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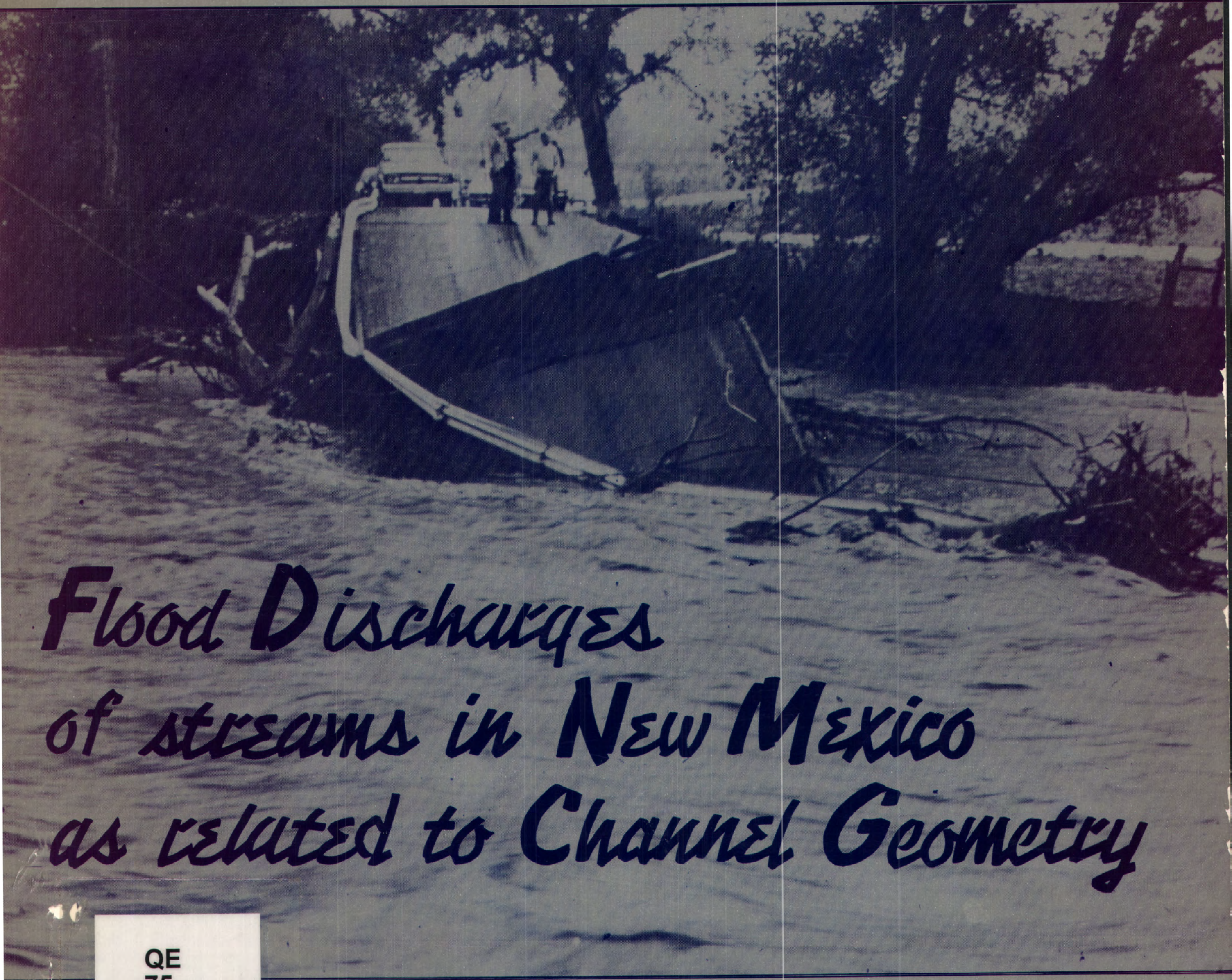

Flood Discharges of streams in New Mexico as related to Channel Geometry

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FLOOD DISCHARGES OF STREAMS IN NEW MEXICO AS RELATED TO CHANNEL GEOMETRY

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FLOOD DISCHARGES OF STREAMS IN NEW MEXICO AS RELATED TO CHANNEL GEOMETRY

By Arthur G. Scott and J. L. Kunkler

Albuquerque, New Mexico

June 1976

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16. Abstract

This report describes the results of a study relating flood characteristics to the reference width of the channel. Data from 79 gaging stations, which would provide estimates of floods of a 10-year recurrence interval and at which channel geometry could be adequately measured in the field, were used in these analyses. The peak discharges for recurrence intervals of 2, 5, 10, 25, and 50 years were determined for each station and are given in tabular form where appropriate. Features that define the reference width vary with location and stream type. A discussion is given of the features that were used in measuring reference widths. The relation between the magnitude of floods of various frequencies and the reference width was reliable with a standard error of about 70 percent for most of the areas of the State; however, no reliable relation could be found for many stream channels in a large area of southeastern New Mexico, and it is recommended that the relation not be used in that area. The reason for this difficulty is believed to be due to recent channel entrenchment in the area.

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ABSTRACT

This report describes the results of a study relating flood characteristics to the reference width of the channel.

Data from 79 gaging stations, which would provide estimates of floods of a 10-year recurrence interval and at which channel geometry could be adequately measured in the field, were used in these analyses. The peak discharges for recurrence intervals of 2, 5, 10, 25, and 50 years were determined for each station and are given in tabular form where appropriate.

Features that define the reference width vary with location and stream type. A discussion is given of the features that were used in measuring reference widths.

The relation between the magnitude of floods of various frequencies and the reference width and main-channel slope was reliable with a standard error of about 65 percent for most of the areas of the State; however, no reliable relation could be found for many stream channels in a large area of southeastern New Mexico, and it is recommended that the relation not be used in that area. The reasons for this difficulty is believed to be due to recent channel entrenchment in the area.

