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Rates and Amounts of Runoff for the Blacklands of Texas[1]

By

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Runoff studies at the Blacklands experimental watershed near Waco, Tex., were started in 1937 as a cooperative project of the Soil Conservation Service and the Texas Agricultural Experiment Station. By 1939, records were being collected from enough areas of different sizes to indicate the probability of a reasonable relationship between peak rate of runoff and size of area. The collection of records from most of the areas was interrupted by World War II, and measurements from all but three of the areas were discontinued in 1943. Work was resumed on a reduced scale in 1945.

At the time this work was started, little information was available on the runoff from small agricultural watersheds. Some was available for small plots at various erosion experiment stations and State experiment stations and for extensive areas where stream discharge was measured by the United States Geological Survey, but none for

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[2] The authors gratefully acknowledge the assistance of the U. S. Geological Survey and the U. S. Weather Bureau in making available their unpublished records.

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areas of 5 to 5,000 acres. The Blacklands experimental watershed and similar experimental watershed projects located near Coshocton, Ohio, and Hastings, Nebr., were established to provide information for areas within this size range.

The results obtained at the Waco watershed are generally applicable to the Blacklands of Texas, Arkansas, and Oklahoma, the boundaries of which are shown in figure 1.

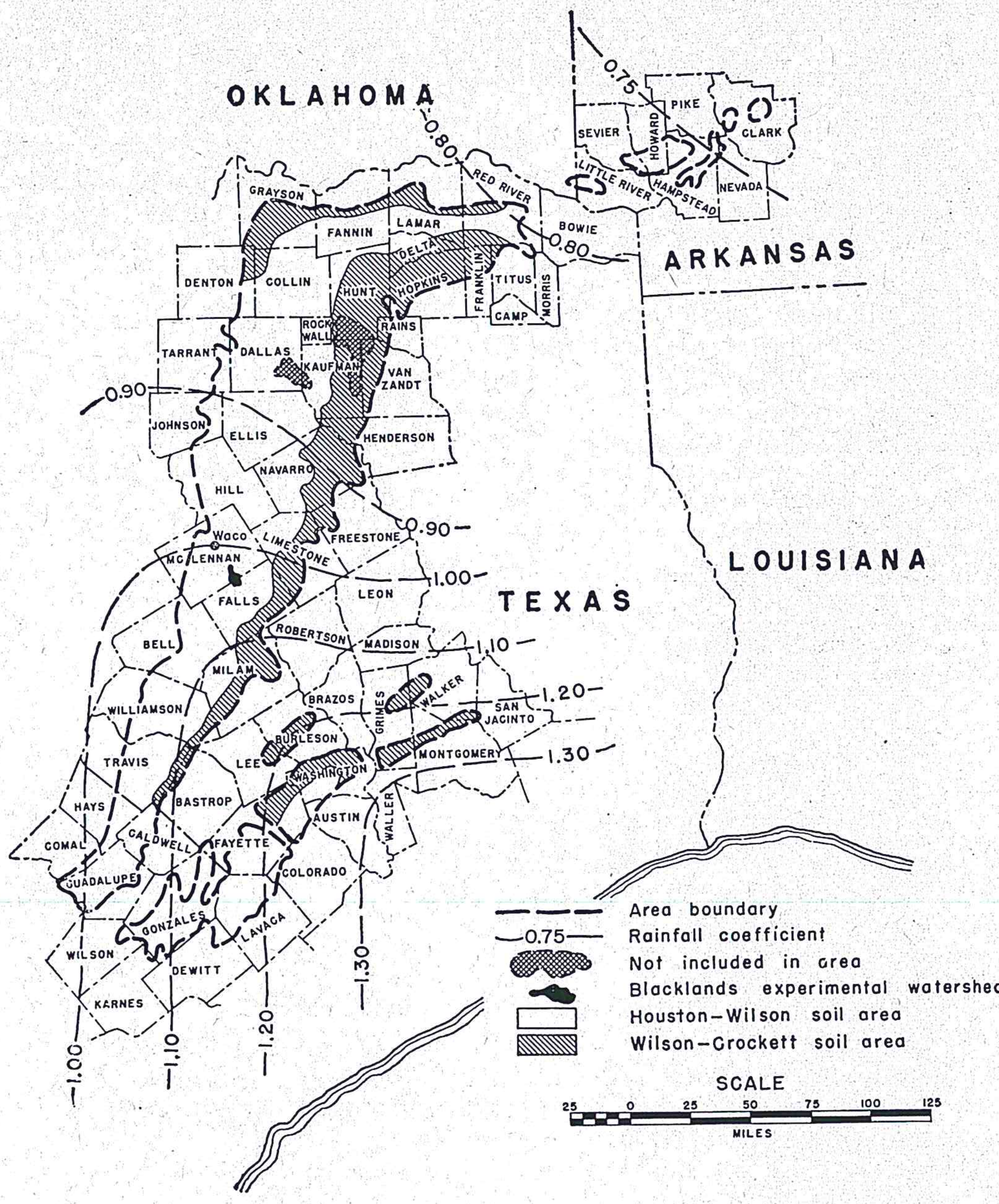

FIGURE 1.—Part of Blacklands area to which this bulletin applies showing principal soil groups and generalized rainfall coefficients.

THE BLACKLANDS AREA

Climate

The climate of the area is characterized by long, hot summers and short, relatively mild winters. Most of the Blackland prairie has an average annual rainfall from 35 to 40 inches. Short storms of high intensities are more common than storms of long duration with large total amounts of rainfall. United States Weather Bureau records for Waco give the normal rainfall by months as follows: January, 2.19 inches; February, 2.37 inches; March, 3.08 inches; April, 4.24 inches; May, 4.56 inches; June, 3.16 inches; July, 2.08 inches; August, 2.33 inches; September, 2.94 inches; October, 2.59 inches; November, 2.69 inches; December, 2.81 inches; annual, 35.04 inches. The actual rainfall in any specific month or year may differ widely from these amounts.

Agriculture

The dominant native vegetation of the Blacklands in early days was prairie grasses and scattered patches of mesquite trees. About 1880, the movement began to divide and sell the large holdings of grass lands in smaller blocks and to break the sod for cultivated crops. Cultivation reached a peak during World War I and has continued at fairly high levels in subsequent years. Since about 1937, there has been a tendency to reduce row-crop farming slightly, with the result that some land formerly in row crops is now in grass, small grains, or clovers. Also, a considerable acreage of badly eroded land has ceased to be profitable for cultivation. Most of this land has grown up to Johnson grass, other grasses, and weeds. Although the acreage of grain crops is increasing, cotton is still the primary cash crop.

THE BLACKLANDS EXPERIMENTAL WATERSHED

Watershed Characteristics

These studies were made on a tract at the headwaters of Brushy Creek, a small stream in the Brazos River basin southeast of Waco. This area, which is typical of the Blacklands of Texas, lies between latitudes 31°27′ and 31°32′ N. and between longitudes 96°51′ and 96°54′ W. Elevations range from 464 to 595 feet above mean sea level. The total area of the watershed is 5,860 acres. Several smaller experimental watersheds, ranging in extent from slightly less than 3 acres to more than 1,000 acres, were established within the main area. The size, physiographic character, and type of land use in experimental areas of the Blacklands experimental watershed are shown in table 1.

TABLE 1.—*Watershed characteristics*

Watershed	Size	Form factor	Slope: Area in slope range of— Less than 1 percent	Slope: Area in slope range of— 1 to 3 percent	Slope: Area in slope range of— 3 to 6 percent	Slope: Area in slope range of— 6 percent or more	Slope: Average slope	Land use in 1939: Cultivated land	Land use in 1939: Permanent grass	Land use in 1939: Roads	Land use in 1939: Farmsteads
	Acres		*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
2	2. 70	0. 734	0	100	0	0	1. 91	100	0	0	0
3	3. 09	. 667	0	100	0	0	1. 91	100	0	0	0
5	3. 09	. 667	0	48	52	0	3. 27	100	0	0	0
6	3. 04	. 787	0	38	62	0	3. 18	100	0	0	0
7	3. 15	. 620	11	89	0	0	1. 67	100	0	0	0
11	3. 23	. 878	75	25	0	0	. 94	100	0	0	0
12	2. 97	. 896	0	22	78	0	3. 81	0	100	0	0
13	3. 19	. 752	0	77	23	0	3. 07	100	0	0	0
14	3. 02	. 939	0	100	0	0	1. 55	100	0	0	0
16	3. 17	. 711	0	100	0	0	2. 58	100	0	0	0
17	2. 99	. 903	0	100	0	0	1. 83	100	0	0	0
18	3. 04	. 627	72	28	0	0	1. 14	100	0	0	0
Y10	21	. 846	0	85	15	0	1. 88	97. 5	0	2. 5	0
Y8	20. 8	. 369	22	67	11	0	2. 24	97. 5	0	2. 5	0
Y6	20. 9	. 720	10	35	55	0	3. 21	99. 1	0	. 9	0
Y7	40. 0	. 602	9	91	0	0	1. 87	100	0	0	0
Y4	79. 9	. 521	3	61	36	0	2. 86	96. 1	3	. 9	0
Y2	132	. 532	6	67	27	0	2. 57	92. 0	6. 9	1. 1	0
W6	42. 3	. 639	0	99	1	0	2. 03	75. 1	17. 7	7. 2	0
W1	176	. 262	11	75	14	0	2. 19	86. 5	9. 3	2. 6	1. 6
Y	309	. 531	3	79	18	0	2. 41	79. 8	18. 5	1. 2	. 5
D	1, 110	. 353	15	72	13	0	2. 10	84. 4	11. 0	3. 2	1. 4
J	5, 860	. 199	17	69	11	3	2. 14	80. 6	15. 7	2. 3	1. 4

SOIL AND GEOLOGY

Gentle slopes, deep soils, and poorly defined stream channels are characteristic of the experimental watershed and general area. The soils are predominantly of the Houston series and have the typical shrinkage cracks when dry. The geologic materials from which the main Blackland prairies developed belong primarily to three groups in the Gulf series of the Cretaceous system. These, in ascending order of the geologic profile, are Austin, Taylor, and Navarro. Small areas have soils from the Eagle Ford and other formations. All of the experimental watershed lies on formations of the Taylor group. In this locality these strata dip approximately 80 feet per mile in a general S. 75° W. direction. Three strata of the Taylor group—sandy marl, chalk, and highly calcareous marl—occur on the watershed. All of these are calcareous, the calcium-carbonate content ranging from 5 to 25 percent in sandy marl and from 70 to 80 percent in the chalk. The calcareous marl has about 50 percent of calcium carbonate. The soils strongly reflect the character of the geologic material from which they are formed. Those developed from the sandy marl are largely of the Crockett and Wilson series; those from the chalk, of the Austin series; and those from the calcareous marl, of the Houston series. Soils of the Houston series occupy a major portion of the 5,860-acre watershed. The soils of the Crockett and Wilson series occur primarily in the northern part.[3] The various soil types and the average depths of the soils on the individual watersheds of the experimental area are listed in tables 2 and 3.

