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6.

CHARACTERISTICS OF PRECIPITATION (IN THE RANGELANDS) OF THE SOUTHWEST

Joel E. Fletcher[1/]

The recording raingage network on the Walnut Gulch Experiment Watershed in Southern Arizona, which has an approximate density of one gage per square mile over a 60 square mile area, was used as a source of the data reported here. In addition, the cooperative weather bureau stations at Tombstone and Fairbank were utilized for long time records of 24 hour rainfall.

Area-Depth Relationships.

The rainfall at all stations which fell during the fifteen largest runoff producing storms was used to plot isohyetal maps of each storm. The depth represented by each isohyet was plotted against the log of the area enclosed by that isohyet. The scatter diagram of Figure I shows these points and their regression line for the years from 1954 through 1959.

While the points from the individual storms follow regular individual curves, each has characteristics of its own. No storm in the group had points falling along the regression line. The storms whose points ranged above the regression line caused the greatest flood peaks.

Approximately twenty storms have occurred since the gage network was installed which fell completely within the confines of the network and yet were of sufficient depth and intensity to cause runoff. For each storm (all were greater than 0.90 inches) the log of the area enclosed by each isohyetal line was plotted against the log of the depth of precipitation at the storm center minus the value for the particular isohyet. The result may be seen in Figure 2. The points diverge widely as the lower values are approached. If only those storms which did not cause runoff are used in the plot, the points all fall in a random fashion. The relation shown is very close to that found by Schwalen and Woolhiser for the Tucson area.

Occurrence of Storm Cells.

It was hypothesized that convective cells occurred in a random fashion over an area where moisture and temperature conditions were suitable. This was suggested by inspection of a large number isohyetal maps of

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1/ Soil Scientist, Watershed Technology Research Branch, Soil and Water Conservation Research Division, Agricultural Research Service, U.S. Department of Agriculture, Boise, Idaho.

storms on Walnut Gulch Watershed. This is especially noticeable if the storms are carefully sorted with respect to time.

To test the hypothesis return frequencies were calculated using 61 years of point rainfall at Tombstone which is near the center of the network. This was compared with similar return frequencies calculated from 17 raingages, each having 5 to 7 years of record. The data were handled on a gage year basis using exceedance techniques. It was found that if a minimum of three years of record was used from each gage, the return frequencies were identical to those from the long time Tombstone record. This comparison may be seen in Figure III where the Tombstone points are shown on the same plot as those from the Walnut Gulch network. The regression line is from the Tombstone data.

The implications of this hypothesis are profound. Immediately, it means that a group of raingages placed in a network and operated for a period of a few years may yield equally reliable information to that from a single gage operated for a long time, if their spacing is greater than a storm radius.

The location and density of storm cells in space is of utmost importance in determining runoff peaks. The peak flow on Walnut Gulch, for example, was the result of three cells which individually were not unusual but were spaced in time and position such that the peaks from each coincided at the gaging site. The frequency with which these cells occur together in multiples is given in Figure IV for Walnut Gulch. It appears that multiple occurrence of cells is the rule rather than the exception.

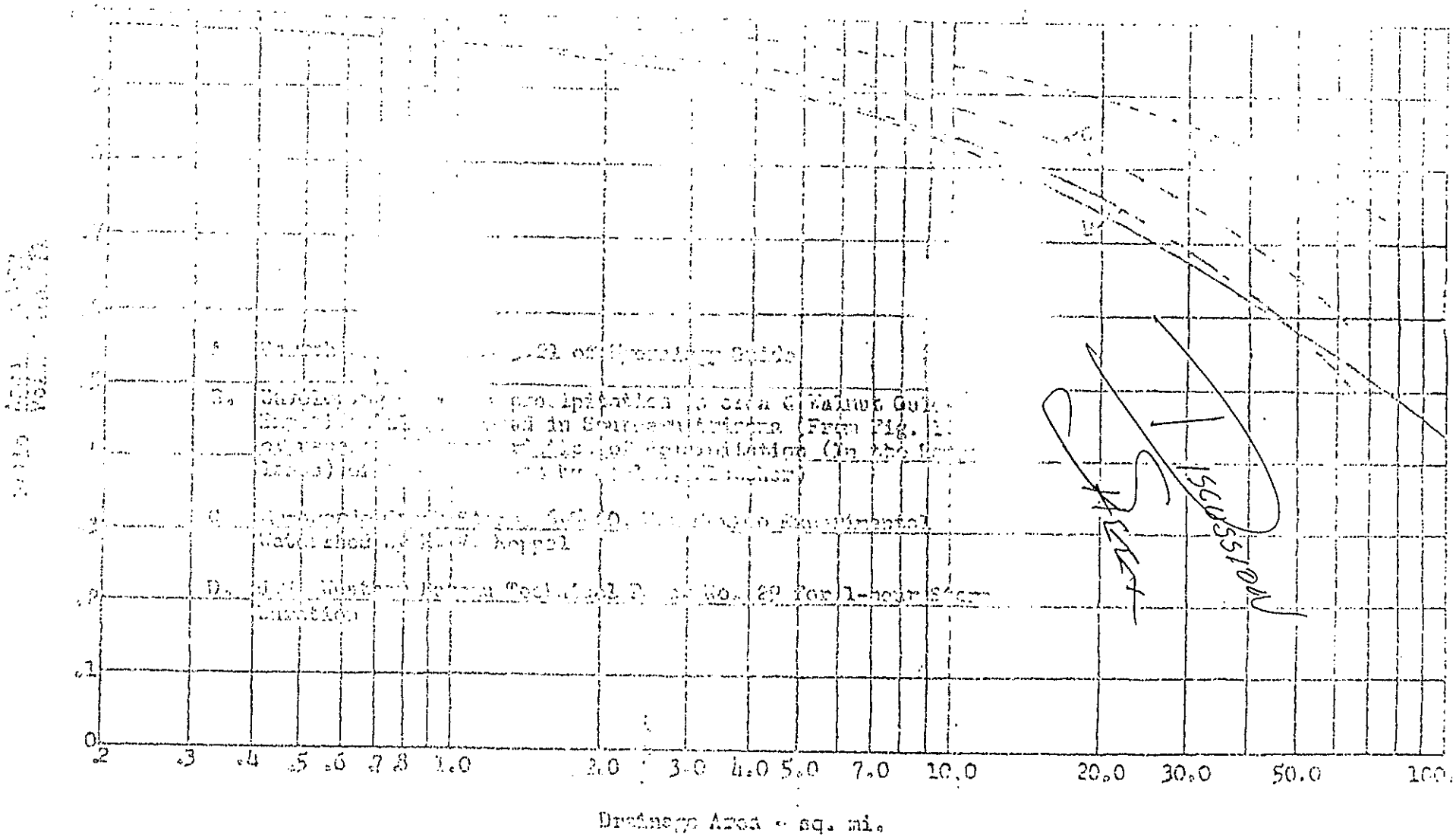
The sizes of the individual cells are much smaller than has generally been assumed. For example, Figure V, which is the areal distribution of 811 storms for Walnut Gulch, shows that 80% of the storms occupy areas smaller than 4½ square miles or, in other words, have diameters smaller than 2.4 miles. Reference to Figure III might lead one to believe that the runoff producing storms are much larger, but it must be remembered that Figure III involves multiple numbers of cells.