INTRODUCTION

It has been known for many years that stream morphology is a function of geology, topography, and climate. Generalizations drawn from these relations form many of the principles of geomorphology. What is less certain is whether these principles can be quantified and applied to discrete areas of only a few square miles or square kilometres. There are many skeptics such as Thornbury (1958, p. 14) who warn, "It is indeed questionable whether the many variable factors which are involved in the origin of complex landscapes can ever be reduced to mathematical equations"; and to reinforce this opinion he adds that of Baulig, "The laws of geomorphology are complex, relative, and rarely susceptible of numerical expression." Despite these wise and well intentioned warnings there are compelling reasons for attempting to quantify geomorphology. The utility and economy of bridge, dam, and urban designs are greatly dependent upon the reliability of predicted magnitudes and probability of occurrence of floods. If some method can be devised for estimating these values by quantifying geomorphology, the results may be worth the professional risk. This paper presents a series of mathematical relations in which various geomorphic variables are quantified to give estimates of the magnitudes and recurrence intervals of floods in the state of New Mexico.

The specific objective of this study was to measure channel widths (W) and cross-sectional mean depths (d) and relate these measured variables mathematically to the magnitude of floods of various recurrence intervals (Q_t).

A previous analysis (Scott, 1971) related flood-flow characteristics to physical and climatic basin characteristics measured from available topographic maps. However, the reliability of these relations is low. Investigations by Moore (1968) in Nevada, by Hedman (1970) in California, and by Hedman and Kastner (1972) in Kansas have shown the feasibility of estimating the mean-flow magnitude from the width and average depth measured at cross sections between depositional bars in the stream channel. Other investigations by Fields (1974) in Utah, by Hedman and others (1974) in Kansas, by Hedman and others (1972) in Colorado, by Moore (1974) in Nevada, and Riggs (1974) have shown the feasibility of relating flood-flow magnitude to channel features.

This report was prepared in cooperation with the New Mexico State Highway Department and the Federal Highway Administration. The opinions, findings, and conclusions are those of the author and not necessarily those of the cooperating agencies.

DATA USED

Streamflow data

Data from 79 gaging stations were used in these analyses. Stations were selected which would provide estimates of floods of a 10-year recurrence interval and at which channel-geometry could be adequately measured in the field. The locations of these stations is shown in figure 1.

The discharges for recurrence intervals of 2, 5, 10, 25, and 50 years were determined for each station by the log-Pearson Type III method (Water Resources Council, 1967) and are shown in table 1 where appropriate. Adjustment to log-Pearson curves for some stations was made on the basis of historical data or "data outliers." The estimated long-term recurrence interval values for some stations with short records were used collectively for this statistical analysis but should not be used individually.

Channel measurements

Reaches of streams at which channel measurements were to be made were selected to conform as closely as possible to the following criteria:

(1) Channel shape should be uniform throughout.

(2) The bed and banks should be of a material that has permitted the channel to develop into a normal size and shape for the flow regimen.

(3) Channel banks should appear to have been permanent for some years.

Based upon these criteria channels which contained bedrock in the bed or banks, which were entirely vegetated—such as grassy swales subject to headcutting and braided channels—were eliminated from consideration. Additionally, channels on streams which were subject to significant regulation were not considered.

The channel feature used to determine widths and depths for this investigation was the "active channel." This feature is described by Hedman and others (1974, p. 3-6) as follows:

