ᶠlood Inundation and Effects of Urbanization n Metropolitan Charlotte North Carolina

LAWRENCE A. MARTENS

YDROLOGIC EFFECTS OF URBAN GROWTH

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'repared in cooperation with the
'ty of Charlotte, North Carolina

l study of factors influencing
'rban runoff

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FLOOD INUNDATION AND EFFECTS OF URBANIZATION IN METROPOLITAN CHARLOTTE, NORTH CAROLINA

By LAWRENCE A. MARTENS

ABSTRACT

Investigation of floods on seven streams in metropolitan Charlotte, N.C., indicates that significant increases in flood potential accompany urban development of the basins.

Urbanization affects both the hydrology and hydraulics of drainage systems. Rainfall excess increases with the development of urban areas which are more impervious than rural areas, largely because of structures such as buildings, paved streets, and parking lots. The magnitude of the mean annual flood increases with an increase in the degree of imperviousness. The effect of impervious area diminishes with increased flood recurrence intervals becoming negligible for floods exceeding 50 years. Basin lag time for fully developed basins was found to be about one-fourth the lag time before development. The increase in impervious area and decrease in lag time associated with the urbanization of a basin will about double the discharge of a 20-year flood.

Computed flood elevations of the 20-year flood along 60 miles of stream channels reflect increases in elevation of as much as 6 feet for some areas as a direct result of extensive watershed development. In other areas, where channel and flood-plain improvements have been made, the increase in elevation of the 20-year flood is as small as 1 foot. Seventy-five percent of the channels in metropolitan Charlotte will reflect an increase of about 3½ feet in the elevations of the 20-year flood as a result of the change in the basins from undeveloped to urbanized conditions.

Studies to determine the feasibility of selecting cross-section properties directly from detailed topographic maps, when computing flood profiles, indicate that about a three-tenths-foot error can be expected in profile elevations of floods at about bankful stage; a lesser error can be expected in profile elevations of floods above bankful stage.

INTRODUCTION

PURPOSE

City engineers and planners for many years have been concerned about flooding of streets, businesses, and homes located on the flood plains of rivers and streams. They have long recognized that urbanization changes the runoff characteristics of areas but lacked sufficient technical data to design drainage structures, such as bridges, culverts, and sewers, that have adequate flood capacities. This same lack of data has hampered their efforts to regulate development in areas where flooding problems could become more intense in the future.

In order to alleviate flood problems in presently urbanized areas, to design adequate structures in newly developed areas, and to enact zoning regulations to control development of the remaining flood plains, the city of Charlotte entered into a cooperative study program with the U.S. Geological Survey in January 1962. This report presents the results of that study. The program of study undertaken under the agreement had the following objectives:

1. Evaluate quantitatively the flood potential of watersheds in the Charlotte area for undeveloped, partly developed, and extensively urbanized conditions. These three degrees of urbanization are defined as follows:
   a. Undeveloped condition: Watersheds for this condition of development were in their natural rural state, with little or no canalizing or sewering and with impervious areas being negligible.
   b. Partly developed condition: Watershed development for this condition was based on the extent of development existing in 1964 and 1965 in the Little Sugar Creek basin above the gaging station on Little Sugar Creek at Tyvola Road, Charlotte. Canalizing and storm sewering had been completed on about one-half the streets; many of the streets were paved and contained curbs. The impervious cover of this basin was about 15 percent.
   c. Extensively developed condition: Watersheds for this condition were extensively urbanized with all stream channels canalized, storm sewering and curb and guttering complete, and about 40 percent impervious cover of the watersheds.
2. Compute water-surface profiles for selected discharges for each condition described above for all streams in metropolitan Charlotte having drainage areas in excess of 5 square miles. These profiles are to be unrestricted, with the effect of manmade encroachments eliminated.
3. Develop methods of forecasting magnitude of future floods based on extent of urban development.
4. Document reaches of streams where channel or flood-plain improvements have been carried out and tabulate extent of percent impervious cover of the basins in metropolitan Charlotte at the time of the study in 1964 and 1965.

EXPLANATION OF SYMBOLS

A	Drainage area in square miles.
a	A constant defining the slope of the curves indicating effect of basin development on lag time. In this report, $a=0.52$.
C	Coefficient developed to compute lag time. Its value is in inverse proportion to the degree of urban development.
hF	Mean sea-level elevation of floods computed using surveyed or field data.
hM	Mean sea-level elevation of floods computed using data selected from maps.
Δh	Difference between the mean sea-level elevation of a flood computed using field data from that using map data.
I	The percent impervious area of a watershed.
K	Coefficient that accounts for the percent impervious cover in the equations of discharge.
L	The length of the stream, in miles. It is measured along the thalweg between the point in question and the rim of the watershed.
$\overline{Q}$	Mean annual flood, in cubic feet per second (cfs). Based on Gumbel's theory, the mean annual flood is taken, by practice of the Geological Survey, as the 2.33-year flood from the graphic frequency curve.
R	Ratio to the mean annual flood. That value the mean annual flood will be multiplied by, owing to percent impervious area and frequency.
S	The bed slope of a stream, in feet per mile.
T	Lag time, in hours. That time between the center of mass of rainfall on a basin and the center of mass of the resultant runoff of the basin.

GEOGRAPHY

Location and population.—The city of Charlotte is located in Mecklenburg County in the south-central part of North Carolina. It is in the Piedmont physiographic province about midway between the Atlantic Coastal Plain and the Appalachian Mountains.

Maps covering the entire city have been available since 1957 when the city was mapped to a scale of 1 inch equals 200 feet, with a contour interval of 2 feet. Details, such as wooded areas, fence lines, buildings, parking areas, roads, streams, and numerous vertical control points, are shown. Additional areas of the city are being mapped as annexation takes place, as are potential growth areas within the county. The boundaries of the project area, as shown on plate 1, were selected on the basis of the maps available in 1962.

The population of the city in 1960 was 201,000. The rate of growth in the Charlotte area has been quite rapid. Present estimates are that the city will exceed 427,000 people by 1980 and will encompass the entire metropolitan area now being studied.

Topography and drainage.—Streams within the metropolitan area are relatively small and flow southwestward to the Catawba River. The channels are well entrenched and have sandy bottoms except at the several places where they are composed of rock. The topography is gently rolling; elevations range from 550 to 850 feet above mean sea level. Stream slopes average slightly more than 0.4 percent, or equivalent to a fall of about 21 feet per mile. The Catawba River forms the western boundary of Mecklenburg County, but is not close enough to the city to present any concern of flooding. For the most part, flooding is caused by streams that head in the northern and eastern part of the metropolitan area and flow southward through the city. These streams include Stewart, Sugar, Irwin, Little Sugar, Briar, McMullen, and McAlpine Creeks. Extensive developments have taken place and are continuing in these watersheds and in flood plains along the streams, with the result that problems of drainage and flooding are being aggravated.

Climate.—The Charlotte area has a moderately humid climate. July is the wettest month with an average rainfall of 4.88 inches and November the driest with an average rainfall of 2.53 inches. The average annual precipitation is 43.38 inches. Average annual snowfall in the area is 5.7 inches. Although hurricanes occasionally pass through the Charlotte area, most flooding occurs as the result of local storms.

July is also the warmest month, having an average maximum daily temperature of 88.8°F. The winters in the Charlotte area are relatively mild. December is the coldest month, having an average daily maximum of 53.3°F. The record high and low for the period of record in Charlotte has been 103° and −5°F, respectively.

ACKNOWLEDGMENTS

The operation and maintenance of streamflow stations and the collection of other miscellaneous field data were done by W. H. Eddins under the direct supervision of E. G. Wollin, engineer-in-charge of the Geological Survey Subdistrict Office in Statesville, N.C. A. L. Putnam, engineer, Geological Survey, Raleigh, N.C., assisted in collecting many of the field data and performed many of the computations. The cooperation of L. C. Cheek, City Engineer of Charlotte, was vital to the prosecution of this project.

This report was prepared under the general direction of E. B. Rice, District Chief, Water Resources Division.

COLLECTION AND DEVELOPMENT OF DATA

STREAMFLOW

At the beginning of the investigation, streamflow data in the immediate vicinity of Charlotte consisted of the 40 years of record collected at the gaging station on Little Sugar Creek at Tyvola Road, Charlotte. These data were supplemented during the study by data from four gaging stations that were installed as the initial step of the project. In addition, seven crest-stage stations were established in order to develop stage-discharge relations at selected locations along the several streams crossing the city. The gaging station and crest-stage gage network was designed to provide an adequate range of streamflow and basin conditions within the project area. The location of each gaging station is shown on plate 1. Table 1 contains information regarding the type of station, drainage area, period of record, length-slope ratios, percent of impervious area in the drainage basin, and calculated lag time of floods for each station.

TABLE 1.—*Stream-gaging and rainfall stations in the Charlotte study area*

Station No.	Station Name	Lag time (hr)	Impervious area (percent)	Drainage area (sq mi)	$\frac{\text{Length}}{\sqrt{\text{slope}}}$	Type of station	Beginning of record
2-1462.80	Stewart Creek at Charlotte		8.3	9.40	1.05	Crest stage	1962
1463.00	Irwin Creek at Charlotte	2.95	10.9	30.5	3.03	Continuous record and rainfall.	1962
1463.15	Taggart Creek at New Dixie Rd.		8.6	5.49		Crest stage	1962
1463.30	Sugar Creek near Charlotte		9.0	43.7	5.08	do	1962
1464.20	Little Sugar Creek at Hillside Ave.	1.54	22.3	15.4	2.20	do [1]	1962
1464.40	Briar Creek at East Seventh St		8.5	14.5	1.66	Crest stage	1962
1464.50	Briar Creek at Sharon Rd	2.99	9.5	18.5	2.35	Continuous record and rainfall.	1962
1465.00	Little Sugar Creek at Tyvola Rd.	3.39	14.6	41.0	2.87	do	[2] 1924
1465.30	Little Sugar Creek at Pineville			48.7	5.14	Crest stage	1965
1466.00	McAlpine Creek at Sardis Rd	5.81	2.1	38.3	1.87	Continuous record and rainfall.	1962
1466.55	McAlpine Creek at State Hwy. 51.			51		Crest stage	1962
1467.00	McMullen Creek at Sharon View Rd.	2.99	6.3	6.98	1.01	Continuous record and rainfall.	1962
1467.25	McMullen Creek near Griffith			13		Crest stage	1962
1	Douglas Airport WB rain gage					Hourly rainfall	1905
2	City Hall rain gage					Continuous rainfall	1963
3	Methodist Home rain gage					do	1963
4	Vest Station rain gage					do	1963

[1] Continuous record since 1964. [2] Rainfall record since 1962.

Data collected at gaging stations in central North Carolina were used to validate needed flow equations. The criteria used to select these stations were that they have sufficient length of record to provide a reliable value for the mean annual-flood discharge and that they be located in areas for which topographic maps are available so that drainage area, stream length, and bed slope could be determined. The location and station number of the stations meeting these requirements are shown in figure 1. The names of the stations are given along with other pertinent information in table 2.

IMPERVIOUS AREAS

Imperviousness, as used in this report, refers to the inability of water to penetrate those areas of the land surface occupied by manmade structures, such as buildings, paved streets, and parking lots. The percent of impervious cover on a watershed is a measure of the

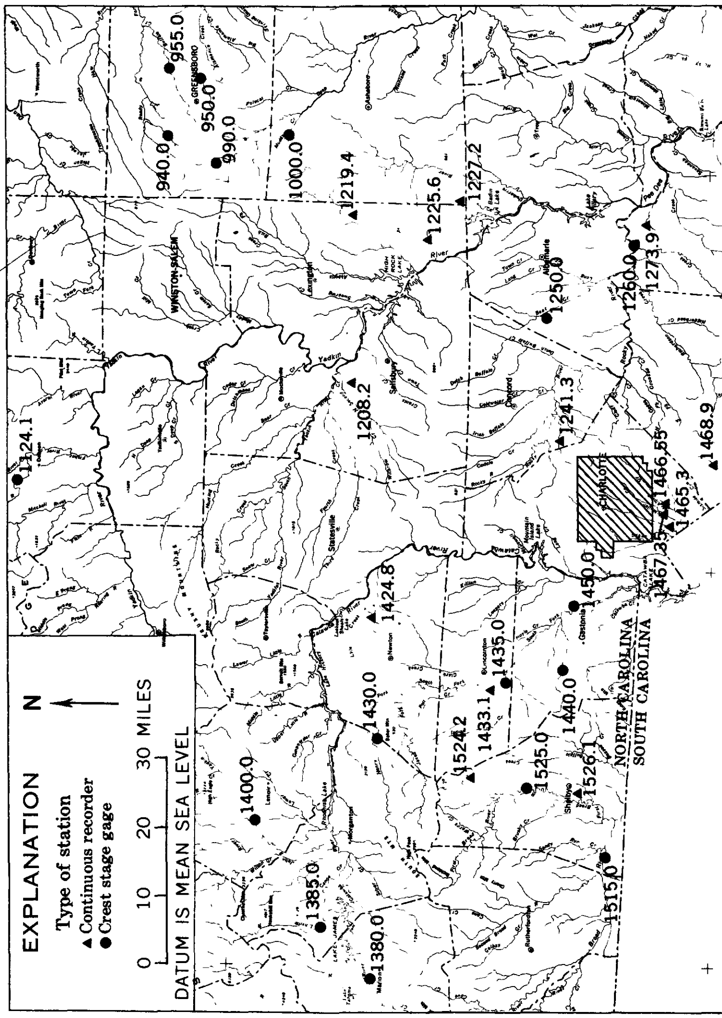

FIGURE 1.—Map of central North Carolina showing area surrounding Charlotte and the location of stream-gaging stations.

degree of development of that watershed. Impervious areas of the watershed were determined during the study, and the percent of those areas were calculated.

TABLE 2.—*Stream-gaging stations used to define the mean annual flood*

Station No.	Station Name	Drainage area (sq mi)	$L/\sqrt{S}$	Type of station	Period of record used
[1]2- 685	Dan River near Francisco	124	9.09	Continuous record	1924–63
[1]2- 815	Tar River near Tar River	167	10.1	do	1939–62
[1]2- 925	Trent River near Trenton	168	16.8	do	1951–62
2- 940	Horsepen Creek at Battle Ground	159	1.76	do	1925–59
2- 950	South Buffalo Creek near Greensboro	33.6	4.90	do	1928–58
2- 955	North Buffalo Creek near Greensboro	37.0	4.51	do	1928–63
2- 990	East Fork Deep River near High Point	14.7	1.39	do	1928–63
2-1000	Muddy Creek near Archdale	16.7	2.31	do	1934–41
2-1124.1	Fisher River near Bottom	44.7	2.38	Crest stage	1954–63
2-1208.2	Deals Creek near Salisbury	3.9	.47	do	1954–63
2-1219.4	Flat Swamp Creek near Lexington	6.56	1.62	do	1954–63
2-1225.6	Cabin Creek near Jackson Hill	13.7	1.42	do	1954–63
2-1227.2	Beaverdam Creek tributary near Denton	2.90	.45	do	1954–63
2-1241.3	Mallard Creek near Charlotte	20.7	1.18	do	1954–63
2-1250	Big Bear Creek near Richfield	55.7	2.97	Continuous record	1954–63
2-1273.9	Palmetto Branch at Ansonville	.86	.12	Crest stage	1953–63
2-1380	Catawba River near Marion	171	3.64	Continuous record	1941–62
2-1385	Linville River at Branch	67.2	7.29	do	1922–63
2-1424.8	Hagan Creek near Catawba	7.8	.67	Crest stage	1954–63
2-1430	Henry Fork near Henry River	79.7	5.86	Continuous record	1925–31, 1941–63
2-1433.1	South Fork Catawba River tributary near Lincolnton.	1.0	.15	Crest stage	1954–63
2-1435	Indian Creek near Laboratory	68.4	6.10	Continuous record	1951–63
2-1440	Long Creek near Bessemer City	31.4	2.36	do	1952–63
2-1450	South Fork Catawba River at Lowell	630	32.1	do	1942–62
2-1468.9	East Fork Twelve Mile Creek near Waxhaw	42.3	2.75	Crest stage	1954–63
2-1515	Broad River near Boiling Springs	865	13.0	Continuous record	1925–62
2-1524.2	Big Knob Creek near Fallston	16.4	1.28	Crest stage	1953–63
2-1525	First Broad River near Lawndale	198	14.2	Continuous record	1940–62
2-1526.1	Sugar Branch near Boiling Springs	1.49	.30	Crest stage	1954–63
[1]3-1600	Fairforest Creek near Union, S.C	183	10.3	Continuous record	1940–62
[1]3-4500	Beetree Creek near Swannanoa	5.46	.16	do	1926–63

[1] Not on figure 1.

The determination of the percent impervious area, I, of the watersheds within the Charlotte study area was done by a sampling process directly from the maps. Each map sheet measures 20 by 30 inches, representing 24 million square feet in area and has the North Carolina coordinate system preprinted on it. These coordinate lines intersect to form 5-inch squares representing 1 million square feet in area. To simplify computations of impervious areas, the 5-inch sections were numbered 1 through 24 beginning at the upper left corner. A 5-inch square transparent sheet having a grid containing 100 points of intersection was superimposed over these sections.

The percent impervious area, I, was determined by counting the number of intersections that overlay impervious areas. Figure 2 is a

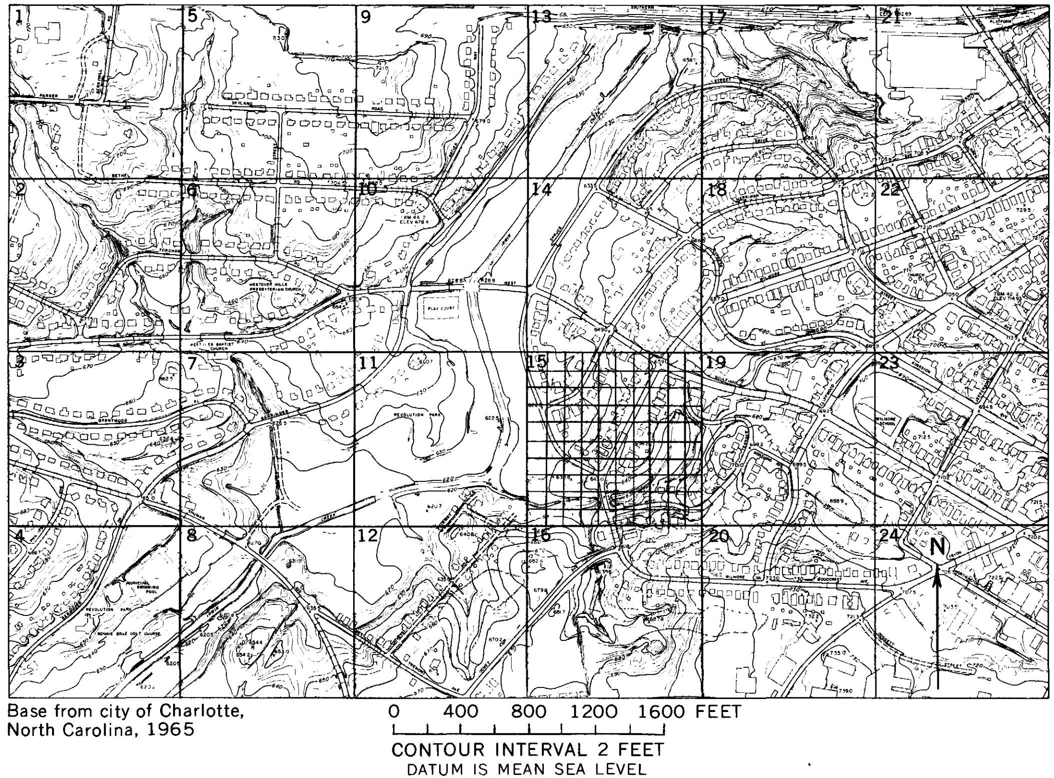

Figure 2.—Sample detail topographic map showing system of determining percent of impervious area.

reproduction of map sheet No. 15 with the transparent grid superimposed over one section. The tabulation of sections and intersection points for map sheet No. 15 are given in table 3. The calculation of the percent of impervious area in the Irwin Creek basin is given in table 4.

The values of I for each watershed that was investigated in the Charlotte area are given in table 1.

TABLE 3.—*Sample, Impervious-area computation sheet*

Impervious-area computation sheet

Basin: Irwin Creek at Charlotte D.A.=30.5 sq mi
Map: Sheet No. 15

Section No.	Number of intersections	Section No.	Number of intersections
1	9	13	10
2	7	14	15
3	13	15	24
4	5	16	12
5	10	17	8
6	16	18	16
7	10	19	25
8	4	20	18
9	16	21	44
10	9	22	31
11	3	23	32
12	13	24	33

Number of sections contributing to basin: 24
Number of intersections: 383

RAINFALL

Rainfall in Charlotte has been measured by the U.S. Weather Bureau since 1878. Since 1905 these data have been collected with continuous recorders. The Weather Bureau's rainfall station was located in downtown Charlotte until 1939 when it was moved to its present location at Douglas Airport, a few miles west of the city.

In order that the areal variability in storm rainfall distribution could be determined more accurately and rainfall-runoff comparisons made, additional recording rain gages were installed at each of the five continuous-record gaging stations. These stations were supplemented by an additional three recording rain gages located at strategic points within the city. Plate 1 shows the location of all recording rain gages used. A number of nonrecording gages also were placed throughout the city and were used to determine the areal uniformity of recorded storms.