The depths of precipitation in the cell centers is illustrated by the frequency distribution of the annual maxima in Figure VI and by the frequency distribution of rainfall amounts in Figure VII.

Intensity Characteristics.

It was shown above that storm cells occurred randomly with respect to space if at least a three-year record was considered. It is only a slight extension of this to assume that the intensities would also follow such a relation. Following along with this assumption, some 216 gage years of data were utilized in calculating return frequencies. These properties are summarized in Figures VIII and IX. As might be expected, both sets of curves seem to be approaching some intensity value more or less asymptotically.

Table I gives a brief compilation of the one year, 10 year, and


.2
.3
.4
.5
.6
.7
.8
1.0
2.0
3.0
4.0
5.0
7.0
10.0
20.0
30.0
50.0
100.
Drainage Area - sq. mi.

100 years recurrence amounts for Tombstone and Fairbank and for the network which surrounds Tombstone.

Table I
Recurrence Amounts of Rainfall
for a 24-Hour Period

	1 Yr.	10 Yrs.	100 Yrs.
Tombstone	1.33	2.54	3.75
Fairbank	0.55	2.43	3.82
Network	1.28	2.57	3.84

It is perhaps significant that a record of 5.03 for a single 24-hour period at one gage on the network was recorded during the third year of its operation.

Dorroh (J. H. Dorroh, 1954 "Southwestern Runoff Determination" M-2266) presented a table of rainfall frequencies. His highest and lowest in each class are reproduced in Table II for comparison to those from Walnut Gulch. It may be seen that the Walnut Gulch values are within the range or slightly above those given by Dorroh.

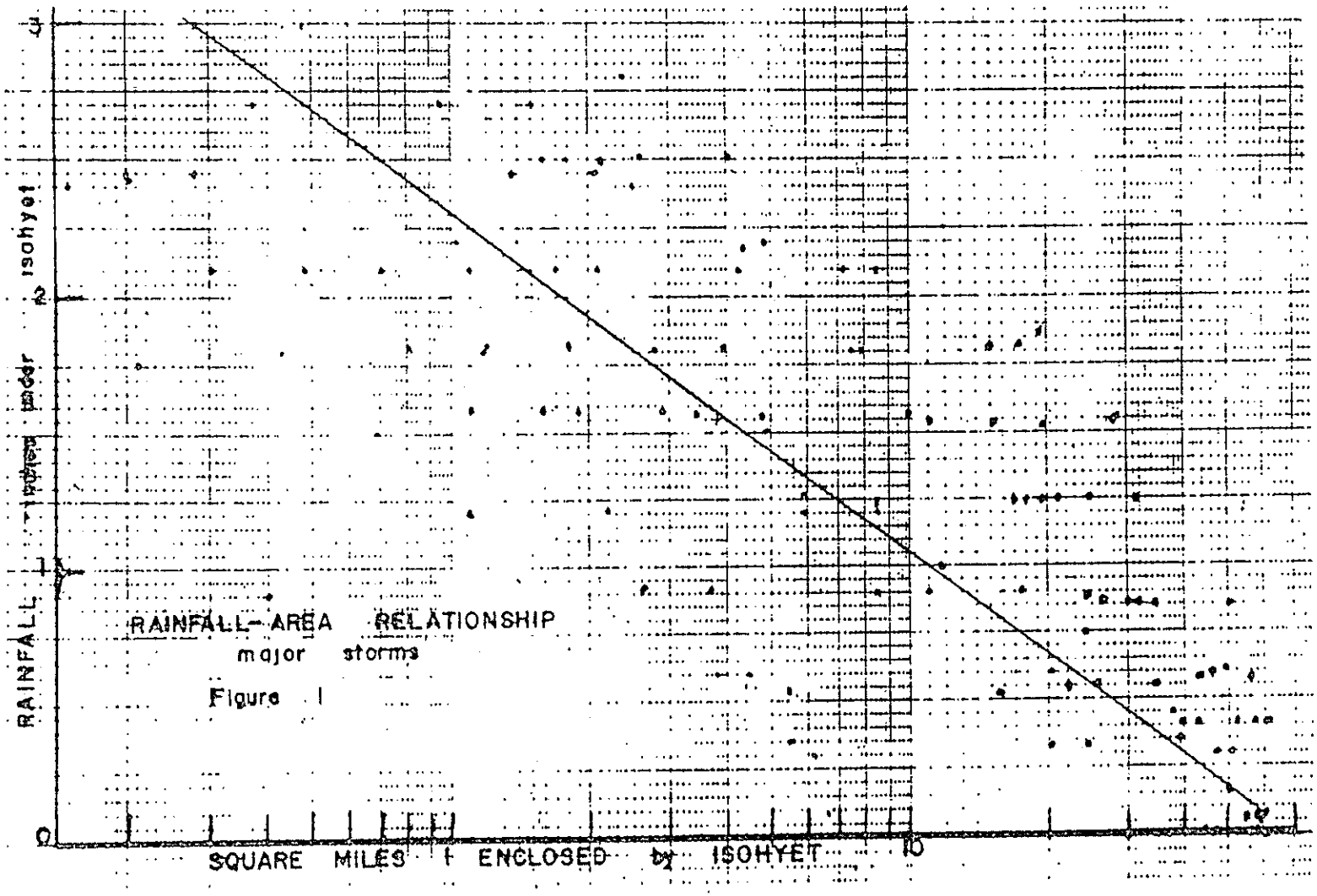
Rainfall Runoff Relations.