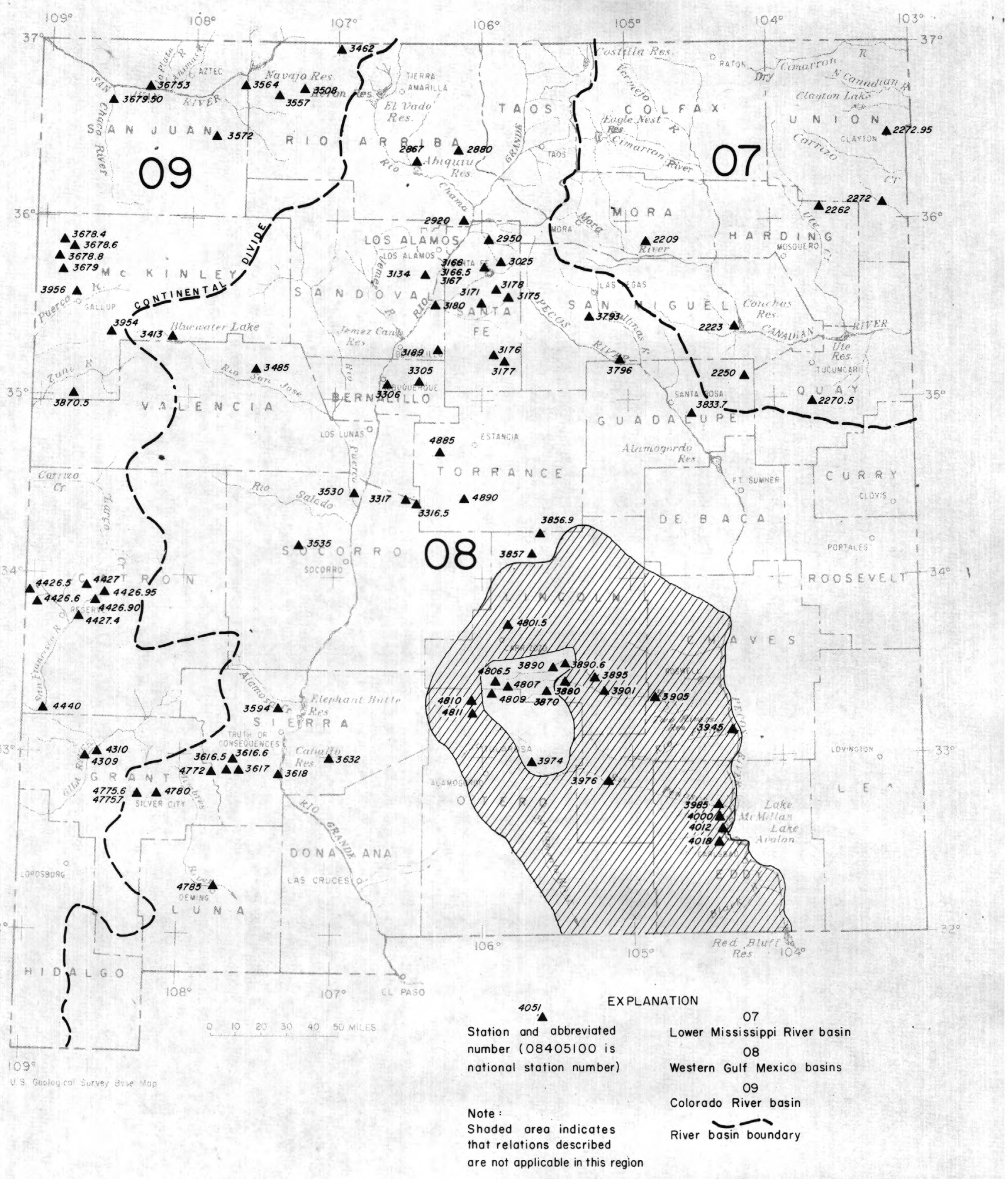


Figure 1—Map of New Mexico showing location of gaging stations at which channel-geometry characteristics were obtained.

Table 1.--Channel and streamflow characteristics for selected partial-record gaging stations and selected continuous-record gaging stations in New Mexico

Station Number	Station Name	Length of Record (year)	Channel Characteristics: Active channel width (ft)	Channel Characteristics: Active channel depth (ft)	Streamflow Characteristics: 2-year flood discharge (ft^3/s)	Streamflow Characteristics: 5-year flood discharge (ft^3/s)	Streamflow Characteristics: 10-year flood discharge (ft^3/s)	Streamflow Characteristics: 25-year flood discharge (ft^3/s)	Streamflow Characteristics: 50-year flood discharge (ft^3/s)
07220900	Dog Cr nr Shoemaker, NM	19	30	1.0	1,260	2,360	3,270	4,610	5,740
07222300	Trementina Cr nr Trementina, NM	15	60	1.3	2,480	5,690	8,170	11,400	-
07225000	Pajarito Cr at Newkirk, NM	18	34	.8	1,300	2,170	2,850	3,820	4,620
07226200	Bueyeros Cr at Bueyeros, NM	12	42	.5	2,730	3,850	4,900	6,500	-
07227050	Plaza Larga Cr tr nr Ragland, NM	22	14	.4	211	400	566	815	1,030
07227200	Tramperos Cr nr Stead, NM	10	76	1.5	3,500	7,600	12,500	-	-
07227295	Sand Draw tr nr Clayton, NM	22	8	.4	53	156	267	466	661
08286700	Arroyo Seco nr Abiquiu, NM	15	25	1.9	559	1,090	1,520	2,120	-
08288000	El Rito nr El Rito, NM	34	23	.6	222	420	582	821	1,020
08292000	Santa Clara Cr nr Espanola, NM	23	14	.9	111	281	444	712	953
08295000	Rio Nambe nr Nambe, NM	33	38	1.3	195	618	1,260	2,350	3,460
08302500	Tesuque Cr ab Div nr Santa Fe, NM	32	14	1.0	75	227	399	718	1,040
08313400	Bland Canyon nr Cochiti, NM	12	9	1.0	39	83	120	168	-
08316600	North Frijoles Arroyo nr Santa Fe, NM	12	14	.8	147	262	326	391	-
08316650	Arroyo de los Frijoles, Locust Tree Reach, nr Santa Fe, NM	14	72	1.7	494	1,190	1,650	2,140	-

Table 1.--Channel and streamflow characteristics for selected partial-record gaging stations and selected continuous-record gaging stations in New Mexico - Continued

Station Number	Station Name	Length of Record (year)	Channel Characteristics: Active channel width (ft)	Channel Characteristics: Active channel depth (ft)	Streamflow Characteristics: 2-year flood discharge (ft^3/s)	5-year flood discharge (ft^3/s)	10-year flood discharge (ft^3/s)	25-year flood discharge (ft^3/s)	50-year flood discharge (ft^3/s)
08316700	Arroyo de los Frijoles nr Santa Fe, NM	14	90	1.2	421	1,660	3,260	6,600	-
08317100	Arroyo Yupa tr nr Cerrillos, NM	12	6	.2	25	93	190	-	-
08317500	Galisteo Cr at Canconcito, NM	17	46	2.0	986	1,390	1,690	2,090	-
08317600	San Cristobal Arroyo nr Galisteo, NM	17	48	1.9	2,110	4,190	5,690	7,610	-
08317700	Tarhole Cyn nr Galisteo NM	22	20	2.2	400	871	1,340	2,170	3,000
08317800	Canada de las Minas nr Santa Fe, NM	16	30	.8	31	109	181	320	-
08318000	Galisteo Cr at Domingo, NM	27	154	.7	6,600	11,900	16,200	22,700	28,000
08318900	San Pedro Cr nr Golden, NM	19	36	1.0	1,190	2,570	3,820	5,810	7,600
08330500	Tijeras Arroyo at Albuquerque, NM	22	24	.9	960	2,580	4,480	8,330	12,700
08330600	Tijeras Arroyo nr Albuqueruque, NM	17	27	1.8	1,060	1,600	2,020	2,630	-
08331650	Canada Montoso nr Scholle, NM	13	38	.7	460	1,570	3,090	6,560	-
08331700	Abo Arroyo tr nr Scholle, NM	20	12	1.5	85	152	215	319	420
08341300	Bluewater Cr, ab Bluewater Dam, nr Bluewater, NM	16	15	1.1	164	267	339	390	-
08348500	Encinal Cr nr Casa Blanca, NM	10	16	.8	186	375	600	-	-
08353000	Rio Puerco nr Bernardo, NM	32	100	7.0	5,200	8,700	12,000	17,500	23,400
08353500	La Jencia Cr nr Magdalena, NM	12	104	.9	2,580	3,950	4,700	-	-

Table 1.--Channel and streamflow characteristics for selected partial-record gaging stations and selected continuous-record gaging stations in New Mexico - Continued

