AREAL EXTENT OF INTENSE RAINFALLS, NEW MEXICO AND ARIZONA

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The occurrence of intense rainfall covering relatively small areas is a distinctive feature of summer precipitation in the southwestern States. In the design of engineering structures commanding small watersheds, the chance of experiencing one of these cloudbursts over the drainage area is one of the governing factors. Owing to the small areal extent of these rainfalls of high intensity and to the long distances between rain-gages, it is seldom that more than one rain-gage is covered and the net result is a dearth of information on the subject of areal pattern.

In this discussion, the storms of high intensity rainfall which have been centered over a watershed in such a way as to be diagnostic of the areal extent, are described.

Storm of Las Cruces, New Mexico, August 29-30, 1935--Rainfall measured by the intensity-gage at the New Mexico State Agricultural College just south of the City started at $23^h\ 05^m$, August 29, and had totaled 5.85 inches by $02^h\ 25^m$. The rain in the City was said to have started about $22^h\ 30^m$. Flood-water began flowing into Las Cruces from the mesa east of the City shortly after $01^h\ 00^m$, and a large part of the City was inundated within an hour. Water reached a depth of four feet over a considerable part of the residential district and more than 100 houses were destroyed or damaged.

Heavy rains fell during the same night on the watersheds of Santa Teresa Arroyo, Spring Arroyo, and Broad Canyon, all near Hatch, New Mexico, and rains occurred in the Rincon Arroyo Basin. The heaviest storm in the memory of old settlers occurred east of and near the Organ and San Andreas Mountains during the same night.

From investigation of rain-water collected in cans, tubs, and other containers, H. W. YEO [see 1 of "References" at end of paper] constructed a map of the extent of the rainfall which is presented in Figure 1. The recorded rainfall at surrounding stations is shown in Figure 2.

Storm of Parker Creek, Arizona, August 5, 1939--An unusually high rainfall occurred at Parker Creek (Sierra Ancha), the field-post of the Southwestern Forest and Range Experiment Station, 48 miles northeast of Globe, Arizona, August 5, 1939. Due to the concentration of rain-gages at the station, an isohyetal map of the rainfall could be drawn and is presented in Figure 3.

