# Rainfall Intensities for Southeastern Arizona

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## Introduction

Small watershed storm runoff in the southwestern United States is dominated by intense, short-duration convective rains of limited areal extent. Storm drainage design is often based on rainfall information published by the National Weather Service in the National Oceanic and Atmospheric Administration (NOAA) Atlas 2 series (Miller et al. 1973). In NOAA Atlas 2, short-duration rainfall is derived by an extrapolation procedure from maps of 6-hr and 24-hr rainfall amounts with different frequencies. In this study, intensity-duration-frequency values for 1 hr and less, based on data from a dense network of rain gauges in southeastern Arizona, are compared to similar values derived from NOAA Atlas 2. Differences in rainfall intensities obtained from the two methods are illustrated by simulating and comparing peaks and volumes of runoff.

## Previous Studies

In 1973, The National Weather Service (Miller et al. 1973) published an 11-volume atlas for rainfall in the 11 western states. Equations are provided in the publication to estimate 1-hr rainfall from 6-hr and 24-hr rainfall maps for different frequencies. Ratios published in Technical Paper No. 40 (Hershfield 1961) are used to estimate rainfall for 5-, 10-, 15-, and 30-min durations from the 1-hr estimates. Reich (1978) showed the value of computers in developing intensity-duration-frequency relationships from NOAA Atlas 2, but he also warned that computer output was no better than the data from which the estimates were made. Most recently, Petersen (1986) found that estimates for short-duration intensities based on recording rain gauge records near Billings, Montana, were significantly larger for recurrence intervals from 2–100 yrs, than those based on NOAA Atlas 2.

## Rainfall Analysis

Data from a dense-recording rain gauge network on the U. S. Dept. of Agric., Agricultural Research Service's Walnut Gulch experimental watershed, in southeastern Arizona, were used to estimate 2-, 5-, 10-, 25-, 50-, and 100-yr rains for 5-, 10-, 15-, 30-, and 60-min durations. Based on the assumption of independent sampling points for well-separated rain gauges (Reich and Osborn 1982) and the station-year method (Hafstad 1942), three sets of four gauges each were selected to create records of 90, 91, and 92

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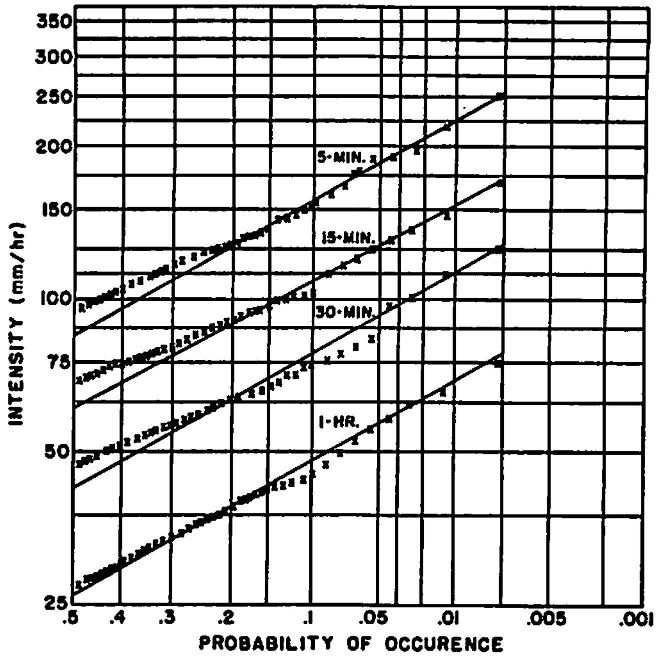


