

VARIATIONS IN PRECIPITATION FROM THUNDERSTORMS
IN THE SOUTHWEST ^{1/}

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ABSTRACT

The Southwest Watershed Research Center of the Agricultural Research Service maintains dense networks of recording rain gages on the 67-square-mile Alamogordo Creek watershed in eastern New Mexico and the 58-square-mile Walnut Gulch watershed in southeastern Arizona. On the Walnut Gulch watershed, for 11 years of record, point intensities for 5-minute periods sometimes approached 10 inches per hour; on Alamogordo Creek, they have exceeded 15 inches per hour. During two exceptional storms in 1960 and 1961 on the Alamogordo Creek watershed, over 3 inches of rain, or hail, fell in 15 minutes. No storms on Walnut Gulch have approached the magnitude of these two events. On the Walnut Gulch watershed, the runoff-producing portion of most thunderstorms lasted for less than 15 minutes and covered less than 5 square miles. For over 90 percent of the storms, heavy rainfall lasted for less than 30 minutes. Duration and areal extent of thunderstorms on Alamogordo Creek are similar to those on Walnut Gulch.

INTRODUCTION

In summer, under certain atmospheric conditions, moist air flows into the Southwest from the Gulf of Mexico. This flow may continue for days, depending upon the relative position of a high-pressure ridge over the central-western United States, and a corresponding low-pressure trough over northern Mexico (Fig. 1). A combination of strong convective heating, orographic influences, and occasional frontal activity may lift the moist air to form thunderstorms. These thunderstorms generally occur in the late afternoon and early evening and are of short duration and limited areal extent. They produce the largest peaks and volumes of runoff from small drainage areas (50 square miles or less) in the Southwest.

EXPERIMENTAL WATERSHEDS

The Southwest Watershed Research Center of the Agricultural Research Service, in its study of water yield from semiarid rangelands, maintains dense networks of recording rain gages on the 58-square-mile Walnut Gulch watershed in southeastern Arizona, and on the 67-square-mile Alamogordo Creek watershed in eastern New Mexico (Fig. 2). There are 92 weighing-type, recording rain gages on the Walnut Gulch watershed, and 65 on the Alamogordo Creek watershed (Fig. 3).

VARIATION IN THUNDERSTORM PRECIPITATION

The Walnut Gulch watershed represents a region in the Southwest where almost all thunderstorms result from purely convective heating; whereas the Alamogordo Creek watershed represents a region where thunderstorms form from combined convective heating and frontal activity, as well as from purely convective heating. Primarily because of the added lift from the occasional weak, summer cold fronts that move across eastern New Mexico, higher intensities and greater volumes of precipitation for individual storms have been measured on the Alamogordo Creek watershed than on the Walnut Gulch watershed. Also, Alamogordo Creek is closer to the primary summer source of moisture, the Gulf of Mexico.

^{1/} Contribution of the Southwest Watershed Research Center, Soil and Water Conservation Research Division, Agricultural Research Service in cooperation with the Agricultural Experiment Stations of the University of Arizona and New Mexico State University.

