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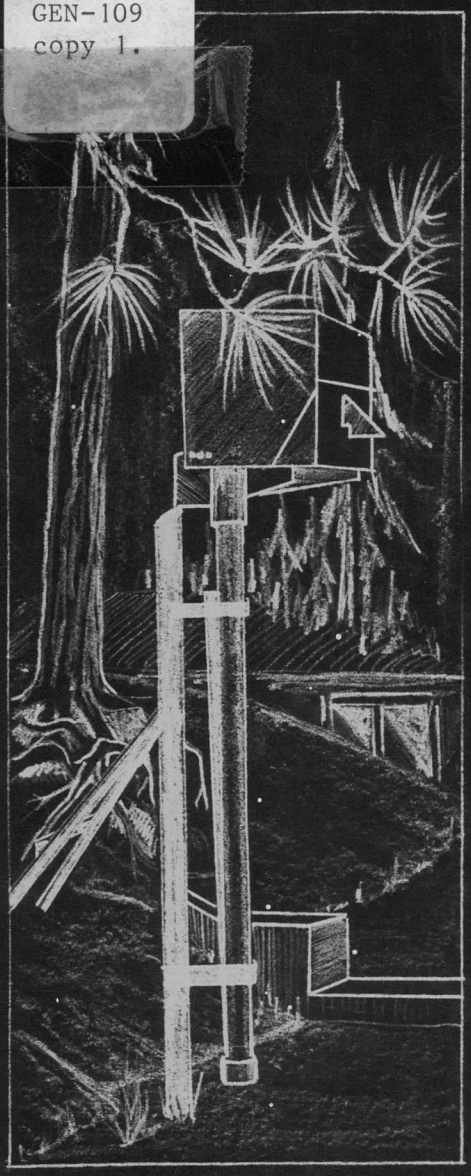
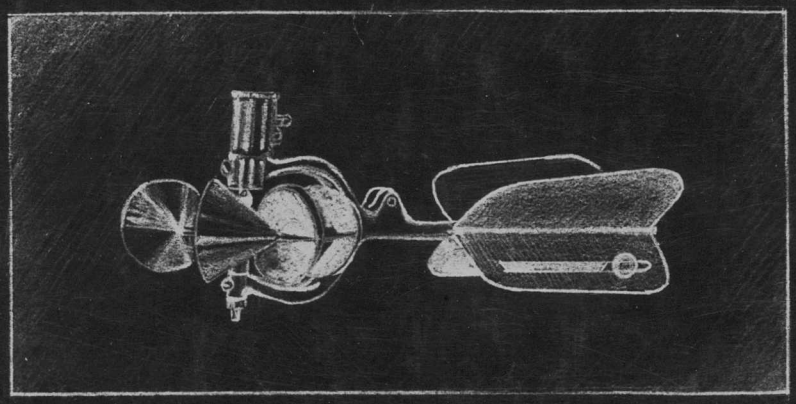
# INVESTIGATION & ANALYSIS OF FLOODS FROM SMALL DRAINAGE AREAS IN NEW MEXICO

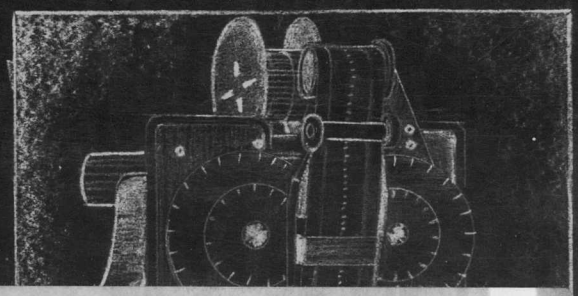
A PROGRESS REPORT

BY

a. G. Scott







UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
Albuquerque, New Mexico

*Prepared by the U. S. Geological Survey in cooperation with the New Mexico State Highway Department and the Federal Highway Administration*

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July 1974

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| inches (in) | meters (m) | 0.0254 |
| feet (ft) | meters (m) | 0.305 |
| miles (mi) | kilometers (km) | 1.61 |
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The progress of this project, through June 1972, is shown graphically and descriptively. The project is progressing satisfactorily and analyses performed to date indicate that the objectives will be met at the end of the 10-year project period.

A trial extension of the record of annual peaks for one station in New Mexico was made by utilizing a rainfall-runoff hydrograph simulation model. A comparison of frequency curves of annual peaks for recorded and simulated data indicates that results of the simulation are reasonable.

Recommendations for additional research in the following three areas are: (1) an attempt should be made to define the relation between channel characteristics and floods for streams in New Mexico: (2) an investigation of rainfall depth-duration-frequency relations and the transferability of rainfall data within the State should be made; (3) an attempt to improve the regression model of flood characteristics in New Mexico should be made.

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# INTRODUCTION

A cooperative program between the New Mexico State Highway Department and the U.S. Geological Survey to investigate the magnitude and frequency of floods in New Mexico has been in progress since July 1951. The early program was essentially concerned with the collection of flood data by the use of crest-stage gages. Flood-frequency analyses were to be made as data became available. The scope of work and methods of study were changed by a Memorandum of Understanding in August 1966 and again in April 1969. These Memorandums of Understanding, in addition to providing for the routine collection of flood data, provide for intensive study of 41 small drainage basins in New Mexico and change the proposed methods of analysis.

The program conducted by the U.S. Geological Survey is currently financed by the New Mexico State Highway Department in cooperation with the Federal Highway Administration.

The objective of the study is to obtain and analyze hydrologic data which can be used in the design of highway structures. More specifically it is to collect sufficient data and to provide an analysis that allows estimation of flood peaks having recurrence intervals of as much as 50 years at any virtually natural flow site and with an accuracy equivalent to the accuracy of the estimate from 10 years of observed flood record of the site.

This report describes the progress of the study through June 1972 and presents an evaluation of the adequacy of the data being collected and an evaluation of the proposed methods of analysis to see if the program objectives can be met. The work schedule and work completed as of June 30, 1972 are shown on figure 1.

The opinions, findings, and conclusions are those of the Geological Survey and not necessarily those of the cooperating agencies.

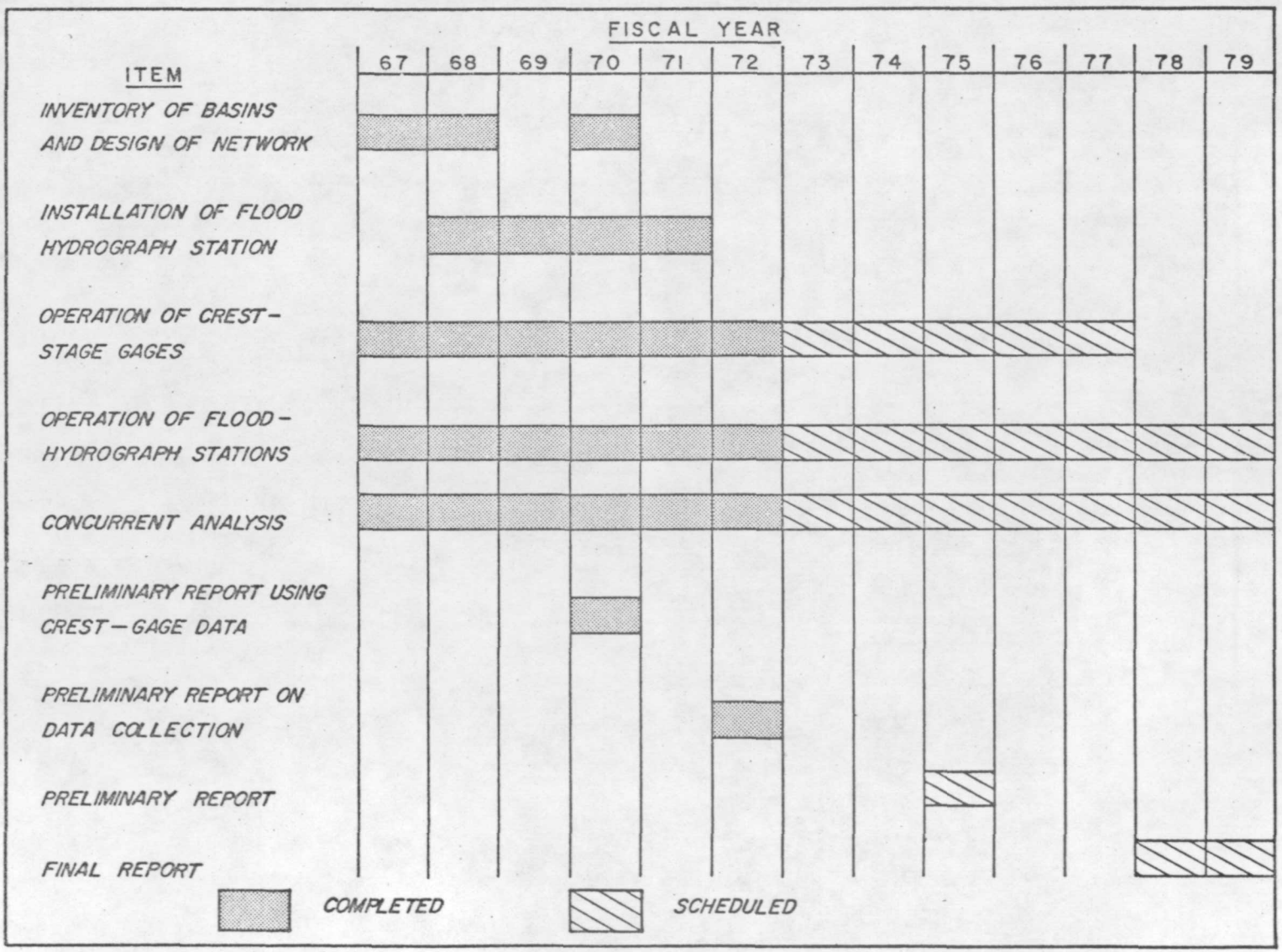


Figure 1.--Work schedule for project and work completed as of June 30, 1972.

## PROGRAM OPERATION

### Crest-stage station network

A crest-stage gage is a device which will record peak stage at a site. By use of supplementary measurements, the annual peak flow at the site may be determined. The crest-stage gage network in New Mexico was started in 1951 to supplement the network of regular streamflow gages. The network at present consists of 126 gages. The number of gages varies from year to year as some are discontinued because of destruction of the gage or control or because the length of record is adequate to define the 50-year flood at the site. At times, gages have been added to the network to extend coverage. The locations of active crest-stage gages are shown in figure 2. At present, stage-discharge relations have been developed for about 70 percent of the gages. The length of record, through the 1971 water year, ranges from 5 to 23 years. The mean length of record from the rated crest-stage gages is 16 years.

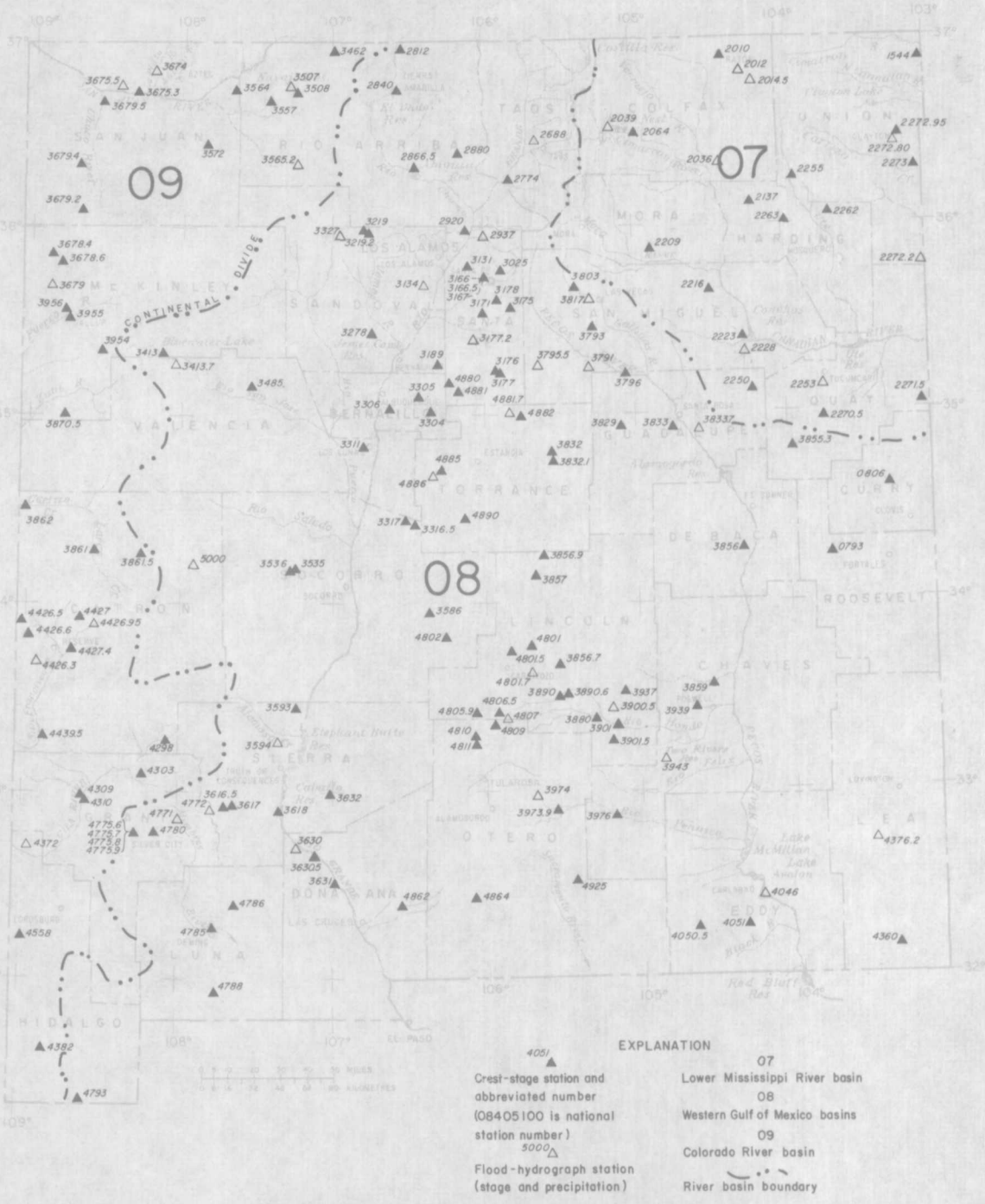


Figure 2.—Map of New Mexico showing location of crest-stage and flood-hydrograph stations.

