TEXAS WATER DEVELOPMENT BOARD

REPORT 159

HYDROLOGIC STUDIES OF SMALL WATERSHEDS
GREEN CREEK, BRAZOS RIVER BASIN, TEXAS
1955-66

By

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United States Geological Survey

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TABLE OF CONTENTS

TABLE OF CONTENTS (Cont'd.)

TABLES

FIGURES

TABLE OF CONTENTS (Cont'd.)

Page

HYDROLOGIC STUDIES OF SMALL WATERSHEDS GREEN CREEK, BRAZOS RIVER BASIN, TEXAS 1955-66

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ABSTRACT

Hydrologic data were systematically collected and compiled for the 46.1-square-mile Green Creek small-watershed study area between 1955 and 1966. During 1954-56, eight floodwater-retarding structures were constructed in the study area. The retarding structures partly control runoff from 22.3 square miles and have a combined capacity of 7,466 acre-feet below the crests of the emergency spillways. Of the 7,466 acre-feet, 1,147 acre-feet is allocated to sedimentation.

The hydrologic data collected in the Green Creek study area afforded analyses in three major areas of hydrology where definition is lacking. These three areas are: (1) The hydrology of small rural watersheds (less than 10 square miles in area) in a semi-arid region; (2) the downstream hydrologic effects of systems of floodwater-retarding reservoirs; and (3) the minimum hydrologic-data collection required in index sampling of watersheds developed with floodwater-retarding reservoirs. The data collected also afforded analyses of the rate of sedimentation of floodwater-retarding reservoirs. These analyses, along with basic data to permit other analyses, are presented in this report.

In the 10-year period October 1956 to September 1966, runoff in the eight small watersheds in the Green Creek study area varied from 8.6 to 34.7 inches. The drainage areas for these small watersheds range from 1.20 to 6.26 square miles. Differences in watershed rainfall and physiography accounted for only a part of this large variation in runoff. The varied hydrology in the study area was further reflected in efforts to derive usable storm rainfall-runoff relationships. A coaxial-graphical relation was found to best fit the data for a 3.34 square-mile watershed. In this same small watershed, flood-frequency analyses showed the 25-year flood to have a peak discharge of 9,000 cfs (cubic feet per second), while the peak discharge for the flood of April 30, 1956 was 11,500 cfs or 3,440 cfs per square mile. The peak of the unit hydrograph for this 3.34 square-mile watershed was found to be 1,230 cfs.

Because most data collection in the 46.1 square mile study area was limited to a period in which runoff from 22.3 square miles of the area was controlled by eight floodwater-retarding structures, definition of the downstream hydrologic effects of the structures was limited. In the 10-year period of study, analyses showed that 37 percent of all inflow (including rainfall on pools) to the eight reservoirs was consumed by evaporation and evapotranspiration. Moreover, this consumption ranged from 17 percent of inflow in 1957 to 94 percent in 1959, and was greater than 50 percent of all inflow in five of the 10 years studied.

Data collection at one of the floodwater-retarding structures indicated the large peak reduction afforded by the structures. During a peak inflow of 11,500 cfs at one structure, only 20 cfs was passing the dam. Moreover, after maximum storage had been reached in the reservoirs, outflow was only 700 cfs. Analyses made in an effort to extend the flood-reducing effects further downstream did not afford specific quantification of the results. Continuous records of outflow from the 46.1 square-mile study area showed streamflow to be zero about 50 percent of the time. Therefore, it was concluded that if ground-water recharge from the reservoirs was occurring, it was not sufficient to cause perennial flow during the period of data collection.

Analyses of the data collection network were made to determine the feasibility of index sampling of both rainfall and runoff. The analyses showed that the seven rain-gage network in the 46.1 square-mile study area could be reduced to a three-gage network with the resulting error in computing average storm rainfall being no more than 10 percent two-thirds of the time. A similar analysis was made of runoff into the eight

floodwater-retarding reservoirs in the study area. This analysis showed that the gaged inflow to one reservoir could be used to estimate the inflow to all reservoirs with a maximum error of about 50 percent.

A sediment survey at one of the eight reservoirs showed that the part of the reservoir storage allotted to sedimentation below crest of drop inlet was decreased about 8 percent during the initial 12-year period of reservoir life. Chemical analyses of the water indicate that dissolved constituents probably have little or no effect upon the flocculating characteristics in relation to accelerated sedimentation.

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INTRODUCTION

Long-term water-development plans have come to the forefront as land use changes and metropolitan areas grow and expand at a rapid rate. These long-term plans must account for the availability of the water resources and should include orderly procedures for supplying and apportioning these resources to the public. To implement a water plan, accurate water data and information are needed to properly evaluate the effects of man's alterations upon the hydrologic characteristics of a watershed. Many small watersheds have undergone alteration in recent years, and studies initiated by the U.S. Geological Survey in some of these small watersheds will provide much of the information and data required by those responsible for water planning and management.

History of the Small Watershed Project

Congressional passage of the Soil Conservation Act of 1935 (Public Law No. 46), the Flood Control Act of June 22, 1936 (Public Law No. 738), the Flood Control Act of December 22, 1944 (Public Law No. 534), and the Watershed Protection and Flood Protection Act (Public Law No. 566), as amended, lead to widespread changes in the natural hydrology of many tributary watersheds. These acts, in general, authorize the U.S. Department of Agriculture to plan and coordinate land- and water-conservation measures in small watersheds. The measures used in a watershed usually include implementing improved land-management practices and constructing floodwater-retarding structures which release flood flows at a rate that normally will not exceed the carrying capacity of the stream channel downstream from the structures.

Prior to September 30, 1966, 1,081 floodwater-retarding structures had been constructed in Texas. These structures partly control flow from a combined drainage area of about 4,300 square miles. According to reports of the U.S. Study Commission-Texas (1962) and the U.S. Soil Conservation Service and Texas Agricultural Experiment Station (1963), a total of 3,438 sites were found where it would be both physically and economically feasible to construct floodwater-retarding structures.

Hydrologic investigations in small watersheds (study areas) were initiated by the Geological Survey in Texas during 1951. Presently, investigations are being made in 11 study areas in the State. These investigations are conducted in cooperation with the Soil Conservation Service, Texas Water Development Board, San Antonio River Authority, city of Dallas, and Tarrant County Water Control and Improvement District No. 1. The study areas were chosen in different geographic locations to provide diverse climate, topography, geology and soils for the statewide investigations. In four of the study areas, streamflow and rainfall records were collected prior to construction of floodwater-retarding structures, thereby affording a comparison of watershed hydrology with and without the structures. Location of the Green Creek study area and locations of the other 10 study areas in Texas are shown in Figure 1. The period of data collection and floodwater-retarding structure development in study areas in the statewide project as of September 30, 1966, are given in Table 1.

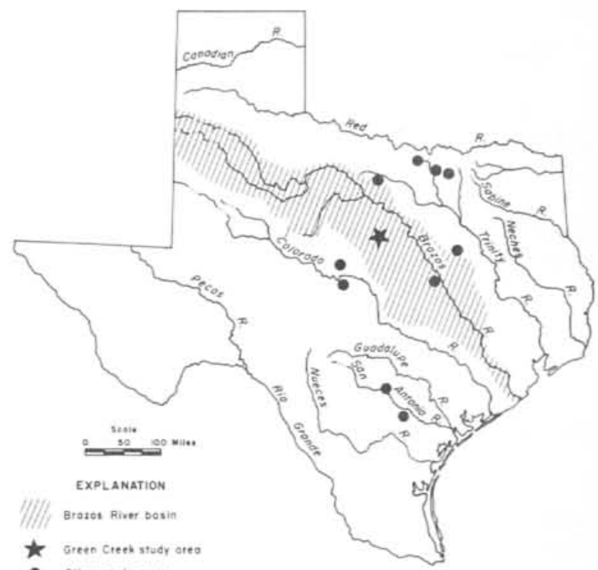

Figure 1.— Location of Green Creek and Other Study Areas

Table 1.—Small Watershed Study Areas in Texas as of September 30, 1966

WATERSHED	DRAINAGE AREA ABOVE STREAM-GAGING STATION (SQ. MI.)	HYDROLOGIC DATA COLLECTION BEGAN	FLOODWATER-RETARDING STRUCTURES ABOVE STREAM-GAGING 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	14	1954-57, 63
Little Elm Creek near Aubrey	75.5	June 1956	8	1966
Honey Creek near McKinney	39.0	July 1951	12	1951-57
Pin Oak Creek near Hubbard	17.6	Sept. 1956	6	1962-63, 65
Brazos River basin:				
Green Creek near Alexander	46.1	Oct. 1954	8	1954-56
Cow Bayou near Mooreville	79.6	Sept. 1954	26	1955-58, 64-65
Colorado River basin:				
Deep Creek near Mercury	43.9*	June 1951	5	1951-53
Mukewater Creek near Trickham	70.0	Aug. 1951	6	1961-62, 65
San Antonio River basin:				
Calaveras Creek near Elmendorf	77.2	Aug. 1954	9	1954-58
Escondido Creek at Kenedy	72.4†	July 1954	10	1954-58

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

The statewide small-watershed investigations are intended to provide sufficient hydrologic information about each watershed so that the effects of a system of floodwater-retarding reservoirs can be areally extrapolated to ungaged watersheds.

Objectives of the Texas Watershed Project

The purpose of these investigations is to collect sufficient data to meet the following objectives:

1. To determine the net effect of floodwater-retarding structures on the regimen of streamflow at downstream points.

2. To determine the effectiveness of the structures as ground-water recharge facilities.

3. To determine the effect of the structures on the sediment yield at downstream points.

4. To develop relationships between maximum rates and/or volumes of runoff with rainfall in small natural watersheds.

5. To develop a stream-system model for basins with floodwater-retarding structures.

6. To determine the minimum instrumentation necessary for estimating the flood hydrographs below a system of structures, as needed for downstream water-management operation.

Periodic hydrologic evaluation reports are to be prepared for each of the 11 study areas in the State to determine if the hydrologic data collected are adequate for accomplishing the objectives of the statewide investigations. These reports present data and interpretations which expand upon the information found in a continuing series of annual Geological Survey basic-data reports for these 11 study areas. This is the ninth evaluation report in the State project. Other study areas for which reports have been prepared are:

1. Cow Bayou (Mills, 1969)

2. Deep Creek (Mills and others, 1965)

3. Elm Fork Trinity River (Gilbert and others, 1962)

4. Escondido Creek (Kennon and others, 1967)

5. Honey Creek (Gilbert and others, 1964)

6. Little Elm Creek (Schroeder, 1966)

7. Mukewater Creek (Sauer, 1965)

8. Pin Oak Creek (Smith and Welborn, 1967)

Purpose and Scope

The purpose of this report is to present hydrologic information about the developed (all floodwater-retarding structures constructed) Green Creek watershed during the period 1955-66.

In presenting this hydrologic information, four of the above six objectives of the statewide investigations are discussed or reported upon. The analytical techniques used to accomplish these four objectives (numbered sequentially), are as follows:

1. A flood-frequency analysis, a unit hydrograph analysis, and a water-budget analysis.

3. An evaluation of the amount of sediment deposited behind a floodwater-retarding structure, and a brief discussion of trap efficiency.

4. A graphical multiple correlation relating rainfall to runoff.

4. A unit-hydrograph analysis.

6. A rain-gage density study.

In addition, several runoff parameters for the Green Creek watershed are compared to those for the North Bosque River watershed, where no floodwater-retarding structures existed prior to the summer of 1966. No data were collected in the Green Creek study area prior to the construction of floodwater-retarding structures.

Acknowledgments

The investigative work in the Green Creek watershed (1955-66) was done in cooperation with the Texas Water Development Board, J. J. Vandertulip, Chief Engineer, Austin, Texas, and the U.S. Soil Conservation Service, H. N. Smith, State Conservationist, Temple, Texas. This report was prepared under the supervision of Trigg Twichell, District Chief, Water Resources Division U.S. Geological Survey, Austin, Texas.

The assistance of Soil Conservation Service personnel, who serviced the instruments and collected much of the basic hydrologic information, is gratefully acknowledged.

DESCRIPTION OF THE STUDY AREA

Location, Topography, and General Features

The Green Creek study area is in the southwestern part of Erath County in north-central Texas. The study area is located between the communities of Dublin on the west and Stephenville on the east. The headwaters of Green Creek originate about 6 miles north of Dublin, and the stream flows southeasterly toward the town of Alexander. Just northwest of Alexander, the study area ends at a stream-gaging station on Green Creek (Figure 2). At the stream-gaging station the drainage area of Green Creek is 46.1 square miles. Green Creek flows past Alexander and empties into the North Bosque River approximately 6 miles southeast of Alexander. The North Bosque River is a tributary of the Brazos River.

The Green Creek study area is composed of gently rolling plains throughout. Altitudes range from 1,170 to 1,480 feet above mean sea level. Weighted-mean streambed slope upstream from Alexander, as measured along the main stem of Green Creek using topographic maps and computed by the method given by Taylor and Schwarz (1952), is 20.6 feet per mile.

According to the Soil Conservation Service, the Green Creek study area has the following land uses: Cultivated, 32 percent; pasture, 61 percent; formerly cultivated, 5 percent; and miscellaneous, 2 percent.

The undeveloped (no floodwater-retarding structures in watershed prior to summer of 1966) North Bosque River watershed shares a common drainage boundary for a short distance with Green Creek. Figure 2 shows the location of the North Bosque River watershed in relation to the Green Creek study area. At Stephenville, there is a stream-gaging station on the North Bosque River (Figure 2), and the drainage area at this location is 93.2 square miles.

The topography of the North Bosque River watershed upstream from Stephenville is similar to that of the Green Creek watershed. Altitudes in the North Bosque River watershed range from 1,220 to 1,450 feet above mean sea level. The weighted-mean streambed slopes of the North Bosque and South Fork North Bosque Rivers are 12.7 feet per mile and 11.3 feet per mile, respectively. The main-stem streambed profiles above the stream-gaging stations on Green Creek, North Bosque River and South Fork North Bosque River are shown in Figure 3.

Agricultural practices in the North Bosque River watershed upstream from Stephenville are similar to those found in the Green Creek Watershed, but may vary slightly in percentages of land use.

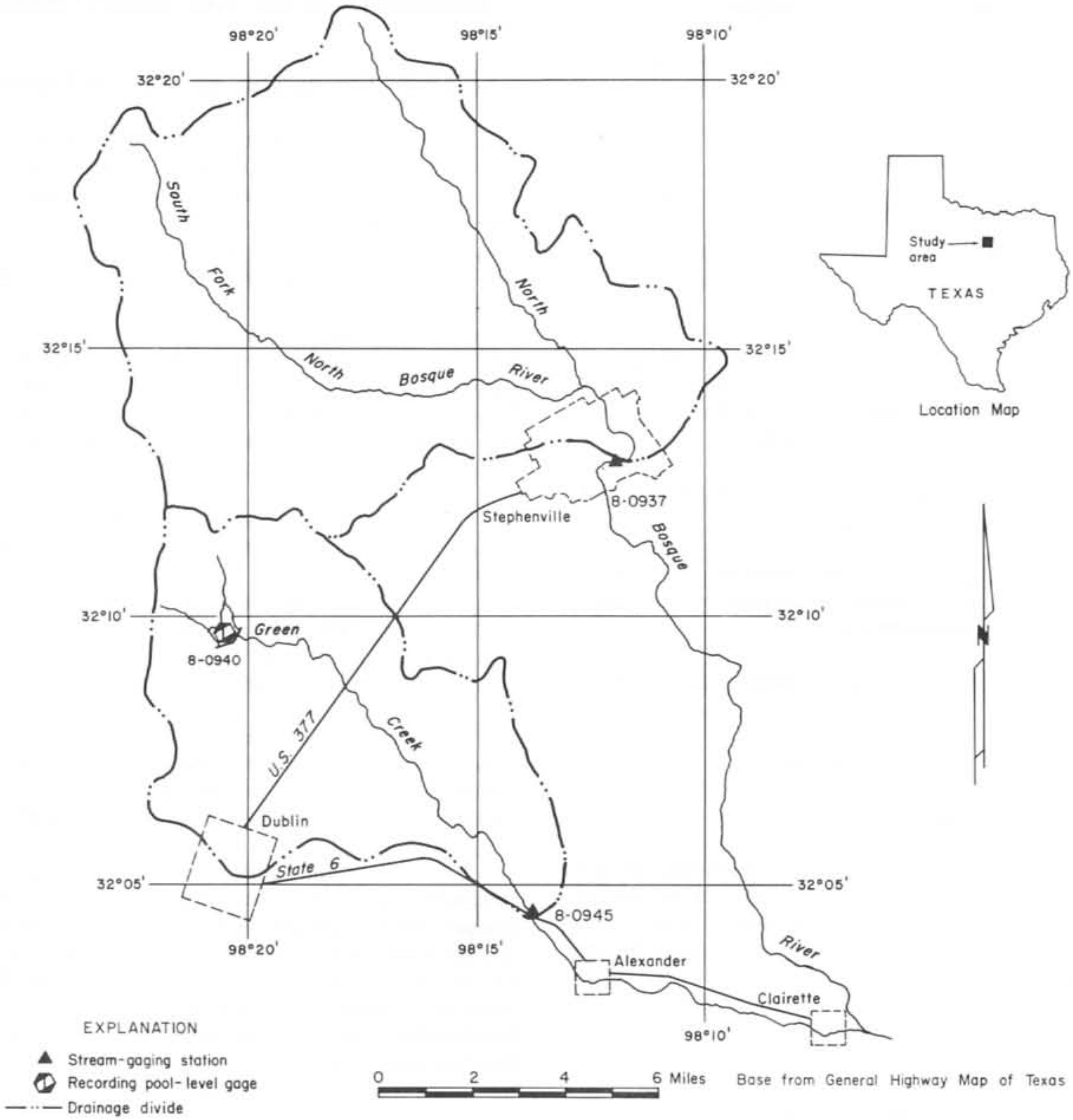

Figure 2.—Location of Recording Stream-Gaging Stations in Green Creek and North Bosque River Watersheds

Soils, Geology, and Climate

Soils in the Green Creek study area are of two basic types (U.S. Soil Conservation Service and Texas Agricultural Experiment Station, 1963). The first type mantles about 80 percent of the area and is a fine sandy loam 10 to 12 inches thick overlying a firm sandy clay. The other type mantles the remaining 20 percent of the area and is a 4- to 8-inch thick silty-clay loam overlying a plastic clay containing a few fragments of limestone. This latter type of soil has a crumbly granular texture. Both types of soil have a relatively high initial infiltration characteristic. The few rock outcrops found in the watershed are limestone with interbeds of shale and sandstone.

Soils in the North Bosque River watershed are generally of the same types as those in the Green Creek study area; therefore, similar runoff characteristics are probable.

The climate of the region is dry-humid (Thornthwaite, 1952). In general, precipitation is seasonal. Storms occurring during the late fall and winter months are usually of long duration and low intensity and cause only small amounts of runoff. The other storms, which occur mainly during the spring and summer months, are squall-line thunderstorms. These thunderstorms are generally of short duration and high intensity and usually cause significant amounts of surface runoff.

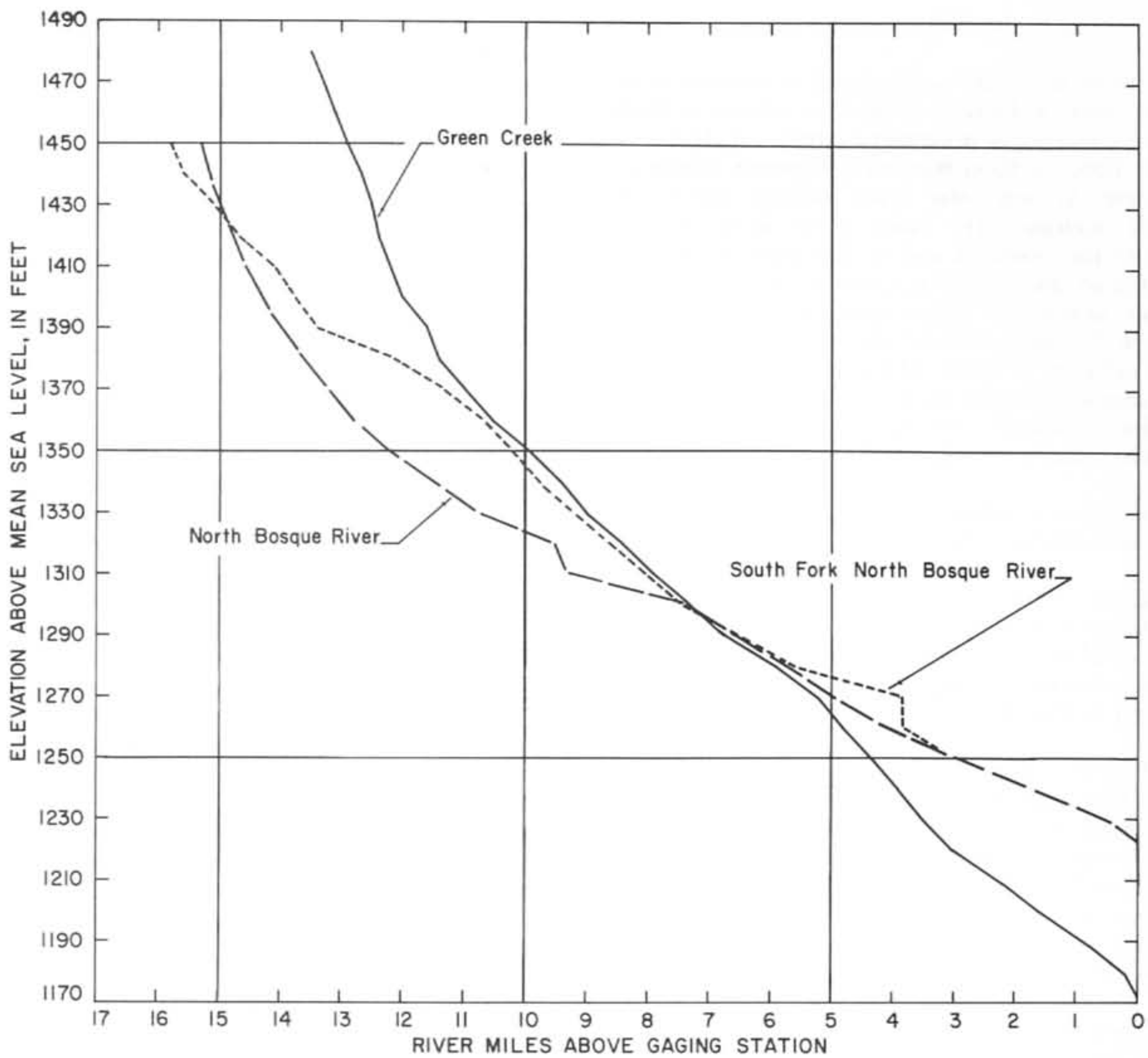

Figure 3.—Streambed Profiles for Green Creek, South Fork North Bosque River, and North Bosque River Upstream From Stream-Gaging Stations

Because of climatic variations within the seasonal precipitation pattern, rainfall amounts vary from one year to the next. Annual rainfall in the Green Creek study area for the period 1955-66 is shown in Figure 4. Rainfall at the U.S. Weather Bureau station at Dublin for the same period is also shown for comparison. During the study period, the wettest year was 1957 with nearly 40 inches of rainfall; the dryest year was 1955, with 22 inches of rainfall. The average annual rainfall at Dublin, based on the period 1931-60, is 31.67 inches.

The average minimum temperature at Dublin for January is about 34°F., and the average maximum temperature for July is about 96°F. The extreme temperatures recorded at Dublin are -9°F. and 114°F., and the average growing season is 238 days (Texas Almanac, 1966).

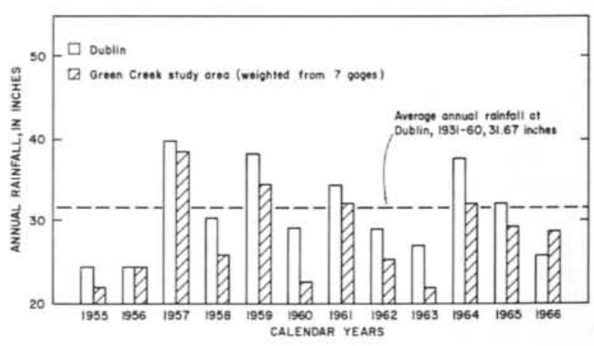

Figure 4.—Comparison of Annual Rainfall in Green Creek Study Area With Annual Rainfall at Dublin, Texas, 1955-66

Floodwater-Retarding Structures

Floodwater-retarding structures are constructed to control runoff and erosion. Reservoirs created by these structures are usually designed to control runoff from a 25-year flood (a flood that has a 4-percent chance of happening in any one year) without emergency spillway discharge. The flood runoff is temporarily stored in the reservoirs and is discharged through an uncontrolled drop outlet at a rate (usually 5-10 cubic feet per second per square mile controlled) so that overbank flow will not occur downstream. The discharge rate is sufficient to empty a full reservoir in a few weeks if no additional runoff occurs. An uncontrolled sodded emergency spillway will discharge floodwater when reservoir capacity is exceeded.

In addition, sediment storage capacity is provided in the reservoirs for a 50- to 100-year period.

Eight floodwater-retarding structures were constructed in the Green Creek study area during the period 1954-56. The location of each structure and a sectional view of a typical floodwater-retarding structure are shown in Figures 5 and 6, respectively.

Pertinent data about each structure and reservoir in the Green Creek study area are given in Table 2. These eight structures partly control flow from 22.3 square miles of drainage area and have a combined capacity of 7,466 acre-feet below the crests of the emergency spillways. Of the 7,466 acre-feet, 6,319 acre-feet is detention storage and 1,147 acre-feet is permanent storage to be used for sedimentation.

During the summer of 1966 (at end of study period), four floodwater-retarding structures were built in the upper North Bosque River watershed. These structures have a total combined capacity of 4,710 acre-feet below the crests of emergency spillways and partly control the flow from 10.4 square miles of drainage area.

DATA COLLECTION

Water-Stage Records

Water stages were obtained at eight floodwater-retarding reservoirs and at the stream-gaging station near Alexander in the Green Creek study area. Stages were also obtained on the North Bosque River at Stephenville (Figures 2 and 5). Beginning in May 1955, water stages were recorded continuously at Reservoir 1, located on the main stem of Green Creek near the headwaters. At Reservoirs 2-8, all located on tributaries to Green Creek, staff gages (nonrecording) were installed shortly after each reservoir was completed (Table 2).

Daily water stages at Reservoirs 2-8 were obtained from plots of at least weekly readings of the staff gages and high-water marks occurring between readings. Continuous water-stage recorders were installed at the Green Creek and North Bosque River stream-gaging stations in May and March 1958, respectively.

