude	Drainage area (mi^2)	Period of record	Annual maximum Date	Annual maximum Gage height (ft)	Annual maximum Discharge (ft^3/s)
50 0617 00	Río Cubuy near Campo Rico Record collected by P.R. Water Resources Authority.	18°15'49"	66°52'16"	2.80	1946-52	10-28-46	5.25	680
						11-07-47	6.78	1,460
						10-22-48	8.30	2,770
						07-09-49	6.46	1,280
						10-07-50	7.85	2,350
						01-05-51	6.05	1,040
						06-11-52	6.90	1,580
0618	Río Canóvanas near Campo Rico	18°19'08"	65°53'21"	9.84	1967-75	07-14-67	2.52	190
						07-15-68	7.24	3,440
						11-09-69	12.0	10,600
						10-09-70	12.0	10,600
						02-20-71	5.79	2,010
						10-23-72	6.34	2,540
						09-05-73	10.6	8,200
						10-24-74	7.12	3,320
						09-16-75	11.40	9,400
0625	Río Herrera near Colonia Dolores	18°21'02"	65°52'00"	2.75	1965-75	12-10-65	13.67	3,800
						11-22-66	15.21	4,210
						07-14-67	9.50	1,200
						12-13-68	13.35	2,710
						11-09-69	12.70	2,350
						12-08-70	12.78	2,390
						02-19-71	11.84	1,990
						10-21-72	11.40	1,810
						09-04-73	13.40	2,740
						10-24-74	13.53	2,840
						09-16-75	12.36	2,190

Annual peak discharge data used in flood-frequency regionalization--Continued

Station number	Station name	Latitude	Longitude	Drainage area (mi^2)	Period of record	Annual maximum Date	Annual maximum Gage height (ft)	Annual maximum Discharge (ft^3/s)
50 0633 00	Río Espíritu Santo near El Verde	18°18'51"	65°49'22"	2.23	1945-52, 1967-73	09-05-45	6.55	2,800
	Record of 1945-52 collected by P.R. Water Resources Authority.					06-18-46	7.50	3,900
						12-01-47	10.80	9,500
						09-02-48	10.90	9,600
						07-27-49	8.45	5,100
						10-07-50	8.30	4,900
						04-28-51	7.50	3,900
						03-10-52	10.15	8,000
						07-14-67	5.03	3,660
						05-25-68	4.95	3,500
						05-21-69	4.97	3,540
						11-09-70	5.74	5,720
						02-20-71	4.68	2,960
						10-29-72	4.72	3,240
						09-04-73	8.68	9,460
0638	Río Espíritu Santo near Río Grande	18°21'37"	65°48'49"	8.62	1966-75	11-22-66	11.20	6,800
						07-14-67	7.87	2,370
						12-13-68	8.63	3,130
						11-09-69	10.30	5,400
						10-09-70	12.5	9,400
						02-20-71	9.43	4,110
						10-21-72	12.88	10,200
						09-04-73	12.61	9,620
						10-23-74	12.86	10,100
						09-16-75	12.74	9,880
0642	Río Grande near El Verde	18°20'43"	65°50'30"	7.31	1967-75	07-14-67	7.42	7,290
						07-15-68	8.10	8,840
						11-09-69	9.90	13,700
						11-09-70	10.0	14,000
						02-19-71	--	(e) 9,000
						09-03-72	5.87	1,540
						09-05-73	10.27	5,590
						10-24-74	8.96	4,150
						09-16-75	15.5	17,400

Annual peak discharge data used in flood-frequency regionalization--Continued

Station number	Station name	Latitude	Longitude	Drainage area (mi^2)	Period of record	Annual maximum Date	Annual maximum Gage height (ft)	Annual maximum Discharge (ft^3/s)
50 0655 00	Río Mameyes near Sabana	18°19'46"	65°45'04"	6.88	1967-73	10-01-67	5.50	1,570
						11-27-68	6.73	2,950
						01-26-69	10.71	11,300
						10-09-70	12.57	18,000
						05-23-71	6.31	2,410
						11-11-72	8.76	6,320
						09-04-73	13.02	19,800
0657	Río Mameyes at Hwy 191 at Mameyes	18°22'03"	65°46'14"	11.8	1966-75	11-22-66	9.75	11,100
						12-10-67	4.95	2,420
						11-27-68	7.27	5,690
						01-26-69	13.5	22,200
						10-09-70	12.5	18,400
						02-20-71	7.08	5,360
						10-21-72	13.55	22,400
						08-15-73	13.95	24,000
						10-24-74	14.79	26,200
						09-16-75	12.05	10,200
0710	Río Fajardo near Fajardo	18°17'56"	65°41'42"	14.9	1960-75	09-06-60	15.9	14,500
						10-15-61	9.74	5,040
						05-02-62	13.75	10,700
						04-08-63	9.47	4,750
						10-09-64	7.60	2,830
						12-24-65	11.04	6,710
						04-20-66	9.50	4,750
						06-26-67	5.84	1,440
						11-27-68	7.48	2,710
						05-05-69	16.28	15,300
						10-09-70	17.5	10,400
						09-02-71	9.97	1,430