In 1970 a flood-frequency regression analysis was made utilizing peak-flow data from crest-stage gages and regular stream gages (Scott, 1971). The standard error associated with the flood-frequency relations which were developed ranged from 72 to 164 percent. These errors may have been due, at least in part, to the use of relatively short-term streamflow records. At the end of this project, in 1979, about 9 additional years of peak-flow data from crest-stage gages will be available for analysis. The additional data should improve the relations. The record of flood peaks from crest-stage gages will supplement those collected at the 41 flood-hydrograph stations in this program and those collected at the regular stream gages in other programs.

## Flood-hydrograph station network

The purpose of the flood-hydrograph station network is to collect an adequate amount of data that may be used with a rainfall-runoff model to simulate a long record of annual peak discharges at each site after a relatively short period to operation. A flood-hydrograph station is a streamflow measuring site at whch a synchronous record of stream stage and rainfall is obtained. In addition to the rainfall recorder at the streamflow measuring site, some basins have additional storage-type rain gages, read by an observer, at other locations within the basin.

The network of flood-hydrograph stations in New Mexico was started in 1968. The number of stations in operation by water year is as follows:

| Water year | Number of flood-hydrograph stations in operation |
|---|---|
| 1968 | 11 |
| 1969 | 16 |
| 1970 | 26 |
| 1971 | 41 |

The locations of the flood-hydrograph stations in New Mexico are shown in figure 2.

A mathematical model, the "rainfall-runoff hydrograph simulation model" (Dawdy and others, 1972), has been developed by the Geological Survey. The model is calibrated to respond to rainfall for a particular drainage basin by using the synchronous record of rainfall and runoff recorded in the basin. Once the model is calibrated, a long-term record of rainfall can be used to simulate a long-term record of annual peaks. The basic data required for the model are as follows:

1. A synchronous record of stream discharge and associated rainfall -- to be obtained from the flood-hydrograph stations.
2. A long-term record of daily rainfall values from a nearby station -- to be obtained from National Weather Service records.
3. Five-minute incremental values of rainfall for selected major storms each year for the period of the long-term record -- to be obtained from National Weather Service records.
4. A nearby record of daily evaporation -- to be taken from National Weather Service records.

To calibrate the model accurately the record of flow events and associated rainfall must cover a wide range of antecedent conditions and a wide range of peak discharges. The exact number of flows required cannot be predicted but it appears to be at least 10. Once a long record of simulated annual peak discharges is obtained at a site, the discharge for floods of a given probability can be computed. These data may then be extended to ungaged sites by a process known as regionalization. At present, the recommended method of regionalization is to relate flood discharges of a given probability to topographic and climatic characteristics of the basin by regression analyses.

Because multiple-regression equations often do not represent actual physical relationships, they should not be applied outside the range of the data from which they were developed. Therefore, the flood-hydrograph station network in New Mexico was designed to sample as wide a range of basin characteristics as possible with given number of stations. It was also necessary to locate the stations so as to achieve good areal distribution. Areal distribution of the stations was important to identify areas within which streams respond similarly.

Table 1 lists the flood-hydrograph stations in New Mexico and selected basin characteristics. The basin characteristics were determined as follows:

Drainage area, in square miles, determined by use of a planimeter from the best available topographic maps.

Basin length, in miles, is the length of the main channel between the gage and the basin divide measured along the channel which drains the largest area. The length was determined by using a wheel-type map-measure on the best available topographic maps.

Basin shape index, dimensionless ratio, is equal to the basin length squared divided by the drainage area.

Channel slope, in feet per mile, is the average slope between points 10 and 85 percent of the distance from the gage to the basin divide. The main-channel slope was computed from the best available maps as the difference in altitude of the 10 and 85 percent points, in feet, divided by the distance, in miles, between the two points.

Basin altitude, in feet above mean sea level, is the average of the altitudes at points 10 percent and 85 percent of the distance along the main channel from the station to the basin divide, determined from the best available maps.

Table 1.--Selected basin characteristics of flood-hydrograph stations in New Mexico

| Station no. | Station name | Drainage area (A) (sq. mi.) | Basin length (L) (miles) | Basin shape index ($L^2/A$) | Channel slope (feet per mile) | Basin altitude (feet above msl) |
|---|---|---|---|---|---|---|
| 07201200 | Chicorica Creek tributary near Raton | a 4.8 | a3.9 | a 3.1 | a 320 | a 6,960 |
| 07201400 | Una del Gato Creek tributary near Raton | a18.0 | b | b | b | b |
| 07203600 | Rio del Plano tributary near Taylor Springs | 6.71 | 4.57 | 3.11 | 66 | 6,276 |
| 07203900 | Graney Creek near Eagle Nest | 1.83 | 2.64 | 3.81 | 854 | 9,670 |
| 07222800 | Garita Creek tributary near Variadero | a11.5 | b | b | b | b |
| 07225300 | Bluewater Creek near Tucumcari | 15.2 | 8.3 | 4.52 | 44 | 4,242 |
| 07227220 | Cramer Creek tributary near Nara Visa | a14.4 | b | b | b | b |
| 07227280 | Sand Draw tributary near Clayton | 1.81 | 4.00 | 8.84 | 45 | 5,338 |
| 08268800 | Rio Grande tributary near Arroyo Hondo | 1.16 | 3,80 | 12.4 | 49 | 6,920 |
| 08293700 | Arroyo Seco tributary near Pojoaque | .72 | 1.76 | 4.30 | 95 | 5,917 |
| 08295200 | Rio En Medio near Santa Fe | .63 | 1.00 | 1.59 | 1,310 | 11,180 |
| 08313400 | Bland Canyon near Cochiti | 7.57 | 8.75 | 10.1 | 296 | 7,320 |
| 08317720 | Canada de la Cueva near Galisteo | 1.79 | 2.40 | 3.22 | 81 | 6,282 |
| 08332700 | San Pablo Canyon near Cuba | 12.8 | 9.15 | 6.56 | 243 | 7,765 |
| 08341370 | Pine Canyon near Thoreau | 6.09 | 5.9 | 5.72 | 174 | 7,470 |
| 08359400 | Lumber Canyon tributary near Monticello | .90 | 3.5 | 13.6 | 114 | 5,230 |
| 08363000 | Rio Grande tributary near Salem | .18 | .94 | 4.88 | 142 | 4,227 |
| 08379100 | Pecos River tributary near Sena | 1.24 | 4.06 | 13.3 | 267 | 6,444 |
| 08379550 | Canon Blanco near Leyba | 11.2 | 5.12 | 2.35 | 118 | 6,919 |
| 08381700 | Canon Piedra Lumbre near Las Vegas | 5.85 | 7.05 | 8.50 | 123 | 7,115 |
| 08383370 | Pecos River tributary near Puerto de Luna | .37 | 1.05 | 2.98 | 317 | 4,645 |
| 08390050 | Rio Hondo tributary at Tinnie | .23 | .80 | 2.78 | 512 | 5,286 |
| 08394300 | Twin Buttes Canyon tributary near Roswell | 5.01 | 5.3 | 5.61 | 65 | 4,340 |
| 08397400 | Hyatt Canyon near Cloudcroft | 3.08 | 2.88 | 2.69 | 359 | 8,060 |
| 08404600 | Pecos River tributary at Carlsbad | .20 | 1.01 | 5.10 | 237 | 3,235 |
| 08437620 | Monument Draw tributary near Monument | 6.23 | 4.8 | 3.70 | 32 | 3,855 |
| 08477100 | Willow Springs Canyon at Mimbres | 3.84 | 6.35 | 10.5 | 200 | 6,595 |
| 08477200 | Iron Creek near Kingston | .74 | 1.15 | 1.79 | 1,020 | 8,240 |
| 08480170 | Nogal Canyon tributary near Nogal | 1.94 | 2.80 | 4.00 | 333 | 7,080 |
| 08480700 | Indian Creek near Three Rivers | 6.80 | 5.7 | 4.78 | 724 | 7,790 |
| 08488170 | Chavez Draw tributary near Clines Corners | 2.73 | 3.9 | 5.60 | 65 | 6,675 |
| 08488600 | Arroyo del Cuervo near Torreon | 11.8 | 6.2 | 3.27 | 300 | 7,180 |
| 08500000 | Swingle Canyon near Datil | 6.35 | 5.10 | 4.10 | 180 | 7,980 |
| 09350700 | Ruben Canyon near Gobernador | 5.06 | 4.45 | 3.91 | 93 | 7,075 |
| 09356520 | Burro Canyon near Lindrith | 9.11 | 5.21 | 2.98 | 79 | 7,146 |
| 09367400 | La Plata River tributary near Farmington | 1.03 | 3.61 | 12.7 | 167 | 5,634 |
| 09367550 | Stevens Arroyo near Kirtland | 4.59 | 5.57 | 6.76 | 68 | 5,416 |
| 09367900 | Black Springs Wash near Mexican Springs | 7.05 | 7.95 | 8.96 | 96 | 6,615 |
| 09437200 | Mexican Canyon at Virden | 3.40 | 7.55 | 16.8 | 99 | 4,175 |
| 09442630 | Mail Hollow near Luna | 4.65 | 5.35 | 6.16 | 181 | 7,480 |
| 09442695 | Negro Canyon at Aragon | 9.62 | 8.70 | 7.85 | 222 | 7,475 |

Footnotes: a-approximately
b-not yet determined. Will be determined when topographic maps are available.

Figures 3 through 6 show graphically the limits of various basin characteristics of the flood-hydrograph station network and compares these limits with the limits of all the stations used in the 1970 regression analysis (Scott, 1971) which have drainage areas of 18 square miles (46.6 $km^2$) or less. The solid line represents the limits of the flood-hydrograph station network. The dashed line represents the limits obtained by plotting 49 stations with drainage areas of 18 square miles (46.6 $km^2$) or less which were used in the regression analysis by Scott (1971).

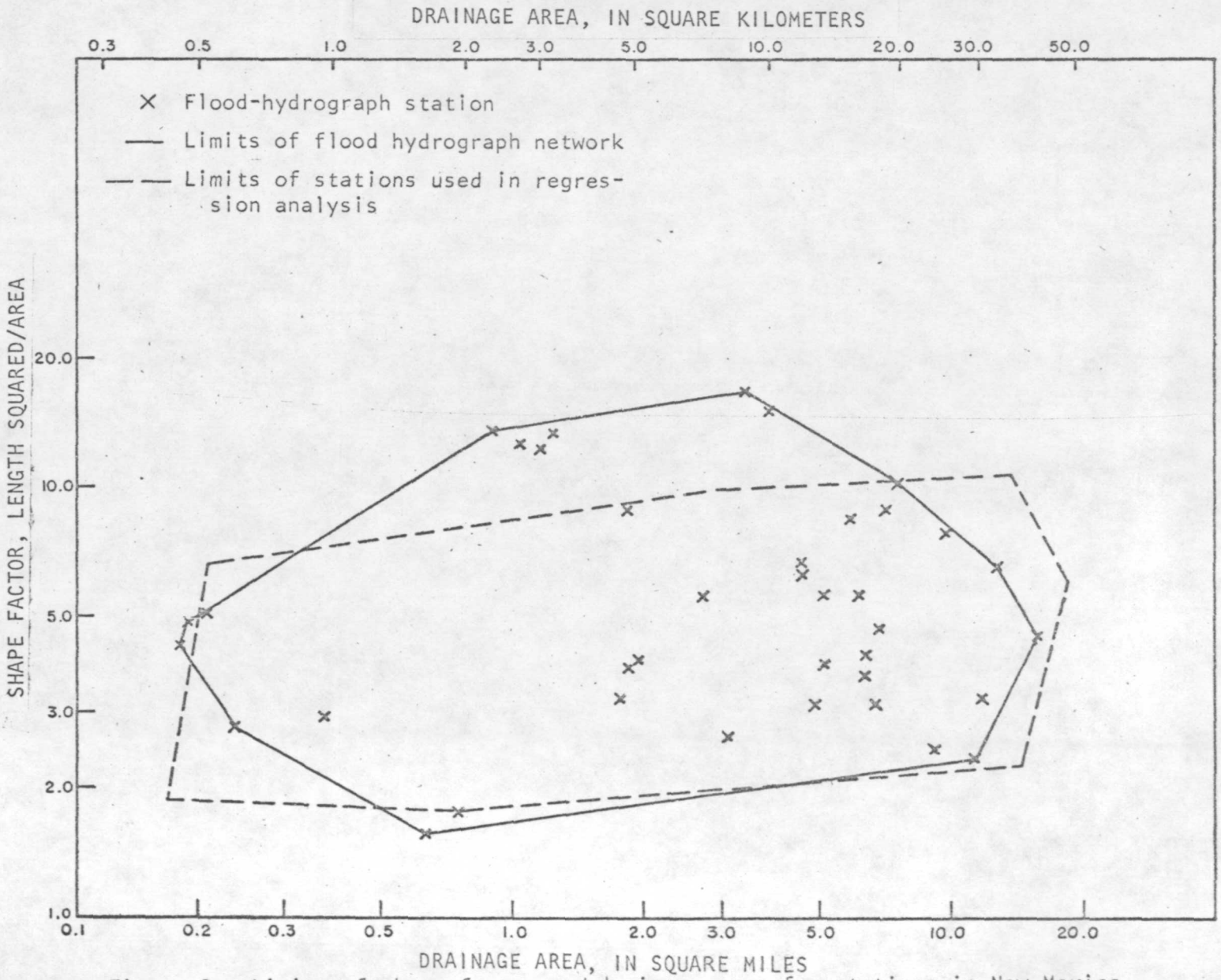


Figure 3.--Limits of shape factor and drainage area for stations in New Mexico.