The relation between rainfall and runoff for one season only is given in Figure X. No attempt will be made at this time to discuss these results other than to say that we can account for quite a bit of the point scatter on the basis of known physical factors.

Table II

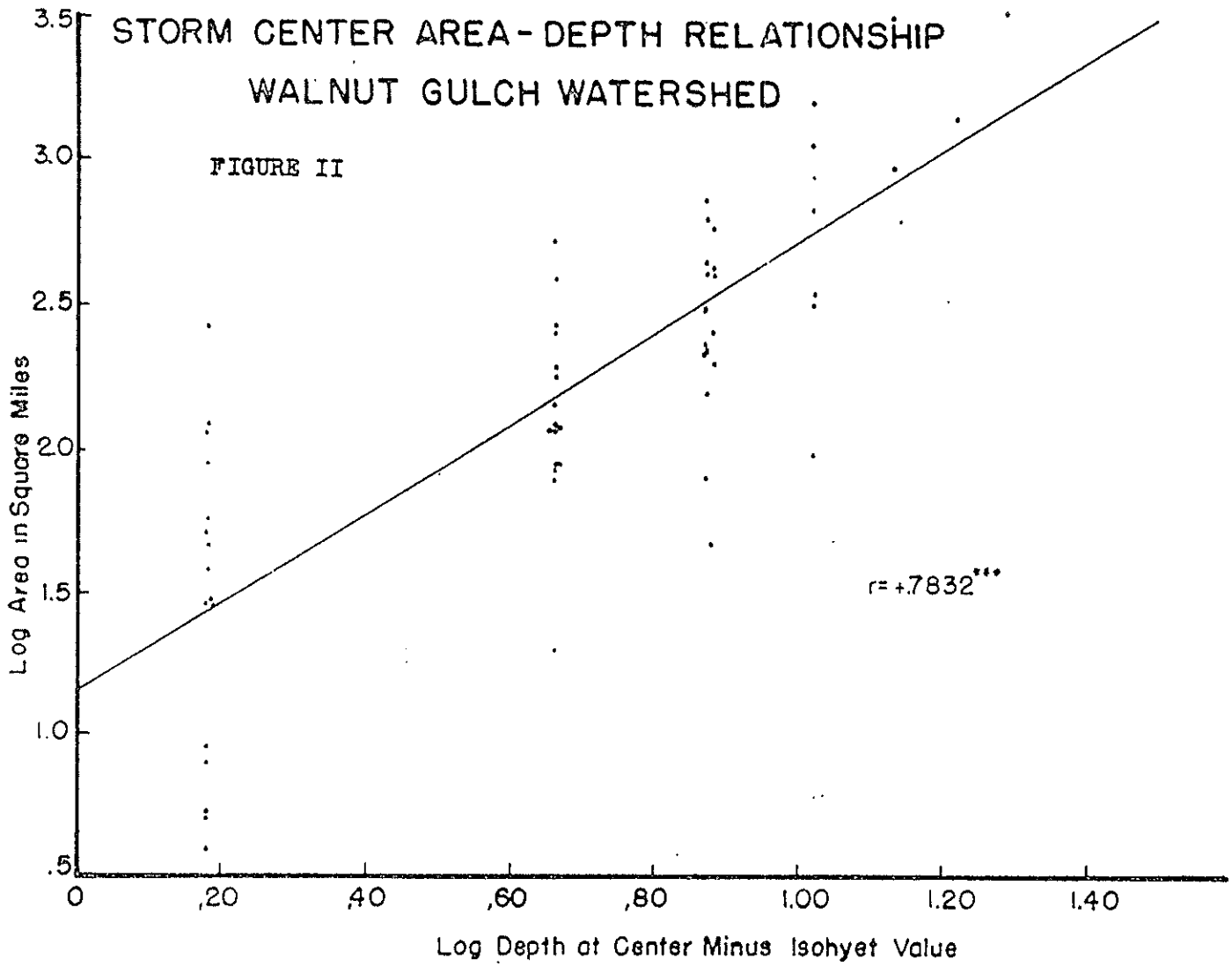
A Comparison of Some of Dorroh's Depth Frequencies
with those from Walnut Gulch