Station Number	Station Name	Length of Record (year)	Channel Characteristics: Active channel width (ft)	Channel Characteristics: Active channel depth (ft)	Streamflow Characteristics: 2-year flood discharge (ft^3/s)	5-year flood discharge (ft^3/s)	10-year flood discharge (ft^3/s)	25-year flood discharge (ft^3/s)	50-year flood discharge (ft^3/s)
08359400	Lumber Cyn tr nr Monticello, NM	22	8	.9	155	375	610	1,060	1,550
08361650	Percha Cr nr Kingston, NM	21	46	1.3	663	1,330	1,750	2,230	2,530
08361660	Percha Cr tr nr Kingston, NM	10	13	.8	74	183	260	369	-
08361700	Percha Cr nr Hillsboro, NM	17	59	.6	1,110	2,730	4,600	8,300	-
08361800	Percha Cr at Caballo Dam, nr Arrey, NM	21	83	1.4	1,250	3,470	5,920	10,400	15,100
08363200	Aleman Draw at Aleman, NM	15	62	1.2	1,830	5,240	9,010	16,000	-
08379300	Tecolote Cr at Tecolote, NM	21	67	1.5	2,050	5,710	9,390	15,500	21,200
08379600	Pecos R tr nr Dilia, NM	22	5	.3	21	68	128	254	397
08383370	Pecos R tr nr Puerto de Luna, NM	8	15	1.3	98	221	435	-	-
08385690	Bonito Cyn tr nr Corona, NM	15	4	.7	18	42	64	100	-
08385700	Cloud Cyn nr Gallinas, NM	16	7	.8	13	123	330	1,000	-
08387000	Rio Ruidoso at Hollywood, NM	15	16	1.5	203	418	671	1,200	-
08388000	Rio Ruidoso at Hondo, NM	38	18	2.6	947	2,970	5,500	10,800	16,700
08389000	Rio Bonito nr Ft. Stanton, NM	12	29	1.0	1,000	1,930	2,660	-	-
08389060	Rio Bonito tr nr Ft. Stanton, NM	19	11	1.1	78	136	175	230	280
08389500	Rio Bonito at Hondo, NM	28	19	2.6	3,040	5,810	7,950	10,900	13,300

Table 1.--Channel and streamflow characteristics for selected partial-record gaging stations and selected continuous-record gaging stations in New Mexico - Continued

Station Number	Station Name	Length of Record (year)	Channel Characteristics: Active channel width (ft)	Channel Characteristics: Active channel depth (ft)	Streamflow Characteristics: 2-year flood discharge (ft^3/s)	5-year flood discharge (ft^3/s)	10-year flood discharge (ft^3/s)	25-year flood discharge (ft^3/s)	50-year flood discharge (ft^3/s)
08390100	Rio Hondo at Picacho, NM	14	24	2.8	2,400	3,640	4,360	5,150	-
08390500	Rio Hondo at Diamond A Ranch, nr Roswell, NM	30	16	2.0	2,650	8,210	16,000	34,000	58,300
08394500	Rio Felix at Old High-way Br, nr Hagerman, NM	35	42	2.5	5,780	16,200	23,100	30,200	34,200
08397400	Hyatt Cyn nr Cloud-croft, NM	16	6	.8	25	70	104	144	-
08397600	Rio Penasco nr Dunken, NM	13	43	2.1	2,270	7,310	16,200	44,000	-
08398500	Rio Penasco at Dayton, NM	18	24	1.0	2,920	9,200	16,000	26,200	38,500
08400000	Fourmile Draw nr Lakewood, NM	17	22	1.0	909	5,010	10,000	18,300	-
08401200	South Seven River nr Lakewood, NM	10	20	1.0	4,500	17,000	25,000	-	-
08401800	Rocky Arroyo nr Carlsbad, NM	13	105	4.0	4,170	12,400	20,900	35,200	-
08477200	Iron Cr nr Kingston, NM	10	4	.6	6	27	64	-	-
08477560	Little Walnut Cr nr Silver City, NM	15	21	.6	558	715	795	875	-
08477570	Silva Cr tr at Silver City, NM	16	19	.6	441	955	1,390	2,020	-
08478000	Cameron Cr at Central, NM	20	22	1.6	606	1,200	1,670	2,320	2,830
08478500	Mimbres R at Deming, NM	17	25	1.5	569	1,140	1,500	1,910	-
08480150	White Oaks Cyn nr Carrizozo, NM	15	42	1.1	1,610	3,200	4,720	7,310	-

Table 1.--Channel and streamflow characteristics for selected partial-record gaging stations and selected continuous-record gaging stations in New Mexico - Continued

Station Number	Station Name	Length of Record (year)	Channel Characteristics: Active channel width (ft)	Channel Characteristics: Active channel depth (ft)	Streamflow Characteristics: 2-year flood discharge (ft^3/s)	5-year flood discharge (ft^3/s)	10-year flood discharge (ft^3/s)	25-year flood discharge (ft^3/s)	50-year flood discharge (ft^3/s)
08480650	Minnie Hall Draw nr Three Rivers, NM	16	50	.8	991	1,910	2,830	4,480	-
08480700	Indian Cr nr Three Rivers, NM	17	18	1.4	172	487	784	1,250	-
08480900	Indian Cr at mouth nr Three Rivers, NM	12	20	1.5	361	727	1,080	-	-
08481000	Three Rivers at Three Rivers, NM	18	32	1.4	2,660	6,140	8,900	12,600	17,300
08481100	Tularosa Basin tr nr Three Rivers, NM	17	16	.9	510	1,290	1,950	3,000	-
08488500	Canon de Torreon at Torreon, NM	15	29	2.1	269	1,150	2,210	4,110	-
08489000	Canada de Leon nr Mountainair, NM	16	9	.8	31	205	490	1,200	-
09346200	Rio Amargo at Dulce, NM	17	22	1.2	1,010	1,530	1,940	2,520	-
09350800	Vaqueros Cyn nr Gobernador, NM	18	17	1.1	270	740	1,220	2,040	2,800
09355700	Gobernador Cyn nr Gobernador, NM	18	25	.6	680	1,180	1,640	2,420	3,100
09356400	Manzanares Cyn nr Turley, NM	18	30	1.0	375	795	1,230	2,020	2,850
09357200	Gallegos Cyn tr nr Nageezi, NM	22	10	.2	105	206	297	442	577
09367530	Locke Arroyo nr Farmington, NM	23	15	.9	119	242	370	600	860
09367840	Yazzie Wash nr Mexican Springs, NM	23	18	.9	390	755	1,000	1,290	1,480
09367860	Chusca Wash nr Mexican Springs, NM	25	28	.9	1,130	2,490	3,690	5,540	7,170
09367880	Catron Wash nr Mexican Springs, NM	18	86	2.5	1,710	3,420	4,650	6,220	7,600