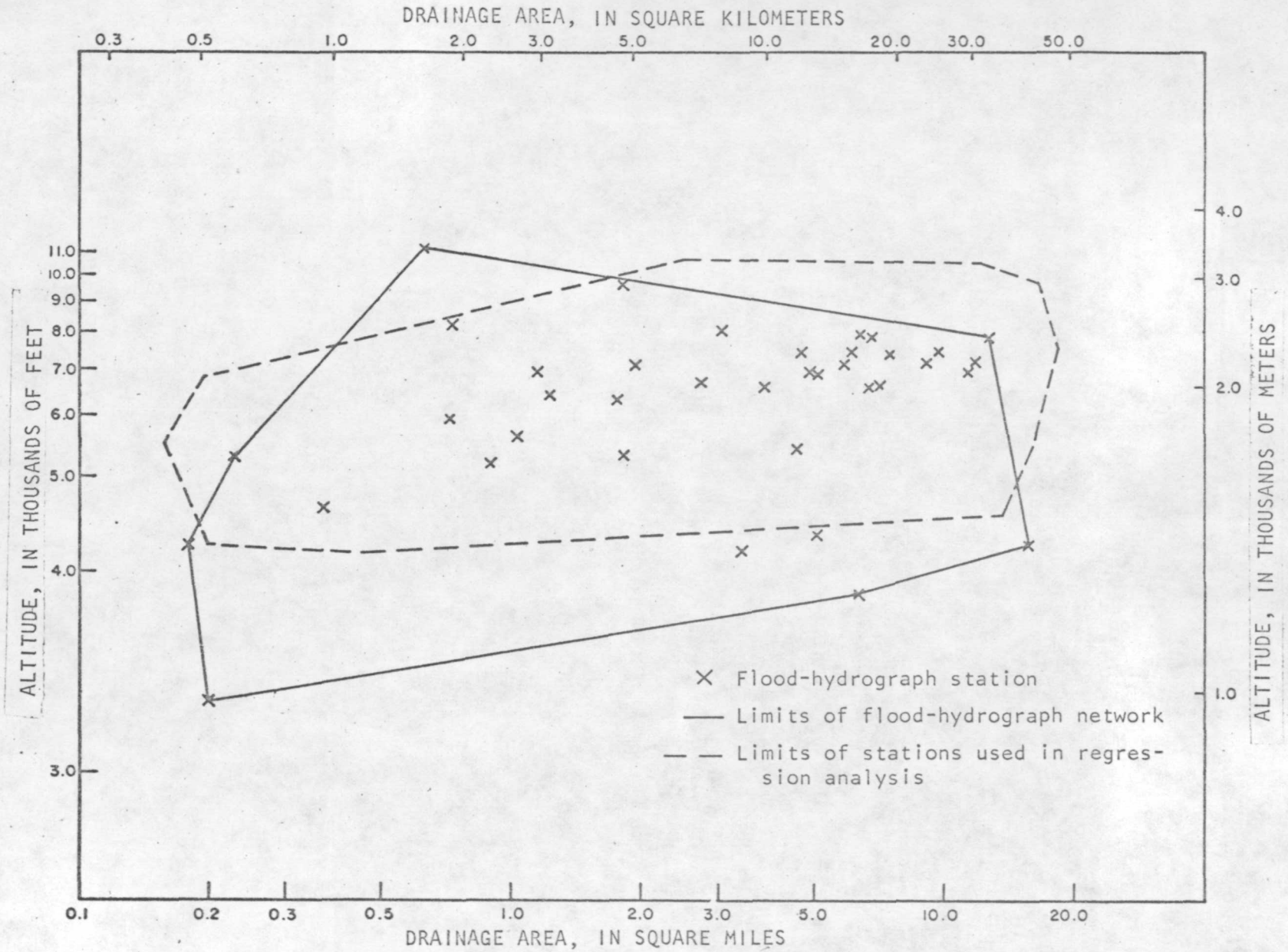


Figure 4.--Limits of basin altitude and drainage area for stations in New Mexico.

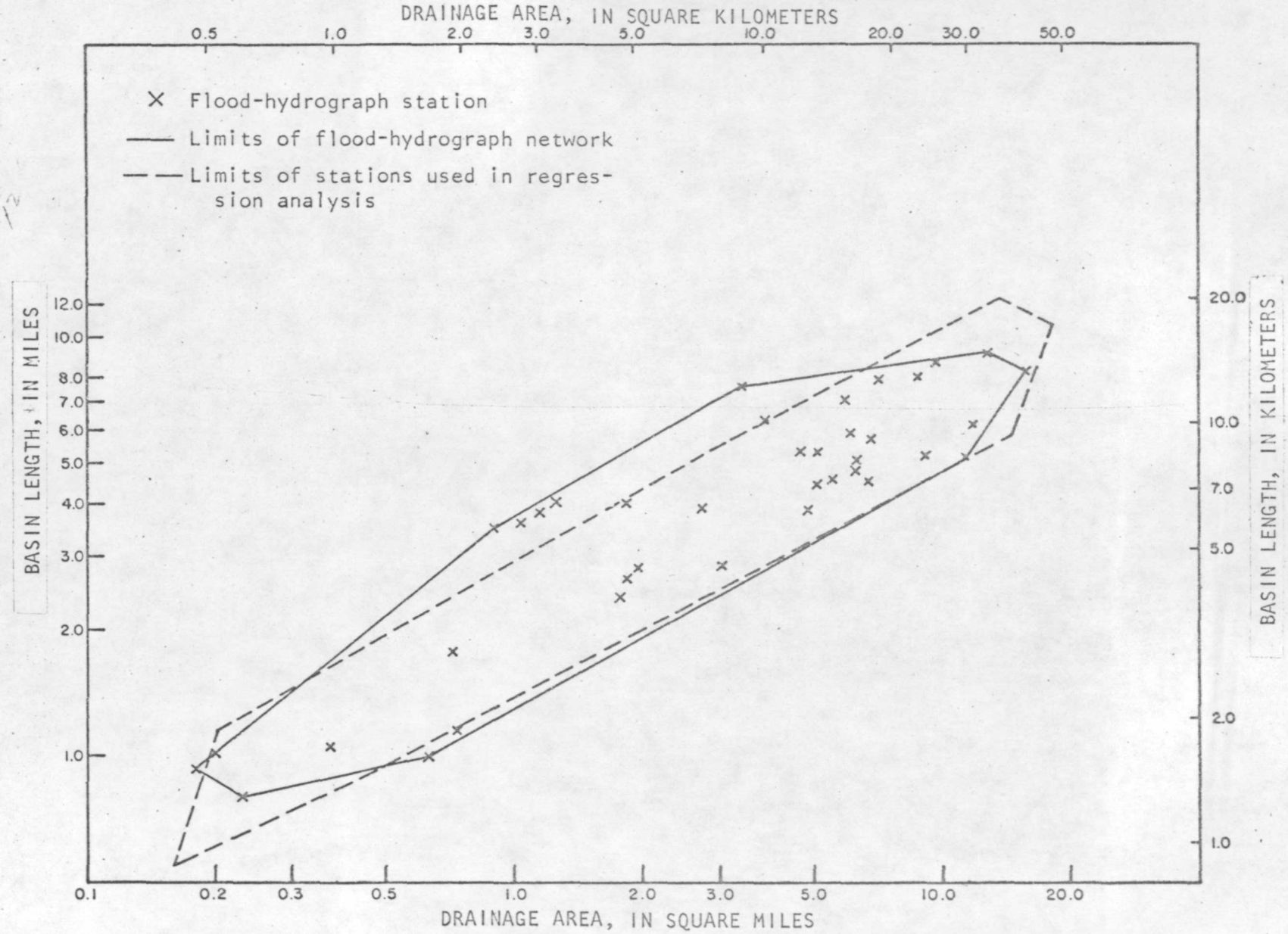


Figure 5.--Limits of basin length and drainage area for stations in New Mexico.

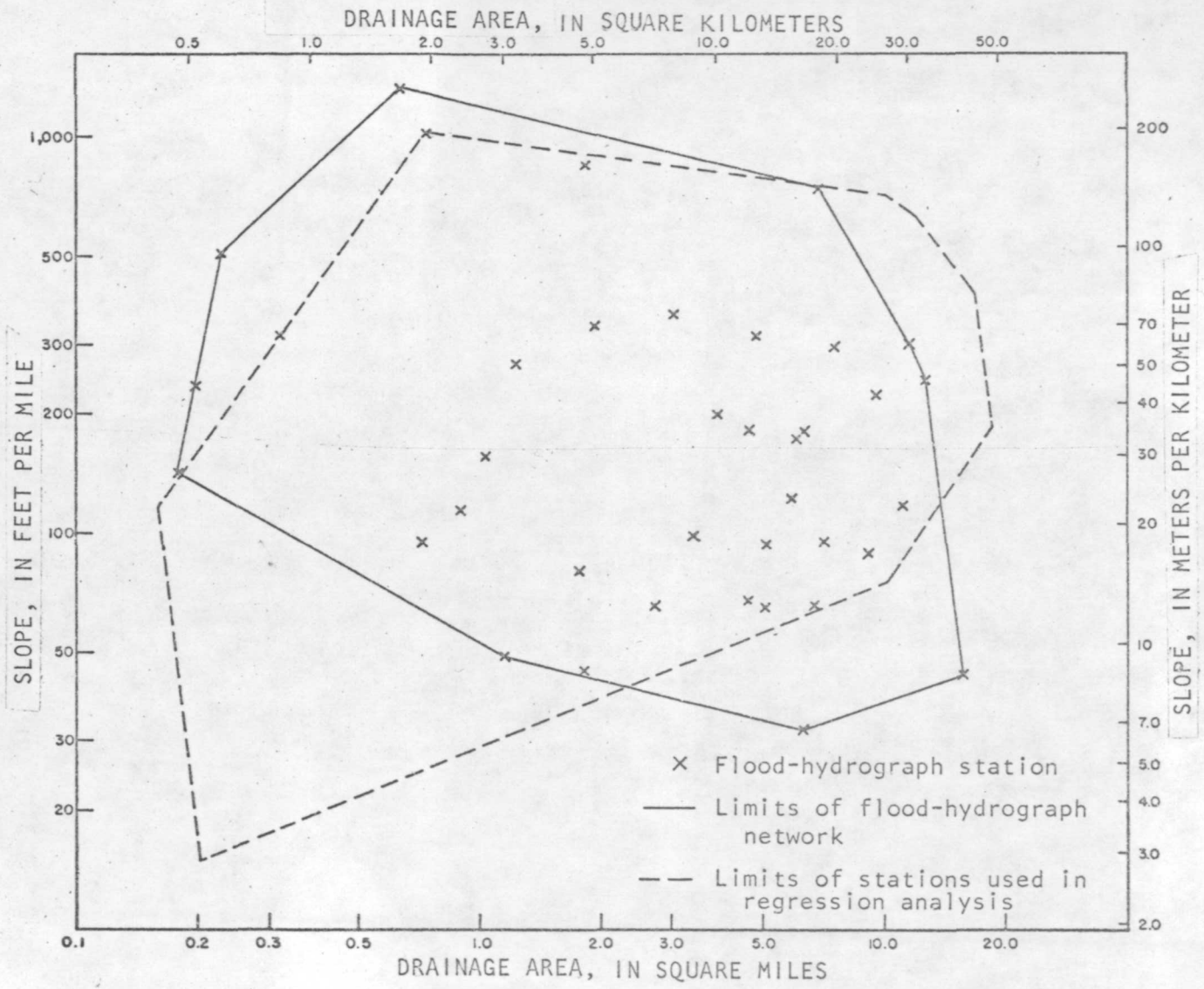


Figure 6.--Limits of main channel slope and drainage area for stations in New Mexico.

## EVALUATION OF DATA COLLECTION

To assess the adequacy of the data being collected, it must be determined whether or not the data are of the correct type, and of sufficient length and sufficient accuracy to be used in the proposed or alternate methods of analysis in order to meet the objective of the project.

The collection of annual-peak data from crest-stage gages is progressing satisfactorily. Stage-discharge relations have been defined for about 70 percent of the gages presently in operation. Many of the gages which are not rated at present require only one or two additional measurements to compute the stage-discharge relation. Ratings should be defined for most of these gages by 1977, the scheduled time for discontinuing the operation of the crest-stage gage network.

The collection of data which are to be used to extend the record of annual peaks at the flood-hydrograph stations also appears to be progressing satisfactorily. Table 2 gives the progress made toward defining the stage-discharge relation at each flood-hydrograph station and the number of usable hydrographs recorded at each station each year. A usable hydrograph is a record of a flow for which a complete synchronous record of stage and rainfall was obtained and for which the recorded rainfall appears to be representative of the average rainfall over the entire basin.

The number of usable flows recorded to date seems to indicate that sufficient flows will be recorded at most stations to be used for the extension of record at the scheduled end of the project in 1979. Table 3 lists the distribution by peak discharge of the flow events recorded at stations for which a stage-discharge relation has been defined. In 4 years of operation only one station, 08268800 Rio Grande tributary near Arroyo Hondo, has had no flows. It is not known whether this is due only to chance or whether flow at this site is as infrequent as indicated. The station is located on a well-defined stream channel, which would indicate that periodic flows do occur.