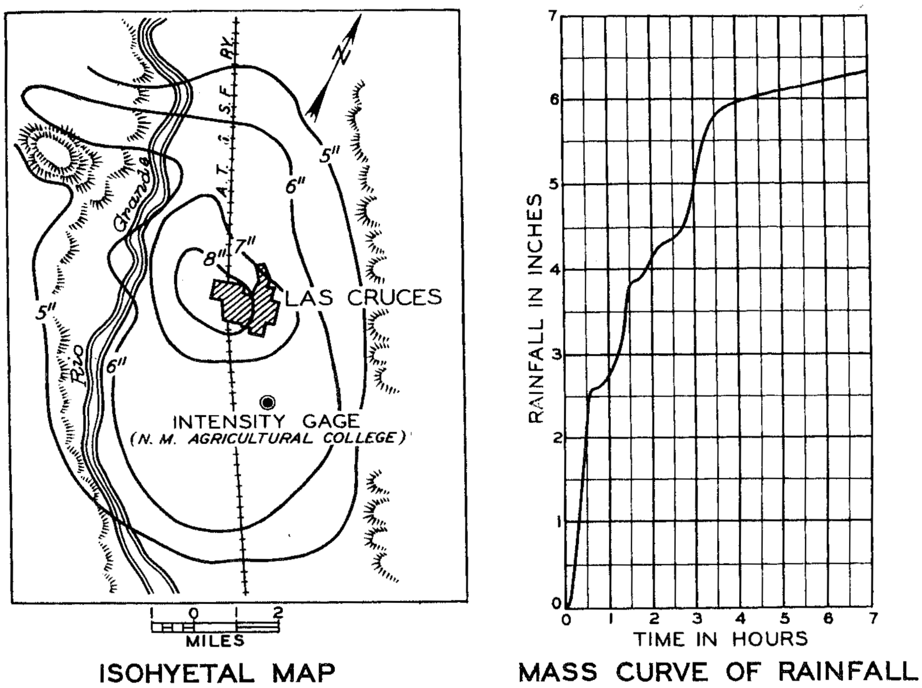

Fig. 1--Areal extent and intensity of storm-rainfall, August 29-30, 1935

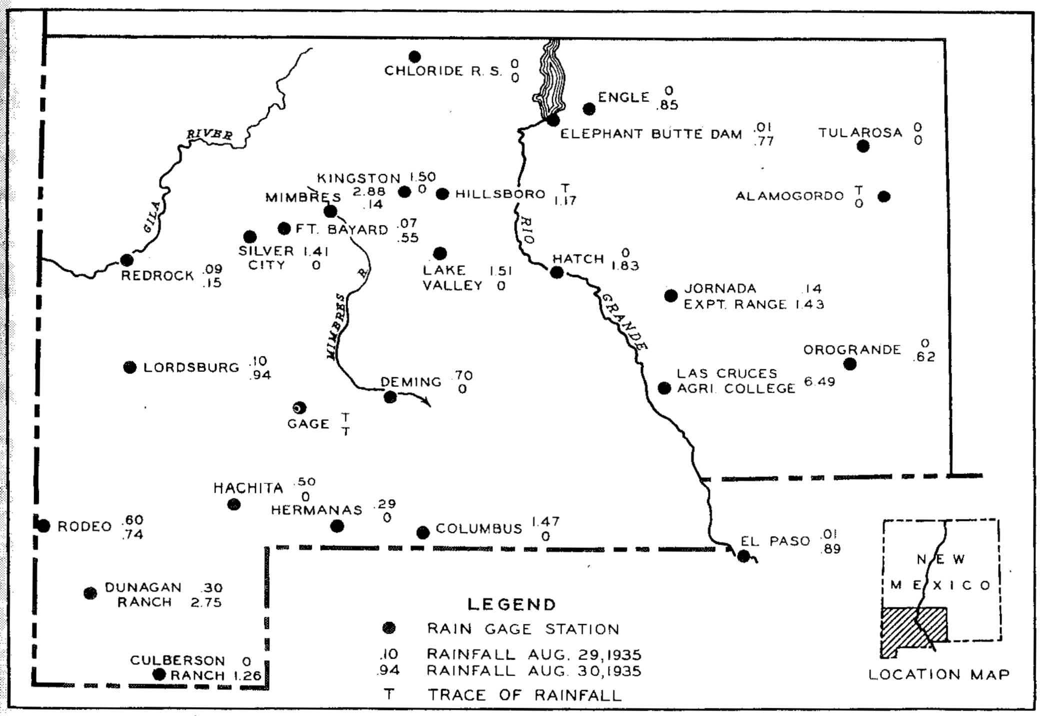

Fig. 2--Rainfall accompanying Las Cruces storm, August 29-30, 1935

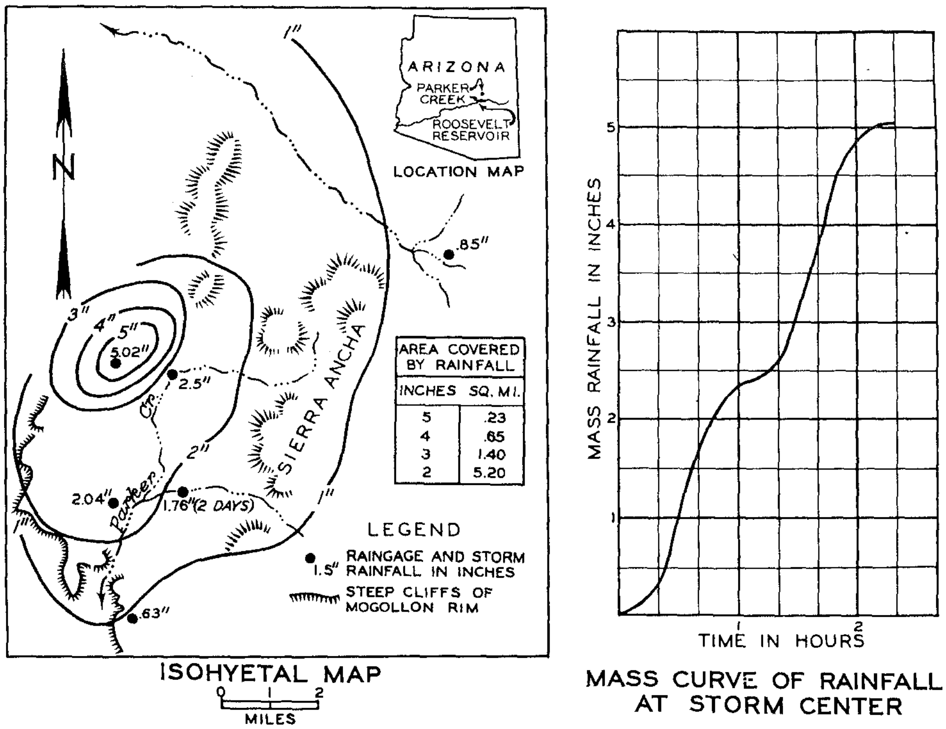

Fig. 3--Storm of August 5, 1939, Parker Creek, Arizona

Storm of Thatcher, Arizona, September, 1939--A high rainfall centered over the numerous rain-gages in the vicinity of Thatcher, Arizona, September 16, 1939. A field-investigation permitted the construction of an isohyetal map, and observations by local people provided some data on storm-movement, particularly time of beginning of rainfall. These data are included in Figure 4. An intensity-gage located about five miles from the storm-center furnished the intensity-pattern presented in Table 1.

Storm of August 12-14, 1940, New Mexico and Arizona--The storm which occurred in southwestern New Mexico and southern Arizona during the afternoon of August 13, 1940, has been described in detail in an excellent report of the United States Engineer Office [2]. Precipitation was general over a large area but the occurrence of very heavy rainfall at high intensity was spotty and confined to relatively small areas. The report of the United States Engineer Office summarized the meteorologic causes of the storm-rainfall as follows:

> "The rainfall apparently was the result of the convergence and weak frontal activity which supplied the necessary 'trigger action' to release the potential energy in the warm air. The resultant convection explains the spotty nature of the rainfall in areas where orographic influence was absent."

There were four widely separated storm-centers in this storm, located near Rodeo (New Mexico), Tumacacori Mountains (Arizona), Tucson (Arizona), and Tombstone (Arizona). The total storm-rainfall at the storm-center was more than four inches near Rodeo, and five inches in the Tumacacori Mountain Area, but in neither of these localities was there an intensity-gage.

Depth-area curves--For the storms described above, sufficiently detailed isohyetal maps are available to warrant the construction of depth-area curves which are presented in Figure 5. In addition, a storm measured at Navajo Experiment Station, Mexican Springs, New Mexico[3], is included. This experimental center of the Soil Conservation Service maintains a large number of standard and recording rain-gages and will in the future provide isohyetal maps of storm-rainfall to greatly augment the data on areal pattern of local storms in the southwest, but unfortunately up to 1940, no very intense rainfalls totalling relatively large amounts of precipitation have occurred over the rain-gages.