FROM DAILY WEATHER MAP, U.S. WEATHER BUREAU

SURFACE WEATHER MAP - Saturday, July 30, 1966

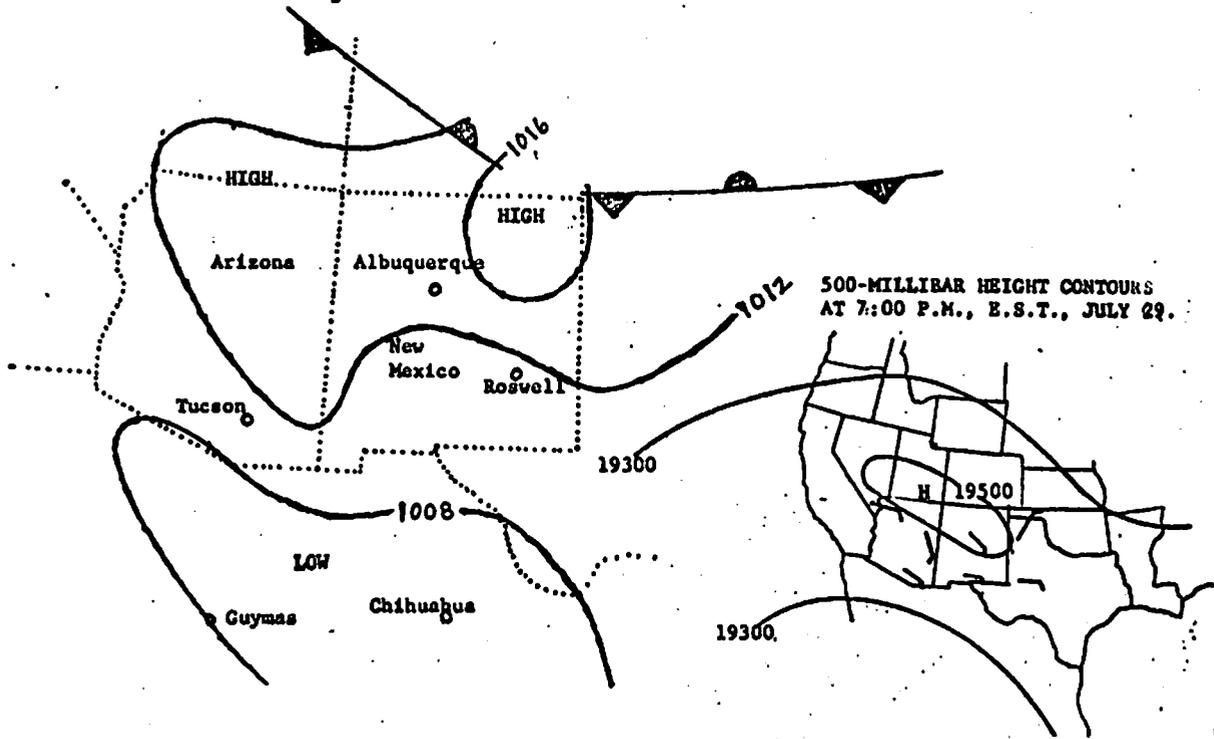
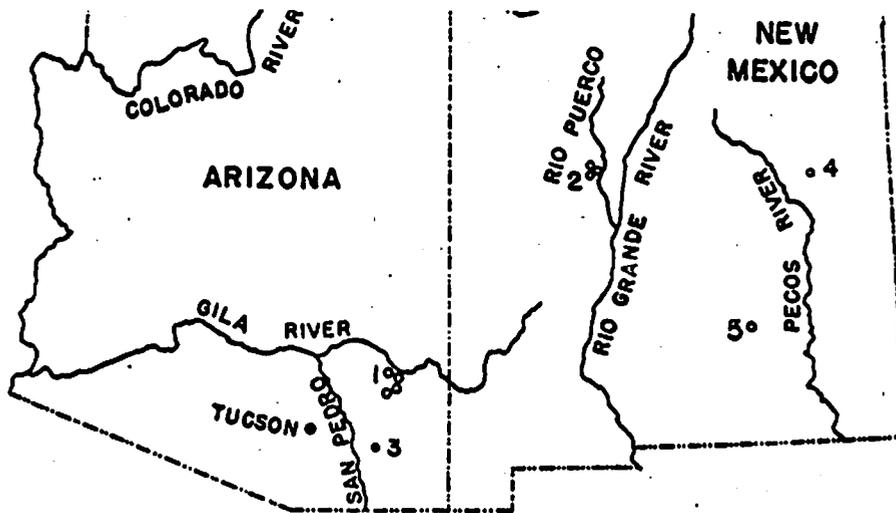
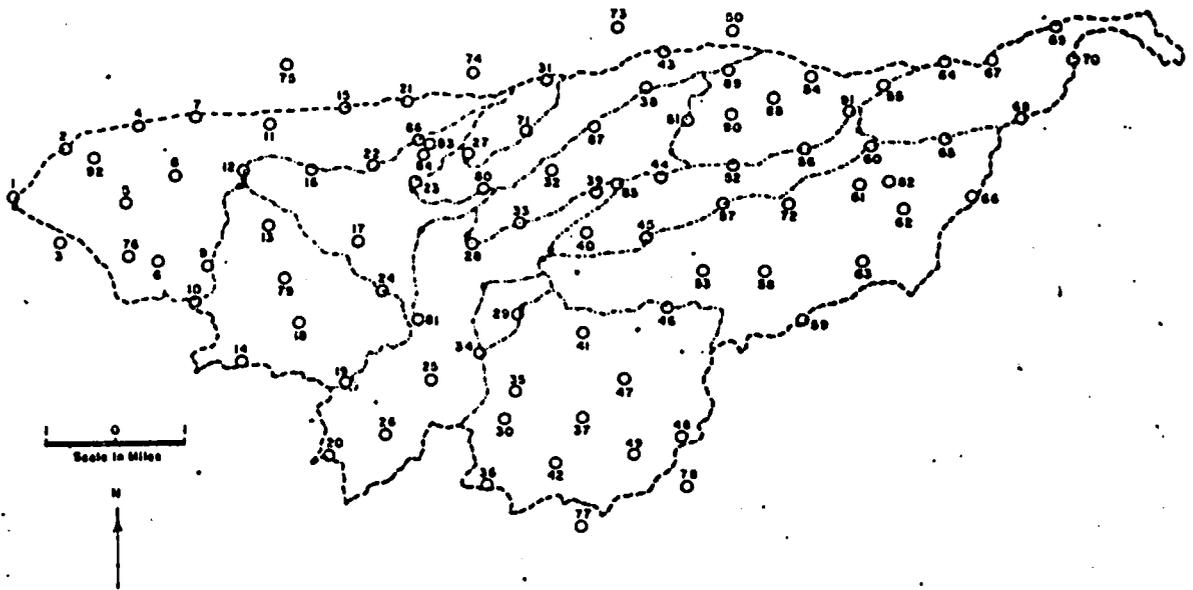