Annual peak discharge data used in flood-frequency regionalization--Continued

Station number	Station name	Latitude	Longitude	Drainage area (mi^2)	Period of record	Annual maximum Date	Gage height (ft)	Discharge (ft^3/s)
50 0710 00	Río Fajardo near Fajardo--Continued					10-07-72	9.77	7,720
						09-04-73	13.04	11,200
						10-24-74	13.62	19,600
						09-16-75	13.26	17,000
0750	Río Icacos near Naguabo Record collected by P.R. Water Resources Authority.	18°16'38"	65°47'09"	1.26	1945-56, 1958-62	12-29-45	4.50	780
						02-24-46	5.85	1,330
						10-25-47	8.10	2,460
						09-03-48	7.60	2,200
						03-29-49	5.60	1,220
						03-21-50	5.78	1,300
						04-28-51	5.70	1,260
						01-12-52	5.50	1,180
						10-25-53	8.10	2,460
						08-21-54	5.63	1,230
						1955	6.10	1,400
						10-10-56	4.70	840
						07-21-58	5.73	1,280
						05-01-59	7.00	1,900
						09-06-60	6.50	1,650
						1961	5.20	1,040
						1962	5.90	1,350
0820	Río Humacao at Hwy 3 at Humacao Peak of 1960 is the highest in the 60-year period, 1911-70.	18°08'49"	65°49'37"	17.3	1960-70	09-06-60	62.0	40,000
						08-27-61	55.4	17,000
						05-01-62	51.1	4,700
						1963	--	4,500
						07-12-64	50.21	3,600
						08-11-65	51.94	6,400
						09-09-66	51.5	5,500
						1967	--	2,500

Annual peak discharge data used in flood-frequency regionalization--Continued

Station number	Station name	Latitude	Longitude	Drainage area (mi²)	Period of record	Annual maximum: Date	Annual maximum: Gage height (ft)	Annual maximum: Discharge (ft³/s)
50 0820 00	Río Humacao					1968	--	1,500
	at Hwy 3 at					11-09-69	53.25	9,200
	Humacao--					10-09-70	54.91	13,000
	Continued							
0920	Río Grande	18°02'04"	66°01'58"	18.3	1966-75	05-27-66	9.74	6,380
	de Patillas					07-04-67	6.69	1,360
	near					08-07-68	7.83	2,840
	Patillas					11-09-69	9.60	6,100
						10-07-70	11.45	11,200
						08-24-71	8.56	4,050
						10-07-72	8.47	3,890
						10-11-73	14.2	23,700
						10-23-74	9.08	5,160
						09-16-75	12.45	14,800
0930	Río Grande	18°01'18"	66°01'15"	25.6	1944-46,	07-13-44	--	3,330
	de Patillas				1948-54,	09-13-45	--	3,330
	at Lago Patillas				1957-61	10-26-46	--	761
Record collected by P.R.						10-19-48	--	4,590
Water Resources Authority.						09-22-49	--	1,760
Peak flow computed by						09-22-50	--	12,400
U.S.G.S.						10-09-51	--	2,180
						09-23-52	--	7,860
						09-06-53	--	8,260
						10-13-54	--	6,100
						10-03-57	--	4,820
						07-21-58	--	27,300
						10-14-59	--	680
						09-06-60	--	25,300
						08-27-61	--	20,300