TABLE 4.—*Sample, Impervious-area summary sheet*

Impervious-area summary sheet

Gaging Station: 2—1463.00 Irwin Creek at Charlotte

Sheet No.	Sections	Intersections	Sheet No.	Sections	Intersections
59	1	1	107	14	123
60	8	31	105	18	53
31	7	55	151	24	149
32	23	74	152	24	105
33	24	143	190	16	71
34	24	175	191	24	203
30	2	25	192	24	156
13	11	127	193	4	28
14	21	320	Stewart Cr.	316	2, 616
15	24	383	Estimated	42	143
61	6	56	Total	845	9, 211
4	8	414			
35	13	213			
16	14	270			
5	21	1, 493			
6	1	43			
18	22	452			
19	6	194			
39	18	309			
40	4	75			
68	15	199			
69	24	246			
70	4	57			
105	12	73			
106	24	179			

Total Sections: 845
Total Intersection Points: 9,211
Impervious Area=9,211/845=10.9 percent

BASIN LAG TIME

Lag time, *T*, is the difference in hours, measured at selected locations on a stream, between the center of mass of rainfall, excluding infiltration and other minor losses, and the center of mass of the resultant runoff. Sherman (1940) developed methods of determining infiltration curves for a watershed. By use of his methods, infiltration curves were computed and rainfall adjusted to obtain the time-volume distribution of that portion of the rainfall entering the stream. Basin lag time was computed for watersheds in the Charlotte area where streamflow and rainfall data were available. Average values of lag time for streams are given in table 1.

DATA ANALYSIS

FLOOD DISCHARGES

DISCHARGE EQUATION

Studies of the effects of urbanization upon flood discharges necessarily require that several factors be considered. As compared with regional flood magnitude and frequency studies, where drainage area is usually the dominant factor for evaluating floods, flooding in urban areas has been found to be closely related to other factors as well as to drainage area.

Urban development of a watershed affects flood runoff in two ways. It increases the rate at which storm runoff moves across the basin and enters the stream (reduction in lag time, T,) and it decreases the amount of infiltration. Thus, the change in lag time, T, and the percent impervious area, I, are measures of the degree of urbanization of a basin. As an area becomes progressively more urbanized, T decreases and I increases. With an increase in I, the percentage of total rainfall reaching the stream as runoff increases. At the same time, a decrease in T shortens the runoff period, which also results in an increase in the rate of runoff. The combined effect of the two is to increase peak discharges and flood elevations. A change in T affects runoff of all magnitudes and therefore can be applied to computations of the mean annual flood, $\overline{Q}$. The percent of impervious area on the other hand, although permanently affecting basin hydrology, does not have this same effect on the runoff of all storms. Once the initial infiltration capacity of a watershed has been satisfied, most of the remainder of the rainfall becomes storm runoff regardless of the degree of impervious area. It was, therefore, necessary that the effects of I be dealt with later in conjunction with the development of the magnitude and frequency of floods.

As mentioned above, streamflow data in the Charlotte area were limited to that of one gaging station when the project began. To develop flood discharges for Charlotte streams, it was first necessary to find a means of computing $\overline{Q}$. Secondly, it was necessary to develop methods of relating $\overline{Q}$ to changing urban conditions.

Carter (1961) and D. W. Anderson (written commun., 1962) have conducted studies involving peak flows from urban watersheds. The theory and general relations they derived for computing urban runoff were combined and extended using data collected in Charlotte.

As a first step in the analysis, the $\overline{Q}$ determined by Hinson (1965) from station data for those streamflow stations in central North Carolina given in table 2 were plotted on figure 3 against drainage area and defined by the equation:

$$\overline{Q}=180A^{0.66}.$$

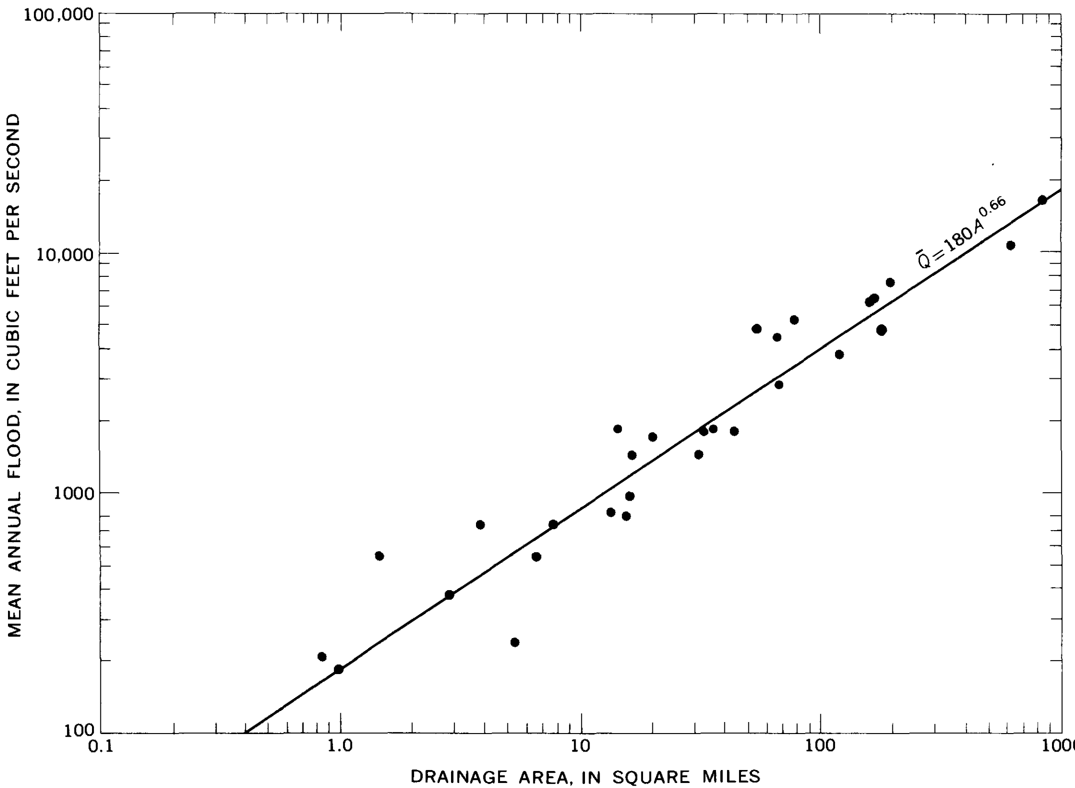

Figure 3.—Variation of observed values of mean annual flood with drainage area.

$\bar{Q}$ for these same stations was computed using the methods and following the flood formula described by Carter (1961):

$$\frac{\bar{Q}}{K}=223A^{0.85}T^{-0.45}, \tag{1}$$

where
$\bar{Q}$=Mean annual flood in cubic feet per second,
A=Drainage area, in square miles,
T=Basin lag time, in hours, and
K=Coefficient of imperviousness.

Values of T are normally obtained from concurrent records of rainfall and streamflow data. Because few basins in North Carolina are instrumented to record rainfall data, other means were used to establish values of T. The following equation for T was developed by Carter and modified by Anderson using data collected from undeveloped basins in the Piedmont region of Virginia and Maryland:

$$T=C\,(L\div\sqrt{S})^{a}, \tag{2}$$

where
L=Stream length, in miles,
S=Channel slope, in feet per mile,
C=Coefficient reflecting the degree of urban development, and
a=A constant.

Anderson computed T for basins in undeveloped areas in the vicinity of Washington, D.C., and plotted them against stream length-slope ratios and obtained values of C and a equal to 4.18 and 0.52, respectively. Substituting, results in

$$T=4.18(L\div\sqrt{S})^{0.52} \tag{3}$$

for undeveloped conditions. This equation was used to compute lag time for those gaging stations in North Carolina given in table 2 which are located generally in the same physiographic region as those stations in the Washington area used by Anderson and Carter. Stream lengths were determined by measuring the distances in miles, following the principal channel, between the gaging station and the rim of the basin. Channel slope in feet per mile was computed by obtaining the difference in elevation between points located 10 and 85 percent of the distance upstream from the gaging station, and divided by the distance in miles between these points. Length-slope ratios are defined as the quotient of length and square root of the slope. With these ratios, a representative T value for each station was computed using equation 3. Knowing that the percent impervious cover of basins drained by

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these streams is negligible, K can be set to equal 1.00. Having T and K, $\overline{Q}$ for each stream was determined from equation 1. A plot of resulting discharge versus drainage area is shown in figure 4 and defined by the equation:

$$\overline{Q}=170A^{0.67}.$$

Comparison of the curves of figures 3 and 4, as defined by the equation: $\overline{Q}=180A^{0.66}$ for station data and $\overline{Q}=170A^{0.67}$ for computed data, indicates that satisfactory estimates of the mean annual flood can be made using developed equations for lag time and discharge. In addition, the discharge equation contains parameters that reflect the development of a basin.

URBANIZATION FACTORS

With a flood-discharge equation available to determine $\overline{Q}$, methods of applying the effect of a change in the flow characteristics of an urban basin must still be developed.

Studies by Carter, Anderson, and others have verified that T decreases as a basin becomes developed. They also have found that, although T decreases with basin development, the exponent in equation 2 remains, for all practical purposes, constant. This being so, equations for T for each degree of development being considered in Charlotte can be determined.

Because of the differences in the extent of urbanization, both from basin to basin and within basins in the Charlotte area, representative conditions were needed which would best represent present development for the major part of the metropolitan area. The Little Sugar Creek basin above the gaging station on Tyvola Road appeared to best represent these conditions. This basin includes the Briar Creek watershed which has been partly developed as well as the highly urbanized area of Little Sugar Creek upstream from Hillside Avenue. U.S. Weather Bureau rainfall records at Douglas Airport along with rainfall and runoff data collected at the gaging station were used to determine T. The length-slope ratio for the site and T were substituted into equation 2, and a resulting value of C equal to 1.83 was computed. The new equation for T defining existing development in metropolitan Charlotte was then:

$$T=1.83\ (L\div\sqrt{S})^{0.52}. \qquad (4)$$

In order that the study might best serve the needs of the city and be of benefit to other urban areas in the Piedmont physiographic region, it was decided to select and study a basin in that area that would represent foreseeable urbanized conditions in the Charlotte area and to base all computations on the data collected from this watershed.

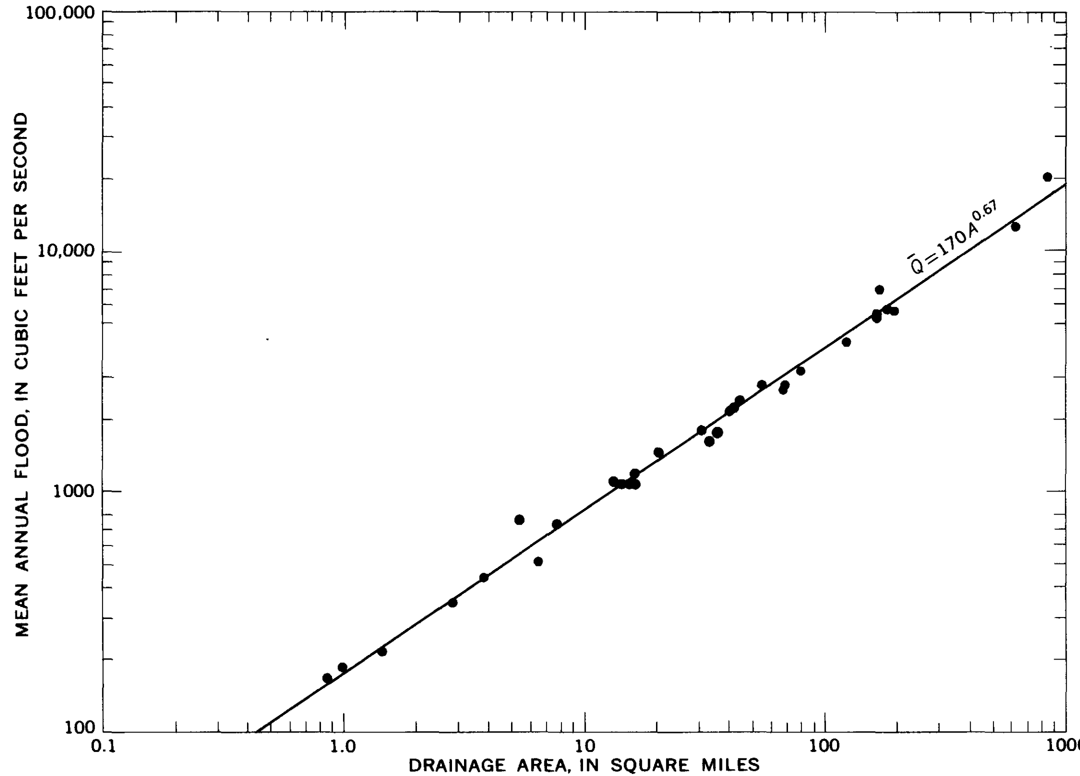

FIGURE 4.—Variation of computed values of mean annual flood.

The criteria desired in the selection of this basin were:

1. The watershed be at least 5 square miles in area.
2. That the main channels be improved and maintained.
3. That overland drainage devices, such as curbing, gutters, and storm sewering be complete.
4. That it be developed areally to about the same degree throughout the watershed.

None of the streams in metropolitan Charlotte met all these desired conditions, but Little Sugar Creek above Hillside Avenue with a drainage area of 15.4 square miles came closest and was selected. About 70 percent of its main and tributary channels are maintained to some degree and an overland drainage system is practically complete for the lower two-thirds of the basin. The basin, although not uniformly developed areally, is more than 22 percent impervious, which is unusually high for a watershed of this size. The headwater area, representing one-third of the basin, consists of both industrial and residential developments and is approximately 12 percent impervious. The central one-third of the watershed includes a large part of the business area of the city and has an impervious cover on more than 40 percent of the area. The lower section of this basin is primarily residential and has about 14 percent impervious cover.

With the selection of the Hillside Avenue station as a representative sample of urbanized conditions, a recorder was installed and stage hydrographs were obtained. Following the collection of a number of flood hydrographs, T was computed and $L/\sqrt{S}$ was determined from topographic maps. Values of T and $L/\sqrt{S}$ were substituted into equation 2, and C was found to be 1.0. The resulting equation defining T for urbanized conditions in Charlotte could then be written in the form:

$$T=(L\div\sqrt{S})^{0.52}. \quad (5)$$

Equations 3–5 as represented by the three curves plotted in figure 5 show how lag time varies with L and S under undeveloped conditions and the two conditions of development in the Charlotte metropolitan area. Equation 3 defines undeveloped conditions, equation 4, existing conditions, and equation 5, urban conditions. The equations indicate that T for a particular point on a stream may be reduced to less than one-fourth of its natural value as a basin becomes fully developed. Under the conditions previously outlined, these equations can be used to compute $\overline{Q}$ after the drainage area and length-slope ratio have been defined.

MAGNITUDE AND FREQUENCY

The study of flood magnitude and frequency incorporating an evaluation of the effects of urbanization requires that factors such as

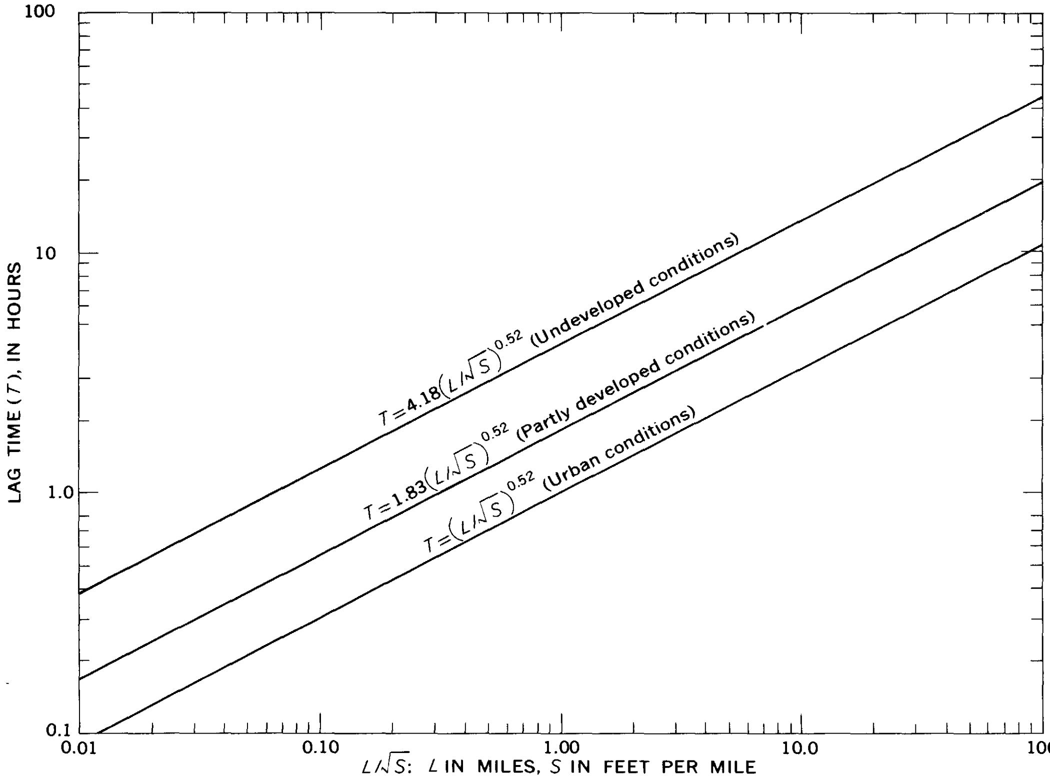

Figure 5.—Effect of basin development on lag time.

rainfall-runoff time differences, basin shape, and stream slope be considered.

The effects of these factors, evaluated for the Charlotte area, must be incorporated into flood-magnitude and frequency data available for small watersheds under natural-runoff conditions in the area. For the most part, this study adapts or adjusts the magnitude and frequency of peak discharges under natural-runoff conditions to those applicable under the urbanized or changing urban conditions found in the small drainage areas in the Charlotte area.

Hinson (1965) determined the mean annual floods, $\overline{Q}$, and the relationship of these to floods of other frequencies for small natural streams in North Carolina having drainage areas between 1 and 150 square miles. He used annual peak-discharge records from 104 crest-stage gages and 77 continuous-record gaging stations having drainage areas less than 150 square miles to develop frequency ratios for recurrence intervals of as much as 50 years. Procedures used to determine these ratios are described by Dalrymple (1960). The composite flood-frequency curve applicable to natural streams in the Charlotte area has been obtained from Hinson's report and reproduced as figure 6.

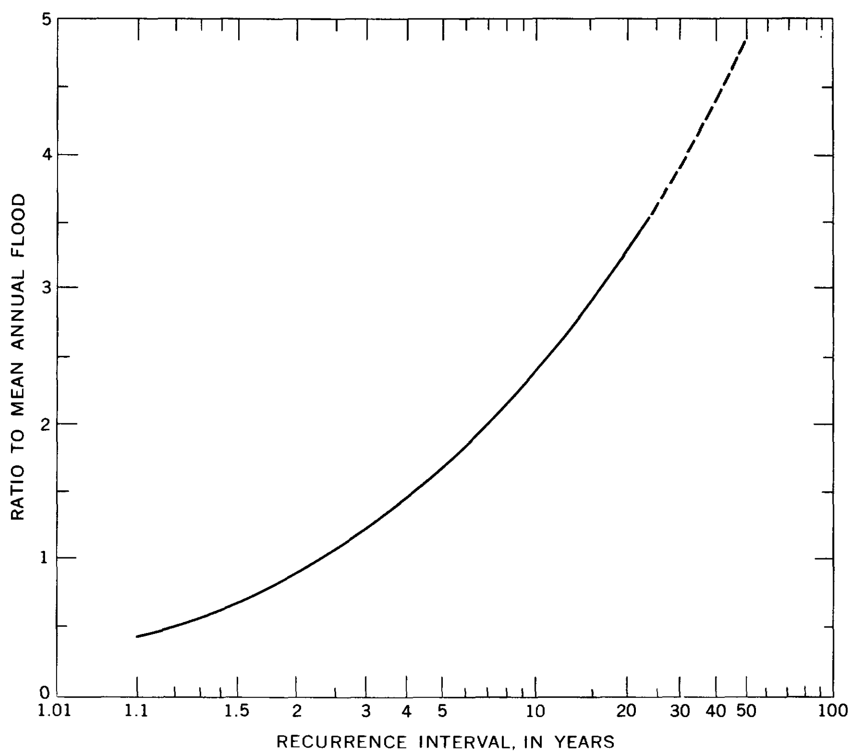

FIGURE 6.—Composite flood-frequency curve.

In order that the data in figure 5 could be applied to streams being investigated in metropolitan Charlotte, the ratio of floods of different frequencies to the mean annual flood must be adjusted to include the effect of urban development.

Streamflow data from impervious drainage basins have not been collected long enough to establish flood-frequency ratios for urban conditions, but theoretical frequency ratios were established to predict the effect of urbanization on flood peaks. Runoff from a completely impervious watershed will be directly proportional to the precipitation falling on the watershed. Rainfall frequencies have been computed and the data published by the U.S. Weather Bureau (1955) for the city of Charlotte.

The mean annual-peak rainfall intensity, in inches per hour, was determined using Weather Bureau data for duration periods of from 5 minutes to 24 hours. Peak rainfall intensities for frequencies of 5, 10, 25, and 50 years were also computed for each duration period. Ratios to the mean annual-peak rainfall intensity for each frequency were computed for each duration period. Ratios for all durations having the same frequency were averaged to obtain the composite rainfall-frequency curve plotted on figure 7.