TABLE 2.—*Soil types and average depth*[1] *of soil in watersheds C, D, and J*

Soil group and type	Watershed C		Watershed D		Watershed J	
	Area	Average depth	Area	Average depth	Area	Average depth
1. Prairie soils, granular structure, alkaline throughout:						
a. Normal profile:	*Percent*	*Inches*	*Percent*	*Inches*	*Percent*	*Inches*
1. Houston black clay	0.8	51	2.4	53	48	59
2. Houston black clay, gravelly phase	[2] .1	48	[2] .1	48	[2] .1	59
3. Houston-Hunt clay	44.6	55	44.3	49	17.8	50
4. Houston black clay, saline phase	0	------	0	------	[2] .1	60
Total	45.5	------	46.8	------	66.0	------
b. Shallow to parent material:						
5. Houston black clay, shallow phase	0	------	0	------	4.2	44
6. Houston black clay, over chalk	0	------	0	------	1.9	28
7. Austin clay, shallow phase	0	------	0	------	.2	6
8. Chalk outcrop	0	------	0	------	[2] .1	0
Total	0	------	0	------	6.4	------
2. Prairie soils, moderately calcareous substrata:						
a. Dense:						
9. Wilson clay	2.3	12	4.3	14	5.0	13
10. Wilson clay loam	1.3	14	1.8	13	3.9	12
11. Wilson fine sandy loam	2.4	5	1.8	9	1.4	9
Total	6.0	------	7.9	------	10.3	------
b. Moderately friable:						
12. Crockett clay loam	9.5	6	11.7	5	4.8	6
13. Crockett fine sandy loam	17.4	7	13.2	7	3.1	7
Total	26.9	------	24.9	------	7.9	------

[1] Depth to parent material in soil group 1 and to B horizon in soil group 2. Depth classifications not made for colluvial and alluvial soils.
[2] Less than 0.1 percent.

[3] SOIL CONSERVATION SERVICE, U. S. DEPARTMENT OF AGRICULTURE. THE AGRICULTURE, SOILS, GEOLOGY, AND TOPOGRAPHY OF THE BLACKLANDS EXPERIMENTAL WATERSHED. U. S. Dept. Agr. Hydrol. Bul. 5, 38 pp. illus. 1942.

TABLE 2.—*Soil types and average depth*[1] *of soil in watersheds C, D, and J*—Continued

Soil group and type	Watershed C		Watershed D		Watershed J	
	Area	Average depth	Area	Average depth	Area	Average depth
3. Colluvial soils:	*Percent*	*Inches*	*Percent*	*Inches*	*Percent*	*Inches*
14. Houston-Hunt clay, colluvial phase	0	------	0	------	. 4	------
15. Wilson clay, colluvial phase	7. 8	------	7. 9	------	2. 6	------
16. Wilson clay loam, colluvial phase	7. 7	------	6. 4	------	1. 5	------
17. Wilson fine sandy loam, colluvial phase	. 4	------	. 8	------	. 3	------
18. Crockett clay loam, colluvial phase	0	------	. 2	------	. 1	------
19. Crockett fine sandy loam, colluvial phase	3. 7	------	2. 0	------	. 4	------
Total	19. 6	------	17. 3	------	5. 3	------
4. Alluvial soils:						
20. Trinity clay	0	------	0	------	. 9	------
21. Catalpa clay	1. 3	------	1. 8	------	2. 9	------
22. Kaufman clay	. 7	------	. 8	------	. 2	------
23. Kaufman fine sandy loam	0	------	. 5	------	. 1	------
Total	2. 0	------	3. 1	------	4. 1	------

[1] Depth to parent material in soil group 1 and to B horizon in soil group 2. Depth classifications not made for colluvial and alluvial soils.

TABLE 3.—*Soil types and average depth of soil in watersheds Y and W and their subdivisions*

Watershed	Houston black clay		Houston black clay, gravelly phase		Houston black clay, shallow phase		Houston black clay, shallow phase over chalk		Austin clay, shallow phase		Trinity clay
	Area	Average depth	Area	Average depth	Area	Average depth	Area	Average depth	Area	Average depth	Area
	Percent	*Inches*	*Percent*	*Inches*	*Percent*	*Inches*	*Percent*	*Inches*	*Percent*	*Inches*	*Percent*
Y	65. 7	57	0	----	15. 2	47	17. 5	27	1. 1	6	0. 5
Y2	75. 2	75	0	----	0	----	22. 5	26	1. 8	6	. 5
Y4	73. 9	58	0	----	0	----	23. 8	26	2. 3	6	0
Y6	34. 6	60	0	----	0	----	58. 1	26	7. 3	6	0
Y7	84. 5	60	0	----	15. 5	48	0	----	0	----	0
Y8	93. 0	57	0	----	0	----	7. 0	48	0	----	0
Y10	93. 9	59	0	----	0	----	4. 7	24	1. 4	6	0
WI	66. 4	55	0	----	33. 4	47	0	----	0	----	. 2
W2	69. 8	50	16. 0	57	13. 6	46	0	----	0	----	. 6
W6	98. 7	60	0	----	1. 3	48	0	----	0	----	0
W10	61. 0	51	39. 0	57	0	----	0	----	0	----	0
12	100	59	0	----	0	----	0	----	0	----	0
17	70. 4	60	0	----	29. 6	24	0	----	0	----	0

Land Use

In 1939, 15.7 percent of the 5,860 acres in the watershed as a whole (area J) was pasture or hay land, 3.7 percent was in farmsteads and roads, and the remainder or 80.6 percent was cultivated. Of the cultivated land, 38.0 percent was cropped to cotton, 30.0 percent to corn, 13.2 percent to other row crops, and 15.0 percent to broadcast or drilled crops. No crop was grown on 3.8 percent of the cultivated land. This general crop distribution has varied only slightly from year to year. This is a type of land use which, without adequate soil conservation measures, is conducive to large amounts and high rates of runoff and severe erosion damage.

The small experimental areas of about 3 acres each were cropped to several different crops—cotton, corn, and oats—during the period of record, but only one kind of crop was grown on each area in any one year. Area 12 is a small area of native grass which had never been plowed and from which one cutting of hay was obtained each year. The 20-acre tracts consisted entirely of cultivated land except for small areas where cultivation was impractical due to excessive road drainage. Crops on these tracts included cotton, corn, and oats each year. The larger areas have all the land uses mentioned and in proportions comparable to those in the area as a whole (watershed J).

Rainfall and Runoff Records

On the experimental watershed, a number of rain gages of the recording type furnished data on both rainfall amounts and intensities. Records from 10 of the gages were used in preparing this report. The records were selected so that a reasonable areal distribution was obtained for each of the watersheds from which runoff measurements were used.

The watersheds from which runoff measurements were obtained, together with some of the watershed characteristics, are given in table 1. Stages were obtained with automatic water-stage recorders equipped with charts having an open time scale so that rises could be accurately measured. Calibrated flumes were used with the water-stage record to determine the runoff from the areas of less than 300 acres. For the larger areas, artificial controls were constructed in the stream channels, and the discharges were obtained by means of current-meter measurements and from rating curves developed from the measurements.

AREA OF APPLICATION

All the studies on the effect of conservation practices were made on deep, fine-textured, slowly permeable soils of the Blacklands. The soil of a major part of the areas studied is Houston black clay. The lands along Brushy Creek include considerable areas of deep, fine-textured, very slowly permeable soils of the Blacklands, mostly Crockett clay loam and Wilson clay and clay loams. There are also smaller areas of deep, medium-textured, very slowly permeable soils, mostly Crockett and Wilson fine sandy loams. The results obtained on the effects of conservation practices on peak rates of runoff are particularly applicable to the deep, fine-textured, slowly permeable soils that comprise the major portion of that part of the Blacklands area shown in figure 1 as the Houston-Wilson area. The results are somewhat less applicable to the deep, fine- and medium-textured, very slowly permeable soils of the Wilson-Crockett area and to the shallow, fine-textured, permeable soils found primarily on the Austin formations.

For the areas larger than the 5,860-acre tract where records were obtained by the United States Geological Survey, the major soil types are included in about the ratios that could be expected throughout the Blacklands.

The differences in rainfall in different parts of the Blacklands result in different peak rates of runoff. To compensate for these rainfall differences it is necessary to make appropriate adjustments in runoff values. The degree of adjustment is shown in figure 1 as rainfall coefficients, which are percentages of the rainfall values at Waco.

FLOOD PEAKS FOR USE IN DESIGN OF CONSERVATION STRUCTURES

Analytical Procedures

It is not the purpose of this bulletin to describe in detail the analytical procedures used to determine the flood peaks that might be expected for various recurrence intervals. These procedures have been fully set forth in another publication.[4] A brief outline of the procedures at this point, however, will assist in an understanding of the extent to which the estimated peak rates are supported by the experimental data.