Table 2.--Status of rating and number of usable hydrographs recorded at flood-hydrograph stations in New Mexico

| Station no. | Station name | Rating status as of 1-1-72 | Number of usable hydrographs | | | | |
|---|---|---|---|---|---|---|---|
| | | | 1968 | 1969 | 1970 | 1971 | Total |
| 07201200 | Chicorica Creek tributary near Raton | Rated | - | - | - | 7 | 7 |
| 07201450 | Una del Gato Creek tributary near Raton | 0 Measurement | - | - | - | 2 | 2 |
| 07203600 | Rio del Plano tributary near Taylor Springs | 1 Measurement | - | - | - | 2 | 2 |
| 07203900 | Graney Creek near Eagle Nest | 1 Measurement | - | - | - | 0 | 0 |
| 07222800 | Garita Creek tributary near Variadero | Rated | - | - | - | 1 | 1 |
| 07225300 | Bluewater Creek near Tucumcari | 2 Measurements | - | - | - | 2 | 2 |
| 07227220 | Cramer Creek tributary near Nara Visa | 1 Measurement | - | - | - | 1 | 1 |
| 07227280 | Sand Draw tributary near Clayton | 1 Measurement | 0 | 3 | 0 | 1 | 4 |
| 08268800 | Rio Grande tributary near Arroyo Hondo | 0 Measurement | 0 | 0 | 0 | 0 | 0 |
| 08293700 | Arroyo Seco tributary near Pojoaque | Partially rated | - | - | - | 3 | 3 |
| 08295200 | Rio en Media near Santa Fe | Rated | - | - | - | 14 | 14 |
| 08313400 | Bland Canyon near Cochiti | Rated | 0 | 6 | 3 | 0 | 9 |
| 08317720 | Canada de la Cueva near Galisteo | 3 Measurements | - | - | 2 | 5 | 7 |
| 08332700 | San Pablo Canyon near Cuba | 2 Measurements | - | - | 3 | 7 | 10 |
| 08341370 | Pine Canyon near Thoreau | 1 Measurement | - | 0 | 1 | 0 | 1 |
| 08359400 | Lumber Canyon tributary near Monticello | Rated | 0 | 5 | 2 | 2 | 9 |
| 08363000 | Rio Grande tributary near Salem | 0 Measurement | - | - | - | 1 | 1 |
| 08379100 | Pecos River tributary near Sena | 0 Measurement | - | - | - | 0 | 0 |
| 08379550 | Canon Blanco near Leyba | 1 Measurement | - | - | - | 2 | 2 |
| 08381700 | Canon Piedra Lumbre near Las Vegas | 1 Measurement | - | - | - | 1 | 1 |
| 08383370 | Pecos River tributary near Puerto de Luna | Rated | 1 | 4 | 2 | 3 | 10 |
| 08390050 | Rio Hondo tributary at Tinnie | 1 Measurement | - | - | - | 8 | 8 |
| 08394300 | Twin Buttes Canyon tributary near Roswell | 1 Measurement | - | 1 | 0 | 7 | 8 |
| 08397400 | Hyatt Canyon near Cloudcroft | 0 Measurement | - | 3 | 1 | 3 | 7 |
| 08404600 | Pecos River tributary at Carlsbad | 0 Measurement | - | - | - | 3 | 3 |
| 08437620 | Monument Draw tributary near Monument | 0 Measurement | 0 | 1 | 0 | 1 | 2 |
| 08477100 | Willow Springs Canyon at Mimbres | 1 Measurement | - | - | 0 | 0 | 0 |
| 08477200 | Iron Creek near Kingston | Rated | - | 1 | 1 | 3 | 5 |
| 08480170 | Nogal Canyon tributary near Nogal | Partially rated | 4 | 2 | 2 | 0 | 8 |
| 08480700 | Indian Creek near Three Rivers | Rated | 0 | 8 | 7 | 7 | 22 |
| 08488170 | Chavez Draw tributary near Clines Corners | Rated | 1 | 4 | 0 | 0 | 5 |
| 08488600 | Arroyo del Cuervo near Torreon | Rated | - | 4 | 1 | 6 | 11 |
| 08500000 | Swingle Canyon near Datil | 1 Measurement | - | - | 2 | 6 | 8 |
| 09350700 | Ruben Canyon near Gobernador | 0 Measurement | - | - | 5 | 3 | 8 |
| 09356520 | Burro Canyon near Lindrith | Rated | - | - | - | 2 | 2 |
| 09367400 | La Plata River tributary near Farmington | 2 Measurements | - | - | 0 | 4 | 4 |
| 09367550 | Stevens Arroyo near Kirtland | 1 Measurement | - | - | 0 | 5 | 5 |
| 09367900 | Black Springs Wash near Mexican Springs | Rated | 0 | 0 | 2 | 0 | 2 |
| 09437200 | Mexican Canyon at Virden | 1 Measurement | 0 | 0 | 0 | 2 | 2 |
| 09442630 | Mail Hollow near Luna | 1 Measurement | - | - | 0 | 6 | 6 |
| 09442695 | Negro Canyon at Aragon | Rated | - | - | 2 | 1 | 3 |

- Station not in operation during water year.

Table 3.--Distribution by peak discharge of flows at selected flood-hydrograph stations in New Mexico

| Station no. | Station name | Number of flows | | | | | |
|---|---|---|---|---|---|---|---|
| | | less than 10 $ft^3/s$ | 10 $ft^3/s$ to 25 $ft^3/s$ | 25 $ft^3/s$ to 50 $ft^3/s$ | 50 $ft^3/s$ to 100 $ft^3/s$ | 100 $ft^3/s$ to 1,000 $ft^3/s$ | Greater than 1,000 $ft^3/s$ |
| 07201200 | Chicorica Creek tributary near Raton | 1 | 3 | 1 | 1 | 1 | - |
| 07222800 | Garita Creek tributary near Variadero | - | - | - | - | - | 1 |
| 08295200 | Rio en Medio near Santa Fe | 14 | - | - | - | - | - |
| 08313400 | Bland Canyon near Cochiti | 8 | - | 1 | - | - | - |
| 08359400 | Lumber Canyon tributary near Monticello | - | 2 | 1 | 2 | 4 | - |
| 08383370 | Pecos River tributary near Puerto de Luna | - | 2 | 4 | 1 | 2 | 1 |
| 08477200 | Iron Creek near Kingston | 4 | 1 | - | - | - | - |
| 08480700 | Indian Creek near Three Rivers | 12 | 3 | - | 3 | 4 | - |
| 08488170 | Chavez Draw tributary near Clines Corners | 1 | - | 2 | 1 | 1 | - |
| 08488600 | Arroyo del Cuervo near Torreon | 2 | 2 | 2 | 2 | 2 | 1 |
| 09356520 | Burro Canyon near Lindrith | - | - | 1 | - | 1 | - |
| 09367900 | Black Springs Wash near Mexican Springs | - | - | - | - | 2 | - |
| 09442695 | Negro Canyon at Aragon | - | - | - | 2 | 1 | - |

The storms which produce flood runoff in New Mexico are generally intense rainstorms and generally cover a small area. The recorded rainfall must be representative of the rainfall over the entire basin to use the flow in the model calibration.

Supplementary storage-type rain gages were installed on seven basins in 1969. The drainage areas of these basins range in area from 0.74 to 11.8 square miles (1.92 to 30.6 $km^2$). The gages are read by observers who are instructed to read the gage after each storm. Average rainfall was computed by the Thiessen method for each storm on each basin. The basin average was then plotted against the recorded rainfall for each storm. These plots are shown on figures 7 through 13. The plots show a large scatter of points for basins which have a drainage area greater than about 5 square miles (13.0 $km^2$). The plots indicate very little bias between mean and recorded rainfall. However, the large amount of random scatter for the larger basins indicates that a careful selection of flows to be used to calibrate the model will have to be made for drainage basins over about 5 square miles (13.0 $km^2$).

Another item of concern is the availability of long-term rainfall records with which to extend the record of annual peaks at the flood-hydrograph stations. Figure 14 shows the approximate location of National Weather Service recording precipitation gages which have over 25 years of record.

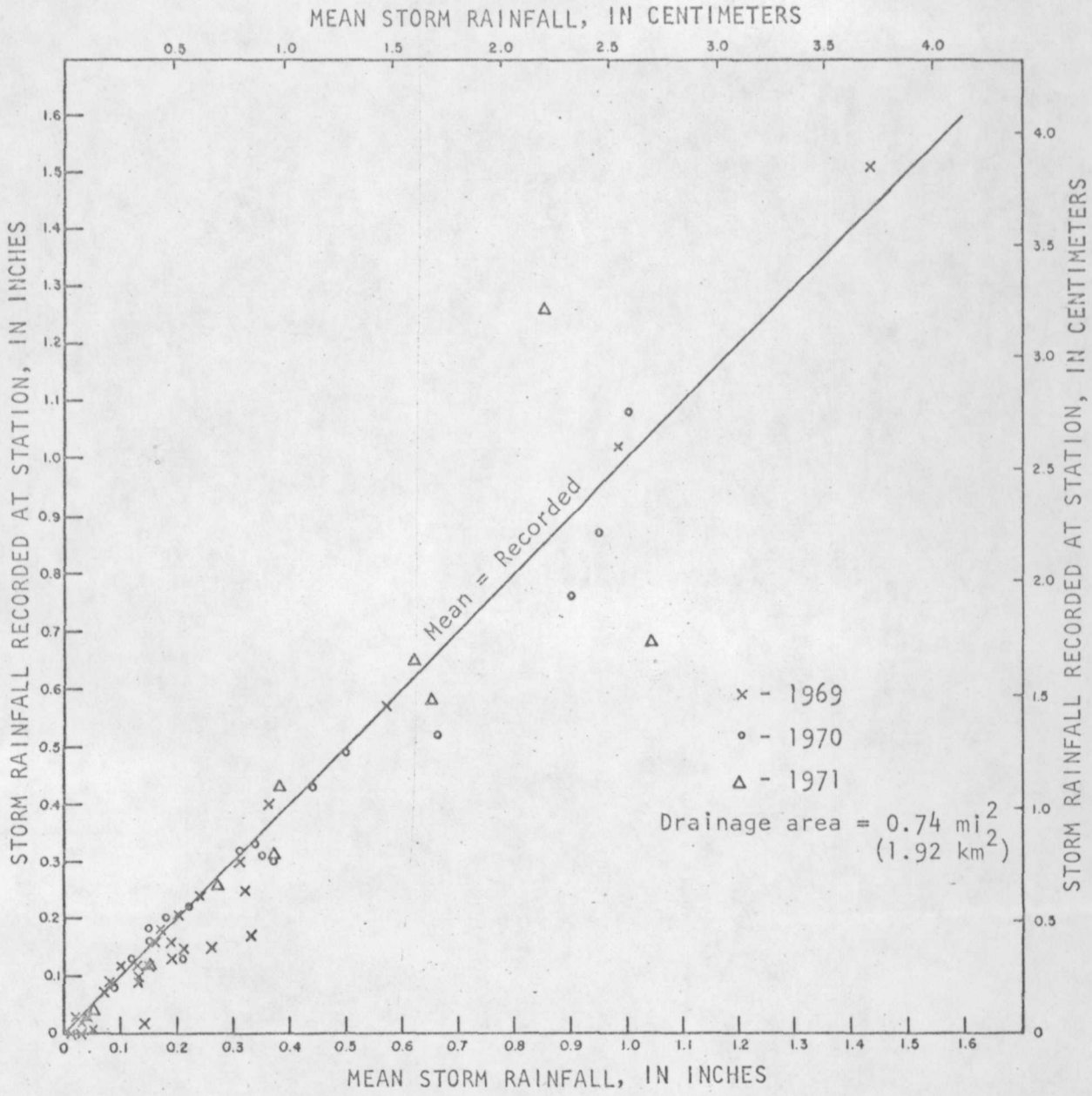


Figure 7.--Relation of recorded to mean rainfall for station 08477200, Iron Creek near Kingston.

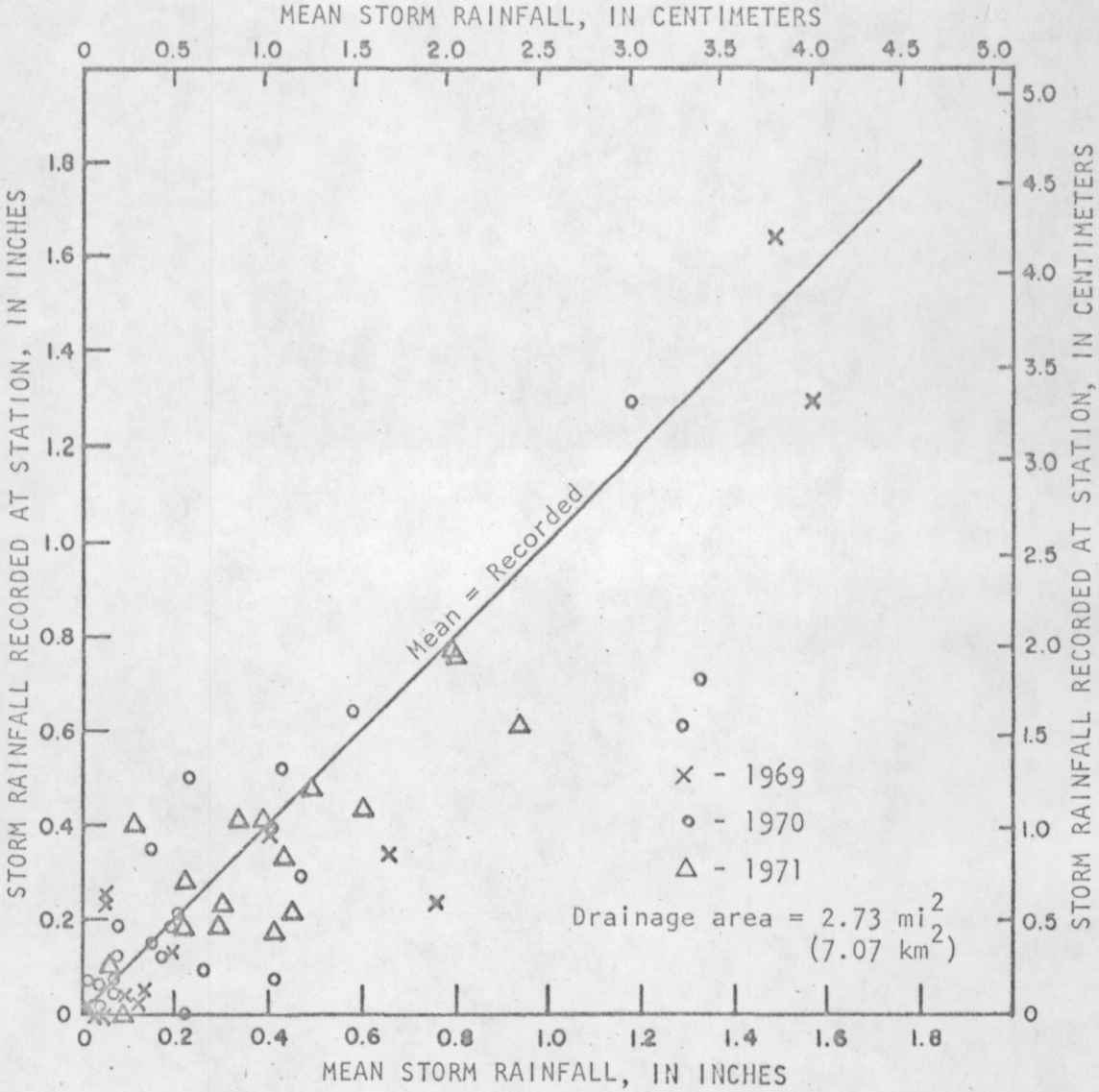


Figure 8.--Relation of recorded to mean rainfall for station 08488100, Chavez Draw tributary near Clines Corners.