Precipitation Records

Precipitation was measured at seven locations in the Green Creek study area, and at one location outside the study area near Dublin. Figure 5 shows the locations where rain gages were installed to measure precipitation. Precipitation measurements obtained from three other locations in the Green Creek drainage basin downstream from the study area were not used in this report.

Precipitation that fell on the 46.1-square mile Green Creek study area was measured using Weather Bureau type rain gages. Of the eight rain gages, two were 8-inch continuous-recording weighing type, one was a continuous-recording tipping-bucket type, and five were 8-inch standard nonrecording type. These gages were installed in accordance with Weather Bureau recommendations. The installation of rain gages was completed prior to mid-December 1954 at locations that gave adequate geometric coverage of the study area. The recording rain gages at sites 1-R, 7-R, and 11-R, and the nonrecording gages at sites 2-S, 3-S, 4-S, 5-S, and 6-S were serviced and precipitation measured weekly. Intermittent instrumentation difficulties at recording site 11-R caused unreliable and incomplete records; therefore, data from this location were not used in this study.

In this report a storm is defined as a period of precipitation separated by at least 6 hours from the occurrence of prior or subsequent precipitation. Because the nonrecording rain gages were serviced weekly and more than one storm was frequently represented by the weekly precipitation, the storm precipitation was distributed to separate storm periods on the basis of the storm precipitation occurring at the nearest recording rain gage. Rain gages located nearest to each reservoir were used for determining precipitation that fell on the surface of the reservoirs. A summary of the storm and monthly and annual precipitation measured at each rain gage (except 11-R) during the period May 1955 to September 1966 (study period) are given in Table 8. Precipitation amounts given in Table 8 and Thiessen polygons were used to determine the weighted-mean precipitation on the study area. Thiessen polygon weighted factors are given at the end of Table 8.

Reservoir Contents

The Soil Conservation Service furnished reservoir-area and capacity information for the Green Creek study area. Prior to construction of the floodwater-retarding structures, semi-controlled aerial photographs of the area were obtained. The aerial

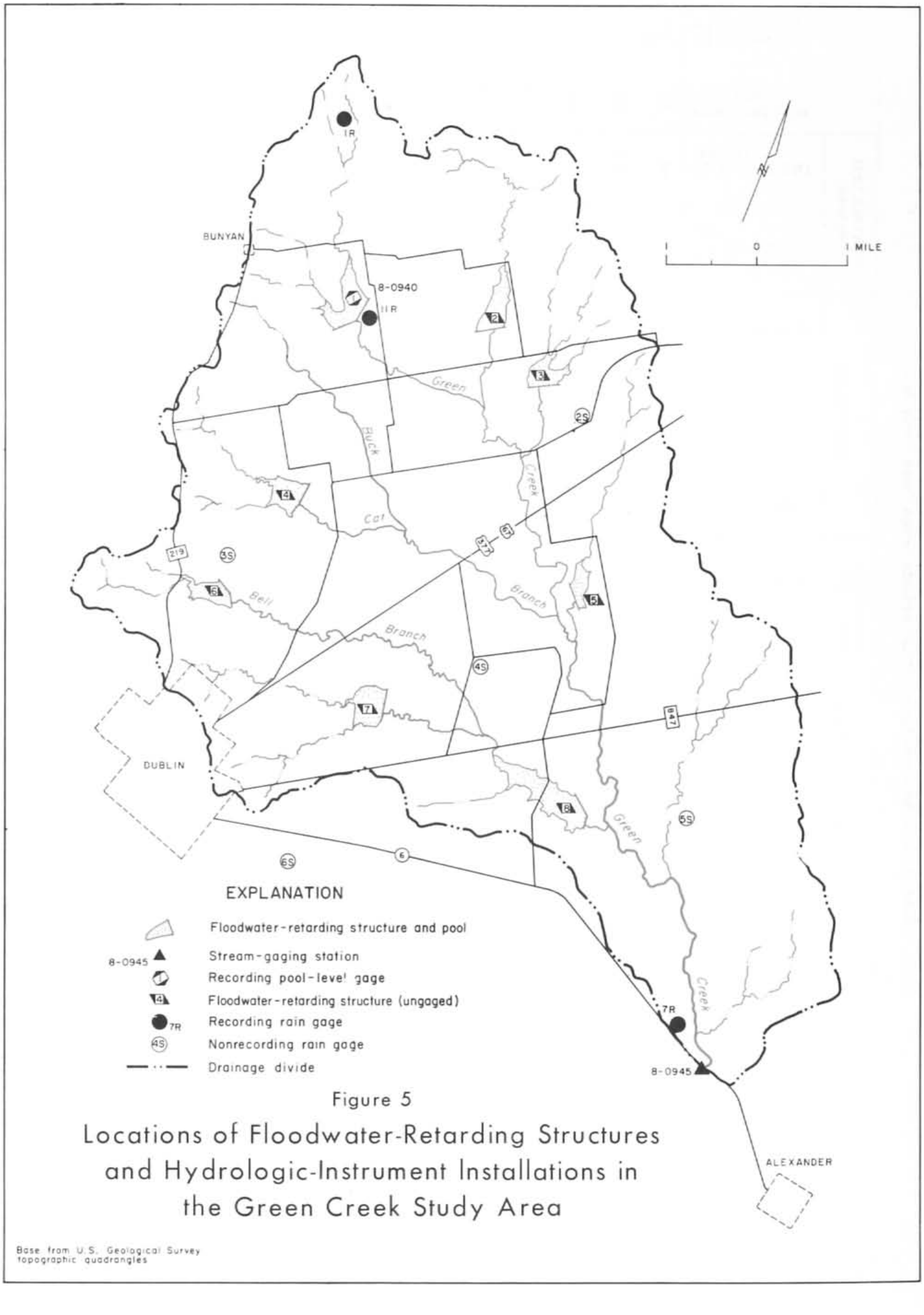

Figure 5

Locations of Floodwater-Retarding Structures and Hydrologic-Instrument Installations in the Green Creek Study Area

Table 2.—Floodwater-Retarding Structure Data, Green Creek Study Area

SITE NUMBER	DRAINAGE AREA (SQ. MI.)	DATE DAM COMPLETED	DATE GAGE ESTABLISHED	DATUM OF GAGE ABOVE MEAN SEA LEVEL	EMERGENCY SPILLWAY			PRINCIPAL SPILLWAY		PORTHOLES			CONTROLLED OPENING		PIPE THROUGH DAM (IN)	RANGE OF STAFF GAGES
					NUMBER AND WIDTH (FT)	GAGE HEIGHT (FT)	CONTENT (AC-FT)	GAGE HEIGHT (FT)	POOL CONTENT (AC-FT)	NUMBER AND SIZE (IN)	GAGE HEIGHT AT BOTTOM (FT)	POOL CONTENT (AC-FT)	GAGE HEIGHT AT BOTTOM (FT)	POOL CONTENT (AC-FT)		
1	3.34	4-25-55	5-12-55	1,408.0	1 (250)	21.8	1,097	11.0	223	–	–	–	3.76	34	14	3.4-26.6
2	2.52	2-27-55	10-18-55	1,381.9	1 (200)	25.0	726	15.0	111	1 12" x 24"	10.67 plugged	28	7.33	6.0	14	
3	1.58	9- 5-54	10-18-55	1,369.8	1 (150)	24.6	590	15.0	108	–	–	–	7.00	.4	14	
4	1.99	6- 5-55	10-18-55	1,401.5	1 (175)	26.5	642	15.0	48	–	–	–	8.00	0	22a/	
5	2.20	9-29-55	4-12-56	1,306.4	1 (200)	26.4	692	15.0	147	–	–	–	1.00	4	22b/	
6	1.20	10- 5-55	10-18-55	1,422.4	1 (100)	29.9	647	15.0	68	–	–	–	7.00	6.2	17c/	
7	3.20	3-28-56	4-12-56	1,347.0	1 (200)	28.3	1,166	15.0	148	–	–	–	5.00	16.6	17d/	
8	6.26	9-24-56	12-10-56	1,256.0	2 (100) (300)	37.0	1,906	18.0	294	2 8" x 8" 2 8" x 10"	15.0	188	0	40	17	

a/ 10-inch baffle.
b/ 9-inch baffle.
c/ 11-inch baffle.
d/ 12-inch baffle.

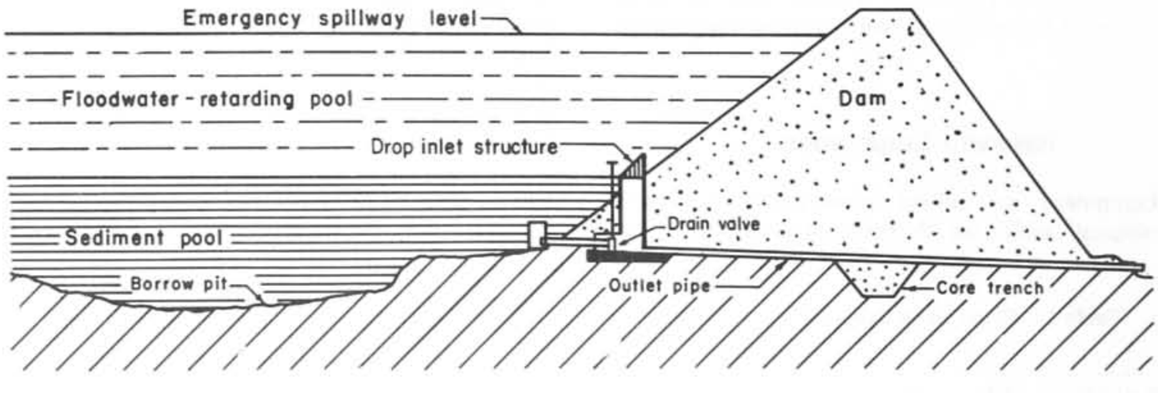

Figure 6.—Typical Floodwater-Retarding Structure

photographs and the most recent topographic maps were used to prepare area and capacity tables for each reservoir. These tables give the relation between water stage, in feet, and (1) reservoir surface area, in acres, and (2) reservoir contents, in acre-feet. During construction of the dams, some fill material was borrowed from the reservoir site and placed in the dams. The original capacity tables, unadjusted for this borrow, were used throughout the study period except at Reservoir 1, where the original table was used only to September 1958. New area and capacity tables were prepared for Reservoir 1 based on a sedimentation survey made by the Soil Conservation Service in 1962. These survey data were used to draw a 2-foot contour interval topographic map from which new area and capacity tables were prepared. The decreased capacity determined by the 1962 survey at Reservoir 1 was considered to be applicable back to October 1958, and the new tables were used from that date until the end of the study period. No sediment surveys were made for the other seven reservoirs.

The use of capacity tables unadjusted for borrow from the bottom of the reservoirs was not critical in computation of change-in-contents at the stages experienced in this study. The slope of the stage-capacity curve at the stages experienced was almost the same with or without adjustment.

Water Discharge

Streamflow was measured at the gaging station on Green Creek near Alexander, at Green Creek Reservoir 1, and at the gaging station on North Bosque River at Stephenville. All three stations were equipped with continuous water-stage recorders. The stations were regularly visited at intervals of 4 to 5 weeks, and more frequently during times of heavy rainfall. Current-meter measurements were made on each visit to the stations. At the streamflow stations, curves of relation between stage and discharge were prepared.

Concurrent with visits to the recording sites, all nonrecording reservoir sites were visited. During these visits, channel conditions below each floodwater-retarding structure were noted and current-meter measurements of drop-outlet pipe discharge were made. Inflow to the reservoir was also measured.

Most of the reservoir outflow was confined to discharge through the drop-outlet. Discharge over the emergency spillway was infrequent. A curve of relation between reservoir stage and drop-outlet discharge was prepared for each reservoir using current-meter measurements made at various stages. This curve, together with the reservoir stage record, was used to compute reservoir drop-outlet discharge. At Reservoirs 3, 6, and 7, no current-meter measurements of outflow (drop-outflow discharge) were available, and weir and orifice formulas were used to develop the curves relating stage and outflow. Continuous records of stage were available at Reservoir 1, but at the nonrecording reservoirs only weekly stage readings were generally made. At Reservoirs 2-8 (nonrecording), daily stages were estimated from graphs drawn using weekly stage readings, peak marks, periodic engineers' readings, weather records, and the continuous records obtained at Reservoir 1. Flow over the emergency spillways occurred at Reservoirs 1, 2, 3, 4, and 5 on May 1, 1956. Curves of relation between stage and spillway discharge were prepared using Soil Conservation Service design discharges for earthen spillways. Because of the rarity and short duration of emergency spillway discharge, no current-meter measurements were obtained.

All curves of relation were checked by comparing outflow discharges and reservoir change-in-contents. The curves of relation were considered accurate as long as the outlets remained free of debris. Drift and debris caused only minor trouble for short periods of time. On occasions when the reservoirs were drained by opening gate valves at the bottom of the drop-outlet structure, outflow discharges were obtained using stage records and change-in-contents. The stage records reflected these man-controlled releases by showing a faster than normal recession rate.

Reservoir Evaporation

Equipment to collect water-temperature and climatological data for determining evaporation by utilizing the mass-transfer theory (Harbeck, 1962) was installed at Reservoir 1 in March 1964 and removed in September 1966. At present, only preliminary analyses of these data have been made; therefore, evaporation determined by the mass-transfer method is not given. Monthly evaporation used in analyses for this report were furnished by the Texas Water Rights Commission and are given in Table 3.

Table 3.—Gross Lake Evaporation in Feet for Green Creek Study Area, May 1955 to September 1966

WATER YEAR	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966
October	—	0.42	0.42	0.28	0.22	0.32	0.32	0.33	0.36	0.43	0.40	0.34
November	—	.27	.23	.15	.19	.18	.22	.18	.20	.23	.23	.21
December	—	.19	.19	.20	.16	.17	.12	.17	.14	.11	.20	.14
January	—	.18	.13	.14	.18	.18	.15	.17	.17	.22	.21	.12
February	—	.18	.17	.14	.13	.20	.20	.26	.24	.22	.17	.19
March	—	.41	.25	.20	.40	.28	.36	.34	.44	.37	.27	.38
April	—	.44	.27	.35	.42	.42	.45	.42	.48	.50	.47	.41
May	.52	.62	.37	.51	.48	.59	.58	.64	.46	.58	.44	.54
June	.63	.71	.57	.62	.58	.69	.52	.56	.62	.68	.60	.55
July	.67	.73	.69	.71	.58	.62	.57	.66	.76	.75	.74	.72
August	.60	.74	.65	.60	.60	.56	.57	.71	.68	.67	.71	.52
September	.50	.65	.42	.34	.47	.51	.45	.43	.50	.42	.52	.37
TOTALS	—	5.54	4.36	4.24	4.41	4.72	4.51	4.87	5.05	5.18	4.96	4.49

Note: Monthly data furnished by Texas Water Rights Commission.

The Texas Water Rights Commission's values for evaporation were determined by a method developed by McDaniels (1960). This method utilizes some of the results from research by Kohler, Nordenson, and Fox (1955). Table 3 gives the maximum monthly evaporation to be 0.76 foot in July 1963 and the minimum monthly evaporation to be 0.11 foot in December 1964. The maximum yearly evaporation of 5.54 feet occurred in 1956 and the minimum yearly evaporation of 4.24 feet occurred in 1958. Weather Bureau Technical Paper 37 (Kohler, Nordenson, and Baker, 1959) indicates that the average-annual lake evaporation is 59 inches (4.92 feet) for the study area. The values of evaporation given in Table 3 are used in a later section of this report.

Surface-Water Samples

Water samples were collected in the study area to define any changes in the chemical quality of surface runoff due to impoundment, particularly as these changes affect the flocculating characteristics of the suspended sediment. Water samples were obtained annually at Reservoirs 2-8 during the period October 1962 to September 1966. At Reservoir 1 and at the Green Creek stream-gaging station, samples were obtained one or more times per year during the study period. The samples were "dipped" from the bank and are considered as surface samples. Chemical analyses were made of all samples collected. A brief discussion of chemical quality in relation to use and to its effects on flocculation is presented later in this report.

HYDROLOGIC-DATA ANALYSES

The Green Creek hydrologic data represent the results of systematic collection of precipitation and surface-runoff information from throughout the study area. The data were collected during and after the time in which floodwater-retarding structures were constructed. The construction of these retarding structures altered the natural hydrologic environment of the watershed; therefore, studies of the methods of collecting and analyzing the hydrologic data are an essential part of the continuing statewide small-watershed investigations.

Precipitation

Rain-Gage Density

Information on storm rainfall is obtained by using a procedure of index sampling (point rainfall). Index sampling is used because the measurement of all areal rainfall is not feasible. Knowledge of the probable error between the index samples lends confidence to the hydrologic studies and provides guidelines for designing rain-gage networks.

Precipitation data given in Table 8 are used in three graphical correlations to determine the resulting error when a minimum number of rain gages are used. A total of 165 storms with 0.4 inch or more of rainfall are used in each correlation. Storms with rainfall less than 0.4 inch were not used because they are usually insignificant in hydrologic studies. All the correlations use the Thiessen-polygon weighted-mean storm rainfall from seven rain gages as the independent variable. The arithmetic-average storm rainfall from three different combinations of rain gages are used as the dependent variable.

The three combinations of rain gages are: (1) Rain gage 4-S, located nearest to the geometric center of the study area; (2) rain gages 1-R and 7-R, located at the extreme north and south ends of the study area; and (3) rain gages 1-R, 4-S, and 7-R, located along the north-south axis at the ends and near the center of the study area (all gage locations are shown on Figure 5). Because of the small size, narrowness, and orientation of the study area, other combinations of rain gages were not investigated. Figures 7,8, and 9 show the correlation.

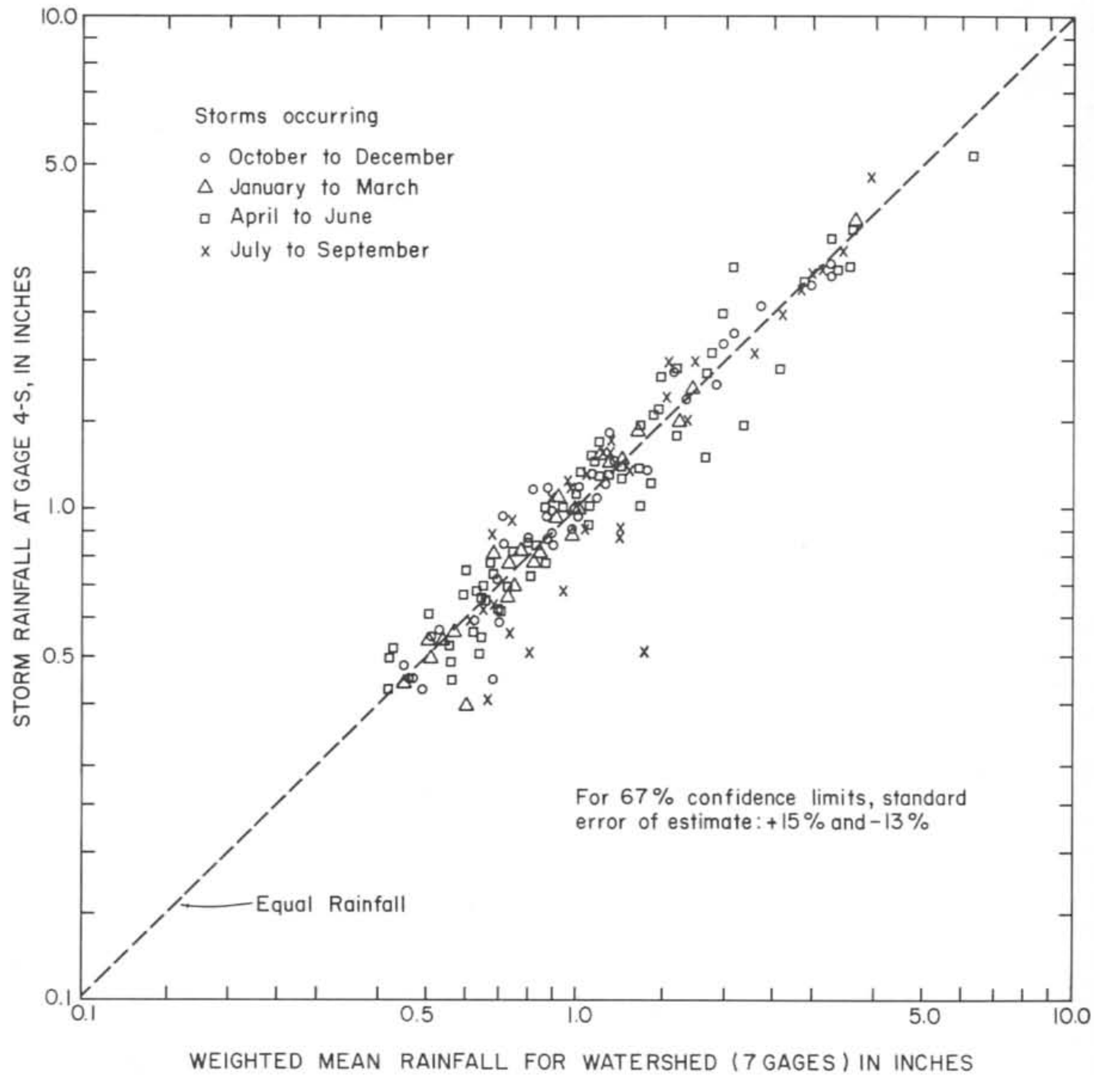

Figure 7.—Comparison of Concurrent Storm Rainfall Using Seven Rain Gages and Rain Gage 4-S

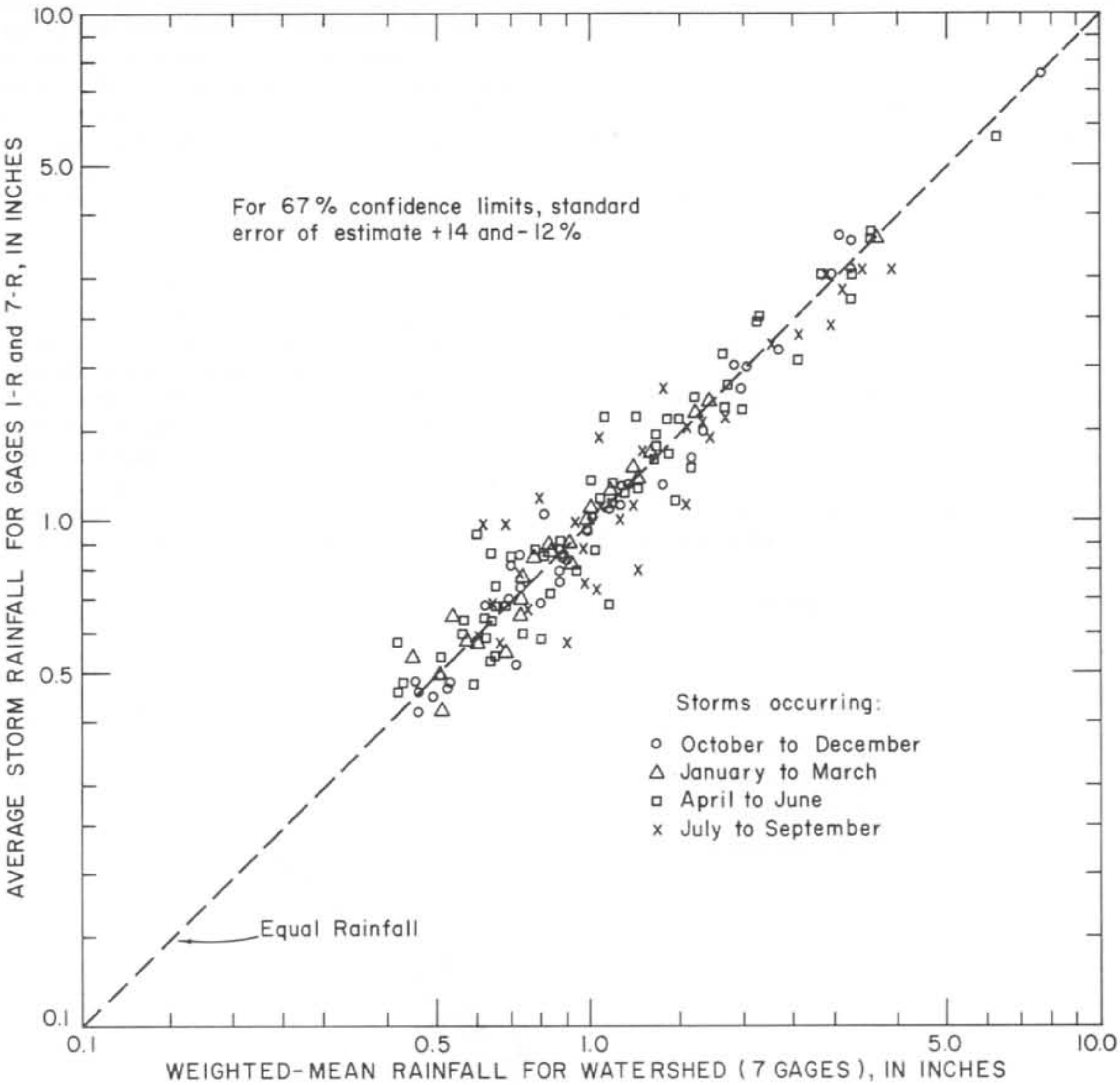

Figure 8.—Comparison of Concurrent Storm Rainfall Using Seven Gages and Rain Gages 1-R and 7-R

Because of differences in areal distribution, duration, and intensity of rainfall, there is scatter about the equal-rainfall line (considered to be the curve of relation). Seasonal variations do not explain any of the scatter shown. For each correlation, the error of estimate was computed using a 67-percent confidence limit. The errors in average storm rainfall amounts determined from one, two, and three rain gages, and based on the above confidence limit, are +15 percent and -13 percent, +14 percent and -12 percent, and +11 percent and -9 percent, respectively. The smallest error of estimate was for the correlation using three rain gages (Figure 9). The other correlations (Figures 7 and 8) indicate that for two-thirds of the storms, one or two rain gages could be used to determine average study-area rainfall with a resulting error of 15 percent or less. It is evident that the error of estimate decreases as the number of rain gages used to compute the rainfall is increased. Therefore, it is assumed that the rain-gage network operated in the study area during the study period was adequate for the size of the watershed.