Table 1--Rainfall-intensity record at Freeman Flat near Safford, Arizona, September 16, 1939

Time	Minutes, cum.	Inches, cum.	Time-increment	Intensity
h m			min	in/hr
09 48 PM	0	0.00		
			2	3.00
09 50	2	0.10		
			5	2.40
09 55	7	0.30		
			5	1.68
10 00	12	0.44		
			5	2.52
10 05	17	0.65		
			5	2.76
10 10	22	0.88		
			5	1.68
10 15	27	1.02		
			5	1.44
10 20	32	1.14		
			5	0.48
10 25	37	1.18		
			5	2.40
10 30	42	1.38		
			5	2.04
10 35	47	1.55		
			5	1.44
10 40	52	1.67		
			5	0.72
10 45	57	1.73		
			5	0.12
10 50	62	1.74		
			20	0.09
11 10	82	1.77		
			25	0.02
00 35 AM	107	1.78		
			5	0.60
00 40	112	1.83		
			50	0.08
01 30	162	1.90		

The depth-area curves of Figure 5 are approximately parallel with the exception of that curve for the Mexican Springs storm. Due to the exceptionally large number of gages recording the latter storm, the isohyetal pattern is better defined than for the other storms. It may be that the other curves would also tend to flatten toward the left as does the curve for the Mexican Springs storm if the data were more complete. From the few depth-area curves available for this type of storm it appears that for purposes of design, an areal pattern for any storm can be derived if the maximum rainfall at the storm-center is given. This maximum may be determined by drawing rainfall-frequency curves for stations near the watershed under consideration, choosing a value of total rainfall for design purposes. Then a depth-area pattern may be obtained by interpolating a line parallel to the curves presented in Figure 5. Due to the meager data such a depth-area pattern would be a rough approximation which can be improved upon by more records of cloudburst-storms.

Intensity-time patterns for such storms are much better defined than depth-area curves owing to the records of automatic rain-gages which have been in operation in the southwestern States, particularly during the period since 1939. The intensity-time patterns for summer-type, local storms are very similar even for storms occurring in widely separated areas all over New Mexico and Arizona [4]. The highest intensity ordinarily comes at or immediately after the beginning of rainfall and tends to decrease during the storm.

