TEXAS WATER DEVELOPMENT BOARD

REPORT 14

HYDROLOGIC STUDIES OF SMALL WATERSHEDS

LITTLE ELM CREEK, TRINITY RIVER BASIN

TEXAS, 1956-62

By

Elmer E. Schroeder

Prepared by the U.S. Geological Survey
in cooperation with the
Texas Water Development Board
and the
City of Dallas

January 1966

Published and distributed
by the
Texas Water Development Board
Post Office Box 12386
Austin, Texas 78711

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ABSTRACT

Tabulated and analyzed here are hydrologic data collected during the period June 1956 to September 1962 on a 75.5-square-mile rural watershed in northeast Texas. This is the fourth of a series of similar small watershed reports under the U.S. Geological Survey statewide "Small Watershed Project."

A coaxial graphical correlation analysis of antecedent precipitation, storm duration, precipitation, and storm runoff was made. This analysis, involving 28 storms, indicated that reasonably accurate estimates of runoff could be obtained from the derived coaxial correlation.

A study of unit hydrographs for the Little Elm Creek watershed shows that flood peaks may be computed for defined ideal storms. The watershed appears to produce two distinct unit hydrographs, one of which has a duration of 2 hours (peak, 2,600 cfs--cubic feet per second) and the other 4 hours (peak, 2,000 cfs). Rainfall distribution, storm duration, storm intensity, and watershed shape appear to be the dominant factors affecting the computed unit hydrographs.

Flood-frequency analyses show that, even for a period as short as 7 years, more reliable results are obtained with the annual-flood series data than with the partial-duration series data. The analyses also indicate that the regional flood-frequency data for the study area agree fairly well with the limited station data.

The maximum flood during the study period was only of 7-year frequency in spite of extremely heavy rainfall and runoff during April and May 1957. Rainfall during this 2-month period totaled 29.44 inches, about 10 inches below average annual total, and runoff was 20.63 inches. During the 7-year period, annual rainfall ranged from 25.47 inches in 1959 to 56.75 inches in 1957, and runoff ranged from 0.40 inch in 1959 to 22.06 inches in 1957.

The collection of hydrologic data under the current program should continue until the proposed floodwater-retarding structures have been built so that a representative sample of hydrologic events for a variety of climatic cycles can be obtained. After the floodwater-retarding structures have been built, an expanded program will be required to collect the data needed to make a comparison of the runoff characteristics with pre-development characteristics as well as to evaluate the efficiency of the structures. A more complex unit hydrograph study is recommended as part of the subsequent report.

H Y D R O L O G I C   S T U D I E S   O F   S M A L L   W A T E R S H E D S

L I T T L E   E L M   C R E E K ,   T R I N I T Y   R I V E R   B A S I N

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INTRODUCTION

Available water supply is one of the factors that frequently limits the economic growth of any geographic area, whether that growth finds expression as more people in a metropolitan area or as greater productivity in an agrarian area. Where the available water supply is a limiting factor, conflicts of interest may develop over water use for domestic or municipal supply, irrigation, recreation or industrial, or other purposes. The solution of these conflicts of interest and the determination of the best ways to conserve and utilize the water resources will require wise decisions based upon accurate information about the amount and variability of the supply, and an impartial analysis of how alternative methods of manipulation of the supply will affect the hydrologic system. The small watershed studies by the U.S. Geological Survey will provide information and analyses needed by those responsible for managing the water supply.

These studies were started because of the expressed interest of numerous water resources planning agencies in the effect of floodwater-retarding structures on quantity and mode of occurrence of surface-water runoff downstream from developed watersheds. In addition, hydrologists recognize the opportunity afforded by these developments to obtain hydrologic data on small watersheds, as the lack of such data is presently critical in the overall hydrologic picture.

History of the Statewide Small Watershed Project

Small watershed projects have evolved as the product of four enabling acts of the Federal Congress. These four acts are: the Soil Conservation Act of 1935 (Public Law No. 46, 74th Congress), the Flood Control Act of June 22, 1936 (Public Law No. 738, 74th Congress), the Flood Control Act of December 22, 1944 (Public Law No. 534, 78th Congress, 2d Session), and the Watershed Protection and Flood Prevention Act (Public Law No. 566, 83rd Congress), as amended. This legislation provides, in essence, that the U.S. Department of Agriculture shall plan and coordinate the development of small watersheds.

Part of the plan of the Department of Agriculture through the Soil Conservation Service is to reduce floods and soil erosion in a watershed by applying land-treatment measures and upstream floodwater-retarding structures. The structures are designed to release floodflows at a rate that will not normally exceed the channel capacity immediately downstream.

As of September 30, 1963, approximately 763 floodwater-retarding structures had been built in Texas. These structures control flow from an area of about 3,170 square miles. According to reports of the U.S. Study Commission-Texas (1962) and the U.S. Soil Conservation Service (1963), a total of 3,438 structures have been found physically and economically feasible for installation in Texas. Thus, only about 22 percent of feasible structures had been built at the end of the water year 1963.

This watershed-development program will have varying but important effects on the natural surface-water resources and possibly some effect on the ground-water resources of river basins, especially where a large number of the floodwater-retarding structures are built. A need has, therefore, developed for basic hydrologic data from small watersheds so that the hydrology may be compared under natural and developed conditions. Specifically, the essential aim of hydrologic studies is to determine the extent to which floodwater-retarding structures affect the yield and mode of occurrence of runoff.

Statewide hydrologic investigations in Texas were started in 1951 and are now being made on 11 small watersheds (study areas) to provide some of the needed data and analyses (Figure 1). The U.S. Soil Conservation Service, Texas Water Development Board, San Antonio River Authority, city of Dallas, and the Tarrant County Water Control and Improvement District No. 1 are cooperating with the U.S. Geological Survey in these investigations. The 11 study areas were chosen on a statewide basis to sample watersheds having different conditions of rainfall, topography, geology, and soils. On four of the study areas of which this is one, streamflow and rainfall records are being collected prior to construction of the floodwater-retarding structures, thus affording the opportunity for analyses of the conditions before and after development. A summary of the development of floodwater-retarding structures on each study area as of September 30, 1963, is shown in Table 1.

The broad purpose of the statewide project is to collect as much basic data as possible on the hydrologic system of smaller watersheds both before and after development, and to analyze these data in terms of hydrologic relations that may or may not be related to the development.

Specific objectives to which these statewide studies are directed are:

1. To obtain basic hydrologic data on small watersheds needed to satisfy the broad purposes.

2. To obtain basic data which will aid in determining the net effect of floodwater-retarding structures on the regimen of streamflow at downstream points.

3. To determine the effect of the structures on the underlying ground-water reservoir.

4. To determine the effect of the structures on the sediment yield of the watershed and to determine the trap efficiency of the structures.

5. To develop computation techniques that will give more accurate estimates of runoff resulting from a given amount of rainfall on small watersheds.

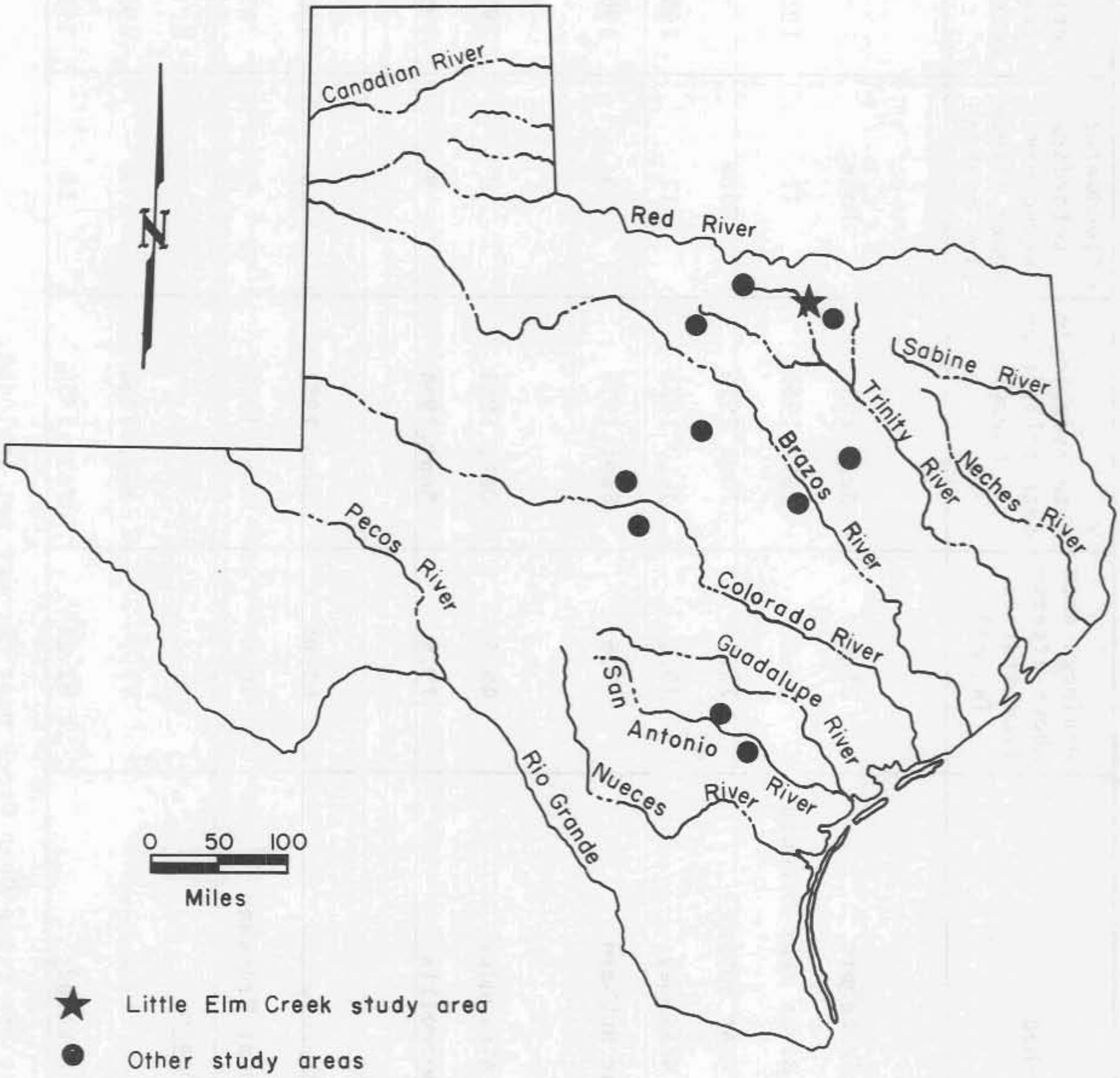

Figure 1

Map of Texas Showing the Location of Little Elm Creek and Other Study Areas

U. S. Geological Survey in cooperation with the Texas Water Development Board and the City of Dallas

Table 1.--Small watershed study areas in Texas as of September 30, 1963

Watershed	Drainage area above streamflow station (sq mi)	Date hydrologic data collection began	Floodwater-retarding structures above streamflow station	Period the structures were built
Trinity River Basin				
North Creek near Jacksboro	21.6	Aug. 1956	None	--
Elm Fork Trinity River near Muenster	46.0	July 1956	11	1954-57
Little Elm Creek near Aubrey	75.5	June 1956	None	--
Honey Creek near McKinney	39.0	July 1951	12	1951-57
Pin Oak Creek near Hubbard	17.6	Sept. 1956	5	1962-63
Brazos River Basin				
Green Creek near Alexander	45.5	Oct. 1954	8	1954-56
Cow Bayou near Mooreville	79.6	Sept. 1954	9	1955-58
Colorado River Basin				
Deep Creek near Mercury	43.9*	June 1951	6	1951-53
Mukewater Creek near Trickham	70.0	Aug. 1951	5	1961
San Antonio River Basin				
Calaveras Creek near Elmendorf	77.2	Aug. 1954	9	1954-58
Escondido Creek at Kenedy	82.2†	July 1954	10	1954-58

* 8.31 sq mi above Dry Prong Deep Creek near Mercury not included.
† 8.43 sq mi above Escondido Creek subwatershed No. 11 (Dry Escondido Creek) near Kenedy not included.

6. To develop relationships between maximum rates of runoff and rainfall in small watersheds that will enable more accurate design of small storm-drainage structures.

7. To check the applicability of flood-routing procedures and techniques for small watersheds.

8. To determine the minimum instrumentation necessary for making reliable estimates of total storm inflow to the structures.

This is the fifth in a series of interpretive reports covering investigations in the small watersheds. Already published are:

1. Honey Creek: U.S. Geological Survey Water-Supply Paper 1779-F, "Hydrologic Studies of Small Watersheds, Honey Creek Basin, Collin and Grayson Counties, Texas, 1953-59."

2. Deep Creek: Texas Water Development Board Report 3, "Hydrologic Studies of Small Watersheds, Deep Creek, Colorado River Basin, Texas, 1951-61."

3. Elm Fork Trinity River: U.S. Geological Survey Open-File Report 64, "Hydrologic Studies of Small Watersheds, Elm Fork Trinity River Basin, Montague and Cooke Counties, Texas, 1956-60."

4. Mukewater Creek: Texas Water Development Board Report 6, "Hydrologic Studies of Small Watersheds, Mukewater Creek, Colorado River Basin, Texas, 1952-60."

The first three of these reports cover hydrologic investigations in areas on which floodwater-retarding structures were constructed prior to or near the beginning of the data-collection program. The fourth report is similar to this report in that data and analyses cover a period of hydrologic investigation prior to construction of floodwater-retarding structures.

Beginning in 1960, a series of annual basic-data reports have been prepared for each of the 11 study areas. All data for these study areas are in the files of the U.S. Geological Survey in Austin, Texas.

In addition to the 11 small watersheds mentioned above, which are located in rural areas, the Geological Survey is collecting data from small urban watersheds: Waller Creek at Austin, and Bachman Branch, Joes Creek, Turtle Creek, and White Rock Creek at Dallas. An interpretive report on Waller Creek is in preparation.

Purpose and Scope of This Report

The purpose of this report is to present data on and analyses of the hydrologic characteristics of the Little Elm Creek watershed during the period 1956-62 prior to watershed development by the U.S. Soil Conservation Service.

Of the foregoing eight statewide objectives, this report deals with five of them, namely, numbers 1, 2, 5, 6, and 8. These objective numbers are listed below, together with the topics in this report which relate to the fulfillment of the objectives.

1. Compilations of rainfall and runoff data.

2. A flood-frequency analysis.

2 and 5. A multiple-correlation analysis of the rainfall-runoff relations.

6. A unit-hydrograph analysis.

8. A rain-gage density study.

DESCRIPTION OF THE STUDY AREA

The small watershed covered by this report is the Little Elm Creek drainage area above the stream-gaging station. It is referred to hereafter as the "watershed" or "study area" and comprises 75.5 square miles. The physical features of the study area were obtained from U.S. Geological Survey $7\frac{1}{2}$-minute topographic maps.

Location and General Features

Little Elm Creek rises in Grayson County near Gunter (Figure 2), flows southwesterly through the northwest corner of Collin County, then into Denton County, and discharges into Garza-Little Elm Reservoir about 4 miles downstream from the stream-gaging station (Little Elm Creek near Aubrey, Texas). The study area is located about 40 miles north of Dallas and comprises only about $4\frac{1}{2}$ percent of the total drainage area above the dam forming Garza-Little Elm Reservoir. The stream-channel length is about 29 miles between the headwaters and the stream-gaging station. The principal tributaries to Little Elm Creek are Clarks Branch, Hearne Branch, and Walnut Fork which together with unnamed tributaries form a dendritic network.

The low-water channel changes in elevation from 840 feet above mean sea level, at the headwater divide, to 540 feet above mean sea level, at the stream-gaging station. In the 1-mile reach immediately downstream from the divide, 80 feet in elevation is lost. Between river mile 27 and 21, measured upstream from the stream-gaging station, the streambed has an average slope of 7 feet per mile. Between river mile 14 and 21 the average bed slope is 4 feet per mile, and from river mile 0 to 14 the average bed slope is $2\frac{1}{2}$ feet per mile. Figure 3 is a graphical illustration of the streambed profile.

The watershed is about 19 miles long and has a maximum width of about 7 miles. It has an east-to-west tilt, the eastern divide being some 60 to 80 feet higher than the western divide. The main channel splits the watershed into unequal areas, and the smaller western area has a more gentle valley slope.

The stream as a whole has a relatively straight course, although in detail it is distinctly sinuous and old channels, cutoff meander loops, and the remnants of several oxbow lakes are present in the lower reach. Thus, the stream has a relatively wide flood plain in the lower half of the watershed.

According to the U.S. Department of Agriculture, the watershed has the following land use: cropland about 60 percent, pasture about 34 percent, woodland about 3 percent, and miscellaneous about 3 percent.