Probability studies were made of the maximum annual flood peaks for the experimental watersheds listed in table 1. Similar studies were also made of United States Geological Survey data for six large watersheds located elsewhere within the Texas Blacklands.

The flood peaks, as determined by the probability studies, were then corrected to what they would have been if the rainfall at each watershed during the period of runoff record had been a good sample of a long-term rainfall record at Waco. To determine these corrections, probability studies based on long-term Waco rainfall were made of maximum annual amounts of rainfall for 10-, 30-, 60-, and 180-minute periods and of the product of annual rainfall and the number of excessive storms.[5] Similar probability studies were made of these rainfall characteristics for each watershed in the experimental area for the period of runoff record.

A comparison of the probability curves of rainfall intensities at any watershed with those computed for long-term Waco rainfall formed the basis for correcting the magnitude of the flood peaks. Likewise, a comparison of the probability curves of the product of annual rainfall and number of excessive storms formed the basis for correcting the frequency of the flood peaks.[4]

The corrected values of flood peaks for a recurrence interval of 10 years were then plotted against the corresponding watershed size, and least-square curves were computed to express the relationship. Figure 2 shows these computed curves together with the plotted points of

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[4] Potter, W. D. EFFECT OF RAINFALL ON MAGNITUDE AND FREQUENCY OF PEAK RATES OF SURFACE RUNOFF. Amer. Geophys. Union Trans. 30: 735–751. 1949.

[5] Potter, W. D. NORMALCY TESTS OF PRECIPITATION AND FREQUENCY STUDIES OF RUNOFF ON SMALL WATERSHEDS. U. S. Dept. Agr. Tech. Bul. 985, 24 pp., illus. 1949.

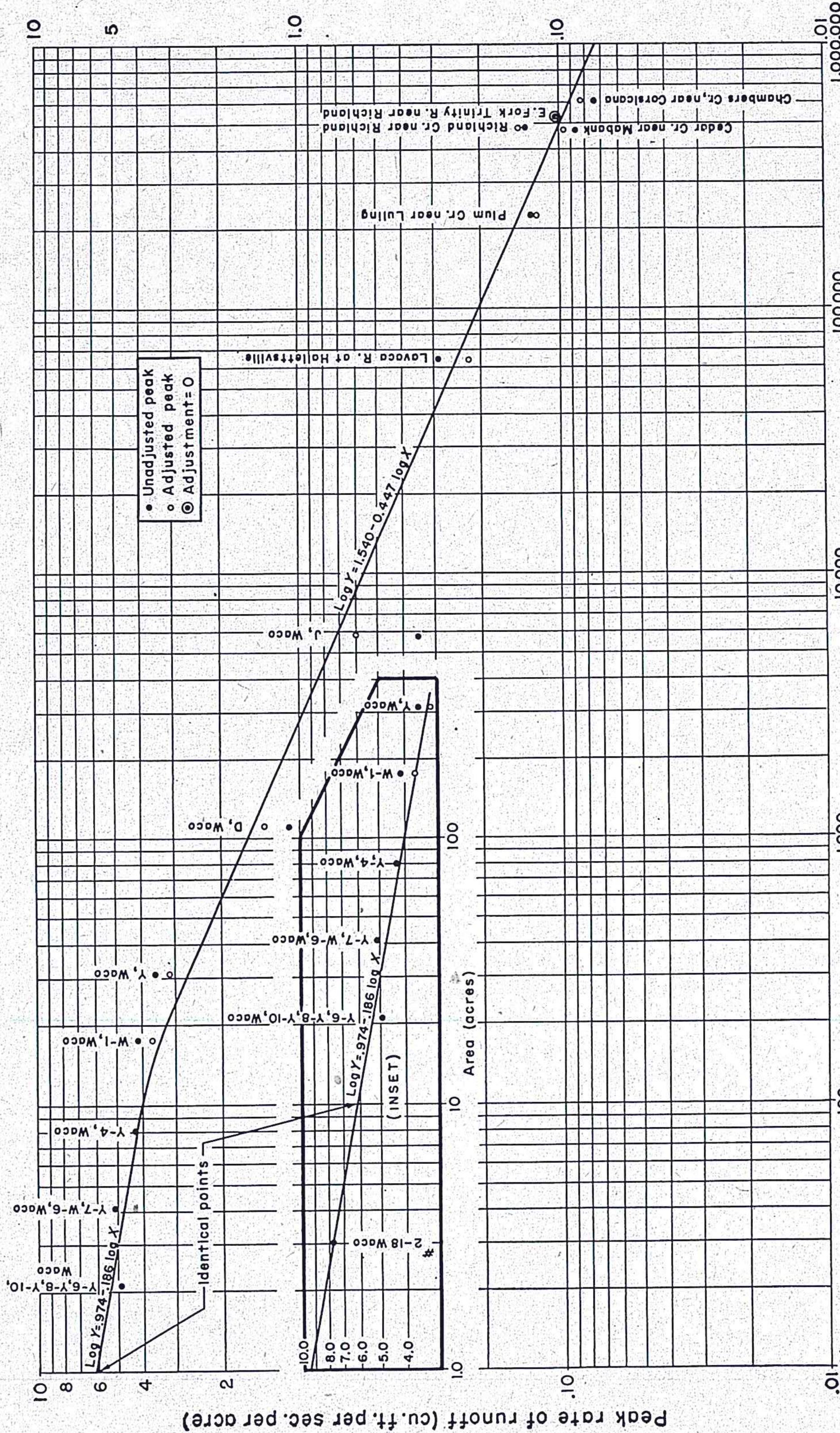

FIGURE 2.—Relationship between area of watershed and peak rate of runoff for a recurrence interval of 10 years.

both corrected and uncorrected values of the flood peaks. A comparison of the standard error computed from uncorrected flood peaks with that computed from the corrected values indicated that the correction for rainfall differences had reduced the scatter of the plotted points by more than 50 percent. In other words, the reliability of the computed flood peak versus area relationship had been increased by 50 percent by correcting for rainfall differences.

Reduced Peaks for Small Areas

It will be noted in figure 2 that the area versus peak-rate relationship is not constant for all areas but is expressed by two curves; one for areas less than 100 acres and one for areas greater than 200 acres with a transition zone for areas between these limits. If the relationship had been constant and could have been expressed by the curve for areas greater than 200 acres extended to include the smaller areas, then the peak rates for these areas would have been higher than those indicated by the experimental data and defined by the computed curve for areas less than 100 acres. This difference would have been greatest for an area of 1 acre and would have decreased uniformly to zero difference for an area of 150 acres.

Two explanations are advanced for the relatively low flood peaks from the areas less than 100 acres. One explanation ascribes the low peaks to the fact that the small watersheds do not have well-defined drainage channels and that a considerable proportion of the watershed is made up of relatively flat slopes. The runoff from these flat slopes does not reach the gaging station until some time after the flood peak has passed, and thus does not contribute to its magnitude. The larger the watershed, the greater is the proportion of total area drained by well-defined channels and the smaller is the proportion of flat noncontributing areas. Thus, the effect of the noncontributing areas on the magnitude of the flood peak decreases with the size of the watershed and is negligible for a watershed of 150 acres.

The other explanation ascribes the low peaks from the small watersheds to the amount of excess rainfall that enters surface cracks in the soil. These cracks (figs. 3 and 4) appear at the surface when the soil is dry. They are very numerous and may extend many feet into the subsoil. When the soil becomes wet, the soil particles swell and the cracks close. This wetting and closing is many times limited to the surface soil (fig. 4), thus sealing the crack at the surface but otherwise leaving it unaffected. When storms occur at a time when cracks are open at the surface, a large amount of rainfall excess may be intercepted for short periods of time before the soil particles become wet and surface sealing takes place. The rainfall excess thus lost to cracks may amount to a large proportion of the total excess rainfall for these short-time intervals. As the time interval is increased, the ratio of rainfall excess lost to cracks to the total rainfall excess for the time interval becomes less. Thus, for small watersheds having an average time of concentration of from 5 to 15 minutes, the rainfall excess lost to cracks has an appreciable effect on the magnitude of flood peaks. This effect becomes less and less as the size of the watershed and the average time of concentration is increased and is negligible when the area of the watershed exceeds 150 acres.

FIGURE 3.—Surface cracks in Houston black clay soil during dry weather.

Existing experimental data are insufficient to determine the relative importance of these factors, but it may be safely assumed that both noncontributing areas and surface cracks contribute to the relatively low flood peaks that may be expected from areas of less than 100 acres.

USE OF FLOOD-PEAK DATA IN DESIGN OF STRUCTURES

Flood-peak values appropriate for use in the design of conservation structures were derived from the curves shown in figure 2. The values for recurrence intervals of 2, 5, 10, 25, and 50 years and for areas of from 2 to 10,000 acres are presented in tabular form in table 4. The values for a recurrence interval of 10 years are presented graphically in figure 5. The coefficients that should be applied to any value in this curve to obtain corresponding values for 2–, 5–, 25–, and 50-year recurrence intervals are as follows:

for 2-year recurrence interval multiply by 0.470;
for 5-year recurrence interval multiply by 0.785;
for 25-year recurrence interval multiply by 1.270;
for 50-year recurrence interval multiply by 1.470.

ADJUSTMENT OF FLOOD-PEAK VALUES FOR DIFFERENCES IN CULTURAL AND PHYSIOGRAPHIC FACTORS

For areas of 20 acres or less the values given in table 4 and figure 5 were obtained from 100-percent-cultivated areas where approximately 50 percent of the area was in cotton, 25 percent in corn, and 25 percent in oats. No part of the areas was in permanent grass. For areas greater than 20 acres the values were obtained from mixed-

FIGURE 4.—Cracks in the face of a gully in Houston black clay soil after approximately 3 inches of rain had wet the surface soil and closed the cracks in the surface. The cracks in the subsurface remained open.

cover watersheds where approximately 80 percent of the land was cultivated, the principal crops being cotton and corn with some small grains. The remaining 20 percent of such areas included land in permanent grass, pasture or hay land, brush, farmstead, and roads.