Figure 1.

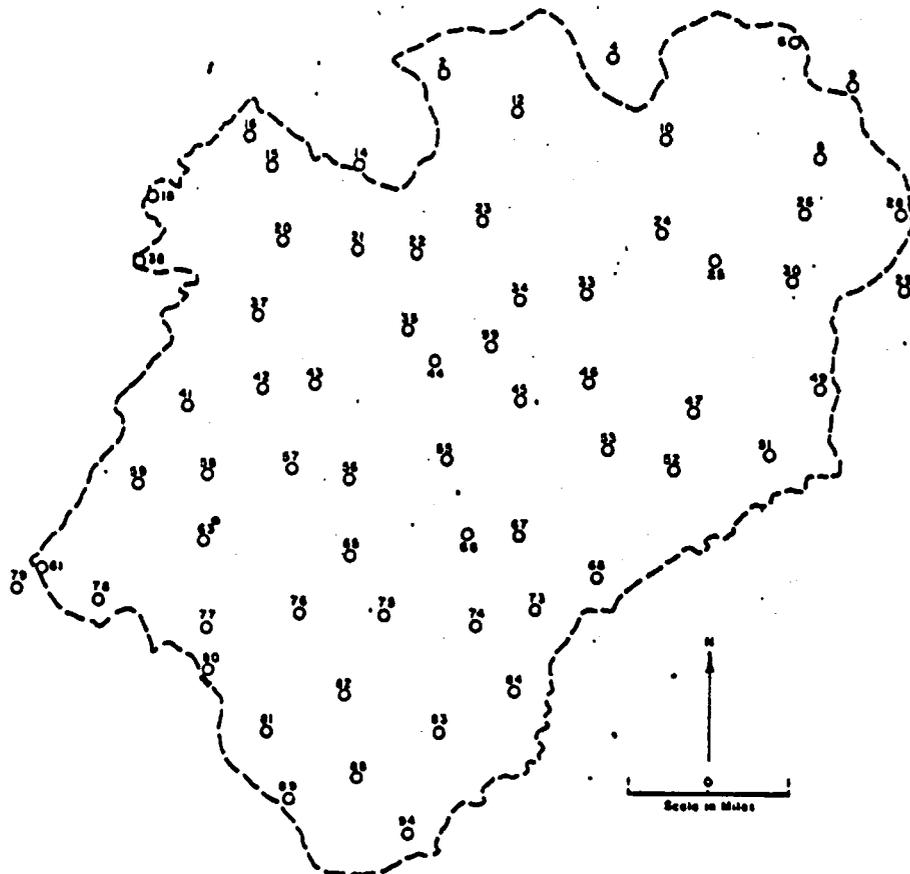


1. SAFFORD, ARIZONA
 2. ALBUQUERQUE, NEW MEXICO
 3. WALNUT GULCH nr TOMBSTONE, ARIZONA
 4. ALAMOGORDO CREEK nr SANTA ROSA, NEW MEXICO
 5. FORT STANTON, NEW MEXICO
- LOCATIONS OF EXPERIMENTAL WATERSHEDS**

Figure 2.