Comparison With Historical Data

Even in a climatically homogeneous area, rainfall sometimes varies widely from year to year. These variations take on significance when evaluating the effects of "dry" and "wet" years, and when determining how a short-term record (a sampling period) compares with a long-term record. The Green Creek rainfall data collected during the study period was compared to the historical rainfall data collected at Dublin, on the western edge of the study area. The Weather Bureau has

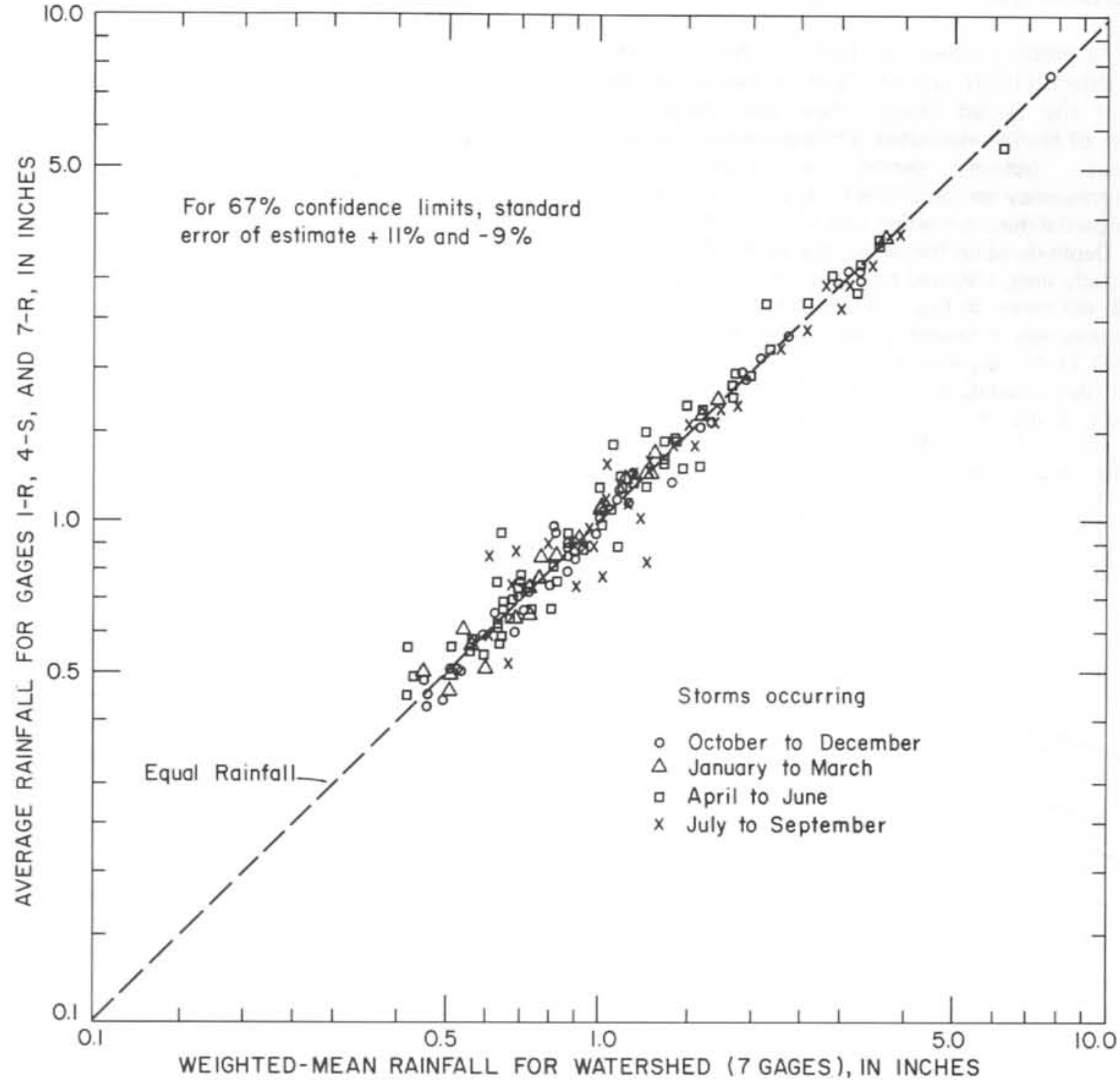

Figure 9.—Comparison of Concurrent Storm Rainfall Using Seven Gages and Rain Gages 1-R, 4-S, and 7-R

collected rainfall data at Dublin since 1896 except for the years 1905-6, 1919-21, and 1948. Rainfall amounts for these missing years were estimated from records for nearby stations. In showing the time variation of annual rainfall, the method of 3-year moving averages was used to smooth out irregularities. Figure 10 shows the 3-year moving average rainfall at Dublin for the period 1896-1966 and in the Green Creek study area for the period 1955-66 (beginning and ending years are eliminated by the moving-average method). The Green Creek data generally follow the trend shown at Dublin; however, the 3-year average rainfall for the Green Creek study area is 1 to 5 inches less than the average at Dublin. A reason for this difference is not apparent. The plot in Figure 10 shows the severity and duration of the drought period of the early 1950's, which ended in 1957.

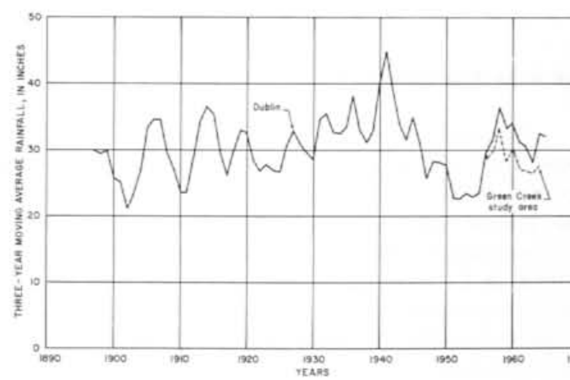

Figure 10.—Comparison of 3-Year Moving-Average Rainfall, Green Creek Study Area and Dublin, Texas

Rainfall Depth, Duration, and Frequency

The Weather Bureau, in Technical Paper No. 40, by Hershfield (1961), compiled various rainfall data on maps of the United States. These maps show the amounts of rainfall associated with a given duration and frequency (return period in years). The rainfall-frequency computations for the maps were based on the partial-duration series (use of many events in a year). Depth-duration-frequency curves for the Green Creek study area, prepared from data in Technical Paper No. 40, are shown in Figure 11. Storm rainfall totaling 8.40 inches was measured October 3-4, 1959, at rain gage 1-R (Table 8), in the northern end of the study area. Of this amount, approximately 8 inches fell within 12 hours. Using the curves presented in Figure 11, a return period of about 100 years (a 1-percent chance of occurring in any year) is obtained for this point rainfall.

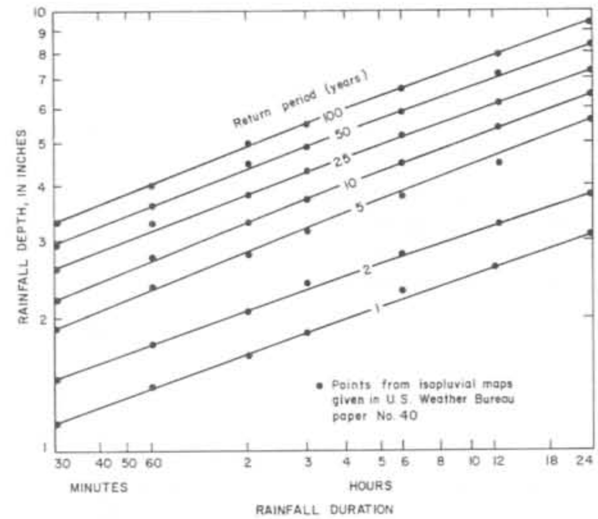

Figure 11.—Rainfall-Frequency Curves for Green Creek Study Area

Surface Runoff

Discharge into Reservoir 1

Reservoir 1 is the only reservoir in the Green Creek study area equipped with a continuous water-stage recorder. With reliable capacity tables and a stage record with a large time scale, rates of inflow to the reservoir are computed on the basis of change-in-contents per unit of time. A 5-minute time increment is the smallest used. Complete discharge hydrographs for the most significant storms during the period of study were developed using this technique.

The following table lists the annual maximum peak discharge into Reservoir 1 (drainage area, 3.34 square miles) for water years 1955-66:

Annual Maximum Peak Discharge into Reservoir 1

WATER YEAR	DATE		DISCHARGE (CFS)
1955	May	18, 1955	3,630
1956	Apr.	30, 1956	11,500
1957	Apr.	26, 1957	887
1958	July	22, 1958	748
1959	June	26, 1959	498
1960	Oct.	3, 1959	1,540
1961	July	9, 1961	261
1962	Sept.	7, 1962	516
1963	Apr.	28, 1963	621
1964	Sept.	21, 1964	2,090
1965	May	15, 1965	365
1966	Apr.	30, 1966	645

The peak discharge was computed from reservoir change-in-contents during a 5-minute interval and adjusted for precipitation on the reservoir surface and any outflow during the interval. These peak discharges are used in flood-frequency studies presented in a following section of this report.

The above listed storm of April 30, 1956, is indicative of the large flood peak reduction afforded by floodwater-retarding structures. During the peak inflow of 11,500 cfs, the outflow was only 20 cfs. Moreover, after maximum storage had been reached during this storm, maximum outflow was only 700 cfs.

Rainfall-Runoff Correlation

While rainfall is the primary factor in rainfall-runoff relationships, other factors may have appreciable effects. Various approaches ranging from empirical formulas to mathematical models have been devised for estimating runoff from rainfall. Some of the approaches neglect many of the climatic and physiographic factors affecting the rainfall-runoff relation while others become impractical without the use of electronic computers. A convenient and straight-forward method of relating rainfall and runoff is the coaxial method of graphic correlation described by Kohler and Linsley (1951). Basically, the method graphically relates three measurable hydrologic parameters and season of the year to runoff by a family of curves. The coaxial method usually requires several successive approximations to achieve the best-fit curves.

The coaxial method of graphic correlation was applied to hydrologic data collected in the Green Creek Reservoir 1 drainage basin of 3.34 square miles. This small area was used because the runoff data was unaffected by floodwater-retarding structures located upstream.

The hydrologic parameters used in the correlation were: (1) The API (antecedent-precipitation index), (2) the duration of storm rainfall, (3) the total amount of storm rainfall, and (4) the month of occurrence of the storm. Other factors that may have affected the correlation include surface and subsurface geology, topography, vegetation, and land-management practices. The topography and surface and subsurface geology were considered to be nonchanging factors. Any effects from changing land-management practices could not be defined. Although the hydrologic effect of a change in vegetal cover could not be isolated, it is probably taken into account in the correlation by using months of the year as a parameter.

Because of the small size of the drainage area above Reservoir 1, rainfall measured at rain gage 1-R (see Figure 5) was considered to be uniformly distributed over the area. The API (antecedent-precipitation index) was computed from the formula given by Linsley, Kohler, and Paulhus (1958), $API_t = API_o K^t$,

where: API_o is the initial value of antecedent-precipitation index,

API_t is the antecedent-precipitation index "t" days later, and

K is the recession-factor depending upon watershed physiography.

The formula assumes that soil moisture is being depleted at an exponential rate during periods of no precipitation. When precipitation occurs, the change in the antecedent precipitation index depends primarily upon the amount and rate of rainfall infiltration into the soil. This study indicated that the rate of infiltration is a significant factor in the coaxial rainfall-runoff relation for the Green Creek Reservoir 1, drainage basin, and measurements of soil moisture prior to each storm would be very helpful.

Kohler and Linsley (1951) state that "theoretically the value of the recession factor K is a function of the physiographic characteristics of the basin, but experience has shown that the factor is not critical—values range from 0.85 to 0.90 over most of the eastern and central portions of the United States." Because of the relatively high infiltration rate found, a value of 0.86 was selected for the area above Green Creek Reservoir 1.

For this report, total storm rainfall was considered to contribute to the API. However, soil moisture was assumed to be depleted in the usual manner during the day upon which rainfall occurred. Thus, the API at the end of any day with rainfall is equal to the API of the previous day multiplied by the recession factor K plus the rainfall during the day. A more accurate API can be determined by subtracting runoff from rainfall and adding this residual to the previous API. The logic of this procedure is evident because storm runoff does not add to the residual soil moisture. However, the minor improvements in accuracy by use of this procedure do not ordinarily justify the added computations (Linsley, Kohler, and Paulhus, 1958).

The API_o value for the May 18-19, 1955, storm (first large storm in study period) was computed by going back in time to the first rain in the 1955 calendar year. Storms were chosen this far in advance of the first storm so that an appropriate API_o could be determined (Sauer, 1965).

The duration of storm rainfall was considered to be the time from the beginning to the end of any measurable rainfall. This time period was used in order to be consistent with the use of total storm rainfall in the computation of the API.

Figure 12 shows the graphical coaxial rainfall-runoff correlation derived for the 3.34-square mile drainage area above Green Creek Reservoir 1. The correlation was developed using data from the 65 storms given in Table 4, and the curves shown are the ones that best fit the data. An example of the use of the graphs is shown on Figure 12 by determining the runoff for the storm of September 20-21, 1964.

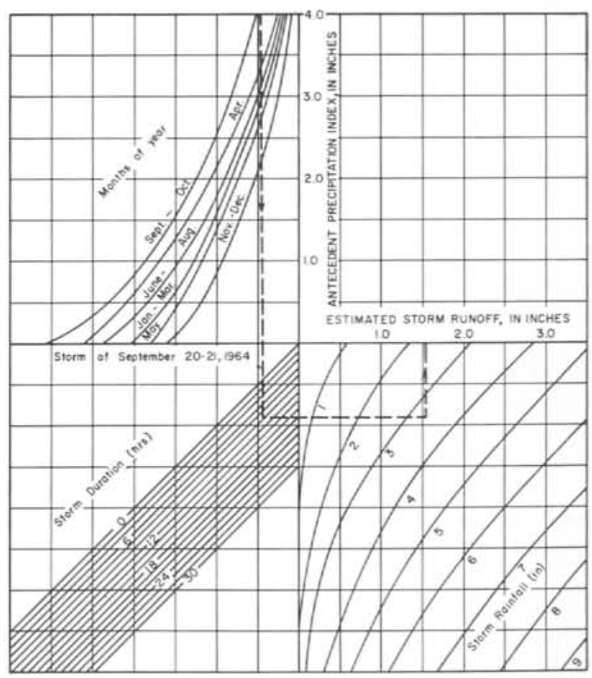

Figure 12.—Coaxial Rainfall-Runoff Correlation for Area Above Green Creek Reservoir 1

The "month of year" curves for April and May are out of sequence with regard to the curves for the remaining months. The position of the May curve is influenced by the fact that most May storms selected were of the recurring type and therefore had larger than average values of API (see Table 4). The position of the April curve may be due to the rather sudden change in vegetal cover which occurs during this month. About 20 percent of the watershed is cultivated and about 60 percent is in good native pasture.

The standard error of estimate of runoff for the 65 storms is 54 percent, assuming four degrees of freedom lost in the regression.

Unit Hydrographs

In order to compare runoff characteristics and thus illustrate the hydrologic effects imposed by a system of floodwater-retarding reservoirs, unit hydrographs were developed for runoff into Green Creek Reservoir 1, for the stream-gaging station on Green Creek near Alexander, and for the stream-gaging station on North Bosque River at Stephenville.

Chow (1964) defines a unit hydrograph as: ". . . a hydrograph of direct runoff resulting from 1 inch of effective rainfall generated uniformly over the basin area at a uniform rate during a specified period of time or duration." The following assumptions are made when developing a unit hydrograph:

1. The effective rainfall is uniformly distributed within its duration of specified period of time.

2. The effective rainfall is uniformly distributed throughout the whole area of the drainage basin.

3. The base or time duration of the hydrograph of direct runoff due to an effective rainfall of unit duration is constant.

4. The ordinates of the direct-runoff hydrographs of a common base time are directly proportional to the total amount of direct runoff represented by each hydrograph.

5. For a given drainage basin, the hydrograph of runoff due to a given period of rainfall reflects all the combined physical characteristics of the basin.

Although these assumptions are restrictive, many unit hydrographs are developed successfully, particularly for small watersheds.

The unit hydrograph is constructed from observed hydrographs by subtracting base flow (if any) and then adjusting the direct-runoff ordinates so that the volume of runoff is equal to 1 inch. The direct-runoff ordinates are adjusted by multiplying each ordinate by the appropriate conversion factor. Under ideal conditions, the runoff from all storms having rainfall excess occurring in unit time will produce similar unit hydrographs for the same watershed.

Generally, the unit time used in developing a unit hydrograph is the duration of effective rainfall. To properly determine the duration of effective rainfall, it is necessary to know or assume a corresponding infiltration rate. Determining the infiltration presents a difficult problem and in lieu of knowing the infiltration during the storm period, duration of storm rainfall may be used as the unit time. Mitchell (1948) states, ". . .there usually is a lack of synchronization of rainfall between various portions of the basin so that the equivalent effective duration of the storm may be somewhat uncertain. Thus, it is usually permissible to allow the storm duration to vary between 50 percent and 200 percent of the unit hydrograph duration before any correction for this effect will become necessary."

Only storms that produced one-half inch or more of surface runoff were used in constructing unit hydrographs for inflow to Green Creek Reservoir 1 and the stream-gaging station on North Bosque River at Stephenville. Storms that produced smaller amounts of runoff were not used because of the desirability to limit the analyses to storms that were known to cause runoff from all parts of the drainage basin.

From Figure 5 it is obvious that unit-hydrograph criteria, which relate to uniform runoff contribution from all parts of the drainage basin, cannot be followed at the stream-gaging station below the floodwater-retarding structures. Of the 46.1-square-mile total drainage area above the station, 22.3 square miles is behind floodwater-retarding structures. Therefore, unit hydrographs were computed for only the 23.8-square-mile drainage below the floodwater-retarding structures merely to illustrate the hydrologic effects of cutting off the upper drainage of a watershed. In constructing the unit graphs for the Green Creek gaging station, outflow from the reservoirs was deducted from the flow at the gaging station.

Eight representative storms for Reservoir 1 and six storms for each of the stream-gaging stations were available for deriving the unit hydrographs. Figures 13, 14, and 15 show the unit hydrographs derived for inflow to Green Creek Reservoir 1, for the stream-gaging station on Green Creek near Alexander, and for the stream-gaging station on North Bosque River at Stephenville, respectively. The time of rise, peak discharge, and effects of differences in areal distribution of rainfall for the derived unit hydrographs are discussed in the following paragraphs. Time of rise as used herein is the time interval from start of direct runoff to the unit hydrograph peak.

The unit hydrographs for inflow to Green Creek Reservoir 1 (Figure 13) indicate a general uniformity in

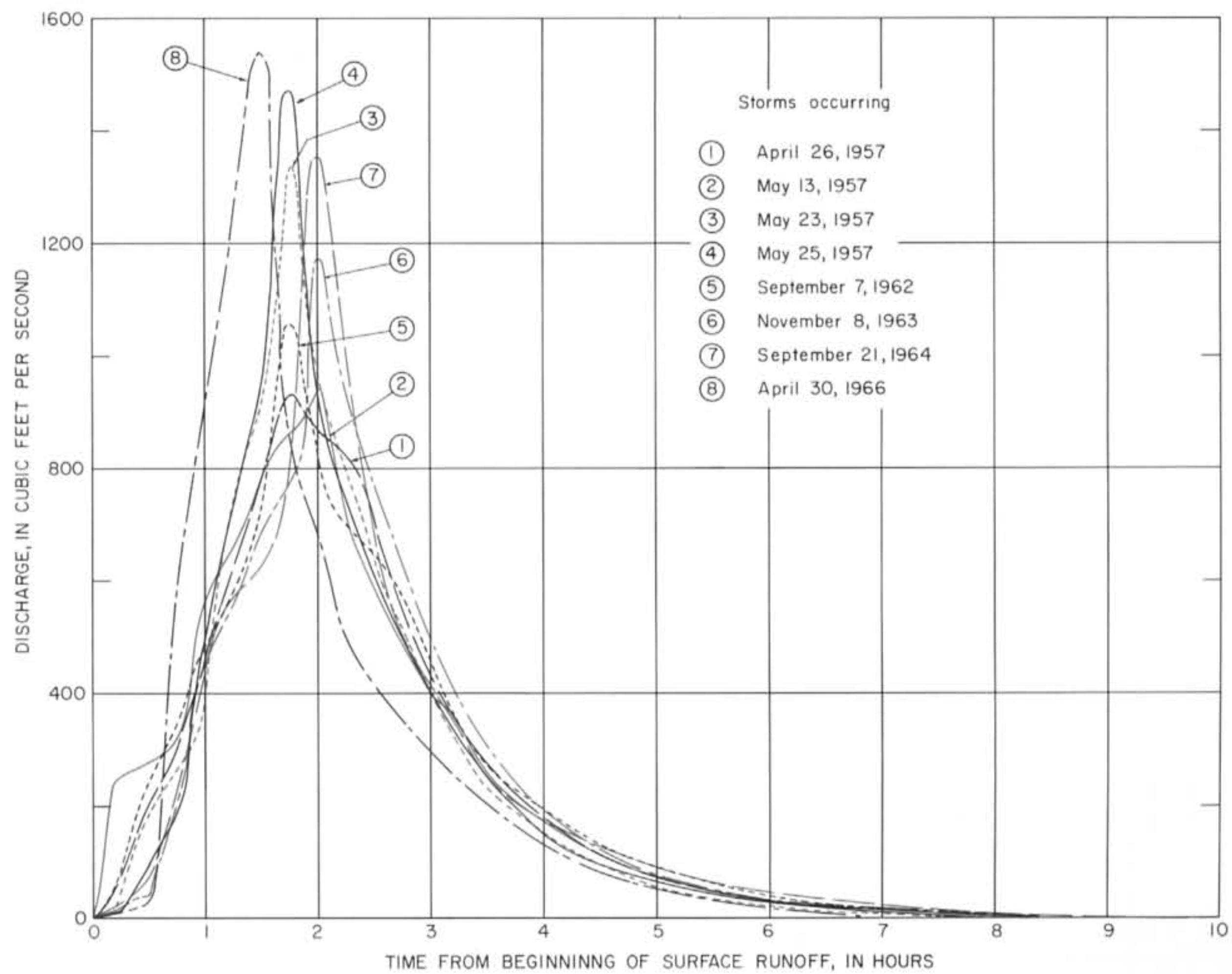

Figure 13
Unit Hydrographs for Inflow to Green Creek Reservoir 1

Table 4.—Parameters Used in Deriving the Graphical Coaxial Rainfall-Runoff Relation for Reservoir 1, Green Creek Study Area

[Drainage Area 3.34 Square Miles]

DATE OF STORM	RAINFALL (INCHES)	DURATION OF STORM (HOURS)	INFLOW RUNOFF (INCHES)	API[1] (INCHES)
1955 Water Year:				
May 18-19	4.92	3.0	3.43	1.27
May 26	.95	.5	.23	2.15
Sept. 23	2.64	4.0	.23	.03
1956 Water Year:				
Apr. 30	11.34	11.0	7.27	1.26
1957 Water Year:				
Apr. 26	3.72	8.0	1.68	1.74
Apr. 28	.65	2.0	.40	4.04
May 11	.87	3.0	.19	1.58
May 13	1.10	1.0	.62	2.01
May 17-18	1.72	6.0	.62	1.70
May 23	1.65	1.5	.68	1.61
May 25	1.80	1.0	.93	2.40
May 27	.65	2.0	.27	3.12
July 23	.50	1.0	.10	.99
1958 Water Year:				
Oct. 13	2.30	.5	.18	.25
Nov. 3	2.34	5.5	.49	.58
Nov. 23	1.22	5.0	.03	.52
Mar. 5	.71	.75	.11	.65
Apr. 30	.74	1.0	.18	1.00
July 6	1.65	.75	.10	.37
July 22	2.14	3.0	.50	1.14
1959 Water Year:				
June 26	3.16	6.0	.92	2.80
July 20	1.49	7.0	.02	1.49
Aug. 30-31	1.70	.75	.01	.11
Sept. 30	(2.54)	2.5	.02	.29
1960 Water Year:				
Oct. 3- 4	8.40	26.0	3.30	1.80
Nov. 3	1.25	1.0	.11	.90
Dec. 31	.99	3.0	.02	.28
Jan. 4- 5	1.79	22.0	.16	.69
Feb. 3	.97	4.0	.06	.05
May 4	1.42	.75	.23	.55
June 8	1.40	1.0	.05	.22
July 14	1.15	1.0	.04	.36
1961 Water Year:				
Jan. 6- 7	3.80	23.0	.26	.26
Feb. 5	1.91	16.0	.10	.26
Feb. 15-16	.74	1.25	.04	.58
July 9-10	1.54	1.0	.27	1.40
1962 Water Year:				
Oct. 2	2.10	5.0	.17	.16
Oct. 9	2.40	8.0	.33	.79
Nov. 22	.72	1.0	.01	.28
Apr. 4	1.22	5.0	.01	.18
July 26	2.86	8.0	.05	.11
Aug. 2	1.25	7.0	.05	1.03
Sept. 6	1.43	4.0	.06	.04
Sept. 7	3.73	21.0	.70	1.26

Table 4.—Parameters Used in Deriving the Graphical Coaxial Rainfall-Runoff Relation for Reservoir 1, Green Creek Study Area—Continued

DATE OF STORM	RAINFALL (INCHES)	DURATION OF STORM (HOURS)	INFLOW RUNOFF (INCHES)	API1/ (INCHES)
1963 Water Year:				
Oct. 8	3.17	11.0	.32	.13
Apr. 28	2.63	4.0	.51	.69
May 28	1.25	6.5	.05	.73
May 30	1.23	3.0	.20	1.46
1964 Water Year:				
Nov. 8	3.68	5.0	.83	.14
Apr. 21	2.52	5.0	.29	.04
Aug. 22	3.14	4.0	.04	.52
Sept. 20	2.97	10.0	.48	1.22
Sept. 20-21	3.30	9.0	1.59	4.19
1965 Water Year:				
Nov. 17-18	.96	9.0	.18	1.47
Nov. 18-19	.48	1.0	.08	2.43
Feb. 8- 9	1.95	13.0	.26	.10
May 14	1.20	2.0	.30	2.24
May 15-16	2.40	24.0	.56	2.96
May 18	.85	2.0	.07	3.97
1966 Water Year:				
May 1	.82	4.0	.13	3.55
June 13	3.55	5.5	.40	0
Aug. 13-14	1.70	6.0	.02	.52
Sept. 8- 9	2.10	2.0	.04	.72
Sept. 15	1.25	3.0	.13	1.56
Sept. 17	.65	1.0	.05	2.08