The qualifying physiographic features upon which the flood-peak determinations are based are given in the description of the Experimental Watershed and in tables 1, 2, and 3.

Within the general area of application small local areas may be found where physiographic and cultural conditions differ materially from those prevailing on the experimental watersheds. For such areas the field technician must use his judgment in deciding whether the noted differences would result in larger or smaller flood peaks than those specified in table 4 or figure 5.

ADJUSTMENT FOR RAINFALL DIFFERENCES

Figure 1 shows the coefficients that should be applied to the values given in table 4 or figure 5 to compensate for rainfall differences throughout the area of application.

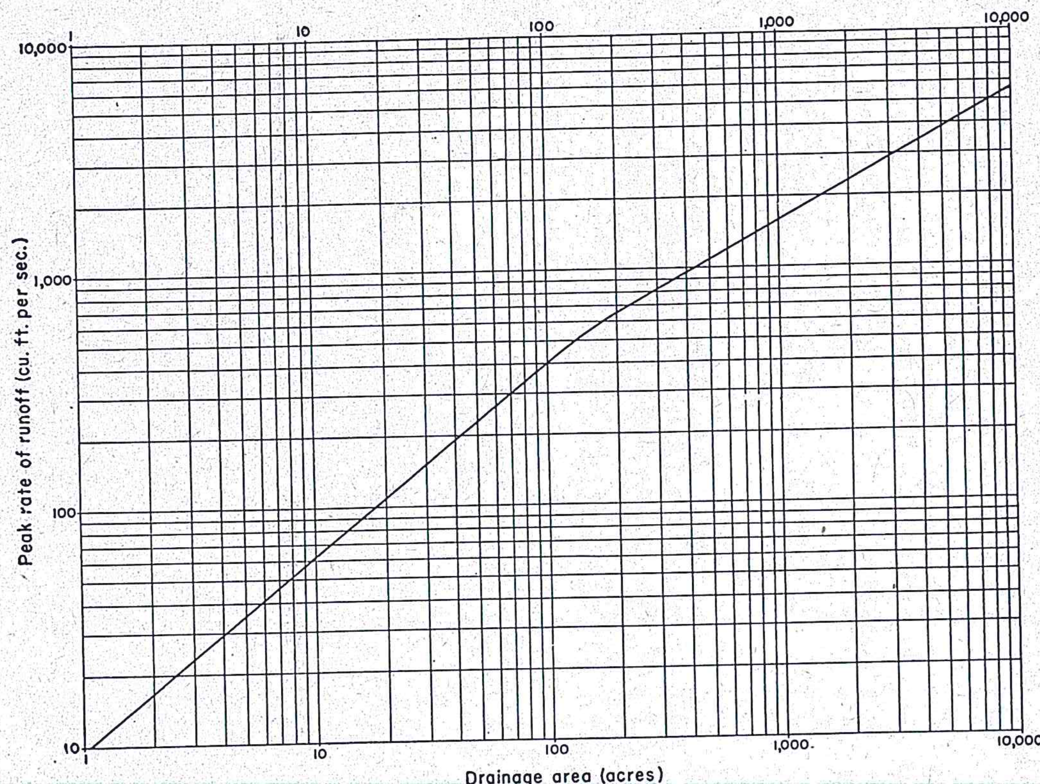

FIGURE 5.—Relation of peak rates of runoff to size of drainage area for recurrence interval of 10 years. This curve is applicable only for physiographic and cultural features similar to those indicated on page 12 and in tables 1, 2, and 3.

EXAMPLE

The following example illustrates the use of the various figures and tabulations in determining flood peaks:

Given: A 500-acre mixed-cover watershed in the vicinity of Dallas, Tex.

Required: Flood peaks that may be expected for recurrence intervals of 10, 25, and 50 years.

Solution: From table 4, the flood peaks from 500 acres for 10-, 25-, and 50-year recurrence intervals are found to be 1,080 cubic feet per second, 1,370 cubic feet per second, and 1,590 cubic feet per second,

TABLE 4.—*Peak rates of runoff for design of conservation structures*[1]

Area (acres)	Recurrence interval				
	2 years	5 years	10 years	25 years	50 years
	Cu. ft. per sec.	*Cu. ft. per sec.*	*Cu. ft. per sec.*	*Cu. ft. per sec.*	*Cu. ft. per sec.*
2	7. 8	13. 0	16. 6	21. 1	24. 4
4	13. 7	22. 8	29. 1	37. 0	42. 8
6	19. 0	31. 8	40. 5	51. 4	59. 5
8	24. 1	40. 2	51. 2	65. 0	75. 3
10	28. 8	48. 2	61. 4	78. 0	90. 2
20	50. 8	84. 8	108. 0	137. 0	159. 0
30	70. 5	118. 0	150. 0	190. 0	220. 0
40	89. 3	149. 0	190. 0	241. 0	279. 0
50	107. 0	179. 0	228. 0	290. 0	335. 0
60	124. 0	207. 0	264. 0	335. 0	388. 0
70	140. 0	235. 0	299. 0	380. 0	440. 0
80	157. 0	262. 0	334. 0	424. 0	491. 0
90	172. 0	288. 0	367. 0	466. 0	539. 0
100	188. 0	314. 0	400. 0	508. 0	588. 0
200	306. 0	510. 0	650. 0	826. 0	956. 0
300	382. 0	638. 0	813. 0	1, 032. 0	1, 200. 0
400	448. 0	748. 0	953. 0	1, 210. 0	1, 400. 0
500	508. 0	848. 0	1, 080. 0	1, 370. 0	1, 590. 0
600	559. 0	934. 0	1, 190. 0	1, 510. 0	1, 750. 0
700	611. 0	1, 020. 0	1, 300. 0	1, 650. 0	1, 910. 0
800	658. 0	1, 100. 0	1, 400. 0	1, 780. 0	2, 060. 0
900	700. 0	1, 170. 0	1, 490. 0	1, 890. 0	2, 190. 0
1,000	743. 0	1, 240. 0	1, 580. 0	2, 000. 0	2, 320. 0
2,000	1, 090. 0	1, 820. 0	2, 320. 0	2, 950. 0	3, 410. 0
3,000	1, 360. 0	2, 280. 0	2, 900. 0	3, 680. 0	4, 260. 0
4,000	1, 600. 0	2, 670. 0	3, 400. 0	4, 320. 0	5, 000. 0
5,000	1, 810. 0	3, 020. 0	3, 850. 0	4, 890. 0	5, 660. 0
6,000	2, 000. 0	3, 340. 0	4, 260. 0	5, 410. 0	6, 260. 0
7,000	2, 180. 0	3, 640. 0	4, 640. 0	5, 890. 0	6, 820. 0
8,000	2, 340. 0	3, 920. 0	4, 990. 0	6, 340. 0	7, 340. 0
9,000	2, 510. 0	4, 190. 0	5, 340. 0	6, 780. 0	7, 850. 0
10,000	2, 660. 0	4, 430. 0	5, 650. 0	7, 180. 0	8, 310. 0

[1] Values in this table are applicable only for physiographic and cultural features approximating those indicated on page 12 and in tables 1, 2, and 3.

respectively, for areas in the vicinity of Waco, Tex. From figure 1, the rainfall coefficient for Dallas is found, by interpolation, to be 0.86.

The expected flood peaks in cubic feet per second are, therefore:

1,080 × 0.86 = 929 for recurrence interval of 10 years;
1,370 × 0.86 = 1,180 for recurrence interval of 25 years;
1,590 × 0.86 = 1,370 for recurrence interval of 50 years.

As an alternative method, the flood peak from 500 acres in the vicinity of Waco, Tex., is found from figure 5 to be 1,080 cubic feet per second for a recurrence interval of 10 years. The adjustment factors for recurrence intervals of 25 and 50 years are 1.27 and 1.47, respectively. The rainfall coefficient for Dallas is 0.86 (fig. 1).

The expected flood peaks in cubic feet per second are, therefore:

1,080 × 0.86 = 929 for recurrence interval of 10 years;
1,080 × 1.27 × 0.86 = 1,180 for recurrence interval of 25 years;
1,080 × 1.47 × 0.86 = 1,370 for recurrence interval of 50 years.

EFFECT OF CONSERVATION PRACTICES ON PEAK RATES OF RUNOFF

Rainfall and runoff records have been obtained from two similar areas of about 300 acres each and from 10 smaller areas within these 300-acre areas since 1939. Through 1942, both of the 300-acre watersheds were cropped and cultivated as nearly alike as possible in straight rows and with ordinary farm practices. In the fall of 1942 and spring of 1943, conservation practices were established on one area; on the other, the farming practices formerly used were continued. The conservation practices included the conversion of part of the cultivated acreage to grass land, improved rotations, and the planting of legumes and installation of terraces on the reduced area of cultivated crop land. Table 5 gives the land use distribution for individual watersheds within the two 300-acre areas for 1942 before conservation practices were established and for 1948 after the conservation system was fairly stable and well established. The lay-out of the terrace and drainage systems and the extent of grass land before and after conservation treatment are shown in figure 6.

On the conservation area good agronomic practices have been continued, and the terraces, waterways, and structures have been carefully maintained. The terraces have been plowed at least 2 years of every 3 with a two-way plow, turning the furrows toward the terrace ridge and leaving the dead furrow in the terrace channel. Pastures have been mowed for weed control at least once each year. A large part of the pasture areas have a good stand of bur clover which has reseeded annually and is spreading. On some pasture areas other legumes have been seeded. Commercial fertilizer has been applied on a few small areas.