WALNUT GULCH WATERSHED
RAIN GAGE NETWORK



ALAMOGORDO CREEK WATERSHED
RAIN GAGE NETWORK

Figure 3.

Measurement Limitations:

Even with dense networks of rain gages covering many square miles, such as those on the Walnut Gulch and Alamogordo Creek watersheds, it is unusual to record the complete precipitation pattern from individual thunderstorms. Most thunderstorms are multicellular systems that occur partially on and partially off the watersheds. Therefore, the measured areal extent of the runoff-producing rainfall is the area within a defined watershed boundary, and not the total area receiving runoff-producing rainfall. Radar was installed on Walnut Gulch several years ago, primarily to help in determining the total areal extent of runoff-producing rainfall from individual thunderstorms. Unfortunately, because of the rugged topography and the basic problems in quantitative determination of rainfall with radar, our radar has not helped to solve this problem.

Normal Variations:

On the Walnut Gulch watershed, intensities for 5-minute periods sometimes approach 10 inches per hour; on the Alamogordo Creek watershed, they may exceed 15 inches per hour. On Walnut Gulch, intensities for 15-minute periods often exceed 5 inches per hour, but rarely reach 8 inches per hour; on Alamogordo Creek, they sometimes exceed 10 inches per hour. In spite of the greater intensities recorded on the Alamogordo Creek watershed, the average annual rainfall for both watersheds is about 12 inches.

The storms of July 28 and July 30, 1966, on Walnut Gulch, help to illustrate the extreme variabilities, as well as the similarities, in thunderstorm precipitation in the Southwest. The storm of July 28 covered the entire watershed with runoff-producing precipitation, whereas the storm of July 30 centered on the upper end of the watershed, and more than half of the watershed received no rainfall (Figs. 1, 4, and 5). Both storms extended over an unknown area outside of the watershed. The storms were similar in that the maximum intensities for both storms were about 5 inches per hour, and both storms lasted for a little over an hour.

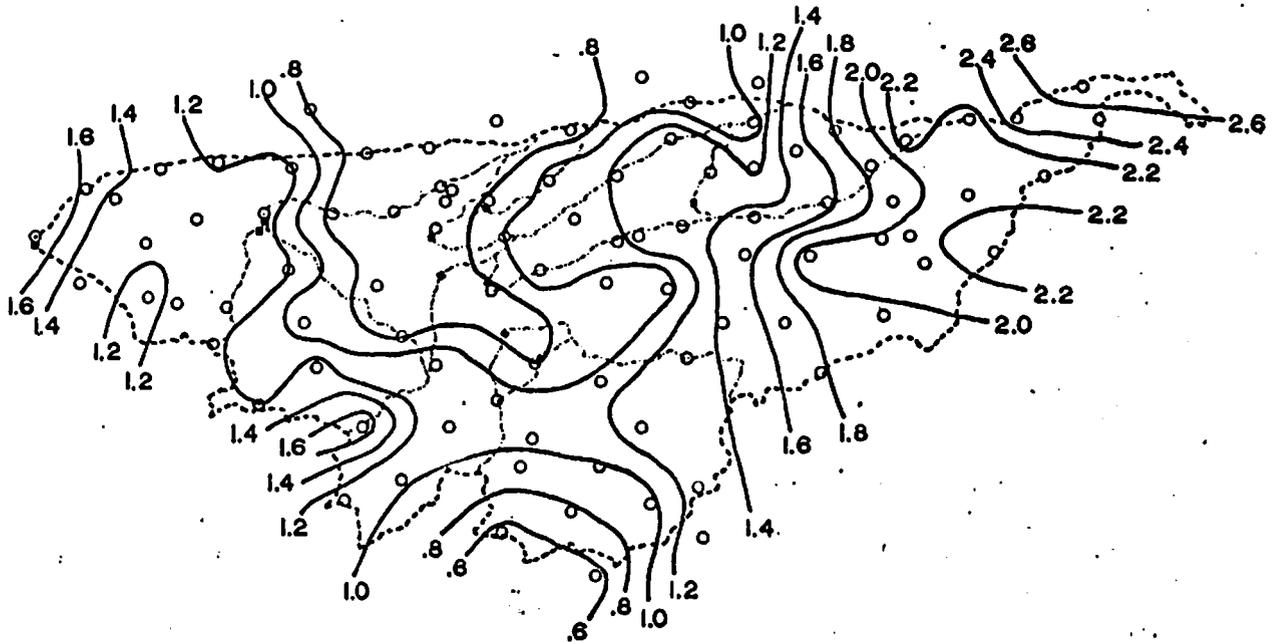
Actually, the runoff-producing portions of the majority of thunderstorms on the Walnut Gulch watershed last for less than 15 minutes and cover less than 5 square miles of the watershed. For example, there were a total of 71 significant thunderstorm events on Walnut Gulch watershed during the summer seasons (June - September) of 1960 through 1962. (A significant thunderstorm event is defined here as one that produces at least 0.25 inch of rainfall with at least a maximum intensity of 0.60 inch/hour). Of these 71 storms, in three years, 24 produced runoff in the main channels at Walnut Gulch. Of these latter 24 storm events, 18 covered 6 square miles or less of the watershed with runoff-producing rainfall; 10 covered less than 10 square miles; and only 2 covered over 30 square miles. The runoff-producing portion of most thunderstorms lasted less than 15 minutes, and for over 90 percent of the storms, less than 30 minutes.