**FIG. 1. Intensity-Frequency Relationships for 5-, 15-, 30-min, and 1-hr Durations for Walnut Gulch, Arizona**

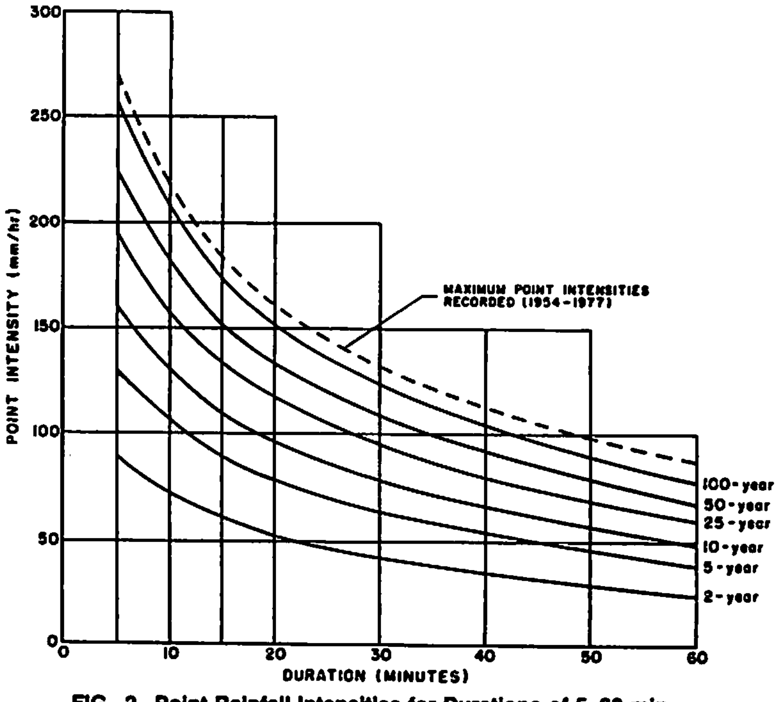


**FIG. 2. Point Rainfall Intensities for Durations of 5–60 min.**

**TABLE 1. Point Depth, Duration, Frequency Rainfall for Southeastern Arizona, Annual Series**

| Return Period and Duration (min) (1) | Walnut Gulch Data (mm) (2) | National Oceanic and Atmospheric Administration Atlas (mm) (3) |
|---|---|---|
| | (*a*) 2 Years | |
| 5 | 7.0 | 7.6 |
| 10 | 11.4 | 12.0 |
| 15 | 14.6 | 15.2 |
| 30 | 21.0 | 21.6 |
| | (*b*) 5 Years | |
| 5 | 10.2 | 10.2 |
| 10 | 17.8 | 16.5 |
| 15 | 22.8 | 21.6 |
| 30 | 31.8 | 29.2 |
| | (*c*) 10 Years | |
| 5 | 12.0 | 12.0 |
| 10 | 21.6 | 20.3 |
| 15 | 28.0 | 25.4 |
| 30 | 38.0 | 34.3 |
| | (*d*) 25 Years | |
| 5 | 16.5 | 15.2 |
| 10 | 25.4 | 22.8 |
| 15 | 34.3 | 29.2 |
| 30 | 48.2 | 39.4 |
| | (*e*) 50 Years | |
| 5 | 19.0 | 16.5 |
| 10 | 30.5 | 25.4 |
| 15 | 38.0 | 31.8 |
| 30 | 55.8 | 44.4 |
| | (*f*) 100 Years | |
| 5 | 21.6 | 18.0 |
| 10 | 35.6 | 28.0 |
| 15 | 44.4 | 35.6 |
| 30 | 63.5 | 48.0 |

yrs. Twelve different gauges made up the three sets, and the four gauges in each set were separated by at least four mi. Estimates for 5-min, 15-min, 30-min, and 1-hr rainfall were plotted on log probability paper (Fig. 1). The relationships from Fig. 1 were used to derive intensity-duration-frequency curves (Fig. 2). The 6-hr and 24-hr rainfall maps in NOAA Atlas 2, Vol. 8 (Arizona) were used, along with the appropriate equations and ratios, to derive depths for 2-, 5-, 10-, 25-, 50-, and 100-yr rainfall for 5-, 10-, 15-, 30-,

**TABLE 2. Comparison of Runoff Peaks and Volumes for a 100-yr, 1-hr Storm Based on Walnut Gulch and NOAA Atlas 2 Estimates**

| | | Peak (cms/ha) | | | | Volume (mm) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | "Dry" | | "Wet" | | "Dry" | | "Wet" | |
| Watershed (1) | Area (ha) (2) | Walnut Gulch (3) | National Oceanic and Atmospheric Administration (4) | Walnut Gulch (5) | National Oceanic and Atmospheric Administration (6) | Walnut Gulch (7) | National Oceanic and Atmospheric Administration (8) | Walnut Gulch (9) | National Oceanic and Atmospheric Administration (10) |
| 63105 | 0.24 | 0.50 | 0.35 | 0.54 | 0.41 | 50.0 | 33.5 | 62.5 | 45.7 |
| 63011 | 810 | 0.12 | 0.06 | 0.17 | 0.12 | 30.5 | 15.2 | 42.0 | 26.7 |

and 60-min durations (Table 1). Rainfall depths for the same return periods and durations were derived from Walnut Gulch data and compared to the NOAA Atlas 2 estimate (Table 1). The differences appeared appreciable for the less frequent events, particularly the 50- and the 100-yr storms, as opposed to the Peterson (1986) study in which the difference were appreciable for all recurrence intervals.

## Runoff

One method of illustrating the significance of differing estimates of short-duration rainfall intensities is to study the differences in flood peaks and volumes when the rainfall estimates are entered into a mathematical rainfall-runoff model. A kinematic cascade rainfall-runoff model, KINEROS (Rovey et al. 1977), which has been adapted for use on Walnut Gulch (Osborn 1984), was used in this evaluation. KINEROS is a well-tested nonlinear, deterministic, distributed parameter model. Inputs are: (1) Hyetographs of actual or simulated rainfall; (2) the watershed surface geometry and topography; (3) parameters for surface roughness; (4) infiltration parameters (based on Green-Ampt); and (5) the channel network, including slope, cross-sectional area, cross-sectional shape, hydraulic roughness, and a subroutine for channel abstraction (Smith 1981; Osborn 1984). Data from two natural rangeland watersheds were used to validate the model—a very small (0.24 ha, 0.6 ac) watershed, and a large (810 ha, 2,000 ac) watershed. Rainfall was assumed to cover the 0.24 ha watershed evenly, but was varied both in time and space over the 810 ha watershed using an elliptical model based on earlier modeling efforts (Osborn and Laursen 1973). Runoff peaks and volumes were obtained for "wet" and "dry" antecedent conditions for the 100-yr, 1-hr rain (Table 2). "Dry" antecedent conditions normally prevail in southeastern Arizona, but "wet" antecedent conditions, often assumed in engineering design, occur occasionally. Runoff peak and volume estimates based on Walnut Gulch rainfall data were substantially greater than those based on the NOAA Atlas estimates for all durations for the 50- and 100-yr storms, somewhat greater for the 25-yr storms, and substantially the same for the more frequent events.

## Conclusions

For southeastern Arizona, estimates of short-duration precipitation intensities, based on NOAA Atlas 2, were substantially lower than estimates based on data from a dense rain gauges network for less frequent events (50- and 100-year frequencies). Runoff peaks and volumes, as estimated with a distributed mathematical rainfall-runoff model, were underestimated for the less frequent events, particularly for the 100-yr storm, based on NOAA Atlas 2.

## Appendix I. References


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