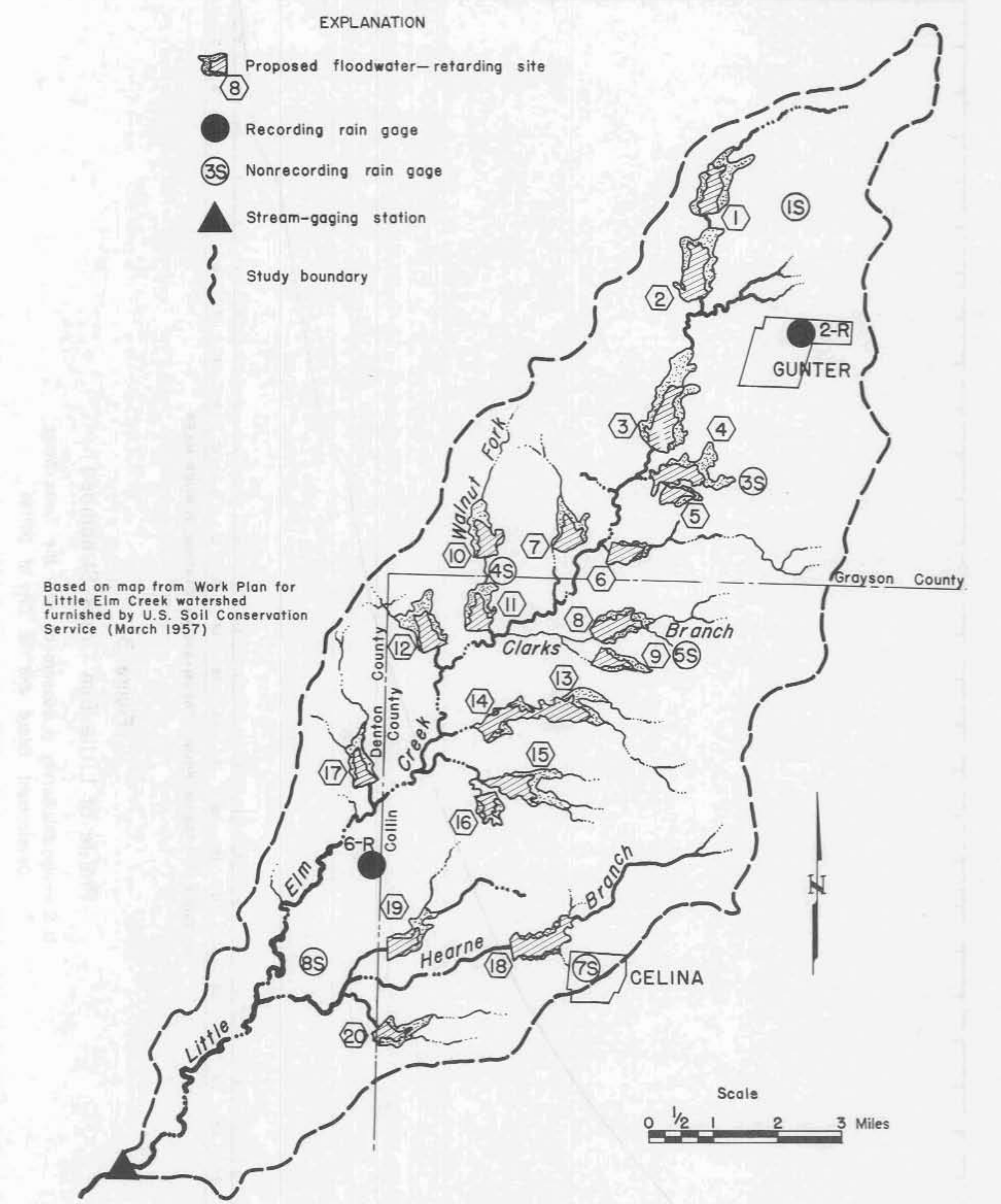

Figure 2

Map of Little Elm Creek Study Area Showing Locations of Proposed Floodwater-Retarding Structures

U. S. Geological Survey in cooperation with the Texas Water Development Board and the City of Dallas

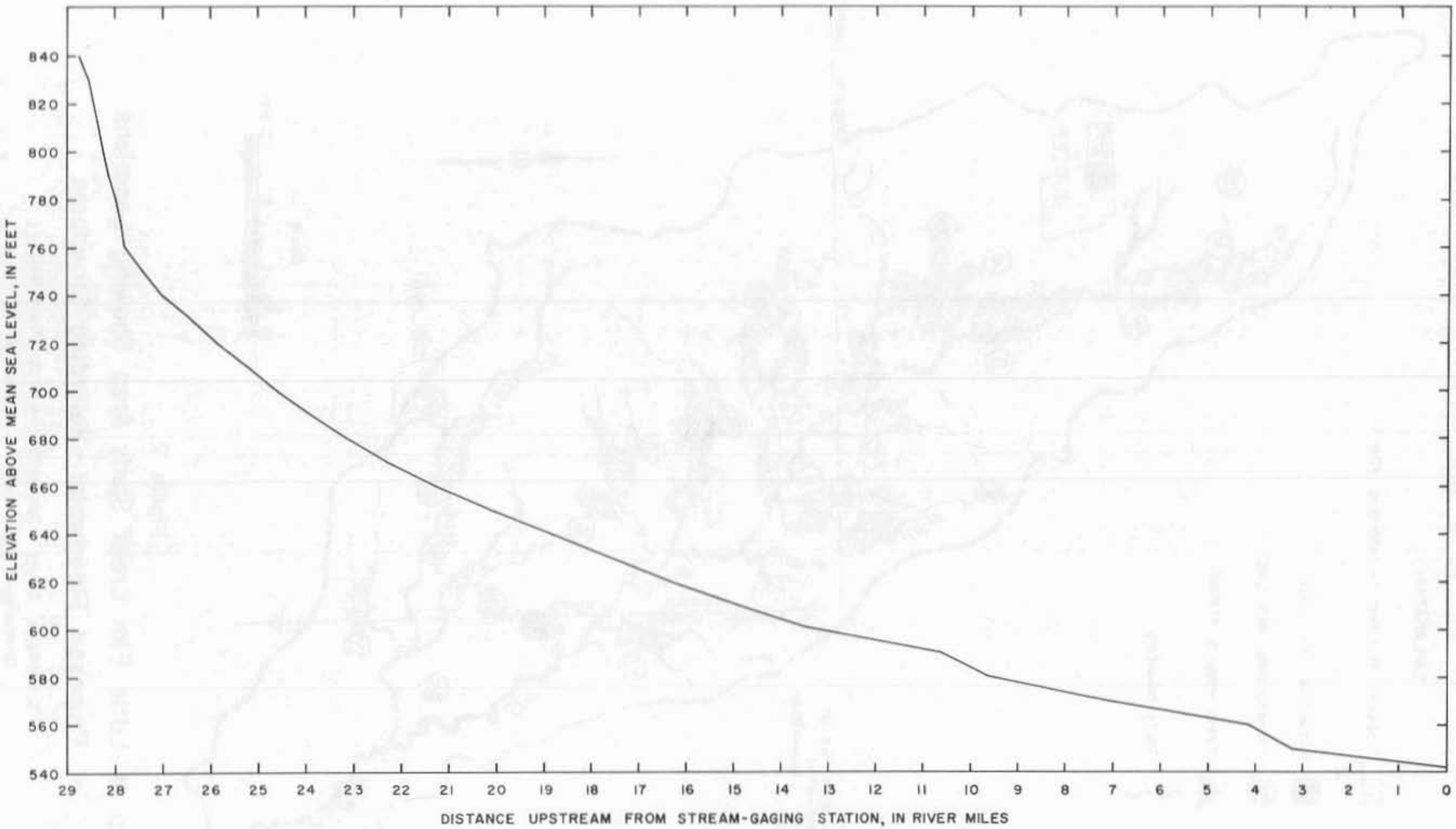

Figure 3

Profile of Little Elm Creek Streambed

U. S. Geological Survey in cooperation with the Texas Water Development Board and the City of Dallas

Climate

Rainfall over the watershed is produced from different types of storms. Low intensity, long-duration storms are common in the fall and winter from continental polar fronts which become stationary. The same type of general storm occurs when the remnants of hurricanes, which are large, low-pressure, maritime tropical air masses, move inland. However, the most common type of storm is the squall-line thunderstorm, which occurs mainly during the spring and summer.

The mean annual rainfall during the base period 1930-61 at the U.S. Weather Bureau station at McKinney is about 39 inches. During the study period 1956-62, the annual rainfall at the station ranged from 23.31 inches, in 1956, to 53.90 inches, in 1957, and averaged 37.94 inches.

The average annual temperature is about 65°F. Average daily temperatures range from about 45°F in the winter to 85°F in the summer.

Proposed Developments

A system of 20 floodwater-retarding structures is planned for this watershed by the U.S. Soil Conservation Service. The 20 structures will control floodwater from 49.3 of the 75.5 square miles in the study area. These 20 structures will have a combined capacity at emergency spillway crest of 17,370 acre-feet, of which 13,170 acre-feet is floodwater-retarding capacity and 4,200 acre-feet is sediment capacity. Capacity allocated to sediment pool will be used for conservation capacity until eliminated by sedimentation. The above figures are taken from the work plan for Little Elm Creek watershed prepared by the Soil Conservation Service in March 1957[1]. Location of the proposed structures is shown in Figure 2.

INSTRUMENTATION AND DATA COLLECTION

Hydrologic data for this report consist of rainfall records at eight sites within the study area and continuous records of streamflow at the downstream end of the area. A water-stage recorder in operation since June 8, 1956 is located at river mile 0. Discharge measurements are obtained at regular intervals and also during floodflow periods for definition of a stage-discharge relation. Records of discharge have been published under the name: Little Elm Creek near Aubrey, Texas, in the U.S. Geological Survey annual series of water-supply papers through the water year 1960, and in the annual series of State reports since that time, and also in the Texas Board of Water Engineers Bulletin 5807A through September 30, 1957.

A rain-gage network, consisting of two 8-inch recording gages and six 8-inch nonrecording gages, was established in December 1956. Records of the monthly mean rainfall computed for these gages are published in Geological Survey annual reports with the previously mentioned discharge records. The network of rain gages is operated and maintained by the U.S. Weather Bureau (USWB)

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[1] Work Plan, Little Elm and Laterals Watershed of the Trinity River Watershed, Collin, Denton, and Grayson Counties, Texas, 1957: Soil Conservation Service, U.S. Dept. Agriculture, Temple, Texas.

through an agreement with the Geological Survey. The gages are USWB type and located in accordance with USWB procedures to obtain the best geometric coverage of the area (Figure 2). See Table 5 for a summary tabulation of rainfall data collected for the period covered by this report.

RAIN-GAGE DENSITY STUDY

A study was made to evaluate the density of the rain gages in operation during the period covered by this report, as compared to a minimum density required to determine total rainfall on the watershed. Three correlations were prepared, in each of which the average storm rainfall, the arithmetic mean of eight rain gages, was plotted as the independent variable on the abscissa, and the average storm rainfall for the following combination of gages was plotted as the dependent variable along the ordinate: 2R; 2R and 6R; and 2R, 4S, and 6R, respectively. (See Figures 4-6.)

All storms with a rainfall total of 0.4 inch or more were plotted. For the purpose of this study, a storm is defined as a period of rainfall separated by at least 6 hours from prior or subsequent rainfall. For each graphical analysis, the standard error of estimate was computed using a 67-percent confidence limit. The fact that the plot using two gages (Figure 5) gave the best overall results is of special interest. When only those storms with 2 inches of rain or more were considered, the best results were obtained from the comparison using three gages (Figure 6). The standard error of estimate was computed from the equal rainfall line which is considered to be the curve of relation.

Figures 5 and 6 indicate that two or three rain gages would probably be sufficient to provide average watershed precipitation amounts for individual runoff-producing storms. However, after reservoirs are constructed accurate precipitation amounts on each reservoir will be needed for water-budget computations. Thus, a rain gage near each reservoir would be desirable after watershed development.

The rain-gage network in the study area is considered to be adequate for the present investigations, but insufficient for a fully developed watershed.

FLOOD-FREQUENCY ANALYSES

One of the most useful tools available to the designer of structures which are located in, on, or near streams, is the flood-frequency curve. This section discusses the development of flood-frequency curves for the Little Elm Creek watershed prior to watershed development proposed by the Soil Conservation Service Work Plan.

Generally, station flood-frequency curves derived from less than 10 years of data are subject to large errors. As only 6 years of continuous flood data in the Little Elm Creek watershed were available for this report, only a limited analysis was made. All peaks above a base of 1,000 cfs (cubic feet per second) were tabulated (Table 2). Using techniques described in U.S. Geological Survey Water-Supply Paper 1543-A, recurrence intervals were computed for both the annual-flood series and the partial-duration series. As these data do not cover a sufficiently long hydrologic period to afford good definition of a flood-frequency curve, the computations were made in order that they may be compared with a regional frequency curve.