However, the large, more unusual events are those that are reported and remembered. Also, the occasional exceptional event often produces more surface runoff and sediment discharge than many years of average events. Therefore, the exceptional events, as well as commanding more general interest, are also the design storms for engineering structures.

Exceptional Variations:

Two exceptional storms have been recorded on the Alamogordo Creek watershed in 11 years of record. The first, on the afternoon of June 5, 1960, resulted from a weak cold front and normal strong convective heating (Keppel). Several Weather Bureau stations in northeastern New Mexico recorded 1.00 to 1.50 inches of rain as this front passed. Rainfall varied from 0.15 inch to 4.09 inches within the watershed, with 5 gages recording over 4 inches (Fig. 6). At Rain Gage 34, near the center of the watershed, 3.09 inches fell in the first 15 minutes. About 95% of the rainfall over the watershed fell in the first hour of the storm. Only 0.38 inch was recorded at the watershed outlet, less than 5 miles from the storm center.

The second exceptional storm (Fig. 7) occurred in the early hours of July 13, 1961, as a weak cold front moved across the watershed. A short, intense burst of rainfall, followed by a heavy fall of giant hail, produced a maximum of 3.5 inches of precipitation at Rain Gage 21. At this gage, 3.09 inches fell in the first 15 minutes, which equaled the maximum precipitation intensity recorded the previous year.