The coefficient, K, that adjusts $\overline{Q}$ for I is determined from the following equation:

$$K=\frac{0.30-0.30(I\div100)+0.75(I\div100)}{0.30}. \tag{6}$$

Equation 6 was developed by Carter (written commun., 1963), where 0.30 represents runoff from natural basins and 0.75 represents runoff

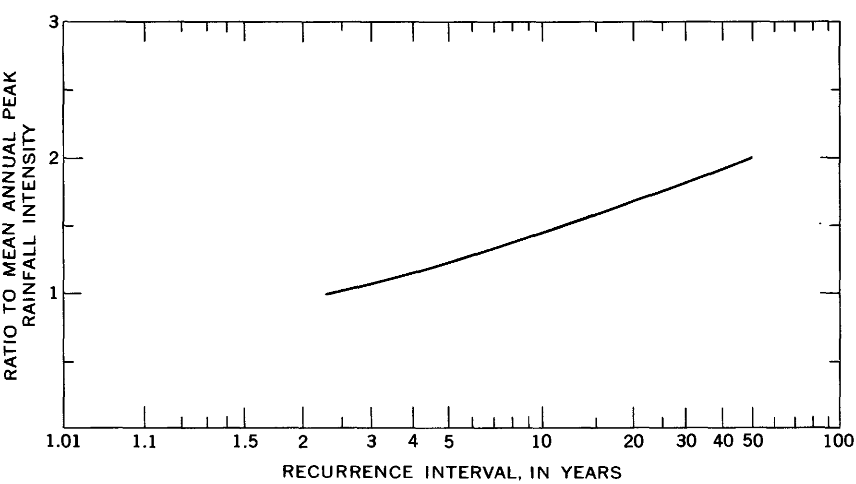

FIGURE 7.—Composite rainfall-frequency curve.

from completely impervious basins. Results of rainfall-runoff studies of flood volumes having peak discharges equivalent in magnitude to the mean annual flood for streams near Charlotte verify that about 30 percent of the rainfall appears as direct runoff. There are no basins in the study area sufficiently developed to verify the 75 percent, but that figure appears to be reasonable. Solving equation 6 for K using an $I=100$ percent gives a value of 2.5, which represents the factor by which $\bar{Q}$ would be increased when runoff results from completely impervious watersheds.

Having the ratio to $\bar{Q}$ for natural basins and the ratios to mean annual-rainfall intensity representing completely impervious basins, figure 8 was developed so that the flood potential of basins having any value of I could be determined. Along the left edge of figure 8

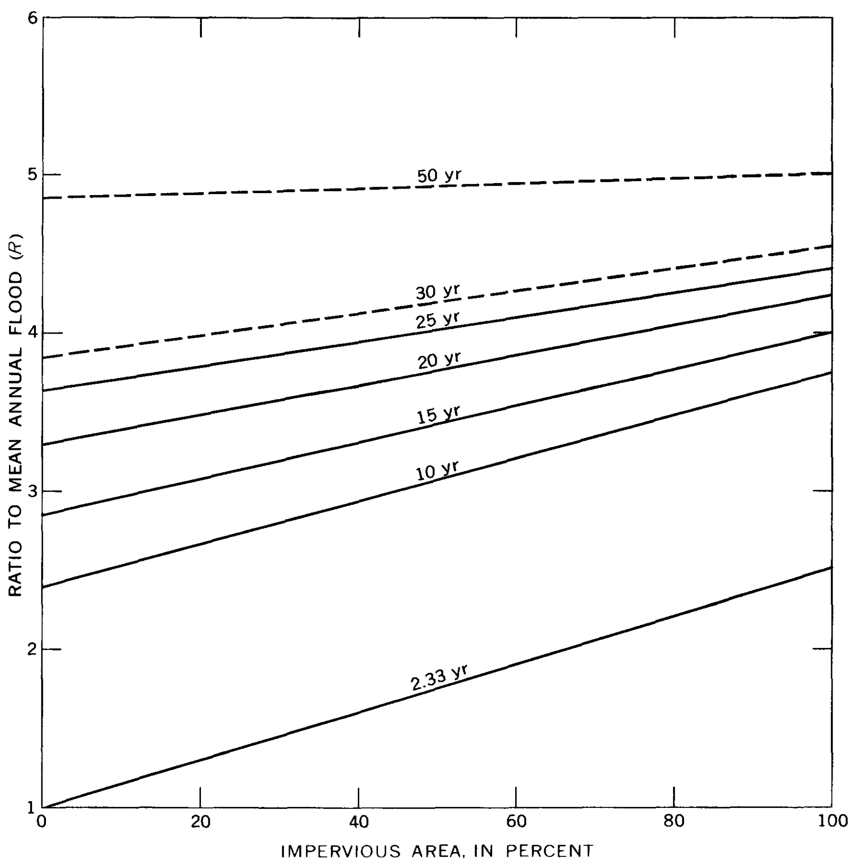

FIGURE 8.—Graph showing variation of flood-frequency ratio with percent of impervious area.

are plotted selected ratios of $\overline{Q}$ taken from figure 6. Ratios for completely impervious basins were established by selecting the appropriate ratios from figure 7, multiplying these ratios by 2.5, the effect of K, and plotting the values along the right edge of figure 8. The figure was then completed by connecting ratios of equal frequency with straight lines. R, the ratio to $\overline{Q}$ for all values of I, can then be selected from figure 8.

The effect of I on a watershed remains practically constant, but as shown in figures 6 and 7, flood-frequency ratios for urban streams do not increase at the same rate as those for natural streams owing to the high rate of initial runoff from urban basins. As the recurrence interval becomes greater, the difference between ratios developed for urban basins on the basis of I and rainfall frequency and ratios derived for natural basins become smaller until they are virtually the same. This indicates that as storm magnitudes on natural basins increase, the percentage of rainfall that infiltrates into the ground, or is trapped in surface pools, or is lost by evaporation becomes less and less until it has little or no effect on the runoff. This is demonstrated in figure 8 by the relatively flat slopes of the lines corresponding to the higher recurrence intervals.

Establishing the ratio to $\overline{Q}$, R, which includes the effect of imperviousness of a watershed, figure 8, and having means of computing $\overline{Q}$ on the basis of values of T selected from figure 5, equation 1 can be modified to include varying conditions of urban development and for recurrence intervals as much as 50 years. The modified equation can be presented in the form:

$$Q=223RA^{0.85}T^{-0.45}. \quad (7)$$

DATA APPLICATION

PROJECT FLOODS

With equations available to determine flood magnitudes for practically any condition of basin development and frequency in metropolitan Charlotte, the magnitude of each of the project floods had to be selected.

Zoning regulations for the city of Charlotte are based on the 20-year flood, and city engineers requested that this value be used in computations for natural and extensively urbanized conditions. Frequency of occurrence was not a criterion in selecting the magnitude of floods computed for partly developed conditions. A discharge was purposely selected which would create a flood elevation that would fall about midway between the elevations of floods computed for natural and extensively developed conditions. This would provide a computed stage-discharge relation at any location desired. The recurrence interval of this flood was computed to be 16 years.

Having established criteria for selecting magnitude of flooding, the next phase of the project was to determine peak discharges for the project floods corresponding to the three separate conditions of basin development as shown by the three curves of figure 5.

UNDEVELOPED CONDITIONS

Peak discharges expected under natural undeveloped conditions were computed using eqation 7. With I assumed to be zero and recurrence intervals of 20 years selected, R was determined from figure 8. Drainage areas and length-slope ratios were obtained from figures 9–15 at sufficient points to define changes in discharge. These points were selected at locations along the channels where changes in drainage area exceeded about 10 percent. Using $L/\sqrt{S}$ as the abscissa, T was determined from figure 5. Solving equation 7 using values of R, A, and T as defined above, 20-year discharges were determined for undeveloped conditions for the major streams in the project area that have drainage areas in excess of 5 square miles. These computed discharges are tabulated in the second column of tables 6–12, which follow "References cited." For those streams where little or no development has taken place, these discharges represent the actual 20-year floods expected. For others, these figures can be used for purposes of comparison to examine the effects of urbanization as basins develop.

PARTLY DEVELOPED CONDITIONS

Peak discharges were computed using the development defined for the basin above the gaging station on Little Sugar Creek at Tyvola Road, Charlotte (No. 2–1465), as a base. Following a procedure similar to that used for undeveloped conditions, peak flows were determined with T values obtained from the middle curve of figure 5 and for R selected from figure 8 on the basis of I equals 15, the value representing the extent of impervious cover, and a recurrence interval of 16 years. These peak flows are tabulated in the fourth column of tables 6–12.

URBAN CONDITIONS

Repeating procedures used previously, discharges simulating conditions of urban development were computed for streams in the project area. T was selected from the bottom curve in figure 5 and R was determined from figure 8 using recurrence interval of 20 years and I equals 40.

The use of I equals 40 percent for impervious cover of urbanized basins in the Charlotte area was selected after reviewing the present development pattern of the city and forecasting the type of develop-

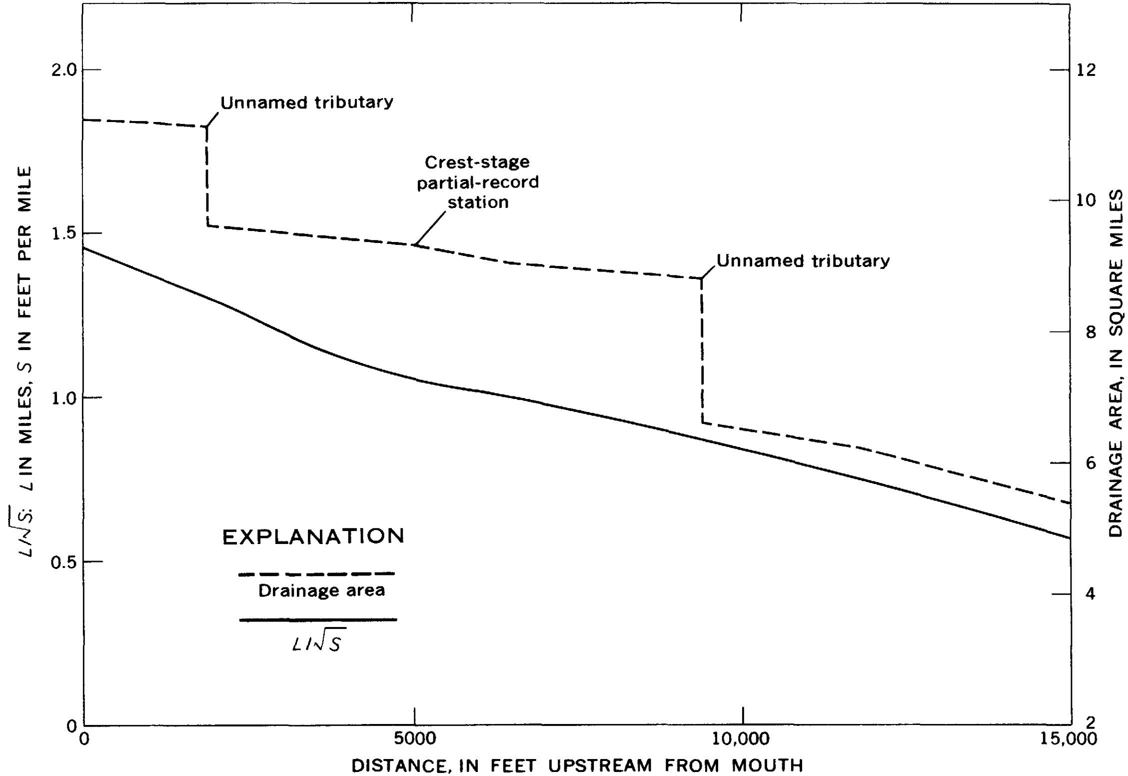

FIGURE 9.—Length-slope ratio and drainage area along Stewart Creek.

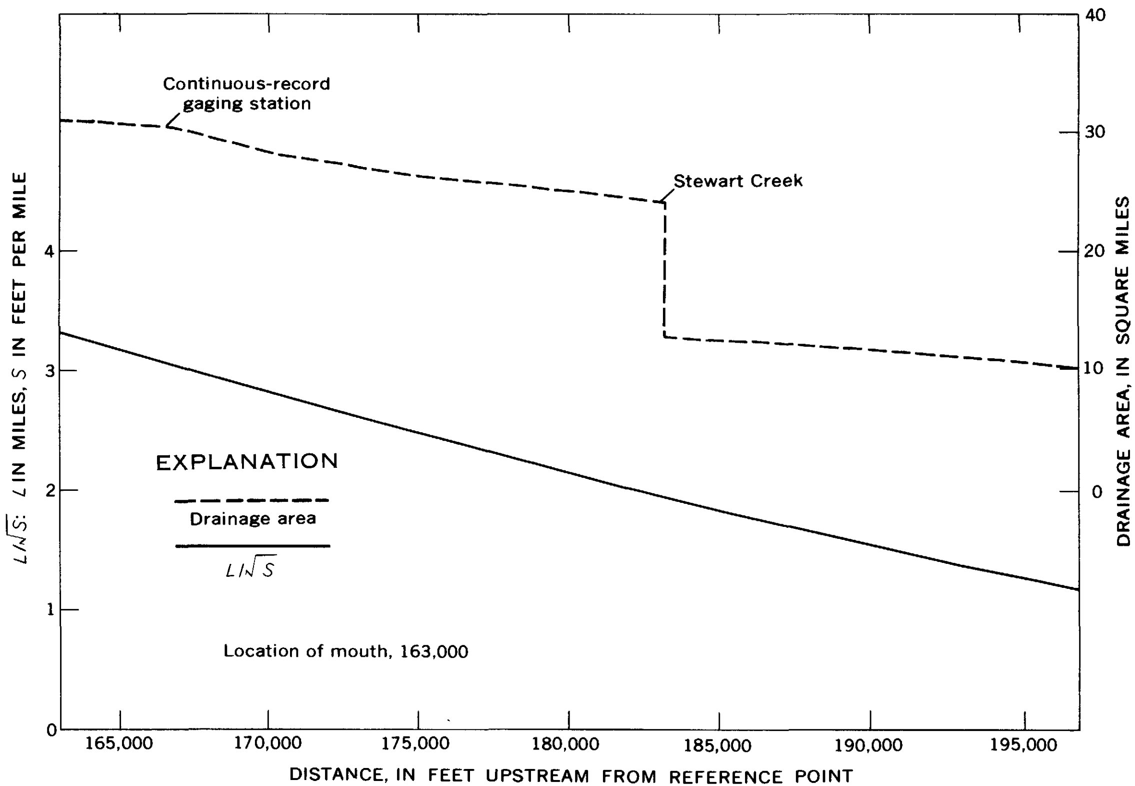

Figure 10.—Length-slope ratio and drainage area along Irwin Creek.

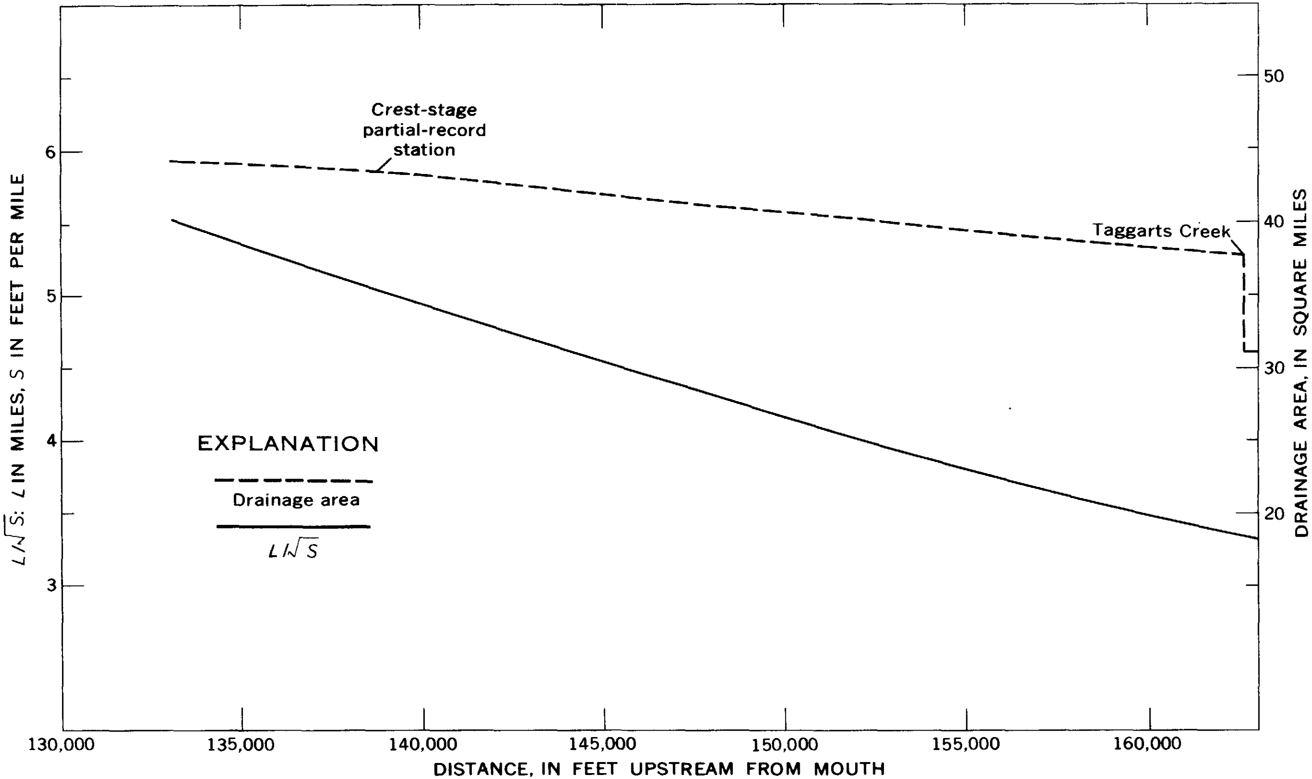

FIGURE 11.—Length-slope ratio and drainage area along Sugar Creek.

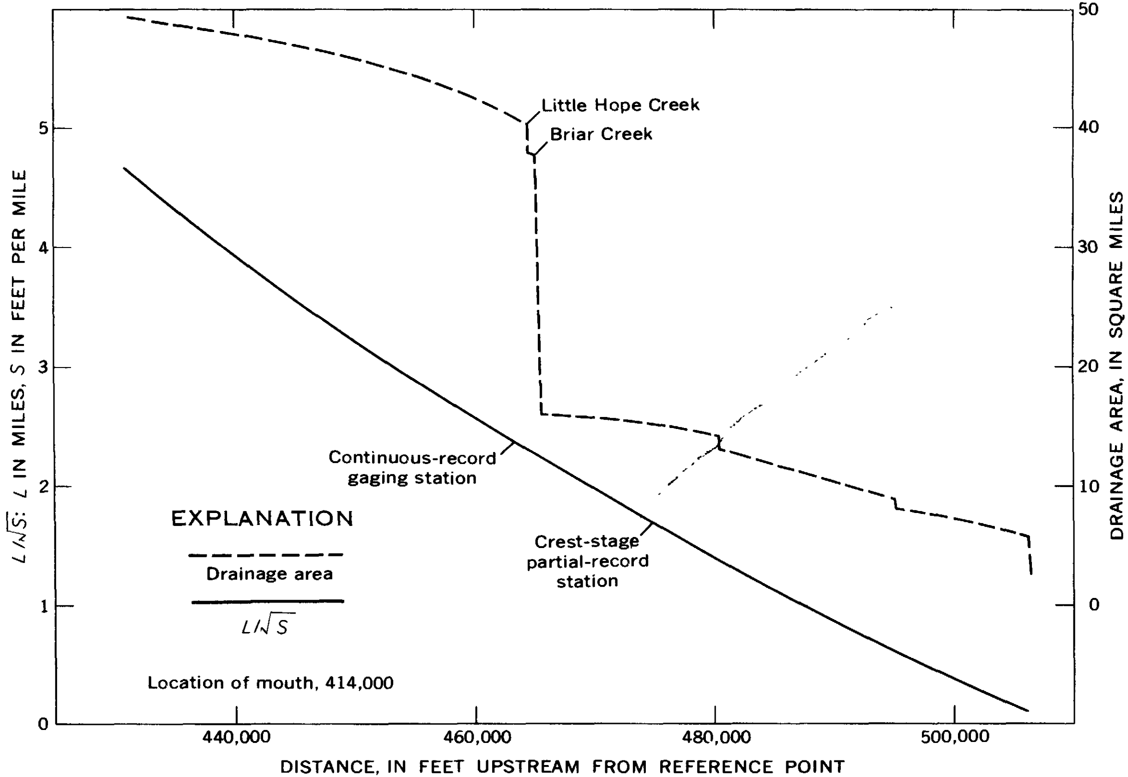

FIGURE 12.—Length-slope ratio and drainage area along Little Sugar Creek.