No attempt was made in these studies to isolate and evaluate separately the effect of different conservation practices. Instead, the aim was to determine the combined effect of all the measures included in the conservation plan. This was done by comparing the relationship of the rainfall-minus-runoff values for a pair of areas (W and Y)[6]; first, when both areas had the same treatment, and then for the period when one area (Y) had conservation practices applied. Sufficient measurements were available for the period July 1943 to May 1946 from two of these areas—Y–2 (132 acres) and W–1 (176 acres)—to serve as the basis for these comparisons. The studies on these areas showed that conservation practices appreciably reduce the peak rates of runoff. Furthermore, the reduction in peak rate is relatively constant regardless of flood magnitude. For area Y–2 the amount of the reduction is about 0.48 inch per hour. Thus, if the expected flood for a 10-year recurrence interval from an area of this size without conservation practices is 3.80 inches per hour, a peak runoff rate of only 3.32 inches per hour could be expected after conservation practices have been applied. This represents a reduction in peak rate of runoff of 0.48 inch per hour, or approximately 12.6 percent (fig. 7). Fur-

[6] BAIRD, RALPH W. THE EFFECT OF CONSERVATION PRACTICES ON PEAK RATES OF RUNOFF. Tex. Engin. 16(8) : 8–15. 1946.

TABLE 5.—*Percentage of each watershed in crops or other land use, 1942 and 1948*

Watershed	Year	Kind of crop or land use											Total area
		Cotton	Corn	Oats	Oats with hubam clover	Hubam clover	Sorghum	Pasture	Meadow	Other crops	Farm-steads	Roads	
		Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Acres*
SW-12	1942	0	0	0	0	0	0	0	100	0	0	0	2. 97
	1948	0	0	0	0	0	0	0	100	0	0	0	2. 97
SW-17	1942	0	0	100	0	0	0	0	0	0	0	0	2. 99
	1948	0	0	0	0	0	0	100	0	0	0	0	2. 99
Y-10	1942	48. 5	25. 2	23. 8	0	0	0	0	0	0	0	2. 5	21
	1948	27. 1	28. 1	---	29	0	0	13. 3	0	0	0	2. 5	21
Y-8	1942	50. 0	24. 0	23. 5	0	0	0	0	0	0	0	2. 5	20. 8
	1948	31. 7	32. 2	0	30. 3	0	0	3. 3	0	0	0	2. 5	20. 8
Y-6	1942	49. 8	24. 9	24. 4	0	0	0	0	0	0	0	. 9	20. 9
	1948	33. 0	32. 2	0	19. 1	0	0	14. 8	0	0	0	. 9	20. 9
Y-7	[1] 1942	---	---	---	---	---	---	---	---	---	---	---	40
	[1] 1948	---	---	---	---	---	---	---	---	---	---	---	40
Y-4	1942	44. 3	20. 9	19. 1	0	0	3	11. 8	0	0	0	. 9	79. 9
	1948	21. 0	27. 3	0	22. 4	0	0	28. 4	0	0	0	. 9	79. 9
Y-2	1942	45. 6	22. 4	18. 3	0	0	3. 7	8. 9	0	0	0	1. 1	132
	1948	18. 3	27. 6	0	23. 9	0	0	29. 1	0	0	0	1. 1	132
Y	1942	37. 0	20. 8	14. 9	0	0	3. 3	20. 5	1. 8	0	. 5	1. 2	309
	1948	20. 7	21. 1	0	16. 5	2. 9	. 3	35. 0	1. 8	0	. 5	1. 2	309
W-10	1942	49. 3	25. 9	24. 8	0	0	0	0	0	0	0	0	19. 7
	1948	49. 3	25. 9	24. 8	0	0	0	0	0	0	0	0	19. 7
W-6	1942	39. 2	16. 4	19. 5	0	0	0	15. 2	2. 5	0	0	7. 2	42. 3
	1948	19. 2	19. 5	36. 4	0	0	0	15. 2	2. 5	0	0	7. 2	42. 3
W-2	1942	24. 8	20. 1	16. 6	0	0	2. 7	20. 8	9. 1	. 3	. 7	4. 9	130
	1948	22. 7	19. 1	18. 6	0	0	3. 6	21. 0	9. 1	. 3	. 7	4. 9	130
W-1	1942	45. 2	22. 5	14. 2	0	0	3. 4	7. 1	3. 4	0	1. 6	2. 6	176
	1948	37. 4	18. 0	12. 8	0	0	6. 4	14. 6	3. 4	3. 2	1. 6	2. 6	176

[1] No record of crops—largely private land.

thermore, a smaller flood would be reduced the same amount; i. e., a flood with a peak rate of 1.00 inch per hour without conservation practices would be reduced through the application of conservation practices to 0.52 inch per hour.

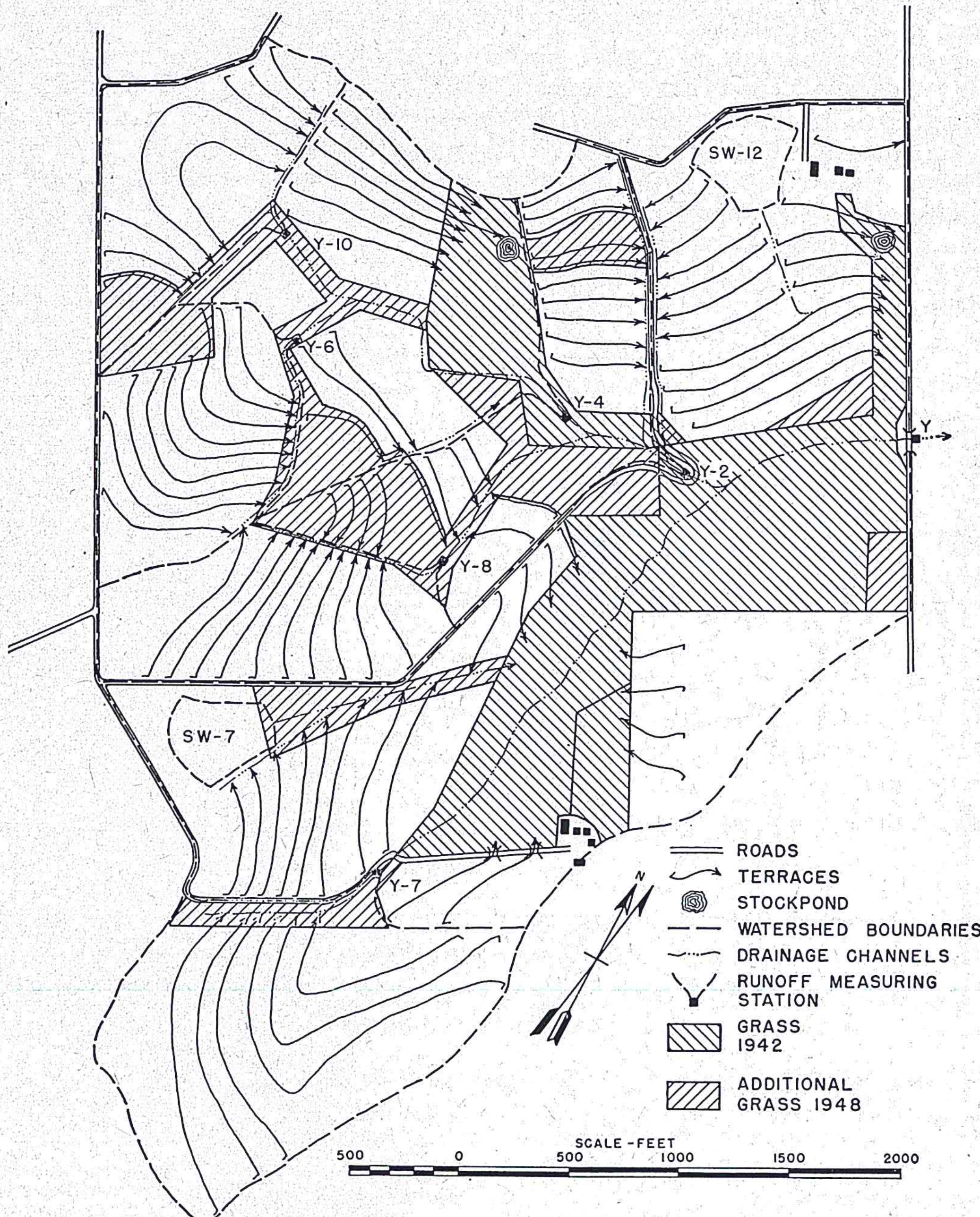

FIGURE 6.—Map of area Y showing drainage system, lay-out of terraces, and extent of grass areas before and after conservation treatment.

Much less data are available for the larger area Y (309 acres) and a smaller area Y–6 (20.9 acres). Comparing these 2 areas with areas W–1 (176 acres) and W–10 (19.7 acres) respectively, relationships similar to those at Y–2 are obtained. The larger area shows a reduction in peak rate of runoff of 0.44 inch per hour and the smaller area a reduction of 0.61 inch per hour compared to the 0.48 inch per hour reduction at Y–2. These reductions, again, are nearly the same regardless of the size of the flood. Also, when these reductions are compared to the corresponding uncorrected probability peaks it is clear that the percentage reductions for the areas are practically the same regardless of the size of the area. Table 6 gives the amount of the reduction in peak runoff rate in inches per hour, the uncorrected probable peak rate of runoff for the three areas (Y–6, Y–2, and Y) for different recurrence intervals, and the percentage reduction in peak rate of runoff. For any recurrence interval the mean reduction can be used for an area of any size up to 500 acres. Since the area from which this type of information is available (area Y) is not larger than 309 acres, direct application of these data to areas greater than 500 acres is not recommended.