Table 1.--Channel and streamflow characteristics for selected partial-record gaging stations and selected continuous-record gaging stations in New Mexico - Concluded

Station Number	Station Name	Length of Record (year)	Channel Characteristics: Active channel width (ft)	Channel Characteristics: Active channel depth (ft)	Streamflow Characteristics: 2-year flood discharge (ft^3/s)	5-year flood discharge (ft^3/s)	10-year flood discharge (ft^3/s)	25-year flood discharge (ft^3/s)	50-year flood discharge (ft^3/s)
09367900	Black Springs Wash nr Mexican Springs, NM	22	25	1.6	437	1,040	1,580	2,410	3,130
09367950	Chaco R nr Waterflow, NM	11	54	1.3	3,340	7,130	9,730	-	-
09387050	Galestena Cyn tr nr Black Rock, NM	17	13	1.0	195	378	503	652	-
09395400	Milk Ranch Cyn nr Ft Wingate, NM	16	22	1.4	57	245	465	930	-
09395600	Wagon Trail Wash nr Gamerco, NM	23	8	1.5	80	188	278	405	505
09430900	Duck Cr at Cliff, NM	17	48	.6	3,590	5,670	7,060	8,730	-
09431000	Gila R nr Cliff, NM	29	88	1.9	6,010	10,500	13,300	16,300	18,400
09442650	Romero Cr nr New Mexico-Arizona State Line, nr Luna, NM	16	6	.3	53	133	226	414	-
09442660	Trout Cr at Luna, NM	20	23	.9	136	402	710	1,280	1,880
09442690	Tularosa R nr Aragon, NM	8	9	.8	137	259	344	-	-
09442695	Negro Cyn at Aragon, NM	15	21	.9	201	855	1,700	3,390	-
09442700	Apache Cr nr Apache Creek, NM	17	20	.8	335	910	1,690	3,220	-
09442740	Tularosa R nr Reserve, NM	18	29	1.2	394	849	1,250	1,850	2,380
09444000	San Francisco R nr Glenwood, NM	45	64	1.8	2,500	4,250	6,000	10,000	16,000

"The active channel is the lower portion of the channel entrenchment in the flood plain that is actively involved in the transportation of water and sediment during the usual regimen of a stream. Depositional features within the active channel are altered and shifted regularly during the normal fluctuation of streamflow. Beyond the boundaries of the active channel, the geomorphic features are relatively permanent and generally are vegetated. The sides of the active channel occur as steeply sloping banks in straight reaches and as stabilized point bars on the inside or convex side of a channel bend. The reference point used in measuring the geometry of the active channel is selected at the upper edge of the banks or point bars where they abruptly change to a flatter slope. This reference point is above and shoreward from the reference point defined by the lowest channel bars. Annual vegetation generally is present above the reference point and can often be used as a clue in identifying this point. However, judgment is required in using the vegetation line as a guide. In regions where high flows are infrequent, some grasses and sedges may grow part of the way down the banks or even into the water. On the other hand, in extremely arid regions the banks may be completely devoid of vegetation."

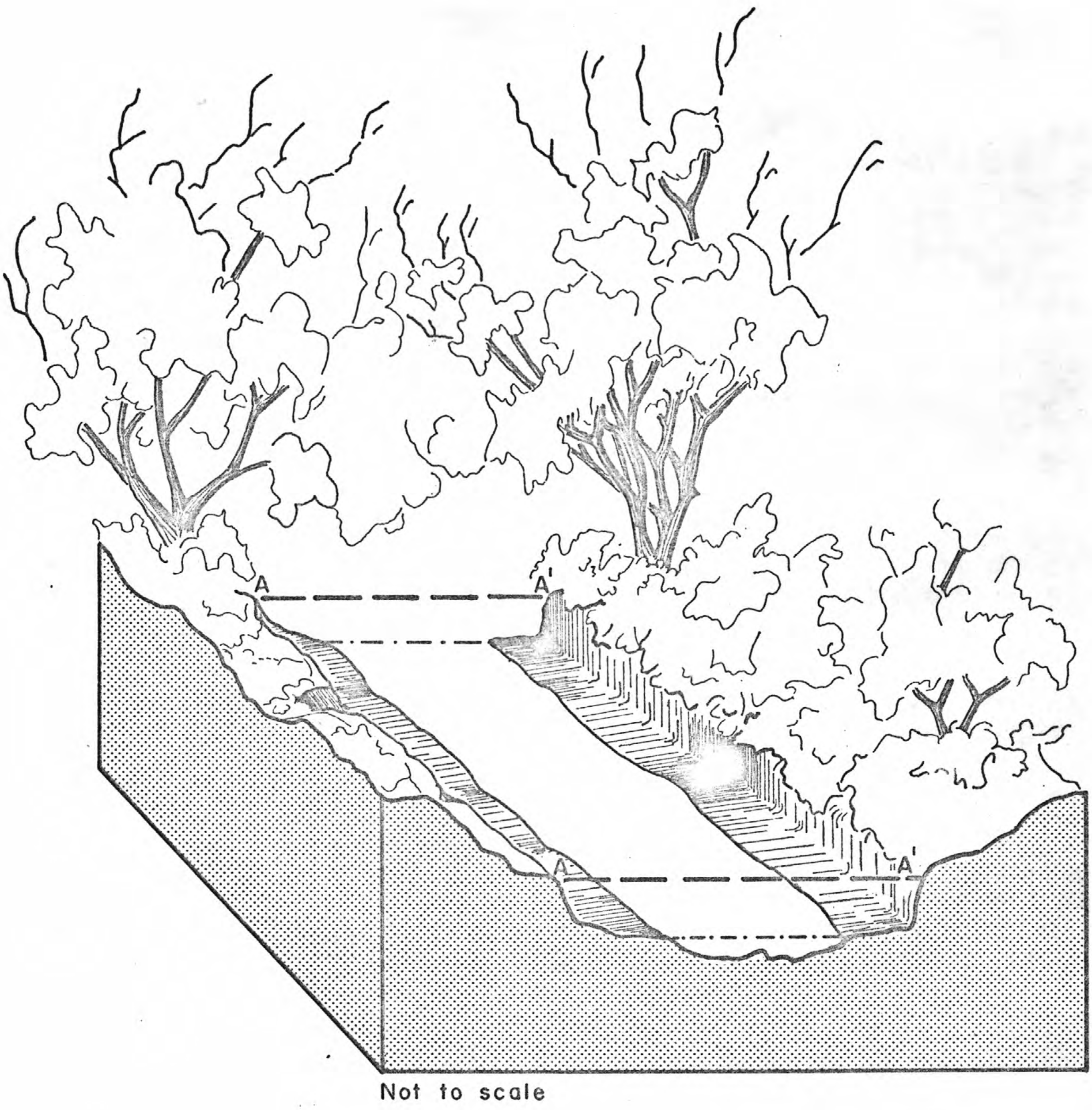
Because of the diversity of stream-channel morphology in New Mexico, it is to be expected that the features forming the active channels will vary with location and even with flow regimen.