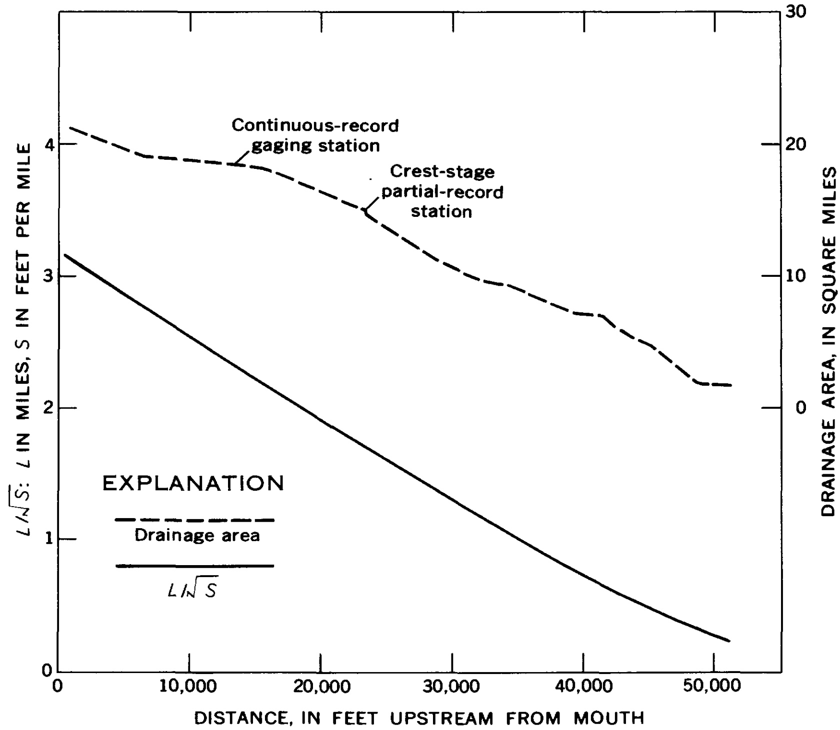

FIGURE 13.—Length-slope ratio and drainage area along Briar Creek.

ment to be expected in those parts of the watersheds presently undeveloped or undergoing a change in type of development. City officials agreed that the 40-percent figure was a realistic value for urban development of watersheds having drainage areas exceeding 5 square miles.

The resulting discharge values determined for the various reaches for which cross sections are available are tabulated in the sixth column of tables 6–12.

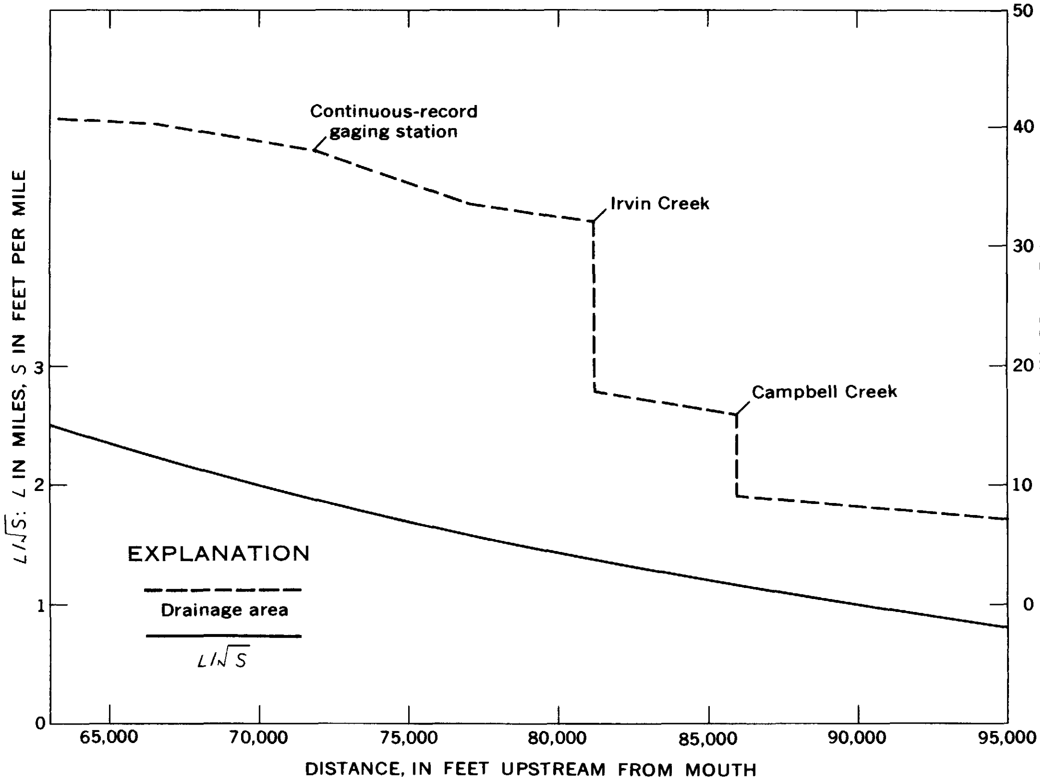

FIGURE 14.—Length-slope ratio and drainage area along McAlpine Creek.

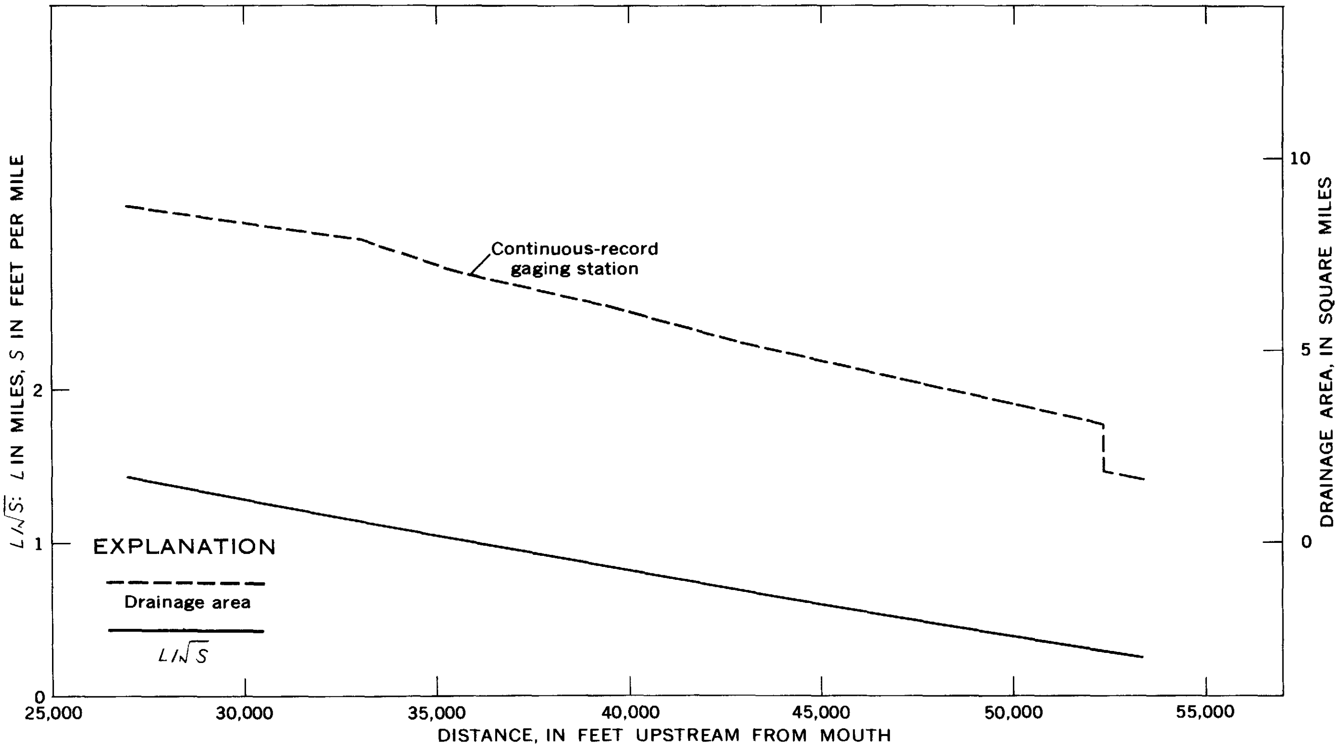

Figure 15.—Length-slope ratio and drainage area along McMullen Creek.

EXAMPLE OF COMPUTING FLOOD DISCHARGES

The following example illustrates the technique used to compute flood discharges.

Problem: Compute flow of 20-year flood using expected urban conditions and an $I=40$.

McMullen Creek at Sharon View Road (Charlotte)

Stationing=35,920 feet

$$Q=223RA^{0.85}T^{-0.45}$$

From figure 15, Drainage area (A)=6.98 sq mi

From figure 15, $L/\sqrt{S}=1.01$

From figure 5, $T=1.00$

From figure 8, $R=3.67$

$$Q=(223)(3.67)(6.98)^{0.85}(1.00)^{-0.45}=4{,}260 \text{ cfs.}$$

FLOOD PROFILES

METHOD OF COMPUTATION

The computer program used for this study to determine water-surface profile elevations was developed jointly by D. G. Anderson and W. L. Anderson,[1] of the U.S. Geological Survey, and uses the Burroughs 220 electronic computer to obtain solutions to step-backwater computations as described by Chow (1959). Given a stage-discharge relationship at the beginning point, the channel hydraulic data at the beginning point and at sections upstream, the energy equation is balanced between the beginning and a selected upstream section.

FIELD SURVEYS

In addition to the data that were collected at gaging stations and used in developing the discharge equation, flood plains and channels of each stream in the project area were visually inspected in order to estimate roughness values, document areas of improvement as shown on plate 1, and evaluate problem areas. About 60 miles of stream channels and adjacent flood plains were inspected.

Field surveys to obtain cross sections presented a problem because of the magnitude of the task. As a first step in obtaining these data, a pilot study was made to determine the feasibility of selecting necessary cross-section parameters from topographic maps. A 2.3-mile reach of Briar Creek, plate 2, was selected for this study. Cross sections defining the entire valley, channel as well as flood plain, were obtained

[1] Anderson, D. G., and Anderson, W. L., 1964, Computation of water-surface profiles in open channels: written commun. to be published as U.S. Geol. Survey Tech. Water-Resources Inv.

at about 500-feet intervals in the field using transit-stadia surveys. These cross sections were then plotted on transparent paper, and their locations transferred to the topographic maps. Cross-section data were then obtained from the maps at these same locations. Locations were purposely selected to define natural conditions. Road fills, bridges, and other artificial changes in the valley were eliminated. With roughness values determined during the survey, profile elevations for the reach were computed by electronic computer for both sets of cross-section data.

Three discharges representing three conditions of flooding were used in developing profiles for the short reach of Briar Creek. Q_1 (flood of Apr. 11, 1962) represented flow at just above bankfull stage, Q_2 (20-year flood under natural or undeveloped conditions) represented flow when the flood plain was under about 2 feet of water, and Q_3 (20-year flood under extensively urbanized conditions) was selected to represent flow when the water was from 3–5 feet deep on the flood plain. Profile elevations computed for both sets of cross-section data (*hF* representing elevations computed using data observed in the field and *hM* based on comparable map data) are tabulated in table 5. On the bottom of table 5, note that the average difference between profiles (Δh) is about 0.31 foot, the algebraic average is from -0.03 to $+0.05$ foot, and the standard error ranges from 0.36 to 0.45 foot.

Plate 2, in addition to defining the general area of the pilot study, shows the extent and location of the cross sections and the areas of inundation created by flows 1 and 3. It is interesting to note that, although the discharges of Q_3 were about 3½ times that of Q_1, there is less than 55 percent increase in inundated area. The topography of the Briar Creek flood plain is typical of flood plains in the Charlotte area; these same results, therefore, can be expected on other basins within the project.

It was intended that the study reach used should vary enough to give a representative sample of the streams in the Charlotte area and that it also should remain unchanged between the time the area was mapped and the time the field surveys were made. Unfortunately, this was not the case. Section 157 was eliminated because of man-made changes to the section. Section 171 was also removed since it was an abandoned roadbed and did not represent average conditions. Other sections where some type of alteration had occurred are footnoted in table 5, but these changes were not considered significant enough to exclude the sections from the study.

Comparison between map and field cross-section data indicates that most of the changes during the interim period were primarily on the flood plain and had little effect on the channel. This also is

TABLE 5.—*Profile comparison between field and map cross-section data, Briar Creek pilot study*

Section	Flow condition on the flood plain											
	Partially inundated				Generally inundated				Completely inundated			
	Q_1 (cfs)	h_1F (ft)	h_1M (ft)	Δh_1 (ft)	Q_2 (cfs)	h_2F (ft)	h_2M (ft)	Δh_2 (ft)	Q_3 (cfs)	h_3F (ft)	h_3M (ft)	Δh_3 (ft)
150	2,260	616.96	616.96	0	3,770	619.12	619.12	0	8,160	622.90	622.90	0
151	2,260	617.33	617.40	+.07	3,770	619.44	619.50	+.06	8,160	623.40	623.13	−.27
152	2,260	617.84	618.05	+.21	3,770	619.92	620.13	+.21	8,160	623.87	623.81	−.06
153	2,260	618.00	618.34	+.34	3,770	620.08	620.31	+.23	8,160	624.04	624.00	−.04
154	2,260	618.12	618.58	+.46	3,770	620.17	620.50	+.33	8,160	624.12	624.12	0
155	2,260	618.50	619.00	+.50	2,770	620.48	620.81	+.33	8,160	624.34	624.38	+.04
156	2,260	619.28	619.35	+.07	3,770	621.07	621.14	+.07	8,160	624.70	624.67	−.03
158	2,240	621.04	620.64	−.40	3,770	622.53	622.25	−.28	8,160	625.72	625.55	−.17
159	2,220	621.66	621.25	−.41	3,770	623.07	622.85	−.22	8,160	626.07	626.00	−.07
160	2,200	622.24	622.50	+.26	3,690	623.62	623.89	+.27	7,970	626.51	626.64	+.13
161	2,160	622.93	623.55	+.62	3,610	624.40	624.88	+.48	7,780	627.14	627.36	+.22
[1]162	2,140	623.63	624.05	+.42	3,610	625.13	625.42	+.29	7,780	627.54	627.75	+.21
[1]163	2,140	624.45	624.43	−.02	3,610	625.69	625.75	+.06	7,780	627.90	627.95	+.05
[1]164	2,140	625.25	624.84	−.41	3,610	626.56	626.07	−.49	7,780	628.46	628.25	−.21
[1]165	2,140	626.06	625.75	−.31	3,610	627.38	627.25	−.13	7,780	629.31	629.00	−.31
[1]166	2,140	626.83	626.55	−.28	3,610	628.32	628.00	−.32	7,780	630.41	629.69	−.72
[1]167	2,140	627.70	627.32	−.38	3,610	628.91	628.56	−.35	7,780	630.86	630.25	−.61
[1]168	2,120	628.00	627.68	−.32	3,540	629.12	628.75	−.37	7,625	631.01	630.43	−.58
[1]169	2,100	628.64	628.50	−.14	3,470	629.66	629.25	−.41	7,470	631.36	630.75	−.61
[1]170	2,100	629.85	629.45	−.40	3,470	630.66	630.05	−.61	7,470	631.98	631.33	−.65
172	2,100	631.62	631.25	−.37	3,470	632.87	632.59	−.28	7,470	634.78	634.31	−.47
173	2,100	632.06	631.84	−.22	3,470	633.41	633.50	+.09	7,470	635.48	636.17	+.69
174	2,100	632.50	632.75	+.25	3,470	633.97	634.58	+.61	7,470	636.24	637.13	+.89
175	2,080	633.08	633.75	+.67	3,420	634.73	635.50	+.77	7,375	637.13	637.95	+.82
[1]176	2,060	633.73	634.25	+.52	3,370	635.54	636.00	+.46	7,280	637.96	638.74	+.78
[1]177	2,060	634.24	634.67	+.43	3,370	636.33	636.63	+.30	7,280	639.69	639.76	+.07
[1]178	2,060	634.67	634.82	+.15	3,370	636.66	636.64	−.02	7,280	639.71	639.76	+.05
All sections, average difference				0.32				0.30				0.32
Algebraic difference				+1.31				+1.08				−.85
Algebraic average				+.05				+.04				−.03
Standard error				.37				.36				.45
11 sections, average difference				.30				.23				.09

[1] Flood-plain alteration between time of mapping and field surveys.

borne out by observing the differences in h_1. This difference is spread quite uniformly throughout the entire reach with no noticeable trend in the data. Assuming this to be representative, one can expect approximately 0.3-foot difference in computed water-surface elevations at bankfull stage when using map data. One would expect that as flood magnitudes increase and spread out over the flood plain, the difference between the two methods would be less even though there would probably be a greater difference in cross-sectional area. Comparison of h_1, h_2, and h_3 data in table 5 seems to verify this. The overall difference between field and map data for the three flow conditions is about 0.3 foot. If one computes the difference using the first 11 sections, those sections without alterations, h_1 differences remain at about 0.3 foot, h_2 differences drop to about 0.2 foot, and h_3 differences decrease to about 0.1 foot.

Based on the results of this pilot study, it was decided that carefully subdivided cross sections taken directly from the maps would meet the needs of the project.

Methods having been tested, cross sections of all the streams being investigated were determined from the maps. Every effort was made to locate cross sections at points representative of each reach. These sections were usually located at about 500–1,000 feet intervals, except where natural or artificial constrictions required closer intervals. Data taken from the maps included streambed and flood-plain elevations, as well as stationing along streams. The maps represented the topography in 1958–62 when the areas were mapped. Roughness values and points of subdivision of the cross section for roughness and channel shape were selected in the field in 1964 and 1965, and reflect the condition of the channels and flood plains at that time.

Reaches of channel and flood plain where some degree of improvement has taken place are so marked on plate 1. The stationing of the cross sections along streams are shown in the first column of tables 6–12.

PROFILE COMPUTATIONS

After the documentation of cross sections and other hydraulic properties, water-surface elevations at the cross sections were determined by electronic computer for the three project floods previously defined. Stage-discharge relations at the downstream end of each stream reach being investigated were estimated based on slope-conveyance studies, and starting elevations were selected from these relations.

In compiling profile data for streams in the Charlotte area, floods of selected frequencies, 16 and 20 years, were used for all reaches. It rarely happens that peaks from all tributary streams would be of the same frequency, and that all tributary peaks would be timed to reach the main channel so as to produce a peak of equal frequency. This study was not intended to define a single flood profile, but rather to define the profile of floods of predetermined magnitude at selected points.

Flood-plain zoning for new developments in the Charlotte metropolitan area is based on the elevations of floods computed for extensively urbanized watersheds and having recurrence intervals of 20 years. The city engineering department has the responsibility of establishing these elevations. In order that the computed data would be of lasting value to the city, profiles were determined on the basis of existing channel conditions excluding the effect of any manmade constrictions in the channel or flood plain. Many of the drainage structures in the Charlotte area were built before the development of the watersheds. As urban areas grow and flood runoff increases, these structures must be replaced or enlarged with the result being a change in the profiles. Rather than furnish profiles that would only represent conditions that presently existed, the decision was made to eliminate the effect of bridges and culverts from the computations. The backwater effect at these localities could readily be determined at any time once the discharge and elevation for natural channel conditions are known.

PROFILE RESULTS

Flood-profile elevations derived from the computer program for each condition of development are documented in tables 6–12. These profile data represent different stages of basin development, but as mentioned previously, all three are based on the extent of channel and flood-plain development that existed when the city was mapped and visual inspections were made.

The differences in water-surface profiles for a 20-year flood due to urban development are strongly influenced by stream-channel and flood-plain conditions. Comparisons of water-surface elevations along unimproved reaches of Irwin Creek, and Sugar Creek below the mouth of Irwin Creek, reflect increases of as much as 5½ feet that would be expected to occur because of urbanization. Conversely, in reaches along Little Sugar Creek near East Boulevard and Briar Creek below Randolph Road, which have undergone extensive channel and flood-plain improvements, the increase in water-surface elevation reflected by urban development is less than one foot. Differences in 20-year flood elevations between undeveloped and urban conditions for streams having varying degrees of channel and flood-plain improvements average about 3½ feet for about 75 percent of the channel reaches investigated, neglecting extremes such as those mentioned above.

It is likely that many of the flood plains and channels will be changed when their respective watersheds are developed to the high degree anticipated. This additional development will not automatically mean that profile elevations will increase; in fact, it is quite likely that valley and channel reaches will be improved without any major topographic change, and the resulting effect will be a reduction in roughness values which, in turn, results in lowering the profile elevations listed under urban conditions in tables 6–12.