Figure 1 shows the coefficients that must be applied to peak rates of runoff to compensate for rainfall differences. Since the percentage

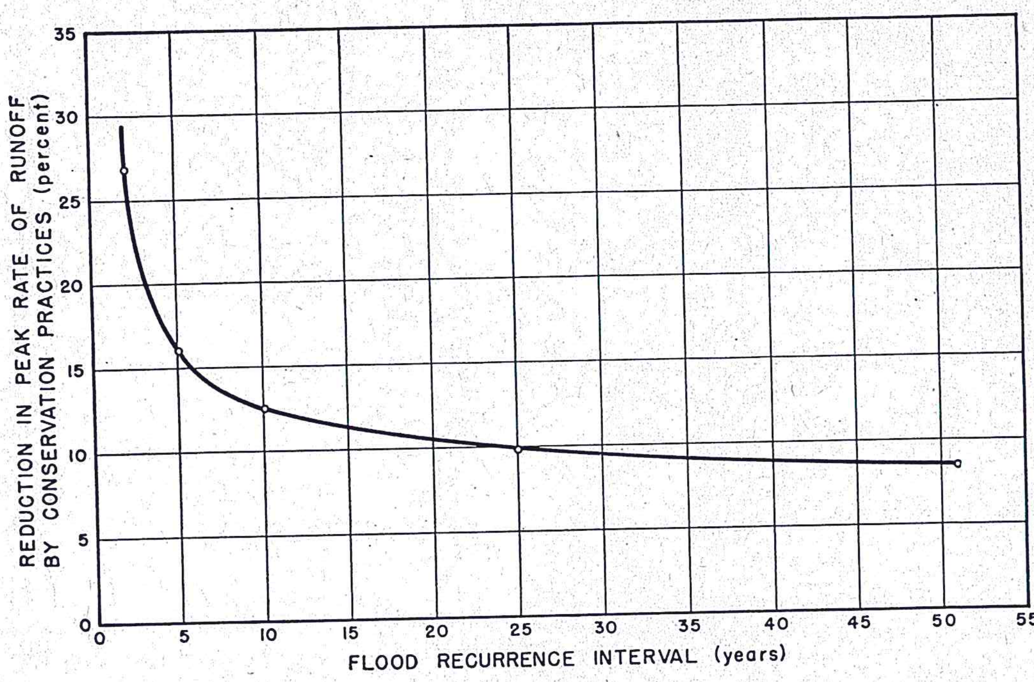

FIGURE 7.—Reduction of peak rates of runoff by conservation practices for various recurrence intervals.

TABLE 6.—*Reduction in peak rates of runoff for floods of different recurrence intervals and for areas of different size*

Watershed	Area	Recurrence interval									
		2-year		5-year		10-year		25-year		50-year	
		Peak rate	Reduction	Peak rate	Reduction	Peak rate	Reduction	Peak rate	Reduction	Peak rate	Reduction
	Acres	*In./hr.*	*Percent*	*In./hr.*	*Percent*	*In./hr.*	*Percent*	*In./hr.*	*Percent*	*In./hr.*	*Percent*
Y–6	20. 9	2. 31	26. 5	3. 86	15. 8	4. 92	12. 4	6. 22	9. 8	7. 16	8. 5
Y–2	132	1. 78	27. 0	2. 98	16. 1	3. 80	12. 6	4. 82	10. 0	5. 59	8. 6
Y	309	1. 64	26. 8	2. 75	16. 0	3. 50	12. 6	4. 59	9. 6	5. 34	8. 2
Average		-----	26. 8	-----	16. 0	-----	12. 5	-----	9. 8	-----	8. 4

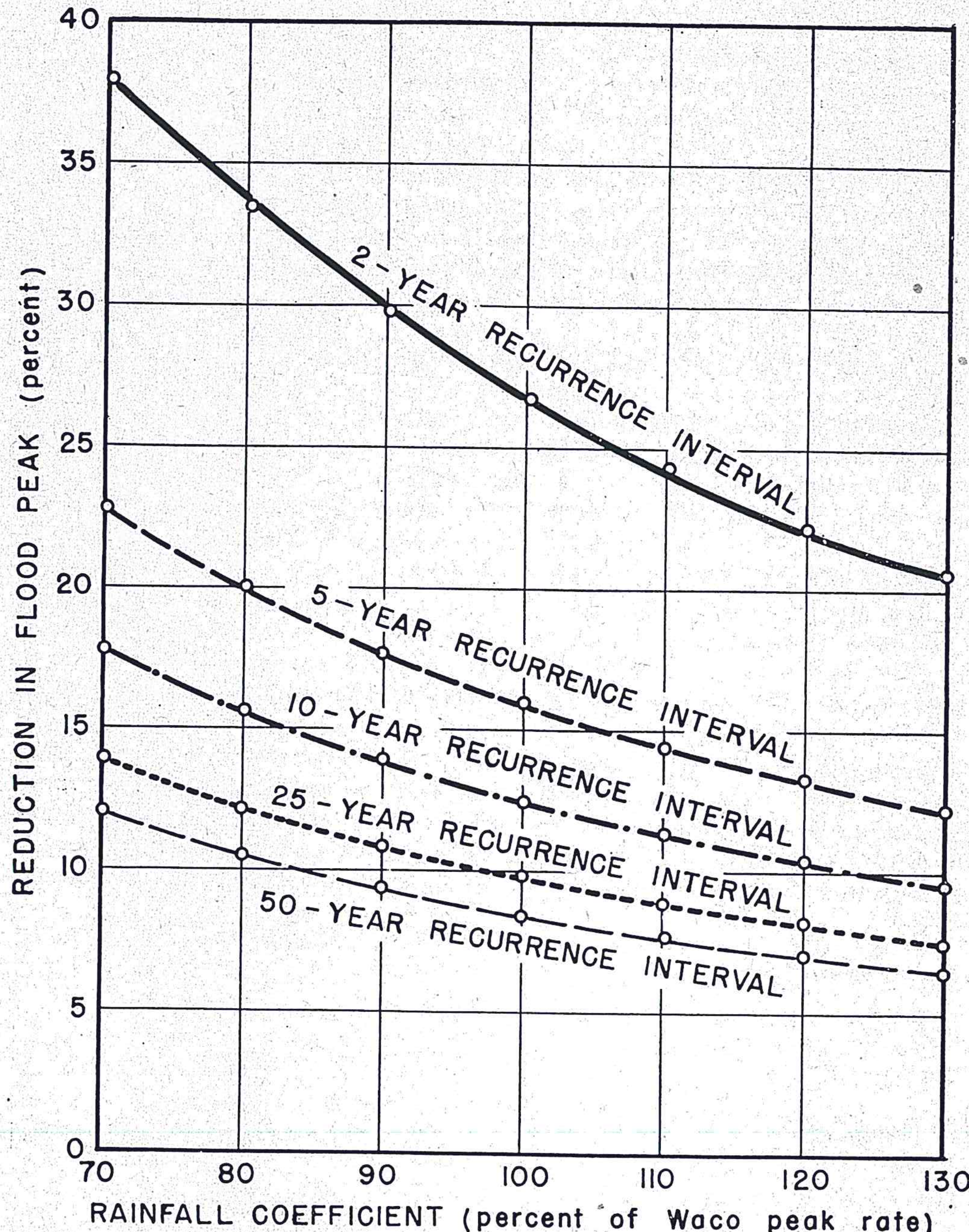

FIGURE 8.—Reduction in peak rates of runoff by conservation practices for various recurrence intervals and rainfall coefficients.

reduction that may be expected due to conservation practices is dependent upon the magnitude of the flood peak, corresponding corrections will be necessary when applying the percentages given in table 6. Figure 8 shows the percentage reductions in peak rates of runoff for floods of different recurrence intervals corresponding to the rainfall coefficients in figure 1.

EXAMPLE

The following example illustrates the use of figure 8 in determining the reduction in peak rate of runoff from areas with conservation practices.

Given: A mixed-cover watershed of 400 acres without conservation practices, near Dallas, Tex.

Required: The peak rate of runoff from this area after conservation practices are established, for recurrence intervals of 10 years and 25 years.

Solution: Table 4 shows that the peak rates of runoff to be expected near Waco for 10- and 25-year recurrence intervals would be 953 cubic feet per second and 1,210 cubic feet per second, respectively. Since the rainfall coefficient for areas near Dallas is 0.86 (fig. 1), the corrected values for untreated areas in cubic feet per second would be:

$0.86 \times 953 = 820$ for a 10-year recurrence interval;
$0.86 \times 1{,}210 = 1{,}040$ for a 25-year recurrence interval.

From figure 8 it is found that for a rainfall coefficient of 0.86 the percentage reduction in peak rate of runoff due to conservation practices for 10-year and 25-year recurrence intervals would be 14.5 percent and 11.3 percent, respectively. Therefore, the peak rates of runoff in cubic feet per second to be expected from this area after conservation practices are established would be:

820—14.5 percent of 820=701 for a 10-year recurrence interval;
1,040—11.3 percent of 1,040=922 for a 25-year recurrence interval.

EFFECT OF CONSERVATION PRACTICES ON AMOUNT OF RUNOFF

Studies have not progressed to the point where definite conclusions can be drawn regarding the extent of reduction in amount of runoff due to the establishment of conservation practices. There is some evidence to indicate that planting of legumes and possibly other accepted conservation practices will in time have a beneficial influence.