1/ Antecedent Precipitation Index

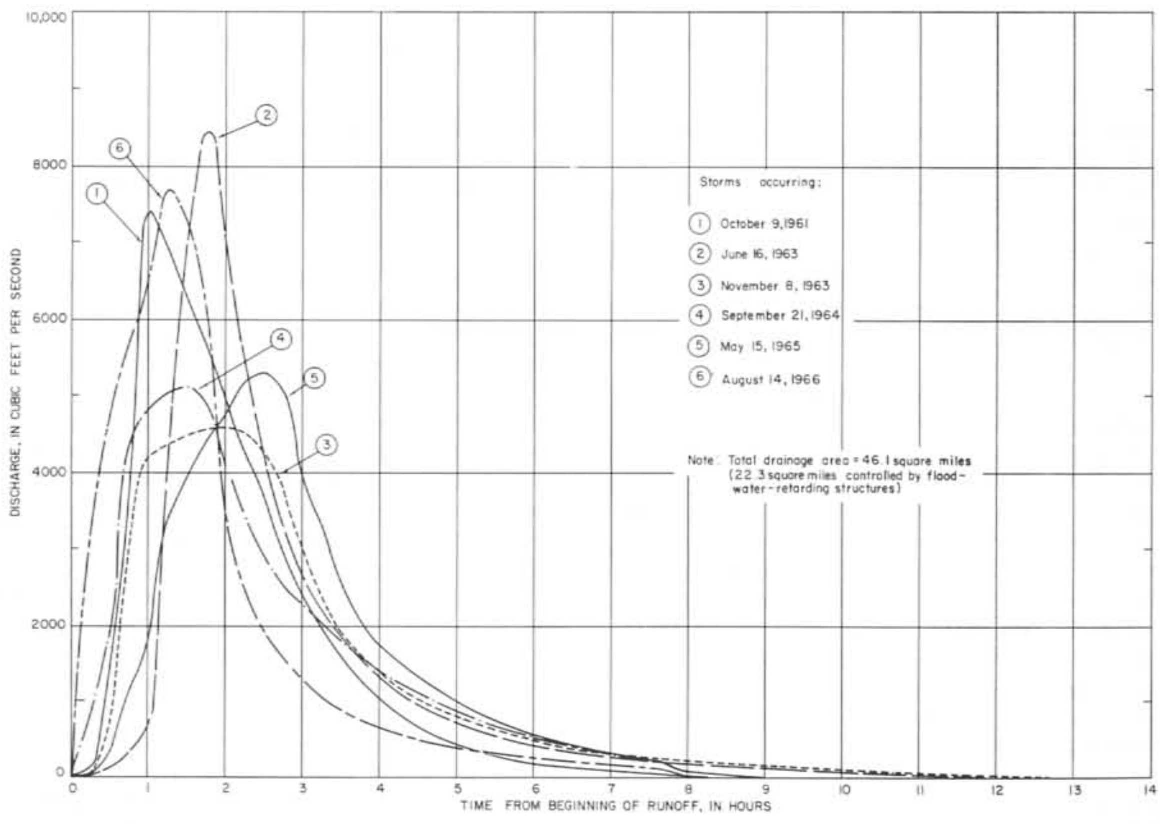

Figure 14.—Unit Hydrographs for Green Creek Near Alexander

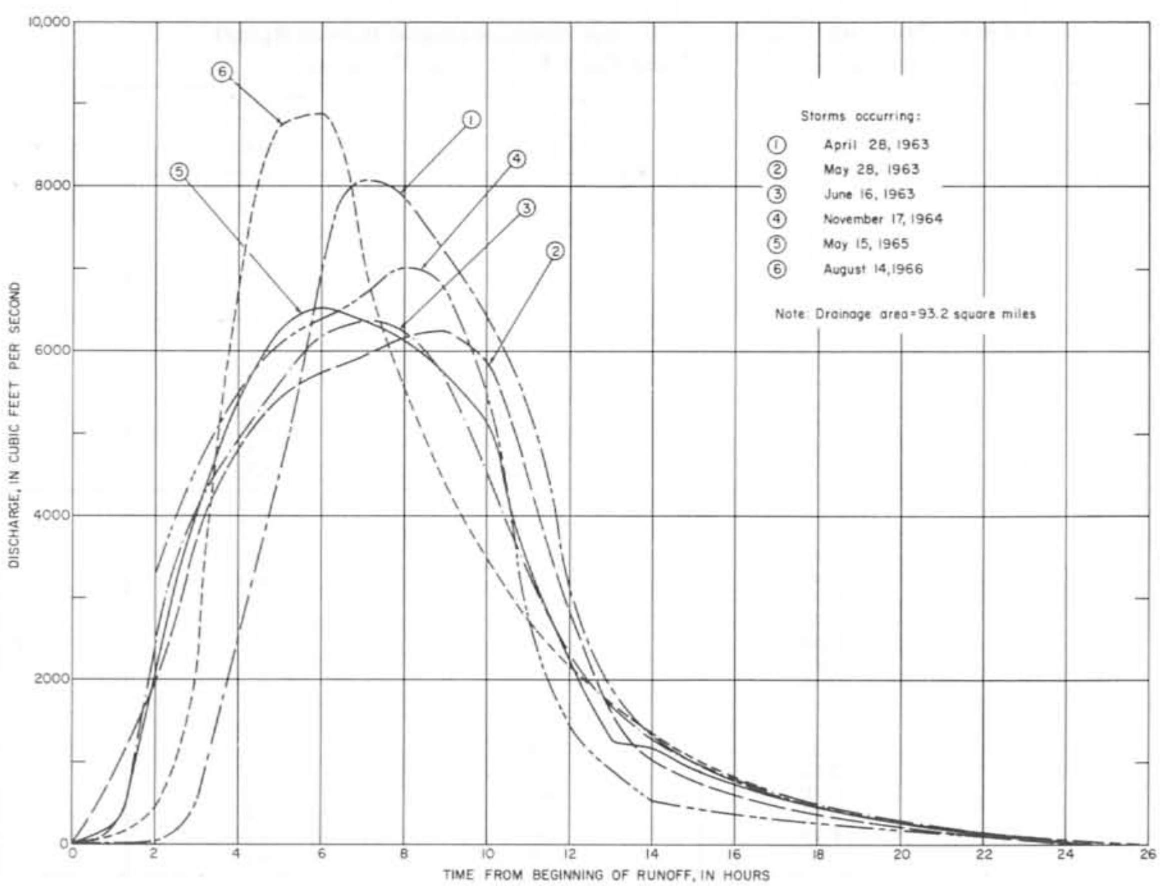

Figure 15.—Unit Hydrographs for North Bosque River at Stephenville

the storm-runoff characteristics. The time of rise is consistent, varying from 1.5 to 2.0 hours, with an average of 1.8 hours for the eight storms studied. The unit-hydrograph peak discharges ranged from 937 to 1,540 cfs (cubic feet per second) with the average equal to 1,230 cfs or 368 cfs per sq. mi. (cubic feet per second per square mile). The direct runoff into Reservoir 1 lasts 7 to 10 hours.

A comparison of recorded rainfall data with inflow hydrographs indicates that the time from intense storm rainfall to peak discharge is from 1 to 1½ hours. On the basis of studies by Mitchell (1948), the unit-hydrograph duration for inflow to Green Creek Reservoir 1 is approximately one-quarter hour. No attempt was made to approximate the unit-hydrograph duration by the use of summation curves because of the uncertainty of the method when applied to small watersheds, and because of the large amount of work involved. As previously stated, a 5-minute computation interval was used for hydrograph studies involving inflow to Green Creek Reservoir 1.

If a composite unit hydrograph were drawn on Figure 13, it would be nearly triangular until a low point on the recession limb is reached. This shape is typical of the unit hydrograph for a small watershed. The type of storm appears to have little effect upon the shape of the hydrograph.

The unit hydrographs for the stream-gaging station on Green Creek near Alexander (Figure 14) tend to cluster into two groups. One group shows consistently higher peak discharges than the other group. The hydrographs with higher peaks tend to rise rapidly to a maximum similar to those for inflow to Reservoir 1. The hydrographs with the lower peaks tend to rise rapidly to a point about one-half the value of the higher peaks and then suddenly round off. The recession limbs of all hydrographs are similar. The difference between the two groups of hydrographs is attributed to the difference in rainfall intensity and areal distribution. High intensity storms located near the center and downstream end of the study area produced the highest peaks. These storms were predominantly "summer" storms. The storms causing the lower peaks were fairly evenly distributed over the entire area and were of longer duration. The storms associated with the lower peaks occurred in the fall and spring months. The lower group of hydrographs reflect the initial runoff coming from the area closest to the station and then the arrival of runoff from upstream areas in the vicinity of the floodwater-retarding structures, thereby "sustaining" the flow and causing the more rounded hydrograph shape.

The time of rise of the highest group of graphs varied from 1.0 to 1.75 hours, with an average of 1.3 hours; the peak discharges varied from 7,400 to 8,450 cfs with the average equal to 7,900 cfs. For the lowest group of graphs, time of rise varied from 1.5 to 2.5 hours with an average of 2.0 hours; the associated peaks varied from 4,580 to 5,300 cfs with the average equal to 4,990 cfs. A study of rainfall data and flood hydrographs indicates a unit-hydrograph duration of about 30 minutes.

The two different average peak discharges give unit rates of peak discharge ranging from 210 cfs per sq. mi. to 332 cfs per sq. mi. (based on 23.8 sq. mi.) for 1 inch of rainfall excess. This latter unit rate is comparable to that for Green Creek Reservoir 1. The direct runoff at the station lasts 8 to 13 hours. The difference in time (0.7 hour) between the average times of rise for the high and low groups might be a "rough estimate" of the minimum average flow-through time for floods originating in upstream areas in the vicinity of the floodwater-retarding structures. More detailed studies are needed to determine precise flow-through times for the Green Creek study area.

The unit hydrographs for the stream-gaging station on North Bosque River at Stephenville (Figure 15) also indicate some differences in individual storm runoff characteristics. Some hydrographs tend to round-off at a low peak discharge while others have higher peaks but are skewed one way or the other. This skew is attributed to differing concentration times for flood flows from each upstream fork of the river (Figure 2). The time of rise varied from 6.0 to 9.0 hours with an average of 7.4 hours. The peak discharge ranged from 6,200 cfs to nearly 8,900 cfs and averaged 6,800 cfs, which is equivalent to 73 cfs per sq. mi. for this 93-square mile drainage basin. The direct runoff at this station lasts 24 to 26 hours. A study of rainfall data and flood hydrographs indicates a unit-hydrograph duration of about 2 hours.

Some conclusions regarding the flood-reducing effects of the eight floodwater-retarding reservoirs can be drawn from the preceding unit-hydrograph analyses. The maximum outflow from the eight reservoirs during any of the storms analyzed was about 150 cfs. Therefore, the average peak of the unit hydrograph at the stream-gaging station on Green Creek can be computed as 3,900 cfs (instead of 7,900 cfs) when the entire 46.1 square-mile drainage area is considered. The unit rate of discharge would then become 85 cfs per square mile. This value is much less than the unit rate of discharge of 368 cfs per square mile for the unit-hydrograph peak found for Reservoir 1. Although some of this difference can be attributed to the difference in size of the two watersheds and to the difference in unit-hydrograph duration, it is obvious that considerable reduction in peak discharge at the stream-gaging station has been effected by the reservoirs.

For further comparison, the unit hydrographs for inflow to Reservoir 1, the stream-gaging station on Green Creek near Alexander (drainage below structures only), and the stream-gaging station on the North Bosque River at Stephenville were converted to dimensionless hydrographs. The ordinate on the dimensionless hydrograph is the ratio of unit hydrograph discharges to the unit hydrograph peak discharge. The abscissa (time scale) is the ratio of time to time-of-rise. Reducing the unit hydrograph to a dimensionless hydrograph eliminates the effect of the basin size and much of the effect of basin shape (Chow, 1964). Figure 16 shows the dimensionless hydrographs for inflow to Reservoir 1, for the stream-gaging station on Green Creek near Alexander (using the average of all unit hydrographs shown on Figure 14), and for the stream-gaging station on North Bosque River at Stephenville (using the average of all unit hydrographs shown on Figure 15).

The dimensionless hydrographs for the two stream-gaging stations are similar except on the recession limb of the hydrograph, where the dimensionless flow time for the Green Creek station is longer than that for the North Bosque station. The longer dimensionless flow time is due to the much shorter time of rise for the Green Creek station unit hydrograph. Dimensionless hydrographs for all watersheds below a system of floodwater-retarding structures will probably exhibit this longer flow time characteristic. The dimensionless hydrograph for inflow to Reservoir 1 exhibits the triangular shape characteristic of small watersheds.

Flood Frequency

In an effort to isolate the effect of floodwater-retarding structures on the magnitude and frequency of downstream floods, a flood-frequency analysis was made from data collected in the Green Creek study area. Flood-frequency curves were prepared for Green Creek Reservoir 1 and for Green Creek near Alexander. A flood-frequency curve for the North Bosque River at Stephenville is not included because only 7 years of data were available.

The flood-frequency curves for the two locations in the Green Creek study area are based on 12 years (1955-66) of continuous records of runoff. The maximum discharge at Green Creek near Alexander since at least 1910 occurred on May 23, 1952 (discharge, 55,800 cfs). No attempt was made to include this peak in the flood-frequency analysis because it occurred prior to the upstream development of the watershed with floodwater-retarding structures.

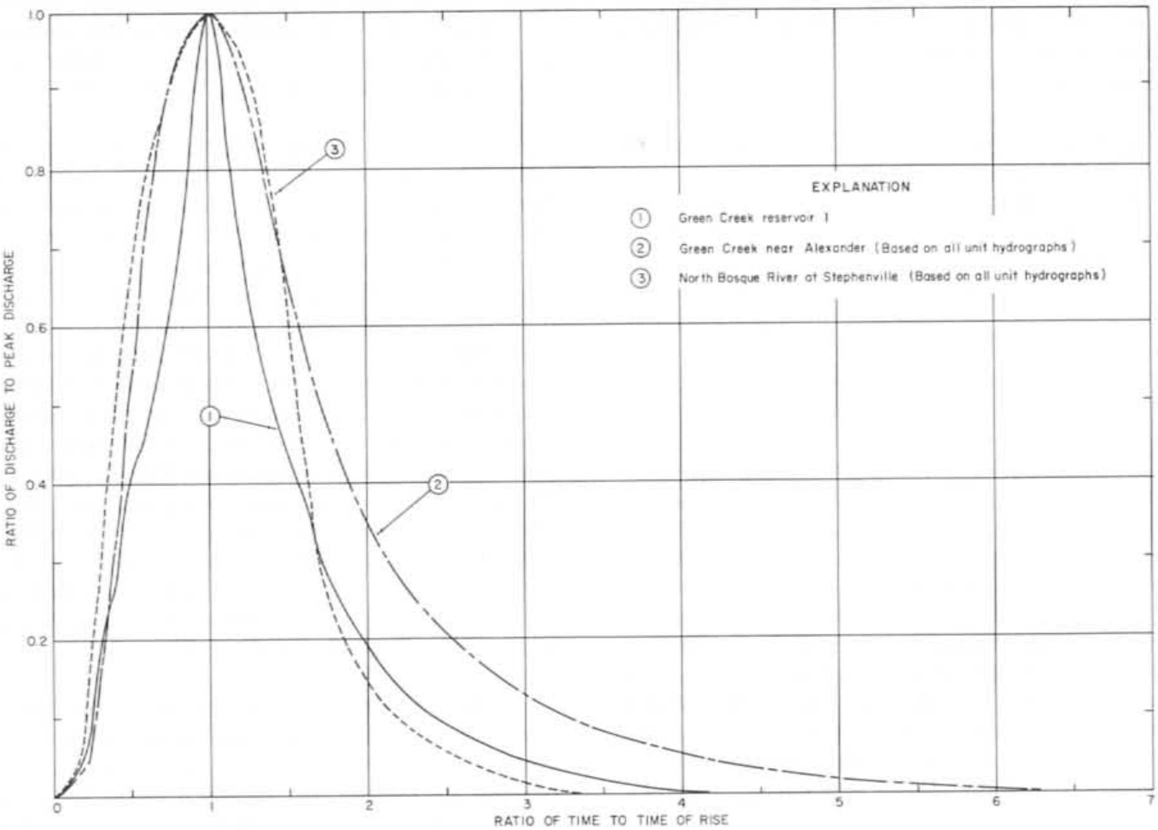

Figure 16.—Average Dimensionless Hydrographs for Inflow to Green Creek Reservoir 1, Green Creek Near Alexander, and North Bosque River at Stephenville

Plotting positions (recurrence probabilities) for the maximum annual peak discharges were computed using the formula

$$P = \frac{m}{n + 1}$$

where: P is the recurrence probability;

m is magnitude of flood, the highest being 1; and

n is the number of years of record.

Maximum annual peak discharges and their respective recurrence probabilities for inflows to Reservoir 1 and for Green Creek near Alexander are given in Tables 5 and 6, respectively.

Recently the Hydrology Committee, Water Resources Council (1967) recommended that a uniform technique be used for determining flood-flow frequencies. The recommended method is the log-Pearson Type III Method. Details of the log-Pearson Type III Method are given in the above reference and in other publications. This method, which is a mathematical fitting of the data, has the advantage of standardization in that the results can be evaluated by statistical parameters.

The derived flood-frequency curves for inflow to Green Creek Reservoir 1 and Green Creek near Alexander are shown on Figures 17 and 18. The actual data points as well as the log-Pearson Type III distribution curves are shown on both figures. Three statistical parameters for each Pearson curve are given on Figures 17 and 18. The actual data and theoretical curves generally agree for recurrence intervals of less than 10 years. Above this interval, the log-distribution curves are below the maximum annual peak discharges (outliers) for the 12-year period of record. From the curves, the maximum annual peak discharge for the 12-year period of record at each site is indicated to have a recurrence interval greater than 25 years. Because of these extreme outliers in relatively short periods of record, the log-Pearson distribution curve is considered more accurate than a curve fitted by eye through the actual data.

A comparison of the flood-frequency curves for Green Creek Reservoir 1 and Green Creek near Alexander does not give significant quantitative results that can be used in evaluating the effects of the floodwater-retarding structures on the magnitude and frequency of downstream floods.

Table 5.—Annual Flood Data for Green Creek Reservoir 1, 1955-66

[Drainage Area, 3.34 Square Miles]

WATER YEAR	DATE	PEAK DISCHARGE CFS[1]	ANNUAL FLOODS SERIES ORDER (M)	ANNUAL FLOODS SERIES RECURRENCE PROBABILITY
1955	May 18, 1955	3,630	2	.154
1956	Apr. 30, 1956	11,500	1	.077
1957	Apr. 26, 1957	887	5	.384
1958	July 22, 1958	748	6	.461
1959	June 26, 1959	498	10	.769
1960	Oct. 3, 1959	1,540	4	.308
1961	July 9, 1961	261	12	.923
1962	Sept. 7, 1962	516	9	.692
1963	Apr. 28, 1963	621	8	.615
1964	Sept. 21, 1964	2,090	3	.231
1965	May 15, 1965	365	11	.846
1966	Apr. 30, 1966	645	7	.539

[1] Computed from change-in-contents during 5-minute interval.

Table 6.—Annual Flood Data for Green Creek Near Alexander, Texas, 1955-66

[Drainage Area, 46.1 Square Miles]

WATER YEAR	DATE	PEAK DISCHARGE CFS	ANNUAL FLOODS SERIES ORDER (M)	ANNUAL FLOODS SERIES RECURRENCE PROBABILITY
1952	May 23, 1952	55,800[a]	–	–
1955	May 19, 1955	4,000	4	.308
1956	Apr. 30, 1956	23,900	1	.077
1957	Apr. 26, 1957	5,400	3	.231
1958	[b]	1,170	10	.769
1959	June 26, 1959	274	12	.923
1960	Oct. 4, 1959	3,190	6	.461
1961	Jan. 7, 1961	580	11	.846
1962	Oct. 9, 1961	2,880	7	.539
1963	June 16, 1963	1,460	9	.692
1964	Sept. 21, 1964	9,160	2	.154
1965	May 15, 1965	3,910	5	.384
1966	Aug. 14, 1966	1,590	8	.615

[a] Not included in computation of recurrence interval (prior to development of watershed).
[b] October or November 1957, time unknown.

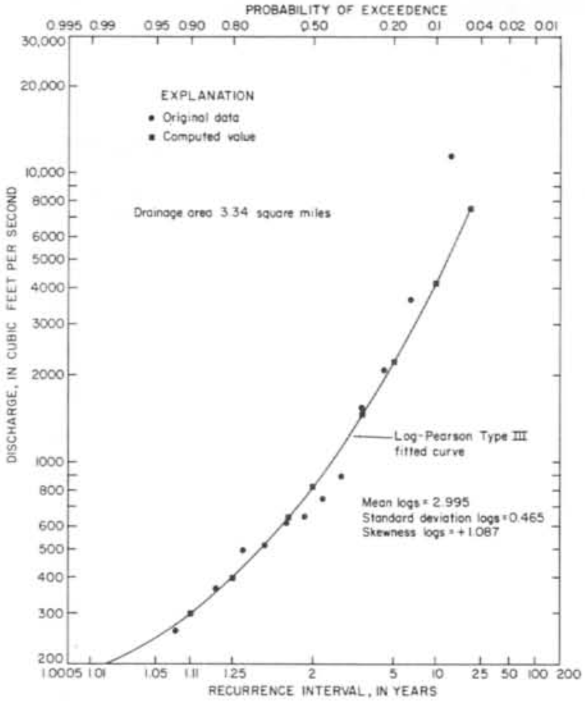

Figure 17.—Flood-Frequency Curve for Inflow to Green Creek Reservoir 1

Surface-Water Budget of the Study Area

The surface-water budget of the Green Creek study area is an accounting of surface water that enters and leaves the study area. This accounting is necessary for proper planning for downstream water supplies and helps toward a better understanding of the hydrologic characteristics of the area. The general water-budget equation used is of the form

$$Q_i = Q_o \pm \Delta S + C$$

where Q_i is combined reservoir inflow in acre-feet and includes combined rainfall on the reservoir surfaces;

Q_o is combined reservoir outflow in acre-feet through the reservoir outlet works;

ΔS is combined change in reservoir contents in acre-feet; and

C is combined total reservoir consumption in acre-feet, which is composed of evaporation, transpiration, infiltration, and other small depletions.

The term "C" from the above equation may be divided into two components, evaporation plus other depletions. Rewriting the above equation for the two components of "C" and isolating rainfall on the pools as a separate term,

$$Q_n = Q_o \pm \Delta S + C_e + C_s - R$$

where Q_n is combined reservoir inflow in acre-feet and does not include combined rainfall on the reservoir surfaces;

Q_o and ΔS were defined previously;

C_e is the combined evaporation from reservoir surfaces in acre-feet, the first component of total consumption;

C_s is combined remainder of reservoir depletions in acre-feet after evaporation, the second component of total consumption; and

R is combined rainfall on the reservoir surfaces in acre-feet.

Monthly evaporation in the study area, C_e, was furnished by the Texas Water Rights Commission and was determined as explained in a preceding section, *Reservoir Evaporation*. Total consumption "C" at each reservoir was computed from the recession in reservoir stage during periods of no inflow or outflow. Obviously, an extension of the same reservoir-recession rate into long periods of storm inflow would not give accurate results; fortunately, the periods of inflow in the Green Creek study area were usually short and thus the error introduced by extending recession rates was small. A different recession rate was usually found and used after periods of storm inflow. Other depletions, C_s, were determined by subtracting evaporation, C_e, from the total consumption, C. No attempt was made to divide C_s into its components. The rainfall from the nearest gage and average surface area of the reservoir during the rain were used in the water budget to adjust for rain that fell on the reservoir surface.

All terms in the general surface-water budget for gaged sites in the Green Creek study area are given in Table 9 by month and year for the period May 1955 to September 1966. Table 9 includes the monthly weighted-mean rainfall in the study area and the surface runoff recorded at the stream-gaging station. Continuous records at the stream-gaging station were unavailable prior to May 27, 1958. The data in Table 9 were compiled from data for individual reservoirs and were summarized for each term in the water budget.

Because of the importance of individual reservoir hydrology in the composite study-area water budget, inflow to each reservoir is presented. Figures 19 and 20 are mass curves of monthly inflow to each Green Creek reservoir. Inflow is given in inches and was computed using the drainage area above the reservoir excluding the surface area of the reservoir. The mass diagrams begin in

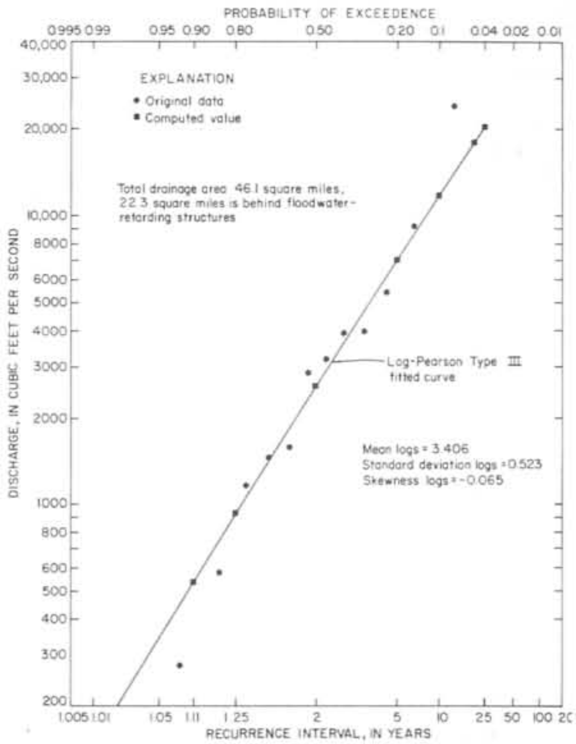

Figure 18.—Flood-Frequency Curve for Green Creek Near Alexander

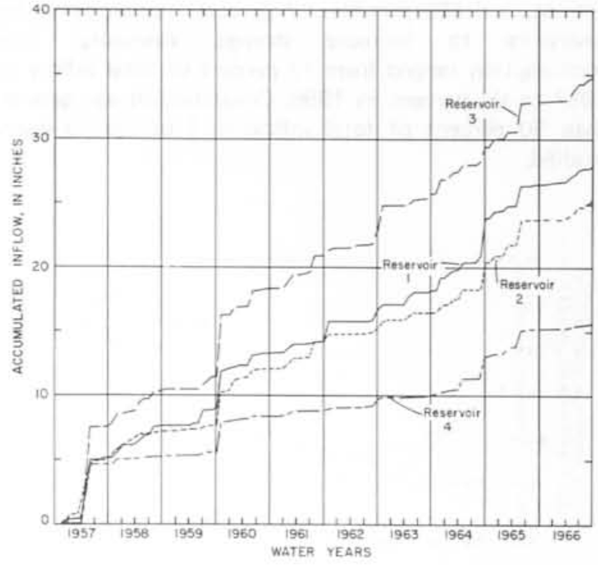

Figure 19.—Mass Diagram of Inflow to Green Creek Reservoirs 1 to 4

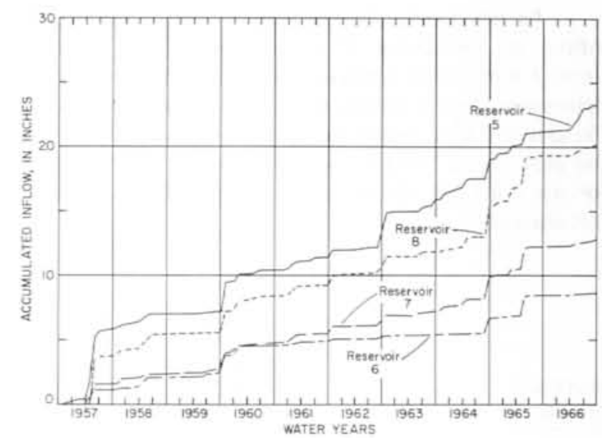

Figure 20.—Mass Diagram of Inflow to Green Creek Reservoirs 5 to 8

October 1956, after data collection was begun at all but one reservoir. The data for Reservoir 8 was estimated for the period October to December 1956.