Stage-discharge relations were developed at continuous-record and crest-gage stations on each of the streams that were investigated. Curves in figures 16–24 define these relations with the lower parts being defined by measurements and the high ends being extended by the use of computed profile data. In some cases, stages were adjusted

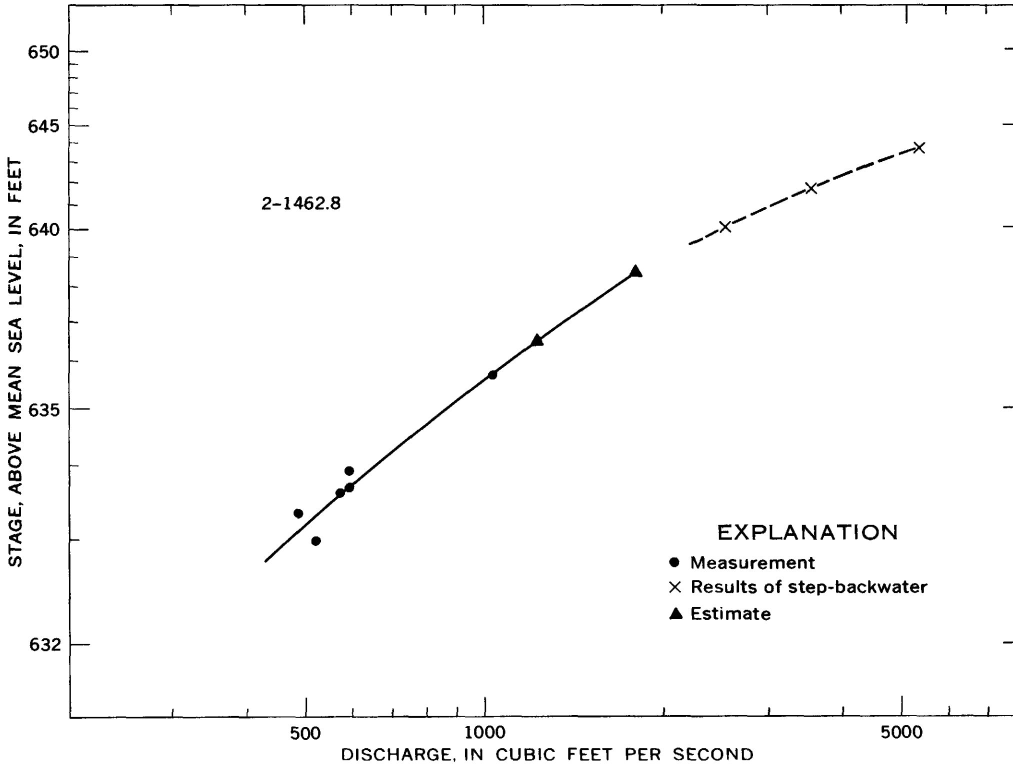

FIGURE 16.—Stage-discharge relation for Stewart Creek at Charlotte, N.C.

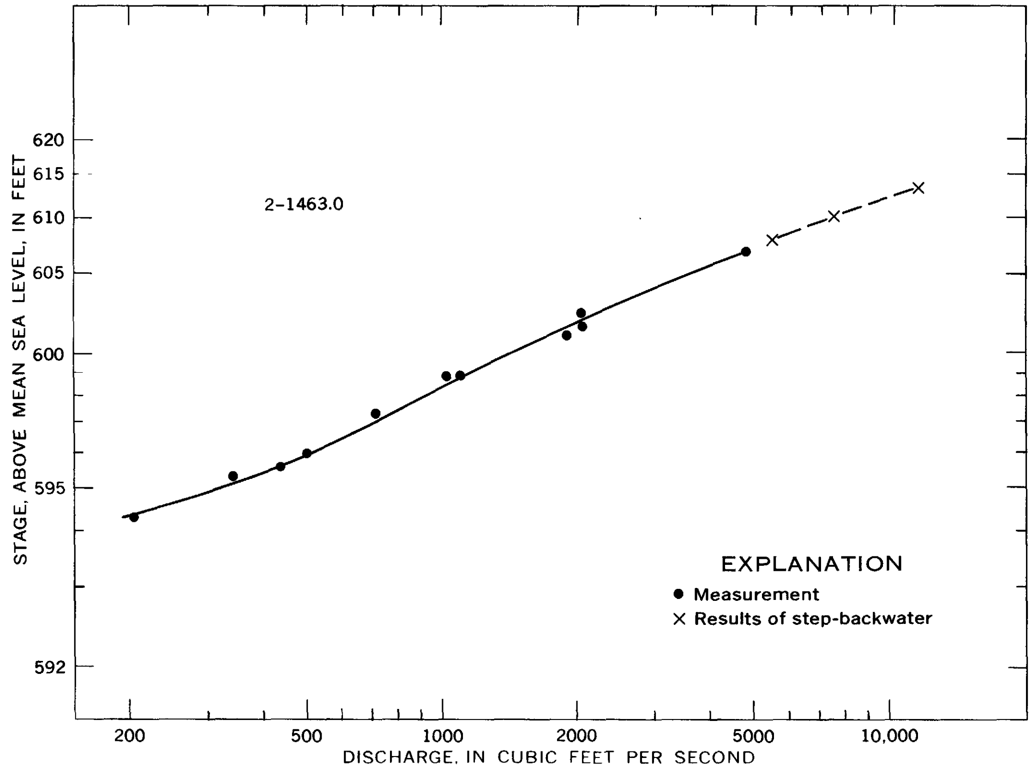

Figure 17.—Stage-discharge relation for Irwin Creek near Charlotte, N.C.

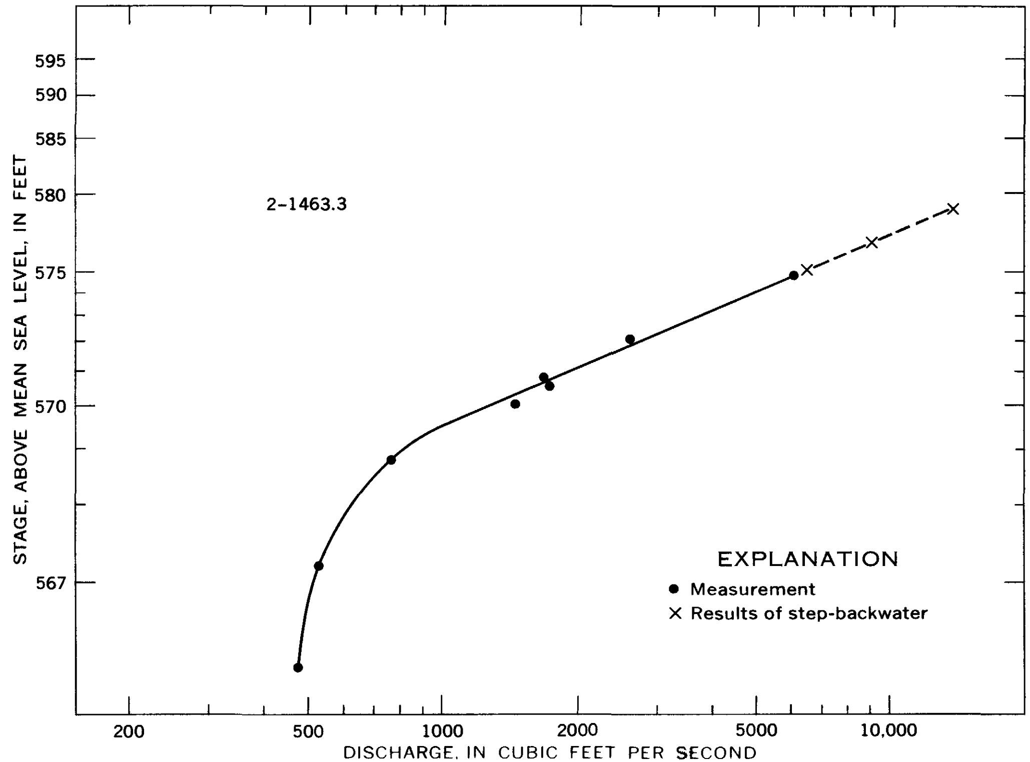

Figure 18.—Stage-discharge relation for Sugar Creek near Charlotte, N.C.

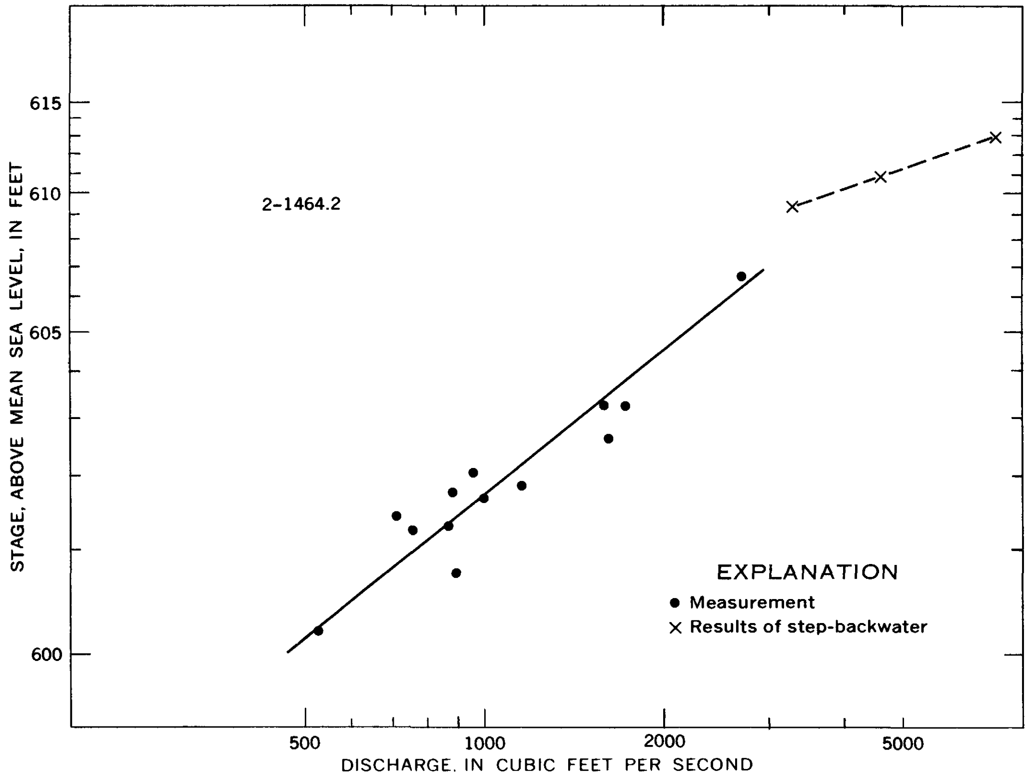

Figure 19.—Stage-discharge relation for Little Sugar Creek at Hillside Avenue, Charlotte, N.C.

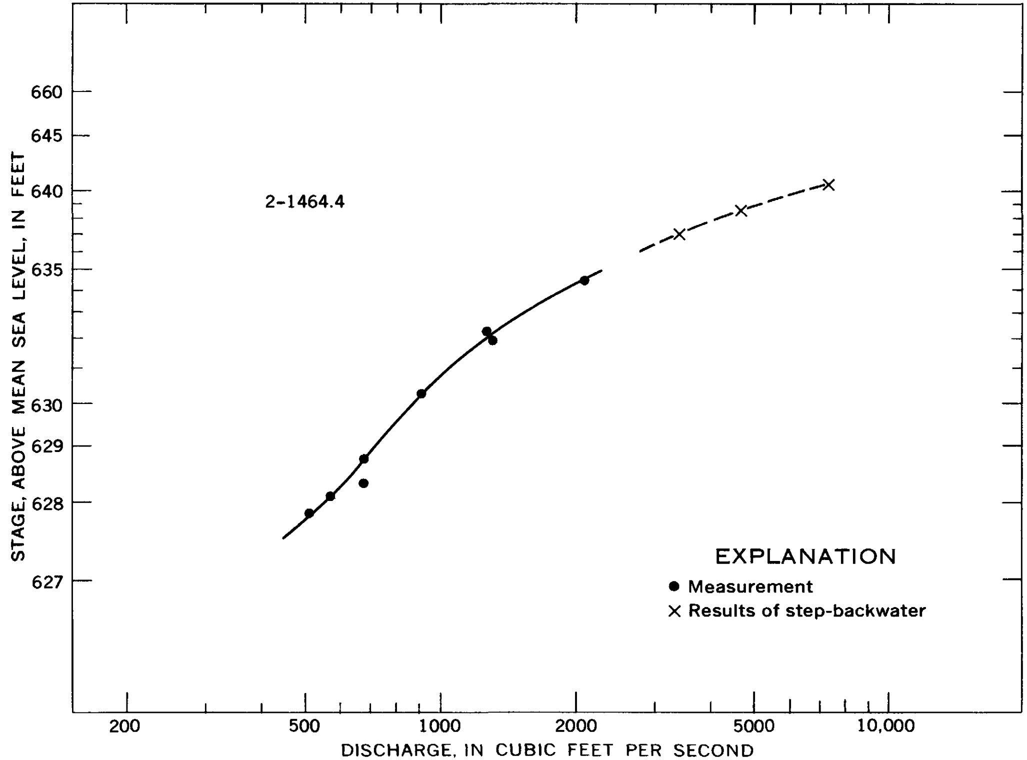

Figure 20.—Stage-discharge relation for Briar Creek at East Seventh Street, Charlotte, N.C.

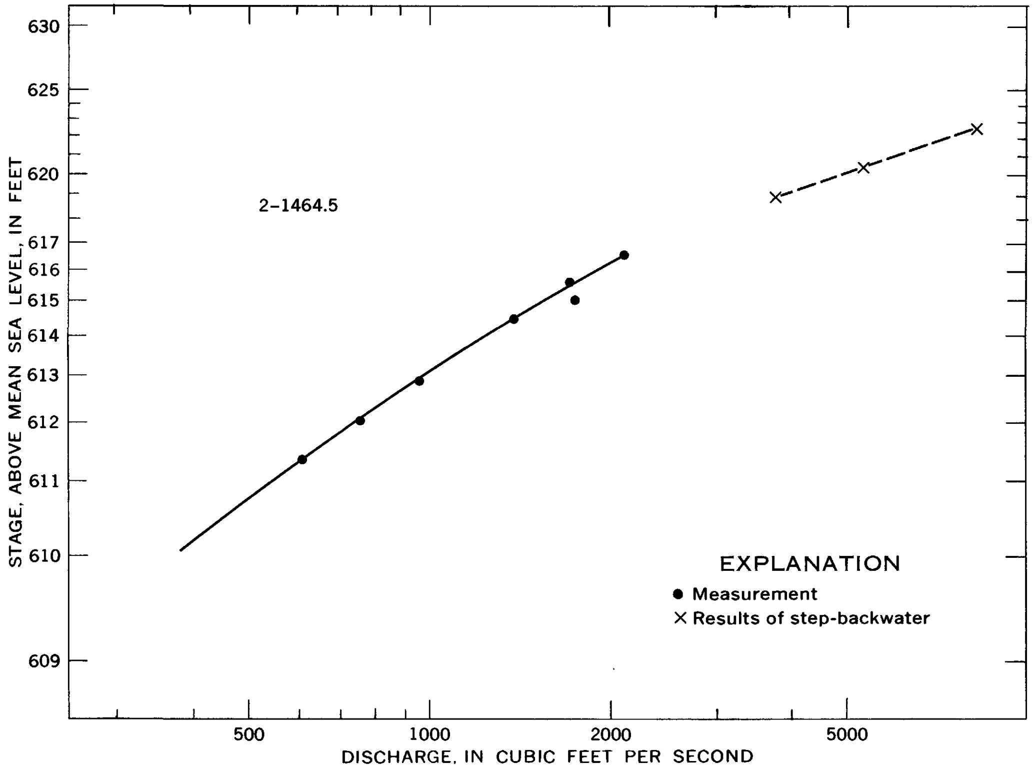

FIGURE 21.—Stage-discharge relation for Briar Creek at Sharon Road, Charlotte, N.C.

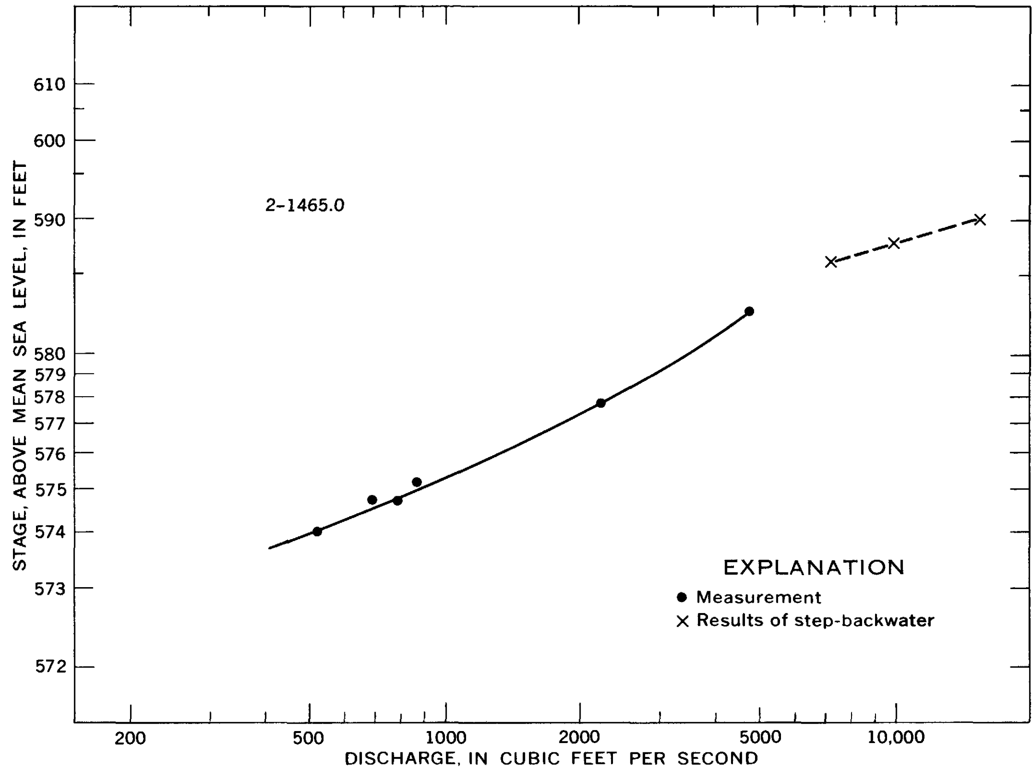

Figure 22.—Stage-discharge relation for Little Sugar Creek at Tyvola Road, Charlotte, N.C.

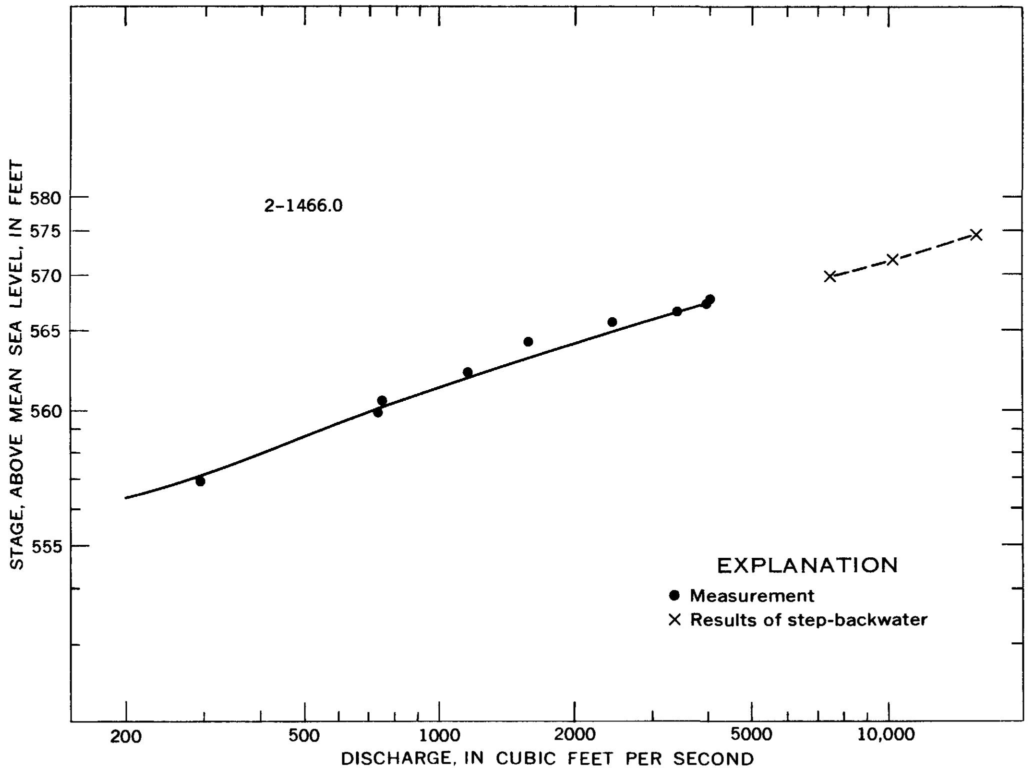

Figure 23.—Stage-discharge relation for McAlpine Creek at Sardis Road, Charlotte, N.C.