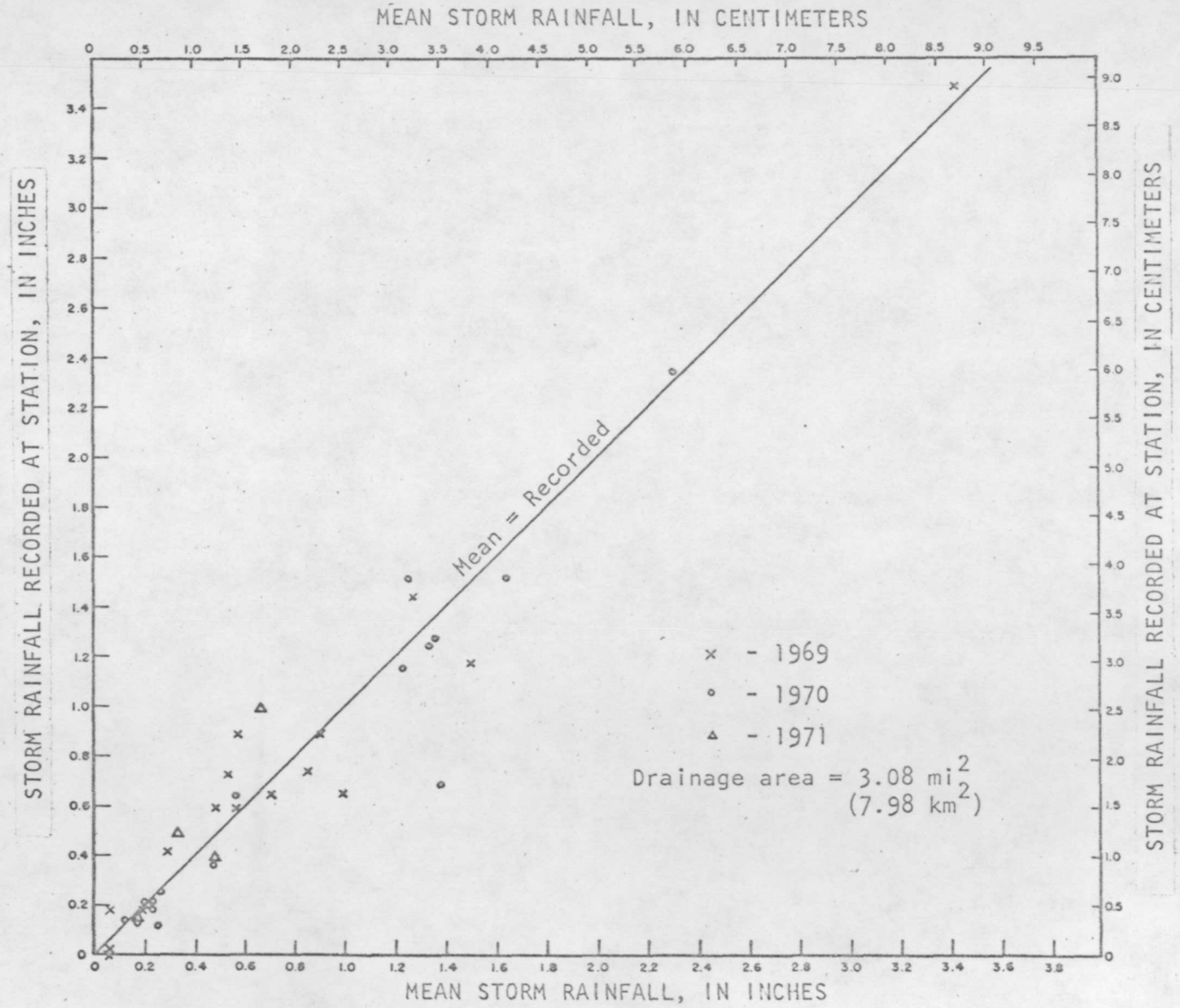


Figure 9.--Relation of recorded to mean rainfall for station 08397400, Hyatt Canyon near Cloudcroft.

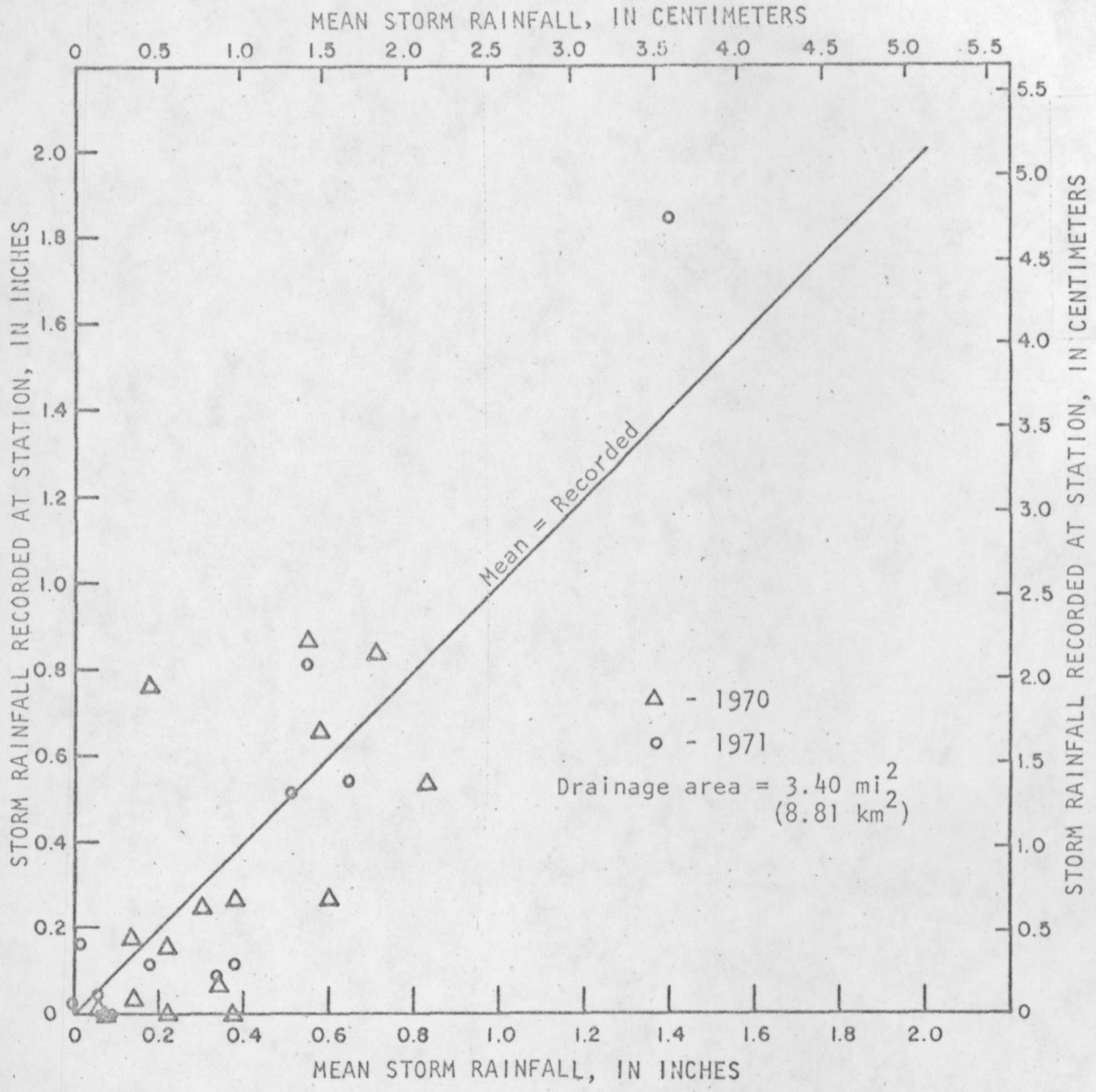


Figure 10.--Relation of recorded to mean rainfall for station 09437200, Mexican Canyon near Virden.

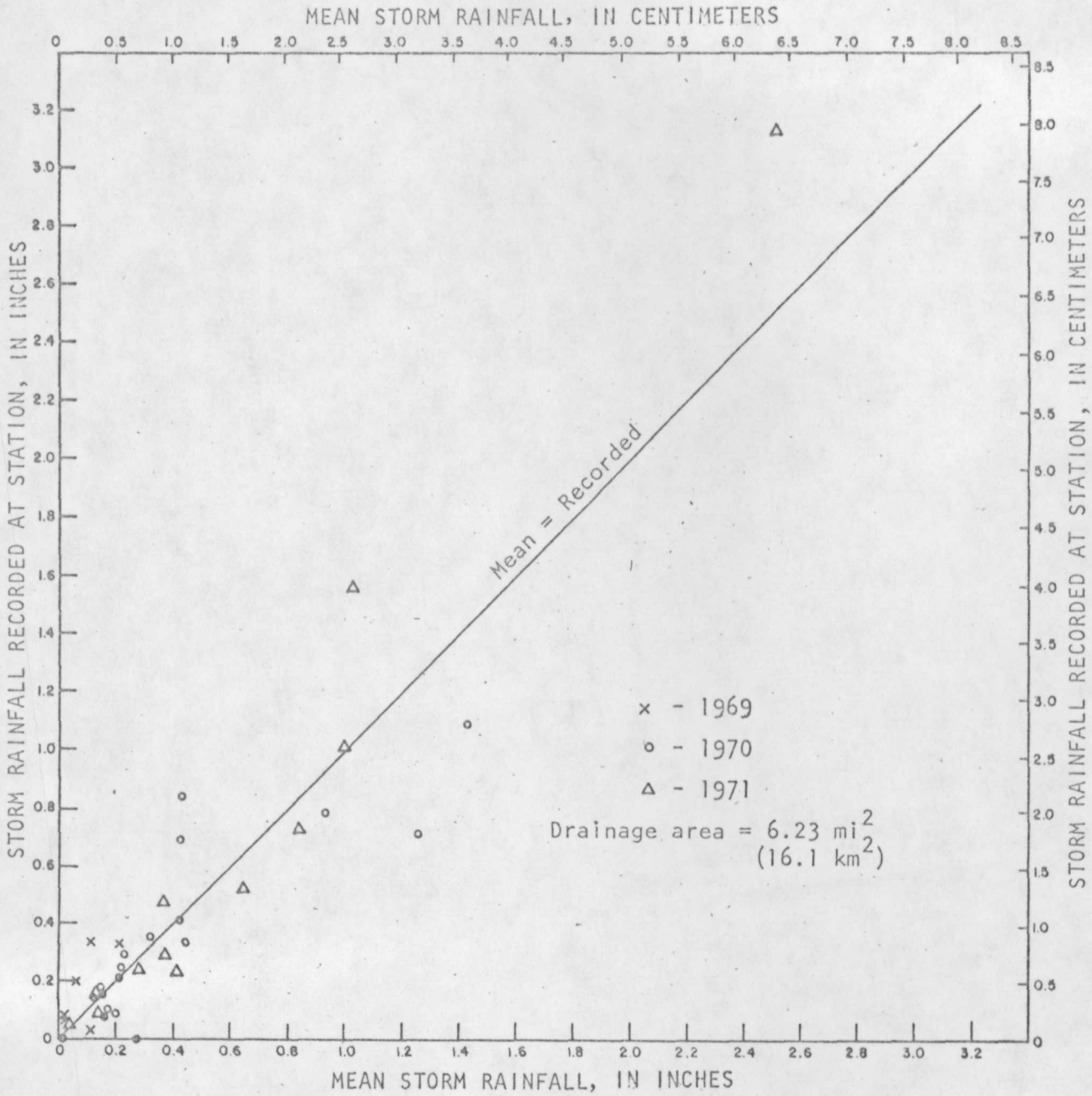


Figure 11.--Relation of recorded to mean rainfall for station 08437620, Monument Draw tributary near Monument.