Inflow to Reservoirs 6 and 7 (Figure 20) during the study period was low. The low inflow to Reservoir 6 is due to a reduction in effective contributing drainage area caused by several closures in an abandoned railroad fill that traverses the upper part of the drainage basin. In addition several private farm ponds are located in the drainage basin. The area above the railroad fill is essentially non contributing except during extreme floods. Above Reservoir 7, fills for another railroad and U.S. Highway 377 retard the storm runoff and probably cause less flow to reach the reservoir. Reservoirs 6 and 7 are located upstream from Reservoir 8, therefore total runoff into this reservoir is also affected.

The consumption at each reservoir is also an important factor in the study-area water budget. Figures 21 and 22 show the monthly averages of reservoir consumption other than evaporation (C_S, in feet, for each reservoir during the study period. These depletions vary seasonally, being lowest in winter and highest in summer. The depletions were found to be largest at Reservoir 6. This is probably due to abundant phreatophytic growth around the reservoir. During the study period, little or no surface flow, identifiable as seepage from the reservoirs, was observed in the stream channels below the reservoirs.

Mass curves of each term appearing in the surface-water budget equation for the system of reservoirs for the period 1957-66 are shown on Figure 23. The mass curves emphasize the relative consistency of annual consumption in spite of large changes in annual inflow and outflow. For the 10-year period 1957-66, there was 26,100 acre-feet combined inflow to the eight reservoirs and 3,700 acre-feet combined rainfall on the reservoir surfaces for a total input of 29,800 acre-feet. Of the 29,800 acre-feet, 18,200 acre-feet (61 percent) was discharged through the retarding structure outlet works, 11,000 acre-feet (37 percent) was consumed by evaporation, transpiration, and other actions, and 600 acre-feet (2 percent) remained in the reservoirs to increase storage. Annually, the consumption ranged from 17 percent of total inflow in 1957 to 94 percent in 1959. Consumption was greater than 50 percent of total inflow in 5 of the 10 years studied.

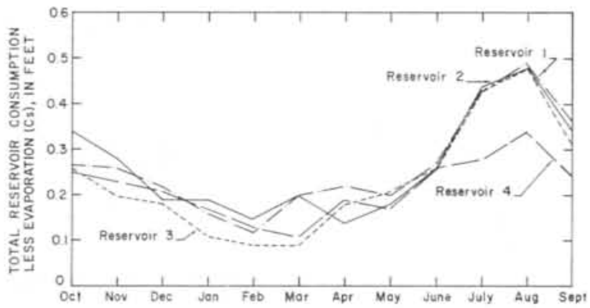

Figure 21.—Monthly-Average Consumption Other Than Evaporation at Green Creek Reservoirs 1 to 4

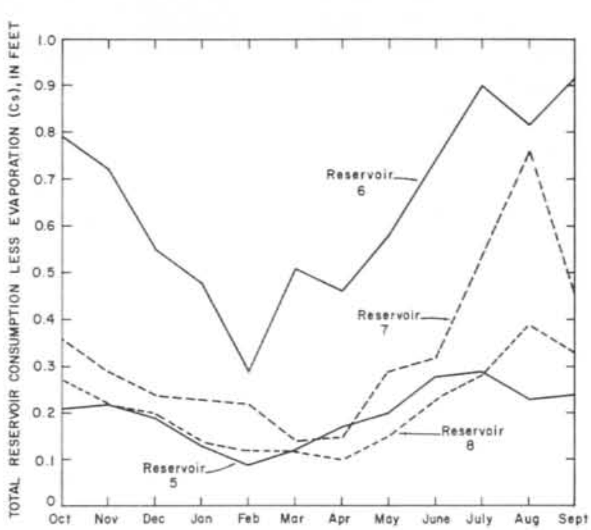

Figure 22.—Monthly-Average Consumption Other Than Evaporation at Green Creek Reservoirs 5 to 8

As previously shown, a significant portion of the inflow to the Green Creek reservoirs was discharged through the outlet works and flowed on downstream. To determine approximately how much of the flow passing the downstream stream-gaging station was runoff from the area below the reservoirs (assuming no channel loss for the outflow), the equation $Q_a = Q - Q_o$ was used. In this equation,

Q_a is runoff from the area below the reservoirs in acre-feet;

Q is the flow past the stream-gaging station in acre-feet; and

Q_o is combined reservoir outflow in acre-feet.

As previously mentioned, continuous streamflow data is available for the stream-gaging station beginning with the 1959 water year. Annual values for each term in the above equation are given in the following table:

WATER YEAR	FLOW PAST STREAM-GAGING STATION, Q (ACRE-FEET)	OUTFLOW FROM RESERVOIRS, Q_o (ACRE-FEET)	RUNOFF FROM AREA BELOW THE RESERVOIRS, Q_a (ACRE-FEET)
1959	158.1	136.3	21.8
1960	7,318.2	3,430.0	3,888.2
1961	1,894.0	465.5	1,428.5
1962	2,030.0	735.8	1,294.2
1963	1,339.2	886.7	452.5
1964	7,020.0	2,828.4	4,191.6
1965	7,799.9	3,754.9	4,045.0
1966	1,617.1	419.8	1,197.3

For the 8-year period 1959-66, this analysis shows that 57 percent of the flow was from the area below the reservoirs and 43 percent was outflow from the reservoirs. Neglecting channel losses between the reservoirs and the gaging station, the average annual yield from the 23.8-square mile area below the reservoirs was computed as 87 acre-feet per square mile; which compares with an annual yield of 106 acre-feet per square mile for the 22.3-square mile area above the reservoirs. For the same period, the average annual yield for the nearby (Figure 2) North Bosque River at Stephenville (93.2-square mile drainage area) was 124 acre-feet per square mile.

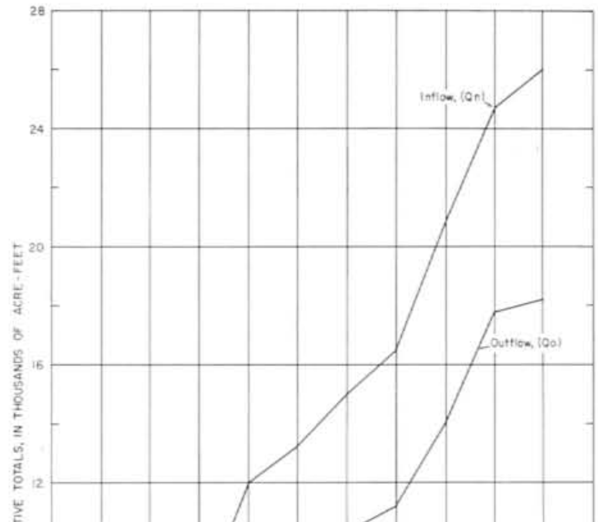

Figure 23.—Mass Diagram of Surface-Water Budget Variables for All Reservoirs in Green Creek Study Area, 1957-66

Sedimentation of Reservoirs

The amount of suspended sediment that is deposited in a reservoir depends upon such factors as sediment characteristics, detention-storage time, and the type and location of the outlet. The ability of a reservoir to trap and retain sediment is known as trap efficiency, and is usually expressed as a percentage. Many of the factors influencing trap efficiency have not been completely evaluated, but it stands to reason that if the reservoir capacity-inflow ratio (capacity in acre-feet per annual inflow in acre-feet) is nearly equal to 1.0, then most of the suspended sediment may be retained, resulting in a trap efficiency that approaches 100 percent. Conversely, as the capacity-inflow ratio gets smaller, lesser amounts of sediment are retained and the trap efficiency drops off.

The reservoirs in the Green Creek study area were designed to have capacity-inflow ratios of nearly always one or greater, thus a high trap efficiency. Based on data given in Tables 2 and 9, and using a curve presented in Chow (1964, sec. 17, p. 22) which relates the capacity-inflow ratio to percent of sediment trapped, it is estimated that the trap efficiency of the Green Creek reservoirs (collectively) was between 90 and 100 percent during the period of study. More detailed studies would be a necessary prerequisite for determining precise reservoir trap efficiencies in the Green Creek study area.

The Soil Conservation Service made a sediment survey of Reservoir 1 in June 1967. The survey showed that 32.0 acre-feet of sediment had been deposited in the reservoir since storage began in April 1955. Of the total deposition, 19.0 acre-feet was below the elevation of the uncontrolled outlet and the remainder was in the flood-detention pool. The 19.0 acre-feet of sediment deposition in the conservation pool represents an 8 percent decrease in the original capacity of the pool during the initial 12 years. This rate of sedimentation is consistent with that used in the design of the structure.

Chemical Quality of Water

Water samples were collected periodically in the Green Creek study area and chemical analyses were made. The water-quality data are given in Table 7. Because the chemical-quality data are limited, no attempts were made to define time variations or to develop curves of relation between dissolved constituents and water discharge. However, the data for the stream-gaging station show a general trend whereby the dissolved solids are diluted by increased discharge. The data do show that the waters of the Green Creek study area are of good to excellent quality, and they should be satisfactory for municipal and industrial uses and excellent for irrigation. The waters are generally moderately hard to hard (greater than 100 milligrams per liter), and they are mixed type with calcium, sodium, bicarbonate, and chloride as the principal ions.

In floodwater-retarding reservoirs and other impoundments, the water type (principal ions in solution) is important because it may affect the flocculation rate of clay particles. Calcium and bicarbonate ions in water tend to increase flocculation, whereas sodium ions depress flocculation by increasing dispersion. The mixed type waters of the Green Creek study area probably have little effect on sedimentation in the floodwater-retarding reservoirs.

MINIMAL-GAGE NETWORK

At the beginning of the small-watersheds project in Texas, the plan was to collect sufficient data in each study area in a reasonable period of time to afford analyses which would show phases of the more intensive data collection that could be reduced without seriously impairing the achievement of long-range objectives. Besides the economic benefits to the investigation, a byproduct of the analyses was to be results which could be used by those responsible for discharging flood storage in large reservoirs. The lengthening of the period during which flow occurs immediately below the

Table 7.--Chemical Analyses of Surface Water in the Green Creek Study Area, October 1962 to September 1966
(Results in Milligrams Per Liter, Except as Indicated)

DATE OF COLLECTION	DISCHARGE (CFS)	SILICA (SiO_2)	IRON (Fe)	CAL-CIUM (Ca)	MAG-NE-SIUM (Mg)	SODIUM (Na)	PO-TAS-SIUM (K)	BI-CAR-BON-ATE (HCO_3)	CAR-BON-ATE (CO_3)	SULFATE (SO_4)	CHLORIDE (Cl)	FLUO-RIDE (F)	NI-TRATE (NO_3)	BO-RON (B)	DISSOLVED SOLIDS: MILLI-GRAMS PER LITER	DISSOLVED SOLIDS: TONS PER ACRE-FOOT	DISSOLVED SOLIDS: TONS PER DAY	HARDNESS AS $CaCO_3$: CAL-CIUM, MAG-NE-SIUM	HARDNESS AS $CaCO_3$: NON-CAR-BON-ATE	SO-DIUM AD-SORP-TION RATIO	SPECIFIC CON-DUCT-ANCE (MICRO-MHOS AT 25°C)	pH
Reservoir 1																						
Oct. 17, 1962	--	4.9	--	29	4.4	18	--	95	0	10	29	0.3	0.2	--	143	0.19	--	90	13	0.8	267	6.2
May 22, 1963	--	4.7	--	40	5.2	21	--	138	0	15	26	.3	.5	--	181	.25	--	121	8	.8	338	6.7
Aug. 15, 1963	--	1.6	--	18	3.4	25	--	70	0	10	31	.3	2.0	--	125	.17	--	59	2	1.4	240	6.7
Dec. 6, 1963	--	2.6	--	27	3.1	12	--	92	--	10	14	.2	.2	--	114	.16	--	80	5	.6	220	7.0
Apr. 29, 1964	--	2.1	--	34	4.2	12	--	121	--	9.6	13	.2	.2	--	135	.18	--	102	3	.5	257	6.7
June 11, 1964	--	1.2	--	29	4.3	21	--	114	--	9.8	22	.2	.8	--	144	.20	--	90	0	1.0	278	7.0
Mar. 11, 1965	--	.8	--	35	7.2	18	--	132	--	15	22	.2	.0	--	163	.22	--	117	9	.7	313	7.2
June 8, 1966	--	3.0	--	36	4.4	16	5.6	120	0	12	24	.2	2.0	--	162	.22	--	108	10	.7	296	7.1
Reservoir 2																						
Oct. 17, 1962	--	3.8	--	36	7.3	30	--	100	0	23	55	.2	.2	--	204	.28	--	120	38	1.2	387	6.5
June 11, 1964	--	1.7	--	30	7.6	46	--	100	--	24	69	.3	1.2	--	229	.31	--	106	24	1.9	459	6.9
Mar. 11, 1965	--	.3	--	43	8.9	40	--	118	--	38	67	.2	.2	--	256	.35	--	144	47	1.5	494	7.7
June 8, 1966	--	4.8	--	46	7.2	27	5.9	129	0	28	53	.2	.8	--	236	.32	--	144	39	1.0	442	7.2
Reservoir 3																						
Oct. 17, 1962	--	2.7	--	31	5.6	28	--	84	0	17	52	.3	.0	--	178	.24	--	100	32	1.2	343	6.3
June 11, 1964	--	1.4	--	29	6.5	32	--	98	--	18	49	.2	.8	--	185	.25	--	99	19	1.4	370	7.0
Mar. 11, 1965	--	.9	--	37	5.3	24	--	118	--	20	34	.2	.0	--	179	.24	--	114	17	1.0	349	7.5
June 8, 1966	--	1.6	--	30	6.2	28	7.9	96	0	21	50	.3	.2	--	192	.26	--	100	22	1.2	373	7.0
Reservoir 4																						
Oct. 17, 1962	--	2.0	--	39	6.5	25	--	102	0	23	50	.3	.5	--	196	.27	--	124	40	1.0	376	6.4
June 11, 1964	--	3.4	--	37	7.7	33	--	88	--	29	66	.3	.5	--	220	.30	--	124	52	1.3	426	7.0
Mar. 11, 1965	--	2.4	--	60	9.4	40	--	150	--	48	71	.2	.5	--	306	.42	--	188	65	1.3	565	7.1
June 8, 1966	--	2.8	--	32	7.3	34	6.5	75	0	32	70	.2	1.2	--	223	.30	--	110	48	1.4	433	7.0
Reservoir 5																						
Oct. 17, 1962	--	1.7	--	29	8.5	22	--	88	0	17	45	.3	.0	--	166	.23	--	107	35	.9	323	6.5
Mar. 11, 1965	--	.4	--	42	12	22	--	124	--	33	46	.3	.0	--	217	.30	--	154	53	.8	420	7.5
June 8, 1966	--	10	--	28	7.8	13	5.0	92	0	14	29	.3	.2	--	155	.21	--	102	27	.6	280	7.2
Reservoir 6																						
Oct. 16, 1962	--	5.3	--	30	3.3	4.8	9.8	98	0	9.4	12	.2	3.0	--	126	.17	--	88	8	.2	224	6.3
June 11, 1964	--	6.8	--	31	3.1	12	--	90	--	11	22	.2	.2	--	130	.18	--	90	16	.5	263	6.9
Mar. 11, 1965	--	.9	--	37	2.8	10	--	128	--	8.0	8.6	.1	.2	--	131	.18	--	104	0	.4	242	7.3
June 8, 1966	--	1.4	--	46	4.1	18	12	130	0	34	27	.4	3.0	--	210	.29	--	132	25	.7	380	7.0
Reservoir 7																						
Oct. 17, 1962	--	.4	--	31	6.8	35	--	100	0	37	42	.3	.2	--	202	.27	--	105	23	1.5	373	6.5
June 11, 1964	--	3.5	--	38	6.9	18	--	145	--	19	15	.4	1.5	--	173	.24	--	123	4	.7	318	7.2
Mar. 11, 1965	--	.4	--	42	8.6	26	--	147	--	35	27	.2	1.0	--	212	.29	--	140	20	1.0	398	7.2
June 8, 1966	--	1.4	--	39	14	56	7.5	140	0	58	74	.4	.5	--	320	.44	--	155	40	2.0	594	7.2

Table 7.--Chemical Analyses of Surface Water in the Green Creek Study Area, October 1962 to September 1966--Continued
(Results in Milligrams Per Liter, Except as Indicated)

DATE OF COLLECTION	DISCHARGE (CFS)	SILICA (SiO_2)	IRON (Fe)	CAL-CIUM (Ca)	MAG-NE-SIUM (Mg)	SODIUM (Na)	PO-TAS-SIUM (K)	BI-CAR-BON-ATE (HCO_3)	CAR-BON-ATE (CO_3)	SULFATE (SO_4)	CHLORIDE (Cl)	FLUO-RIDE (F)	NI-TRATE (NO_3)	BO-RON (B)	DISSOLVED SOLIDS MILLI-GRAMS PER LITER	DISSOLVED SOLIDS TONS PER ACRE-FOOT	DISSOLVED SOLIDS TONS PER DAY	HARDNESS AS $CaCO_3$ CAL-CIUM, MAG-NE-SIUM	HARDNESS AS $CaCO_3$ NON-CAR-BON-ATE	SO-DIUM AD-SORP-TION RATIO	SPECIFIC CON-DUCT-ANCE (MICRO-MHOS AT 25°C)	pH
Reservoir 8																						
Oct. 18, 1962	--	3.9	--	29	9.6	33	--	122	0	24	40	0.5	0.2	--	[a]210	0.29	--	112	12	1.4	366	6.3
June 11, 1964	--	1.2	--	29	9.6	24	--	137	--	16	23	.4	1.0	--	171	.23	--	112	0	1.0	325	7.4
Apr. 16, 1965	--	.6	--	37	21	59	--	186	--	56	67	.5	1.0	--	333	.45	--	179	26	1.9	632	7.0
June 8, 1966	--	1.2	--	27	14	43	6.0	137	0	35	50	.4	1.8	--	245	.33	--	125	13	1.7	456	7.2
Green Creek near Alexander																						
Oct. 18, 1962	0.25	3.6	--	41	10	32	--	134	0	29	51	.3	.0	--	233	.32	--	143	34	1.2	429	6.6
Jan. 18, 1963	.65	3.3	--	47	18	40	--	197	0	38	55	.4	.2	--	299	.41	--	192	30	1.3	530	7.6
Dec. 5, 1963	.01	4.4	--	49	14	26	--	184	--	29	38	.3	.0	--	251	.34	--	180	29	.8	466	7.6
Feb. 4, 1964	91.8	5.3	--	32	8.3	18	--	114	--	19	28	.2	1.0	--	168	.23	--	114	21	.7	323	6.9
Feb. 5, 1964	25.4	4.7	--	30	7.1	22	--	101	--	20	33	.2	.2	--	167	.23	--	104	21	.9	317	6.8
Feb. 6, 1964	9.95	3.5	--	35	9.2	28	--	118	--	27	43	.2	.0	--	204	.28	--	125	28	1.1	389	6.9
Apr. 21, 1964	540	5.5	--	54	6.4	16	--	181	--	16	20	.3	1.0	--	208	.28	--	161	13	.5	382	6.9
Apr. 29, 1964	2.86	2.4	--	45	14	36	--	168	--	32	54	.3	.5	--	267	.36	--	170	32	1.2	503	6.9
Mar. 10, 1965	1.45	2.7	--	80	36	90	--	304	--	90	141	.5	.0	--	589	.80	--	348	98	2.1	1,060	7.8
May 16, 1965	720	7.7	--	36	5.4	13	--	123	--	14	17	.1	1.0	--	154	.21	--	112	11	.5	283	6.8

[a] Residue at 180°C.

floodwater-retarding structures because of the draining of stored water may require modification of flood-control operations downstream. Also, as more and more floodwater-retarding structures are built on watersheds tributary to major streams below large flood-control dams, it is foreseeable that the efficient operation of these large reservoirs will depend on adequate knowledge of the outflow from these systems of floodwater-retarding reservoirs. Gaging the outflow from each structure would be economically infeasible. Therefore, a minimal gage network is desirable.

With the above in mind, a correlation study was made of inflow to Reservoir 1 versus total inflow to all reservoirs in the Green Creek study area. As might be expected from data given on Figures 19 and 20, the variation in runoff in the study area almost precludes good results from the correlation study. However, for monthly inflow of 0.25 inch or more, a regression with a standard error of estimate of +65 percent and -40 percent was found. Considering that the Reservoir 1 drainage area constitutes 15 percent of the total drainage area from which runoff is to be estimated, and considering the 0.25 inch constraint, the results are very poor. The regression equation found can be expressed as:

$$Q_t = 5.51\, Q_{r_1}$$

where

Q_t is runoff in acre-feet from entire controlled drainage area of 22.3 square miles; and

Q_{r_1} is runoff in acre-feet from the 3.34 square-mile drainage of Reservoir 1.

This equation gives results which are almost 20 percent less than those obtained when the ratio of drainage areas is applied. With probable errors as given, the above equation can be used to estimate runoff into the eight reservoirs of the Green Creek study area when the runoff into Reservoir 1 is known. For a given significant storm period, outflow from the system of reservoirs will be almost equal to inflow. With an outflow rate of 10 acre-feet per square mile per day the duration of discharge from the reservoirs can be computed.

The results of the rain-gage density analyses showed that three rain gages can be used to determine average storm rainfall on the 46 square-mile study area and yield results within 10 percent of those attainable with seven rain gages.

The analyses of reservoir consumption yielded sufficient results regarding probable streamflow depletion by a system of floodwater-retarding reservoirs in this locality. Therefore, data collection for pool consumption at the reservoirs with nonrecording lake-level gages are no longer needed. Data collection at Reservoir 1 is needed in order that any changes in reservoir consumption may be defined and to provide much needed hydrologic data from a small watershed. The stream-gaging station gaging the outflow from the study area is needed to define changes in flow regimen that will probably occur as the floodwater-retarding structures fill with sediment.

SUMMARY AND CONCLUSIONS

Hydrologic data collected in the Green Creek study area between 1955 and 1966 provides much needed information about the water resources of the area, about the hydrology of small watersheds in the area, and about the effects which floodwater-retarding structures have on these water resources. These data served as the basis for making hydrologic analyses aimed at achieving four of the six objectives of the State small watershed project as listed on page 4. The results of these analyses and the objective to which they apply are summarized below:

I. Objective No. 1;

A. Flood reducing effects of structures:

1. The flood-reducing aspects of a floodwater-retarding structure were illustrated by data collected at Green Creek Reservoir 1. A peak inflow of 11,500 cfs was computed for the storm of April 30, 1956; whereas the maximum outflow was 700 cfs.

2. Other analyses were made in an effort to define these effects further downstream. Using data from eight storms, unit hydrographs were developed for the 3.34 square-mile drainage area above Green Creek Reservoir 1. These unit graphs (1/4-hour) indicate that the average time of rise is 1.8 hours, with an average unit peak discharge of 1,230 cfs or 368 cfs per square mile for 1 inch of rainfall excess.

Unit hydrographs (1/2-hour) for the Green Creek stream-gaging station (applicable to the 23.8 sq. mi. below floodwater-retarding structures) were derived from six storms and tended to cluster into two groups; one group with a greater peak discharge than the other. The group with the greater peak discharge was representative of short-duration summer storms which were located over the center and lower portion of the uncontrolled area. The storms associated with the group of unit hydrographs with the lower peak discharge caused fairly uniform amounts of rainfall over the entire basin and were of longer duration. The average time of rise and average peak discharge for the higher and lower groups of unit hydrographs were 1.3 and 2.0 hours, and 7,900 and 4,900 cfs, respectively. These peak discharges are equivalent to 332 and 210 cfs per square mile, respectively. However, when the entire drainage area above the stream-gaging station (46.1 sq. mi.) is used, an average unit-hydrograph peak of 3,900 cfs was computed (structure outflow is 150 cfs). The unit rate of (dischargel would then become 85 cfs per square mile. This unit rate may be compared with the unit rate of

368 cfs per square mile found for Reservoir 1. Although some of the difference in peak unit rate of runoff is due to difference in size of the two watersheds, a considerable reduction in peak discharge at the stream-gaging station is indicated.

For purposes of comparison, six unit hydrographs (2-hour) were developed for the nearby North Bosque River at Stephenville gaging station, where drainage was unaffected by floodwater-retarding structures. These unit hydrographs had an average time of rise of 7.4 hours and an average peak discharge of 6,800 cfs, or 73 cfs per square mile.

A comparison of the average unit hydrograph for Green Creek Reservoir 1 with the average unit hydrograph for the Green Creek stream-gaging station below the eight floodwater-retarding reservoirs indicated a sizeable reduction in peak discharge effected by the reservoirs. However, the comparison did not afford accurate quantification of this peak discharge reduction. Further studies in this area of the investigations should be made when basic data becomes available.

3. From log-Pearson Type III frequency-distribution curves of maximum annual peak discharges at Green Creek Reservoir 1 and at the stream-gaging station Green Creek near Alexander, the flood of April 29-May 1, 1956, is seen to have a recurrence interval greater than 25 years.

A lack of flood data at the stream-gaging station prior to the construction of upstream floodwater-retarding structures precludes the use of the flood-frequency analyses to illustrate the quantitative effect of the structures on downstream floods. However, a comparison of the unit rates of discharge for the 25-year flood at the two sites would infer considerable reduction of flood discharge at the stream-gaging station.