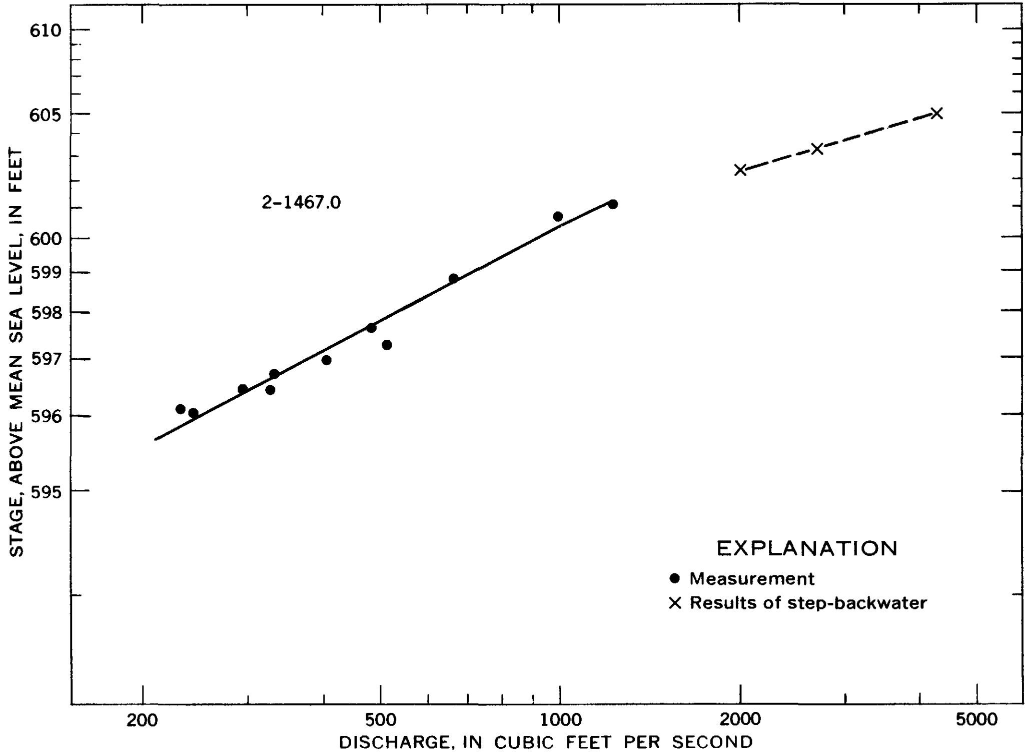

FIGURE 24.—Stage-discharge relation for McMullen Creek at Sharon View Road near Charlotte, N.C.

to account for local backwater at bridges. These stage-discharge relations were developed primarily as a check on the accuracy of completed profiles. Discharge values used in profile computations were much greater than any flows observed since the project originated. This makes a direct comparison impossible, but the extension of the curves based on profile data appears reasonable except in a few cases. A notable exception is the relation of Little Sugar Creek at Hillside Avenue, figure 17. This station was difficult to rate even at lower stages, as indicated by the scatter of the measurements. The highest measurement on the curve was made indirectly, just below bankful stage. The low point of the computer data was determined just above bankful stage. A slight difference between individuals in selection of roughness values at this stage probably could cause this spread.

The accuracy of profile computations is limited by the accuracy of the topographic mapping, and the profile data should be used in conjunction with the city maps.

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TABLES 6–12

TABLE 6.—*Water-surface elevation and discharge of selected floods on Stewart Creek*

Stationing (feet) [1]	Undeveloped conditions		Partly developed conditions		Urban conditions	
	Discharge (cfs)	Elev (feet) msl [2]	Discharge (cfs)	Elev (feet) msl [2]	Discharge (cfs)	Elev (feet) msl [2]
340	2, 820	631. 7	3, 860	633. 2	5, 940	635. 4
780	2, 820	632. 1	3, 860	633. 5	5, 940	635. 7
1,375	2, 820	632. 8	3, 860	634. 0	5, 940	635. 9
Morehead Street						
1,525	2, 820	633. 6	3, 860	634. 7	5, 940	636. 4
1,902	2, 820	634. 8	3, 860	635. 9	5, 940	637. 5
2,220	2, 550	635. 6	3, 510	636. 7	5, 390	638. 2
Freedom Drive						
2,445	2, 550	635. 8	3, 510	637. 0	5, 390	638. 7
2,868	2, 550	636. 1	3, 510	637. 2	5, 390	638. 9
3,235	2, 550	636. 6	3, 510	637. 8	5, 390	639. 4
3,662	2, 550	638. 0	3, 510	639. 4	5, 390	641. 4
4,120	2, 550	638. 9	3, 510	640. 3	5, 390	642. 5
4,771	2, 550	639. 6	3, 510	641. 0	5, 390	643. 3
Piedmont and Northern Railroad Spur						
4,825	2, 550	639. 8	3, 510	641. 2	5, 390	643. 5
5,064	2, 550	640. 0	3, 510	641. 4	5, 390	643. 7
Tuckasegee Road						
5,169	2, 550	640. 1	3, 510	641. 5	5, 390	643. 8
5,598	2, 550	640. 6	3, 510	642. 0	5, 390	644. 1
6,091	2, 550	641. 8	3, 510	643. 0	5, 390	645. 0
6,419	2, 550	643. 2	3, 510	644. 2	5, 390	646. 1
State Street						
6,592	2, 550	644. 3	3, 510	645. 5	5, 390	647. 4
6,617	2, 550	644. 4	3, 510	645. 6	5, 390	647. 5
Piedmont and Northern Railroad						
6, 816	2, 550	645. 0	3, 510	646. 2	5, 390	648. 1
7, 060	2, 550	645. 5	3, 510	646. 8	5, 390	649. 0
7, 495	2, 550	645. 9	3, 510	647. 2	5, 390	649. 3
7, 932	2, 550	646. 2	3, 510	647. 5	5, 390	649. 5
8, 306	2, 550	647. 0	3, 510	648. 1	5, 390	650. 0
8, 553	2, 550	647. 4	3, 510	648. 4	5, 390	650. 2
8, 675	2, 550	647. 6	3, 510	648. 6	5, 390	650. 4
8, 771	2, 550	648. 0	3, 510	649. 0	5, 390	650. 6
8, 912	2, 550	649. 0	3, 510	650. 1	5, 390	651. 8
9, 049	2, 550	649. 8	3, 510	651. 0	5, 390	653. 0
9, 455	1, 990	651. 8	2, 740	653. 0	4, 190	654. 7
Rozzelles Ferry Road						
9, 595	1, 990	653. 2	2, 740	654. 6	4, 190	656. 5
9, 940	1, 990	654. 1	2, 740	655. 3	4, 190	657. 2
10, 232	1, 990	654. 5	2, 740	655. 6	4, 190	657. 3
10, 574	1, 990	655. 3	2, 740	656. 2	4, 190	657. 7
10, 827	1, 990	656. 2	2, 740	657. 1	4, 190	658. 4
West Trade Street						
10, 941	1, 990	657. 0	2, 740	657. 9	4, 190	659. 5
11, 304	1, 990	658. 3	2, 740	659. 2	4, 190	660. 9
11, 749	1, 990	659. 4	2, 740	660. 4	4, 190	662. 0

[1] Station at mouth is 0.
[2] Mean sea level, city of Charlotte bench marks.

TABLE 6.—*Water-surface elevation and discharge of selected floods on Stewart Creek*—Continued

Stationing (feet) [1]	Undeveloped conditions		Partly developed conditions		Urban conditions	
	Discharge (cfs)	Elev (feet) msl [2]	Discharge (cfs)	Elev (feet) msl [2]	Discharge (cfs)	Elev (feet) msl [2]
Seaboard Airline Railroad						
12, 017	1, 990	661. 0	2, 740	662. 0	4, 190	663. 6
12, 441	1, 990	664. 7	2, 740	665. 6	4, 190	666. 7
12, 832	1, 990	665. 7	2, 740	666. 5	4, 190	667. 8
13, 297	1, 990	666. 2	2, 740	667. 1	4, 190	668. 4
13, 739	1, 990	667. 3	2, 740	668. 2	4, 190	669. 4
14, 075	1, 990	669. 1	2, 740	670. 1	4, 190	671. 5
LaSalle Street						
14, 149	1, 990	669. 9	2, 740	671. 0	4, 190	672. 5
14, 505	1, 990	670. 9	2, 740	671. 8	4, 190	673. 2
15, 002	1, 840	672. 6	2, 540	673. 3	3, 880	674. 6
15, 438	1, 840	673. 2	2, 540	674. 1	3, 880	675. 6
15, 900	1, 840	673. 6	2, 540	674. 5	3, 880	676. 0
16, 348	1, 840	674. 4	2, 540	675. 2	3, 880	676. 6
16, 788	1, 840	675. 7	2, 540	676. 6	3, 880	678. 1

[1] Station at mouth is 0.
[2] Mean sea level, city of Charlotte bench marks.

TABLE 7.—*Water-surface elevation and discharge for selected floods on Irwin Creek*

Stationing (feet) [1]	Undeveloped conditions		Partly developed conditions		Urban conditions	
	Discharge (cfs)	Elev (feet) msl [2]	Discharge (cfs)	Elev (feet) msl [2]	Discharge (cfs)	Elev (feet) msl [2]
163, 112	5, 470	604. 0	7, 500	606. 1	11, 500	609. 6
163, 439	5, 470	604. 4	7, 500	606. 6	11, 500	610. 1
163, 849	5, 470	605. 0	7, 500	607. 2	11, 500	610. 8
164, 319	5, 470	605. 6	7, 500	608. 0	11, 500	611. 6
164, 529	5, 470	605. 9	7, 500	608. 2	11, 500	611. 8
164, 780	5, 470	606. 2	7, 500	608. 7	11, 500	612. 4
165, 039	5, 470	606. 6	7, 500	609. 1	11, 500	612. 8
165, 449	5, 470	606. 9	7, 500	609. 3	11, 500	613. 0
165, 868	5, 470	607. 0	7, 500	609. 4	11, 500	613. 0
166, 280	5, 470	607. 2	7, 500	609. 4	11, 500	613. 0
166, 667	5, 470	607. 9	7, 500	610. 0	11, 500	613. 4
Disposal Plant Road						
166, 756	5, 470	608. 2	7, 500	610. 1	11, 500	613. 4
166, 856	5, 470	608. 3	7, 500	610. 2	11, 500	613. 6
167, 139	5, 470	608. 5	7, 500	610. 4	11, 500	613. 7
167, 499	5, 470	608. 8	7, 500	610. 6	11, 500	613. 8
167, 945	5, 470	609. 5	7, 500	611. 2	11, 500	614. 2
168, 428	5, 470	610. 8	7, 500	612. 0	11, 500	614. 7
168, 781	5, 270	611. 8	7, 250	613. 0	11, 100	615. 5
169, 339	5, 270	612. 5	7, 250	613. 8	11, 100	615. 9
169, 859	5, 270	613. 8	7, 250	615. 6	11, 100	618. 6
170, 362	5, 270	614. 5	7, 250	616. 2	11, 100	619. 2
170, 709	5, 270	615. 2	7, 250	617. 0	11, 100	620. 0
171, 172	5, 270	616. 1	7, 250	618. 0	11, 100	621. 0
171, 671	5, 270	616. 8	7, 250	618. 6	11, 100	621. 4
171, 869	5, 270	617. 2	7, 250	619. 2	11, 100	622. 4

[1] Station at mouth is 162,611 feet.
[2] Mean sea level, city of Charlotte bench marks.

TABLE 7.—*Water-surface elevation and discharge for selected floods on Irwin Creek*—Continued

Stationing (feet)[1]	Undeveloped conditions		Partly developed conditions		Urban conditions	
	Discharge (cfs)	Elev (feet) msl[2]	Discharge (cfs)	Elev (feet) msl[2]	Discharge (cfs)	Elev (feet) msl[2]
172, 141	5, 270	617. 9	7, 250	619. 9	11, 100	623. 1
172, 596	5, 060	618. 1	6, 960	620. 1	10, 600	623. 2
172, 947	5, 060	618. 2	6, 960	620. 2	10, 600	623. 2
173, 220	5, 060	618. 2	6, 960	620. 2	10, 600	623. 3
173, 601	5, 060	618. 5	6, 960	620. 5	10, 600	623. 5
173, 874	5, 060	618. 6	6, 960	620. 6	10, 600	623. 6
174, 252	5, 060	618. 8	6, 960	620. 8	10, 600	623. 6
174, 647	5, 060	619. 0	6, 960	620. 9	10, 600	623. 8
175, 142	5, 060	619. 2	6, 960	621. 0	10, 600	623. 9
Barringer Drive						
175, 226	5, 060	619. 4	6, 960	621. 1	10, 600	623. 9
175, 434	5, 060	619. 6	6, 960	621. 2	10, 600	624. 0
175, 827	5, 060	619. 8	6, 960	621. 4	10, 600	624. 1
176, 084	5, 060	619. 9	6, 960	621. 5	10, 600	624. 1
176, 687	5, 060	620. 5	6, 960	621. 8	10, 600	624. 3
177, 208	5, 060	621. 3	6, 960	622. 6	10, 600	624. 8
177, 801	5, 060	622. 5	6, 960	623. 9	10, 600	625. 9
Remount Road						
177, 979	5, 060	622. 9	6, 960	624. 3	10, 600	626. 5
178, 376	5, 060	623. 2	6, 960	624. 7	10, 600	626. 8
178, 641	5, 060	623. 3	6, 960	624. 8	10, 600	626. 9
179, 009	5, 060	623. 4	6, 960	624. 8	10, 600	626. 9
179, 450	5, 060	624. 2	6, 960	625. 5	10, 600	627. 6
179, 734	5, 060	624. 4	6, 960	625. 6	10, 600	627. 8
179, 947	5, 060	624. 6	6, 960	625. 8	10, 600	627. 8
180, 140	5, 060	624. 7	6, 960	625. 8	10, 600	627. 9
180, 440	5, 060	625. 0	6, 960	626. 2	10, 600	628. 2
West Boulevard						
180, 554	5, 060	625. 1	6, 960	626. 2	10, 600	628. 3
180, 769	5, 060	625. 6	6, 960	626. 6	10, 600	628. 5
181, 157	5, 060	626. 2	6, 960	627. 2	10, 600	629. 0
181, 559	5, 060	627. 1	6, 960	628. 1	10, 600	629. 8
181, 899	5, 060	627. 9	6, 960	629. 2	10, 600	630. 9
182, 299	5, 060	628. 7	6, 960	630. 0	10, 600	631. 9
Southern Railroad						
182, 532	5, 060	629. 0	6, 960	630. 3	10, 600	632. 2
182, 678	5, 060	629. 2	6, 960	630. 5	10, 600	632. 5
Independence Boulevard						
182, 827	5, 060	629. 2	6, 960	630. 5	10, 600	632. 4
183, 162	5, 060	629. 9	6, 960	631. 4	10, 600	633. 4
183, 387	2, 910	631. 3	4, 000	632. 9	6, 210	635. 1
183, 605	2, 910	631. 7	4, 000	633. 2	6, 210	635. 3
183, 967	2, 910	632. 0	4, 000	633. 4	6, 210	635. 6
Walnut Avenue						
184, 177	2, 910	632. 1	4, 000	633. 5	6, 210	635. 6
184, 458	2, 910	632. 6	4, 000	633. 9	6, 210	635. 9
184, 787	2, 910	633. 1	4, 000	634. 4	6, 210	636. 2
Summit Avenue						
184, 909	2, 910	633. 5	4, 000	634. 8	6, 210	636. 6
185, 373	2, 910	634. 6	4, 000	636. 1	6, 210	638. 0
185, 724	2, 910	635. 5	4, 000	637. 0	6, 210	639. 0
186, 261	2, 910	636. 6	4, 000	638. 2	6, 210	640. 5

[1] Station at mouth is 162,611 feet.
[2] Mean sea level, city of Charlotte bench marks.

TABLE 7.—*Water-surface elevation and discharge for selected floods on Irwin Creek*—Continued

Stationing (feet)[1]	Undeveloped conditions		Partly developed conditions		Urban conditions	
	Discharge (cfs)	Elev (feet) msl[2]	Discharge (cfs)	Elev (feet) msl[2]	Discharge (cfs)	Elev (feet) msl[2]
West Morehead Street						
186, 462	2, 910	636. 9	4, 000	638. 6	6, 210	641. 0
186, 743	2, 910	637. 3	4, 000	638. 9	6, 210	641. 0
187, 178	2, 910	638. 4	4, 000	640. 1	6, 210	642. 6
Piedmont and Northern Railroad						
187, 307	2, 910	638. 9	4, 000	640. 5	6, 210	642. 9
187, 760	2, 870	639. 1	3, 940	640. 8	6, 050	643. 1
188, 323	2, 870	639. 3	3, 940	641. 0	6, 050	643. 3
188, 693	2, 870	639. 5	3, 940	641. 0	6, 050	643. 3
189, 302	2, 870	640. 9	3, 940	642. 6	6, 050	645. 0
West Trade Street						
189, 429	2, 870	641. 0	3, 940	642. 8	6, 050	645. 2
189, 982	2, 870	641. 8	3, 940	643. 6	6, 050	646. 1
West Fifth Street						
190, 166	2, 870	641. 9	3, 940	643. 7	6, 050	646. 2
190, 644	2, 870	642. 3	3, 940	644. 0	6, 050	646. 5
191, 125	2, 870	643. 4	3, 940	645. 0	6, 050	647. 3
191, 645	2, 870	644. 2	3, 940	645. 9	6, 050	648. 2
Seaboard Airline Railroad						
191, 981	2, 870	645. 2	3, 940	646. 8	6, 050	649. 1
192, 281	2, 870	646. 2	3, 940	647. 8	6, 050	649. 9
192, 629	2, 620	647. 2	3, 600	648. 8	5, 560	651. 1
193, 000	2, 620	647. 8	3, 600	649. 2	5, 560	651. 5
193, 243	2, 620	648. 2	3, 600	649. 6	5, 560	651. 7
193, 770	2, 620	649. 2	3, 600	650. 7	5, 560	652. 8
194, 300	2, 620	650. 7	3, 600	652. 0	5, 560	654. 1
194, 795	2, 620	651. 5	3, 600	652. 9	5, 560	655. 0
Oaklawn Avenue						
194, 933	2, 620	651. 8	3, 600	653. 2	5, 560	655. 2
195, 052	2, 620	652. 8	3, 600	654. 0	5, 560	656. 1
195, 432	2, 620	653. 5	3, 600	654. 7	5, 560	656. 7
195, 990	2, 620	654. 2	3, 600	655. 3	5, 560	657. 2
196, 430	2, 620	655. 2	3, 600	656. 3	5, 560	658. 2
196, 869	2, 620	655. 9	3, 600	657. 0	5, 560	658. 8
197, 301	2, 620	657. 1	3, 600	658. 3	5, 560	660. 3
197, 617	2, 620	658. 1	3, 600	659. 4	5, 560	661. 6
197, 885	2, 620	658. 4	3, 600	659. 8	5, 650	661. 9
198, 259	2, 620	658. 8	3, 600	660. 0	5, 560	662. 2
198, 811	2, 620	659. 6	3, 600	660. 8	5, 560	662. 8
199, 221	2, 620	660. 8	3, 600	661. 8	5, 560	663. 5
199, 620	2, 620	662. 2	3, 600	663. 1	5, 560	664. 6
Newland Avenue						
199, 805	2, 620	663. 1	3, 600	663. 9	5, 560	665. 2
200, 241	1, 810	664. 5	2, 500	665. 2	3, 800	666. 5
200, 870	1, 810	665. 5	2, 500	666. 2	3, 800	667. 4
Statesville Avenue						
201, 014	1, 810	665. 9	2, 500	666. 6	3, 800	667. 8
201, 380	1, 810	667. 2	2, 500	668. 2	3, 800	669. 6
201, 786	1, 810	667. 8	2, 500	668. 8	3, 800	670. 3

[1] Station at mouth is 162,611 feet.
[2] Mean sea level, city of Charlotte bench marks.

TABLE 8.—*Water-surface elevation and discharge for selected floods on Sugar Creek*

Stationing (feet)[1]	Undeveloped conditions		Partly developed conditions		Urban conditions	
	Discharge (cfs)	Elev (feet) msl[2]	Discharge (cfs)	Elev (feet) msl[2]	Discharge (cfs)	Elev (feet) msl[2]
Arrowood Road						
138, 993	6, 590	575. 2	9, 050	576. 7	13, 800	578. 8
139, 189	6, 590	575. 3	9, 050	576. 9	13, 800	579. 0
139, 694	6, 590	575. 6	9, 050	577. 1	13, 800	579. 3
140, 094	6, 590	575. 9	9, 050	577. 4	13, 800	579. 6
140, 442	6, 590	576. 2	9, 050	577. 7	13, 800	579. 9
140, 763	6, 590	576. 2	9, 050	577. 8	13, 800	580. 0
141, 028	6, 590	576. 3	9, 050	577. 8	13, 800	580. 1
141, 223	6, 590	576. 5	9, 050	578. 0	13, 800	580. 2
141, 691	6, 590	576. 8	9, 050	578. 2	13, 800	580. 5
142, 097	6, 590	576. 8	9, 050	578. 4	13, 800	580. 6
142, 465	6, 590	577. 1	9, 050	578. 6	13, 800	580. 9
142, 968	6, 590	577. 6	9, 050	579. 1	13, 800	581. 5
143, 302	6, 590	578. 1	9, 050	579. 7	13, 800	582. 1
143, 501	6, 590	578. 2	9, 050	579. 8	13, 800	582. 3
143, 801	6, 590	578. 3	9, 050	579. 9	13, 800	582. 4
144, 161	6, 590	578. 4	9, 050	580. 0	13, 800	582. 4
144, 556	6, 500	578. 6	8, 990	580. 2	13, 700	582. 6
144, 964	6, 500	578. 9	8, 990	580. 4	13, 700	582. 8
145, 227	6, 500	579. 1	8, 990	580. 6	13, 700	583. 0
145, 525	6, 500	579. 4	8, 990	581. 0	13, 700	583. 3
145, 876	6, 500	579. 8	8, 990	581. 2	13, 700	583. 6
146, 382	6, 500	580. 2	8, 990	581. 6	13, 700	583. 9
146, 803	6, 500	580. 6	8, 990	582. 0	13, 700	584. 2
147, 211	6, 500	581. 1	8, 990	582. 5	13, 700	584. 6
147, 655	6, 500	581. 9	8, 990	583. 1	13, 700	585. 2
147, 951	6, 500	582. 7	8, 990	583. 9	13, 700	585. 9
148, 449	6, 500	584. 1	8, 990	585. 5	13, 700	587. 5
148, 910	6, 500	585. 6	8, 990	587. 2	13, 700	589. 8
York Road (NC Highway 49)						
149, 053	6, 500	585. 6	8, 990	587. 2	13, 700	589. 7
149, 224	6, 500	586. 6	8, 990	588. 2	13, 700	590. 6
149, 320	6, 500	586. 6	8, 990	588. 0	13, 700	590. 2
149, 564	6, 500	587. 5	8, 990	589. 4	13, 700	592. 4
150, 239	6, 500	587. 9	8, 990	589. 8	13, 700	592. 8
150, 734	6, 500	588. 0	8, 990	589. 8	13, 700	592. 8
151, 265	6, 500	588. 1	8, 990	589. 9	13, 700	592. 9
151, 722	6, 500	588. 2	8, 990	590. 0	13, 700	593. 0
152, 346	6, 500	588. 5	8, 990	590. 2	13, 700	593. 2
152, 845	6, 500	589. 2	8, 990	590. 8	13, 700	593. 5
153, 357	6, 500	589. 8	8, 990	591. 2	13, 700	593. 8
153, 943	6, 500	590. 2	8, 990	591. 6	13, 700	594. 2
154, 367	6, 500	590. 7	8, 990	592. 1	13, 700	594. 5
154, 781	6, 500	591. 2	8, 990	592. 6	13, 700	594. 9
154, 956	6, 500	591. 4	8, 990	592. 7	13, 700	595. 0
155, 212	6, 390	591. 8	8, 770	593. 2	13, 400	595. 8
155, 693	6, 390	592. 6	8, 770	594. 1	13, 400	596. 5
156, 111	6, 390	593. 4	8, 770	595. 2	13, 400	597. 9
156, 500	6, 390	594. 2	8, 770	595. 9	13, 400	598. 6
156, 825	6, 390	594. 7	8, 770	596. 5	13, 400	599. 6
157, 254	6, 390	595. 4	8, 770	597. 1	13, 400	600. 0
157, 692	6, 390	596. 4	8, 770	598. 2	13, 400	601. 3
158, 268	6, 390	597. 2	8, 770	599. 0	13, 400	601. 9
158, 490	6, 390	597. 6	8, 770	599. 3	13, 400	602. 2

[1] Station at mouth is 0.
[2] Mean sea level, city of Charlotte bench marks.

