Estimating the Magnitude and Frequency of Floods in Rural Basins of North Carolina

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ABSTRACT

A statewide study was conducted to develop two methods for estimating the magnitude and frequency of floods in rural ungaged basins in North Carolina. Flood-frequency estimates for gaged sites in North Carolina were computed by fitting the annual peak flows for each site to a log-Pearson Type III distribution. As part of the computation of flood-frequency estimates for gaged sites, new values for generalized skew coefficients were developed. Basin characteristics for these gaged sites were computed by using a geographic information system and automated computer algorithms. Flood-frequency estimates and basin characteristics for 317 gaged sites were combined to form the data base that was used for this analysis.

Regional regression analysis, using generalized least-squares regression, was used to develop a set of predictive equations that can be used to estimate the 2-, 5-, 10-, 25-, 50-, 100-, 200-, and 500-year recurrence interval discharges for rural ungaged basins in the Blue Ridge-Piedmont, Coastal Plain, and Sand Hills hydrologic areas. The predictive equations are all functions of drainage area. Average errors of prediction for these regression equations range from 38 to 56 percent.

A region-of-influence method also was developed that interactively estimates recurrence interval discharges for rural ungaged basins in the Blue Ridge-Piedmont and Coastal Plain hydrologic areas of North Carolina. Regression techniques are used to develop a unique relation between flood discharge and basin characteristics for a subset of gaged sites with similar basin characteristics. This, then, can be used to estimate flood discharges at ungaged sites. Because the computations required for this method are somewhat complex, a computer application was developed that performs the computations and compares the predictive errors for this method. The computer application also includes the option of using the regression equations to compute estimated flood discharges and errors of prediction specific to each ungaged site.

Root mean square errors, computed for each recurrence interval and hydrologic area, are generally only slightly lower for the region-of-influence method than for the regression equations and do not provide sufficient basis for recommending one method over the other. In addition, the region-of-influence method is a new method that is still being improved. As a result, the regional regression equations are considered to be the primary method for computing flood-frequency estimates at ungaged sites.

INTRODUCTION

Reliable estimates of the magnitude and frequency of floods are needed by State and local designers and managers. The design of highway and railroad stream crossings, delineation of flood plains and flood-prone areas, management of water-control structures, and management of water supplies are all activities that require estimates of the frequency distribution of flood events. Such estimates can be computed directly by using statistical methods at gaged sites that have at least 10 years of annual peak record; the longer the record of annual peak flows, the more reliable the estimate. It is not feasible, however, to collect 10 years of annual peak record for every location where an estimate of the flood-frequency distribution is needed, nor is it reasonable to wait 10 years for an estimate once a site has been identified.

Estimates that are derived solely from gage records do not provide sufficient spatial coverage to satisfy the need for reliable estimates of the magnitude and frequency of floods. Traditionally, to meet this need, annual peak records at gaged sites have been regionalized, or extended in space. By this process, flood-frequency estimates at gaged sites are related to measurable basin characteristics so that reliable flood-frequency estimates can be made at ungaged sites. In response to the need to improve the accuracy of estimates of flood discharges for ungaged rural basins, the U.S. Geological Survey (USGS), in cooperation with the North Carolina Department of Transportation, initiated an investigation in 1996 to further define the relation between flood discharges of selected recurrence intervals and selected basin characteristics for rural North Carolina basins.

In the past, regionalization was achieved by means of regional regression analysis. Data from gaged sites were used to define a set of relations between selected recurrence interval discharges and drainage area. Once defined, these relations were then used to estimate discharges at selected recurrence intervals for ungaged sites. Often the area of study was subdivided into regions of similar hydrology in order to improve the predictive ability of the equations. Gunter and others (1987) used this approach to develop regional relations for estimating the magnitude and frequency of floods in rural North Carolina basins.

Recently, however, a different approach to regionalization has been developed. This new approach, known as the region-of-influence method, interactively estimates recurrence interval discharges for ungaged sites based on data from gaged sites with similar basin characteristics. For each ungaged site selected, a subset of gaged sites having similar basin characteristics is selected from the entire data base of rural gaged sites. Regression techniques are used to develop a unique relation between flood discharge and basin characteristics for this subset of gaged sites. This relation is then used to estimate flood discharges at the ungaged site. Although computationally intensive, the region-of-influence method is easily automated and performed by a computer application that is discussed later in this report. Because only gaged sites with similar basin characteristics are used to estimate flows at ungaged sites, there is less chance of extrapolation beyond the limits of the explanatory data. Tests of this approach in Texas (Tasker and Slade, 1994) and in Arkansas (Hodge and Tasker, 1995) yielded estimates with lower prediction errors than those produced by using traditional regional regression techniques.