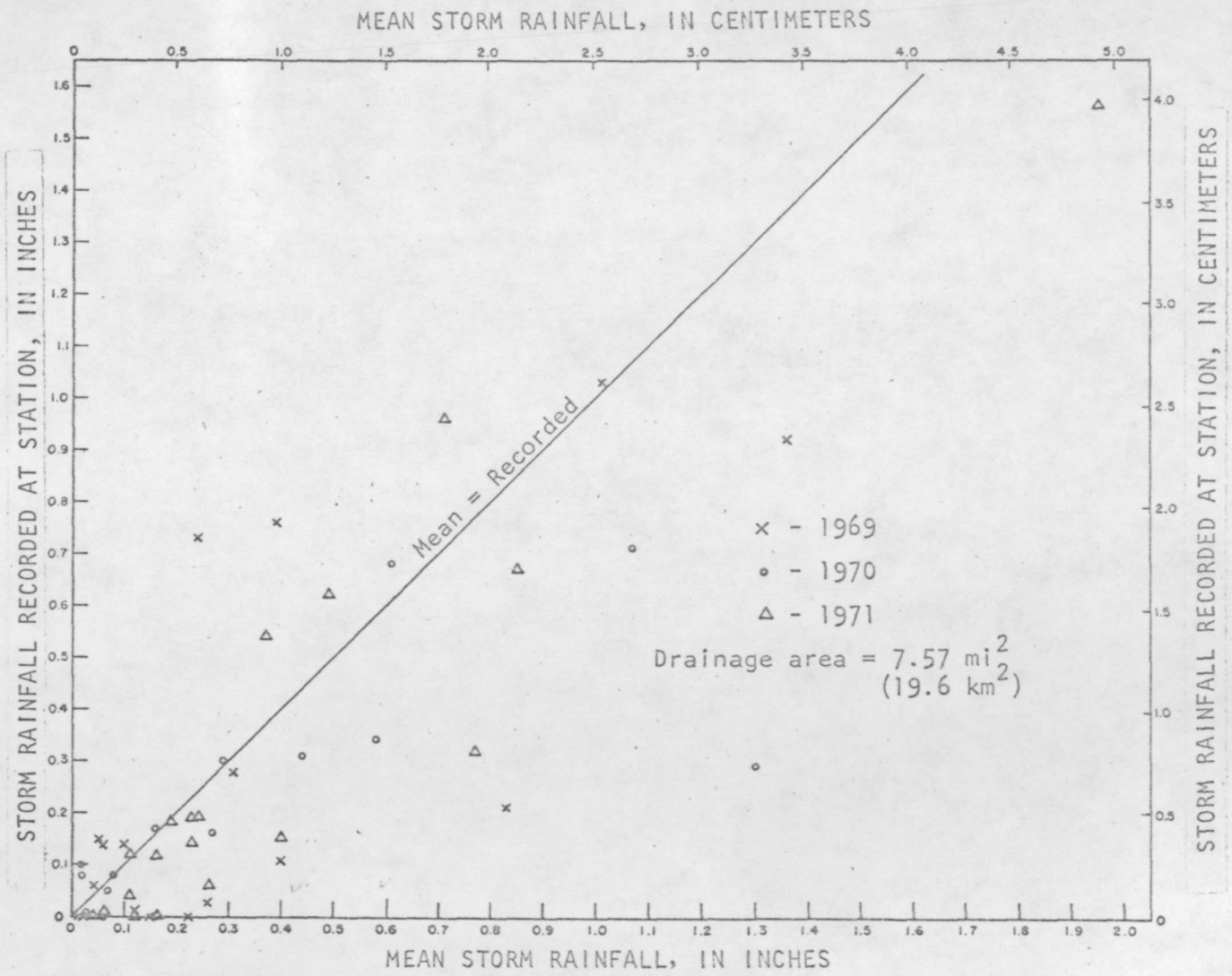


Figure 12.--Relation of recorded to mean rainfall for station 08313400, Bland Canyon near Cochiti.

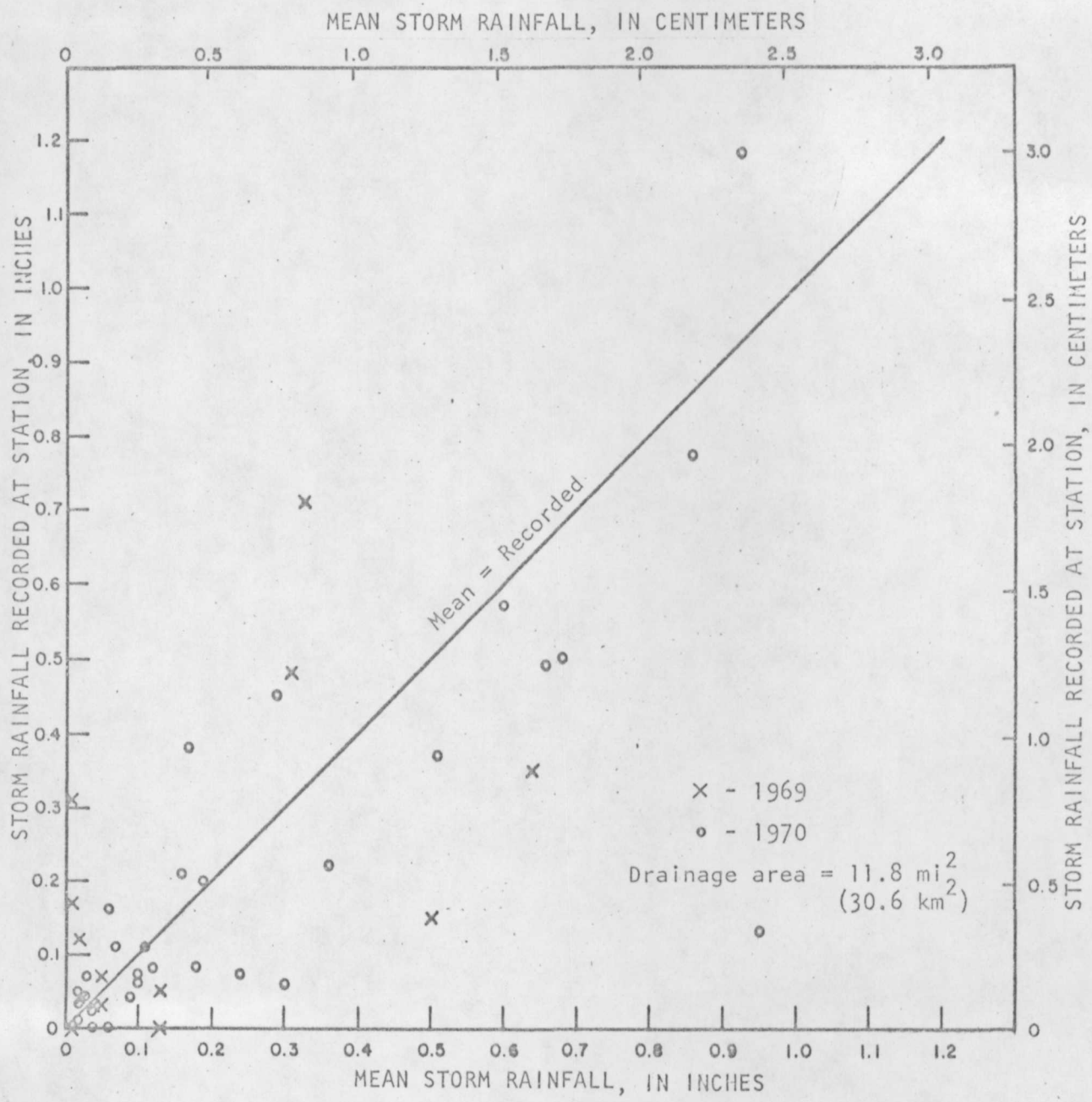


Figure 13.--Relation of recorded to mean rainfall for station 08488600, Arroyo del Cuervo near Torreon.

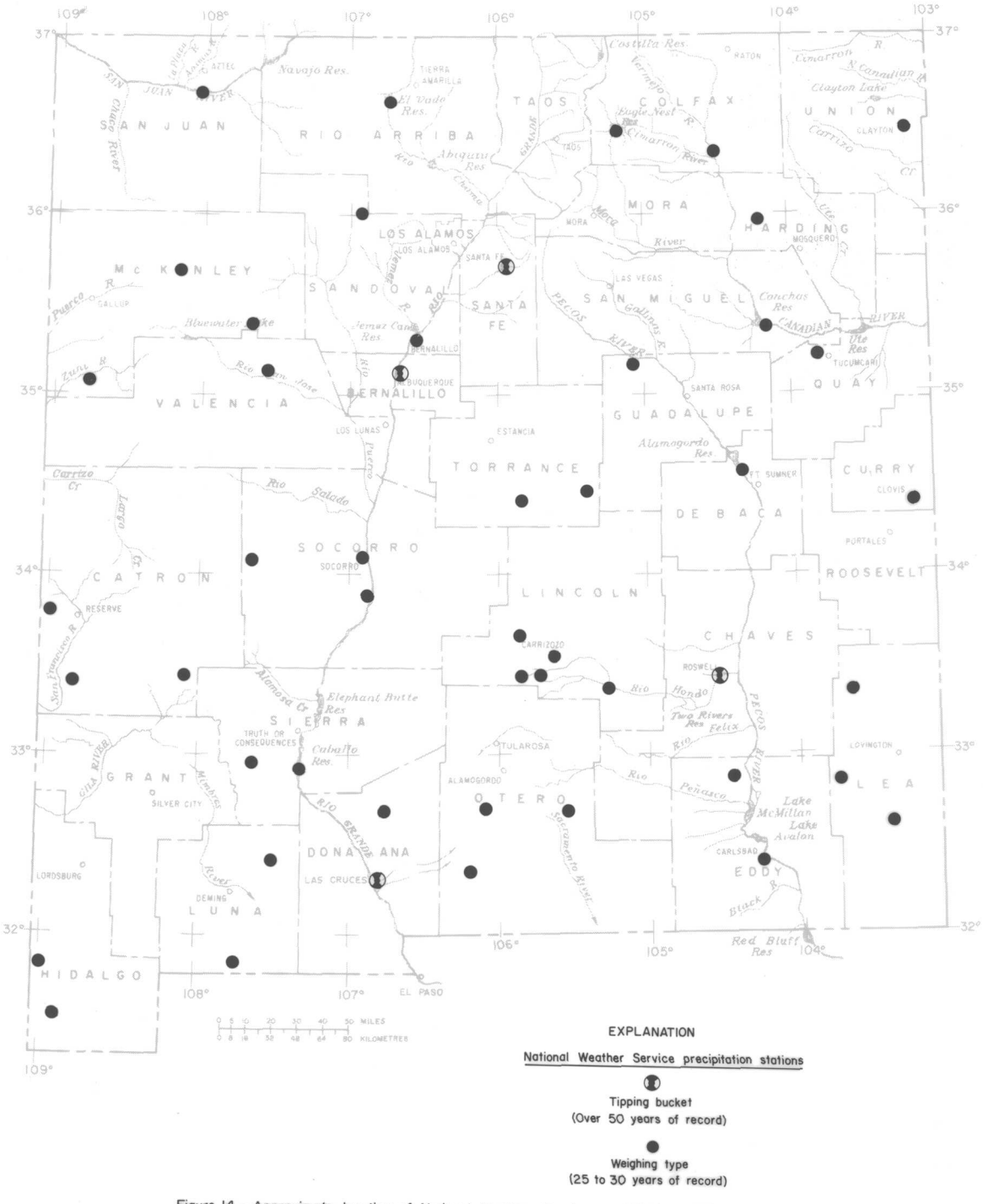


Figure 14.—Approximate location of National Weather Service precipitation stations with over 25 years of record.

Each flood-hydrograph station will require a representative long-term rainfall record with selected storms detailed in 5-minute intervals. The detailing of a long-term rainfall record is rather costly at present, ranging from about $2,000 to $4,000 for a 60-year record. Because of the cost, a few long-term records will have to be selected and then transferred to various flood-hydrograph sites. Caution will have to be used in transferring the records from one location to another because of the extreme variability of topography and weather patterns within the State.

Another consideration in the use of these long-term rainfall records is the length of record available. There is presently some question as to whether or not a simulated record using less than about 50 years of rainfall data is an improvement over the original record because of imperfections in the model and data.

## EXTENSION OF RECORD BY MODEL

The Geological Survey rainfall-runoff model is basically a moisture-accounting and flood-routing system. The model consists of three components; (1) the antecedent moisture-accounting component, (2) the infiltration component, and (3) the surface-runoff routing component. The antecedent moisture-accounting component establishes soil moisture conditions at the beginning of a storm. The infiltration component determines rainfall excess during a storm. The surface-runoff routing component routes the rainfall excess and determines the peak discharge for the storm. The model requires the evaluation of 10 parameters which are indices of average physical conditions of the basin. The parameter values are determined for each drainage basin by an optimization process, which is built into the model, during the calibration phase of the model.

One basin in New Mexico was selected for use in the rainfall-runoff model to test the adequacy of the data being collected and the proposed method of extending records of annual peaks. Station 08383370, Pecos River tributary near Puerto de Luna, was selected because a wide range of flows have been recorded at the site, recorded rainfall seems to be representative of that on the basin, and a short period of annual peaks is available with which to compare results. There are 10 flows recorded at this station. Two of these flows are complex hydrographs which consist of two peaks each.

During the calibration phase for this station it was found that the use of very low flows produced unreasonable parameter values. The final calibration was run using only selected flows. The 10 model parameters appear to be fairly reliable, considering the small number of flows which were used for the calibration.

The following data were used to obtain a simulated long-term record of annual peak discharges:

1. Model parameters as determined by calibration process described above.
2. Rainfall record for Roswell, N. Mex., for period 1905 through 1970.
3. Daily evaporation values for Alamogordo Dam, N. Mex., for 1938 through 1970.

The results of a log Pearson Type III frequency analysis of the annual peaks recorded at the station and the simulated annual peaks are given in table 4 and shown graphically in figure 15. The period of record of recorded annual peaks used was 1961-69 and 1971-72. The 1970 annual peak was considered to be an outlier for this period of record and was not included in the analysis.