The features given by Hedman and others (op. cit.) are shown in figure 2 and these features were used when they were present. If these features or others subsequently described were present on both sides of the channel, the measurement of a reference width and mean depth was simple. A tape measure or tagline was stretched across the active channel, the width was recorded, and the mean depth was calculated as the average of depths at about 10 equidistant intervals. If there was a distinguishing feature on one side of the channel but none on the other side, and a more suitable reach was not discovered, the tape or tagline was set at the top of the distinguishing feature and stretched level across the channel to the point of intersection with the channel bank. It should be noted that selection of the active-channel reference point requires training and experience.

Within a selected reach measurements were made, if possible, at two or three cross sections located a stream width apart and then the results averaged.

The average width and depth measured near each gaging station are shown in table 1.

At some sites there were successive sets of lateral bars that might be used for defining the active channel, and this situation posed the question of which set should be used. This question was usually resolved by arbitrarily picking the lowest prominent set. In most of these cases, the selection of other sets would have greatly changed the measured mean depth, but would have had relatively little effect upon the value of the reference width.



EXPLANATION

A — A' Active-channel reference width

—·—·— low-flow water level

Figure 2.--Block diagram showing active-channel and reference width. (Modified from Hedman and others, 1974.)

The active channel was defined frequently by a more or less smooth line of vegetation on one or both sides; and more often than not, this line conformed with the edge of a lateral channel bar. At mountainous or foothill sites the channels were often floored with cobbles or boulders, and if the boulders were not greater in diameter than about 10 percent of the width of the channel, they presented no difficulty in defining reference channel widths. At several such sites the edge of the active channel was defined by a difference in the amount of scouring between cobbles or boulders. Both conditions existed. At places, the active channel contained more fine material than the edges, and at other places it contained less of this than the edges. Generally, these edges also had other distinctive features such as vegetation or raised lateral bars.

A few arroyos had none of the distinctive features which were used for defining the active channel; and with few exceptions, these channels were entrenched within nearly vertical banks of alluvium. The channel floors were composed mostly of sand or silt better sorted than the material forming the arroyo walls. At these sites the active channel was measured as the distance between arroyo walls and at a height generally less than 1 foot (0.3 m) above the channel floor.

Some channels containing perennial streams provided an active controversy on the definition of the active channel. Most of the confusion caused at these sites was due to the formation of wide pools between relatively narrow reaches of moving water. At many sites on perennial streams it was decided that the waters edges defined the active channel, but in general higher features were used for this reference.

Photographs of active channels measured at sites in New Mexico are shown in figures 3 through 6. These sites are not typical of all streams in New Mexico but were chosen because of the clarity of the photographs in illustrating the channel features which define the active-channel width.

METHOD OF ANALYSIS AND RESULTS

Each of the flood discharges of a given recurrence interval was relations to channel and basin characteristics by using step-backward multiple-regression techniques. Computations were made by use of a digital computer. The resulting equation has the form $Q_t = aW^b$, where "Q_t" is a flood discharge of "t" recurrence interval, "W" is channel width, "a" is the regression constant, and "b" is a regression exponent. A summary of the regression equations is shown in table 2.

Figure 3.--Active-channel width at ungaged stream site near Hospah, N. Mex. White line indicates width of active channel.

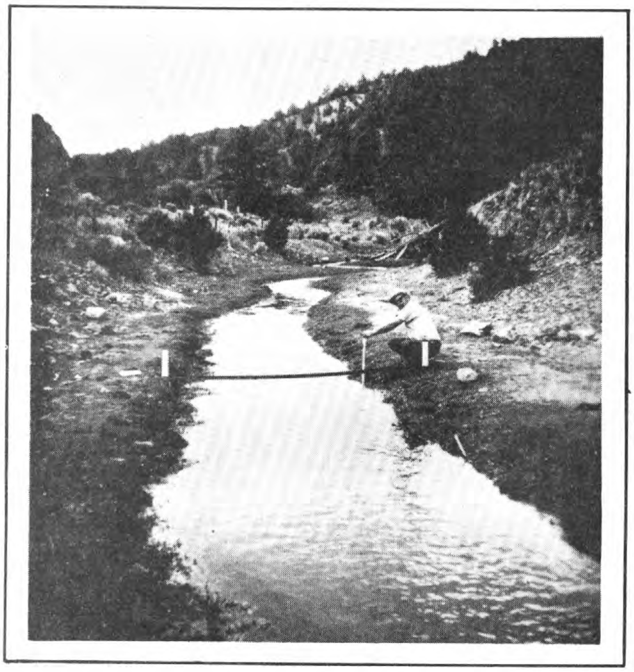


Figure 4.--Active-channel width near gaging station 09442692, Tularosa River above Aragon, N. Mex. Limits of active channel are indicated by white vertical lines.