TABLE 8.—*Water-surface elevation and discharge for selected floods on Sugar Creek*—Continued

Stationing (feet)[1]	Undeveloped conditions		Partly developed conditions		Urban conditions	
	Discharge (cfs)	Elev (feet) msl[2]	Discharge (cfs)	Elev (feet) msl[2]	Discharge (cfs)	Elev (feet) msl[2]
159, 161	6, 390	598. 4	8, 770	600. 3	13, 400	603. 4
159, 509	6, 390	599. 3	8, 770	601. 3	13, 400	604. 1
159, 971	6, 390	600. 1	8, 770	602. 1	13, 400	605. 5
160, 301	6, 390	600. 8	8, 770	602. 9	13, 400	606. 2
160, 580	6, 390	601. 0	8, 770	603. 1	13, 400	606. 4
160, 820	6, 390	601. 4	8, 770	603. 5	13, 400	606. 8
161, 242	6, 390	601. 9	8, 770	604. 0	13, 400	607. 3
Yorkmont Road						
161, 340	6, 390	602. 1	8, 770	604. 2	13, 400	607. 8
161, 667	6, 390	602. 5	8, 770	604. 6	13, 400	608. 1
162, 023	6, 390	602. 8	8, 770	605. 0	13, 400	608. 5
162, 549	6, 390	603. 4	8, 770	605. 6	13, 400	609. 2

1 Station at mouth is 0.
2 Mean sea level, city of Charlotte bench marks.

TABLE 9.—*Water-surface elevation and discharge of selected floods on Little Sugar Creek*

Stationing (feet)[1]	Undeveloped conditions		Partly developed conditions		Urban conditions	
	Discharge (cfs)	Elev (feet) msl[2]	Discharge (cfs)	Elev (feet) msl[2]	Discharge (cfs)	Elev (feet) msl[2]
452, 788	7, 360	565. 6	10, 100	567. 0	15, 800	569. 0
453, 383	7, 360	566. 1	10, 100	567. 5	15, 800	569. 5
453, 770	7, 360	566. 8	10, 100	368. 4	15, 800	570. 8
454, 204	7, 360	567. 2	10, 100	568. 9	15, 800	571. 3
454, 383	7, 360	567. 7	10, 100	569. 4	15, 800	572. 0
454, 454	7, 360	568. 0	10, 100	569. 8	15, 800	572. 6
454, 738	7, 360	568. 2	10, 100	569. 9	15, 800	572. 8
455, 127	7, 360	568. 4	10, 100	570. 2	15, 800	573. 1
455, 498	7, 360	568. 7	10, 100	570. 5	15, 800	573. 3
455, 951	7, 360	569. 1	10, 100	570. 7	15, 800	573. 5
456, 465	7, 360	570. 1	10, 100	571. 6	15, 800	574. 1
457, 128	7, 360	571. 5	10, 100	572. 9	15, 800	575. 4
457, 603	7, 360	572. 2	10, 100	573. 7	15, 800	576. 0
457, 998	7, 360	572. 7	10, 100	574. 1	15, 800	576. 4
458, 442	7, 240	573. 2	10, 000	574. 7	15, 500	577. 1
458, 915	7, 240	573. 8	10, 000	575. 2	15, 500	577. 5
459, 335	7, 240	574. 2	10, 000	575. 9	15, 500	578. 4
459, 847	7, 240	574. 9	10, 000	576. 8	15, 500	579. 5
460, 236	7, 240	575. 4	10, 000	577. 3	15, 500	580. 1
460, 726	7, 240	576. 4	10, 000	578. 2	15, 500	581. 2
461, 228	7, 240	577. 6	10, 000	579. 5	15, 500	582. 4
Reid Road (Archdale)						
461, 348	7, 240	578. 1	10, 000	579. 9	15, 500	583. 0
461, 888	7, 240	580. 6	10, 000	582. 4	15, 500	584. 8
462, 308	7, 240	582. 2	10, 000	584. 2	15, 500	587. 3
462, 570	7, 240	582. 9	10, 000	585. 0	15, 500	588. 2
463, 070	7, 240	583. 8	10, 000	585. 8	15, 500	389. 0
463, 402	7, 240	584. 7	10, 000	586. 6	15, 500	589. 5
463, 724	7, 240	585. 5	10, 000	587. 2	15, 500	590. 0

1 Station at mouth is 413,923 feet.
2 Mean sea level, city of Charlotte bench marks.

TABLE 9.—*Water-surface elevation and discharge of selected floods on Little Sugar Creek*—Continued

Stationing (feet) [1]	Undeveloped conditions		Partly developed conditions		Urban conditions	
	Discharge (cfs)	Elev (feet) msl [2]	Discharge (cfs)	Elev (feet) msl [2]	Discharge (cfs)	Elev (feet) msl [2]
Tyvola Road						
463, 819	7, 240	586. 1	10, 000	587. 6	15, 500	590. 1
464, 270	7, 240	586. 9	10, 000	588. 3	15, 500	590. 6
464, 680	6, 720	587. 5	9, 330	589. 0	15, 500	591. 4
465, 122	6, 720	588. 0	9, 330	589. 5	14, 400	592. 1
465, 362	6, 720	588. 2	9, 330	589. 8	14, 400	592. 2
465, 645	6, 720	588. 2	9, 330	589. 8	14, 400	592. 3
465, 930	6, 720	588. 4	9, 330	590. 0	14, 400	592. 6
466, 335	3, 270	588. 6	4, 510	590. 2	7, 030	592. 8
466, 748	3, 270	588. 7	4, 510	590. 3	7, 030	592. 8
466, 979	3, 270	588. 9	4, 510	590. 5	7, 030	593. 0
Park Road						
467, 187	3, 270	589. 3	4, 510	591. 0	7, 030	593. 6
467, 583	3, 270	589. 9	4, 510	591. 6	7, 030	594. 2
468, 027	3, 270	590. 6	4, 510	592. 2	7, 030	595. 0
468, 515	3, 270	591. 4	4, 510	593. 1	7, 030	595. 8
468, 998	3, 270	592. 2	4, 510	594. 0	7, 030	596. 8
469, 466	3, 270	593. 0	4, 510	594. 8	7, 030	597. 8
469, 946	3, 270	593. 8	4, 510	595. 5	7, 030	598. 3
470, 591	3, 290	595. 2	4, 560	596. 8	7, 110	599. 5
471, 157	3, 290	596. 5	4, 560	598. 1	7, 110	600. 8
471, 833	3, 290	598. 0	4, 560	599. 7	7, 110	602. 3
472, 296	3, 290	599. 4	4, 560	601. 1	7, 110	603. 6
Woodlawn Road						
472, 411	3, 290	600. 0	4, 560	601. 8	7, 110	604. 5
472, 774	3, 290	601. 2	4, 560	603. 1	7, 110	605. 8
473, 067	3, 290	603. 3	4, 560	605. 1	7, 110	607. 8
Brandywine Road						
473, 241	3, 290	604. 1	4, 560	605. 9	7, 110	608. 6
473, 782	3, 290	605. 8	4, 560	607. 1	7, 110	609. 6
474, 367	3, 290	606. 5	4, 560	607. 7	7, 110	609. 9
474, 831	3, 290	607. 8	4, 560	608. 8	7, 110	610. 5
474, 996	3, 290	608. 2	4, 560	609. 2	7, 110	610. 9
475, 385	3, 290	608. 9	4, 560	610. 1	7, 110	612. 0
Hillside Avenue						
475, 505	3, 290	609. 3	4, 560	610. 7	7, 110	612. 8
476, 011	3, 290	609. 6	4, 560	610. 9	7, 110	613. 0
476, 531	3, 290	609. 6	4, 560	611. 1	7, 110	613. 2
477, 029	3, 290	612. 0	4, 560	612. 8	7, 110	614. 2
477, 397	3, 210	612. 4	4, 460	613. 2	6, 910	614. 6
477, 751	3, 210	613. 0	4, 460	613. 9	6, 910	615. 1
478, 186	3, 210	613. 9	4, 460	614. 9	6, 910	615. 9
Princeton Avenue						
478, 315	3, 210	614. 5	4, 460	615. 9	6, 910	617. 8
478, 809	3, 210	615. 3	4, 460	616. 3	6, 910	618. 0
479, 291	3, 210	615. 9	4, 460	616. 8	6, 910	618. 3
479, 779	3, 210	616. 5	4, 460	617. 4	6, 910	618. 9
480, 116	3, 210	617. 3	4, 460	618. 5	6, 910	620. 2
480, 492	2, 980	618. 3	4, 150	619. 4	6, 400	621. 0
481, 009	2, 980	619. 4	4, 150	620. 0	6, 400	621. 2
481, 649	2, 980	621. 4	4, 150	621. 9	6, 400	622. 2
482, 179	2, 980	622. 2	4, 150	622. 8	6, 400	623. 6
482, 404	2, 980	622. 7	4, 150	623. 4	6, 400	624. 2

[1] Station at mouth is 413,923 feet.
[2] Mean sea level, city of Charlotte bench marks.

TABLE 9.—*Water-surface elevation and discharge of selected floods on Little Sugar Creek*—Continued

Stationing (feet) [1]	Undeveloped conditions		Partly developed conditions		Urban conditions	
	Discharge (cfs)	Elev (feet) msl [2]	Discharge (cfs)	Elev (feet) msl [2]	Discharge (cfs)	Elev (feet) msl [2]
East Boulevard						
482, 553	2, 980	623. 0	4, 150	623. 8	6, 400	625. 2
483, 033	2, 870	624. 5	3, 990	625. 8	6, 230	627. 6
483, 517	2, 870	626. 0	3, 990	627. 4	6, 230	629. 5
483, 733	2, 870	626. 2	3, 990	627. 5	6, 230	629. 6
484, 228	2, 870	626. 6	3, 990	627. 8	6, 230	629. 8
484, 532	2, 870	627. 1	3, 990	628. 0	6, 230	629. 9
484, 919	2, 870	627. 9	3, 990	629. 1	6, 230	631. 0
Brunswick Avenue						
485, 055	2, 870	628. 1	3, 990	629. 3	6, 230	631. 3
485, 590	2, 870	628. 8	3, 990	630. 0	6, 230	631. 8
485, 906	2, 870	629. 4	3, 990	630. 8	6, 230	632. 5
East Morehead Street						
486, 093	2, 870	629. 9	3, 990	631. 5	6, 330	633. 5
486, 671	2, 730	630. 6	3, 770	632. 2	5, 930	634. 6
487, 311	2, 730	631. 6	3, 770	633. 1	5, 930	635. 5
487, 559	2, 730	632. 6	3, 770	634. 2	5, 930	636. 8
487, 908	2, 730	633. 1	3, 770	634. 8	5, 930	637. 5
488, 398	2, 730	633. 5	3, 770	635. 1	5, 930	637. 6
489, 010	2, 730	635. 3	3, 770	636. 8	5, 930	638. 8
Independence Boulevard						
489, 178	2, 730	635. 5	3, 770	637. 2	5, 930	639. 4
489, 495	2, 730	637. 2	3, 770	638. 0	5, 930	639. 5
489, 566	2, 730	637. 3	3, 770	638. 1	5, 930	640. 2
489, 673	2, 730	639. 3	3, 770	641. 1	5, 930	644. 2
490, 273	2, 730	640. 0	3, 770	641. 6	5, 930	644. 8
490, 608	2, 730	640. 9	3, 770	642. 4	5, 930	645. 2
East 4th Street						
490, 717	2, 730	641. 1	3, 770	642. 7	5, 930	645. 4
490, 991	2, 440	642. 0	3, 400	643. 7	5, 230	646. 6
491, 162	2, 440	642. 2	3, 400	643. 8	5, 230	646. 6
Elizabeth Avenue						
491, 295	2, 440	642. 5	3, 400	644. 0	5, 230	646. 9
491, 581	2, 440	643. 5	3, 400	645. 1	5, 230	647. 6
491, 871	2, 440	643. 9	3, 400	645. 4	5, 230	647. 8
492, 153	2, 440	644. 4	3, 400	645. 7	5, 230	647. 9
492, 511	2, 440	644. 8	3, 400	646. 0	5, 230	648. 2
East 7th Street						
492, 625	2, 440	645. 0	3, 400	646. 2	5, 230	648. 4
493, 045	2, 440	646. 2	3, 400	647. 6	5, 230	649. 8
493, 420	2, 440	647. 0	3, 400	648. 2	5, 230	650. 5
East 9th Street						
493, 501	2, 440	647. 0	3, 400	648. 2	5, 230	650. 4
493, 915	2, 440	648. 2	3, 400	649. 5	5, 230	651. 8
East 10th Street						
494, 071	2, 440	648. 5	3, 400	649. 8	5, 230	651. 8
494, 447	2, 440	651. 2	3, 400	652. 7	5, 230	655. 1
494, 766	2, 280	652. 0	3, 180	653. 6	4, 880	655. 8
495, 225	2, 280	652. 1	3, 180	653. 8	4, 880	655. 9
495, 643	2, 280	652. 4	3, 180	653. 9	4, 880	656. 0

[1] Station at mouth is 413,923 feet.
[2] Mean sea level, city of Charlotte bench marks.

TABLE 9.—*Water-surface elevation and discharge of selected floods on Little Sugar Creek*—Continued

Stationing (feet) [1]	Undeveloped conditions		Partly developed conditions		Urban conditions	
	Discharge (cfs)	Elev (feet) msl [2]	Discharge (cfs)	Elev (feet) msl [2]	Discharge (cfs)	Elev (feet) msl [2]
Seaboard Air-line Railroad						
495, 825	2, 280	652. 9	3, 180	654. 1	4, 880	656. 1
496, 121	2, 280	653. 9	3, 180	654. 9	4, 880	656. 6
496, 475	2, 280	655. 2	3, 180	656. 2	4, 880	657. 7
Belmont Avenue						
496, 562	2, 280	655. 2	3, 180	656. 2	4, 880	657. 8
497, 055	2, 200	656. 7	3, 060	657. 9	4, 770	659. 9
497, 405	2, 200	657. 8	3, 060	658. 9	4, 770	660. 7
497, 902	2, 200	660. 8	3, 060	661. 8	4, 770	663. 4
498, 306	2, 200	662. 2	3, 060	663. 0	4, 770	664. 0
498, 680	2, 200	663. 4	3, 060	664. 5	4, 770	666. 1
East 18th Street						
498, 752	2, 200	663. 4	3, 060	664. 5	4, 770	666. 1
499, 038	2, 200	665. 0	3, 060	666. 2	4, 770	668. 0
499, 365	2, 200	665. 7	3, 060	666. 9	4, 770	668. 8
Parkwood Avenue						
499, 449	2, 200	665. 9	3, 060	667. 2	4, 770	669. 1
499, 904	2, 200	666. 8	3, 060	668. 0	4, 770	670. 0
500, 109	2, 200	667. 2	3, 060	668. 4	4, 770	670. 4
500, 287	2, 200	667. 4	3, 060	668. 6	4, 770	670. 5
500, 372	2, 200	667. 5	3, 060	668. 6	4, 770	670. 5
Davidson Street						
500, 524	2, 200	667. 8	3, 060	668. 6	4, 770	670. 2
500, 644	2, 200	668. 6	3, 060	669. 8	4, 770	671. 4
500, 876	2, 200	669. 5	3, 060	670. 8	4, 770	672. 4
501, 086	2, 090	670. 0	2, 900	671. 2	4, 550	672. 8
501, 316	2, 090	670. 4	2, 900	671. 6	4, 550	673. 3
501, 658	2, 090	670. 9	2, 900	672. 0	4, 550	673. 7
501, 914	2, 090	671. 7	2, 900	672. 6	4, 550	674. 2
502, 056	2, 090	671. 8	2, 900	672. 7	4, 550	674. 2
502, 569	2, 090	673. 5	2, 900	674. 7	4, 550	676. 4
502, 964	2, 090	674. 2	2, 900	675. 5	4, 550	677. 2
Spur Railroad						
503, 031	2, 090	674. 2	2, 900	675. 5	4, 550	677. 2
503, 060	2, 090	674. 4	2, 900	675. 7	4, 550	677. 4
Brevard Street						
503, 122	2, 090	674. 8	2, 900	676. 2	4, 550	677. 9
503, 277	2, 090	675. 6	2, 900	677. 0	4, 550	678. 9
503, 754	2, 090	676. 9	2, 900	678. 2	4, 550	680. 2
504, 220	2, 090	678. 6	2, 900	680. 0	4, 550	682. 2
Southern Rail-road						
504, 540	2, 090	679. 3	2, 900	680. 6	4, 550	682. 7
504, 946	1, 850	679. 7	2, 620	680. 9	4, 040	682. 9
505, 512	1, 850	680. 5	2, 620	681. 5	4, 040	683. 3
505, 980	1, 850	681. 6	2, 620	682. 4	4, 040	683. 9
506, 293	1, 850	682. 0	2, 620	682. 8	4, 040	684. 1
Southern Rail-road Spur						
506, 403	1, 850	682. 5	2, 620	683. 3	4, 040	684. 6

[1] Station at mouth is 413,923 feet.
[2] Mean sea level, city of Charlotte bench marks.