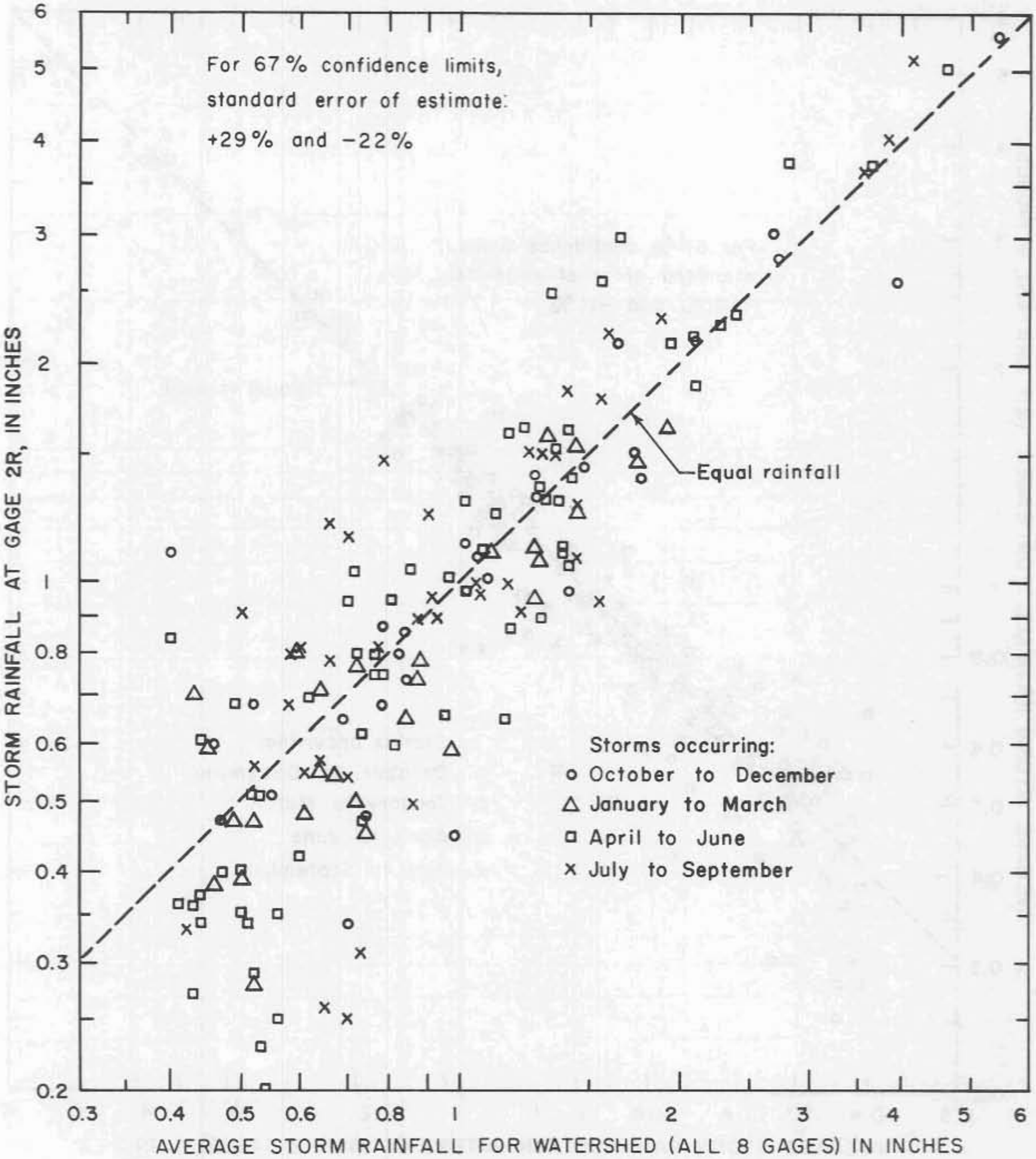

Figure 4

Comparison of Concurrent Storm Rainfall, One Gage (2R) and Eight Gages

U. S. Geological Survey in cooperation with the Texas Water Development Board and the City of Dallas

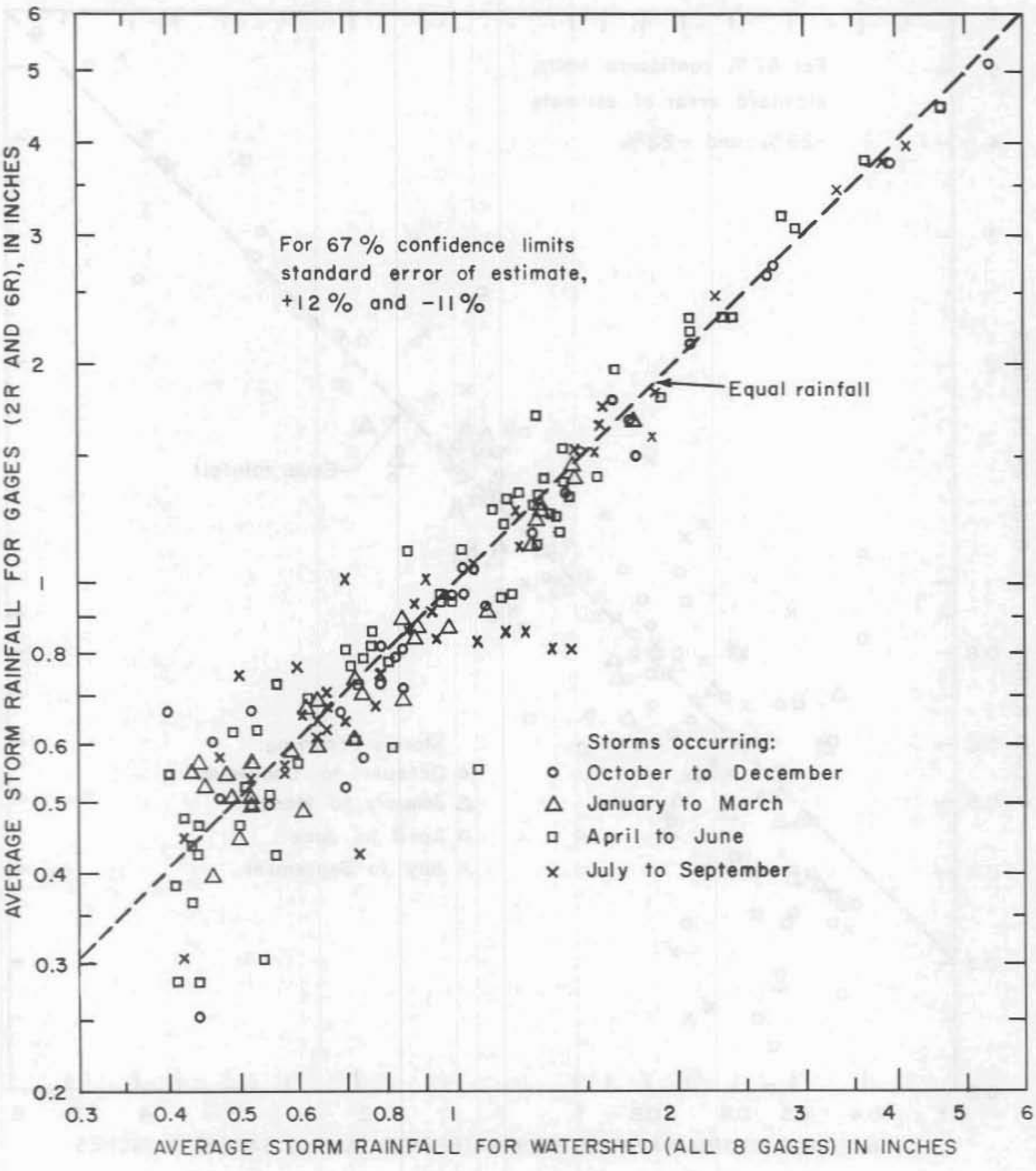

Figure 5

Comparison of Concurrent Storm Rainfall, Two Gages (2R and 6R) and Eight Gages

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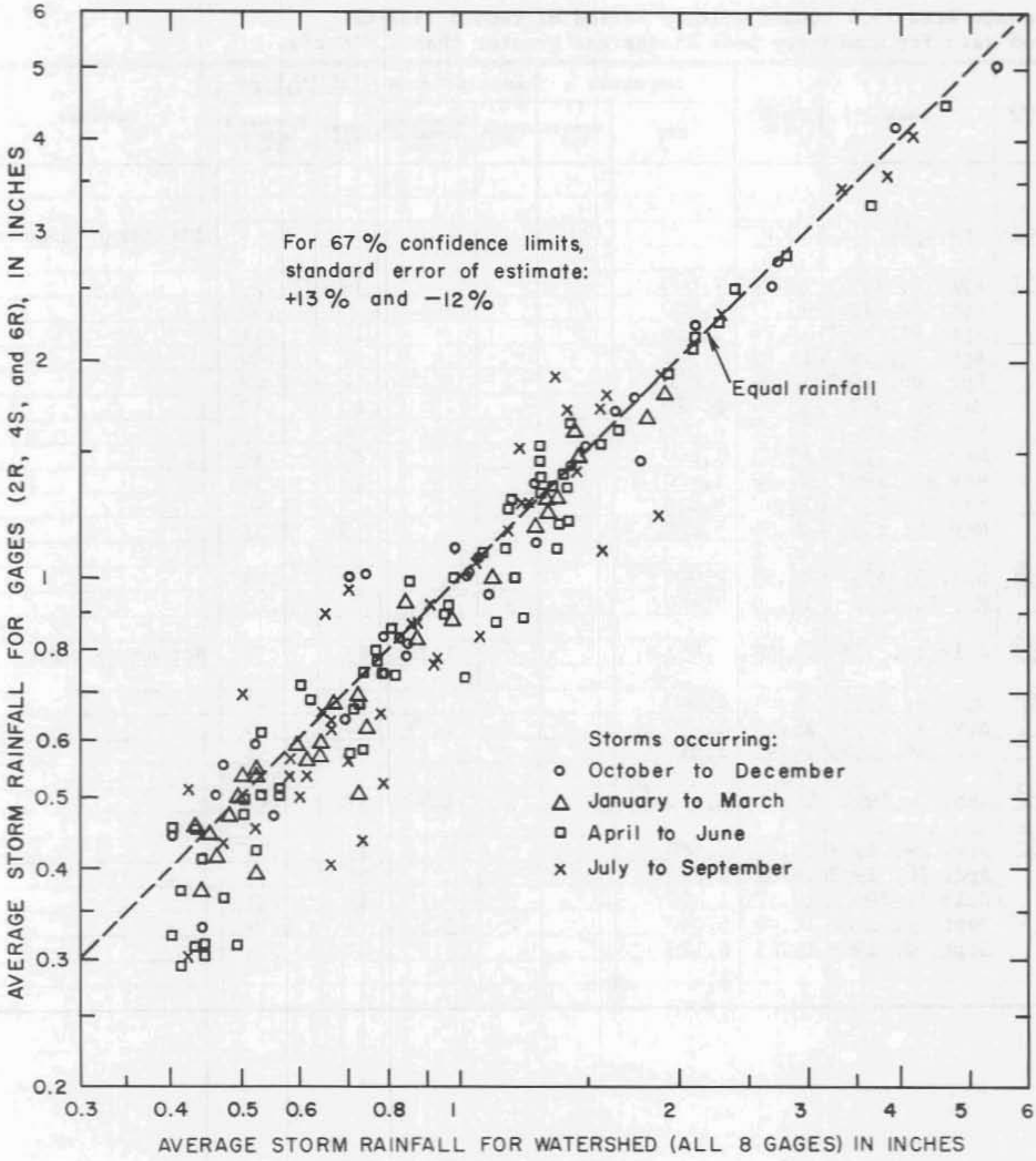

Figure 6

Comparison of Concurrent Storm Rainfall, Three Gages (2R, 4S, and 6R) and Eight Gages

U. S. Geological Survey in cooperation with the Texas Water Development Board and the City of Dallas

Table 2.--Flood data for Little Elm Creek near Aubrey, Texas

Drainage area 75.5 square miles. Period of record 1957-62.
Flood data for momentary peak discharges greater than 1,000 cfs.

WATER YEAR	DATE	GAGE HEIGHT (Feet)	DISCHARGE		ANNUAL FLOODS		PARTIAL DURATION SERIES		REMARKS
			CFS	RATIO TO $Q_{2.33}$	ORDER (M)	RECURRENCE INTERVAL (Years)	ORDER (M)	RECURRENCE INTERVAL (Years)	
1941	May 1941	18.2							Discharge unknown
1957	Apr. 1, 1957	14.70	1,680				14	.50	
	Apr. 20, 1957	15.77	3,300				8	.88	
	Apr. 21, 1957	14.28	1,480				16	.44	
	Apr. 23, 1957	15.83	3,520				7	1.00	
	Apr. 26, 1957	17.34	7,830		1	7.00	1	7.00	
	May 4, 1957	15.24	2,420				10	.70	
	May 13, 1957	16.87	6,080				2	3.50	
	May 18, 1957	13.73	1,200				22	.32	
	May 22, 1957	14.22	1,420				18	.39	
	May 23, 1957	16.40	4,830				5	1.40	
	May 25, 1957	16.56	5,220				3	2.33	
1958	Nov. 5, 1957	15.55	2,900				9	.78	
	May 1, 1958	16.26	4,460		3	2.33	6	1.16	
1959	July 17, 1959	11.29	451		6	1.16	23	.30	Not above base
1960	Oct. 4, 1959	14.84	1,640				15	.47	
	Nov. 4, 1959	15.10	1,930		4	1.74	12	.58	
	Dec. 16, 1959	14.43	1,310				20	.35	
1961	Jan. 8, 1961	14.60	1,440		5	1.40	17	.41	
1962	Apr. 24, 1962	14.87	1,680				13	.54	
	Apr. 28, 1962	14.31	1,240				21	.33	
	July 1, 1962	14.57	1,420				19	.37	
	Sept. 6, 1962	16.48	5,030		2	3.50	4	1.74	
	Sept. 8, 1962	15.23	2,120				11	.63	

A synthetic flood-frequency curve was prepared for the Little Elm Creek watershed by use of data from Patterson's (1963) flood-frequency report. A curve from Patterson's report relating the mean annual flood to drainage area is shown as Figure 7. From this curve a mean annual peak of 3,320 cfs was found to be applicable for a drainage area of 75.5 square miles. The mean annual flood is defined as the flood having a recurrence interval of 2.33 years. Also given in Patterson's report is a curve showing variation of peak discharge, expressed as a ratio to the mean annual flood, with recurrence interval. This curve is shown herein as Figure 8. By use of the value of 3,320 cfs for the mean annual flood and the curve values of Figure 8, a synthetic flood-frequency curve was prepared and is shown as Figure 9. For comparative purposes the values shown in Table 2 for the annual floods are plotted on Figure 9. The plotted points indicate that, in this instance, a fairly reliable flood-frequency curve could probably have been derived from this short period of record in the Little Elm Creek watershed.

Some hydrologists contend that where only a short period of flood record is available, a frequency curve derived from partial-duration series data is more reliable than an annual-flood series curve. This contention is based on the fact that the annual-flood series data often omit supplementary peaks which are higher than the annual peak of some years. For purposes of comparison, the curve values of Figure 9 were converted to partial-duration series values and plotted as shown by the curve of Figure 10. The conversion relation used was that developed by Langbein (1949) and is as follows:

Recurrence intervals in years

Partial-duration series	Annual-flood series
0.5	1.16
1.0	1.58
1.45	2.00
2.0	2.54
5.0	5.52
10	10.5
20	20.5
50	50.5
100	100.5

The values computed for the partial-duration series shown in Table 2 are plotted on Figure 10 for comparison. Although only six points are available from the annual-flood series, the regional-frequency curve fits the annual data fairly well. The partial-duration series data for the study area tend to define a curve considerably to the left of the regional curve. This can be explained, in part, by the fact that 11 of the 22 peaks above the base occurred during one year (1957). Having one-half of the events occur in one year distorts the

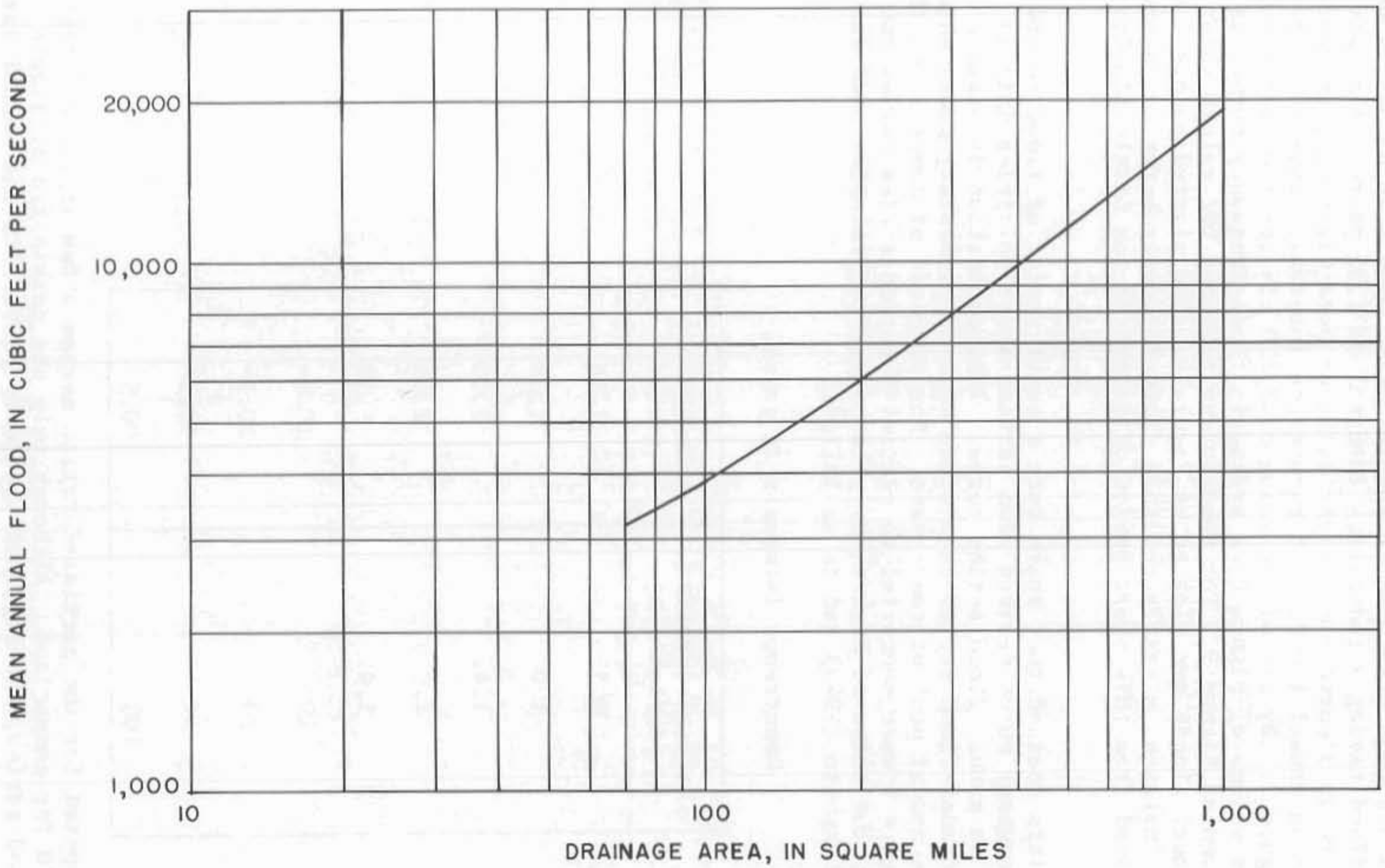

Figure 7

Variation of Mean Annual Flood with Drainage Area in Region Including the Little Elm Creek Watershed

(From Patterson, 1963; regional data is for Region C, Area 3, Dallas, Texas vicinity)