Gunter and others (1987) contains annual peak-flow data collected from gages throughout North Carolina through the 1984 water year[1], whereas this report contains peak-flow data collected through the 1996 water year. Thus, gaged sites that have continued in operation since 1984 have as much as 12 additional years of peak-flow data available for computation of flood-frequency estimates. The 12 intervening years (1985–96) include several years of pronounced drought (1985–88) as well as years in which maximum peaks of record were recorded (1992–93, 1996) for North Carolina streams. In addition, 64 gaged sites that were not used in Gunter and others (1987) are now available for analysis.

Purpose and Scope

This report describes the development, application, and evaluation of two methods for estimating the magnitude and frequency of floods at ungaged, unregulated, rural basins in North Carolina—(1) the regional regression method and (2) the region-of-influence method. A comparison of these two methods, based on their predictive ability and ease of application, also is presented. In order to compare the two methods on an equal basis, each method was applied to the same available data. The regional regression and region-of-influence methods of estimation were applied to the current data base of 317 sites with at least 10 years of unregulated peak-flow record and evaluated.

Approach

A set of eight basin characteristics was computed and compiled for each of 366 gaged rural sites in North Carolina that have peak-flow record. Sites that have

[1]Water year is the period October 1 through September 30 and is identified by the year in which it ends.

flows affected by regulation or channelization were identified, and where possible, records for such sites were divided into periods of unregulated and regulated flows. Weighted regional average skew values were used to compute flood-frequency estimates for 317 sites with at least 10 years of unregulated peak-flow record. Flood-frequency estimates and the computed basin characteristics for these 317 sites were combined to form the data base used in the regional analyses.

Generalized least-squares regression analysis was used to develop predictive equations relating the 2-, 5-, 10-, 25-, 50-, 100-, 200-, and 500-year recurrence interval flood discharges to selected basin characteristics for rural basins throughout North Carolina. In addition, a region-of-influence method was developed that interactively estimates the recurrence interval flood discharges for ungaged rural basins in the Blue Ridge-Piedmont and Coastal Plain hydrologic areas.

Computation and compilation of basin characteristics and of the selected recurrence interval discharges are described in the following sections. All aspects of each analysis, including the initial exploratory multiple regression analysis using ordinary least-squares regression, final regional regression using generalized least-squares regression, and the region-of-influence analysis, are described. Finally, a comparison of the results of each method is presented.

Data Compilation

The first step in the regionalization of flood-frequency estimates is the compilation of a list of all gaged sites with annual peak-flow record. Such sites are either continuous-record sites or crest-stage sites. At continuous-record sites, the water-surface elevation, or stage, of the stream is recorded at fixed intervals, typically ranging from 5 to 60 minutes. At crest-stage sites, only the crest, or highest, stages that occur between site visits, usually 6 to 8 weeks, are recorded. Regardless of the type of gage, measurements of discharge are determined throughout the range of recorded stages, and a relation between stage and discharge is developed for the gaged site. Using this stage-discharge relation, or rating, discharges for all recorded stages are determined. The highest peak discharge that occurs during a given year is the annual peak for the year, and the list of annual peaks is the annual peak-flow record. The three hydrologic areas identified and described by Gunter and others (1987), consisting of (1) the combined Blue Ridge and Piedmont physiographic provinces, (2) the Coastal Plain Province, and (3) a subdivision of the Coastal Plain Province known as the Sand Hills, also were used in this study (fig. 1).

An initial list of 366 rural sites with annual peak-flow record was compiled (fig. 1; table 1, p. 19–30). Records for these sites were then examined to determine the extent of available basin characteristic data and to identify sites with flows affected by channelization or regulation. The only consistently available basin characteristics for most sites were drainage area and location. A complete evaluation of all possible relations between flood discharges and other characteristics of rural basins requires a more complete set of basin characteristics. The computation and compilation of the required basin characteristics for all of the 366 initial sites are described in the following section.

Examination of the flow records for the 366 sites revealed 19 sites with record containing only regulated/channelized flows, 27 sites with record that could be divided into periods of unregulated/unchannelized and regulated/channelized flows, and 320 sites with records unaffected by any known regulation/channelization. Of the 347 sites with at least some period of unregulated flow record, 317 sites had the requisite 10 or more years of record for computation of flood-frequency estimates (table 1). Flood-frequency estimates for these sites were computed and combined with the basin characteristics to form the data base that was used for the regional analyses (table 2, p. 31–42). This data base contained 222 sites in the Blue Ridge-Piedmont hydrologic area, 80 sites in the Coastal Plain hydrologic area, and 15 sites in the Sand Hills hydrologic area (table 2). Of the 46 sites with regulated flow records, flood-frequency estimates were computed for 42 sites with periods of regulated flow longer than 10 years but were not included in either regional analysis.