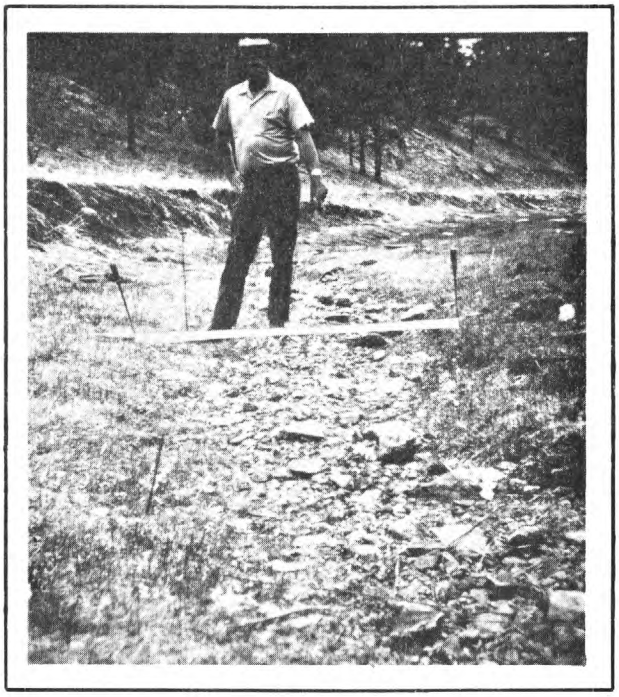


Figure 5.--Active-channel width near gaging station 09442650, Romero Creek near New Mexico-Arizona State line near Luna, N. Mex. White line indicates width of active channel.

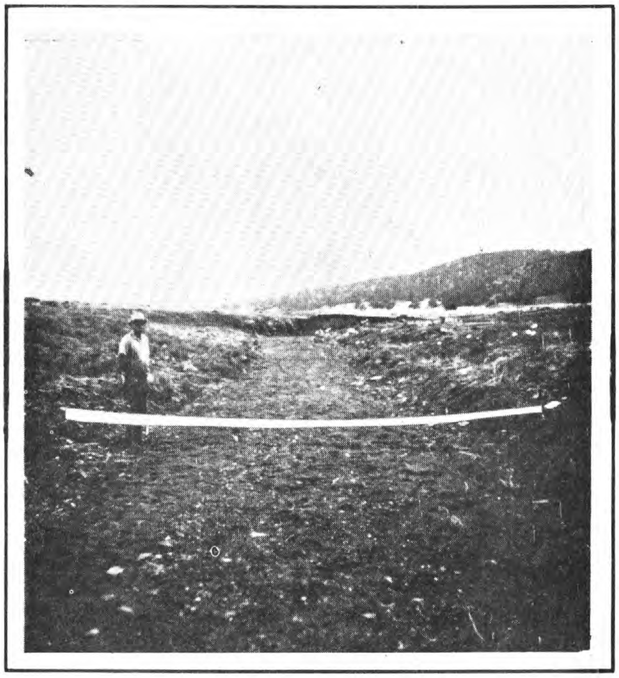


Figure 6.--Active-channel width near gaging station 09442695, Negro Canyon at Aragon, N. Mex. White line indicates width of active channel.

Table 2.--Summary of regression equations relating floods of various recurrences (Q_t) to active channel widths (W) for 79 stream sites in New Mexico $Q_t = aW^b$

[Values for exponents statistically significant at the 1 percent level.]

Recurrence interval, T, in years	Basin characteristics included	Regression constant		Exponent of channel characteristic	Standard error of estimates			
		Log a	a	Width (b)	Log units	Positive (percent)	Negative (percent)	Average (percent)
2	-	-	-	-	X0.684	383	79	231
	W	0.2308	1.70	1.67	.326	112	53	82
5	-	-	-	-	X .614	311	76	193
	W	.7680	5.86	1.55	.259	82	45	63
10	-	-	-	-	X .592	291	74	183
	W	1.036	10.9	1.49	.256	80	45	62
25	-	-	-	-	X .579	279	74	176
	W	1.326	21.2	1.42	.278	90	47	68
50	-	-	-	-	X .578	278	74	176
	W	1.519	33.0	1.37	.304	101	50	76

X Standard deviation of logs of dependent variable.

Mean depth was not found to be statistically significant at the 1-percent level in these relations.

Table 3 shows a comparison of the results of a regression analysis utilizing basin characteristics (Scott, 1971) and the results of this investigation. It should be noted that the basin characteristics can all be determined from maps, whereas the channel characteristics must be measured in the field. Also the standard errors of the two sets of relations are not directly comparable because of errors in the dependent variables.

These relations may be used to estimate floods of a given recurrence interval. For example:

The flood discharge with a 50-year recurrence interval, (Q_{50}), is desired for a site in New Mexico.

1. From table 2, $Q_{50} = 33.0\ W^{1.37}$.
2. From a field measurement at the site, active-channel width is determined to be 38 feet.
3. $Q_{50} = 33.0(38)^{1.37} = 33.0(146) = 4{,}820\ ft^3/s$.