U. S. Geological Survey in cooperation with the Texas Water Development Board and the City of Dallas

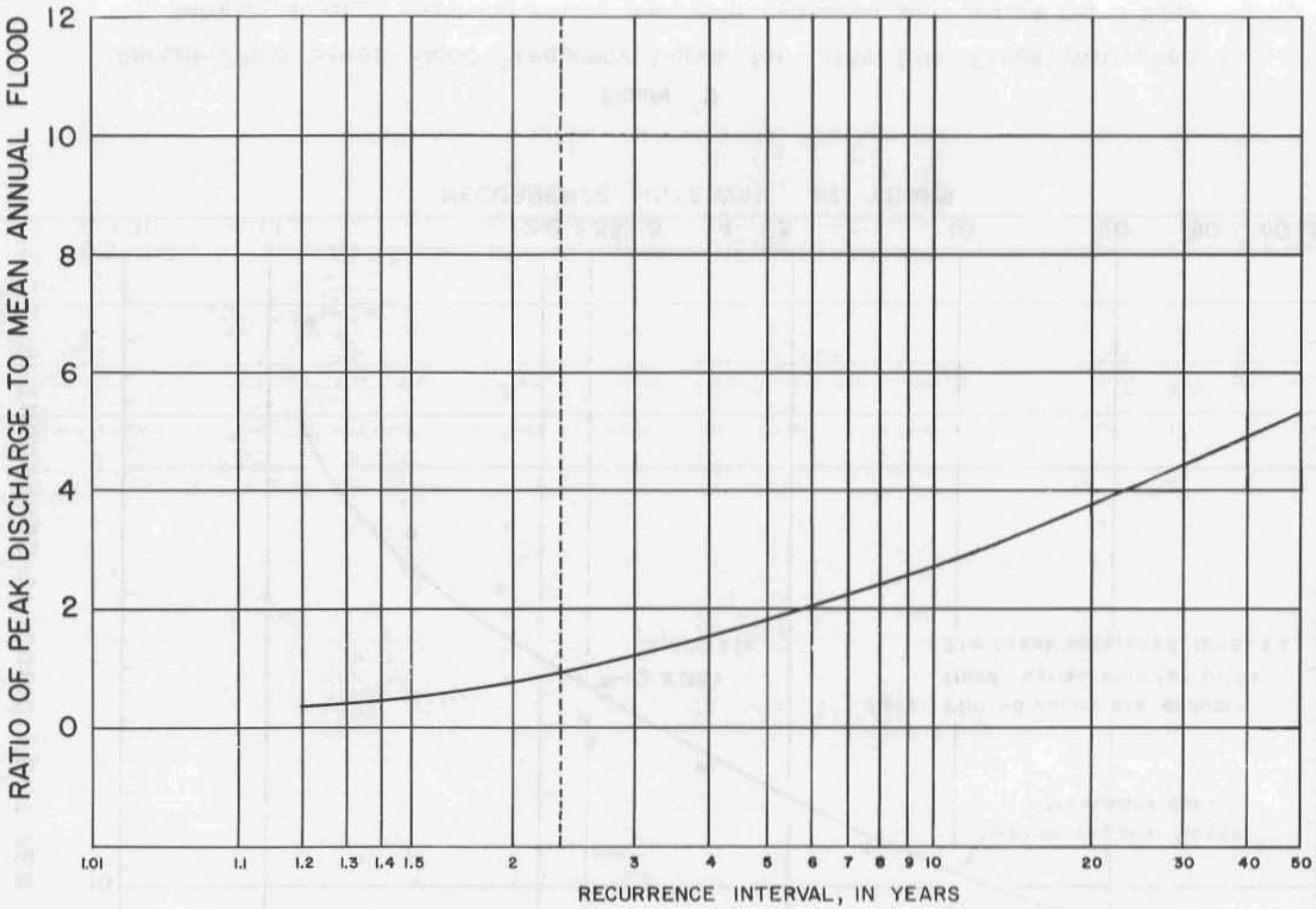

Figure 8

Composite Frequency Curve for Little Elm Creek Watershed

(From Patterson, 1963; regional data is for Region C, Area 3, Dallas, Texas vicinity)

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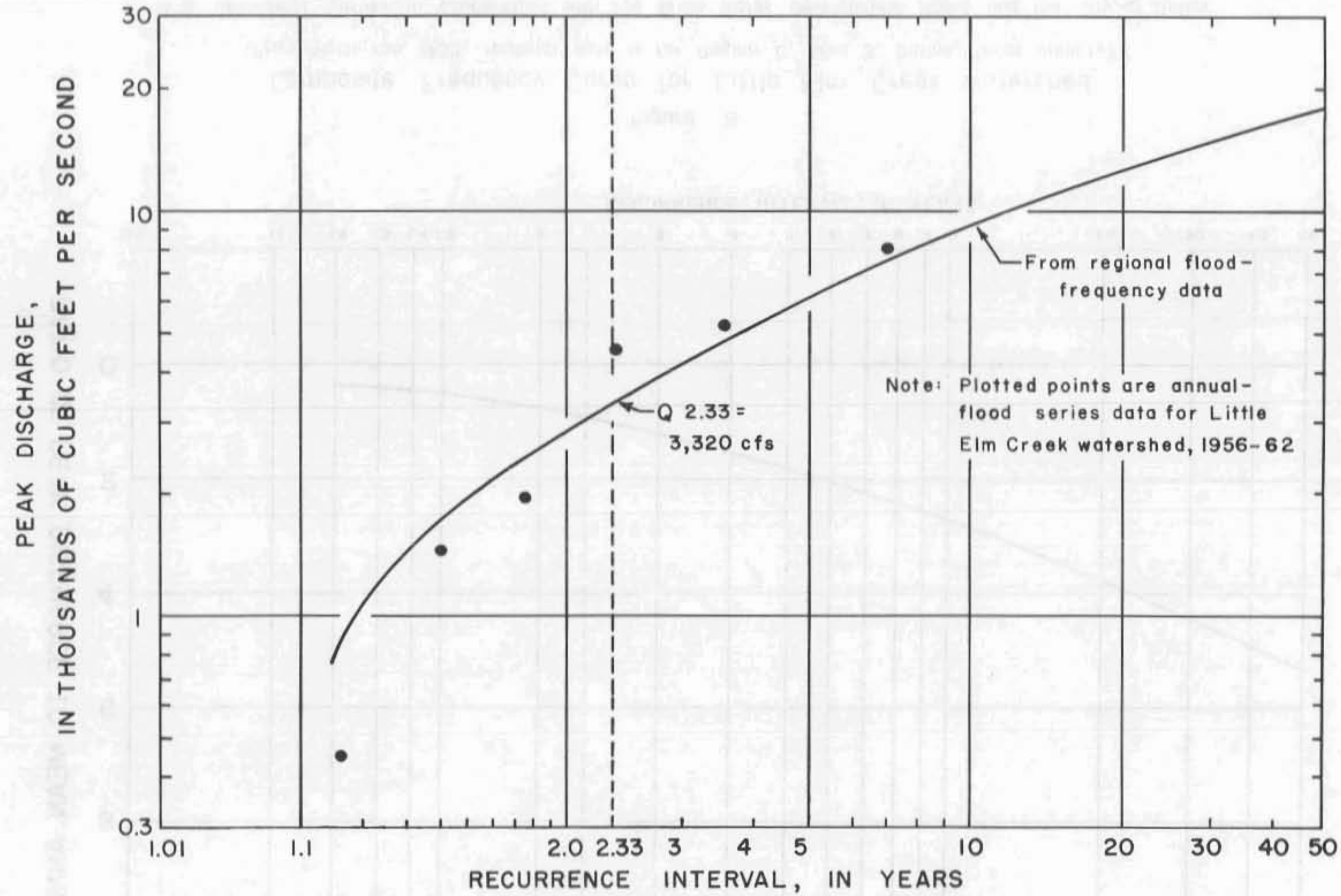

Figure 9

Annual-Flood Series Flood-Frequency Curve for Little Elm Creek Watershed

U. S. Geological Survey in cooperation with the Texas Water Development Board and the City of Dallas

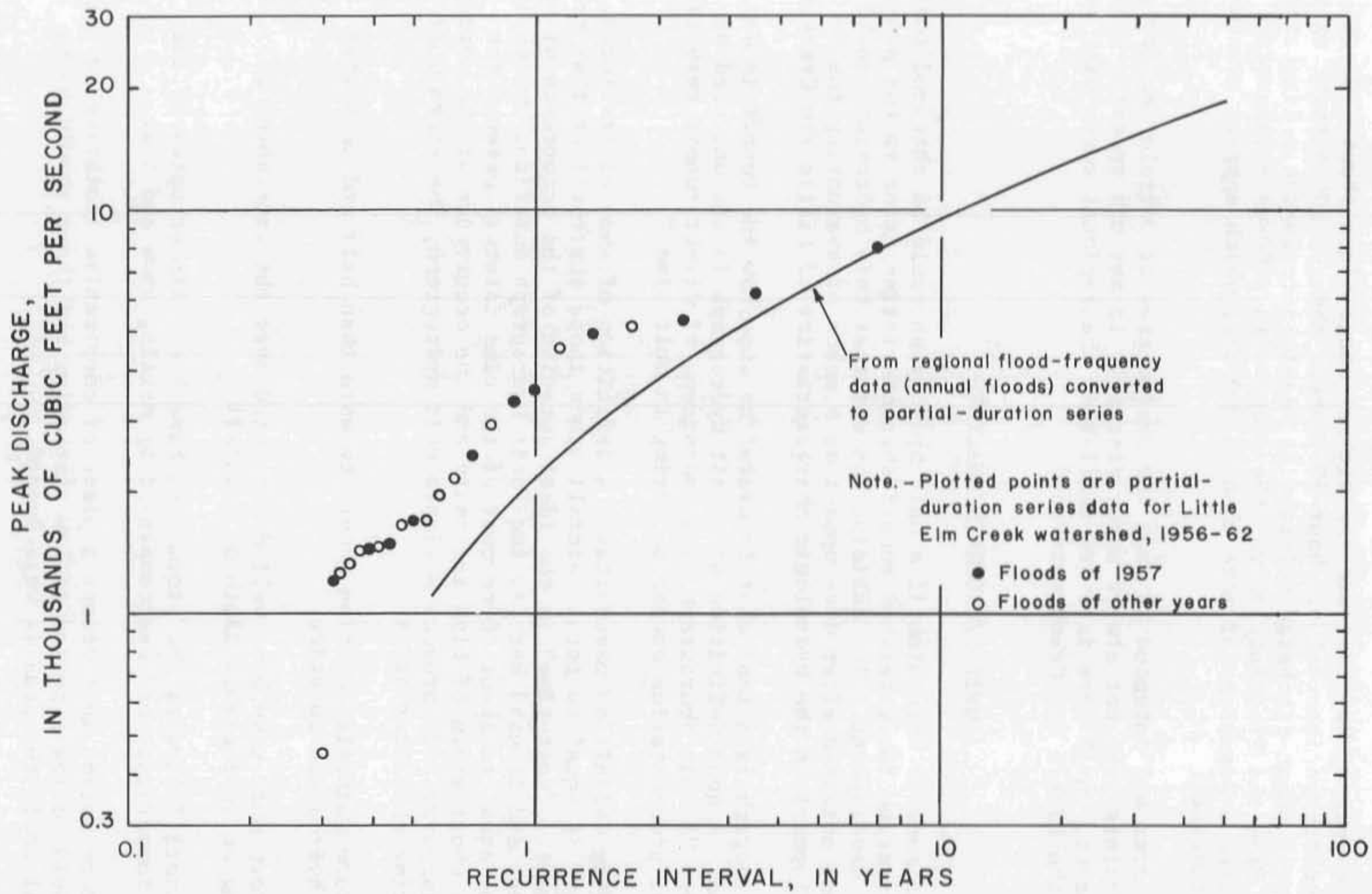

Figure 10

Partial-Duration Series Flood-Frequency Curve for Little Elm Creek Watershed

U. S. Geological Survey in cooperation with the Texas Water Development Board and the City of Dallas

frequency. A study of data shown on Figures 9 and 10 indicates that any adjustment of the regional curve to get better agreement with one series of data will worsen the agreement with the other series.

The historic peak of May 1941 was the highest stage since about 1900 and would imply a recurrence interval of about 60 years. About a 300-percent extension of the present stage-discharge relation is required to assign a discharge to this stage. From the frequency curve, the flood with a 60-year recurrence interval would have a discharge of more than 18,000 cfs, which appears reasonable for this watershed.

Regional curves are intended to show the best degree of correlation for a region, and therefore will not always apply precisely to any one specific basin watershed. However, until more data are available, the regional curve will be most useful in the Little Elm Creek watershed.

UNIT HYDROGRAPH ANALYSES

A study was made to determine if a unit hydrograph could be obtained that would help to describe the watershed runoff characteristics prior to the proposed watershed development. The anticipation was that this hydrograph could be compared with one obtained after development as a means of evaluating the effects of development on the hydrologic characteristics of Little Elm Creek.

A unit hydrograph is a tool that is useful to show how the runoff is distributed in time. A good definition of a unit hydrograph is the one used by Mitchell (1948): "A unit hydrograph is a hydrograph of direct runoff resulting from one inch of precipitation excess occurring in unit time."

The foregoing definition necessitates a definition of some of its terms. "Rainfall excess" is equal to total rainfall minus those abstractions that prevent direct runoff. "Unit time" is the ideal duration of the occurrence of precipitation excess and is used here as the "unit hydrograph duration," which is a period of time equal to about 20 percent of the time interval between the occurrence of a short storm of high intensity and the occurrence of the corresponding peak discharge. To produce a simple unit hydrograph, the storm must have the following characteristics:

1. The storm rainfall duration should be more than half and less than twice the unit hydrograph duration.

2. The storm must have been well distributed over the watershed, all stations showing an appreciable depth of rainfall.

3. The runoff following the storm must have been uninterrupted by the effects of low temperature and unaccompanied by melting snow and ice.

4. The storm period must occupy a place of comparative isolation in the record. It should follow a period of low streamflow and there should be no further rainfall until the peak is well passed.

A simple unit hydrograph is constructed from observed hydrographs by simply reducing the ordinates to a sum of 1 inch of runoff. This is accomplished by multiplying the ordinates of the observed storm hydrograph by the ratio obtained when the total storm runoff, in inches, is divided into 1 inch. Under ideal conditions, then, the runoff from all storms, having precipitation excess occurring in unit time, will produce similar unit hydrographs in any one drainage basin.

In actuality, conditions are never so simple or so uniform and ideal conditions suitable for unit hydrograph computation rarely exist. The basic unit hydrograph treatment to distribute the runoff in a natural basin therefore has to be modified, adjusted, refined, and amended.

Linsley, Kohler, and Paulhus (1949) state, "If the available storms show a wide variation in areal distribution of rainfall, it is necessary to develop several unit graphs and note on each the general rainfall distribution causing it." Short-duration, high-intensity storms tend to produce higher peaks because the proportion of surface runoff to interflow is greater. High-intensity storms have a tendency to produce flood waves of the translatory type rather than the normal, slower, monoclinal type. This condition can also produce higher peaks.

A total of 14 storms, which agreed with most criteria for reasonably uniform hydrographs and rainfall, were selected for study in the Little Elm Creek watershed. Storm hydrographs for these were reduced to unit hydrographs. The unit hydrographs were plotted with the hope of finding a correlation between duration of rainfall, time of rise, and unit hydrograph peak. Time of rise is defined as the time interval between the minimum and maximum unit hydrograph discharge on the rising limb. No reliable correlation was evident from plots of the 14 unit hydrographs. Eight of the 14 unit hydrographs are plotted on Figure 11. The data indicate that the 2-hour duration graph has a unit peak of about 2,600 cfs, and that the 4-hour duration graph has a unit peak of about 2,000 cfs.

The unit hydrographs have been numbered chronologically on Figure 11 for identification purposes. Hydrograph No. 7 does not strictly qualify as a unit hydrograph because the rainfall occurred in the extreme lower end of the watershed. It was plotted merely to illustrate the necessity of adjusting some unit hydrographs for rainfall distribution. Hydrograph No. 3 has about the same unit hydrograph duration as No. 7. The storm for No. 3 was well distributed over the watershed and was of short duration and high intensity. No. 8 is a unit hydrograph of a storm that had runoff producing rains over the entire watershed but had much greater amounts at the upper end of the watershed.

Unit hydrographs should afford a means of comparing runoff distribution before and after watershed development. For example, a direct comparison can be made of unit hydrographs of comparable storms before and after development; or, the unit hydrograph of a storm after development can be compared to a synthetic unit hydrograph of the same storm based on predevelopment conditions; or, unit hydrographs, based on several years of record after development, can be compared to those prepared in this period before development. The unit hydrograph comparisons are expected to show the flood peak reduction which can be attributed to the floodwater-retarding structures.