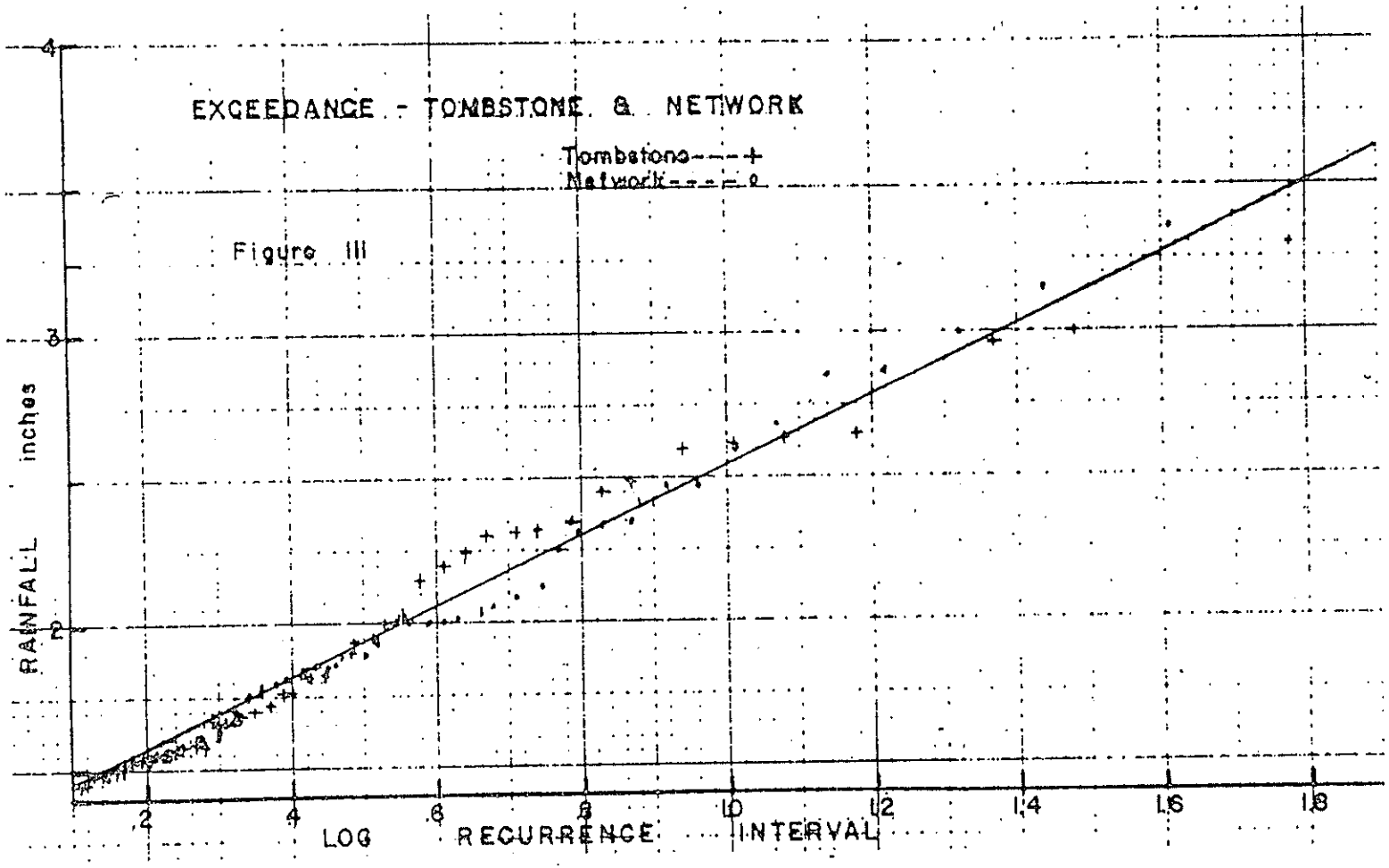
	Walnut Gulch				Dorroh's Values			
Return period	15-min.	30-min.	1 hr.	2 hr.	15-min.	30-min.	1 hr.	2 hr.
10-year	1.09	1.51	1.80	1.84	.65-1.08	.80-1.40	1.00-1.68	1.07-2.02
50-year	1.37	2.05	2.51	2.70	.85-1.49	1.01-2.08	1.31-2.36	1.44-2.61
100-year	1.45	2.36	2.65	2.70	.91-1.67	1.06-2.26	1.42-2.65	1.59-2.80