Annual peak discharge data used in flood-frequency regionalization--Continued

Station number	Station name	Latitude	Longitude	Drainage area (mi^2)	Period of record	Annual maximum Date	Annual maximum Gage height (ft)	Annual maximum Discharge (ft^3/s)
50 0952 00	Río Guamaní at Guayama	18°00'06"	66°06'48"	8.22	1961-70	08-27-61	15.4	13,300
Peaks of 1961 and 1970 are, respectively, the second and third highest in the 43-year period, 1928-70.						10-19-62	6.60	1,540
						04-16-63	4.65	172
						10-11-64	4.72	190
						08-10-65	7.29	1,500
						10-02-66	5.27	350
						1967	--	300
						1968	--	500
						03-05-69	6.44	850
						10-06-70	11.0	6,300
0955	Río Guamaní near Guayama	17°57'30"	66°08'20"	12.3	1961-70	08-27-61	11.95	20,000
Peaks of 1961 and 1970 are, respectively, the second and third highest in the 43-year period, 1928-70.						10-19-62	--	400
						04-16-63	--	100
						10-11-64	--	120
						08-10-65	6.40	1,100
						1966	--	200
						1967	--	150
						1968	--	330
						05-21-69	5.85	735
						10-06-70	11.0	5,500
1007	Río Majada at Rabo del Buey	18°02'17"	66°14'27"	22.2	1960-62, 1965-70	09-06-60	33.0	11,000
						08-27-61	32.1	10,000
						10-15-62	29.9	7,600
						06-07-65	27.4	4,700
						1966	--	3,000
						1967	--	3,000
						06-04-68	26.85	4,100
						11-09-69	20.01	6,600
						10-09-70	31.92	10,000

Annual peak discharge data used in flood-frequency regionalization--Continued

Station number	Station name	Latitude	Longitude	Drainage area (mi^2)	Period of record	Annual maximum Date	Gage height (ft)	Discharge (ft^3/s)
50 1065 00	Río Coamo near Coamo	18°03'52"	66°22'10"	46.0	1960, 1963, 1965-72	09-06-60	--	11,600
						08-28-63	--	5,700
						12-24-65	10.4	5,400
						11-21-66	12.2	8,290
						10-24-67	8.29	2,770
						11-02-68	11.64	7,340
						11-09-69	16.21	16,300
						10-09-70	21.4	22,000
						04-19-71	6.60	1,370
						09-20-72	7.0	1,650
1080	Río Descalabrado near Los Llanos	18°03'08"	66°25'34"	12.9	1965-72, 1975	11-22-65	8.3	2,500
						11-21-66	8.57	2,800
						11-23-67	7.30	1,500
						11-01-68	8.50	2,700
						05-21-69	11.50	5,650
						10-09-70	20.51	12,300
						11-02-71	7.67	1,870
						03-22-72	7.41	1,610
						1973	--	(e) 2,000
						1974	--	(e) 2,000
						09-16-75	19.7	11,900

Annual peak discharge data used in flood-frequency regionalization--Continued

Station number	Station name	Latitude	Longitude	Drainage area (mi^2)	Period of record	Annual maximum: Date	Annual maximum: Gage height (ft)	Annual maximum: Discharge (ft^3/s)
50 1113 00	Río Jacaguas	18°05'16"	66°30'08"	43.5	1940,	05-19-40	--	78,000
	at Lago				1943-70	10-14-43	--	14,300
	Guayabal					05-19-44	--	24,400
	Record collected by P.R.					05-27-45	--	10,400
	Water Resources Authority.					1946	--	5,000
	Peak flow computed by					10-24-47	--	5,740
	U.S.G.S. and Hydrographic					10-22-48	--	7,500
	Section of P.R. Water					09-21-49	--	4,130
	Resources Authority.					11-30-50	--	22,500
	Peaks of 1940 and 1970					10-27-51	--	9,780
	are, respectively, the first					08-24-52	--	16,400
	and second highest in the					11-07-53	--	15,600
	71-year period, 1900-70.					10-12-54	--	22,300
						09-12-55	--	22,000
						06-17-56	--	16,000
						11-05-57	--	1,720
						09-12-58	--	11,200
						1959	--	3,500
						04-29-60	--	19,600
						11-12-61	--	6,360
						1962	--	5,000
						05-17-63	--	12,300
						10-21-64	--	10,400
						1965	--	4,000
						10-17-66	--	4,940
						08-05-67	--	5,200
						11-03-68	--	3,000
						11-09-69	--	10,000
						10-09-70	--	57,400