RELATING RAINFALL AND RUNOFF

Discussion of Methods

Hydrologists have been attempting to relate storm rainfall to resulting runoff ever since man first began to collect runoff records. The oldest and

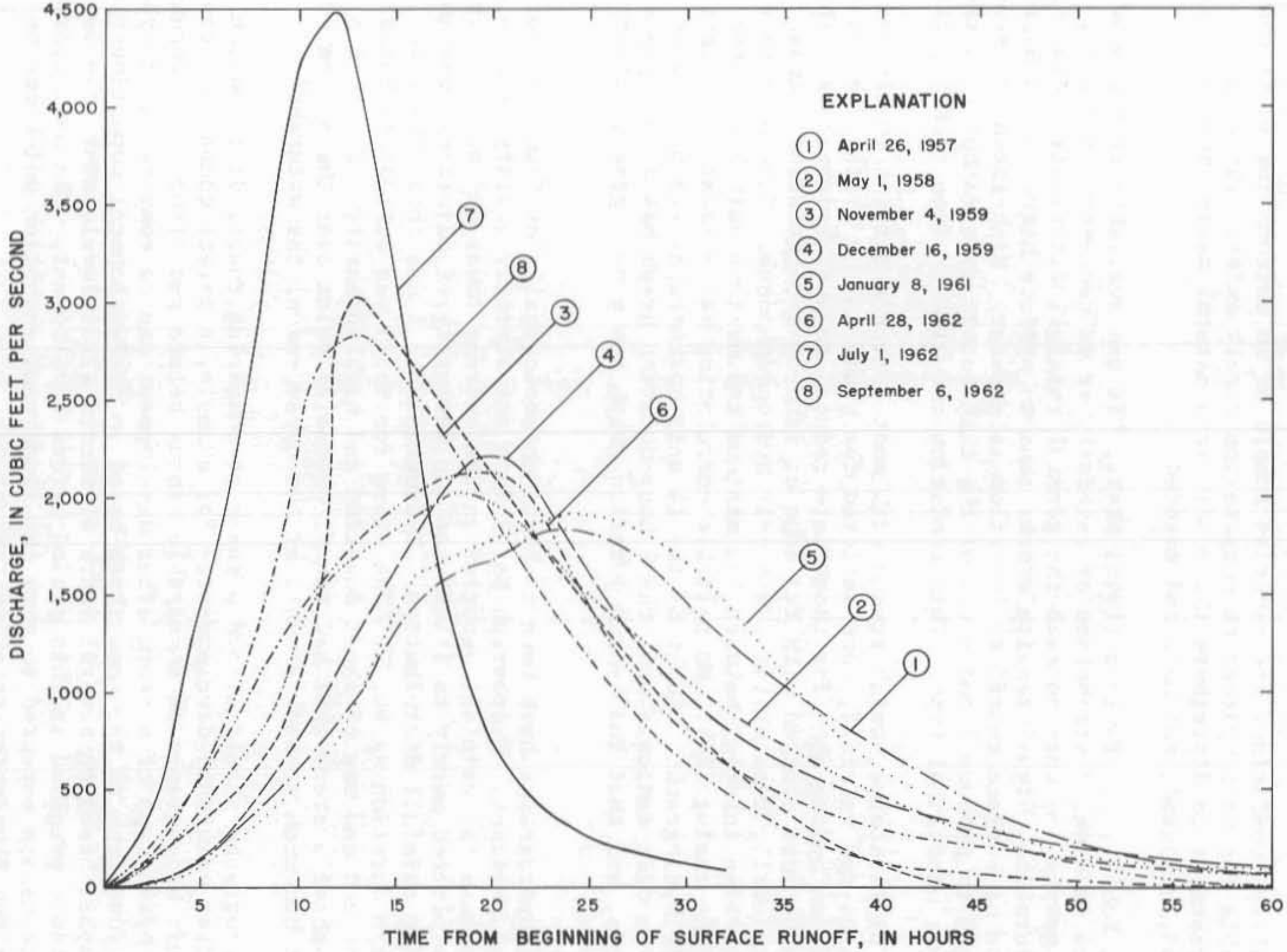

Figure 11

Unit Hydrographs for Little Elm Creek Watershed

U. S. Geological Survey in cooperation with the Texas Water Development Board and the City of Dallas

simplest method was to plot the amount of storm runoff against the amount of storm rainfall. This method, of course, gave a very poor correlation. Obviously, while the rainfall-runoff relation may be a straight-line relation, more than two variables are involved. Runoff is a function of precipitation, duration, intensity, distribution, antecedent soil moisture content, vegetal cover, type of soil, land use, soil condition, basin shape, basin slope, depression storage, infiltration rate, temperature, and many other minor parameters. Owing to this large number of variables, pure mathematical solution is impossible.

One of the most successful solutions to this problem has been the use of techniques which evaluate the infiltration rate of the soil in the watershed. This procedure requires an intimate knowledge of the watershed as well as a considerable amount of field observation to prepare the infiltration curves. Time and available funds did not permit an exploration of the infiltration approach for this report.

Multiple-Correlation Analysis

Of the several methods advanced by hydrologists, the graphical coaxial multiple-correlation method has been found to be the most practical and accurate technique of computing runoff from rainfall from the data available for this study. This method is described in detail by Kohler and Linsley (1951) in the U.S. Weather Bureau Research Paper 34.

The method, in essence, is an interrelation of three or more families of curves, each of which describes certain selected measurable parameters. A valid graphical correlation has the characteristic of absorbing or minimizing the effect of minor parameters. For example, stage-discharge curves are graphical correlations of the two measurable parameters--stage and discharge. After the curves have been developed, a value is obtained for discharge simply by knowing the stage. The numerous variables which are present in a mathematical equation of flow in an open channel need not be considered directly. The stage-discharge relation, an engineering application of a scientific principle, has become practical and reasonably accurate.

The parameters used in this report to predict runoff from rainfall are: antecedent precipitation index (API), month of occurrence, storm duration, and total storm precipitation.

The API may be determined mathematically using a series-type equation. One method which may be readily adapted to computer programming uses the reciprocal of the time (in days) multiplied by the precipitation on that day for the terms of the equation. The method preferred for this, a manually computed program, uses a logarithmic regression whereby the API for any day is determined by multiplying a predetermined exponentially varied factor (K) by the API for the previous day. The factor K is largely a reflection of the potential evapotranspiration. The Little Elm Creek study area is in a general area of moderate evapotranspiration; therefore, a value of 0.90 for K appears logical. When rainfall occurs, it is added to the API. A more accurate API could be determined if runoff were subtracted from rainfall and this residual added to the previous API. The logic of this procedure is evident since runoff does not quantitatively add to the soil moisture. However, the minor improvements in accuracy do not justify the added computations (Linsley, Kohler, and Paulhus, 1958); therefore, total rainfall was used for API computations given in this report.

Figure 12 is a graphical method of obtaining the API for the day rainfall occurred. This figure was plotted from table 16-1, page 416 of "Applied Hydrology" by Linsley, Kohler, and Paulhus (1949).

Values of rainfall duration and amount were obtained from the rain-gage network. Table 3 is a tabulation of the data for 28 storms selected to develop the correlation.

Figure 13 is the relation that has been developed to estimate runoff for the Little Elm Creek study area.

Some improvement in the plotting position probably could be attained by subdividing those days when several bursts of rainfall occurred. Future modifications probably will be required because the maximum storm rainfall experienced during the period of record was only 5.16 inches, and because no significant runoff occurred in February, March, or December. Use of the relation for storms occurring in these months requires interpolation between the curves shown for November and April. Any graphical correlation with five variables requires considerable trial and error work for a solution. A different shape for any one group of curves would require a change in shape of the other family of curves. The solution shown is that which best fitted the data.

The monthly and annual rainfall and corresponding runoff during the period covered by this report are tabulated in Table 4. The data are indicative of the variation in runoff from a given amount of rainfall for periods of months or years in the Little Elm Creek watershed. The mean ratio of annual runoff to precipitation is 0.20 for the study period. During the wettest year, 1957, with 56.75 inches of precipitation, the ratio was 0.39 while for the driest year, 1959, with 25.47 inches of precipitation the ratio was 0.016. The variations shown for the monthly values emphasize the difficulty in correlating rainfall and runoff on a storm basis. Some of the monthly values of runoff given in Table 4 are influenced by "end-of-month" rainfall for the preceding month. (See Table 5.)

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

The hydrologic data presented in this report, along with the conclusions and recommendations, are summarized as follows:

1. The rain-gage density analyses indicate that if the rain-gage network was reduced from 8 gages to 3 gages, the computed average rainfall would be within 13 percent of that computed from the 8 gages. Because rain gages located near ponds will be needed after floodwater-retarding dams are constructed, no reduction in the network is recommended.

2. Streamflow data have not been collected for a long enough period to define adequately the recurrence interval of floods of varying magnitudes for a flood-frequency study. Available data, when computed by the annual-flood series, agree fairly well with the regional-frequency curve but, when these data are computed by the partial-duration series, poor agreement is achieved.

3. More data are necessary for unit hydrograph studies. This watershed, while apparently hydrologically simple, appears to produce unit hydrographs varying in duration and magnitude.

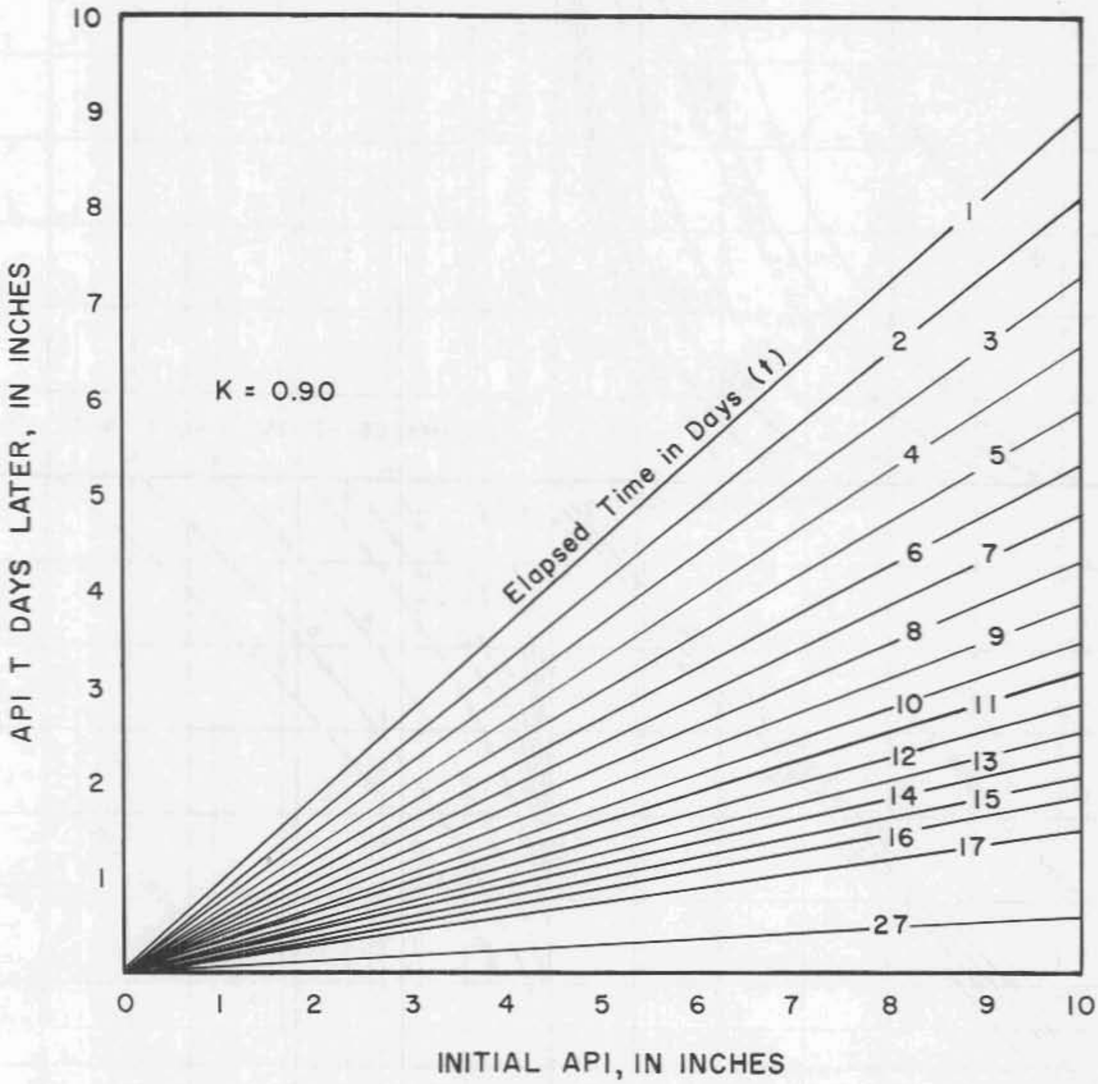

Figure 12

Chart for Computing Antecedent Precipitation Index (API)

U. S. Geological Survey in cooperation with the Texas Water Development Board and the City of Dallas

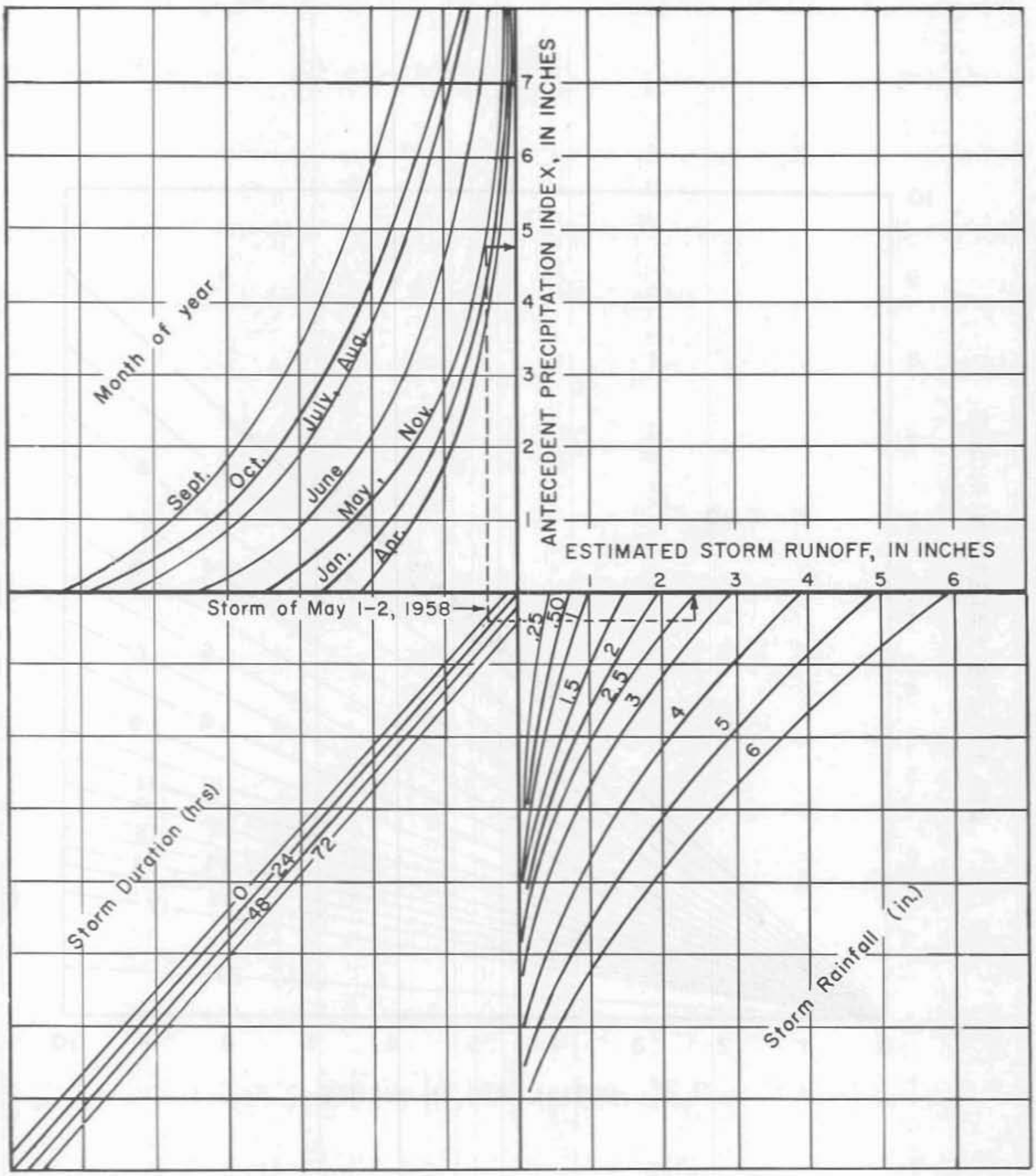

Figure 13

Coaxial Rainfall-Runoff Relation for Little Elm Creek Study Area for Estimating Runoff

(Derived from data in Table 3)

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Table 3.--Storm parameters used in constructing coaxial rainfall-runoff relation

Date of storm	Average storm rainfall (inches)	Storm duration (hours)	Storm runoff (inches)	Antecedent precipitation index (inches)
Apr. 19, 1957	2.80	6	1.62	0.60
20-21	1.35	4	.75	3.35
23	1.94	9	1.79	3.65
25-27	4.62	27	4.27	5.25
May 13	2.26	3	1.62	4.35
Sept. 21-22	3.34	20	.13	.80
Nov. 3-6	5.16	50	1.86	.35
7	.67	12	.54	4.60
Apr. 28-29, 1958	1.54	18	.97	1.60
Apr.30-May 1	2.61	18	2.20	2.70
May 1-2	2.66	15	2.32	4.80
June 15-16	1.43	6	.10	.15
16	1.29	4	.20	1.70
July 16, 1959	1.89	2	.15	1.10
Oct. 3-4	3.97	16	.67	.90
Nov. 3-4	1.74	1.5	.68	1.15
July 19, 1960	.49	1	.12	2.65
25	.48	1	.11	2.70
Jan. 6-7, 1961	1.75	18	.75	1.25
July 22-23	2.29	6	.06	.45
Sept. 11-13	3.85	26	.09	.25
Oct. 2	2.10	6	.17	.75
Apr. 23-24, 1962	1.21	21	.68	1.50
27	1.29	7	.58	2.10
Aug.31-Sept.1	2.96	12	.03	.40
Sept. 2	1.56	6	.36	3.10
6	4.95	12	2.03	3.20
7-8	1.87	6	.62	7.05