RAINFALL-AREA RELATIONSHIP
major storms

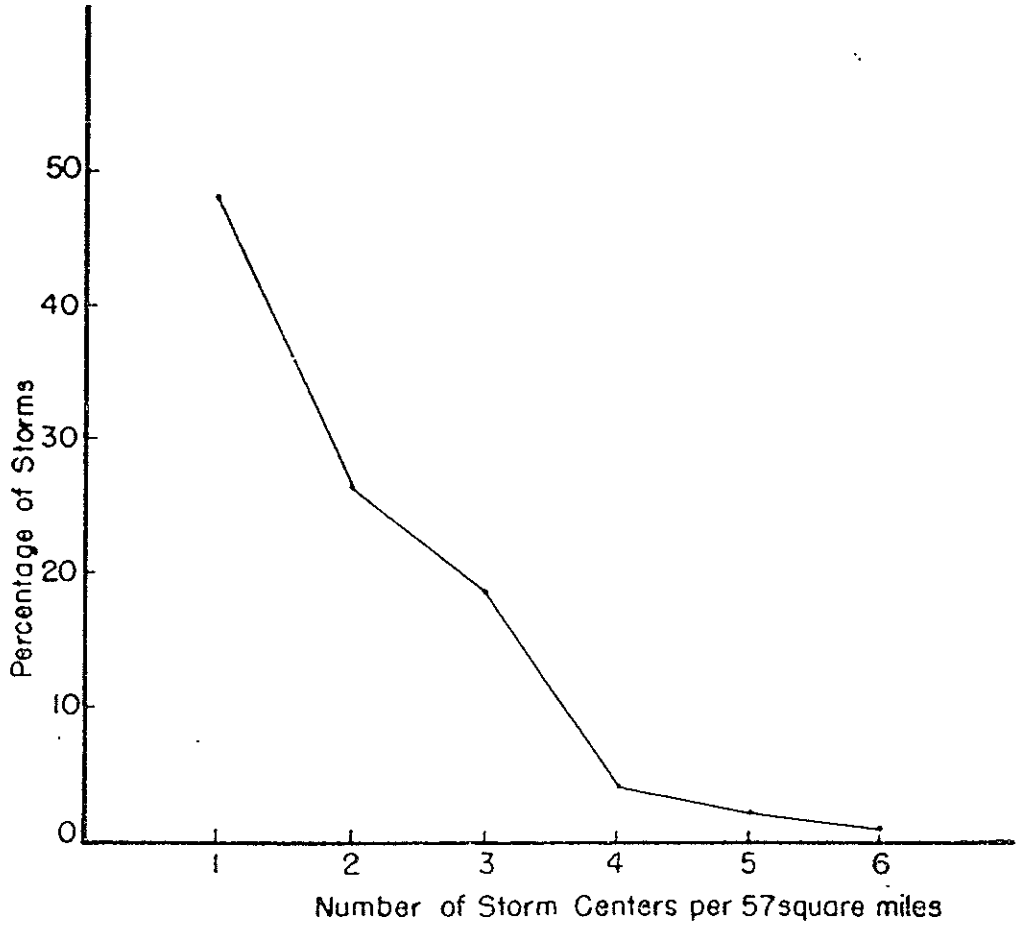
Figure 1

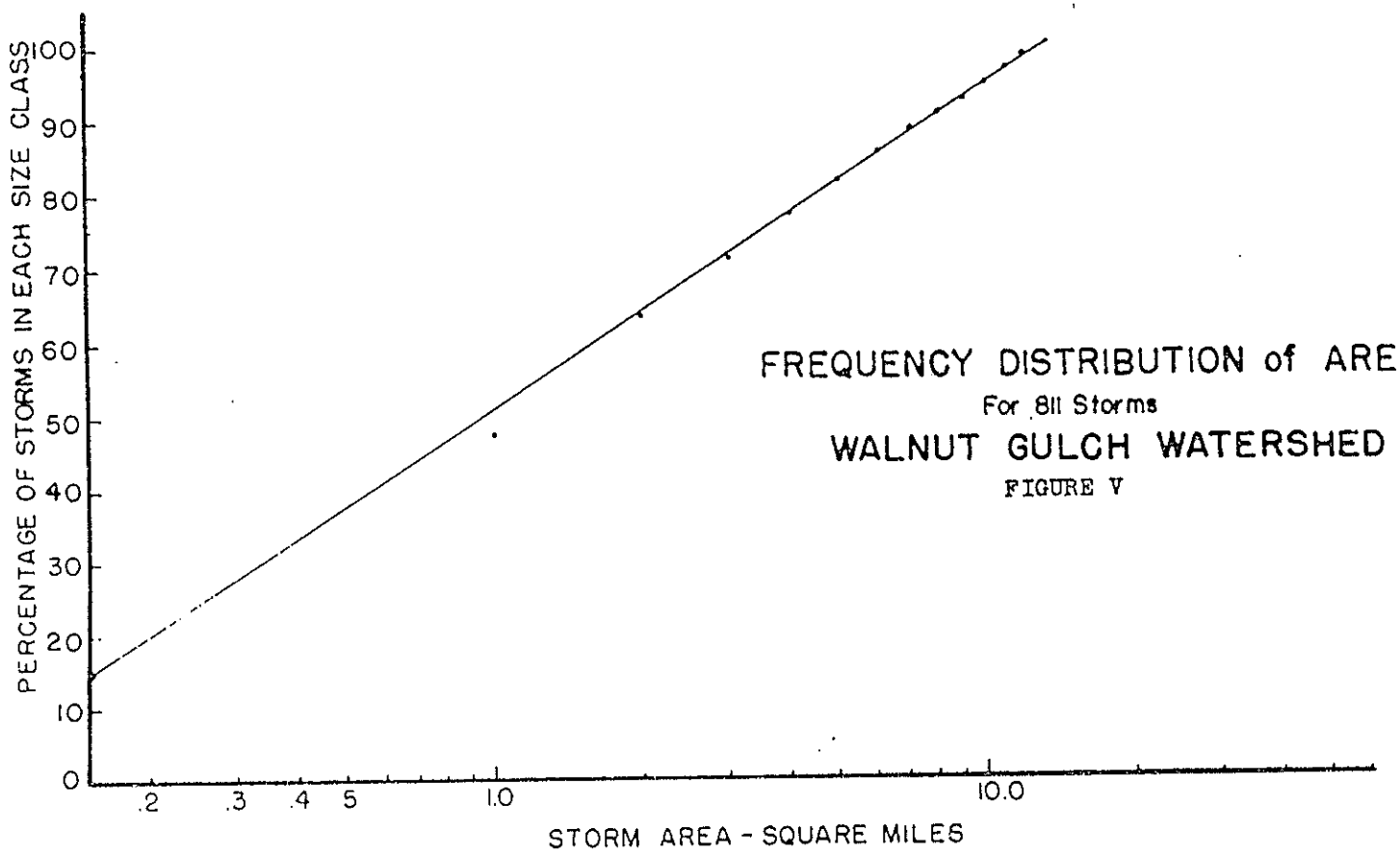

STORM CENTER AREA-DEPTH RELATIONSHIP
WALNUT GULCH WATERSHED
FIGURE II
r= +.7832***
Log Area in Square Miles
3.5
3.0
2.5
2.0
1.5
1.0
.5
0
.20
.40
.60
.80
1.00
1.20
1.40
Log Depth at Center Minus Isohyet Value


EXCEEDANCE - TOMBSTONE & NETWORK
Tombstone - - - +
Network - - - o
Figure III
RAINFALL inches
4
3
2
.2
.4
.6
.8
1.0
1.2
1.4
1.6
1.8
LOG RECURRENCE INTERVAL