TABLE 10.—*Water-surface elevation and discharge of selected floods on Briar Creek*

Stationing (feet) [1]	Undeveloped conditions		Partly developed conditions		Urban conditions	
	Discharge (cfs)	Elev (feet) msl [2]	Discharge (cfs)	Elev (feet) msl [2]	Discharge (cfs)	Elev (feet) msl [2]
673	4, 020	588. 5	5, 580	590. 2	8, 680	592. 8
942	4, 020	588. 5	5, 580	590. 1	8, 680	592. 6
Park Road						
1, 172	4, 020	588. 9	5, 580	590. 6	8, 680	593. 2
1, 716	4, 020	589. 6	5, 580	591. 2	8, 680	593. 9
2, 228	4, 020	590. 8	5, 580	592. 5	8, 680	595. 0
2, 776	4, 020	591. 5	5, 580	593. 3	8, 680	595. 8
3, 324	4, 020	592. 0	5, 580	593. 8	8, 680	596. 3
3, 719	4, 020	592. 4	5, 580	594. 2	8, 680	596. 8
4, 084	4, 020	592. 6	5, 580	594. 4	8, 680	597. 0
4, 296	4, 020	592. 9	5, 580	594. 7	8, 680	597. 2
4, 830	3, 740	593. 5	5, 210	595. 1	8, 100	597. 6
5, 270	3, 740	594. 2	5, 210	595. 8	8, 100	598. 1
5, 720	3, 740	594. 9	5, 210	596. 4	8, 100	598. 8
6, 056	3, 740	595. 3	5, 210	596. 8	8, 100	599. 1
6, 384	3, 740	595. 8	5, 210	597. 0	8, 100	599. 2
6, 560	3, 740	596. 8	5, 210	598. 1	8, 100	600. 1
Barclay Downs Drive						
6, 726	3, 740	596. 8	5, 210	598. 0	8, 100	600. 0
7, 193	3, 770	598. 5	5, 260	600. 0	8, 160	602. 2
7, 717	3, 770	599. 7	5, 260	601. 2	8, 160	603. 5
8, 083	3, 770	600. 5	5, 260	602. 1	8, 160	604. 4
8, 404	3, 770	601. 4	5, 260	603. 0	8, 160	605. 4
8, 914	3, 770	603. 8	5, 260	605. 3	8, 160	607. 8
9, 300	3, 770	606. 8	5, 260	608. 4	8, 160	611. 0
9, 856	3, 770	608. 9	5, 260	610. 7	8, 160	613. 4
10, 031	3, 770	609. 6	5, 260	611. 3	8, 160	614. 0
Colony Road						
10, 235	3, 770	610. 2	5, 260	612. 1	8, 160	614. 9
10, 635	3, 770	611. 0	5, 260	612. 9	8, 160	615. 8
11, 309	3, 770	612. 2	5, 260	613. 8	8, 160	616. 3
11, 777	3, 770	612. 9	5, 260	614. 5	8, 160	616. 9
12, 178	3, 770	614. 5	5, 260	616. 0	8, 160	618. 4
12, 813	3, 770	617. 2	5, 260	618. 5	8, 160	620. 4
13, 077	3, 770	618. 1	5, 260	619. 7	8, 160	622. 3
13, 342	3, 770	618. 8	5, 260	620. 5	8, 160	622. 9
Sharon Road						
13, 452	3, 770	619. 1	5, 260	620. 6	8, 160	622. 9
13, 933	3, 770	619. 8	5, 260	621. 4	8, 160	623. 9
14, 175	3, 770	620. 2	5, 260	621. 8	8, 160	624. 3
14, 490	3, 770	620. 3	5, 260	622. 0	8, 160	624. 6
15, 019	3, 770	620. 5	5, 260	622. 1	8, 160	624. 8
15, 579	3, 770	620. 8	5, 260	622. 4	8, 160	624. 9
16, 043	3, 770	621. 4	5, 260	622. 7	8, 160	625. 2
16, 254	3, 770	621. 6	5, 260	623. 0	8, 160	625. 4
Providence Road						
16, 609	3, 770	621. 8	5, 260	623. 2	8, 160	625. 8
17, 164	3, 770	622. 2	5, 260	623. 7	8, 160	626. 1
17, 664	3, 770	622. 6	5, 260	623. 9	8, 160	626. 2
18, 082	3, 610	623. 5	5, 010	624. 7	7, 780	626. 8
18, 544	3, 610	624. 8	5, 010	625. 8	7, 780	627. 5
18, 880	3, 610	625. 2	5, 010	626. 1	7, 780	627. 8
19, 392	3, 610	625. 5	5, 010	626. 4	7, 780	627. 9

[1] Station at mouth is 0.
[2] Mean sea level, city of Charlotte bench marks.

TABLE 10.—*Water-surface elevation and discharge of selected floods on Briar Creek*—Continued

Stationing (feet) [1]	Undeveloped conditions		Partly developed conditions		Urban conditions	
	Discharge (cfs)	Elev (feet) msl [2]	Discharge (cfs)	Elev (feet) msl [2]	Discharge (cfs)	Elev (feet) msl [2]
19, 863	3, 610	625. 8	5, 010	626. 8	7, 780	628. 2
20, 378	3, 610	627. 6	5, 010	628. 1	7, 780	629. 1
20, 862	3, 610	628. 3	5, 010	628. 9	7, 780	629. 9
21, 339	3, 610	628. 8	5, 010	629. 4	7, 780	630. 3
21, 803	3, 470	629. 0	4, 820	629. 6	7, 470	630. 5
22, 369	3, 470	629. 4	4, 820	629. 9	7, 470	630. 8
22, 838	3, 470	629. 9	4, 820	630. 4	7, 470	631. 2
23, 110	3, 470	631. 0	4, 820	631. 5	7, 470	632. 2
Randolph Road						
23, 230	3, 470	631. 1	4, 820	631. 5	7, 470	631. 8
23, 608	3, 470	632. 6	4, 820	633. 8	7, 470	636. 1
23, 943	3, 470	633. 4	4, 820	634. 6	7, 470	636. 6
24, 271	3, 470	634. 5	4, 820	635. 8	7, 470	637. 5
24, 670	3, 370	635. 9	4, 690	637. 1	7, 280	638. 8
25, 070	3, 370	636. 4	4, 690	637. 6	7, 280	639. 1
25, 268	3, 370	636. 8	4, 690	638. 0	7, 280	639. 8
East Seventh Street						
25, 394	3, 370	637. 1	4, 690	638. 5	7, 280	640. 6
25, 557	3, 370	637. 1	4, 690	638. 5	7, 280	640. 5
25, 683	3, 370	637. 3	4, 690	638. 7	7, 280	640. 8
Seaboard Airline Railroad						
25, 857	3, 370	637. 6	4, 690	639. 0	7, 280	641. 2
26, 358	3, 370	639. 1	4, 690	640. 4	7, 280	642. 5
26, 852	3, 370	641. 0	4, 690	641. 9	7, 280	643. 4
27, 358	2, 810	642. 2	3, 890	642. 9	6, 030	644. 1
27, 859	2, 810	642. 7	3, 890	643. 3	6, 030	644. 5
27, 984	2, 810	643. 0	3, 890	643. 7	6, 030	644. 8
28, 494	2, 810	644. 2	3, 890	645. 2	6, 030	646. 7
28, 672	2, 810	644. 4	3, 890	645. 4	6, 030	646. 9
Independence Boulevard						
28, 882	2, 810	645. 4	3, 890	646. 5	6, 030	648. 4
29, 500	2, 810	648. 3	3, 890	649. 6	6, 030	651. 6
Commonwealth Avenue						
29, 590	2, 810	648. 6	3, 890	649. 9	6, 030	651. 9
30, 088	2, 610	649. 2	3, 640	650. 4	5, 630	652. 4
30, 592	2, 610	650. 0	3, 640	651. 1	5, 630	653. 0
31, 153	2, 610	650. 9	3, 640	652. 0	5, 630	653. 7
31, 591	2, 610	651. 8	3, 640	652. 8	5, 630	654. 4
32, 104	2, 610	653. 8	3, 640	654. 6	5, 630	655. 9
Central Avenue						
32, 218	2, 610	654. 5	3, 640	655. 2	5, 630	656. 4
32, 726	2, 610	655. 6	3, 640	656. 5	5, 630	657. 8
33, 232	2, 610	655. 8	3, 640	656. 7	5, 630	658. 0
33, 741	2, 610	656. 1	3, 640	657. 0	5, 630	658. 4
34, 253	2, 490	656. 6	3, 480	657. 5	5, 380	658. 9
34, 684	2, 490	657. 4	3, 480	658. 2	5, 380	659. 6
Peppercorn Lane						
34, 836	2, 490	658. 0	3, 480	658. 8	5, 380	660. 0
35, 341	2, 490	659. 9	3, 480	660. 5	5, 380	661. 6
35, 818	2, 490	662. 0	3, 480	663. 0	5, 380	664. 4
36, 424	2, 490	664. 6	3, 480	665. 7	5, 380	667. 0

[1] Station at mouth is 0.
[2] Mean sea level, city of Charlotte bench marks.

TABLE 10.—*Water-surface elevation and discharge of selected floods on Briar Creek*—Continued

Stationing (feet) [1]	Undeveloped conditions		Partly developed conditions		Urban conditions	
	Discharge (cfs)	Elev (feet) msl [2]	Discharge (cfs)	Elev (feet) msl [2]	Discharge (cfs)	Elev (feet) msl [2]
36, 903	2, 490	665. 7	3, 480	666. 8	5, 380	668. 2
37, 366	2, 490	666. 1	3, 480	667. 1	5, 380	668. 6
37, 861	2, 230	667. 0	3, 100	668. 0	4, 810	669. 4
38, 367	2, 230	667. 9	3, 100	668. 8	4, 810	670. 2
38, 774	2, 230	668. 8	3, 100	669. 8	4, 810	671. 0
Country Club Drive						
38, 869	2, 230	669. 6	3, 100	671. 0	4, 810	673. 0
39, 402	2, 230	670. 8	3, 100	672. 2	4, 810	673. 8
39, 972	2, 230	672. 0	3, 100	673. 2	4, 810	674. 6
40, 474	2, 200	673. 2	3, 060	674. 0	4, 750	675. 3
40, 942	2, 200	674. 6	3, 060	675. 5	4, 750	676. 7
41, 604	2, 200	676. 8	3, 060	677. 8	4, 750	679. 0
Eastway Drive						
41, 734	2, 200	677. 0	3, 060	678. 0	4, 750	679. 2
42, 234	1, 980	677. 6	2, 760	678. 4	4, 300	679. 7
42, 687	1, 980	677. 9	2, 760	678. 7	4, 300	679. 9
Shamrock Drive						
42, 777	1, 980	678. 0	2, 760	678. 8	4, 300	680. 0
43, 156	1, 980	679. 1	2, 760	679. 9	4, 300	681. 2
43, 783	1, 760	680. 8	2, 420	681. 5	3, 780	682. 6
44, 381	1, 760	681. 9	2, 420	682. 6	3, 780	683. 7
44, 844	1, 760	682. 9	2, 420	683. 6	3, 780	684. 7
45, 432	1, 760	684. 6	2, 420	685. 2	3, 780	686. 2
Norfolk Southern Railway						
45, 837	1, 760	685. 3	2, 420	686. 0	3, 780	687. 0

[1] Station at mouth is 0.
[2] Mean sea level, city of Charlotte bench marks.

TABLE 11.—*Water-surface elevation and discharge of selected floods on McAlpine Creek*

Stationing (feet) [1]	Undeveloped conditions		Partly developed conditions		Urban conditions	
	Discharge (cfs)	Elev (feet) msl [2]	Discharge (cfs)	Elev (feet) msl [2]	Discharge (cfs)	Elev (feet) msl [2]
66, 585	7, 460	566. 4	10, 200	568. 3	15, 700	571. 3
Providence Road						
67, 110	7, 460	567. 2	10, 200	569. 2	15, 700	572. 3
67, 850	7, 460	567. 8	10, 200	569. 7	15, 700	573. 0
68, 510	7, 460	568. 0	10, 200	570. 0	15, 700	573. 2
69, 044	7, 460	568. 4	10, 200	570. 4	15, 700	573. 6
69, 500	7, 460	568. 6	10, 200	570. 5	15, 700	573. 8
69, 985	7, 460	568. 8	10, 200	570. 6	15, 700	573. 8
70, 490	7, 460	568. 9	10, 200	570. 7	15, 700	573. 9
70, 983	7, 460	569. 0	10, 200	570. 8	15, 700	574. 0
71, 505	7, 460	569. 6	10, 200	571. 2	15, 700	574. 4
71, 825	7, 460	569. 8	10, 200	571. 5	15, 700	574. 5
Sardis Road						
71, 969	7, 460	570. 5	10, 200	572. 1	15, 700	575. 0

[1] Station at mouth is 0.
[2] Mean sea level, city of Charlotte bench marks.

TABLE 11.—*Water-surface elevation and discharge of selected floods on McAlpine Creek*—Continued

Stationing (feet) [1]	Undeveloped conditions		Partly developed conditions		Urban conditions	
	Discharge (cfs)	Elev (feet) msl [2]	Discharge (cfs)	Elev (feet) msl [2]	Discharge (cfs)	Elev (feet) msl [2]
72, 520	7, 460	570. 8	10, 200	572. 4	15, 700	575. 3
73, 019	7, 460	571. 0	10, 200	572. 6	15, 700	575. 5
73, 530	7, 460	571. 1	10, 200	572. 6	15, 700	575. 6
74, 040	7, 460	571. 2	10, 200	572. 8	15, 700	575. 7
74, 480	7, 460	571. 4	10, 200	572. 9	15, 700	575. 8
74, 916	6, 940	571. 6	9, 600	573. 0	14, 600	575. 8
75, 360	6, 940	571. 8	9, 600	573. 2	14, 600	576. 0
75, 890	6, 940	572. 0	9, 600	573. 4	14, 600	576. 1
76, 580	6, 940	572. 6	9, 600	574. 0	14, 600	576. 5
76, 984	6, 940	573. 2	9, 600	574. 5	14, 600	576. 8
77, 603	6, 940	573. 9	9, 600	575. 1	14, 600	577. 2
78, 271	6, 940	574. 6	9, 600	575. 9	14, 600	578. 0
78, 895	6, 940	575. 5	9, 600	576. 8	14, 600	578. 8
79, 411	6, 940	576. 4	9, 600	577. 6	14, 600	579. 5
80, 260	6, 940	577. 8	9, 600	579. 0	14, 600	580. 8
Monroe Road						
80, 470	6, 940	578. 2	9, 600	579. 6	14, 600	581. 6
80, 990	6, 940	578. 8	9, 600	580. 1	14, 600	582. 1
81, 207	4, 200	579. 2	5, 740	580. 5	8, 840	582. 4
81, 680	4, 200	579. 4	5, 740	580. 7	8, 840	582. 6
82, 180	4, 200	579. 6	5, 740	580. 8	8, 840	582. 6
82, 689	4, 200	579. 8	5, 740	580. 9	8, 840	582. 8
83, 190	4, 200	580. 1	5, 740	581. 2	8, 840	583. 0
83, 728	4, 200	581. 1	5, 740	582. 0	8, 840	583. 6
84, 321	3, 970	582. 7	5, 460	583. 5	8, 430	585. 0
84, 732	3, 970	583. 7	5, 460	584. 6	8, 430	586. 1
85, 136	3, 970	585. 2	5, 460	586. 2	8, 430	587. 9
85, 433	3, 970	586. 1	5, 460	587. 1	8, 430	588. 8
U.S. Highway 74						
85, 728	3, 970	586. 8	5, 460	587. 9	8, 430	589. 6
86, 068	3, 970	587. 4	5, 460	588. 6	8, 430	590. 4
86, 331	2, 410	587. 8	3, 290	589. 0	5, 080	590. 8
86, 921	2, 410	590. 4	3, 290	591. 0	5, 080	592. 2
87, 204	2, 410	593. 0	3, 290	593. 9	5, 080	595. 2
Margaret Wallace Road						
87, 334	2, 410	593. 6	3, 290	594. 5	5, 080	595. 8
87, 596	2, 410	595. 2	3, 290	596. 2	5, 080	597. 7
88, 115	2, 410	596. 4	3, 290	597. 2	5, 080	598. 6
88, 671	2, 410	598. 4	3, 290	599. 1	5, 080	600. 2
89, 190	2, 410	600. 3	3, 290	600. 9	5, 080	601. 9
89, 606	2, 410	601. 8	3, 290	602. 3	5, 080	603. 2
89, 961	2, 410	603. 0	3, 290	603. 5	5, 080	604. 2
90, 552	2, 410	604. 0	3, 290	604. 5	5, 080	605. 4
91, 190	2, 410	605. 8	3, 290	606. 4	5, 080	607. 4
91, 858	2, 410	608. 2	3, 290	609. 0	5, 080	610. 2
92, 406	2, 410	611. 0	3, 290	611. 7	5, 080	612. 8
92, 935	2, 410	613. 4	3, 290	614. 1	5, 080	615. 2
93, 629	2, 410	617. 6	3, 290	618. 6	5, 080	620. 1
94, 111	2, 410	620. 1	3, 290	621. 0	5, 080	622. 4
95, 007	2, 410	623. 1	3, 290	624. 0	5, 080	625. 4
Idlewild Road						

[1] Station at mouth is 0.
[2] Mean sea level, city of Charlotte bench marks.

TABLE 12.—*Water-surface elevation and discharge of selected floods on McMullen Creek*

Stationing (feet) [1]	Undeveloped conditions		Partly developed conditions		Urban conditions	
	Discharge (cfs)	Elev (feet) msl [2]	Discharge (cfs)	Elev (feet) msl [2]	Discharge (cfs)	Elev (feet) msl [2]
27, 780	2, 270	574. 5	3, 110	575. 5	4, 770	577. 1
28, 202	2, 270	576. 2	3, 110	577. 3	4, 770	579. 1
28, 562	2, 270	577. 4	3, 110	578. 6	4, 770	580. 6
28, 962	2, 270	578. 1	3, 110	579. 3	4, 770	581. 2
29, 412	2, 270	579. 3	3, 110	580. 4	4, 770	582. 2
29, 810	2, 270	580. 6	3, 110	581. 7	4, 770	583. 3
30, 360	2, 270	582. 1	3, 110	583. 2	4, 770	585. 0
30, 935	2, 160	584. 0	2, 990	585. 4	4, 580	587. 4
31, 278	2, 160	585. 3	2, 990	586. 7	4, 580	588. 8
31, 711	2, 160	586. 3	2, 990	587. 6	4, 580	589. 6
32, 138	2, 160	587. 2	2, 990	588. 5	4, 580	590. 5
32, 351	2, 160	587. 6	2, 990	589. 0	4, 580	591. 1
32, 675	2, 160	588. 0	2, 990	589. 4	4, 580	591. 6
32, 811	2, 160	588. 4	2, 990	589. 9	4, 580	592. 2
33, 209	2, 160	589. 6	2, 990	591. 0	4, 580	593. 2
Mountain Brook Road						
33, 360	2, 160	590. 4	2, 990	591. 8	4, 580	593. 8
33, 847	2, 160	593. 6	2, 990	594. 5	4, 580	596. 0
34, 467	2, 010	595. 9	2, 760	596. 9	4, 250	598. 5
34, 925	2, 010	597. 3	2, 760	598. 4	4, 250	600. 2
35, 143	2, 010	598. 4	2, 760	599. 5	4, 250	601. 1
35, 313	2, 010	600. 7	2, 760	601. 9	4, 250	603. 6
35, 860	2, 010	601. 8	2, 760	602. 9	4, 250	604. 6
Sharon View Road						
35, 920	2, 010	602. 2	2, 760	603. 2	4, 250	604. 8
36, 055	2, 010	604. 3	2, 760	605. 6	4, 250	607. 5
36, 200	2, 010	604. 8	2, 760	606. 1	4, 250	608. 1
36, 615	2, 010	606. 4	2, 760	607. 8	4, 250	610. 0
37, 123	2, 010	607. 6	2, 760	608. 9	4, 250	611. 1
37, 560	2, 010	609. 1	2, 760	610. 4	4, 250	612. 4
37, 980	1, 870	610. 4	2, 570	611. 5	3, 930	613. 4
38, 112	1, 870	611. 4	2, 570	612. 5	3, 930	614. 1
38, 502	1, 870	614. 4	2, 570	615. 7	3, 930	617. 1
38, 668	1, 870	615. 0	2, 570	616. 4	3, 930	617. 9
38, 987	1, 870	616. 2	2, 570	617. 4	3, 930	618. 8
39, 392	1, 870	618. 4	2, 570	619. 6	3, 930	620. 8
39, 727	1, 870	619. 8	2, 570	620. 8	3, 930	622. 0
40, 152	1, 870	623. 3	2, 570	624. 0	3, 930	624. 7
40, 620	1, 870	625. 2	2, 570	626. 1	3, 930	626. 9
41, 142	1, 870	625. 8	2, 570	626. 7	3, 930	627. 5
41, 470	1, 740	625. 9	2, 400	626. 8	3, 680	627. 7
41, 957	1, 740	627. 1	2, 400	628. 0	3, 680	629. 1
42, 600	1, 740	629. 2	2, 400	630. 2	3, 680	631. 6
42, 699	1, 740	629. 7	2, 400	630. 6	3, 680	632. 0
42, 910	1, 740	630. 6	2, 400	631. 7	3, 680	633. 2
43, 454	1, 740	633. 0	2, 400	633. 9	3, 680	635. 4
43, 674	1, 740	633. 5	2, 400	634. 5	3, 680	636. 2
44, 587	1, 590	635. 2	2, 180	636. 0	3, 340	637. 4
45, 197	1, 590	636. 8	2, 180	637. 5	3, 340	638. 8
45, 707	1, 590	637. 6	2, 180	638. 3	3, 340	639. 4
45, 993	1, 590	639. 1	2, 180	639. 6	3, 340	640. 6
46, 383	1, 590	642. 5	2, 180	643. 6	3, 340	645. 0
46, 728	1, 590	643. 5	2, 180	644. 5	3, 340	646. 0

[1] Station at mouth is 0.
[2] Mean sea level, city of Charlotte bench marks.

TABLE 12.—*Water-surface elevation and discharge of selected floods on McMullen Creek*—Continued

Stationing (feet) [1]	Undeveloped conditions		Partly developed conditions		Urban conditions	
	Discharge (cfs)	Elev (feet) msl [2]	Discharge (cfs)	Elev (feet) msl [2]	Discharge (cfs)	Elev (feet) msl [2]
Providence Road						
46, 858	1, 590	643. 9	2, 180	644. 8	3, 340	646. 2
47, 356	1, 460	647. 2	2, 010	647. 5	3, 100	648. 2
47, 856	1, 460	649. 5	2, 010	650. 4	3, 100	651. 6
48, 359	1, 460	651. 3	2, 010	652. 3	3, 100	653. 8
48, 896	1, 460	652. 4	2, 010	653. 2	3, 100	654. 6
49, 573	1, 460	654. 1	2, 010	654. 9	3, 100	656. 1
Randolph Road						
49, 593	1, 460	654. 2	2, 010	654. 9	3, 100	656. 2
50, 231	1, 460	656. 8	2, 010	657. 2	3, 100	658. 1
50, 739	1, 460	658. 6	2, 010	659. 2	3, 100	660. 1
51, 241	1, 460	661. 8	2, 010	662. 5	2, 100	663. 5
51, 737	1, 460	664. 0	2, 010	664. 7	3, 100	665. 8
52, 233	1, 460	665. 0	2, 010	665. 8	3, 100	667. 0

[1] Station at mouth is 0.
[2] Mean sea level, city of Charlotte bench marks.