Annual peak discharge data used in flood-frequency regionalization--Continued

Station number	Station name	Latitude	Longitude	Drainage area (mi^2)	Period of record	Annual maximum Date	Gage height (ft)	Discharge (ft^3/s)
50 1125 00	Río Inabón at Real Abajo	18°05'10"	66°33'46"	9.70	1964-75	06-05-64	18.53	5,760
						08-19-65	11.86	2,430
						07-20-66	11.24	2,120
						08-05-67	14.84	3,920
						09-27-68	13.25	3,150
						05-20-69	16.0	4,500
						10-09-70	26.0	8,850
						04-29-71	12.22	1,490
						04-10-72	11.60	1,280
						07-23-73	10.36	908
						11-02-74	11.43	2,500
						09-16-75	18.6	7,000
1140	Río Cerrillos near Ponce	18°04'22"	66°34'53"	17.8	1964-75	10-21-64	6.95	4,560
						06-05-65	4.75	1,300
						07-20-66	6.38	3,270
						08-05-67	6.47	3,480
						09-27-68	6.53	3,560
						10-25-69	6.60	3,700
						10-07-70	8.70	7,900
						10-16-71	5.13	1,480
						10-03-72	5.65	2,110
						07-30-73	6.57	3,640
						05-08-74	7.89	5,780
						09-16-75	11.17	22,000

Annual peak discharge data used in flood-frequency regionalization--Continued

Station number	Station name	Latitude	Longitude	Drainage area (mi^2)	Period of record	Annual maximum Date	Gage height (ft)	Discharge (ft^3/s)
50 1144 00	Río Bucaná near Ponce	18°02'18"	66°35'12"	25.6	1899,	08-08-99	--	47,000
					1954,	10-13-54	--	20,000
Peak of 1899 is the highest in the 74-year period, 1899-1972. Peaks of 1954 and 1958 are, respectively, the highest and second highest in the 19-year period, 1954-72.					1958,	05-06-58	--	12,500
					1961-72	08-27-61	--	10,200
						1962	--	3,000
						08-28-63	--	10,000
						06-05-64	--	4,200
						11-05-65	7.95	2,720
						07-20-66	10.05	4,960
						08-05-67	11.60	7,200
						09-27-68	10.00	4,900
						10-25-69	11.84	7,560
						10-09-70	14.12	12,000
						09-01-71	3.91	3,920
						10-03-72	6.8	6,900
1150	Río Portugués near Ponce	18°04'45"	66°38'03"	8.82	1964-75	10-21-64	6.90	2,050
						05-16-65	7.70	3,050
						09-19-66	6.35	1,530
						09-10-67	5.05	800
						10-09-68	5.91	1,200
						10-25-69	6.69	1,810
						10-09-70	9.86	11,000
						07-21-71	6.87	1,920
						10-03-72	7.42	2,520
						08-04-73	8.84	6,040
						11-11-74	8.54	5,120
						09-16-75	10.1	13,000

Annual peak discharge data used in flood-frequency regionalization--Continued

Station number	Station name	Latitude	Longitude	Drainage area (mi^2)	Period of record	Annual maximum Date	Gage height (ft)	Discharge (ft^3/s)
50 1159 00	Río Portugués at Hwy 14 at Ponce	18°01'09"	66°36'26"	18.6	1899, 1954, 1958-75	08-08-99	22.1	35,000
						10-13-54	18.5	17,600
						05-06-58	16.5	11,900
Peak of 1899 is the highest in the 77-year period, 1899-1975. Peaks of 1954, 1975, and 1958 are, respectively, the first, second, and third highest in the 22-year period, 1954-75.						04-19-59	--	1,600
						04-29-60	--	2,500
						08-27-61	13.2	5,800
						10-29-62	--	1,500
						08-28-63	12.9	5,400
						10-21-64	--	1,000
						05-16-65	8.60	1,660
						11-08-66	8.10	1,360
						09-10-67	6.79	716
						10-09-68	10.75	3,260
						10-25-69	11.51	3,960
						11-10-70	13.32	5,880
						07-21-71	10.37	2,940
						10-03-72	7.80	1,200
						08-14-73	8.68	1,710
						11-02-74	9.88	2,540
						09-16-75	17.38	14,500
1210	Río Tallaboa at Peñuelas	18°03'02"	66°43'19"	24.2	1959-72, 1974-75	04-19-59	6.13	4,360
						04-29-60	8.20	9,640
Peak of 1975 is the highest in the 49-year period, 1927-75.						08-27-61	8.34	10,100
						10-29-62	6.24	4,740
						08-27-63	9.50	14,600
						04-17-64	6.20	3,450
						05-16-65	6.65	4,480
						10-21-66	7.11	5,550
						09-10-67	8.25	9,320
						07-21-68	6.76	4,700