FREQUENCY DISTRIBUTION of STORM CENTERS WALNUT GULCH WATERSHED

FIGURE IV





FREQUENCY DISTRIBUTION of AREAS

For 811 Storms

WALNUT GULCH WATERSHED

FIGURE V

SIZE DISTRIBUTION of ANNUAL MAXIMA

Walnut Gulch, Arizona

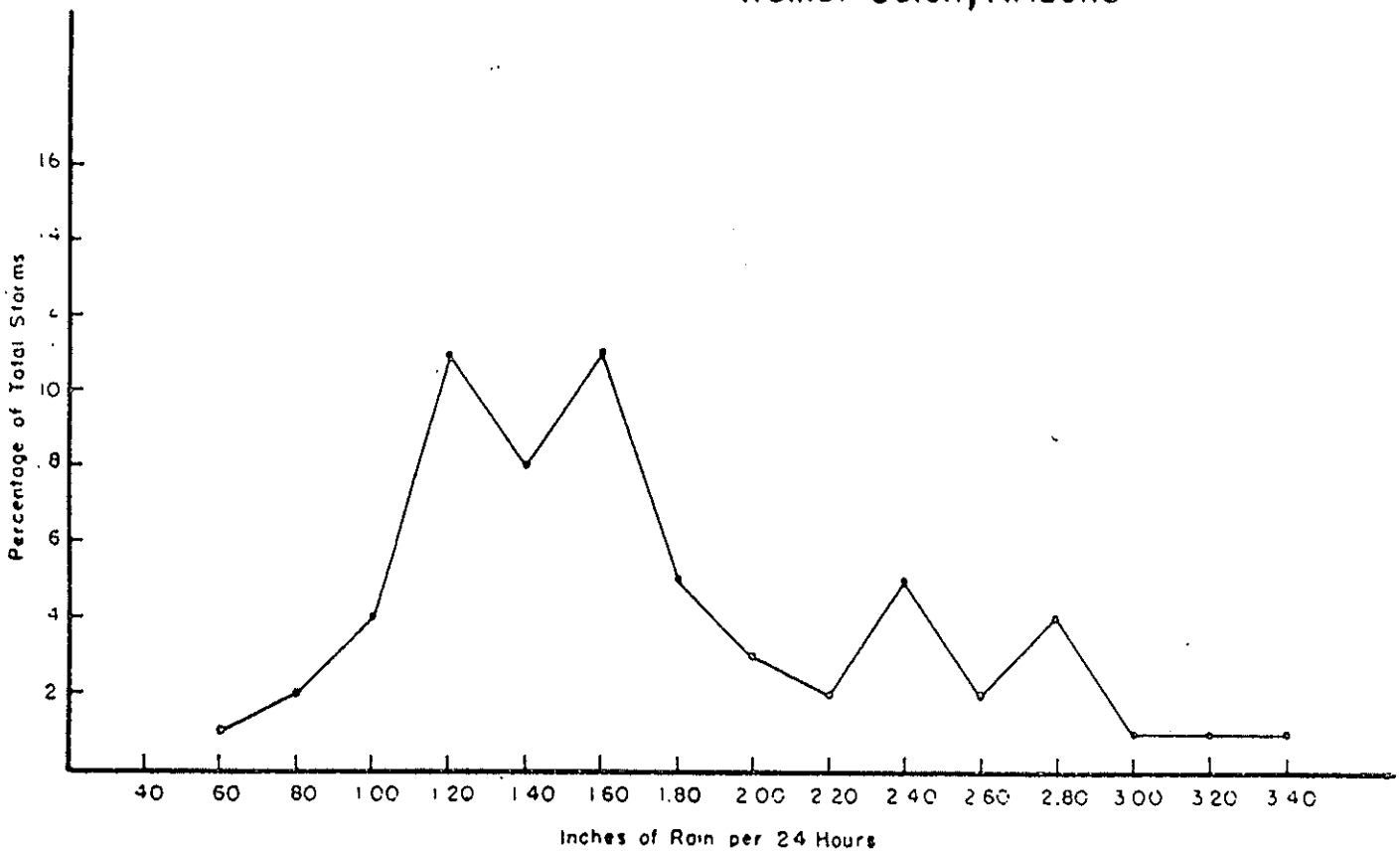
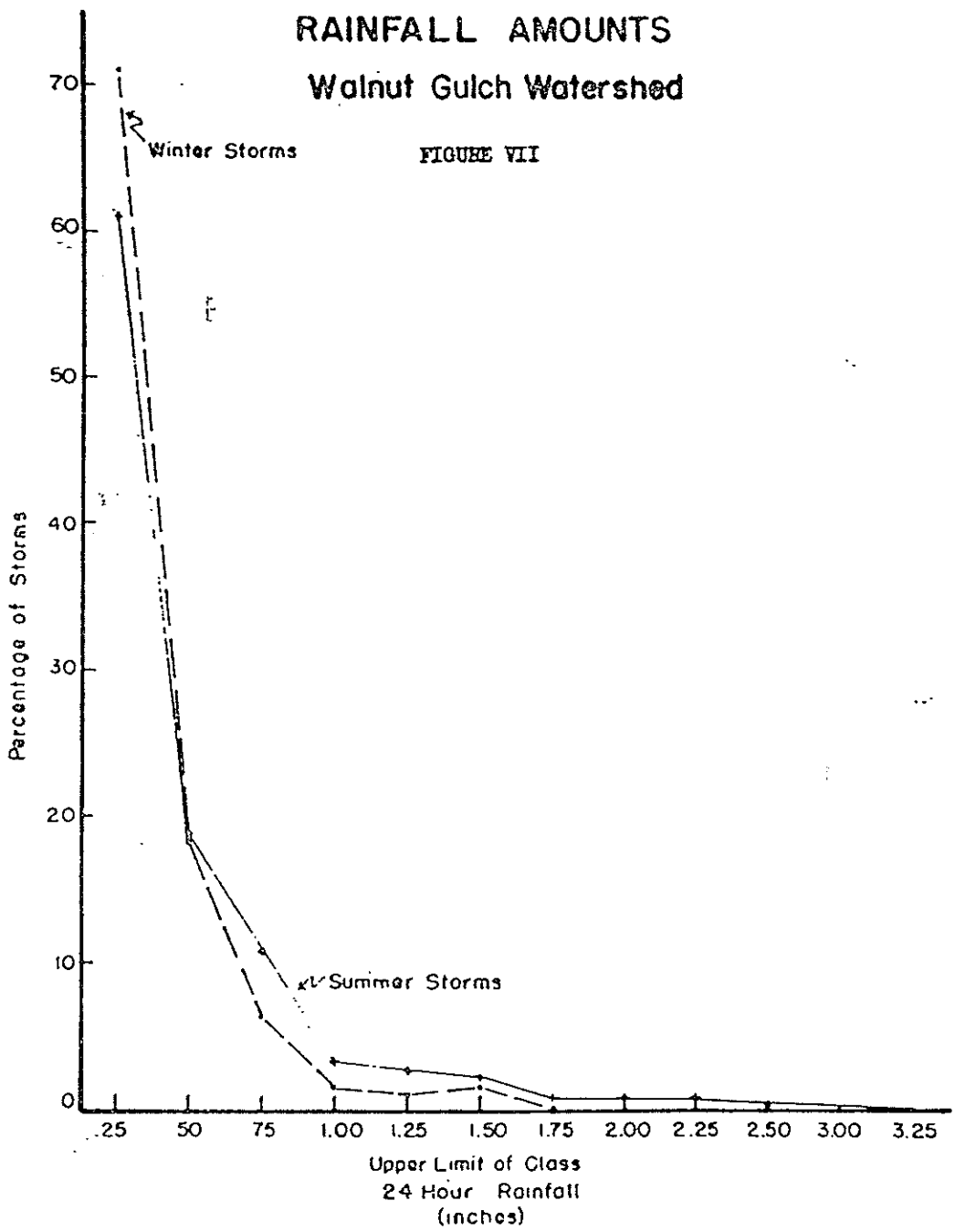