B. Streamflow depleting effects of structures:

1. The surface-water budget of the system of floodwater-retarding reservoirs shows that during the period 1957-66, 26,100 acre-feet of water flowed into eight reservoirs and 3,700 acre-feet of rain fell on the reservoir surfaces. Of the 29,800 acre-feet combined input, 18,200 acre-feet or 61 percent was discharged through the drop-inlet; 11,000 acre-feet or 37 percent was consumed by the actions of evaporation, transpiration, and seepage; and 600 acre-feet was used to increase storage. Further water-budget studies (assuming all outflow from reservoirs passes stream-gaging station), for the 8-year period 1959-66, show that approximately 57 percent of the total flow passing the Green Creek gaging station originates below the reservoirs and approximately 43 percent is outflow from the reservoirs. For the 8-year period, average annual runoff above the structures was gaged as 106 acre-feet per square mile while the average annual runoff for the area below the structures was computed to be 87 acre-feet per square mile. By comparison, the average annual yield of the North Bosque River at Stephenville for this period was 123 acre-feet per square mile.

II. Objective No. 2:

1. Ground-water data are not being collected to achieve this objective in this study area.

III. Objective No. 3:

A. Sediment trap-efficiency of the structures:

1. On the basis of empirical relationships between capacity-inflow ratios and sediment trapped, the sediment trap-efficiency of floodwater-retarding structures in the Green Creek study area was computed to be between 90 and 100 percent.

2. The Soil Conservation Service reported that sediment deposition in Reservoir 1 amounted to 32.0 acre-feet in the period April 1955 to June 1967. They estimated a trap-efficiency of 98 percent for the periods covered by these surveys.

B. No data were collected to define the change in suspended sediment at considerable distance downstream from the structures.

IV. Objective No. 4:

1. A coaxial method of graphical correlation was developed for runoff into Green Creek Reservoir 1 (drainage area, 3.34 sq. mi.). Although the correlation was developed using 65 storms, 38 of which produced runoff less than 0.25 inch, additional data are needed to better define portions of the correlation. The standard error for the correlation of the 65 storms was 54 percent.

2. The unit-hydrograph analysis made for Reservoir 1 (summary of results presented under objective 1) will also aid in achieving this objective. A multiple-regression analysis might yield more usuable data in achieving this objective.

V. Objective No. 5:

1. Analyses aimed at achieving this objective have not been made in this study area.

VI. Objective No. 6:

A. Minimal data-collection network for rainfall:

1. Seven rain gages were operated in the study area during the investigative period 1955-66. For storm rainfall amounts greater that 0.40 inch, analyses showed that three rain gages—one each at the northern and southern extremities of the study area and one near the center—give average rainfall amounts that are within +11 and -9 percent (using a 67-percent confidence limit) of the weighted-mean amounts determined from using seven rain gages. The minimal rainfall network can be used with the coaxial graphical relationship developed for Reservoir 1 to estimate runoff into all eight reservoirs.

B. Minimal data-collection network for runoff to structures:

1. Analyses showed that an estimate of total inflow to the eight reservoirs can be made on the basis of gaged inflow to Reservoir 1 with a standard error of +65 and -40 percent.

Although not listed on page 4 as a specific objective of the Texas small watershed project, the gross lack of hydrologic data for small watersheds necessarily makes the collection and dissemination of such data under this project a major objective. All the hydrologic data collected at each of the eight small watersheds in the Green Creek study area was too voluminous to present in this report. However, these data are compiled and presented annually in a basic-data report. These reports are prepared annually for each of the 11 study areas in the Texas project.

RECOMMENDATIONS

Extensive hydrologic data are being systematically collected in and compiled for 11 small watersheds in Texas. Recommendations regarding the Green Creek and the other small-watershed investigations are summarized as follows:

1. The Green Creek rain-gage density analyses revealed fewer rain gages could be used with only a minor loss in accuracy. It is recommended that the rain-gage network be reduced to gages 1R, 4S, 7R, and 11R. Although gage 11R is not needed for computing average study-area rainfall, it should be continued to provide rainfall at Reservoir 1. Rain-gage density analyses for each study area should be made and correlated.

Because of the importance of areal distribution of storm rainfall with time and the importance of rainfall intensity, only recording rain gages should be used in investigations of rates of runoff from small watersheds.

2. More satisfactory types of crest-stage gages should be installed at the nonrecording reservoir gages in other study areas.

3. A knowledge of the watershed geology and the ground-water movement around and downstream from the floodwater-retarding reservoirs is essential to a more complete water-budget appraisal.

4. Streamflow observations should be made periodically for some distance below the floodwater-retarding structures to support regular observations made immediately below the structures.

5. Collection of flood data at Reservoir 1 and the downstream gaging station should be continued so that flood frequency relationships can be better defined.

6. As more storm-runoff data become available at Reservoir 1, a multiple-regression analysis should be made in an attempt to get a predictor of runoff that is better than that by the coaxial-correlation technique.

7. Pool consumption in the Green Creek study area has been defined. Therefore, it is recommended that gaging of pool contents and outflow at all reservoirs except Reservoir 1 be discontinued. Continued computation of pool consumption at Reservoir 1 should provide historical evidence of the change in pool consumption with time.

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Table 8.—Summary of Rainfall, in Inches, for Green Creek Study Area, May 1955 to September 1966

DATE OF STORM	GAGES 1-R	2-S	3-S	4-S	5-S	6-S	7-R
1955							
May 10-11	0.70	1.19	1.37	1.93	1.66	2.18	1.85
11	.05	.05	.07	.07	.05	.05	0
16	.90	.77	.69	.63	.55	.55	.67
17-18	.18	.29	.23	.25	.23	.25	.33
18-19	4.92	2.62	2.60	1.93	1.50	1.37	1.25
22	0	.01	.09	.05	.03	.12	.08
26	.95	.71	.79	.68	.54	.40	.20
Monthly Totals	7.70	5.64	5.84	5.54	4.56	4.93	4.38
June 4	1.00	.97	1.00	1.01	.88	.74	.60
8	.73	1.05	.99	1.19	1.13	1.04	1.02
14-15	.92	.68	.75	1.00	.95	1.17	.90
15	.28	.13	.16	.17	.14	.15	.06
16	0	.01	.01	.01	.01	.02	.02
18	.20	.16	.19	.22	.25	.17	.17
19	.75	.36	.53	.48	.50	.38	.24
Monthly Totals	3.88	3.36	3.63	4.08	3.86	3.67	3.01
July 13	0	0	0	0	0	0	.22
16	.17	.19	.23	.18	.35	.27	.20
17	.07	.07	.08	.06	.11	.08	.05
18	.26	.36	.40	.35	.70	.57	.48
23	0	0	0	0	0	0	.06
Monthly Totals	0.50	0.62	0.71	0.59	1.16	0.92	1.01
Aug. 9	.07	0	0	1.24	.71	.23	.09
11	.54	0	.04	0	0	.02	.19
21	.07	.07	0	0	.75	0	.15
29	0	.03	.05	.09	.13	.19	.45
30	.10	.11	.29	.26	.34	.36	.46
Monthly Totals	0.78	0.21	0.38	1.59	1.93	0.80	1.34
Sept. 10	.20	.33	.31	.28	.10	.06	.44
23	2.64	3.39	3.18	3.00	3.01	2.50	2.26
24	.10	.06	.14	.05	.10	.06	.05
Monthly Totals	2.94	3.78	3.63	3.33	3.21	2.62	2.75
1955 WATER YEAR TOTALS	–	–	–	–	–	–	–
Oct. 1	.80	.16	1.48	1.80	.41	.62	.15
6	.37	.74	.70	1.08	.56	1.45	.96
Monthly Totals	1.17	0.90	2.18	2.88	0.97	2.07	1.11
Nov. 30	(.40)	.38	.33	.33	.45	.39	.40
Monthly Totals	(0.40)	0.38	0.33	0.33	0.45	0.39	0.40
Dec. 1	(.11)	.13	.11	.14	.16	.15	.17
Monthly Totals	(0.11)	0.13	0.11	0.14	0.16	0.15	0.17
1955 CALENDAR YEAR TOTALS	–	–	–	–	–	–	–
1956							
Jan. 17	.10	.12	.10	.15	.16	.14	.25
19	.55	.50	.45	.54	.59	.48	.75
21-22	.46	.76	.54	.70	.63	.71	.59
Monthly Totals	1.11	1.38	1.09	1.39	1.38	1.33	1.50

Table 8.—Summary of Rainfall, in Inches, for Green Creek Study Area, May 1955 to September 1966—Continued

DATE OF STORM	GAGES 1-R	2-S	3-S	4-S	5-S	6-S	7-R
1956							
Feb. 2	0.16	0.23	0.25	0.20	0.22	0.20	0.25
3	.08	.06	.06	.05	.06	.05	.02
6	.05	.08	.10	.07	.08	.08	.10
7- 8	1.07	1.01	.10	.83	.95	.89	.63
10	.10	.12	.10	.12	.12	.10	.08
17	0	.05	.05	.07	.08	.08	.08
Monthly Totals	1.46	1.55	0.66	1.34	1.51	1.40	1.16
Mar. 12	0	.04	.03	.04	.05	.04	.07
22	0	.03	.03	.02	.03	.01	0
Monthly Totals	0	0.07	0.06	0.06	0.08	0.05	0.07
Apr. 5	1.46	1.87	1.69	1.60	.94	1.01	.75
14	.13	.04	0	.03	.01	0	0
21	.20	.27	.40	.28	.33	.37	.32
29-30	1.15	1.70	1.70	2.50	2.75	2.80	2.18
30	(8.60)	6.32	8.64	5.26	4.37	4.14	2.67
Monthly Totals	11.54	10.20	12.43	9.67	8.40	8.32	5.92
May 1- 2	(3.19)	3.34	4.20	3.04	2.73	2.79	2.30
14-15	.27	.23	.31	.23	.26	.29	.25
24	.85	.94	.58	1.02	1.50	1.30	2.39
31	.30	.13	.24	.16	.06	.04	.05
Monthly Totals	4.61	4.64	5.33	4.45	4.55	4.42	4.99
June 3	.20	.19	.26	.24	.09	.06	.18
8	.30	.23	.10	.52	.61	.22	.30
18	0	0	.01	0	0	.16	.28
Monthly Totals	0.50	0.42	0.37	0.76	0.70	0.44	0.66
July 9	.11	.35	.01	0	.50	.05	.05
24	.05	.14	.15	.62	T	.94	T
Monthly Totals	0.16	0.49	0.16	0.62	0.50	0.99	0.05
Aug. 19	0	0	0	0	0	0	.05
28	0	0	T	.01	T	.05	0
30	.75	.89	.40	.52	.28	.17	.20
Monthly Totals	0.75	0.89	0.40	0.53	0.28	0.22	0.25
Sept. 25	0	0	0	.01	T	T	0
Monthly Totals	0	0	0	0.01	0	0	0
1956 WATER YEAR TOTALS	21.81	21.05	23.12	22.18	18.98	19.78	16.47
Oct. 15	1.10	1.09	1.22	1.13	1.14	1.50	1.05
17	0	.01	.01	.03	.02	.03	.05
17-18	.15	.14	.23	.23	.17	.17	.20
30	.57	.40	.40	.48	.43	.37	.40
Monthly Totals	1.82	1.64	1.86	1.87	1.76	2.07	1.70
Nov. 2	.35	.33	.33	.33	.30	.27	.25
3	0	.03	.02	.03	.04	.04	.06
4	.91	1.01	.99	1.01	1.00	1.00	1.01
Monthly Totals	1.26	1.37	1.34	1.37	1.34	1.24	1.32
Dec 8	.05	.01	T	.03	.02	.01	.05
15-18	2.96	2.98	3.03	2.81	2.92	2.83	3.14
Monthly Totals	3.01	2.99	3.03	2.84	2.94	2.84	3.19
1956 CALENDAR YEAR TOTALS	26.22	25.64	26.70	24.90	23.44	23.32	21.00

Table 8.–Summary of Rainfall, in Inches, for Green Creek Study Area, May 1955 to September 1966–Continued

DATE OF STORM	GAGES 1-R	2-S	3-S	4-S	5-S	6-S	7-R
1957							
Jan. 3- 4	0.15	0.19	0.21	0.21	0.29	0.25	0.42
27	.07	.09	.08	.09	.12	.11	.10
29	.17	.20	.20	.20	.25	.22	.20
31	.17	.22	.21	.22	.27	.25	.24
Monthly Totals	0.56	0.70	0.70	0.72	0.93	0.83	0.96
Feb. 1	.15	.11	.12	.10	.09	.07	.02
16	.16	.12	.12	.11	.11	.11	.08
18	.22	.18	.18	.17	.17	.18	.15
20	.08	.09	.08	.10	.11	.12	.13
22-23	.40	.42	.37	.44	.55	.45	.67
24	.10	.09	.09	.09	.11	.09	.12
Monthly Totals	1.11	1.01	0.96	1.01	1.14	1.02	1.17
Mar. 10-11	.72	.38	.37	.35	.51	.53	.45
14	0	.04	.02	.04	.06	.07	.10
20	.98	1.01	.87	1.00	1.07	1.08	1.10
24	0	.05	.03	.06	.08	.08	.15
31	.60	.68	.85	.80	1.21	.85	1.13
Monthly Totals	2.30	2.16	2.14	2.25	2.93	2.61	2.93
Apr. 3	.48	.34	.48	.35	.47	.29	.23
13	.11	.10	.13	.16	.13	.26	.08
19	.92	.84	.90	.77	.94	.83	.87
21	0	.10	.08	.12	.18	.20	.38
22-23	1.66	1.50	1.61	1.42	1.76	1.57	1.86
24	.35	.34	.36	.32	.41	.37	.45
26	3.72	3.35	3.61	3.12	3.82	3.37	3.70
28	.65	.54	.60	.49	.57	.48	.50
29	.11	.08	.09	.08	.10	.09	.08
30	.10	.08	.09	.08	.10	.09	.10
Monthly Totals	8.10	7.27	7.95	6.91	8.48	7.55	8.25
May 1	.30	.30	.33	.28	.35	.31	.39
3	.45	1.10	.98	1.22	1.74	1.77	2.80
4	.25	.22	.23	.20	.25	.21	.23
9	.80	.69	.63	.62	.62	.57	.27
11	.87	1.16	.93	1.17	1.34	1.38	1.43
12	.23	.22	.18	.20	.20	.20	.15
13	1.10	1.22	1.02	1.18	1.30	1.28	1.25
17-18	1.72	1.62	1.05	1.89	1.96	1.88	1.65
23	1.65	1.03	.90	1.25	.87	1.03	.75
25	1.80	.68	.68	.71	.42	.41	.15
27	.65	.49	.42	.61	.44	.54	.42
Monthly Totals	9.82	8.73	8.35	9.33	9.49	9.58	9.59
June 1	.10	.13	.07	.10	.11	.10	.05
2	.09	.24	.12	.32	.34	.44	.91
12	.55	.50	.25	.52	.40	.27	.40
23	.55	1.15	T	.65	.30	.55	.11
Monthly Totals	1.29	2.02	0.44	1.50	1.15	1.36	1.47
July 22	1.14	.19	.37	.14	.09	.12	.30
23	.50	.06	.14	.04	.03	.03	.06
Monthly Totals	1.64	0.25	0.51	0.18	0.12	0.15	0.36
Aug. 4	0	.07	0	.37	T	T	.08
17	.36	0	0	0	0	0	0
Monthly Totals	0.36	0.07	0	0.37	0	0	0.08
Sept. 2	.81	1.09	.56	.83	1.00	.34	1.00
6- 7	.25	.34	.28	.45	.28	.32	.20
11	.49	.63	.52	.80	.50	.55	.33
13	.32	.19	.46	.72	.51	.06	.07
21-22	.93	1.21	1.00	1.37	1.24	1.32	1.40
25	.20	.20	.19	.21	.18	.18	.14
Monthly Totals	3.00	3.66	3.01	4.38	3.71	2.77	3.14
1957 WATER YEAR TOTALS	33.91	31.87	30.26	32.73	33.99	32.02	34.16

Table 8.–Summary of Rainfall, in Inches, for Green Creek Study Area, May 1955 to September 1966–Continued

DATE OF STORM	GAGES 1-R	2-S	3-S	4-S	5-S	6-S	7-R
1957							
Oct. 8	0.40	0.36	0.53	0.45	0.55	0.53	0.51
13-14	1.20	1.10	.98	1.06	1.14	1.18	1.17
15	.43	.77	.61	.85	1.03	1.20	1.63
21-22	.38	.47	.34	.44	.52	.57	.58
22	.11	.07	.06	.06	0.05	.04	0
Monthly Totals	4.82	4.68	4.26	4.66	5.18	5.44	5.67
Nov. 1	.10	.06	.07	.07	.05	.05	.05
2	.12	.17	.17	.22	.20	.21	.23
2- 3	2.34	1.89	2.16	2.17	1.77	1.60	1.32
4	.08	.12	.12	.16	.14	.15	.15
4- 5	.85	1.12	1.14	1.43	1.32	1.32	1.47
6- 7	.43	.33	.38	.38	.31	.26	.22
9	0	.04	.04	.05	.07	.10	.12
10-11	.07	.11	.12	.13	.15	.20	.21
13	.34	.22	.30	.22	.19	.21	.11
18	0	0	0	.01	.03	.03	0
22	.10	.11	.10	.13	.14	.14	.15
23-24	1.22	1.09	1.06	1.27	1.31	1.24	1.16
Monthly Totals	5.65	5.26	5.66	6.24	5.68	5.51	5.19
Dec. 6	.44	.49	.49	.45	.43	.45	.40
24-25	1.20	.95	1.12	1.13	.97	1.04	.92
Monthly Totals	1.64	1.44	1.61	1.58	1.40	1.49	1.32
1957 CALENDAR YEAR TOTALS	40.29	37.25	35.59	39.13	40.21	38.31	40.13
1958							
Jan. 5	.33	.43	.23	.27	.27	.17	.18
12-13	1.25	1.31	1.29	1.44	1.35	1.15	1.46
18	.17	.15	.16	.15	.14	.16	.14
19	.34	.28	.31	.27	.26	.28	.24
23	0	.02	.02	.02	.03	.04	.05
21-28	0	.02	.02	.02	.02	.02	0
Monthly Totals	2.09	2.21	2.03	2.17	2.07	1.82	2.07
Feb. 5	0	0	0	0	.03	.04	0
9	.26	.21	.20	.21	.25	.26	.20
10	.03	.02	.02	.02	.03	.03	.02
12	.05	.04	.04	.04	.04	.04	.03
14	.08	.08	.06	.07	.09	.11	.09
20	0	0	.01	0	0	.01	0
21-23	1.05	1.13	1.35	1.25	1.30	1.51	1.38
Monthly Totals	1.47	1.48	1.68	1.59	1.74	2.00	1.72
Mar. 1	.30	.41	.30	.35	.37	.49	.43
4	.27	.32	.24	.27	.28	.36	.30
5	.71	.47	.41	.32	.27	.29	.11
6	.05	.12	.10	.13	.16	.17	.30
8	.35	.26	.25	.23	.25	.24	.30
12	.65	.42	.41	.36	.38	.23	.38
17	0	0	0	0	.03	.02	0
22	.07	.08	.15	.12	.14	.15	.07
23	.16	.17	.35	.26	.31	.33	.15
28	0	0	0	.02	.03	.02	0
Monthly Totals	2.56	2.25	2.21	2.06	2.22	2.40	2.04
Apr. 8	1.21	0.45	0.50	0.75	0.83	0.50	0.85
13	1.24	1.38	1.30	1.16	1.20	1.25	1.10
17	.13	.08	.12	.10	.11	.11	.08
20	.68	.51	.70	.65	.71	.78	.67
26	.13	.11	.13	.16	.13	.15	.13
27	.62	.41	.46	.45	.37	.37	.20
28	.21	.49	.43	.69	.73	.92	1.07
29	.08	.09	.09	.10	.10	.11	.11
30	.74	.63	.66	.74	.67	.75	.62
Monthly Totals	5.04	4.15	4.39	4.80	4.85	4.94	4.83

Table 8.—Summary of Rainfall, in Inches, for Green Creek Study Area, May 1955 to September 1966—Continued

DATE OF STORM	GAGES 1-R	2-S	3-S	4-S	5-S	6-S	7-R
1958							
May 1	0.22	0.14	0.18	0.16	0.13	0.13	0.04
1- 2	.33	.40	.38	.50	.49	.58	.58
2- 3	.71	.60	.60	.66	.60	.63	.47
10	.15	.25	.14	.25	.35	.21	.10
14	.10	.07	.05	.05	.05	.02	0
15	.08	.06	.04	.05	.05	.02	0
16	.18	0	0	.06	.08	0	.10
25	.34	.25	.15	.20	.18	.17	.20
Monthly Totals	2.11	1.77	1.54	1.93	1.93	1.76	1.49
June 8	.24	.13	.20	.15	.07	.30	.26
16	1.22	.62	.83	1.08	1.14	1.56	1.18
21	.77	1.28	.63	.93	1.05	1.66	1.15
Monthly Totals	2.23	2.03	1.66	2.16	2.26	3.52	2.59
July 5	.26	.36	.27	.26	.25	.28	.27
6	1.65	1.12	1.00	.68	.56	.55	.34
7	.20	.30	.23	.21	.19	.22	.21
21	1.09	.77	.96	.53	.42	(.37)	.15
22	2.14	.93	1.30	.57	.40	(.33)	.09
Monthly Totals	5.34	3.48	3.76	2.25	1.82	1.75	1.06
Aug. 20-21	.60	.48	1.44	1.04	.94	1.37	.57
23	.10	.05	.10	.13	.08	.09	.08
24	.39	.04	.13	.09	.04	.03	0
Monthly Totals	1.09	0.57	1.67	1.26	1.06	1.49	0.65
Sept. 8	1.68	1.27	.86	1.30	.71	.49	.25
10	.44	.72	.39	.79	.50	.39	.30
16	1.25	1.10	.91	1.14	.66	.67	.52
19	.63	.57	1.06	.40	.64	.66	.57
22	.17	.27	.44	.22	.38	.43	.53
Monthly Totals	4.17	3.93	3.66	3.85	2.89	2.64	2.17
1958 WATER YEAR TOTALS	38.21	33.25	34.13	34.55	33.10	34.76	30.80
Oct. 2- 3	.49	.54	.44	.39	.35	.37	.34
11	.35	.44	.19	.23	.14	.38	.15
14	.22	.14	.07	.06	.03	.05	0
21	.60	.02	.07	0	0	0	0
25	.06	.05	.08	.05	.05	.11	.05
26	.26	.26	.35	.23	.22	.49	.21
Monthly Totals	1.98	1.45	1.20	0.96	0.79	1.40	0.75
Nov. 14	.87	1.00	.90	.85	.94	.97	.79
17	.19	.13	.21	.14	.17	.10	.07
27-28	.28	.35	.38	.42	.55	.45	.48
Monthly Totals	1.34	1.48	1.49	1.41	1.66	1.52	1.34
Dec. 1	.37	.65	.61	.60	.67	.65	.68
29	.60	.52	.62	.59	.75	.70	.75
Monthly Totals	0.97	1.17	1.23	1.19	1.42	1.35	1.43
1958 CALENDAR YEAR TOTALS	30.39	25.97	26.52	25.63	24.71	26.59	22.14
1959							
Jan.	0	0	0	0	0	0	0
Monthly Totals	0	0	0	0	0	0	0
Feb. 1	.07	.11	.11	.14	.19	.20	.22
3	.21	.26	.29	.30	.39	.40	.38
12	.02	.04	.05	.08	.09	.08	.12
13-14	.13	.05	.16	.27	.29	.40	.25
20	.39	.38	.33	.29	.29	.25	.27
Monthly Totals	0.82	0.84	0.94	1.08	1.25	1.33	1.24

Table 8.—Summary of Rainfall, in Inches, for Green Creek Study Area, May 1955 to September 1966—Continued

DATE OF STORM	GAGES 1-R	2-S	3-S	4-S	5-S	6-S	7-R
1959							
Mar. 4	0.23	0.23	0.25	0.21	0.16	0.10	0.15
24	.03	.07	.03	.02	.03	.01	.05
28	.09	.09	.12	.10	.08	.08	.12
Monthly Totals	0.35	0.39	0.40	0.33	0.27	0.19	0.32
Apr. 8	.21	.19	.20	.23	.23	.16	.12
9	0	.04	.03	.05	.07	.08	.12
11	.74	.71	.72	.70	.77	.70	.75
17	.36	.30	.29	.43	.50	.45	.44
18	.36	.29	.29	.41	.48	.43	.41
20	.34	.21	.22	.27	.29	.24	.18
Monthly Totals	2.01	1.74	1.75	2.09	2.34	2.06	2.02
May 2	.24	.24	.28	.29	.21	.05	.24
5	.44	.36	.44	.41	.28	.06	.25
10	.25	.10	.11	.08	.12	.09	.15
15	.27	.16	.26	.26	.29	.25	.19
22	.68	1.31	.71	.85	.61	.52	.48
26	.10	.17	.09	.10	.07	.06	.05
Monthly Totals	1.98	2.34	1.89	1.99	1.58	1.03	1.36
June 2	.76	.76	.67	.82	.80	.89	.44
3	.33	.46	.37	.55	.59	.72	.46
4	.53	.68	.56	.78	.81	.99	.60
21	.35	.11	.18	.08	.09	.04	0
22	.50	.24	.35	.18	.24	.14	.15
23-24	2.49	1.54	2.11	1.28	1.87	1.22	1.78
25-26	3.16	1.80	2.55	1.48	2.11	1.35	1.89
Monthly Totals	8.12	5.59	6.79	5.17	6.51	5.35	5.32
July 15	.30	.03	1.10	.06	.03	.53	0
16	.26	.16	.19	.14	.08	.10	0
19	1.19	1.18	1.19	1.26	.87	1.45	1.08
20	1.49	1.57	1.56	1.69	1.19	2.00	1.55
20-21	.89	1.07	1.04	1.18	.85	1.47	1.22
23	.38	.29	.31	.29	.19	.29	.17
26-27	.29	.27	.28	.27	.18	.27	.17
Monthly Totals	4.80	4.57	5.67	4.89	3.39	6.11	4.19
Aug. 8	.65	.06	.28	.06	.05	0	.05
27	.11	.18	.11	.20	.28	.46	.10
30-31	1.70	1.50	1.84	1.51	1.89	1.68	1.45
Monthly Totals	2.46	1.74	2.23	1.77	2.22	2.14	1.60
Sept. 20	.03	0	0	0	0	0	0
23	.77	1.29	.69	1.12	1.11	.81	.73
30	(2.54)	2.43	1.49	1.86	1.64	1.06	.68
Monthly Totals	3.34	3.72	2.18	2.98	2.75	1.87	1.41
1959 WATER YEAR TOTALS	28.17	28.03	25.77	23.86	24.18	24.35	20.98
Oct. 3- 4	8.40	7.90	7.60	7.60	7.40	6.80	6.85
13	.68	.82	.87	.98	.98	1.07	1.05
29	.25	.09	.15	.08	.06	.04	0
30	.05	.05	.05	.05	.05	.05	.05
30-31	.90	.62	.78	.63	.59	.47	.45
Monthly Totals	10.28	9.48	9.45	9.34	9.08	8.43	8.40
Nov. 3	1.25	.89	1.12	.91	.88	.69	.68
10	.10	.10	.08	.08	.08	.04	0
14	.05	.08	.08	.13	.08	.08	.05
15	0	.02	.02	.05	.05	.06	.07
Monthly Totals	1.40	1.09	1.30	1.17	1.09	.87	.80