Additional records of areal extent of cloudbursts--In some cases, the discharges from various tributaries of a watershed make it possible to determine approximately the areal extent of an intense storm. For example, on September 20, 1941, a thunder-storm centered over Las Calabacillas Arroyo about eight miles north of Albuquerque, New Mexico. No rain-gages were near the storm-center, but there were sufficient gages near the borders of the storm to show the maximum area covered. The highest precipitation was estimated to be over four inches, most of which fell in less than an hour. The storm covered less than 80 square miles and a peak-discharge of 10,000 cfs

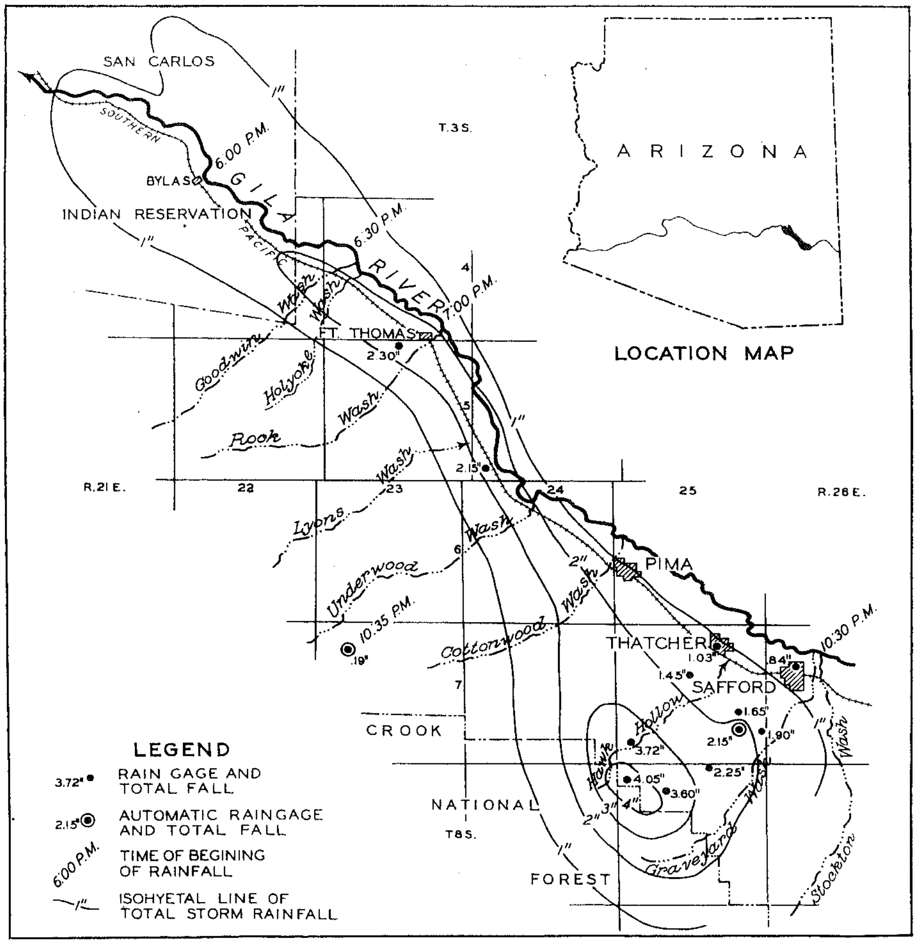

Fig. 4--Areal extent of rainfall near Thatcher, Arizona, September 16, 1939

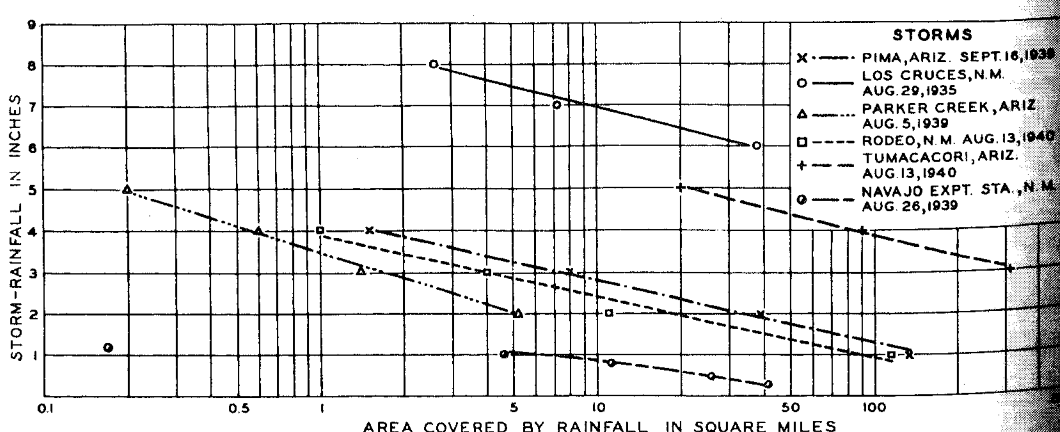

Fig. 5--Depth-area curves for local summer storms, New Mexico and Arizona

was estimated at a point commanding approximately 70 square miles. This flood deposited more than 250 acre-feet of sediment in a fan at the mouth of the wash.