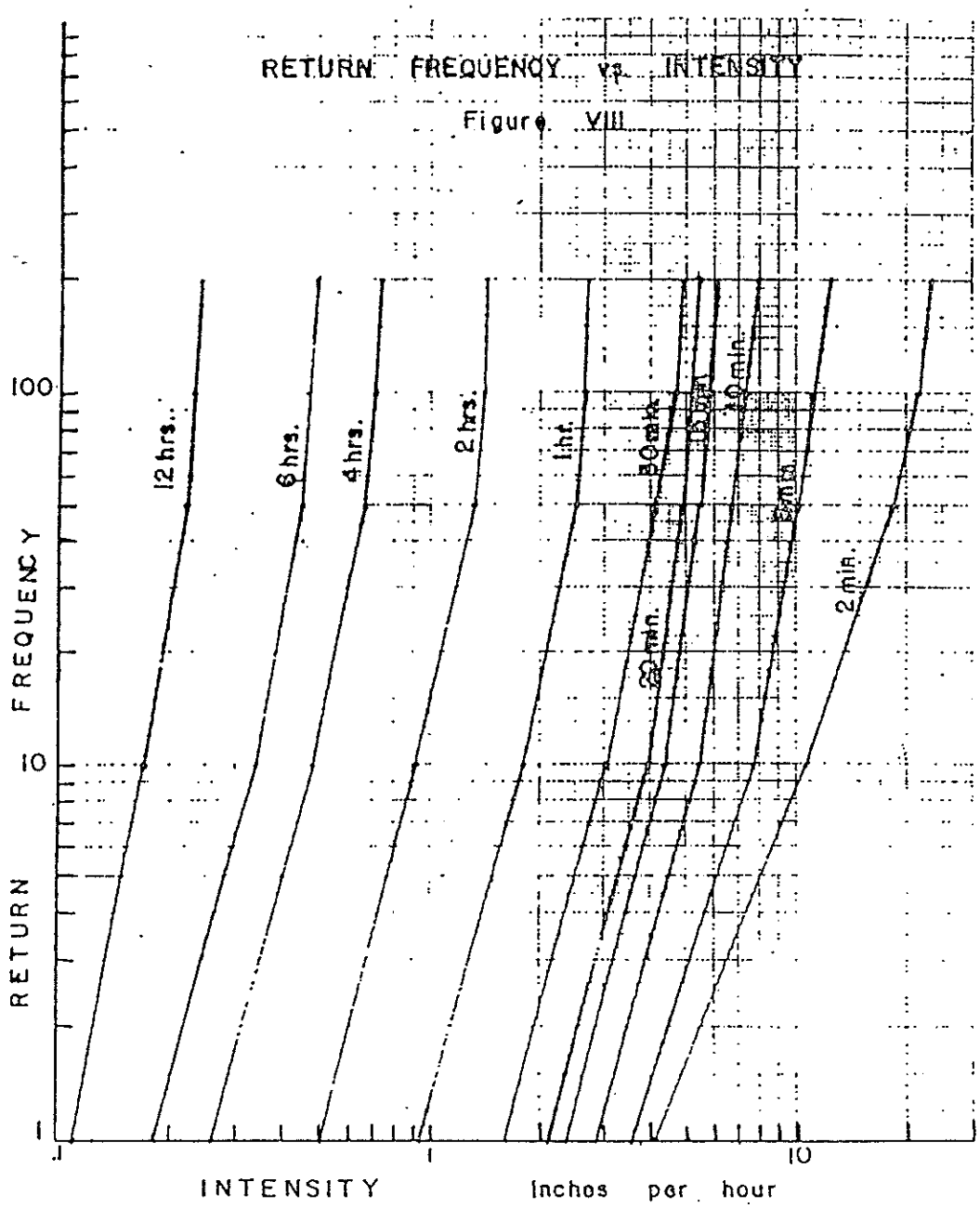
FIGURE VI

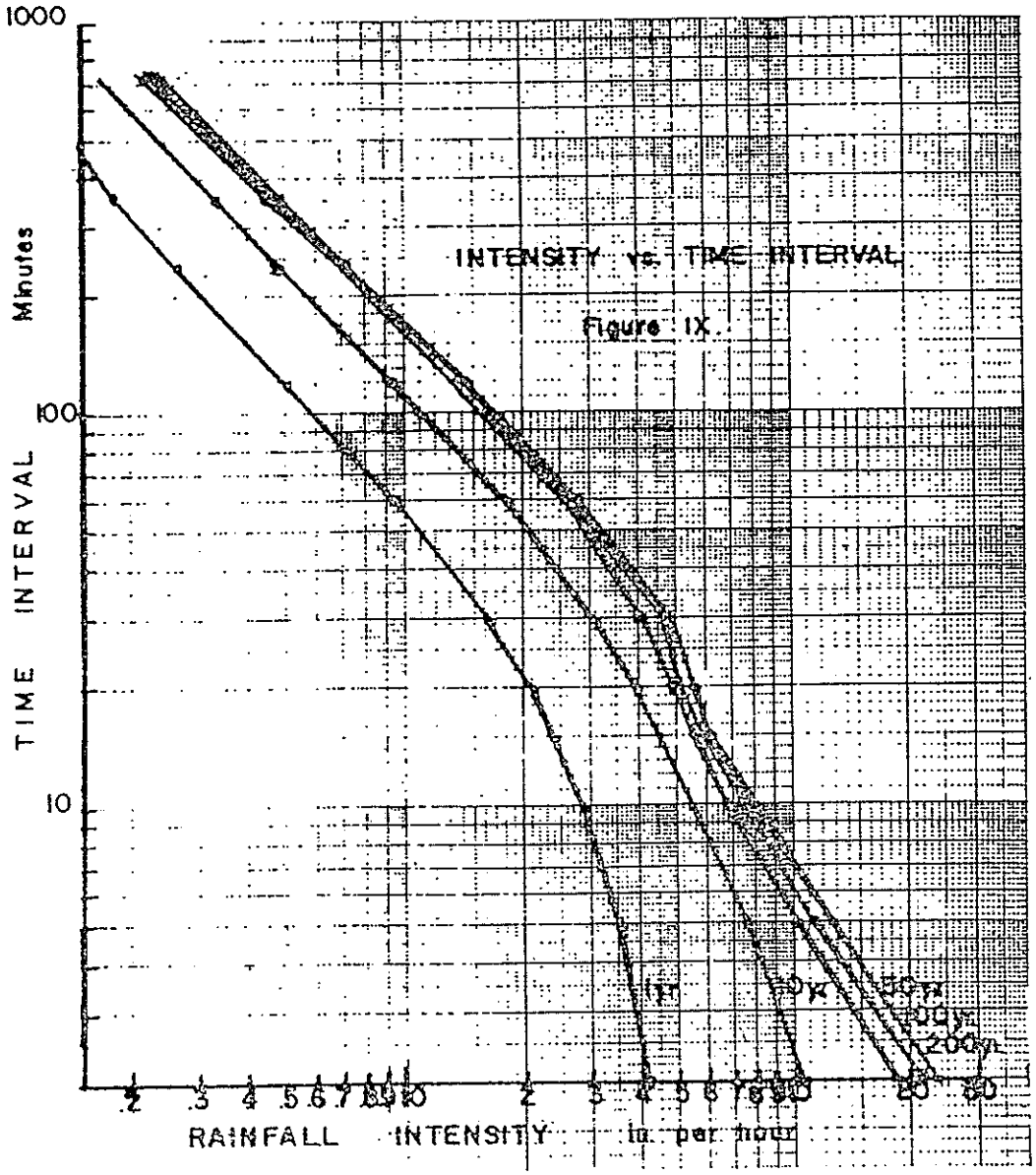
FREQUENCY DISTRIBUTION OF RAINFALL AMOUNTS

Walnut Gulch Watershed

FIGURE VII




RETURN FREQUENCY vs INTENSITY
Figure VIII
12 hrs.
6 hrs.
4 hrs.
2 hrs.
1 hr.
30 min.
20 min.
15 min.
10 min.
5 min.
2 min.
100
10
1
RETURN FREQUENCY
.1