Limits of definition

Because regression equations do not necessarily represent actual physical relationships, they should not be applied outside the range of data from which they were developed. The extremes of the channel characteristics used to develop the relations in table 2 are given below:

	Minimum	Maximum
Active-channel width (W)	4 feet	154 feet

Anomalous stream morphology of southeastern New Mexico

Stream morphology is diverse in New Mexico because of the great variety of bedrock, the large range in annual precipitation, intensity of precipitation, topography, and many other related factors. Extremely youthful stream channels appear to be the rule and mature channels are rare. There are large areas, particularly in the northeast, where the absence or sparcity of stream channels is puzzling,

Table 3.--Comparison between regression equations utilizing basin characteristics and regression equations utilizing channel characteristics for New Mexico

Recurrence interval, in years	Regression based on basin characteristics		Regression based on channel characteristics	
	Significant variables	Standard error in percent	Significant variables	Standard error in percent
2	Area, mean altitude, shape, storage	112	Channel width	82
5	do.	97	do.	63
10	do.	97	do.	62
25	Area, mean altitude, shape, storage, precipitation (Oct-Apr), 2-yr, 24-hr rainfall intensity	99	do.	68
50	do.	102	do.	76

and there are many areas where streams have rapidly entrenched alluvial flood plains within the last century. Kirk Bryan (1925, p. 1) wrote of the alluvial entrenchment "....although subject to great floods, these streams no longer overflow their banks, nor build up their adjacent flood-plains...." "It is evident to all observers that the formation of the channel trenches is recent [because] early settlers in the region can remember the time when many of these valley flood plains were intact and the floods spread widely. At that time, meadows, belts of cottonwood or willow trees, and even swamps characterized the floors of the valleys that now support only scattered sage, greasewood, or mesquite."

Many investigators have studied the causes of this phenomenon, and the suggested reasons range from cyclic climatic changes, overgrazing, and recent uplifting, to the drainage of alluvial aquifers. Most of these problems were recognized at the outset of this study, and for this reason the writers often worked with more skepticism than enthusiasm.

When the data of this study were analyzed and the residuals of the multiple-regression equations were plotted on a map, there was a statistical bias for many stream channels in the southeast. These data were reanalyzed separately and the results showed no statistical relation between W and Q_t.

The characteristics common to the channels in this area were that they were all deeply entrenched in alluvium and the reference widths were generally narrower than expected from the average regional relation between W and Q_t. In general, the reliability of this relation worsened with the depth of entrenchment. This suggests that entrenched channels should be separately classed for studies of this type and that some additional channel parameter should be included in the multiple regression relation. Entrenched alluvial channels are usually recognizable because of their near vertical banks, and in extreme cases the depth of the banks are approximately equal to the width. Even to the untrained eye they appear to be only a temporary compromise with nature.

Many of these entrenched channels have formed on flat alluvial valleys where it is possible to measure or estimate the depth of entrenchment. It was suspected that if this parameter is measured or estimated and used in a multiple regression equation either independently or as a product of the depth of entrenchment times the reference width, a reliable relation between the channel geometry and the magnitude of floods of various recurrence intervals could be obtained. However, when the depth-of-entrenchment parameter was used, no statistically significant relation was defined. Because of this, the relations developed for the rest of New Mexico should not be used in this area as shown on figure 1. However, the relations may be used in the higher mountainous area of this region as shown on figure 1.

The fact that channel geometry did not provide satisfactory estimates of Q_t in a large area of southeastern New Mexico is puzzling. One reason may be the occurrence of channel entrenchment; however, the problem must be more complex and involve other factors because many entrenched channels elsewhere in the State do not pose the same problem. Additional or alternate factors that may be related to the poorly defined relationship were studies.

It is well known that the moisture in most of the large storms originates in the Gulf of Mexico and that this source of moisture is less important in storms for most other areas of New Mexico. Summer and autumn thunderstorms probably are heavier and more intense than in other mountainous areas (Miller and others, 1973) and this is reflected in the magnitudes of floods of various recurrences. We know of no evidence, however, that these large storms are increasing in either magnitude of precipitation or frequency of recurrence. Bachman (1974, p. 65) writes that the water levels of many playas of the area are much lower than formerly, suggesting a trend toward a drier climate.

It was reasoned that if the problem is not due to climatic changes, it might be related to geological factors. The geology of this area has been intensely studied and many features are known to have affected stream entrenchment. Some large faults have been active until at least Pleistocene time, and there are several pediments and terraces that have been cut by the Pecos River at later times. The Pecos River valley is known to be subsiding due to solution collapse but Bachman (1974, p. 71) estimates the subsidence at Nash Draw, one area that is subsiding most rapidly, at about 1 centimetre per century.

When these geological factors were analyzed it was decided that all were insufficient to account for the rapid alluvial entrenchment. Attention was then focused on the possibility that the phenomenon was due to civilized man's activities.

For various reasons civilization came late to this area. According to Fulton (1954, p. 176-182), the first permanent settlements were made during the construction of Fort Stanton (1855-56), and thereafter civilization expanded rapidly. Gold was discovered at Baxters Mountain in 1878 and within a few years the town of White Oaks was founded and grew to a population of more than 2,000. Placer gold was mined in the alluvium of arroyos in the Jicarilla Mountains (Griswold 1964, p. 148), and perhaps the alluvium of other stream channels was explored for this commodity.

Throughout much of this area the only water supply available to early settlers was from streams and the associated perched alluvial aquifers, and it is supposed that this supply was heavily utilized for domestic, industrial, and agricultural purposes. The amount of available water was never great and the heavy exploitation must have greatly and rapidly depleted the alluvial aquifers.

According to Renick (1926, p. 131) one reach of the Rio Peñasco, now entrenched, was formerly a swamp that was deliberately trenched to obtain a water supply. Recent entrenchment of alluvial channels in the southwestern part of New Mexico is described by Trauger (1972, p. 45) who noted that the entrenchment was accompanied by a lowering of the water table in alluvial aquifers: no data were available for these entrenched streams described by Trauger.

It was noted during this study that stream entrenchment was often in areas where alluvial aquifers have been heavily utilized, or where the normal base flow which contributes recharge to the aquifers has been utilized. Either situation can lead to the dewatering of perched alluvial aquifers and, once dewatered, erosion can proceed rapidly.

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