TABLE 7.—*Daily amounts of runoff*

Year	Date	Watershed							
		SW-17	SW-12	Y-10	Y-8	Y-7	Y-6	Y-4	Y-2
1940	Apr. 6	(1)	0	0.3261	0.4549	0.2656	(1)	0.2797	0.3152
	June 15	(1)	0	.2947	.2954	(1)	(2)	.2765	.2514
	June 24	(1)	0	.7715	.4478	.2730	0.5109	.5985	.5663
	July 3	0.6011	0	.4970	.4096	(1)	(2)	.5023	.4410
	Oct. 31	1.0209	(1)	(1)	.2848	.2994	.7485	(1)	(1)
	Nov. 22	2.7804	0.3218	1.9303	2.1566	2.4428	1.8939	1.9222	2.0349
	Nov. 23	1.8377	.7945	1.2657	1.8312	1.3253	1.5600	1.2795	1.4090
	Nov. 24	1.8690	1.7612	1.6636	1.8147	1.7374	1.5765	1.7923	1.7979
	Nov. 25	.2700	(1)	(1)	.2633	.2832	(1)	(1)	.2753
	Dec. 11	.4364	.4112	.5345	.3787	.4101	.4681	.4751	.5786
	Dec. 15	.7832	.6758	.4400	.7316	.3731	.7468	.6649	.8002
1941	Jan. 13	1.7327	1.7540	1.1199	1.4384	(2)	1.4197	1.5188	1.5154
	Jan. 14	(1)	(1)	(1)	(1)	0	(1)	(1)	(1)
	Feb. 1	1.4163	1.6066	1.1775	1.2643	1.1270	1.2749	1.3669	1.3924
	Feb. 23	1.3142	1.3648	1.4827	1.3464	1.2966	1.3275	1.2664	1.2830
	Mar. 6	.4132	.6821	.5793	.5084	.4908	.5745	.5238	.5367
	Mar. 23	.5804	(1)	(1)	.2580	.3500	(1)	(1)	(1)
	Apr. 23	(1)	(1)	.3205	(1)	.2547	(1)	.2513	.2781
	May 4	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)
	May 5	(1)	.2814	(1)	(1)	.2642	(1)	(1)	.3018
	May 19	.5699	(1)	(1)	(1)	(1)	.3462	(1)	.2555
	May 20	.8644	(1)	.3950	.5339	.6137	.4785	.5090	.5396
	May 22	.3760	(1)	.3099	.3476	.2701	.3553	.3633	.3781
	June 2	.6532	(1)	(1)	.3249	.2705	.3720	.3448	.3926
	June 6	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)
	June 7	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)
	June 10	2.2043	1.8125	1.6013	1.7028	1.5241	1.5998	1.7817	1.8279
	June 16	(1)	.2951	0	(1)	(1)	(1)	(1)	.2544
	July 14	(1)	(1)	.3048	.3899	(1)	.4635	.4369	.4658
	July 15	(1)	0	(1)	(1)	(1)	(1)	(1)	(1)

See footnotes at end of table.

Occasionally there have been reductions in the total amount of runoff on the area with conservation practices for storms occurring when the soil-moisture content was low. While this effect may be important in the production of crops, an appreciable reduction in the amount of runoff for the major flood-producing storms has not been experienced. Small areas of native grass cut for hay have usually had small amounts of runoff. However, for the rains of November 24, 1940; January 13, February 1, and March 6, 1941; and June 11, and June 14, 1942, the grass area SW–12 has had amounts of total runoff approximately equal to those from cultivated areas, but the rates have been lower.

For many runoff periods the volume of water from the areas with conservation practices was about the same as from the untreated areas. Marked changes in runoff volume, however, may not take place immediately. During the first 3 years after the establishment of conservation practices on area Y, for example, little effect from the improved agronomic practices was expected, since in the 3-year rotation prescribed for this area legume crops had been raised only one year and it was 1946 before legumes had been grown on all areas. It is significant to note that during 1947, 1948, and 1949 the amount of runoff in certain runoff periods was appreciably less from the area with conservation practices. On most soils the growing of suitable legumes, owing to their more extensive root systems, will undoubtedly result in an increase in the water-absorbing capacity of the soil.

The record of runoff for principal storms on the experimental watersheds will be useful in the hydrologic design of farm ponds, terraces, and other conservation structures. The daily runoffs greater than 0.25 inch from the various watersheds in this area are presented therefore, without detailed analysis, in table 7.

in inches greater than 0.25''

Watershed							
Y	W–10	W–6	W–2	W–1	C	D	J
(1)	(1)	(1)	(1)	0. 2984	0. 3285	0. 3045	(1)
(1)	(1)	(1)	(1)	(1)	. 3351	. 3264	(1)
0. 3978	0. 3453	(1)	(1)	. 3764	(1)	. 3582	0. 4135
. 2775	. 3224	0. 3566	0. 3840	. 4545	. 3288	. 4451	(1)
(1)	. 3530	(1)	(1)	. 3160	(1)	(1)	(1)
2. 0139	[3] 1. 8403	2. 0828	2. 2090	2. 4769	1. 4900	1. 5120	1. 0531
1. 2401	[3] . 7235	1. 3954	1. 2995	1. 4240	1. 3070	1. 3100	1. 5660
1. 6343	[3] 1. 3506	1. 7781	1. 8284	1. 8195	1. 2436	1. 1950	1. 7095
(1)	[3] . 1111	. 2606	. 3014	. 2723	(1)	(1)	. 3016
. 4572	. 3090	. 3448	. 4506	. 4538	. 5913	. 5433	. 4082
. 7094	. 4440	. 6507	. 6923	. 7287	. 6962	. 6760	. 6576
1. 6150	1. 7057	1. 3825	1. 6390	1. 7165	1. 3610	1. 2954	. 9257
(1)	(1)	(1)	(1)	(1)	(1)	(1)	. 5824
1. 4201	1. 6062	1. 3382	1. 4239	1. 4510	1. 3825	1. 4162	1. 2960
1. 2867	1. 5432	. 9558	1. 5562	1. 2142	1. 0334	1. 0662	1. 0732
. 5412	. 4014	. 3325	. 4454	. 4609	1. 0041	1. 0138	. 6276
. 2862	. 4546	. 3396	. 4582	. 4687	(1)	(1)	(1)
. 2537	(1)	(1)	(1)	(1)	(1)	(1)	(1)
(1)	(1)	(1)	(1)	(1)	. 2933	(1)	(1)
. 2878	. 4192	(1)	. 3072	. 2627	1. 4540	1. 4653	. 8938
(1)	(1)	(1)	(1)	(1)	. 5269	. 4955	(1)
. 5553	. 6130	. 5700	. 6188	. 6932	. 4324	. 4267	. 3990
. 3335	(1)	(1)	(1)	(1)	(1)	(1)	(1)
. 3564	. 3297	(1)	(1)	. 3744	(1)	(1)	(1)
(1)	(1)	(1)	(1)	(1)	. 4850	. 3237	(1)
(1)	(1)	(1)	(1)	(1)	(1)	. 2761	. 3026
1. 6159	2. 0600	1. 9913	2. 1854	2. 0356	1. 3345	1. 3799	1. 3594
. 2905	(1)	(1)	(1)	(1)	(1)	(1)	(1)
. 3551	(1)	(1)	(1)	(1)	. 3819	. 4043	. 3814
(1)	0	(1)	(1)	(1)	. 7846	. 6784	(1)

TABLE 7.—*Daily amount of runoff in*

Year	Date	Watershed							
		SW-17	SW-12	Y-10	Y-8	Y-7	Y-6	Y-4	Y-2
1942	Apr. 8	0.5128	(1)	0.3081	(1)	(1)	0.2961	0.2674	0.2657
	Apr. 23	.8201	(1)	.4806	0.4706	0.2786	.4881	.5342	.5280
	Apr. 24	1.0414	(1)	.4418	.4606	.4099	.4871	.4369	.4396
	Apr. 25	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)
	May 7	.6005	(1)	.2978	.3186	.2630	.3579	.4015	.3889
	May 23	.5692	(1)	(1)	.3324	.3133	(1)	(1)	.2762
	June 5	.6229	(1)	(1)	.2680	.3780	(1)	(1)	(1)
	June 6	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)
	June 8	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)
	June 11	1.6142	1.6596	1.5107	1.5529	1.5547	1.5248	1.7186	1.7520
	June 14	(1)	(1)	.3210	(1)	.2852	(1)	.3031	.2880
	June 15	1.0107	1.0726	.6558	.8704	.6783	.7855	.8846	.9022
	Sept. 7	.3001	(1)	.3321	0	.3949	(1)	(1)	(1)
	Sept. 8	2.8267	.7689	1.8497	2.0294	1.6730	1.7287	1.7920	1.8445
	Sept. 9	.7658	(1)	.4525	.4768	.4158	.3779	.4729	.4761
	Nov. 5	.4493	(1)	(1)	.4430	.3355	.2841	(1)	(1)
	Nov. 7	.5756	(1)	.4000	.5258	.5739	.3530	.4219	.4683
	Dec. 26	1.7276	.9947	.6825	1.2413	1.6516	.7420	.8807	1.0814
1943	Mar. 24	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)
	May 30	.5216	0	.2902	.3049	(1)	(1)	(1)	(1)
	June 5	.7257	(1)	.3978	.4265	.3818	.3053	.3018	.2998
1944	Jan. 1	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(1)
	Feb. 8	(2)	(2)	(2)	(2)	(2)	(2)	(2)	1.6352
	Feb. 25	(2)	(2)	(2)	(2)	(2)	(2)	(2)	.4620
	Feb. 26	(2)	(2)	(2)	(2)	(2)	(2)	(2)	.5447
	Mar. 22	(2)	(2)	(2)	(2)	(2)	(2)	(2)	1.6121
	Apr. 29	(2)	(2)	(2)	(2)	(2)	(2)	(2)	1.5979
	Apr. 30	(2)	(2)	(2)	(2)	(2)	(2)	(2)	2.1108
	May 1	(2)	(2)	(2)	(2)	(2)	(2)	(2)	6.0649
	May 2	(2)	(2)	(2)	(2)	(2)	(2)	(2)	.5093
	May 4	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(1)
	May 24	(2)	(2)	(2)	(2)	(2)	(2)	(2)	.3068
	May 25	(2)	(2)	(2)	(2)	(2)	(2)	(2)	.5080
	May 27	(2)	(2)	(2)	(2)	(2)	(2)	(2)	.3997
	Nov. 24	(2)	(2)	(2)	(2)	(2)	(2)	(2)	.5896
	Dec. 5	(2)	(2)	(2)	(2)	(2)	(2)	(2)	.3570
	Dec. 31	(2)	(2)	(2)	(2)	(2)	(2)	(2)	.5202
1945	Jan. 18	(2)	(2)	(2)	(2)	(2)	(2)	(2)	.8926
	Feb. 21	(2)	(2)	(2)	(2)	(2)	(2)	(2)	.3791
	Mar. 2	(2)	(2)	(2)	(2)	(2)	(2)	(2)	.2522
	Mar. 3	(2)	(2)	(2)	(2)	(2)	(2)	(2)	2.3923
	Mar. 30	(2)	(2)	(2)	(2)	(2)	(2)	(2)	1.0076
	Apr. 1	(2)	(2)	(2)	(2)	(2)	(2)	(2)	1.1570
	Apr. 20	(2)	(2)	(2)	(2)	(2)	(2)	(2)	.3624
	Apr. 21	(2)	(2)	(2)	(2)	(2)	(2)	(2)	1.4976
	June 22	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(1)
	Oct. 9	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(1)
	Dec. 2	(2)	(2)	(2)	(2)	(2)	(2)	(2)	2.3669
1946	Feb. 9	(2)	(2)	(2)	(2)	(2)	(2)	(1)	(1)
	Feb. 18	(2)	(2)	(2)	(2)	(2)	(2)	.7334	.8194
	Mar. 13	(2)	(2)	(2)	(2)	(2)	(2)	.3245	.6722
	Mar. 26	(2)	(2)	(2)	(2)	(2)	(2)	.4850	.4710
	May 10	(2)	(2)	.4114	(2)	(2)	(2)	.3317	.3523
	May 12	(2)	(2)	1.5167	(2)	(2)	(2)	1.4936	1.7501
	May 13	(2)	(2)	.7444	(2)	(2)	(2)	.8173	1.0279
	May 15	(2)	(2)	.3733	(2)	(2)	(2)	.3730	.4530
	June 9	(2)	(2)	.3032	(2)	(2)	(2)	(1)	(1)
	Nov. 3	(2)	(2)	.4160	(2)	(2)	(2)	(1)	(1)
	Nov. 5	(2)	(2)	(1)	(2)	(2)	(2)	(1)	(1)
	Dec. 11	(2)	(2)	.3522	(2)	(2)	(2)	.3222	.3747
1947	Jan. 17	(2)	(2)	1.3977	(2)	(2)	(2)	1.0834	1.3062
	Jan. 19	(2)	(2)	(1)	(2)	(2)	(2)	(1)	(1)
	Mar. 7	(2)	(2)	(1)	(2)	(2)	(2)	(1)	.2564
	Mar. 12	(2)	(2)	.2885	(2)	(2)	(2)	.3353	.3524
	Mar. 18	(2)	(2)	.7877	(2)	(2)	(2)	.8388	1.0201
	May 18	(2)	(1)	.4192	(2)	.4788	(1)	.3300	.3744
	May 20	(2)	.5402	.5013	(2)	.6285	.3719	.4564	.5586
1948	Apr. 12	.3889	(1)	(1)	(2)	(1)	(1)	(1)	(1)
	Apr. 13	.3637	(1)	(1)	(2)	.2505	(1)	(1)	(1)
	Apr. 25	2.0017	.2548	.8326	(2)	1.1766	.8493	.8097	1.0817
	May 11	.5816	(1)	.3847	(2)	.6157	.4702	.4558	.4942
	May 27	0	0	0	(2)	.3095	0	(1)	(1)
1949	Jan. 26	0	0	0	0	0	0	0	0
	Mar. 21	.3531	(1)	(1)	(1)	(1)	(1)	(1)	(1)
	Apr. 27	(1)	(1)	.2790	(1)	(1)	.3096	(1)	(1)
	June 15	0	0	(1)	(1)	0	(1)	0	0
	June 25	(1)	0	(1)	(1)	(1)	(1)	(1)	(1)
	July 4	.6709	0	.9582	.5548	.8966	.8937	.8785	.7823