Table 8.—Summary of Rainfall, in Inches, for Green Creek Study Area, May 1955 to September 1966—Continued

DATE OF STORM	GAGES 1-R	2-S	3-S	4-S	5-S	6-S	7-R
1959							
Dec. 11	0	0.16	0.09	0.21	0.28	0.34	0.45
14-15	.73	1.14	.84	1.18	1.34	1.40	1.40
15-16	.49	.58	.46	.57	.60	.58	.45
16	.13	.20	.16	.21	.23	.25	.25
16-17	.46	.50	.41	.46	.47	.42	.24
31	.99	1.07	.94	.97	.99	1.04	1.06
Monthly Totals	2.80	3.65	2.90	3.60	3.91	4.03	3.85
1959 CALENDAR YEAR TOTALS	38.36	35.15	35.50	34.41	34.39	33.41	30.51
1960							
Jan. 4-5	1.79	1.73	1.56	1.51	1.51	1.56	1.49
12	.12	.18	.16	.15	.15	.12	.12
13	.15	.22	.20	.18	.18	.14	.14
16	.09	.18	.16	.17	.19	.14	.19
Monthly Totals	2.15	2.31	2.08	2.01	2.03	1.96	1.94
Feb. 3	.97	.93	.95	.96	.81	.74	.83
4	.11	.09	.10	.09	.08	.07	.07
20	.15	.15	.18	.18	.18	.14	(.10)
23	.16	.18	.22	.24	.24	.19	(.15)
29	0	.05	.04	.06	.08	.10	.13
Monthly Totals	1.39	1.40	1.49	1.53	1.39	1.24	1.28
Mar. 2	.23	.20	.19	.17	.17	.18	.12
13	0	0	0	0	0	0	0
24-25	.80	.68	.78	.78	.68	.61	.60
26	.11	.17	.17	.22	.22	.22	.29
Monthly Totals	1.14	1.05	1.14	1.17	1.07	1.01	1.01
Apr. 25	.15	.24	.20	.22	.25	.23	.34
26	.45	.62	.53	.53	.59	.52	.75
27	.62	.69	.62	.56	.60	.50	.65
29	.33	.38	.34	.31	.33	.28	.36
Monthly Totals	1.55	1.93	1.69	1.62	1.77	1.53	2.10
May 4	1.42	1.53	1.37	1.22	1.27	1.05	1.25
5	.38	.32	.30	.23	.23	.17	.15
10	.05	.06	.06	.05	.04	.03	.03
17	.10	.12	.27	.19	.14	.25	.04
18	.06	.03	.10	.05	.02	.03	0
20	.09	.08	.26	.24	.19	.20	.07
25	0	.02	.04	.06	.06	.08	.04
28	.36	.46	.44	.69	.61	1.04	1.20
30	.31	.21	.23	.27	.20	.28	.16
Monthly Totals	2.77	2.83	3.07	3.00	2.76	3.13	2.94
June 1	.13	.08	.08	.10	.08	.10	.06
8	1.40	1.31	1.66	1.86	1.00	1.51	1.80
14	.55	.19	.12	.42	.44	.11	.38
25	.23	.26	.37	.38	.36	.45	.50
26	.07	.08	.12	.12	.12	.15	.18
Monthly Totals	2.38	1.92	2.35	2.88	2.00	2.32	2.92
1960							
July 7	.70	1.10	1.35	1.55	.15	.89	0
13	.10	.07	.05	.10	.06	.06	.20
14	1.15	.53	.44	.58	.36	.33	.82
14-15	.45	.25	.20	.29	.19	.19	.53
16	.16	.05	.05	.04	.02	.02	0
Monthly Totals	2.56	2.00	2.09	2.56	0.78	1.49	1.55
Aug. 9	.92	1.37	1.01	.88	1.25	.46	.54
10	.20	.33	.43	.17	.23	.20	.13
21	.54	.34	.65	.20	.17	.20	.12
29	.19	0	0	0	0	0	.03
Monthly Totals	1.85	2.04	2.09	1.25	1.65	0.86	0.82

Table 8.—Summary of Rainfall, in Inches, for Green Creek Study Area, May 1955 to September 1966—Continued

DATE OF STORM	GAGES 1-R	2-S	3-S	4-S	5-S	6-S	7-R
1960							
Sept. 6	0.05	0	0	0.08	0.04	0.11	0
9	.56	.10	.06	.10	.30	0	0
23	.75	.74	.64	.92	1.74	1.24	2.18
24	.20	.12	.12	.13	.21	.13	.12
26	.40	.23	.22	.25	.42	.25	.25
27	.07	.03	.04	.03	.05	.02	0
Monthly Totals	2.03	1.22	1.08	1.51	2.76	1.75	2.55
1960 WATER YEAR TOTALS	32.30	30.92	30.73	31.64	30.29	28.62	30.16
Oct. 4	.26	.23	.08	.19	.09	.47	.24
13	.55	.54	.75	1.10	.90	1.44	1.17
15-16	.27	.26	.36	.20	.17	.28	.22
18	.29	.28	.39	.20	.17	.28	.22
25	.06	.14	.12	.14	.26	.22	.16
28	0	0	0	.24	.08	.28	.05
Monthly Totals	1.43	1.45	1.70	2.07	1.67	2.97	2.06
Nov. 8	0	0	0	0	0	.04	.03
20	.20	.21	.19	.37	.44	.52	.27
Monthly Totals	0.20	0.21	0.19	0.37	0.44	0.56	0.30
Dec. 4	.22	.26	.25	0	0	0	0
6- 8	1.85	2.30	2.30	2.60	2.58	2.62	2.51
9	.08	.07	.09	.05	.05	.05	.04
10	.55	.48	.57	.56	.51	.54	.42
28-29	.14	.20	.26	.36	.58	.72	.82
30	.50	.54	.50	.55	.47	.55	.48
Monthly Totals	3.34	3.85	3.97	4.12	4.19	4.48	4.27
1960 CALENDAR YEAR TOTALS	22.79	22.21	22.94	24.09	22.51	24.10	23.74
1961							
Jan. 6- 7	3.80	3.38	3.43	3.82	3.88	3.85	3.30
11	.20	.22	.19	.43	.45	.39	.35
11-12	.75	.88	.78	.65	.67	.58	.55
24	.40	.46	.60	.54	.55	.52	.43
28	.25	.29	.35	.16	.16	.14	.15
29	0	0	0	.21	.20	.18	.20
Monthly Totals	5.40	5.23	5.35	5.81	5.91	5.66	4.98
Feb. 4- 5	1.91	1.61	1.66	1.78	1.69	1.76	1.57
6	.14	.12	.12	.06	.06	.06	.06
7	.20	.17	.18	.16	.15	.16	.14
15-16	.74	.68	.87	.40	.42	.43	.40
20	.48	.45	.57	.50	.53	.54	.50
24	.06	.05	.06	.10	.10	.11	.10
Monthly Totals	3.53	3.08	3.46	3.00	2.95	3.06	2.77
Mar. 16	.62	.39	.62	.46	.39	.52	.39
17	.15	.09	.15	0	0	0	0
25	0	0	0	.12	.20	.12	.22
26	.13	.27	.18	.13	.21	.13	.24
30	.70	.65	.86	.51	.25	.27	.19
Monthly Totals	1.60	1.40	1.81	1.22	1.05	1.04	1.04
Apr. 8	.18	.14	.12	.27	.20	.04	.05
28	.50	.82	.50	.67	.57	.34	.46
Monthly Totals	0.68	0.96	0.62	0.94	0.77	0.38	0.51
May 5	.30	.19	.13	0	0	0	0
6	.95	.61	.42	.15	.17	.11	.08
8	.39	.25	.17	.55	.64	.40	.30
13	.55	.51	.27	.11	.14	.11	.04
22-23	.27	.18	.60	.51	.40	.23	.45
25	.38	.64	.57	.38	.33	.25	.30
26	.12	.20	.18	.32	.28	.22	.25
Monthly Totals	2.96	2.58	2.34	2.02	1.96	1.32	1.42

Table 8.—Summary of Rainfall, in Inches, for Green Creek Study Area, May 1955 to September 1966—Continued

DATE OF STORM	GAGES 1-R	2-S	3-S	4-S	5-S	6-S	7-R
1961							
June 3	0.20	0.22	0.20	0.11	0.10	0.11	0.08
5	.10	.10	.09	.09	.09	.09	.07
6	.50	.54	.49	.53	.50	.52	.37
8	.07	.02	T	T	T	T	.05
14	.05	.05	.10	.10	.15	.10	.15
15	.10	.10	.15	.10	.05	.05	.05
15-18	3.20	3.30	3.65	3.72	3.92	3.72	3.95
25	.13	.10	.17	.12	.14	.13	.15
Monthly Totals	4.35	4.43	4.85	4.77	4.95	4.72	4.87
July 2	.08	.35	.48	.65	.22	.35	.38
8	1.40	.83	.23	.12	.15	.10	.07
9-10	1.54	.90	.42	.22	.28	.18	.13
15	.65	.53	.48	.13	.12	.11	.10
16	.67	.54	.48	.89	.79	.77	.66
22	1.15	.51	.42	.64	.70	.58	.80
23	.20	.09	.08	0	0	0	0
Monthly Totals	5.69	3.75	2.59	2.65	2.26	2.09	2.14
Aug. 7	0	0	0	0	0	0	.05
11	0	0	0	0	0	0	.07
19	.10	.04	T	.14	.07	.07	.60
30	T	0	T	0	.35	0	0
Monthly Totals	0.10	0.04	0	0.14	0.42	0.07	0.72
Sept. 4	.10	.18	.40	.07	.15	.07	.08
11-12	3.23	2.68	2.68	2.84	2.75	2.90	2.87
Monthly Totals	3.33	2.86	3.08	2.91	2.90	2.97	2.95
1961 WATER YEAR TOTALS	32.16	29.84	29.96	30.02	29.47	29.32	28.03
Oct. 2	2.10	1.55	2.40	2.28	2.00	1.95	2.00
3	0	0	0	0	0	0	0
9	2.40	3.04	2.42	3.11	3.80	3.76	4.95
10	.09	.13	.10	0	0	0	0
13	0	0	0	0	0	0	.07
Monthly Totals	4.59	4.72	4.92	5.39	5.80	5.71	7.02
Nov. 2	.90	.81	.98	.89	.93	.84	.78
14-15	.53	.84	.63	.97	.61	.95	.50
21	.05	.05	.04	.11	.13	.11	.08
22	.72	.75	.69	.86	1.07	.87	.66
28	T	.03	.02	.03	.03	.03	T
Monthly Totals	2.20	2.48	2.36	2.86	2.77	2.80	2.02
Dec. 5	.11	.12	.10	.09	.07	.08	.05
8	.10	.10	.10	.18	.14	.17	.10
9	.02	.02	.03	.24	.18	.24	.13
10	.45	.43	.48	0	0	0	0
14	.18	.17	.19	.13	.09	.12	.07
15	.03	.04	.03	0	0	0	0
16	.15	.18	.12	.19	.17	.17	.15
Monthly Totals	1.04	1.06	1.05	0.83	0.65	0.78	0.50
1961 CALENDAR YEAR TOTALS	35.47	32.59	32.43	32.54	32.39	30.60	30.94
1962							
Jan. 3	.03	T	T	T	T	T	.02
9	.05	.03	.03	T	T	T	0
22	.05	T	T	T	T	T	0
25	.05	.05	.04	.08	.09	.12	.08
Monthly Totals	0.18	0.08	0.07	0.08	0.09	0.12	0.10
Feb. 17	.18	.24	.28	.17	.16	.15	.15
23	.65	.69	.66	.81	.67	.63	.45
26	.15	.16	.15	0	0	0	0
27	.19	.20	.19	.09	.08	.07	.05
Monthly Totals	1.17	1.29	1.28	1.07	0.91	0.85	0.65

Table 8.—Summary of Rainfall, in Inches, for Green Creek Study Area, May 1955 to September 1966—Continued

DATE OF STORM		GAGES 1-R	2-S	3-S	4-S	5-S	6-S	7-R
1962								
Mar.	10	0.05	0.02	0.02	0.04	0.04	0.06	0.04
	14	.25	.08	.08	.08	.08	.11	.07
	16	.05	.04	.03	0	0	0	0
	20	.10	.07	.06	.05	.04	.05	.05
	30	.33	.35	.31	0	0	0	0
Monthly Totals		0.78	0.56	0.50	0.17	0.16	0.22	0.16
Apr.	4	1.22	1.42	1.41	1.56	1.48	1.44	1.50
	5	0	0	0	.11	.12	.13	.15
	11	.15	.28	.28	.23	.22	.25	.22
	22	.75	1.48	1.20	1.30	.83	1.00	.63
	26-27	0	0	0	.54	.69	.58	.78
	27	.55	.71	.64	.15	.19	.16	.22
	30	.18	.24	.22	.46	.59	.50	.67
Monthly Totals		2.85	4.13	3.75	4.35	4.12	4.06	4.17
May	28	.80	1.00	.94	.84	.66	.57	.65
Monthly Totals		0.80	1.00	0.94	0.84	0.66	0.57	0.65
June	1	.04	.05	.05	.12	.09	.08	.10
	6-7	.20	.15	.23	.18	.19	.23	.20
	8	.88	.67	1.00	.73	.75	.90	.82
	9	.38	.28	.43	.45	.46	.55	.50
	10	.55	.40	.61	.31	.30	.37	.35
	26	.25	.50	.52	.11	.04	.62	.05
	27	.25	.48	.52	0	0	0	0
	30	.75	.31	.63	.14	.07	.10	.12
Monthly Totals		3.30	2.84	3.99	2.04	1.90	2.85	2.14
July	16	.35	.16	.30	.02	.02	.02	.05
	18	0	0	0	.07	.08	.06	.24
	19	0	0	0	.63	.63	.60	.92
	25	0	0	0	.34	.34	.33	.52
	26	2.86	1.85	1.58	.52	.53	.50	.77
	27	0	0	0	0	0	0	.10
Monthly Totals		3.21	2.01	1.88	1.58	1.60	1.51	2.60
Aug.	2	1.25	1.85	1.02	.55	.25	.11	0
	11	0	0	0	0	0	0	.15
	21	0	.10	0	T	0	0	0
	24	.03	0	0	.07	0	.07	0
Monthly Totals		1.28	1.95	1.02	0.62	0.25	0.18	0.15
Sept.	1	.05	.12	.06	.04	.04	.25	.18
	5	0	0	0	.01	.02	.11	.08
	6	1.43	1.43	1.71	.91	.77	1.14	.72
	7	3.73	3.41	4.07	4.72	3.97	4.36	2.55
	9	.28	.26	.30	.11	.10	.10	.08
	16-17	.75	.20	.30	.25	.03	.10	.15
	25	.17	.15	.14	.05	.05	.06	.07
	26	.12	.10	.09	.22	.21	.26	.28
Monthly Totals		6.54	5.67	6.67	6.31	5.19	6.38	4.11
1962 WATER YEAR TOTALS		27.94	27.79	28.43	26.14	24.10	26.03	24.27
Oct.	8	3.17	3.72	2.34	3.00	4.00	3.17	4.00
	9	.07	.08	.06	.38	.50	.39	.50
	13	.16	.15	.20	.30	.25	.30	.22
	20	.12	.12	.32	.13	.18	.21	.17
	28	1.20	1.46	1.86	1.90	1.41	1.45	1.48
Monthly Totals		4.72	5.53	4.78	5.71	6.34	5.52	6.37
Nov.	19	.04	.04	.04	.08	.07	.09	.07
	20-21	.50	.52	.56	.43	.44	.51	.40
	24	.55	.63	.67	1.11	1.33	1.09	1.05
	26	.30	.35	.36	.29	.36	.29	.28
Monthly Totals		1.39	1.54	1.63	1.91	2.20	1.98	1.80

Table 8.—Summary of Rainfall, in Inches, for Green Creek Study Area, May 1955 to September 1966—Continued

DATE OF STORM	GAGES 1-R	2-S	3-S	4-S	5-S	6-S	7-R
1962							
Dec. 2	0.40	0.33	0.38	0.25	0.35	0.30	0.54
20	.18	.13	.08	.03	.08	.05	.08
25	.10	.14	.18	.15	.15	.18	.10
Monthly Totals	0.68	0.60	0.64	0.43	0.58	0.53	0.72
1962 CALENDAR YEAR TOTALS	26.90	27.20	27.15	25.11	24.00	24.77	23.62
1963							
Jan. 4	.09	.12	.11	.14	.14	.14	.18
11	.02	0	T	T	T	T	.05
19	.12	.15	.13	.19	.20	.21	.20
Monthly Totals	0.23	0.27	0.24	0.33	0.34	0.35	0.43
Feb. 11	.07	.04	.05	.05	.03	.05	.03
Monthly Totals	0.07	0.04	0.05	0.05	0.03	0.05	0.03
Mar. 10	.08	.06	.04	.21	.58	.50	.62
17	.05	.08	.03	.05	.07	.07	.06
Monthly Totals	0.13	0.14	0.07	0.26	0.65	0.57	0.68
Apr. 4- 5	.48	.37	.35	.43	.47	.52	.45
19	.25	.04	.04	.01	.01	T	.04
24	.10	.02	.02	.02	.02	0	.06
27	.65	.23	.22	.50	.50	.50	.52
28	2.63	.92	.89	.08	.08	.08	.08
Monthly Totals	4.11	1.58	1.52	1.04	1.08	1.10	1.15
May 5	.20	.13	.45	.18	.11	.53	.10
19	.07	.05	.07	.55	.72	.82	.70
22	1.65	1.20	1.57	1.02	1.32	1.53	1.30
28	1.25	1.28	.81	1.38	.94	1.08	.92
30	1.23	1.30	1.35	1.48	1.25	1.03	1.60
Monthly Totals	4.40	3.96	4.25	4.61	4.34	4.99	4.62
June 16	.92	1.27	1.60	3.12	2.93	2.84	4.02
19	.81	1.11	1.42	.29	.27	.26	.37
25	0	0	0	0	0	0	0
28	.20	.14	.17	.08	.05	.08	.02
Monthly Totals	1.93	2.52	3.19	3.49	3.25	3.18	4.41
July 9	0	0	0	0	0	0	.03
14	1.55	.68	.31	.20	.20	.07	.15
Monthly Totals	1.55	0.68	0.31	0.20	0.20	0.07	0.18
Aug. 8	.03	.01	.04	.01	.05	.05	.04
13	.35	.15	.41	.25	1.19	1.23	.97
14	.06	0	0	0	0	0	.05
30	1.28	.66	.80	.32	.11	.08	.15
Monthly Totals	1.72	0.82	1.25	0.58	1.35	1.36	1.21
Sept. 12	1.00	1.99	1.69	.87	.80	.92	.60
13	.43	.86	.73	.29	.27	.31	.20
14-15	.80	1.60	1.36	2.00	1.84	2.12	1.38
16	.05	.10	.09	0	0	0	0
18	.05	.10	.09	.04	.04	.05	.03
26	0	0	0	0	.12	0	0
Monthly Totals	2.33	4.65	3.96	3.20	3.07	3.40	2.21
1963 WATER YEAR TOTALS	23.26	22.33	21.89	21.81	23.43	23.10	23.81
Oct. 23	1.57	1.38	1.90	1.20	1.10	1.35	.79
Monthly Totals	1.57	1.38	1.90	1.20	1.10	1.35	0.79

Table 8.—Summary of Rainfall, in Inches, for Green Creek Study Area, May 1955 to September 1966—Continued

DATE OF STORM	GAGES 1-R	2-S	3-S	4-S	5-S	6-S	7-R
1963							
Nov. 8	3.68	3.66	2.85	3.15	3.15	3.64	2.55
9	.05	.06	.05	.05	.05	.06	.05
17	.09	.04	.05	.04	.03	.03	.02
18	.07	.12	.12	.14	.15	.18	.24
19	1.13	.62	.73	.59	.55	.56	.52
22	.23	.14	.19	.22	.12	.18	.06
27-28	.76	.93	.84	.97	.83	.96	.91
Monthly Totals	6.01	5.57	4.83	5.16	4.88	5.61	4.35
Dec. 10-11	.30	.40	.33	.46	.45	.45	.34
13	.07	.10	.09	.11	.12	.13	.11
14	.14	.13	.12	.14	.13	.15	.09
20	.06	.02	.02	.03	.02	.03	.02
22	.06	.03	.03	.04	.04	.04	.03
Monthly Totals	0.63	0.68	0.59	0.78	0.76	0.80	0.59
1963 CALENDAR YEAR TOTALS	24.68	22.29	22.16	20.90	21.05	22.83	20.65
1964							
Jan. 15	T	T	T	T	T	T	T
16	.48	.28	.32	.30	.29	.26	.18
17	.32	.37	.34	.47	.52	.59	.79
29	.83	.74	.74	.70	.72	.72	.71
30	1.40	1.23	1.23	1.15	1.18	1.17	1.15
Monthly Totals	3.03	2.62	2.63	2.62	2.71	2.74	2.83
Feb. 3- 4	1.22	.98	1.00	.89	.89	.87	.79
12-13	.29	.35	.38	.40	.38	.34	.31
20	.05	.06	.07	.09	.08	.14	.03
Monthly Totals	1.56	1.39	1.45	1.38	1.35	1.35	1.13
Mar. 1	.04	0	0	0	0	0	.02
4	.14	.16	.17	.19	.19	.17	.15
8- 9	.69	.88	.89	1.06	1.07	.98	.94
18-19	.88	.92	.90	1.00	1.22	1.14	1.25
Monthly Totals	1.75	1.96	1.96	2.25	2.48	2.29	2.36
Apr. 4- 5	.31	.59	.57	.87	1.18	1.27	1.48
16	T	.05	.04	.06	.05	.06	T
21	2.52	2.70	2.62	2.92	3.25	3.00	3.80
26	.64	.81	.60	.66	.61	.52	.42
Monthly Totals	3.47	4.15	3.83	4.51	5.09	4.85	5.70
May 1	0	0	0	0	0	0	.05
8	.12	.32	.35	.52	.96	1.27	.50
9	.04	.09	.10	.13	.24	.30	.10
22	.03	.20	.26	.16	.16	.26	.02
27	.15	.42	.10	.16	.21	.07	.06
30	.11	.33	.08	.12	.17	.05	.05
Monthly Totals	0.45	1.36	1.89	1.09	1.74	1.95	0.78
June 4	.20	.20	.20	.26	.23	.27	.20
12	0	.06	.03	.07	.15	.10	.35
15	.03	.02	.02	.02	.03	.02	.02
16	.59	.59	.45	.51	.93	.51	1.15
24	.11	T	T	0	0	0	0
Monthly Totals	0.93	0.87	0.70	0.86	1.34	0.90	1.72
July 2	.02	.16	0	.15	.12	.21	.05
25	.02	.02	T	.38	.30	.24	1.02
31	.92	.04	.07	T	T	0	.11
Monthly Totals	0.96	0.22	0.07	0.53	0.42	0.45	1.18

Table 8.—Summary of Rainfall, in Inches, for Green Creek Study Area, May 1955 to September 1966—Continued

DATE OF STORM		GAGES 1-R	2-S	3-S	4-S	5-S	6-S	7-R
1964								
Aug.	15	0.65	0.46	0.56	0.60	0.80	0.46	0.50
	15-16	.47	.26	.34	.31	.38	.20	.15
	17	.05	.13	.13	.21	.32	.21	.31
	22	3.14	1.86	2.65	2.07	1.88	2.93	1.40
	23	0	.04	.05	.06	.07	.13	.09
	27	.50	.09	.15	0	0	0	.02
	30	.02	.02	.03	0	0	0	.02
Monthly Totals		4.83	2.86	3.91	3.25	3.45	3.93	2.49
Sept.	4	.20	0	0	0	0	0	0
	11	.63	.17	.46	.16	.11	.13	.19
	14	.09	.08	.19	.08	.07	.08	.14
	16	1.73	.47	.96	.51	.53	.59	.50
	20	2.97	2.70	3.49	3.08	3.39	3.66	2.73
	20-21	3.30	2.96	3.84	3.37	3.69	3.96	2.93
	21	.10	.05	.08	.05	.04	.04	0
	21-22	.15	.08	.13	.08	.07	.05	0
	23	1.63	1.55	.82	1.26	.81	.68	.39
	24	.07	.05	.03	.03	.02	.01	0
	26	0	.09	.03	.10	.08	.08	.07
	27	.08	.23	.10	.23	.17	.17	.14
Monthly Totals		10.95	8.43	10.13	8.95	8.98	9.45	7.09
1964 WATER YEAR TOTALS		36.14	31.49	32.89	32.58	34.30	35.67	31.01
Oct.	12	.12	.12	.10	.11	.11	.10	.07
	18	.04	.05	.05	.04	.05	.05	.04
	25-26	1.74	2.87	2.19	2.68	2.67	2.47	2.68
Monthly Totals		1.90	3.04	2.34	2.83	2.83	2.62	2.79
Nov.	3	.78	1.10	.92	1.08	1.10	1.08	1.18
	15	.05	.30	.15	.29	.33	.33	.35
	16-17	1.08	.73	.53	.56	.48	.38	.20
	17-18	.96	.86	.58	.75	.67	.58	.44
	18-19	.48	.43	.29	.35	.33	.29	.22
Monthly Totals		3.35	3.42	2.47	3.03	2.91	2.66	2.39
Dec.	9	.55	.54	.55	.55	.52	.57	.51
	18	0	.01	.05	.01	0	.01	0
Monthly Totals		0.55	0.55	0.60	0.56	0.52	0.58	0.51
1964 CALENDAR YEAR TOTALS		33.73	30.87	30.98	31.86	33.82	33.77	30.97
1965								
Jan.	2	.65	.57	.65	.66	.80	.77	1.01
	9	0	.02	T	.03	.06	.03	.20
	21	1.10	1.23	1.05	1.14	1.40	1.22	1.47
Monthly Totals		1.75	1.82	1.70	1.83	2.26	2.02	2.68
Feb.	4	.05	.03	.05	.05	.05	.06	.05
	8- 9	1.95	2.11	2.22	2.07	2.45	2.28	2.90
	15-16	.70	.73	.72	.94	.90	.92	.80
	17	.08	.07	.08	.09	.08	.08	.06
	23	.07	.14	.04	.20	.15	.12	.21
Monthly Totals		2.85	3.08	3.11	3.35	3.63	3.44	4.02
Mar.	11	.08	.11	.20	.24	.19	.14	.08
	16	.03	.12	.15	.33	.33	.32	.60
	25	.18	.22	.18	.09	.08	.06	.05
	29	0	.01	.01	.03	.04	.03	.05
	30	.06	.07	.07	.09	.11	.09	.10
	31	.04	.04	.04	.05	.05	.05	.04
Monthly Totals		0.39	0.57	0.65	0.83	0.80	0.69	0.92