On August 20, 1935, a cloudburst centered over two small ephemeral washes north of Cochiti Pueblo, New Mexico. The peak-discharge was estimated to be 4100 cfs from one wash having a drainage-area of 0.80 square mile and 2000 cfs from the adjacent watershed having a drainage-area of 0.84 square mile [5]. The estimates of flow were made from high-water marks after the flow had ceased and are, therefore, subject to the error inherent in such estimates. The exact areal extent of the heavy rainfall cannot be determined. The nearest rain-gage at Frijoles Canyon, 15 miles north of Cochiti, recorded 2.50 inches on August 20. Alamos Ranch, 20 miles north, recorded 1.46 inches, and Lee Ranch, 15 miles northwest, recorded 1.10 inches. No other stations in the region showed appreciable rainfall. This indicates that an area roughly 20 miles in a north-south direction by 15 miles in an east-west direction received over one inch of rainfall, and the storm-center must have received well over three inches.

Another example of the local nature of the high rainfall of the convective thunder-storms in summer is the rain at Cerro, New Mexico, August 17, 1922. At this station 7.5 inches fell in four hours, yet surrounding stations showed no exceptional precipitation.

Such a rainfall-pattern is common in the Southwest, and, therefore, few heavy rains center over more than one or two rain-gages. Figure 2 shows a typical condition in which one station, Las Cruces, received a heavy rain, 6.49 inches as a total for two days, but most of which fell in three and one-half hours late in the night of August 29. The rainfall-quantities at other stations in the region as shown by Figure 2 indicate the local character of the intense precipitation. To construct an isohyetal map for the whole State for such a storm would be misleading since, owing to the scarcity of gages, the local nature of the storm-centers would be obscured.

Rainfalls lasting over a series of days as in the storms of May 20-28, 1941, in southeastern New Mexico and September 20-24, 1941, in eastern New Mexico, cover much larger areas than the local convective storms discussed in this paper. In general, the intensity of rainfall in the widespread storms is not as high as in the local cloudbursts. For small watersheds, the highest discharges result from the local high-intensity storms, and for such occurrences, the depth-area curves presented in this discussion are applicable.

References

[1] H. W. YEO, Report on the rains of August 29-30, 1935, in Las Cruces, New Mexico, and vicinity, and the flood resulting therefrom, Soil Cons. Serv., unpublished report, Albuquerque, New Mexico, May 6, 1936.
[2] Hydrologic data, storm of August 13-14, 1940, Arizona and New Mexico, U. S. Eng. Off., Los Angeles, California, mimeo. rep. September, 1941.
[3] Progress report of the Navajo Soil and Water Conservation Experiment Station, Mexican Springs, New Mexico, 1934-1939, Soil Cons. Serv. mimeo. E.R.S. report, p. 49, March, 1941.
[4] L. B. LEOPOLD, Characteristics of high rainfall in New Mexico and Arizona, unpublished MS.
[5] H. W. YEO, Report on the rains of August 20, 1935, in the northern part of the Rio Grande Basin in New Mexico, and the floods resulting therefrom, Soil Cons. Serv., unpublished rep., May 6, 1936.

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DISCUSSION

L. L. HARROLD (Soil Conservation Service, Washington, D. C.)--The areal extent of storms, time-area-depth relations, and recurrence-intervals (commonly called "frequency") have been the subject of much discussion. Many have devised frequency-depth relationships for point-rainfall records. Some have applied point-rainfall frequency-depth relationships to large areas. Others have worked entirely with the areal distribution of the storm and its relative position on the area under study. Few have combined recurrence-interval with area and depth of storm.

The author has presented the data for five intense storms in the arid Southwest, including tables, isohyetal maps, and time-depth curves. This in itself is a contribution. He then prepares area-depth curves for each storm and proposes to use these in connection with depth-recurrence-interval curves for rainfall-stations near the watershed under study in order to develop a depth-area pattern.