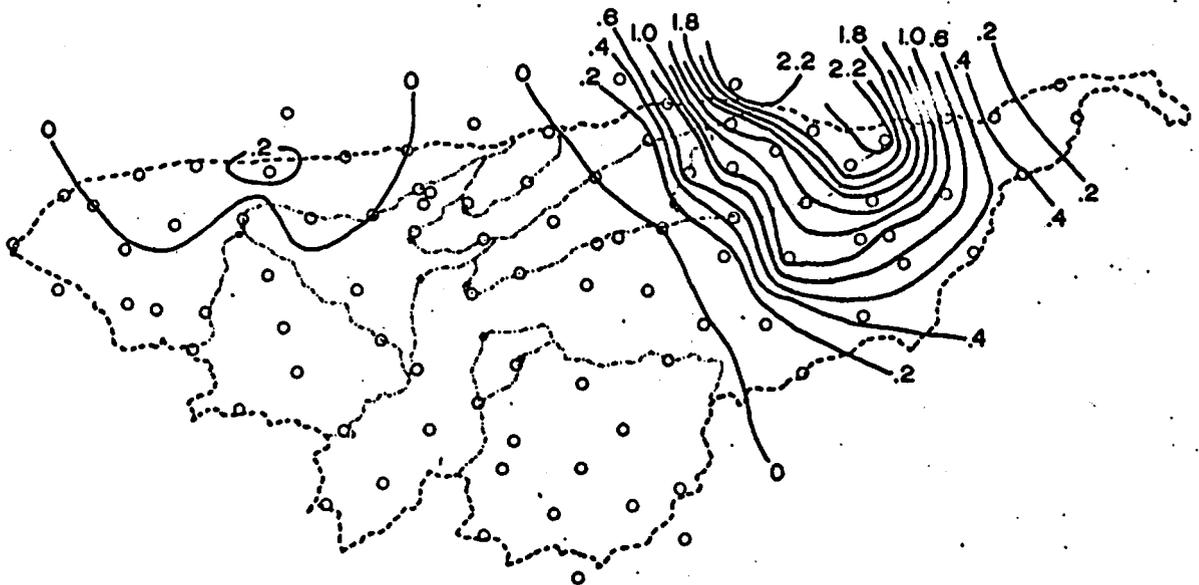
WALNUT GULCH WATERSHED

ISOHYETAL MAP

STORM OF JULY 28, 1966

(1900)

Figure 4.



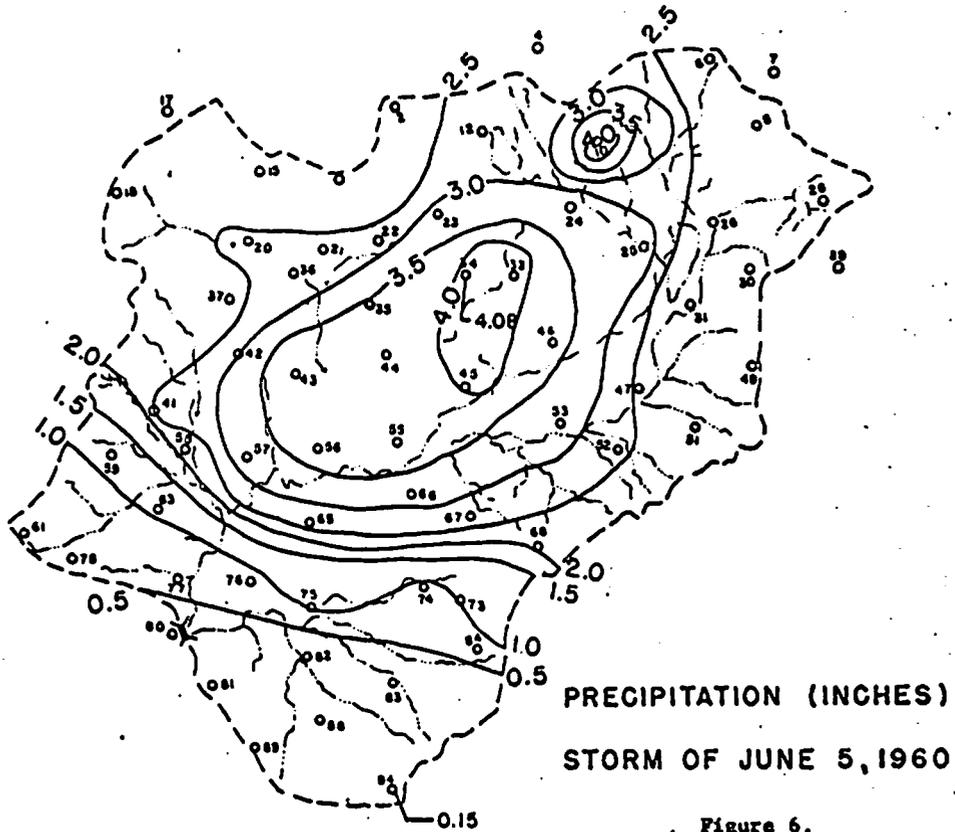


Figure 6.