Table 4.--Average rainfall and runoff on study area, Little Elm Creek, October 1956 to September 1962

Period	Rainfall and runoff, in inches, by water years											
	1957		1958		1959		1960		1961		1962	
	Rainfall	Runoff	Rainfall	Runoff	Rainfall	Runoff	Rainfall	Runoff	Rainfall	Runoff	Rainfall	Runoff
October	2.16	0	2.55	0.05	1.37	0	6.84	0.80	1.70	0	2.65	0.18
November	2.78	.002	7.83	2.85	2.29	0	1.88	.69	.71	0	2.79	.14
December	2.87	.12	1.60	.12	.69	0	4.00	.64	5.80	.49	2.37	.22
Calendar year	1956		1957		1958		1959		1960		1961	
	--	--	60.67	24.95	32.18	7.27	33.84	2.53	33.73	2.29	32.46	2.88
January	2.47	.008	2.06	.33	.38	0	2.18	.83	2.09	.92	1.01	.01
February	2.34	.28	.73	.02	1.05	0	2.03	.35	2.78	.75	1.00	.002
March	5.96	.71	3.60	.63	2.07	.008	1.21	.03	2.93	.29	2.54	.15
April	13.16	9.97	7.22	1.67	.55	.001	2.22	.005	1.41	.02	4.70	1.38
May	16.28	10.66	3.85	4.24	2.16	0	3.21	.13	2.42	.14	1.50	.01
June	.68	.16	4.37	.37	6.76	.18	3.40	.0006	4.38	.06	7.10	1.16
July	1.86	.02	2.23	.01	4.71	.21	6.55	.44	3.29	.06	3.10	.24
August	.20	0	1.81	0	2.10	.0001	2.32	.01	1.06	0	3.34	.008
September	5.99	.13	1.96	0	1.34	0	2.40	0	4.29	.10	9.63	3.38
Water year	56.75	22.06	39.81	10.29	25.47	0.40	38.24	3.93	32.86	2.83	41.73	6.88

4. Additional data would be desirable to provide better definition of the multiple-correlation rainfall-runoff curves.

5. For the purpose of fulfilling the general study objective number 4 (page 4), a complete sediment station should be established at the site of the existing streamflow station, and a streamflow and sediment station should be established at Farm Road 455 crossing, 10½ miles upstream.

6. Basic data should be collected until a representative hydrologic period has occurred.

7. Data collection should extend well past the construction of the proposed floodwater-retarding structures in order to evaluate their effects.

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Table 5.--Summary of rainfall, in inches, for Little Elm Creek study area, December 1956 to September 1962

Date of storm	Storm Averages	Gage number							
		1-S	2-R	3-S	4-S	5-S	6-R	7-S	8-S
		Rain gages installed in December 1956							
1956 Oct.	[a]2.16								
Nov.	[a]2.78								
Dec. 6	.08	0.24	0.16	0.10	0.06	0	0.06	0.10	0.03
18-19	2.74	2.98	2.83	2.70	2.80	2.75	2.56	2.75	2.53
22	.05	.07	.05	0	.02	.05	.08	trace	.05
Monthly totals	2.87	3.29	3.04	2.80	2.88	2.80	2.70	2.85	2.61
1957 Jan. 4	.84	.65	.65	.86	.62	1.03	1.12	.70	1.10
20	.03	.07	.05	0	.05	0	.05	trace	.02
22	.15	.39	.24	.20	.15	.15	.04	.04	.03
27	.13	.21	.12	.05	.30	.15	.08	.03	.07
28	.43	.51	.70	.55	.27	.28	.38	.47	.29
30	.25	.10	.26	.40	.33	.19	.19	.23	.30
31	.64	.71	.55	.49	.52	.63	.63	.78	.77
Monthly totals	2.47	2.64	2.57	2.55	2.24	2.43	2.49	2.25	2.58

Table 5.--Summary of rainfall, in inches, for Little Elm Creek study area, December 1956 to September 1962--Continued

Date of storm		Storm Averages	Gage number							
			1-S	2-R	3-S	4-S	5-S	6-R	7-S	8-S
1957										
Feb.	1	0.23	0.31	0.24	0.21	0.20	0.21	0.22	0.20	0.24
	5	.04	.02	.06	.03	.03	.03	.05	.05	.03
	6	.97	.43	.59	.99	.89	1.00	1.12	1.22	1.50
	7	.20	.18	.16	.17	.19	.18	.18	.20	.35
	18	.34	.36	.35	.35	.21	.47	.30	.36	.32
	22	.49	.43	.47	.55	.50	.40	.53	.55	.50
	23	.04	.07	.05	.04	.04	.03	.05	trace	.05
	25	.03	.02	.10	.02	0	.03	.05	trace	.07
Monthly totals		2.34	1.82	2.02	2.36	2.06	2.35	2.50	2.58	3.06
Mar.	2	1.10	1.07	1.10	1.02	1.18	1.11	.71	1.35	1.27
	17	1.31	1.58	1.60	1.30	1.12	1.32	.97	1.58	1.02
	20	.72	.83	.77	.73	.62	.69	.69	.68	.73
	23	.16	.19	.18	.19	.21	0	.15	.15	.18
	24	.02	trace	.04	.02	.01	0	.05	trace	.04
	27	.80	.72	.73	.87	.65	1.14	.88	.70	.73
	30	.59	.84	.80	.84	.60	.42	.36	.47	.40
	31	1.26	1.00	.96	1.10	1.28	1.47	1.27	1.67	1.30
Monthly totals		5.96	6.23	6.18	6.07	5.67	6.15	5.08	6.60	5.67

Table 5.--Summary of rainfall, in inches, for Little Elm Creek study area, December 1956 to September 1962--Continued

Date of storm		Storm Averages	Gage number							
			1-S	2-R	3-S	4-S	5-S	6-R	7-S	8-S
1957										
April	1	0.05	0	0.13	0	0.12	0	0.05	0	0.10
	2	.10	.16	.13	.15	.05	.10	.07	.06	.07
	3	.36	.49	.41	.46	.22	.40	.29	.30	.28
	18	.14	.14	.22	.15	.05	.10	.07	.16	.22
	19	2.80	3.36	3.40	3.08	2.21	2.90	2.76	2.30	2.42
	20-21	1.37	1.22	1.30	1.20	1.14	1.87	1.13	1.92	1.19
	21	.06	.10	.07	.05	.07	.02	.06	.07	.08
	23	1.94	2.12	2.15	2.10	1.70	2.20	1.90	1.36	1.98
	24	.50	.48	.40	.45	.48	.52	.45	.75	.47
	25-27	4.62	5.88	5.10	5.25	4.51	4.37	3.85	4.13	3.88
	28	.10	trace	.20	.09	.14	.12	.03	.14	.04
	29	.41	.45	.36	.30	.36	.41	.40	.52	.45
	30	.71	1.49	1.04	.60	.45	.48	.48	.62	.54
Monthly totals		13.16	15.89	14.91	13.88	11.50	13.49	11.54	12.33	11.72
May	1	.44	.46	.37	.38	.17	.47	.39	.79	.49
	3	1.28	2.30	2.54	1.04	1.19	.91	.84	.70	.74
	8	.09	.08	.05	.07	.07	.06	.05	.10	.24
	9	.39	.58	.45	.45	.42	.42	.17	.51	.14
	11	.21	.39	.31	.15	.08	.25	.18	.10	.20
	12	1.07	.79	1.11	1.33	1.13	1.34	.99	.92	.91
	13	2.26	1.92	2.69	3.22	2.19	2.61	1.93	1.78	1.78
	15	.10	.31	.25	.05	.05	.10	.05	0	0
	16	.07	.06	.08	.06	.01	.12	.08	.10	.01

Table 5.--Summary of rainfall, in inches, for Little Elm Creek study area, December 1956 to September 1962--Continued

Date of storm		Storm Averages	Gage number							
			1-S	2-R	3-S	4-S	5-S	6-R	7-S	8-S
1957										
May	17-18	1.35	1.60	1.55	1.65	0.83	1.55	0.93	1.48	1.20
	21	1.18	trace	.12	1.43	1.08	1.90	1.80	1.40	1.68
	22	1.17	.61	.87	1.15	1.22	1.19	1.74	.95	1.62
	23	2.09	1.90	2.20	2.32	1.66	2.30	2.38	1.75	2.22
	24	.32	.36	.31	.25	.28	.30	.40	.30	.37
	25-26	3.65	4.43	3.78	2.97	2.26	3.75	3.80	4.70	3.54
	30	.31	.56	.37	.21	.38	.15	.18	.21	.45
	31	.30	.40	.57	.28	.38	.14	.18	.22	.21
Monthly totals		16.28	16.75	17.62	17.01	13.40	17.56	16.09	16.01	15.80
June	1	.09	.03	.05	.05	.08	.08	.11	.10	.20
	3-5	.40	.60	.15	.39	.67	.53	.15	.23	.49
	23	.19	.09	.21	0	.15	0	.40	.27	.39
Monthly totals		0.68	0.72	0.41	0.44	0.90	0.61	0.66	0.60	1.08
July	20	.37	.30	.25	.90	.03	.80	.20	.49	0
	24	.27	.27	.37	.33	.49	.40	.06	.27	0
	25	1.20	.11	.16	.14	2.15	.88	2.31	2.10	1.73
	26	.02	.17	.04	0	0	0	.04	0	0
Monthly totals		1.86	0.85	0.82	1.37	2.67	2.08	2.61	2.86	1.73

Table 5.--Summary of rainfall, in inches, for Little Elm Creek study area, December 1956 to September 1962--Continued

Date of storm	Storm Averages	Gage number							
		1-S	2-R	3-S	4-S	5-S	6-R	7-S	8-S
1957									
Aug. 11	0.07	0.11	0.08	0.10	0.21	0	0.05	trace	trace
15	.08	.02	.13	.20	.02	0	.05	.17	.08
17	.04	0	.07	0	0	0	0	.15	.13
31	.01	0	.07	0	0	0	0	0	trace
Monthly totals	0.20	0.13	0.35	0.30	0.23	0	0.10	0.32	0.21
Sept. 2	.10	.23	.25	.12	0	0	.12	0	.10
6	1.05	.55	1.00	1.72	1.05	1.22	1.10	1.03	.71
6-7	.64	.31	.57	.98	.67	.78	.71	.67	.46
11-12	.77	1.00	.82	.83	.62	.90	.52	.85	.64
14	.08	.18	.16	.14	.20	0	.04	0.	.02
21-22	3.34	4.10	3.38	3.04	3.50	2.70	3.47	3.34	3.21
Monthly totals	5.99	6.37	6.18	6.83	6.04	5.60	5.96	5.89	5.14
1957 WATER YEAR TOTALS	56.75	--	--	--	--	--	--	--	--
Oct. 8	.24	.15	.19	.17	.23	.32	.27	.22	.27
13	1.48	1.52	1.45	1.46	1.52	1.52	1.54	1.35	1.51
14	.25	.42	.20	.20	.25	0	.27	.29	.26
15	.25	0	.36	.20	.22	.47	.19	.37	.21
21	.12	.12	.21	.10	.15	0	.20	.10	.16
21-22	.21	.24	.20	.31	.25	0	.21	.20	.33
Monthly totals	2.55	2.45	2.61	2.44	2.62	2.31	2.68	2.53	2.74

Table 5.--Summary of rainfall, in inches, for Little Elm Creek study area, December 1956 to September 1962--Continued

Date of storm		Storm Averages	Gage number							
			1-S	2-R	3-S	4-S	5-S	6-R	7-S	8-S
1957										
Nov.	3-6	5.43	6.75	5.66	5.70	6.07	5.00	4.55	4.73	4.96
	7	.52	.45	.68	.43	.45	.57	.64	.54	.43
	13-14	.22	.12	.12	.11	.15	.06	.32	.38	.47
	17-18	.84	.75	.74	.87	1.00	.94	.68	.96	.81
	22	.36	.34	.10	.41	.47	.40	.24	.45	.40
	24	.46	.33	.60	.32	.30	.41	.60	.65	.50
Monthly totals		7.83	8.74	7.90	7.84	8.44	7.38	7.03	7.71	7.57
Dec.	6	.55	.57	.51	.51	.43	.60	.47	.75	.50
	24-25	1.05	1.17	1.09	1.06	1.10	.98	1.00	1.09	.94
Monthly totals		1.60	1.74	1.60	1.57	1.53	1.58	1.47	1.84	1.44
1957 CALENDAR YEAR TOTALS		60.67	64.33	63.17	62.66	57.30	61.54	58.21	61.52	58.74
1958										
Jan.	12	.88	..50	.78	.83	.73	.86	.93	.95	1.47
	13	.05	.08	.02	.10	0	.06	.02	.10	0
	14	.07	.23	.26	.07	0	0	0	0	0
	19	.52	.60	.51	.47	.60	.35	.49	.58	.55
	20	.26	.23	.24	.22	.30	.30	.31	.30	.25
	28	.28	.32	.30	0	.35	.46	.26	.28	.24
Monthly totals		2.06	1.96	2.11	1.69	1.98	2.03	2.01	2.21	2.51

Table 5.--Summary of rainfall, in inches, for Little Elm Creek study area, December 1956 to September 1962--Continued

Date of storm		Storm Averages	Gage number							
			1-S	2-R	3-S	4-S	5-S	6-R	7-S	8-S
1958										
Feb.	9-10	0.17	0.08	0.12	0.49	0.20	0	0.20	0.14	0.10
	13-14	.23	.21	.20	.08	.18	.28	.11	.52	.24
	26	.33	.16	.30	.55	.27	.60	.38	.12	.22
Monthly totals		0.73	0.55	0.62	1.12	0.65	0.88	0.69	0.78	0.56
Mar.	4-5	.61	.60	.48	.60	.70	.60	.49	.70	.70
	5	.32	.30	.27	.29	.42	.28	.23	.28	.49
	6	.04	.05	.06	.06	.05	.02	.02	.03	.05
	6-7	.33	.50	.30	.40	.20	.30	.39	.35	.20
	8	.12	.19	.10	.18	0	0	.24	.22	0
	12-13	.64	.74	.71	.69	.40	.45	.66	.75	.68
	23	.67	.70	.54	.53	.76	.73	.70	.65	.76
	28-29	.87	.76	.74	.89	.80	.74	.92	1.07	1.06
Monthly totals		3.60	3.84	3.20	3.64	3.33	3.12	3.65	4.05	3.94
Apr.	4	.36	.21	.30	.37	.26	.52	.35	.50	.43
	7	.17	0	.31	0	.10	.50	.40	0	0
	9-10	.44	1.01	.34	.67	.08	0	.49	.53	.38
	13	.73	.86	.62	.74	.80	.30	.81	.89	.84
	19	.14	.85	.19	.03	0	0	0	trace	.08
	20	.39	.20	.30	.39	.30	.30	.50	.68	.47
	21	.09	0	.02	.05	.10	.05	.16	.10	.24
	25	.09	0	0	0	0	.16	.15	.20	.17
	26	.73	.54	.47	.85	.30	.96	.98	.80	.97

Table 5.--Summary of rainfall, in inches, for Little Elm Creek study area, December 1956 to September 1962--Continued

Date of storm		Storm Averages	Gage number							
			1-S	2-R	3-S	4-S	5-S	6-R	7-S	8-S
1958										
Apr.	27	0.24	0.34	0.58	0.40	0.50	0	0.02	trace	0.06
	28	.96	1.18	1.02	.65	.85	.74	.88	1.23	1.10
	29	.49	.60	.68	.30	.30	(.40)	.56	.62	.45
	30	2.39	2.40	2.35	2.00	2.93	(2.40)	2.26	2.50	2.30
Monthly totals		7.22	8.19	7.18	6.45	6.52	(6.73)	7.16	8.05	7.49
May	1	.30	.34	.35	.30	.47	(.40)	.12	.23	.21
	1-2	2.10	1.49	1.88	1.90	2.05	(2.25)	2.53	2.49	2.21
	2-3	.54	.84	.20	.77	0	(.45)	.40	.75	.85
	14-15	.51	.38	.34	.35	.47	(.50)	.69	.23	1.10
	25	.40	.85	.84	.47	.25	(.25)	.25	.22	.11
Monthly totals		3.85	3.90	3.61	3.79	3.24	(3.85)	3.99	3.92	4.48
June	5	.20	.54	.22	0	0	0	.17	.25	.40
	15-16	1.56	2.00	2.63	3.48	1.80	1.80	.15	.32	.30
	16	1.16	1.39	1.61	2.00	1.30	.90	.80	.52	.73
	19	.05	.12	.10	0	0	.07	0	.10	trace
	20	.10	0	.20	0	.10	.12	.10	.09	.16
	21	.81	.77	.60	.75	1.00	1.00	.58	1.20	.61
	22	.20	.26	.23	.27	.23	0	0	.40	.25
	25-26	.29	.25	.20	.27	.30	.33	.35	.35	.26
Monthly totals		4.37	5.33	5.79	6.77	4.73	4.22	2.15	3.23	2.71