Table 4.--Results of log Pearson Type III frequency analysis for station 08383370, Pecos River tributary near Puerto de Luna

| Recurrence interval in years | Discharge in $ft^3/s$ from recorded data | Discharge in $ft^3/s$ from model data |
|---|---|---|
| 1.25 | 37 | 54 |
| 2 | 95 | 118 |
| 5 | 225 | 240 |
| 10 | 341 | 336 |
| 25 | 519 | 472 |
| 50 | 673 | 580 |

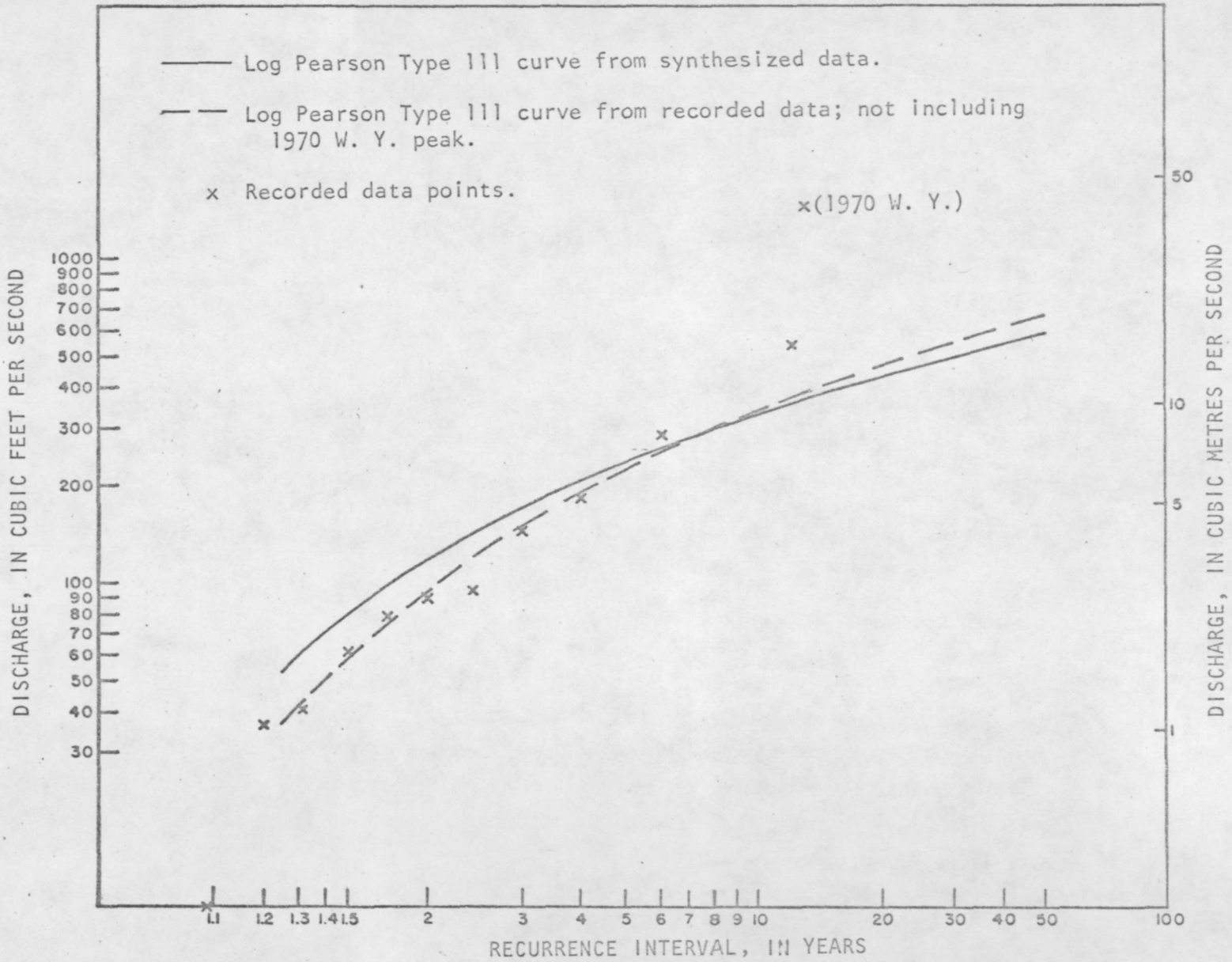


Figure 15.--Graph of log Pearson Type III frequency curves for synthesized and recorded data at station 08383370, Pecos River tributary near Puerto de Luna.

## RAINFALL-RUNOFF RELATIONS

Peak discharge was plotted against two indices of precipitation, total storm rainfall in inches and rainfall intensity in inches per hour for the maximum 15-minute period, to see if a relation between discharge and precipitation could be defined for the flood-hydrograph stations which were rated. In general, maximum 15-minute intensity gave the best correlation with peak discharge. Data were plotted for six sites. No relation could be defined for stations with drainage areas greater than about 5 square miles (13.0 $km^2$). Figure 16 is a graph of peak discharge plotted against maximum 15-minute rainfall intensity for station 08480700, Indian Creek near Three Rivers; drainage area is 6.80 square miles (17.6 $km^2$). Figures 17 through 19 are the same type of plots for stations with drainage areas less than about 5 square miles (13.0 $km^2$).

Enough data have not yet been collected for a detailed analysis of the rainfall-runoff relations. However, figures 17 through 19 indicate that a direct relation exists between peak discharge and precipitation for the smaller drainage areas. This would offer a possible alternative method of extending records on the smaller basins.

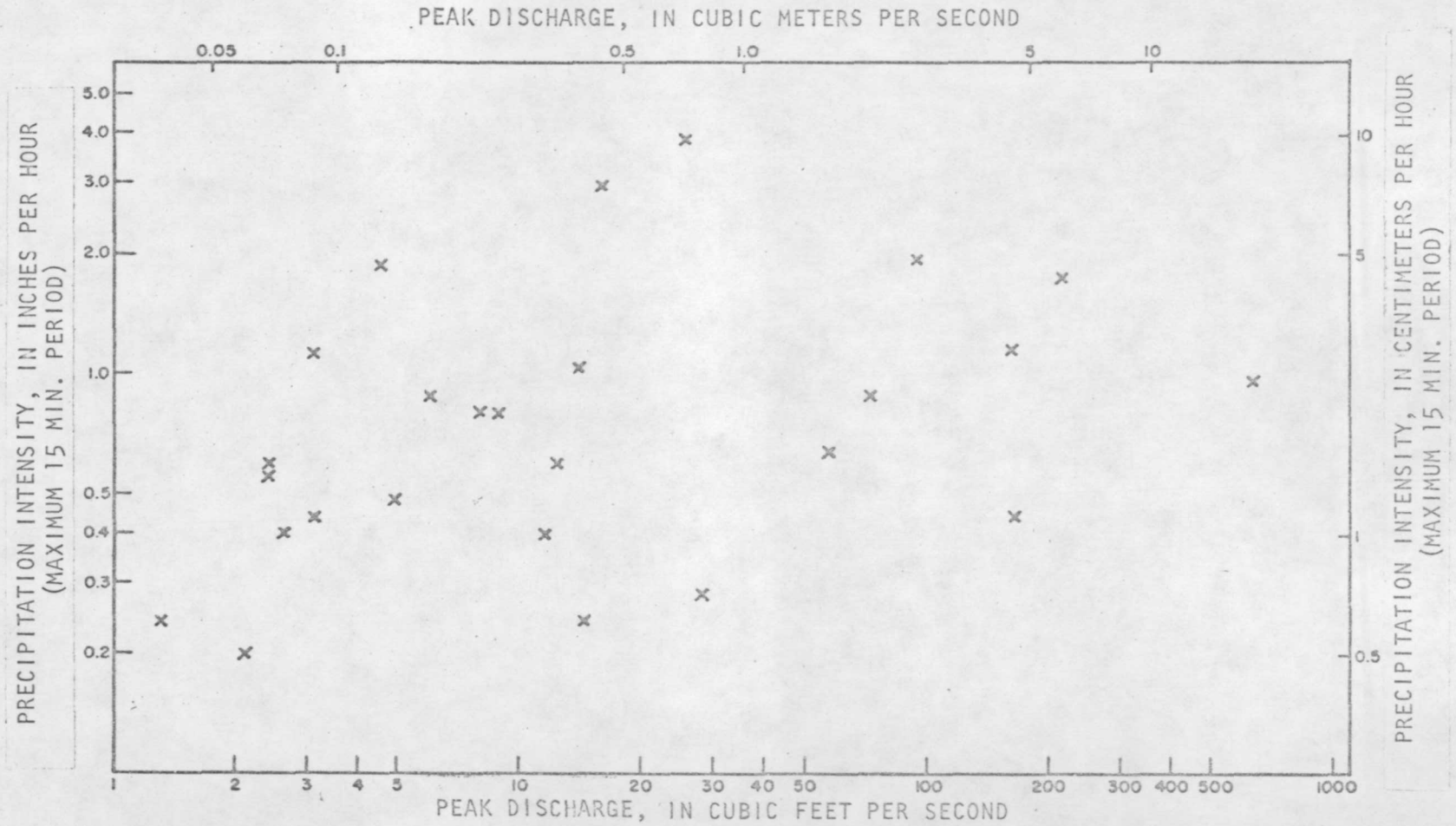


Figure 16.--Relation of precipitation to peak discharge for station 08480700, Indian Creek near Three Rivers.

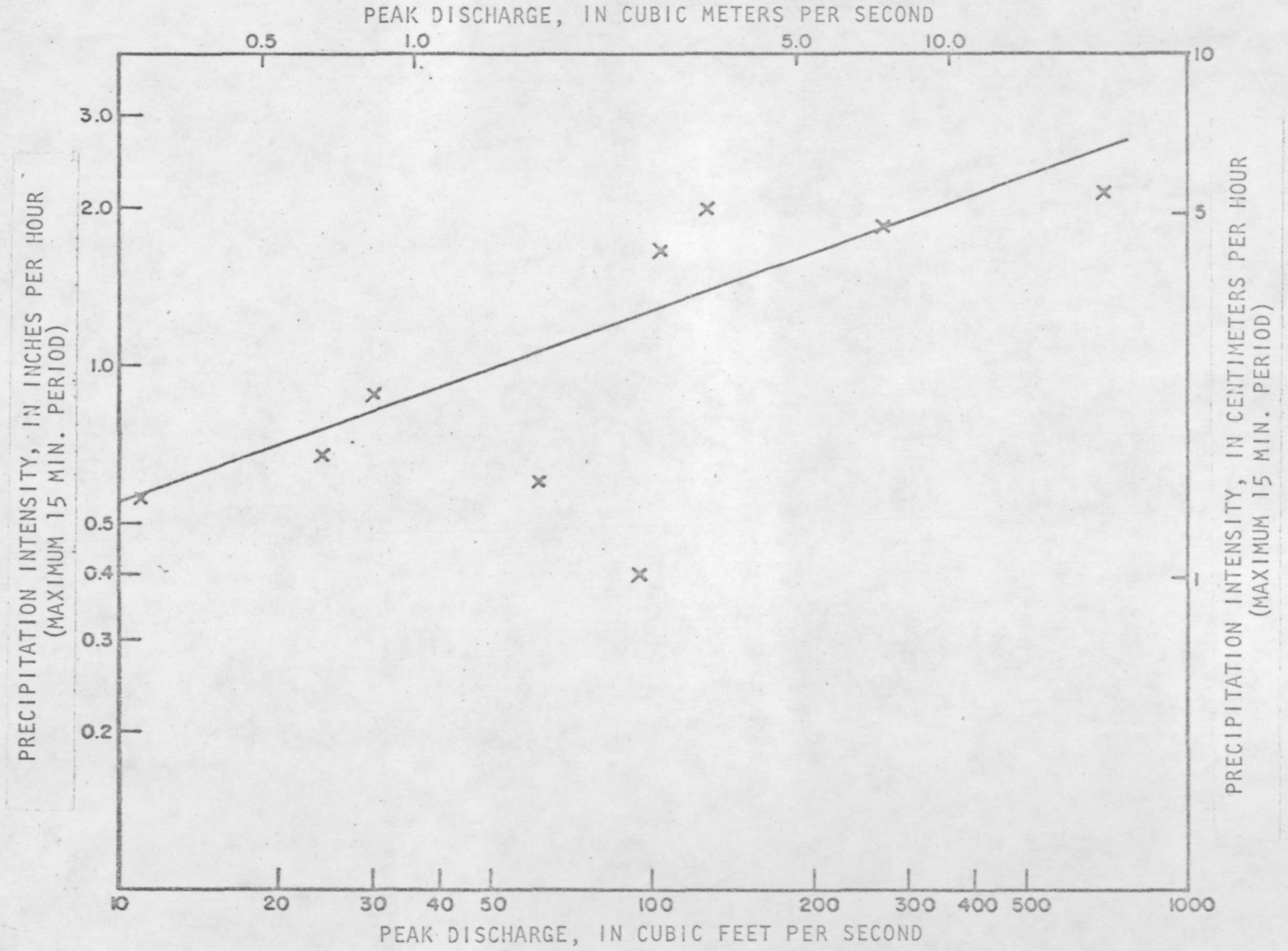


Figure 17.--Relation of precipitation to peak discharge for station 08359400, Lumber Canyon tributary near Monticello.