1 Less than 0.2500 inch.

2 No record.

inches greater than 0.25''—Continued

Watershed							
Y	W-10	W-6	W-2	W-1	C	D	J
(1)	(1)	(1)	(1)	0.3624	0.6731	0.5458	(1)
0.4422	0.5656	0.3168	0.4112	.4678	.7492	.6873	(1)
.3426	.4806	.3252	.3172	.3993	(1)	(1)	0.4201
(1)	(1)	(1)	(1)	(1)	.7745	.7801	.5573
.3744	(1)	(1)	(1)	.2762	.6308	.5701	.4052
.2958	.3170	(1)	(1)	.4120	(1)	(1)	(1)
.2516	.4382	.3076	.2920	.3377	.4129	.5086	.3734
(1)	.6185	(1)	.3280	(1)	(1)	(1)	.2536
(1)	(1)	(1)	(1)	(1)	(1)	(1)	.2896
1.5883	1.5804	1.3143	1.4630	1.4677	1.2460	1.2230	1.4183
.2762	(1)	(1)	(1)	(1)	.7775	.7491	.5329
.8334	.7210	.8041	.8367	.8618	.8164	.7889	.8575
(1)	(1)	0	(1)	(1)	1.6653	1.0775	(1)
1.7258	2.0051	1.5886	1.6656	2.2397	3.1178	2.8635	1.8808
.5201	.3983	.3943	.3233	.4645	.5201	.5139	.5956
(1)	(1)	(1)	(1)	.3298	(1)	(1)	(1)
.5068	.7590	.3001	.4433	.6340	.2510	.2508	.4514
1.2414	1.5974	1.6202	1.7909	1.5262	.4790	.4714	.5975
(1)	(1)	(1)	(1)	(1)	.3356	.2549	(1)
(1)	.2782	(1)	(1)	.2739	.6857	.5986	(1)
.3116	.5290	.3634	.3981	.5159	.5973	.5556	(1)
(2)	(2)	(2)	.3691	.5273	(2)	(2)	(2)
(2)	(2)	(2)	2.0084	2.0377	(2)	(2)	(2)
(2)	(2)	(2)	.3969	.4748	(2)	(2)	(2)
(2)	(2)	(2)	.5514	.6096	(2)	(2)	(2)
(2)	(2)	(2)	1.1440	1.2492	(2)	(2)	(2)
(2)	(2)	(2)	1.3757	1.5510	(2)	(2)	(2)
(2)	(2)	(2)	2.1033	2.1342	(2)	(2)	(2)
(2)	(2)	(2)	5.9666	6.0034	(2)	(2)	(2)
(2)	(2)	(2)	1.2140	1.0813	(2)	(2)	(2)
(2)	(2)	(2)	.2564	.2747	(2)	(2)	(2)
(2)	(2)	(2)	.3573	.4398	(2)	(2)	(2)
(2)	(2)	(2)	.5558	.6018	(2)	(2)	(2)
(2)	(2)	(2)	.4819	.4479	(2)	(2)	(2)
(2)	(2)	(2)	.5271	.6246	(2)	(2)	(2)
(2)	(2)	(2)	(1)	(1)	(2)	(2)	(2)
(2)	(2)	(2)	.3510	.3859	(2)	(2)	(2)
(2)	(2)	(2)	.5983	.7354	(2)	(2)	(2)
(2)	(2)	(2)	.2753	.3236	(2)	(2)	(2)
(2)	(2)	(2)	(1)	(1)	(2)	(2)	(2)
(2)	(2)	(2)	1.7989	2.1815	(2)	(2)	(2)
(2)	(2)	(2)	.6736	.8480	(2)	(2)	(2)
(2)	(2)	(2)	.9111	1.1484	(2)	(2)	(2)
(2)	(2)	(2)	.2906	.4193	(2)	(2)	(2)
(2)	(2)	(2)	.3021	1.3980	(2)	(2)	(2)
(2)	(2)	(2)	(1)	.3008	(2)	(2)	(2)
(2)	(2)	(2)	.2650	.2702	(2)	(2)	(2)
(2)	(2)	(2)	2.1018	1.9399	(2)	(2)	(2)
(2)	(2)	(1)	.2701	(1)	(2)	(2)	(2)
(2)	(2)	.5896	.8040	.7200	(2)	(2)	(2)
(2)	(2)	.3078	.4872	.5759	(2)	(2)	(2)
(2)	(2)	.3844	.4584	.4641	(2)	(2)	(2)
.3286	(1)	.2650	.2729	.3468	(2)	(2)	(2)
1.8866	2.0431	1.9235	2.0649	2.1168	(2)	(2)	(2)
1.1155	.7356	.7855	.9330	.8214	(2)	(2)	(2)
.4862	.3310	.3241	.3686	.3940	(2)	(2)	(2)
(1)	(1)	(1)	(1)	(1)	(2)	(2)	(2)
(1)	.5718	(1)	(1)	.4302	(2)	(2)	(2)
(1)	.2600	(1)	(1)	(1)	(2)	(2)	(2)
.3697	.6835	(1)	.3761	.4152	(2)	(2)	(2)
1.2607	1.3860	.8642	1.2487	1.0983	(2)	(2)	(2)
(1)	.3240	(1)	(1)	(1)	(2)	(2)	(2)
.3052	.3219	(1)	.3640	(1)	(2)	(2)	(2)
.3970	.3674	(1)	.3502	.2568	(2)	(2)	(2)
.9856	1.0593	.7758	.9727	.8261	(2)	(2)	(2)
.4004	.7802	(1)	.4343	.4408	(2)	(2)	(2)
.5652	.7136	.3508	.4620	.4675	(2)	(2)	(2)
(1)	(1)	0	(1)	(1)	(2)	(2)	(2)
(1)	.5021	(1)	(1)	.2818	(2)	(2)	(2)
1.0115	1.4946	1.0973	1.3301	1.1734	(2)	(2)	(2)
.4820	.6952	.2590	.4590	.5269	(2)	(2)	(2)
(1)	(1)	0	(1)	(1)	(2)	(2)	(2)
(1)	0	0	(1)	0	.3454	.2579	(2)
(1)	.3568	.2768	.2884	.2610	(1)	(1)	(2)
(1)	(1)	(1)	(1)	.3511	(1)	(1)	(2)
(1)	(1)	(1)	(1)	(1)	.3055	.3657	(2)
(1)	.2794	(1)	(1)	(1)	(1)	(1)	(2)
.9025	1.0028	.8413	.6808	1.0695	0	(1)	(2)

[3] Incomplete.

[4] No runoff greater than 0.25 inch from July 4, 1949, through Dec. 31, 1949.

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