Table 5.--Summary of rainfall, in inches, for Little Elm Creek study area, December 1956 to September 1962--Continued

Date of storm	Storm Averages	Gage number							
		1-S	2-R	3-S	4-S	5-S	6-R	7-S	8-S
1958									
July 4	0.65	0.39	0.26	0.30	1.40	(1.00)	1.01	0.19	0.67
5	.61	.62	.55	.45	.30	.34	.75	.70	1.15
6	.39	.33	.34	.38	.35	.40	.56	.25	.49
22	.58	.73	.68	.70	.60	(.40)	.40	.45	.64
Monthly totals	2.23	2.07	1.83	1.83	2.65	2.14	2.72	1.59	2.95
Aug. 9	.91	1.03	.95	1.31	.50	1.05	.84	.90	.70
20-21	.90	1.19	1.25	1.07	.77	.10	.75	1.08	1.02
Monthly totals	1.81	2.22	2.20	2.38	1.27	1.15	1.59	1.98	1.72
Sept. 7	.24	0	.25	.50	trace	0	.74	.25	.18
10-11	.47	.51	.11	.10	.15	.36	1.03	1.03	.50
16	.29	.25	.32	.65	.50	.16	.28	.13	.05
17	.13	0	0	0	.20	.20	.05	.12	.44
19	.70	.55	.54	.59	.40	.82	.74	1.18	.81
30	.13	.16	.06	.10	trace	.10	.28	.10	.21
Monthly totals	1.96	1.47	1.28	1.94	1.25	1.64	3.12	2.81	2.19
1958 WATER YEAR TOTALS	39.81	42.46	39.93	41.46	38.21	37.03	38.26	40.70	40.30

Table 5.--Summary of rainfall, in inches, for Little Elm Creek study area, December 1956 to September 1962--Continued

Date of storm		Storm Averages	Gage number							
			1-S	2-R	3-S	4-S	5-S	6-R	7-S	8-S
1958										
Oct.	3	0.08	0.15	0.15	0.03	trace	0	0.12	0.10	0.05
	5	.05	0	0	0	0	.14	.05	.10	.13
	15	.03	.04	.05	0	trace	0	.05	trace	.08
	21	1.09	2.15	1.02	.77	1.00	.80	.83	1.25	.92
	25	.10	.38	.23	.17	0	0	0	0	0
	31	.02	.03	.03	0	trace	.05	.05	trace	.03
Monthly totals		1.37	2.75	1.48	0.97	1.00	0.99	1.10	1.45	1.21
Nov.	14	1.27	1.23	1.32	1.38	1.05	1.58	.99	1.60	1.03
	16-17	.24	.29	.20	.27	.15	.32	.20	.25	.29
	27-28	.78	.70	.87	.78	.88	.80	.75	.72	.70
Monthly totals		2.29	2.22	2.39	2.43	2.08	2.70	1.94	2.57	2.02
Dec.	1	.27	.23	.30	.22	0	.37	.35	.42	.27
	3	.05	.16	0	0	0	.04	.02	.06	.09
	14	.01	.03	.05	0	0	0	.02	0	.01
	30	.21	.19	.25	.07	trace	.27	.35	.23	.30
	31	.15	.17	.10	0	.30	.13	.19	.20	.10
Monthly totals		0.69	0.78	0.70	0.29	0.30	0.81	0.93	0.91	0.77
1958 CALENDAR YEAR TOTALS		32.18	35.28	32.39	33.30	29.00	30.26	31.05	33.55	32.55

Table 5.--Summary of rainfall, in inches, for Little Elm Creek study area, December 1956 to September 1962--Continued

Date of storm		Storm Averages	Gage number							
			1-S	2-R	3-S	4-S	5-S	6-R	7-S	8-S
1959										
Jan.	7	0.01	0.03	0.02	0	0	0	0	0	0
	15	.13	.01	.05	.60	trace	.13	0	.19	.07
	21	.21	.16	.07	0	.40	.19	.12	.54	.18
	23	.02	0	.08	0	0	0	.11	0	0
	26	.01	0	.05	0	0	0	.05	0	0
Monthly totals		0.38	0.20	0.27	0.60	0.40	0.32	0.28	0.73	0.25
Feb.	1	.13	.25	.02	.50	0	.01	.04		.09
	3	.22	.17	.33	0	.44	.26	.22		.20
	9	.07	.10	.05	0	trace	.18	.08		.07
	13-14	.52	0	.47	.66	.60	.69	.65		.59
	20	.09	.10	.08	0	.10	.12	.10		.10
	23	.02	.04	0	0	trace	.05	0		.02
Monthly totals		1.05	0.66	0.95	1.16	1.14	1.31	1.09	(1.05)	1.07
Mar.	4	.50	.59	.39	.32	.70	.34	.50	.75	.44
	11	.44	0	.02	.06	0	.22	1.10	.96	1.16
	21	.07	.10	.05	.13	0	.12	.08	0	.06
	25	.26	.28	.23	.15	.40	.20	.26	.20	.33
	28	.06	.09	.05	0	.10	0	.10	.05	.08
	31	.74	.41	.45	.73	.45	1.02	.95	(1.00)	.95
Monthly totals		2.07	1.47	1.19	1.39	1.65	1.90	2.99	2.96	3.02

Table 5.--Summary of rainfall, in inches, for Little Elm Creek study area, December 1956 to September 1962--Continued

Date of storm		Storm Averages	Gage number							
			1-S	2-R	3-S	4-S	5-S	6-R	7-S	8-S
1959										
Apr.	8	0.04	0	0.05	0	0	0.08	0.08		0.08
	10	.04	.05	.02	0	.15	0	.02		.07
	17	.31	.25	.29	.35	.30	.44	.25		.32
	18	.03	.05	.13	0	0	trace	.05		trace
	19	.07	.15	.08	0	trace	.06	.03		.08
	21	.06	.08	.03	.05	trace	.13	.02		..11
Monthly totals		0.55	0.58	0.60	0.40	0.45	0.71	0.45	(0.55)	0.66
May	5	.38	.38	.31	.36	.40	.42	.36	–	.40
	8	.09	0	.14	.10	.30	.07	0	–	trace
	9	.27	.43	.27	.37	0	.39	0	–	.42
	10	.72	.86	.80	.75	.80	.80	.41	(.60)	.74
	23	.08	.07	.08	0	trace	.10	.05	–	.20
	24	.43	.37	.36	.35	.50	.45	.50	–	.49
	31	.19	.19	0	0	.90	.02	.19	–	.04
Monthly totals		2.16	2.30	1.96	1.93	2.90	2.25	1.51	(2.16)	2.29
June	2	1.01	1.94	1.30	1.03	0	(1.41)	.90	.85	.68
	4	.70	.28	.95	1.16	.40	(.90)	.65	.60	.69
	7	.16	0	0	.15	0	(.40)	.23	.23	.23
	10	.15	.55	.13	.20	trace	(.30)	0	0	0
	12	.37	.59	.61	.60	.17	(.40)	.17	.05	.28
	22	.47	.82	.40	.13	.23	(.60)	.45	.46	.70

Table 5.--Summary of rainfall, in inches, for Little Elm Creek study area, December 1956 to September 1962--Continued

Date of storm		Storm averages	Gage number							
			1-S	2-R	3-S	4-S	5-S	6-R	7-S	8-S
1959										
June	22-23	1.65	4.00	3.00	1.20	0.90	(1.00)	0.90	1.00	1.21
	23	1.22	2.18	1.65	1.84	0	(.50)	1.00	2.02	.58
	25	.27	.50	.25	.20	.20	(.50)	.17	.30	.05
	26	.76	.90	.80	.83	.70	(.75)	.82	.70	.59
Monthly totals		6.76	11.76	9.09	7.34	2.60	(6.75)	5.29	6.21	5.01
July	2	.78	1.18	1.49	.74	.07	2.30	0	.50	0
	13	.34	.13	.34	0	.40	.38	.60	.15	.75
	15	.04	.09	.04	0	.10	0	.10	0	0
	16	1.89	1.87	2.34	2.82	2.00	2.75	1.38	.90	1.08
	17	.08	.21	.10	0	.10	.03	.09	0	.11
	18	.06	.05	.07	0	0	.08	.06	.07	.12
	19	.17	.17	.23	0	.05	.20	.18	.30	.20
	20	.12	.07	.05	0	0	.12	.15	.29	.30
	23	.07	.11	.05	0	.10	0	.05	.08	.13
	26	1.16	1.29	1.00	1.13	1.75	1.28	.70	1.05	1.09
Monthly totals		4.71	5.17	5.71	4.69	4.57	7.14	3.31	3.34	3.78
Aug.	26	.28	.37	.18	0	.20	.60	.20	.27	.47
	27	.58	1.34	.80	1.10	.50	.28	.30	.13	.15
	30-31	1.24	1.54	1.53	1.25	1.10	1.06	1.17	1.17	1.08
Monthly totals		2.10	3.25	2.51	2.35	1.80	1.94	1.67	1.57	1.70

Table 5.--Summary of rainfall, in inches, for Little Elm Creek study area, December 1956 to September 1962--Continued

Date of storm		Storm Averages	Gage number							
			1-S	2-R	3-S	4-S	5-S	6-R	7-S	8-S
1959										
Sept.	3	0.06	0.15	0.08	0	0.10	0.08	0.04	trace	0.05
	10	.07	.25	.08	0	0	.09	.04	0	0.01
	24	.16	.31	.04	0	.65	0	.24	trace	.05
	28	.87	.87	.90	.92	.72	.79	.96	.85	.95
	30	.18	.11	.32	0	.50	.08	.30	.15	trace
Monthly totals		1.34	1.69	1.42	0.92	1.97	1.04	1.58	1.00	1.06
1959 WATER YEAR TOTALS		25.47	32.83	28.27	24.47	20.86	27.87	22.14	24.50	22.84
Oct.	1	.44	.56	.38		.10	.56	.43		.59
	3-4	3.97	3.06	2.62		5.10	2.95	4.86		5.24
	13	1.41	.82	.98		1.65	1.96	1.65		1.41
	30	1.02	.87	.98		1.06	1.10	.95		1.13
Monthly totals		6.84	5.31	4.96		7.91	6.57	7.89	–	8.37
Nov.	3-4	1.74	1.37	1.52	1.75	2.10	2.30	1.70		1.42
	10	.08	.11	.08	0	.15	.12	0		.13
	17	.04	.05	.06	0	0	.10	.04		.04
	22	0	0	.03	0	trace	0	.06		trace
Monthly totals		1.88	1.53	1.69	1.75	2.25	2.52	1.80	–	1.59

Table 5.--Summary of rainfall, in inches, for Little Elm Creek study area, December 1956 to September 1962--Continued

Date of storm		Storm Averages	Gage number							
			1-S	2-R	3-S	4-S	5-S	6-R	7-S	8-S
1959 Dec.	2	0.01	0	0.02	0	0	0	0.04	-	0
	7	.01	0	.02	0	0	0	.05	-	0
	10	.06	.10	.06	0	.10	.10	.05	trace	.09
	13	.01	0	0	0	0	0	.07	trace	0
	15	2.69	3.12	3.05	3.21	2.35	3.22	2.20	2.10	2.29
	16	.16	.15	.15	.16	.30	.08	.05	.20	.20
	23-24	.02	.04	.03	.03	trace	0	.05	trace	.03
	26-27	.35	.22	.45	.45	.22	.42	.30	.50	.23
	31	.69	.77	.65	.70	.60	.73	.67	.62	.75
Monthly totals		4.00	4.40	4.43	4.55	3.57	4.55	3.48	3.42	3.59
1959 CALENDAR YEAR TOTALS		33.84	38.32	34.78	33.92	31.21	37.01	31.34	31.71	32.39
1960 Jan.	4-6	1.31	1.33	1.12	1.33	1.36	1.34	1.37	1.24	1.36
	12	.36	.75	.45	.37	.53	.13	.22	.10	.33
	14	.04	.08	.03	.05	0	.04	.03	.05	.05
	16-17	.47	0	.57	.60	.32	.63	.60	.46	.55
	27	0	0	0	0	trace	trace	0	trace	trace
Monthly totals		2.18	2.16	2.17	2.35	2.21	2.14	2.22	1.85	2.29

Table 5.--Summary of rainfall, in inches, for Little Elm Creek study area, December 1956 to September 1962--Continued

Date of storm		Storm Averages	Gage number 1-S	2-R	3-S	4-S	5-S	6-R	7-S	8-S
1960										
Feb.	3-5	1.51	1.48	1.55	1.55	1.90	1.55	1.35		1.17
	9	.01	0	.03	0	0	0	.05		0
	15	.05	.19	.08	0	trace	trace	.08		trace
	17	.14	.21	.06	0	.32	.17	.07		.15
	20	.19	.20	.21	0	.24	.21	.22		.23
	23-24	.06	.04	.03	0	.24	.03	.03		.05
	28	.07	0	.04	0	.16	.11	.07		.12
Monthly totals		2.03	2.12	2.00	1.55	2.86	2.07	1.87	-	1.72
Mar.	1	.04	.14	0	0	0	.05	.05	.05	.04
	2	.24	.18	.20	0	.19	.31	.32	.40	.28
	14	.17	.25	.26	0	.17	.19	.19	.15	.18
	21	0	0	0	0	0	0	.03	0	0
	24	.46	.41	.38	.48	.45	.66	.40	.54	.34
	25	.30	.31	.29	.36	.40	.36	.22	.30	.19
Monthly totals		1.21	1.29	1.13	0.84	1.21	1.57	1.21	1.44	1.03
Apr.	8-9	.14	.07	.22	0	trace	.14	.22		.31
	11	0	0	0	0	0	0	.03		0
	13	.31	.50	.17	.20	.45	.20	.28		.35
	24	.51	.37	.35	.58	.38	.71	.75		.44
	27	.30	.33	.28	.29	.30	.26	.26		.39
	29	.48	.33	.25	.31	.67	.50	.60		.70
	29-30	.48	.77	.61	.74	.33	.25	.30		.35
Monthly totals		2.22	2.37	1.88	2.12	2.13	2.06	2.44	-	2.54

Table 5.--Summary of rainfall, in inches, for Little Elm Creek study area, December 1956 to September 1962--Continued

Date of storm		Storm Averages	Gage number 1-S	2-R	3-S	4-S	5-S	6-R	7-S	8-S
1960										
May	4	0.98	1.43	1.01	0.75	1.10	0.71	0.88		0.96
	5	.01	0	0	0	.05	0	.1		.04
	18	1.42	1.57	1.40	1.34	2.30	1.11	1.20		1.05
	20	.18	.04	.21	.19	.20	.24	.22		.19
	25	.19	0	.48	0	.10	.17	.28		.30
	29	.26	.31	.24	.30	.25	.25	.24		.23
	30	.17	.22	.32	.23	.10	.12	.12		.05
Monthly totals		3.21	3.57	3.66	2.81	4.10	2.60	3.04	-	2.82
June	1	.43	.29	.27	.47	.50	.60	.45		.44
	5	.34	.22	.43	1.32	trace	.24	0		.19
	7	.20	0	.08	.39	trace	.20	.37		.35
	12	1.00	1.11	.65	1.13	.80	1.05	1.23		1.01
	25	.85	1.01	.95	1.02	1.02	.83	.59		.52
	26	.58	.36	.51	.68	.58	.53	.73		.64
Monthly totals		3.40	2.99	2.89	5.01	2.90	3.45	3.37	-	3.15
July	2	.01	0	0	.10	0	0	0	0	0
	5	.20	1.58	0	0	0	0	0	0	0
	13	.66	.61	.25	0	.65	.65	.78	1.01	1.32
	14	1.60	1.10	.45	0	.62	.51	2.70	3.52	3.90
	15	.04	0	0	0	0	0	.08	.10	.11

Table 5.--Summary of rainfall, in inches, for Little Elm Creek study area, December 1956 to September 1962--Continued