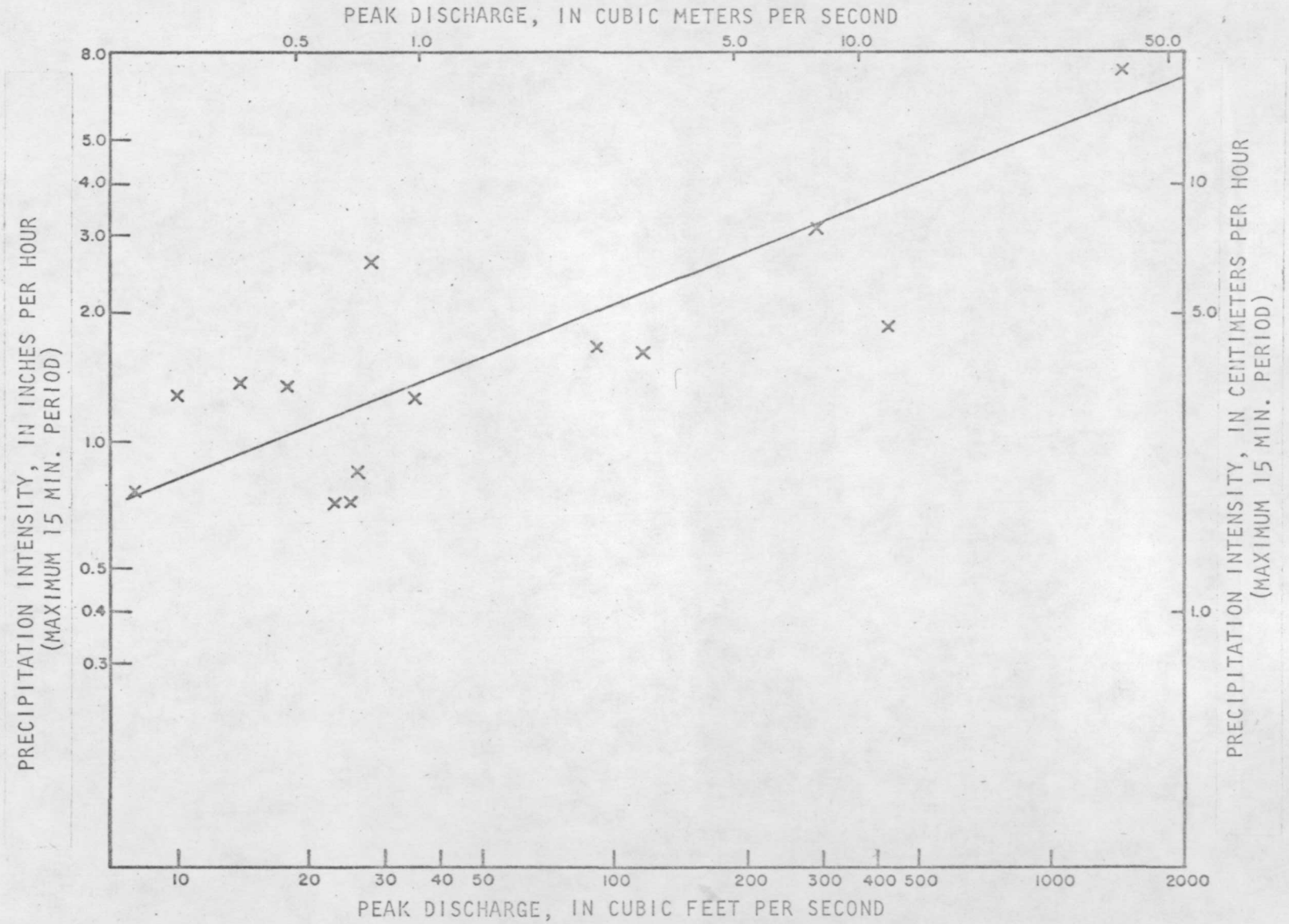


Figure 18.--Relation of precipitation to peak discharge for station 08383370, Pecos River tributary near Puerto de Luna.

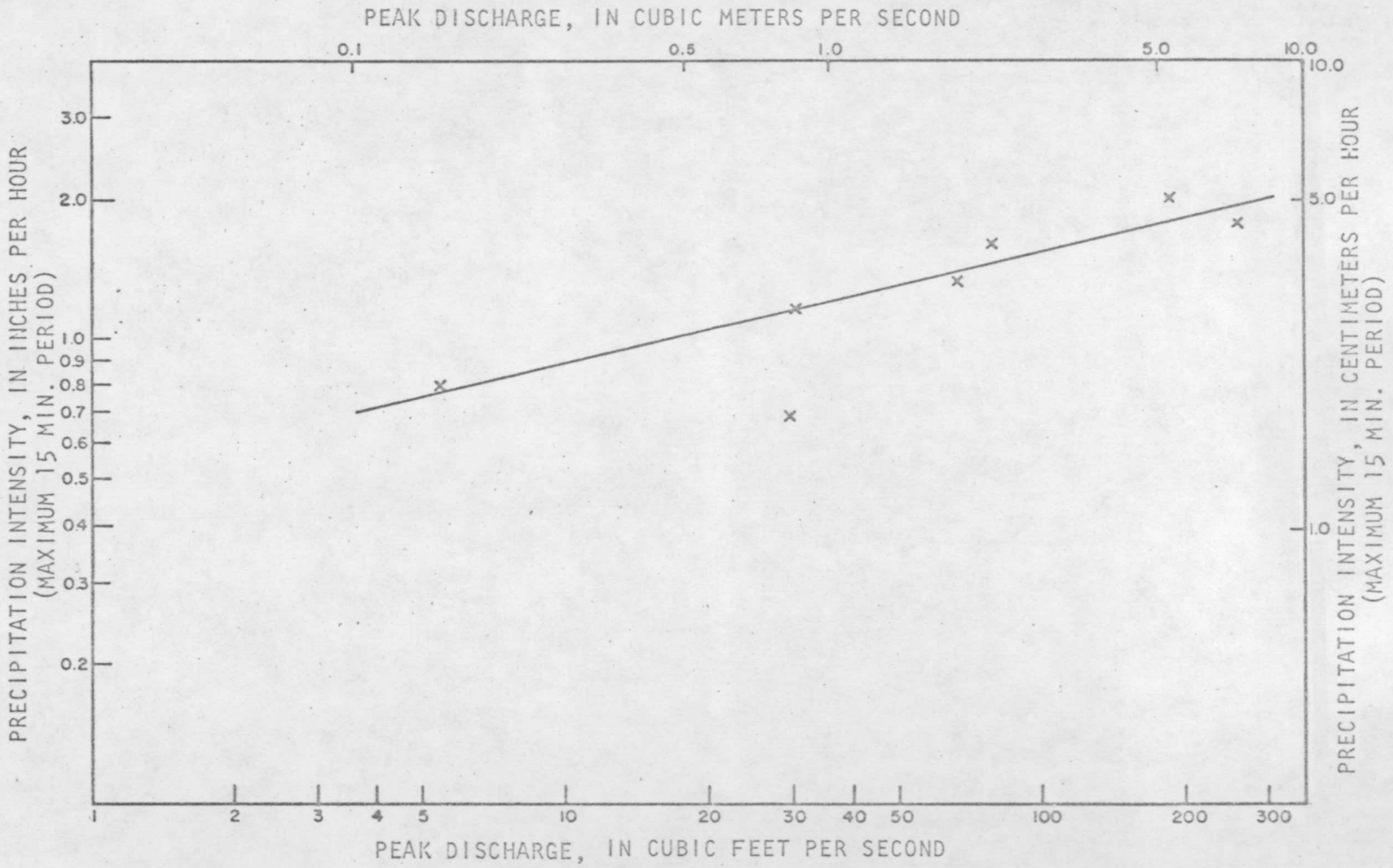


Figure 19.--Relation of precipitation to peak discharge for station 08488170, Chavez Draw tributary near Clines Corners.

The large amount of scatter of the points plotted for the larger drainage basins is probably due to: (1) the recorded rainfall for the flow not being representative, and (or) (2) other variables such as total storm rainfall, daily rainfall or antecedent precipitation are significantly affecting the relation. As more data are available, a multiple-regression analysis considering several variables might provide a relation between peak discharge and rainfall for the larger basins.

## REGIONALIZATION

### Regression analyses

The recommended method to extend flood data to ungaged sites, at present, is to relate flood discharges of a given frequency to topographic and climatic characteristics of the basin by multiple-regression techniques. One problem encountered in the 1971 multiple-regression analyses of flood data (Scott, 1971) was that the standard error of the regression relations was large. The standard error will probably be somewhat reduced by using longer streamflow records to define the flood characteristics at the gages. However, other important considerations in improving the relations are to search for other basin characteristics which might be important in explaining the differences in flood characteristics from basin to basin and to find better measures of the basin characteristics which were previously used in the regression analyses.

Some other basin characteristics which might be important are: (1) an index of the time variability of precipitation, such as number of thunderstorm days or number of days with rainfall exceeding a given value; (2) an improved slope index which will describe the typical steep mountain stream flowing into a flat alluvial valley; (3) an index of potential evaporation or evapotranspiration; or (4) a 15-minute precipitation value of a given recurrence interval.

## Channel geometry

Another method of estimating streamflow characteristics at ungaged sites, which seems to hold promise for semiarid areas such as New Mexico, is the "channel geometry" method. This method is based on the premise that an alluvial channel adjusts its size to the discharge it receives and that the size of a stream channel is a direct indication of the amount of water carried by the stream. A characteristic of the stream channel such as width or depth at a specific geomorphological point in the channel is related to a given flow characteristic. The relation can then be used to determine the same flow characteristic at an ungaged site by measuring the width or depth of the channel at the ungaged site.

Considerable success has been achieved in relating mean annual runoff to channel widths and depths in semiarid areas of Nevada, California and Kansas (Moore, 1968; Hedman, 1970; Hedman and Kastner, 1972). Relations were developed in these studies between mean annual runoff and the depth and width of the stream channel measured between channel features referred to as bars.

Some work is in progress in other states to relate channel characteristics to flood discharges in addition to mean annual runoff. A study in Colorado on perennial mountain streams defined the relation of channel width and depth to flood peaks of 2, 5, 10, 25 and 50-year recurrence intervals. The standard errors for these relations are less than the standard errors for the relations defined to estimate flood peaks from basin characteristics measured on maps (Hedman and others, 1972).

As an exploratory procedure, channel width and depth were measured at nine crest-stage gage sites in western New Mexico. Generally the widths and depths were measured between the lowest well-defined banks of the channel. The discharge of a flood with a 10-year recurrence interval was plotted against these widths and depths. No relation was indicated with depth however, as shown in figure 20, a relation with width is indicated. Because of the small sample used, the relation is not well defined. However, figure 20 does indicate that a relation between the discharge of a 10-year flood and channel width probably exists and that further research in this area should be pursued.

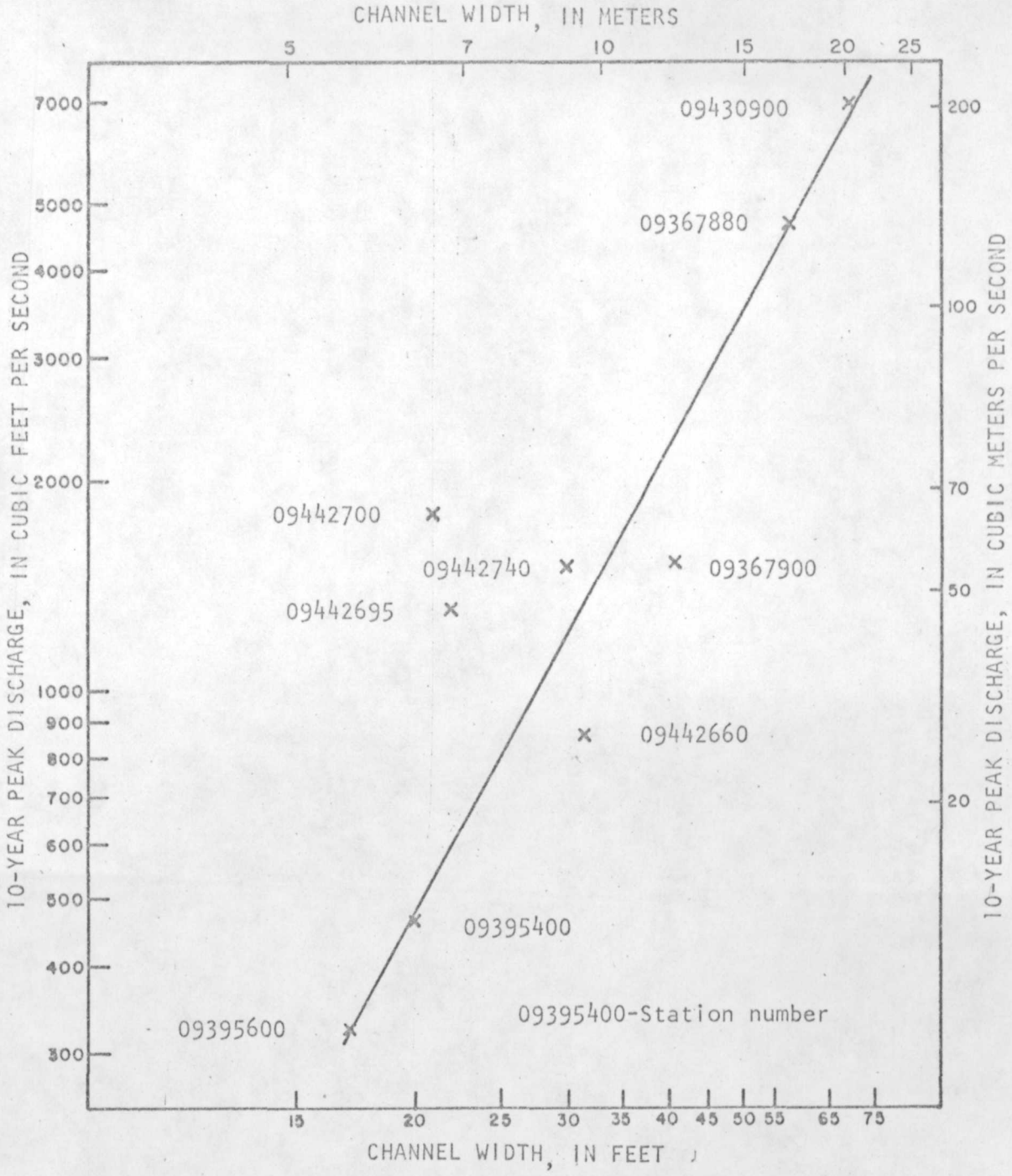


Figure 20.--Relation of 10-year flood to channel width.

## CONCLUSIONS AND RECOMMENDATIONS

The project is progressing satisfactorily. Analyses performed to date indicate that the objectives of the project will probably be met at the end of the 10-year project period. There is no apparent lack of data being collected and the data which are being collected offer several alternatives for analysis. The number and distribution of flood-hydrograph and crest-stage gages are adequate.

As part of this project, additional research is needed in the following areas:

1. Definition of the relation between channel characteristics and floods for ephemeral and perennial streams in New Mexico. This study could provide a useful method of extending flood data to ungaged sites.
2. Investigation of rainfall depth-duration-frequency relations and the transferability of rainfall data within the State. This investigation would be necessary prior to using the limited number of long-term rainfall records for flood-peak simulation.
3. Improvement of the regression model of flood characteristics in New Mexico. The regression can possibly be improved by determining better indices of those topographic and climatic variables which were previously used and by searching for other variables which might explain basin-to-basin differences in flood characteristics.

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