Table 8.—Summary of Rainfall, in Inches, for Green Creek Study Area, May 1955 to September 1966—Continued

DATE OF STORM		GAGES 1-R	2-S	3-S	4-S	5-S	6-S	7-R
1965								
Apr.	1	0.03	0.06	0.05	0.07	0.05	0.05	0.02
	5	.65	.81	.69	.73	.45	.50	.15
	9	.05	0	0	T	T	T	.03
	25-26	.67	.74	.82	.55	.34	.42	.25
Monthly Totals		1.40	1.61	1.56	1.35	0.84	0.97	0.45
May	5	0	.02	T	T	.02	T	.40
	8	.02	.02	.03	.02	.02	.03	.03
	9	.80	.80	.99	1.00	1.08	1.14	1.13
	10	1.05	1.32	1.53	1.73	2.00	2.23	2.65
	12-13	1.25	1.21	1.23	1.35	1.39	1.41	1.50
	14	1.20	.95	1.00	.95	.92	.86	.70
	15-16	2.40	2.54	2.49	2.80	2.91	3.03	3.33
	18	.85	.30	.50	.40	.40	.74	.33
	27	.10	.10	.09	.05	.06	.08	.03
	31	.05	.06	.06	.05	.06	.06	.03
Monthly Totals		7.72	7.32	7.92	8.35	8.86	9.58	10.13
June	5	.65	.80	.94	.95	.95	.76	.80
	11	.08	0	0	0	0	0	0
	22	.08	T	T	0	0	0	0
Monthly Totals		0.81	0.80	0.94	0.95	0.95	0.76	0.80
July	14	.27	.64	1.00	.51	.93	1.36	.77
	15	.55	.37	.90	.30	.05	.09	0
	28	.50	.09	1.10	.56	.30	.30	.05
Monthly Totals		1.32	1.10	3.00	1.37	1.28	1.75	0.82
Aug.	8	.15	.03	.30	.43	.14	.30	.30
	9	.06	.01	.10	.12	.04	.07	.05
	14	.45	.44	.59	.80	.71	1.09	1.25
	15	.53	.45	.65	.82	.70	1.02	1.03
	16	0	.08	.08	.18	.19	.34	.57
	24	.18	.25	T	.04	.08	.03	0
	28	.10	.24	.30	.20	.18	.17	.10
	31	.20	.53	.66	.46	.40	.41	.25
Monthly Totals		1.67	2.03	2.68	3.05	2.44	3.43	2.55
Sept.	1	.11	.28	.36	.25	.22	.22	.14
	3	.10	.05	.09	.18	.45	.44	1.35
	21	.72	.62	.50	.37	.19	.34	.10
	21-22	.50	.61	.46	.40	.25	.47	.18
Monthly Totals		1.43	1.56	1.41	1.20	1.11	1.47	1.77
1965 WATER YEAR TOTALS		25.14	26.90	28.38	28.70	28.43	29.97	30.83
Oct.	3- 4	.65	.68	.69	.72	.69	.73	.75
	4	.31	.23	.25	.22	.18	.17	.12
	18	2.05	1.81	1.80	1.90	1.65	1.67,	1.73
Monthly Totals		3.01	2.72	2.74	2.84	2.52	2.57	2.60
Nov.	3	.68	.94	.90	.87	.94	.94	.85
	8	1.28	1.80	1.71	1.68	1.85	1.87	1.71
Monthly Totals		1.96	2.74	2.61	2.55	2.79	2.81	2.56
Dec.	1	.09	.10	.09	.10	.09	.10	.10
	2	.89	1.00	.99	1.11	1.01	1.10	1.16
	10	.14	.19	.17	.18	.28	(.15)	.12
	17	.08	.12	.09	.12	.13	.14	.18
	18	.05	.09	.07	.09	.10	.11	.15
	18-19	.44	.39	.36	.37	.35	.35	.31
	23	.05	.09	.13	.09	.10	(.10)	.01
Monthly Totals		1.74	1.98	1.90	2.06	2.06	2.05	2.03
1965 CALENDAR YEAR TOTALS		26.05	27.33	30.22	29.73	29.54	31.54	32.33

Table 8.—Summary of Rainfall, in Inches, for Green Creek Study Area, May 1955 to September 1966—Continued

DATE OF STORM	GAGES 1-R	2-S	3-S	4-S	5-S	6-S	7-R
1966							
Jan. 2	0.03	0.08	0.09	0.04	0.05	0.03	0.03
18	.15	.12	.12	.14	.14	.14	(.10)
19	.40	.35	.34	.40	.41	.41	(.31)
21	.05	.08	.06	.09	.11	.11	.10
22	.08	.04	.04	.04	.03	.02	0
23	.12	.06	.08	.06	.04	.03	0
28	.13	.12	.14	.13	.15	.14	.11
Monthly Totals	0.96	0.85	0.87	0.90	0.93	0.88	0.65
Feb. 8	0	.17	.12	.29	.39	.52	.90
9	.75	.95	.96	1.30	1.35	1.48	1.55
23	.13	.05	.05	.07	.06	.01	.10
26	.37	.47	.40	.44	.42	.48	.55
Monthly Totals	1.25	1.64	1.53	2.10	2.22	2.49	3.10
Mar. 12	0	.09	.06	.05	.17	.13	.20
28	.04	.18	.26	.22	.13	.13	.21
Monthly Totals	0.04	0.27	0.32	0.27	0.30	0.26	0.41
Apr. 13	.15	.17	.11	.12	.07	.07	.05
17	.69	.93	.59	.20	.41	.44	.39
22	.78	.59	.69	.55	.69	.63	.50
23-24	.42	.57	.58	.61	.87	.89	1.05
24-25	1.05	.94	1.04	.93	1.24	1.19	1.17
28	.28	.44	.33	.44	.59	.78	.90
29	.70	.68	.56	.63	.79	.98	1.00
30	2.17	1.38	1.24	1.14	1.31	1.45	1.04
Monthly Totals	6.24	5.70	5.14	4.62	5.97	6.43	6.10
May 1	.82	.54	.49	.45	.53	.60	.46
22	0	.05	.03	0	0	.05	.03
Monthly Totals	0.82	0.59	0.52	0.45	0.53	0.65	0.49
June 13	3.55	4.00	2.53	3.52	3.30	2.15	2.60
17	0	.08	.07	.07	.15	.17	.10
18	.27	.92	.95	.48	.95	.94	.35
24	0	0	0	0	0	0	.13
Monthly Totals	3.82	5.00	3.55	4.07	4.40	3.26	3.18
July 7	0	.35	.18	.52	.02	.60	.05
25	.85	.08	.25	.05	.06	.30	1.70
30	0	.15	.50	.22	.17	.23	.60
Monthly Totals	0.85	0.58	0.93	0.79	0.25	1.13	2.35
Aug. 7	.06	.05	.20	.20	.16	.65	.80
11	.20	.25	.27	.21	.24	.19	.17
13	.30	.35	.39	.29	.31	.24	.15
13-14	1.70	2.73	2.76	2.57	3.09	2.69	2.96
24	.95	.88	.91	.56	.44	.37	.62
29	.79	.65	.55	.94	.88	.77	.54
Monthly Totals	4.00	4.91	5.08	4.77	5.12	4.91	5.24
Sept. 3	.85	.18	.28	.20	.21	.14	.05
8- 9	2.10	1.31	1.80	2.00	2.00	.49	.85
14	.50	.36	.44	.30	.22	.26	.17
15	1.25	1.31	1.46	1.22	.99	1.38	1.48
17	.65	.67	.75	.62	.50	.70	.74
27	0	.03	.01	.02	.04	.05	.12
Monthly Totals	5.35	3.86	4.74	4.36	3.96	3.02	3.41
1966 WATER YEAR TOTALS	30.04	30.84	29.93	29.78	31.05	30.46	32.12

( ) Estimated on basis of rainfall at adjacent gages.
Rain gage designation and Thiessen Polygon weight factors in parenthesis are 1-R (.171), 2-S (.183), 3-S (.195), 4-S (.188), 5-S (.161), 6-S (.030), 7-R (.072).

Table 9.—Monthly Surface-Water Budget for Gaged Sites in Green Creek Study Area, 1955-66
[Prior to November 1955, data are for Reservoir 1; November 1955 to April 1956, data are for Reservoirs 1-4 and 6; May 1956 to December 1956, data are for Reservoirs 1-7; after December 1956, data are for Reservoirs 1-8.]

MONTH AND YEAR	WEIGHTED RAINFALL ON STUDY AREA (INCHES)	COMBINED RESERVOIR INFLOW, Q_n (ACRE-FEET)	COMBINED CHANGE IN RESERVOIR CONTENTS, Δs, (ACRE-FEET)	DISCHARGE (ACRE-FEET)		COMBINED RESERVOIR CONSUMPTION, C (ACRE-FEET)		RAINFALL ON RESERVOIR SURFACE, R (ACRE-FEET)
				FROM RESERVOIRS, Q_o	FROM STUDY AREA	EVAPORATION, C_e	OTHER, C_s	
1954								
Oct.	–	–	–	–	–	–	–	–
Nov.	–	–	–	–	–	–	–	–
Dec.	–	–	–	–	–	–	–	–
1955								
Jan.	–	–	–	–	–	–	–	–
Feb.	–	–	–	–	–	–	–	–
Mar.	–	–	–	–	–	–	–	–
Apr.	–	–	–	–	–	–	–	–
May	5.51	782.8	+ 398.7	413.6	–	15.5	3.9	48.9
June	3.64	23.6	- 235.8	243.0	–	26.0	4.5	14.1
July	.79	2.0	- 30.4	0	–	22.6	11.2	1.4
Aug.	1.00	2.9	- 43.5	17.3	–	16.6	14.3	1.8
Sept.	3.18	32.8	+ 10.0	13.1	–	12.0	3.5	5.8
Water Year Total	–	–	–	–	–	–	–	–
1955								
Oct.	1.61	21.3	- 1.1	6.0	–	11.5	7.6	2.7
Nov.	.38	4.2	- 23.4	6.0	–	10.7	12.2	1.3
Dec.	.14	.2	- 13.7	0	–	6.9	7.3	.3
1956								
Jan.	1.32	22.2	- 8.6	17.9	–	6.2	10.1	3.4
Feb.	1.30	20.5	+ 12.3	0	–	6.5	4.0	2.3
Mar.	.06	0	- 24.9	2.0	–	13.7	9.2	0
Apr.	9.50	3,308.3	+3,302.4	105.1	–	22.2	8.7	130.1
May	4.71	1,483.9	-3,860.2	5,286.3	–	214.4	64.6	221.2
June	.56	39.0	- 197.3	79.5	–	104.0	58.7	5.9
July	.42	2.1	- 173.3	50.6	–	79.6	48.3	3.1
Aug.	.47	5.4	- 136.8	52.8	–	60.3	33.2	4.1
Sept.	0	0	- 91.9	39.0	–	40.5	12.4	0
Water Year Total	18.34	–	–	–	–	–	–	–
1956								
Oct.	1.82	23.3	- 28.9	23.4	–	19.6	15.8	6.6
Nov.	1.32	10.5	- 8.8	0	–	10.2	13.6	4.5
Dec.	2.98	213.1	+ 143.4	51.0	–	10.6	18.6	10.5
1957								
Jan.	.77	32.0	- 18.2	22.2	–	9.8	21.9	3.7
Feb.	1.06	13.1	- 9.3	.6	–	11.9	15.8	5.9
Mar.	2.47	27.8	- 5.4	2.5	–	17.3	26.0	12.6
Apr.	7.79	1,476.6	+ 919.6	586.2	–	23.0	29.0	81.2
May	9.27	3,283.6	- 93.2	3,393.3	–	89.4	67.8	173.7
June	1.32	137.9	- 247.3	258.0	–	104.7	43.4	20.9
July	.46	24.6	- 175.0	17.8	–	109.2	80.6	8.0

Table 9.—Monthly Surface-Water Budget for Gaged Sites in Green Creek Study Area, 1955-66—Continued

MONTH AND YEAR	WEIGHTED RAINFALL ON STUDY AREA (INCHES)	COMBINED RESERVOIR INFLOW, Q_n (ACRE-FEET)	COMBINED CHANGE IN RESERVOIR CONTENTS, Δs, (ACRE-FEET)	DISCHARGE (ACRE-FEET)		COMBINED RESERVOIR CONSUMPTION, C (ACRE-FEET)		RAINFALL ON RESERVOIR SURFACE, R (ACRE-FEET)
				FROM RESERVOIRS, Q_o	FROM STUDY AREA	EVAPORATION, C_e	OTHER, C_s	
1957								
Aug.	0.01	0.1	- 193.6	40.2	—	79.8	75.5	1.8
Sept.	3.38	10.9	- 43.2	0	—	45.5	38.7	30.1
Water Year Total	32.65	5,253.5	+ 240.1	4,395.2	—	531.0	446.7	359.5
1957								
Oct.	4.96	206.7	+ 164.3	24.8	—	33.4	27.6	43.4
Nov.	5.60	484.8	+ 245.4	239.0	—	25.9	54.2	79.7
Dec.	1.50	45.9	- 32.1	26.7	—	34.1	39.3	22.1
1958								
Jan.	2.07	85.0	+ 12.2	47.1	—	23.9	32.4	30.6
Feb.	1.67	43.9	- 7.1	23.9	—	23.8	25.3	22.0
Mar.	2.25	118.5	- 12.5	92.7	—	34.3	37.7	33.7
Apr.	4.71	382.9	+ 212.7	149.6	—	60.2	27.9	67.5
May	1.79	293.3	- 194.1	412.8	—	88.2	16.7	30.3
June	2.35	29.4	- 107.8	14.0	65	97.6	52.8	27.2
July	2.78	222.1	+ 25.5	77.7	88	111.2	57.3	49.6
Aug.	1.11	8.3	- 175.8	53.2	0	81.3	60.7	11.1
Sept.	3.33	46.4	- 29.0	14.0	0	40.8	59.3	38.7
Water Year Total	34.12	1,967.2	+ 101.7	1,175.5	—	654.7	491.2	455.9
1958								
Oct.	1.22	5.9	- 34.8	1.6	0	25.2	28.3	14.4
Nov.	1.46	7.5	- 25.6	4.3	0	20.9	21.0	13.1
Dec.	1.25	6.9	- 30.6	7.0	0	17.0	23.7	10.2
1959								
Jan.	0	0	- 25.7	1.8	0	17.9	6.0	0
Feb.	1.07	4.0	- 11.3	0	0	12.4	9.8	6.9
Mar.	.32	2.9	- 51.0	0	0	35.8	20.6	2.5
Apr.	2.00	15.3	- 28.2	7.8	0	34.3	14.3	12.9
May	1.74	5.6	- 31.8	1.0	0	36.1	13.5	13.2
June	6.12	280.8	+ 207.2	55.7	136	43.5	18.2	43.8
July	4.80	153.4	+ 59.6	21.4	14	70.8	49.5	47.9
Aug.	2.02	32.5	- 89.7	32.0	0	67.2	41.4	18.4
Sept.	2.61	36.0	- 19.7	3.7	8.1	46.2	30.9	25.1
Water Year Total	24.61	550.8	- 81.6	136.3	158.1	427.3	277.2	208.4
1959								
Oct.	9.21	2,693.0	+ 559.8	2,172.8	4,500	77.2	74.3	191.1
Nov.	1.10	86.2	- 52.6	78.0	189	36.6	45.4	21.2
Dec.	3.53	126.0	+ 24.9	70.2	316	33.5	42.9	45.5
1960								
Jan.	2.07	661.6	+ 22.9	602.4	1,180	38.2	34.8	36.7
Feb.	1.39	105.4	- 42.2	102.7	336	40.4	28.7	24.2
Mar.	1.08	68.1	- 24.2	27.2	161	54.1	28.8	17.8

Table 9.—Monthly Surface-Water Budget for Gaged Sites in Green Creek Study Area, 1955-66—Continued

MONTH AND YEAR	WEIGHTED RAINFALL ON STUDY AREA (INCHES)	COMBINED RESERVOIR INFLOW, Q_n (ACRE-FEET)	COMBINED CHANGE IN RESERVOIR CONTENTS, Δs, (ACRE-FEET)	DISCHARGE (ACRE-FEET) FROM RESERVOIRS, Q_o	DISCHARGE (ACRE-FEET) FROM STUDY AREA	COMBINED RESERVOIR CONSUMPTION, C (ACRE-FEET) EVAPORATION, C_e	COMBINED RESERVOIR CONSUMPTION, C (ACRE-FEET) OTHER, C_s	RAINFALL ON RESERVOIR SURFACE, R (ACRE-FEET)
1960								
Apr.	1.74	28.9	- 63.5	14.7	80	76.7	27.2	26.2
May	2.93	304.0	+ 21.3	200.3	494	111.7	16.1	45.4
June	2.40	66.8	- 105.7	42.4	62	121.7	42.1	33.7
July	1.86	54.4	- 125.0	62.5	.2	85.6	59.3	28.0
Aug.	1.51	17.7	- 122.0	37.5	0	70.1	51.1	19.0
Sept.	1.84	9.6	- 84.3	19.3	0	55.0	33.0	13.4
Water Year Total	30.66	4,221.7	+ 9.4	3,430.0	7,318.2	800.8	483.7	502.2
1960								
Oct.	1.91	11.2	- 36.8	0	0	31.7	28.7	12.4
Nov.	.32	1.7	- 43.1	3.2	0	20.4	23.0	1.8
Dec.	4.03	31.6	+ 20.7	0	0	10.9	26.5	26.5
1961								
Jan.	5.48	387.9	+ 343.3	52.8	711	20.8	20.0	49.0
Feb.	3.12	309.2	+ 175.3	118.4	694	36.9	21.2	42.6
Mar.	1.31	26.1	- 46.9	14.7	140	64.5	22.1	28.3
Apr.	.69	23.3	- 92.4	11.1	48	78.1	37.1	10.6
May	2.09	31.4	- 64.9	4.4	27	93.4	30.6	32.1
June	4.71	78.9	+ 22.0	1.4	99	79.9	31.9	56.3
July	3.02	331.6	+ 42.2	202.4	175	95.1	45.0	53.1
Aug.	.21	.7	- 180.4	48.1	0	84.1	49.7	.8
Sept.	3.00	16.5	- 62.0	9.0	0	56.7	43.7	30.9
Water Year Total	29.89	1,250.1	+ 77.0	465.5	1,894	672.5	379.5	344.4
1961								
Oct.	5.45	777.4	+ 353.9	387.7	1,210	57.9	42.4	64.5
Nov.	2.50	48.4	+ 2.0	10.2	47	32.6	40.3	36.7
Dec.	.84	23.4	- 17.2	3.6	20	30.9	20.8	14.7
1962								
Jan.	.10	15.8	- 42.1	7.4	10	29.8	22.4	1.7
Feb.	1.03	10.7	- 29.2	0	3.4	43.8	12.8	16.7
Mar.	.36	8.6	- 52.9	0	0	55.1	13.5	7.1
Apr.	3.92	60.1	+ 23.0	3.6	55	66.8	13.1	46.4
May	.78	10.4	- 125.8	5.2	5.6	94.8	46.1	9.9
June	2.72	19.0	- 69.9	4.4	0	72.7	44.2	32.4
July	2.06	22.2	- 100.6	18.5	0	74.2	50.1	20.0
Aug.	.78	24.9	- 92.6	10.4	0	71.7	47.8	12.4
Sept.	5.84	752.9	+ 416.0	284.8	677	61.9	54.3	64.1
Water Year Total	26.38	1,773.8	+ 264.6	735.8	2,030	692.2	407.8	326.6
1962								
Oct.	5.57	759.0	+ 130.3	567.7	814	68.5	74.1	81.6
Nov.	1.78	45.1	- 47.1	20.2	15	39.7	56.7	24.4
Dec.	.60	10.8	- 39.2	9.8	11	25.3	22.7	7.8

Table 9.—Monthly Surface-Water Budget for Gaged Sites in Green Creek Study Area, 1955-66—Continued

MONTH AND YEAR	WEIGHTED RAINFALL ON STUDY AREA (INCHES)	COMBINED RESERVOIR INFLOW, Q_n (ACRE-FEET)	COMBINED CHANGE IN RESERVOIR CONTENTS, Δs, (ACRE-FEET)	DISCHARGE (ACRE-FEET)		COMBINED RESERVOIR CONSUMPTION, C (ACRE-FEET)		RAINFALL ON RESERVOIR SURFACE, R (ACRE-FEET)
				FROM RESERVOIRS, Q_o	FROM STUDY AREA	EVAPORATION, C_e	OTHER, C_s	
1963								
Jan.	0.31	0.5	- 61.2	19.0	24	28.9	17.5	3.7
Feb.	.05	.1	- 53.9	3.5	6.3	38.0	13.3	.8
Mar.	.36	8.2	- 72.4	12.2	0	65.3	5.2	2.1
Apr.	1.65	154.7	+ 55.7	35.8	6.9	64.2	22.2	23.2
May	4.45	192.6	+ 65.2	55.9	81	65.7	56.5	50.7
June	3.14	145.3	- 36.6	76.0	293	97.7	40.1	31.9
July	.46	8.2	- 208.7	38.7	0	105.3	82.0	9.1
Aug.	1.18	14.0	- 145.4	29.4	0	69.6	68.3	7.9
Sept.	3.26	136.1	+ 74.7	18.5	88	45.4	24.9	27.4
Water Year Total	22.81	1,474.6	- 338.6	886.7	1,339.2	713.6	483.5	270.6
1963								
Oct.	1.33	20.5	- 35.6	0	0	40.6	25.9	10.4
Nov.	5.20	544.6	+ 406.8	112.4	651	33.0	48.7	56.3
Dec.	.69	18.6	- 47.2	1.0	0	18.3	56.0	9.6
1964								
Jan	2.74	143.3	+ 76.7	40.0	147	35.8	28.6	37.8
Feb.	1.37	234.5	- 3.6	193.0	274	39.9	26.5	21.3
Mar.	2.15	39.7	- 30.2	8.1	40	65.3	26.2	29.7
Apr.	4.51	712.3	+ 118.9	533.6	1,610	90.5	32.6	63.3
May	1.18	35.5	- 113.0	14.9	33	107.5	42.0	15.9
June	1.05	15.6	- 191.6	55.2	0	108.0	56.7	12.7
July	.55	22.7	- 193.0	81.2	0	88.7	50.7	4.9
Aug.	3.53	138.4	+ 3.9	48.5	0	63.9	49.3	27.2
Sept.	9.14	2,496.2	+ 790.1	1,740.5	4,260	59.3	79.7	173.4
Water Year Total	33.44	4,421.9	+ 782.2	2,828.4	7,020	750.8	522.9	462.5
1964								
Oct.	2.62	148.3	- 275.5	330.0	542	80.1	56.0	42.3
Nov.	2.89	297.2	- 13.5	273.6	386	46.7	43.2	52.8
Dec.	.55	41.6	- 48.2	25.3	51	38.9	34.7	9.1
1965								
Jan.	2.01	52.3	- 17.2	23.7	80	39.6	35.3	29.1
Feb.	3.35	708.8	+ 54.2	639.4	1,230	34.9	36.5	56.2
Mar.	.69	76.0	- 47.0	53.1	103	51.2	28.7	10.0
Apr.	1.17	98.2	- 44.0	51.4	106	88.4	23.4	21.0
May	8.55	2,340.7	+ 148.5	2,223.9	5,130	100.9	30.2	162.8
June	.86	43.5	- 158.6	53.8	121	117.9	45.0	14.6
July	1.52	28.2	- 158.4	26.8	20	121.4	58.5	20.1
Aug.	2.69	17.3	- 136.9	33.2	6.9	94.1	52.7	25.8
Sept.	1.42	5.5	- 107.4	20.7	0	57.9	47.2	12.9
Water Year Total	28.32	3,857.6	- 804.0	3,754.9	7,799.9	872.0	491.4	456.7
1965								
Oct.	2.71	32.6	- 6.6	0	0	36.0	27.9	24.7
Nov.	2.57	25.1	+ 3.5	0	0	22.3	21.6	22.3
Dec.	1.97	5.1	- 3.1	0	0	14.7	10.3	16.8

Table 9.–Monthly Surface-Water Budget for Gaged Sites in Green Creek Study Area, 1955-66–Continued

MONTH AND YEAR	WEIGHTED RAINFALL ON STUDY AREA (INCHES)	COMBINED RESERVOIR INFLOW, Q_n (ACRE-FEET)	COMBINED CHANGE IN RESERVOIR CONTENTS, Δs, (ACRE-FEET)	DISCHARGE (ACRE-FEET)		COMBINED RESERVOIR CONSUMPTION, C (ACRE-FEET)		RAINFALL ON RESERVOIR SURFACE, R (ACRE-FEET)
				FROM RESERVOIRS, Q_o	FROM STUDY AREA	EVAPORATION, C_e	OTHER, C_s	
1966								
Jan.	0.86	5.7	- 15.8	0.8	0	12.3	16.0	7.6
Feb.	2.05	38.1	+ 23.6	.6	57.0	19.8	8.1	14.0
Mar.	.27	8.6	- 36.0	0	0	39.1	7.4	1.9
Apr.	5.74	286.8	+ 270.4	3.8	289	39.9	16.6	43.9
May	.58	238.5	+ 43.3	95.5	221	78.6	28.5	7.4
June	3.90	382.7	+ 73.5	228.3	639	89.4	46.2	54.7
July	.98	8.0	- 187.4	39.7	.1	108.3	56.4	9.0
Aug.	4.86	137.2	+ 33.1	35.6	292	69.5	51.7	52.7
Sept.	4.10	164.0	+ 113.0	15.5	119	56.8	31.9	53.2
Water Year Total	30.59	1,332.4	+ 311.5	419.8	1,617.1	586.7	322.6	308.2