Date of storm		Storm Averages	Gage number							
			1-S	2-R	3-S	4-S	5-S	6-R	7-S	8-S
1960										
July	18	0.91	0.80	0.90	1.36	0.65	0.93	0.76	0.65	1.26
	19	.74	.28	.31	.49	.45	.63	.52	.91	2.36
	24	.84	.68	.50	.94	.88	.34	1.20	1.15	1.01
	25	.41	.03	.02	.04	.64	.12	.87	.83	.73
	28	1.14	1.15	.97	1.57	.85	1.80	.68	1.60	.46
Monthly totals		6.55	6.23	3.40	4.50	4.74	4.98	7.59	9.77	11.15
Aug.	10	.48	0	.91	.87	.58	.43	.57	.40	.12
	15	.17	.12	.10	0	trace	.23	.35	.10	.45
	18	.64	.80	.81	.75	0	.71	.70	.78	.57
	21	.64	.06	.08	.20	.51	.54	1.26	1.24	1.27
	21	.20	.04	.04	.10	.14	.11	.38	.38	.38
	26	.19	0	.23	.45	0	.42	.07	.12	.20
Monthly totals		2.32	1.02	2.17	2.37	1.23	2.44	3.33	3.02	2.99
Sept.	9	.03	0	0	0	trace	.03	.20	trace	trace
	23-24	.26	.30	.20	.22	.16	.39	.18	.50	.13
	25-26	1.68	2.44	2.22	2.40	1.90	1.82	1.25	.75	.67
	26-27	.43	.37	.33	.35	.30	.38	.26	.87	.59
Monthly totals		2.40	3.11	2.75	2.97	2.36	2.62	1.89	2.12	1.39
1960 WATER YEAR TOTALS		38.24	36.10	33.13	37.66	37.47	37.57	40.13	41.02	42.63

Table 5.--Summary of rainfall, in inches, for Little Elm Creek study area, December 1956 to September 1962--Continued

Date of storm	Storm Averages	Gage number 1-S	2-R	3-S	4-S	5-S	6-R	7-S	8-S
1960									
Oct. 4	0.40	0.82	1.10	0.15	trace	0.38	0.21	0.30	0.26
13	.15	.03	0	0	trace	.11	.43	.40	.24
18	.16	.20	.10	.23	.26	.10	.20	.07	.20
25	.98	.55	.45	.80	1.36	1.00	1.48	1.14	1.02
28	.01	0	0	0	0	0	0	0	.05
Monthly totals	1.70	1.60	1.65	1.18	1.62	1.59	2.32	1.91	1.77
Nov. 8	.03	.18	0	0	trace	.04	.04	trace	trace
15	.21	0	.23	.37	0	.63	.31	0	.11
20	.47	.49	.47	.25	.65	.48	.52	.45	.46
Monthly totals	0.71	0.67	0.70	0.62	0.65	1.15	0.87	0.45	0.57
Dec. 4	.10	0	.07	.28	.10	.13	.10	.10	.03
5-6	1.26	2.32	1.41	.98	1.75	.78	.90	.94	1.04
6-8	1.77	2.17	1.40	1.54	1.38	1.58	1.35	1.18	3.59
9-10	1.01	1.25	1.14	1.03	.92	.63	.95	1.06	1.13
27-29	.84	1.02	.86	.82	.74	.83	.73	.85	.79
30-31	.82	.91	.80	.90	.90	.78	.76	.77	.71
Monthly totals	5.80	7.67	5.68	5.55	5.79	4.73	4.79	4.90	7.29
1960 CALENDAR YEAR TOTALS	33.73	34.80	30.08	31.87	31.80	31.40	34.94	36.14	38.71

Table 5.--Summary of rainfall, in inches, for Little Elm Creek study area, December 1956 to September 1962--Continued

Date of storm		Storm Averages	Gage number							
			1-S	2-R	3-S	4-S	5-S	6-R	7-S	8-S
1961										
Jan.	6-7	1.75	1.76	1.48	1.69	1.65	1.77	1.84	1.87	1.91
	11	.12	.13	.10	.15	0	.18	.10	.17	.12
	14	0	.02	0	0	.02	0	0	0	trace
	25	.17	.27	.05	.25	.15	.14	.10	.23	.16
	28	.05	.04	.04	0	0	.12	.05	.10	.06
Monthly totals		2.09	2.22	1.67	2.09	1.82	2.21	2.09	2.37	2.25
Feb.	4-6	1.45	1.51	1.24	1.53	1.64	1.57	1.52	1.27	1.35
	7	.45	.75	.59	.20	.27	.63	.46	.70	0
	17	.01	0	0	0	0	0	0	.09	trace
	19-20	.84	.80	.65	.82	1.40	.80	.72	.73	.77
	24	.03	.07	.03	.03	0	.08	.04	trace	0
Monthly totals		2.78	3.13	2.51	2.58	3.31	3.08	2.74	2.79	2.12
Mar.	5	.24	.16	.22	.18	.30	.22	.25	.32	.25
	16	1.24	1.09	1.08	1.15	1.65	1.27	1.35	1.35	1.36
	17	.52	.40	.28	.48	.20	.53	.70	.73	.82
	20	.02	.04	0	.03	0	0	.05	0	.02
	25	.36	0	.32	.37	.29	.50	.42	.55	.44
	27	.11	.39	.16	0	.02	.02	.04	.20	.08
	30	.39	.51	.44	.46	.20	.42	.35	.38	.38
Monthly totals		2.93	2.59	2.50	2.67	2.66	2.96	3.16	3.53	3.35

Table 5.--Summary of rainfall, in inches, for Little Elm Creek study area, December 1956 to September 1962--Continued

Date of storm		Storm Averages	Gage number 1-S	2-R	3-S	4-S	5-S	6-R	7-S	8-S
1961										
Apr.	5	0	0.02	0	0	0	0	0	0	0
	8	.06	0	.05	.07	.08	.06	.06	.10	.06
	11	.04	0	.04	.04	trace	.12	.05	.07	trace
	15	.03	.05	0	0	trace	.04	.03	.10	trace
	26-27	.13	0	0	.25	.10	.08	.10	.20	.32
	30	1.15	.57	.65	1.47	1.40	1.43	1.25	1.50	.95
Monthly totals		1.41	0.64	0.74	1.83	1.58	1.73	1.49	1.97	1.33
May	1	.40	0	.10	.19	.65	.40	.06	1.12	.73
	8	.78	.72	.75	.70	.74	.83	.73	.95	.84
	18	.10	0	.06	0	0	0	.10	.10	.52
	21	.85	.04	1.05	.58	.75	.65	1.16	1.50	1.04
	26	.29	.28	.34	.46	.33	.45	.15	.13	.15
Monthly totals		2.42	1.04	2.30	1.93	2.47	2.33	2.20	3.80	3.28
June	3	.28	.46	.19	.31	.33	.30	.20	.30	.17
	6	.76	1.05	.75	.16	.67	1.41	.95	.92	.23
	7	.26	.42	.19	.87	.13	.10	.10	.10	.15
	8	.52	.80	.29	.44	.30	.30	.66	.75	.58
	14	.37	.40	.22	.46	0	.47	.45	.62	.35
	16-17	.60	.46	.42	.55	1.00	.13	.70	.67	.85
	24	.31	.20	0	1.47	.24	trace	.17	.20	.20
	25	1.28	.82	1.10	.20	2.10	1.95	1.15	1.63	1.25
Monthly totals		4.38	4.61	3.16	4.46	4.77	4.66	4.38	5.19	3.78

Table 5.--Summary of rainfall, in inches, for Little Elm Creek study area, December 1956 to September 1962--Continued

Date of storm		Storm Averages	Gage number							
			1-S	2-R	3-S	4-S	5-S	6-R	7-S	8-S
1961										
July	2	0.06	0	0.05	0	0	0.16	0	0	0.28
	7	.19	.08	.32	.71	trace	.33	0	0	.11
	12	.70	.43	1.16	.74	.90	.51	.85	.53	.50
	15	.03	.03	0	0	0.10	0	.05	0	.05
	22-23	2.29	2.54	2.51	2.40	1.90	2.31	2.42	2.25	1.98
	25	.02	.02	.06	0	0	0	.04	0	0
Monthly totals		3.29	3.10	4.10	3.85	2.90	3.31	3.36	2.78	2.92
Aug.	6	.04	.08	0	0	.07	.05	0	.02	.11
	8	.14	0	0	0	trace	0	.22	.80	trace
	13	.10	0	0	0	trace	.21	.25	.33	.05
	14	.66	.35	1.21	1.16	.50	1.50	.19	.11	.30
	30	.12	.04	.03	.12	trace	trace	.17	trace	.60
Monthly totals		1.06	0.47	1.24	1.28	0.57	1.76	0.83	1.26	1.06
Sept.	6	.18	0	.02	.29	0	.08	.03	.80	.29
	11-13	3.85	4.60	4.10	3.41	3.20	4.54	3.45	3.75	3.74
	28	.26	.67	.14	.26	.10	.24	.25	.21	.13
Monthly totals		4.29	5.27	4.26	3.96	3.30	4.86	3.73	4.76	4.16
1961 WATER YEAR TOTALS		32.86	33.01	30.51	32.00	31.44	34.37	31.96	35.71	33.88

Table 5.--Summary of rainfall, in inches, for Little Elm Creek study area, December 1956 to September 1962--Continued

Date of storm		Storm Averages	Gage number 1-S	2-R	3-S	4-S	5-S	6-R	7-S	8-S
1961										
Oct.	2	2.10	1.75	2.16	1.85	2.50	1.90	2.06	2.25	2.32
	7	.03	0	.03	0	0	0	.17	0	0
	9	.44	.47	.13	.40	.50	.40	.37	.55	.68
	10	.08	.10	.20	.09	0	.04	.07	.10	.09
	29	0	0	0	0	0	0	0	0	.03
Monthly totals		2.65	2.32	2.52	2.34	3.00	2.34	2.67	2.90	3.12
Nov.	2	.78	.75	.68	.77	.85	.72	.75	.89	.85
	13	.03	0	0	.09	0	trace	0	trace	.14
	15	.35	.41	.25	.35	.45	.30	.48	.15	.42
	21-22	1.63	1.95	2.15	1.56	1.57	1.65	1.38	1.50	1.25
Monthly totals		2.79	3.11	3.08	2.77	2.87	2.67	2.61	2.54	2.66
Dec.	4	.28	.50	.35	.40	.10	.44	.10	.05	.28
	5	.11	0	.10	0	.29	.04	.10	.20	.15
	7	.21	.20	.05	.19	.62	.14	.10	.22	.12
	8-9	.74	.48	.34	.58	1.97	.66	.70	.55	.68
	10	.73	.05	.48	.54	1.89	.70	.66	.85	.64
	13	.06	.10	.05	.08	trace	.09	.05	.10	trace
	16	.24	.27	.20	.27	trace	.27	.27	.38	.31
Monthly totals		2.37	1.60	1.57	2.06	4.87	2.34	1.98	2.35	2.18
1961 CALENDAR YEAR TOTALS		32.46	30.10	29.65	31.82	34.12	34.25	31.24	36.24	32.21

Table 5.--Summary of rainfall, in inches, for Little Elm Creek study area, December 1956 to September 1962--Continued

Date of storm		Storm Averages	Gage number							
			1-S	2-R	3-S	4-S	5-S	6-R	7-S	8-S
1962										
Jan.	3-4	0.18	0.11	0.14	0.25	trace	0.27	0.20	0.27	0.22
	9-10	.05	.05	.02	0	.04	trace	.05	.20	.03
	14	.33	.25	.28	.36	.45	.38	.26	.40	.25
	17	.04	.06	.05	0	0	.04	.05	.05	.06
	21	.22	.29	.11	.39	.37	0	.21	.32	.05
	23	.07	0	0	0	0	.40	0	trace	.20
	25	.08	.15	.11	.13	0	.08	.05	trace	.09
	26	.04	.04	.05	.02	0	.07	.05	trace	.08
Monthly totals		1.01	0.95	0.76	1.15	0.86	1.24	0.87	1.24	0.98
Feb.	15	.08	.12	.03	.05	trace	.10	.07	.20	.08
	23	.72	.70	.50	1.60	.29	.67	.70	.70	.63
	26	.20	.19	.05	.16	.62	.18	.10	.15	.14
Monthly totals		1.00	1.01	0.58	1.81	0.91	0.95	0.87	1.05	0.85
Mar.	10	.14	.10	.10	.19	0	.20	.15	.17	.20
	14	.09	.02	.03	.08	.27	.14	.05	.10	.05
	20	.29	.50	.15	.34	.04	.30	.38	.30	.28
	22	.03	trace	.02	.05	0	.10	.03	.05	0
	24	.07	trace	0	0	.32	0	0	.17	.04
	30	1.92	2.20	1.65	1.87	1.82	2.10	1.90	2.04	1.78
Monthly totals		2.54	2.82	1.95	2.53	2.45	2.84	2.51	2.83	2.35

Table 5.--Summary of rainfall, in inches, for Little Elm Creek study area, December 1956 to September 1962--Continued

Date of storm	Storm Averages	Gage number							
		1-S	2-R	3-S	4-S	5-S	6-R	7-S	8-S
1962									
Apr. 4	0.22	0.32	0.15	0.28	0.11	0.10	0.25	0.25	0.33
10	.47	.02	.15	.34	.80	.37	.60	.70	.77
11	.08	0	.05	.10	trace	.10	.10	.20	.13
22	1.12	1.40	1.25	1.50	.10	1.40	1.25	1.20	.84
23-24	1.39	.88	1.12	2.03	1.85	1.91	1.20	1.46	.67
27	1.28	1.00	1.37	1.25	1.10	1.41	1.15	1.75	1.24
30	.14	.47	.03	trace	.06	.07	.10	.20	.13
Monthly totals	4.70	4.09	4.12	5.50	4.02	5.36	4.65	5.76	4.11
May 27	.12	.34	.22	.15	.28	.10	0	0	0
28-29	1.38	1.29	1.30	1.28	1.25	1.58	1.45	1.75	1.10
Monthly totals	1.50	1.63	1.52	1.43	1.53	1.68	1.45	1.75	1.10
June 1	1.40	1.53	1.64	1.89	.55	1.25	1.40	1.50	1.40
1-2	.53	.19	.23	.20	.25	.65	1.02	.75	.92
6	.27	0	.20	.19	0	1.25	.20	.10	.19
8	1.40	1.60	1.06	1.04	.92	1.51	1.67	1.65	1.74
9	.62	.31	.70	1.34	.67	.38	.68	.45	.44
12	.41	.10	.15	.19	.40	.32	.62	1.25	.22
18	1.29	0	.90	1.12	1.85	1.47	1.70	1.90	1.36
25	.10	.05	.06	.07	.24	0	.10	.17	.12
26	.15	.23	.15	.45	.22	.10	0	.05	trace
27	.03	0	0	0	.12	0	.10	trace	.05
28	.12	.15	.06	0	.16	.30	.09	.14	.08
29	.22	0	0	0	.17	0	1.18	.15	.31
30	.56	0	.35	.31	.15	.15	1.10	.12	2.30
Monthly totals	7.10	4.16	5.50	6.80	5.70	7.38	9.86	8.23	9.13

Table 5.--Summary of rainfall, in inches, for Little Elm Creek study area, December 1956 to September 1962--Continued

Date of storm		Storm Averages	Gage number							
			1-S	2-R	3-S	4-S	5-S	6-R	7-S	8-S
1962										
July	15-16	1.44	0.72	1.09	1.74	1.61	1.45	1.50	1.70	1.75
	17	.03	.05	.05	0	0	0	0	.15	trace
	22	.02	0	0	0	0	0	.10	0	.09
	26	.16	.41	.10	.16	0	.32	.10	.08	.15
	27	1.45	1.08	1.26	1.31	1.43	1.22	1.74	1.85	1.69
Monthly totals		3.10	2.26	2.50	3.21	3.04	2.99	3.44	3.78	3.68
Aug.	1-2	1.13	.97	.92	.91	1.34	.90	1.30	1.40	1.31
	4	.11	.03	.04	.15	.25	.04	.14	.20	.07
	24	.49	.64	.78	.42	0	.42	.45	.27	.95
	31	1.61	1.20	.95	1.50	2.15	1.00	2.05	2.00	2.00
Monthly totals		3.34	2.84	2.69	2.98	3.74	2.36	3.94	3.87	4.33
Sept.	1	1.35	1.20	1.51	1.50	2.10	1.00	1.09	.90	1.50
	2	1.56	2.90	1.80	1.88	0	1.25	1.46	1.70	1.45
	6	4.19	5.75	5.25	4.24	4.30	5.56	2.65	2.85	2.92
	7-8	1.40	1.70	1.84	1.55	2.16	1.25	1.15	.86	.72
	9	.24	.06	.06	.23	.32	.50	.34	.10	.35
	25	.37	.20	.24	.25	.31	.32	.45	.68	.51
	30	.52	.86	.56	.21	.30	.47	.50	.34	.89
Monthly totals		9.63	12.67	11.26	9.86	9.49	10.35	7.64	7.43	8.34
1962 WATER YEAR TOTALS		41.73	39.46	38.05	42.44	42.48	42.50	42.49	43.73	42.83

[a]From U.S. Weather Bureau station at McKinney, Texas.
()Estimated on basis of rainfall at adjacent gages.