Annual peak discharge data used in flood-frequency regionalization--Continued

Station number	Station name	Latitude	Longitude	Drainage area (mi²)	Period of record	Annual maximum Date	Gage height (ft)	Discharge (ft³/s)
50 1210 00	Río Tallaboa					11-09-69	7.09	5,520
	at Peñuelas--					10-08-70	8.07	8,480
	Continued					11-02-71	4.19	900
						03-22-72	4.37	1,050
						1974	8.32	9,480
						09-16-75	11.10	23,500
1245	Río Guayanilla	18°02'01"	66°47'57"	20.8	1899,	08-08-99	--	39,000
	at Guayanilla				1928,	1928	--	23,000
Prior to 1970 at site					1932,	1932	--	28,000
1.1 mi (1.8 km) upstream,					1961-72,	09-14-61	7.99	3,240
published as 50 1240 00.					1974-75	10-30-62	5.94	1,530
Peaks of 1899, 1932, 1928,						08-03-63	10.00	5,600
and 1975 are, respectively,						10-19-64	6.90	2,210
the first through fourth						11-12-65	7.32	2,590
highest in the 77-year						11-22-66	7.14	2,400
period, 1899-1975.						11-20-67	5.35	1,120
						09-27-68	5.77	1,380
						11-09-69	6.97	2,280
						10-08-70	7.46	4,530
						09-02-71	5.50	1,800
						11-01-72	6.78	3,390
						11-02-74	8.19	5,220
						09-16-75	15.8	22,400
1259	Río Duey	18°06'45"	66°49'50"	3.40	1952-68	09-23-52	5.60	3,220
	near Lago					10-24-53	6.90	5,250
	Luchetti					10-13-54	8.60	8,700
Record collected by P.R.						09-19-55	5.10	2,620
Water Resources Authority.						04-18-56	4.25	1,820

Annual peak discharge data used in flood-frequency regionalization--Continued

Station number	Station name	Latitude	Longitude	Drainage area (mi^2)	Period of record	Annual maximum Date	Annual maximum Gage height (ft)	Annual maximum Discharge (ft^3/s)
50 1259 00	Río Duey near Lago Luchetti--Continued					1957	3.80	1,460
						05-16-58	6.02	3,730
						03-12-59	3.52	1,260
						09-06-60	5.90	3,580
						10-02-61	8.60	8,700
						06-24-62	3.25	1,080
						09-27-63	6.00	3,700
						09-05-64	3.95	1,570
						08-14-65	6.40	4,300
						10-24-66	7.67	6,740
						1967	6.22	4,030
						07-21-68	6.07	3,800
1338	Río Duey near Rosario	18°08'52"	67°03'37"	4.42	1960-64	09-05-60	6.50	2,090
Record collected by P.R. Water Resources Authority.						07-26-61	8.30	3,610
						06-12-62	6.40	2,060
						05-17-63	9.70	4,940
						10-21-64	8.55	3,890
1360	Río Rosario at Rosario	18°10'24"	67°04'27"	17.6	1960-68, 1975	10-14-60	8.88	7,800
Record of 1960-68 collected by P.R. Water Resources Authority.						12-07-61	8.50	6,500
						10-12-62	7.65	4,650
						05-13-63	8.50	6,500
						10-21-64	7.70	4,850
						05-21-65	8.95	8,000
						10-29-66	9.40	6,400
						09-10-67	6.05	2,250
						09-27-68	8.50	6,500
						09-16-75	19.6	33,600