Scale in Miles

ALAMOGORDO CREEK WATERSHED

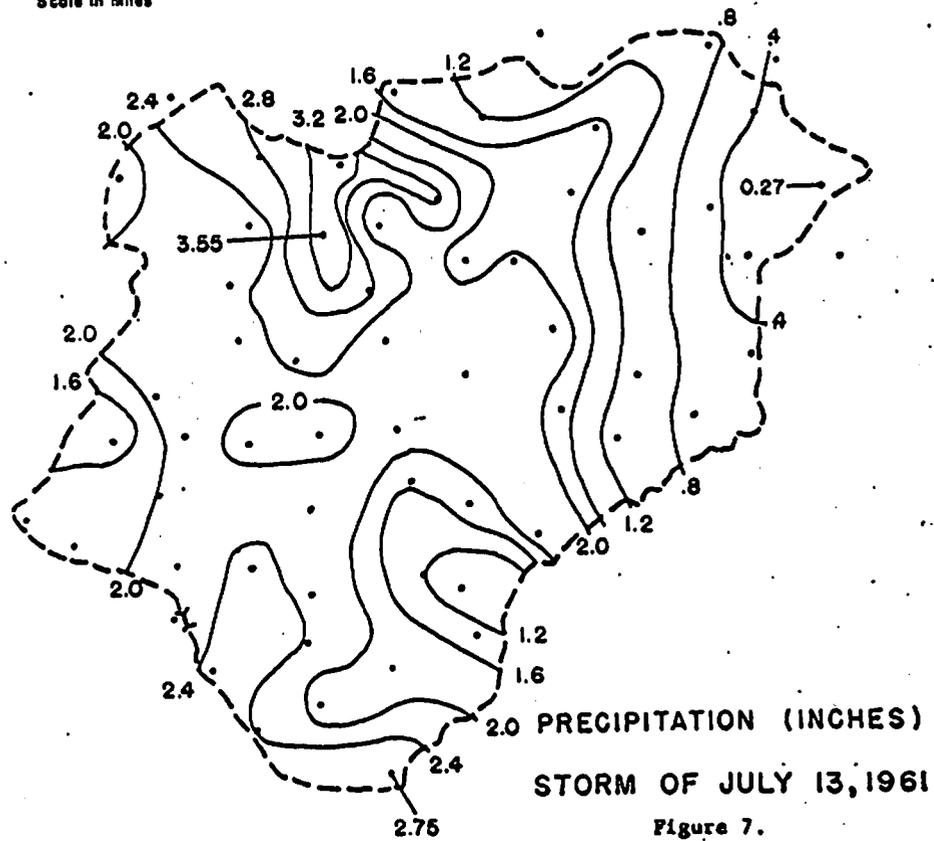


Figure 7.

"The hail storm moved in a southerly direction covering approximately 35 square miles of the watershed. Over the 35-square-mile area, hail was several inches deep, over a 10-square-mile area, considerably deeper; and ten hours after the storm, drifts up to two feet deep impeded travel in a 4-wheel drive vehicle. Some hailstones as large as hen eggs were observed on the ground as late as noon of the 13th. So intense was the hail storm in this area that many juniper trees, wild sunflowers, and elm trees were completely stripped of foliage." (Osborn and Reynolds.)

Weather Bureau stations in the region recorded up to 1.00 inch of rainfall, and there were no other reports of hail damage. It seems highly probable that such extreme events occur quite regularly in the region, but because of the very limited areal extent of the high-intensity rain or hail, and scarcity of Weather Bureau stations, they are seldom recorded.

Walnut Gulch has experienced several exceptional storms during the period of record, but none to compare with the two events at Alamogordo Creek.

CONCLUSION

Because weather stations are widely scattered throughout the Southwest, it has been difficult to determine the frequencies for thunderstorms of various magnitudes. The intense networks of rain gages on the Walnut Gulch and Alamogordo Creek watersheds accurately measure the portions of the thunderstorms that fall on the watershed areas, and these records should yield dependable estimates for the frequencies of thunderstorms of varying magnitudes and durations for 60-square-mile watersheds and less for much of the semiarid rangelands of the Southwest. Mathematical models should help increase the knowledge of precipitation-runoff characteristics from watersheds with varying hydrologic patterns and topographic features, but the verification of these models and the determination of frequencies for a given thunderstorm on a watershed of finite size will be made when longer periods of basic data are obtained.

REFERENCES

- Keppel, Robert V. A Record Storm Event on the Alamogordo Creek Watershed in Eastern New Mexico. *J. Geophysical Research*, 68: 4877-4880, August 15, 1963.
- Osborn, Herbert B., and Reynolds, William N. Convective Storm Patterns in the Southwestern United States. *Internat'l. Assoc. Sci. Hydrol. B.*, 8(3):71-83, September 1963.