1
10
INTENSITY Inches per hour


INTENSITY vs. TIME INTERVAL
Figure IX
TIME INTERVAL Minutes
1000
100
10
RAINFALL INTENSITY in. per hour
.2
.3
.4
.5
.6
.7
.8
.9
1.0
2
3
4
5
6
7
8
9
10
20
30
1yr
10yr
50yr
100yr
200yr

WALNUT GULCH
RUNOFF vs RAINFALL UNIT SOURCE WATERSHEDS
1959

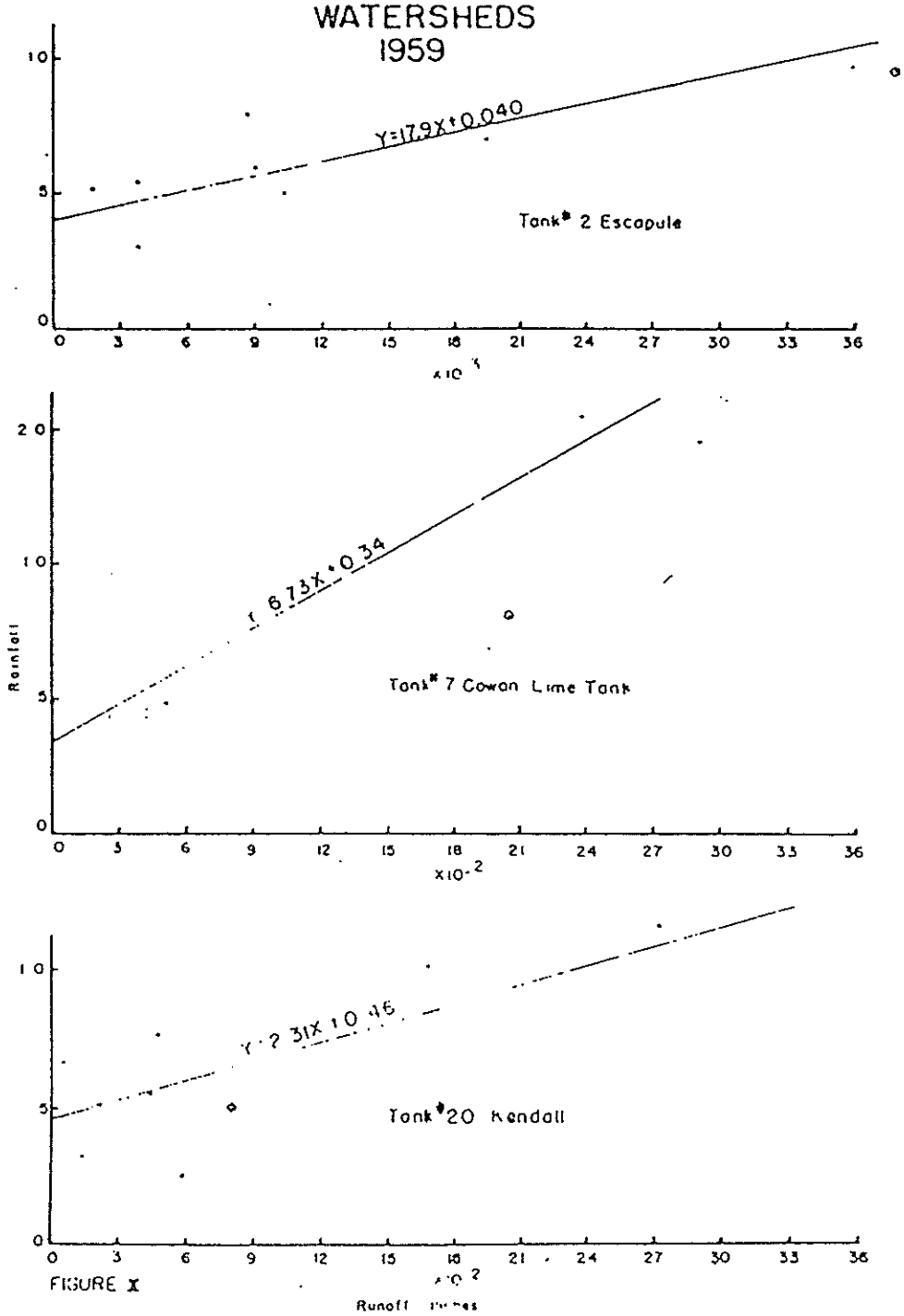


FIGURE X