Annual peak discharge data used in flood-frequency regionalization--Continued

Station number	Station name	Latitude	Longitude	Drainage area (mi^2)	Period of record	Annual maximum Date	Gage height (ft)	Discharge (ft^3/s)
50 1410 00	Río Yahuecas	18°12'19"	66°48'01"	15.4	1946-70	10-22-46	--	7,700
	near Adjuntas					10-29-47	--	5,050
	Record collected by P.R.					10-22-48	--	4,630
	Water Resources Authority.					07-24-49	--	2,680
						11-30-50	--	2,580
						10-26-51	--	4,550
						09-23-52	--	8,420
						10-24-53	--	5,370
						10-13-54	--	17,000
						09-29-55	--	6,000
						08-12-56	--	9,140
						09-21-57	--	10,300
						09-10-58	8.80	8,050
						07-09-59	3.66	1,220
						09-06-60	5.70	3,280
						11-16-61	7.92	8,250
						09-23-62	6.60	4,500
						09-27-63	10.70	11,700
						10-30-64	8.65	7,780
						06-28-65	8.75	7,960
						1966	8.56	7,630
						09-12-67	6.90	4,960
						11-28-68	7.40	5,730
						10-11-69	8.50	7,510
						10-10-70	6.50	3,040

Annual peak discharge data used in flood-frequency regionalization--Continued

Station number	Station name	Latitude	Longitude	Drainage area (mi²)	Period of record	Annual maximum: Date	Annual maximum: Gage height (ft)	Annual maximum: Discharge (ft³/s)
50 1416 00	Río Guayo at	18°13'23"	66°49'56"	10.1	1949-55	10-25-49	3.70	1,320
	mouth near					12-01-50	3.33	920
	Lares					08-21-51	6.52	4,240
Record collected by P.R.						09-23-52	6.50	4,200
Water Resources Authority.						06-06-53	7.82	7,850
						10-13-54	7.10	6,350
						08-01-55	6.00	4,300
1427	Río Prieto	18°11'50"	66°52'55"	14.4	1949-58	09-22-49	5.55	1,750
	near Lares					10-01-50	9.50	6,850
Record collected by P.R.						10-18-51	8.85	5,760
Water Resources Authority.						09-23-52	9.20	6,340
						06-06-53	8.92	5,880
						10-13-54	13.00	14,000
						07-31-55	7.37	3,630
						11-04-56	8.88	5,810
						11-14-57	3.28	354
						05-02-58	3.67	510
1440	Río Grande de	18°17'00"	67°03'02"	134	1963-75	09-27-63	17.03	15,500
	Añasco near					10-15-64	10.30	5,630
	San Sebastián					08-25-65	14.70	11,600
Drainage area includes						06-18-66	12.86	8,800
39.7 mi² (103 km²)						09-01-67	12.30	8,020
above Guayo, Yahueca,						11-08-68	13.66	9,990
and Prieto reservoirs;						05-17-69	16.48	14,400
usable storage,						09-24-70	11.85	7,440
17,300 acre-ft (21.3 hm³).						10-26-71	19.61	20,300
						10-21-72	17.28	16,000
						08-11-73	12.18	7,860
						09-27-74	12.35	8,090
						09-16-75	37.8	140,000

Annual peak discharge data used in flood-frequency regionalization--Continued

Station number	Station name	Latitude	Longitude	Drainage area (mi^2)	Period of record	Annual maximum		
						Date	Gage height (ft)	Discharge (ft^3/s)
50 1478 00	Río Culebrinas at Hwy 404 near Moca	18°21'42"	67°05'33"	71.2	1967-75	11-19-67	18.27	4,850
						11-27-68	28.7	30,000
						10-30-69	27.4	24,700
						05-07-70	26.05	20,300
						10-15-71	24.74	16,500
						10-21-72	29.58	33,800
						10-13-73	24.45	15,700
						05-26-74	24.61	16,100
						09-16-75	36.6	69,000

(e) Estimated value.

Floods of October 1970--Bridge over Río Jacaguas at Juana Díaz was demolished.

Cover photo.--Highway 1 at Río Coamo between flood peaks in October 1970. Bridge and culvert drop-structure was completely destroyed later in the floods.

A common scene along the southern coast of Puerto Rico during the floods of October 1970.

Factors for converting inch-pound units to International System (SI) units:

Multiply inch-pound units	by	to obtain SI units
	Length	
inches (in)	25.40	millimeters (mm)
feet (ft)	0.3048	meters (m)
miles (mi)	1.609	kilometers (km)
	Area	
square miles (mi^2)	2.590	Square kilometers (km^2)
	Volume	
acre-feet (acre-ft)	0.001233	cubic hectometer (hm^3)
	Flow	
cubic feet per second (ft^3/s)	0.02832	cubic meters per second (m^3/s)