Acknowledgments

The authors gratefully acknowledge the assistance and support of Mr. Archie Hankins of the North Carolina Department of Transportation. The peak-flow data used in the analyses described herein were collected throughout North Carolina at stream gages operated in cooperation with a variety of Federal, State, and local agencies. The authors also would like to recognize the dedicated work of the USGS field

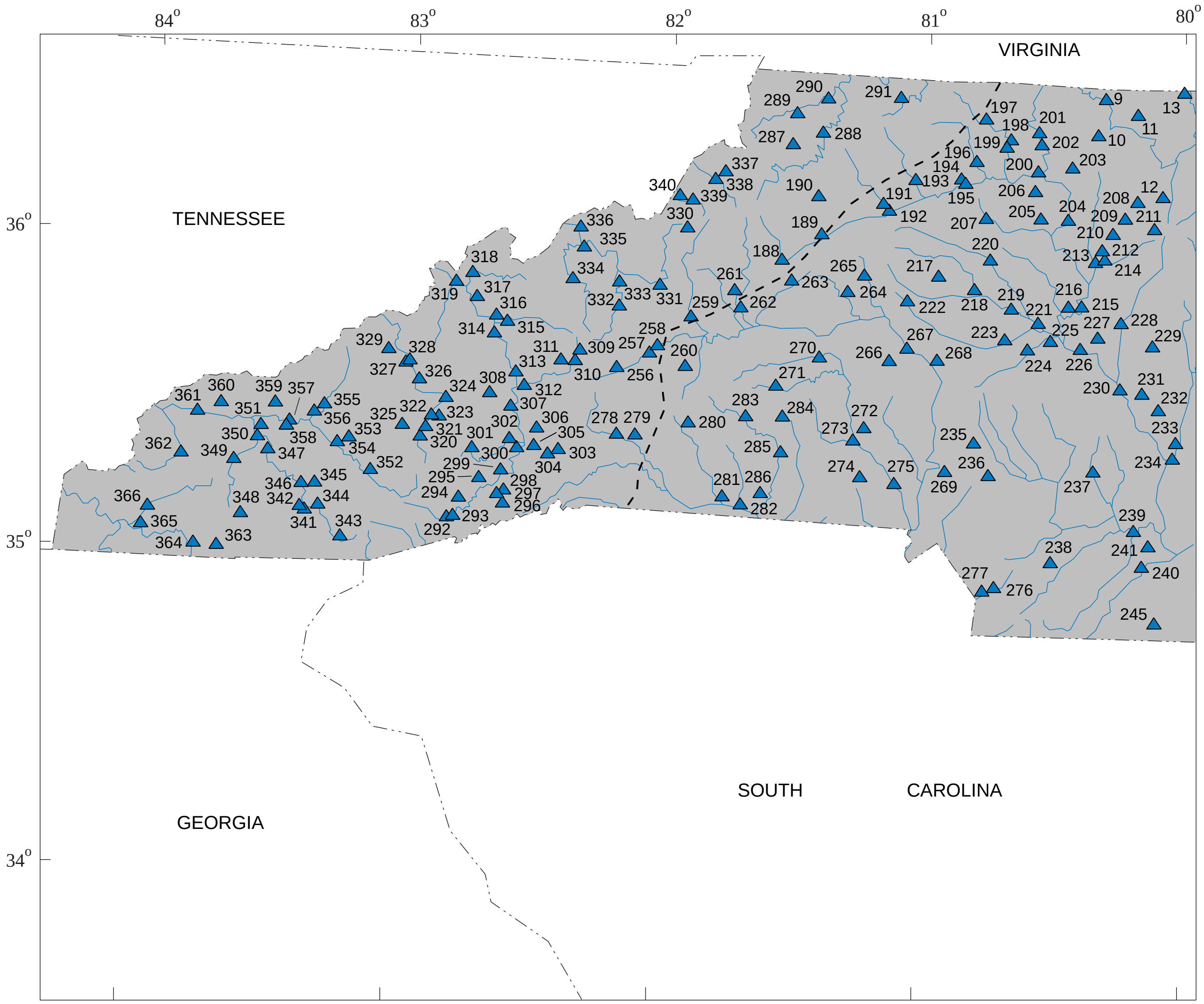
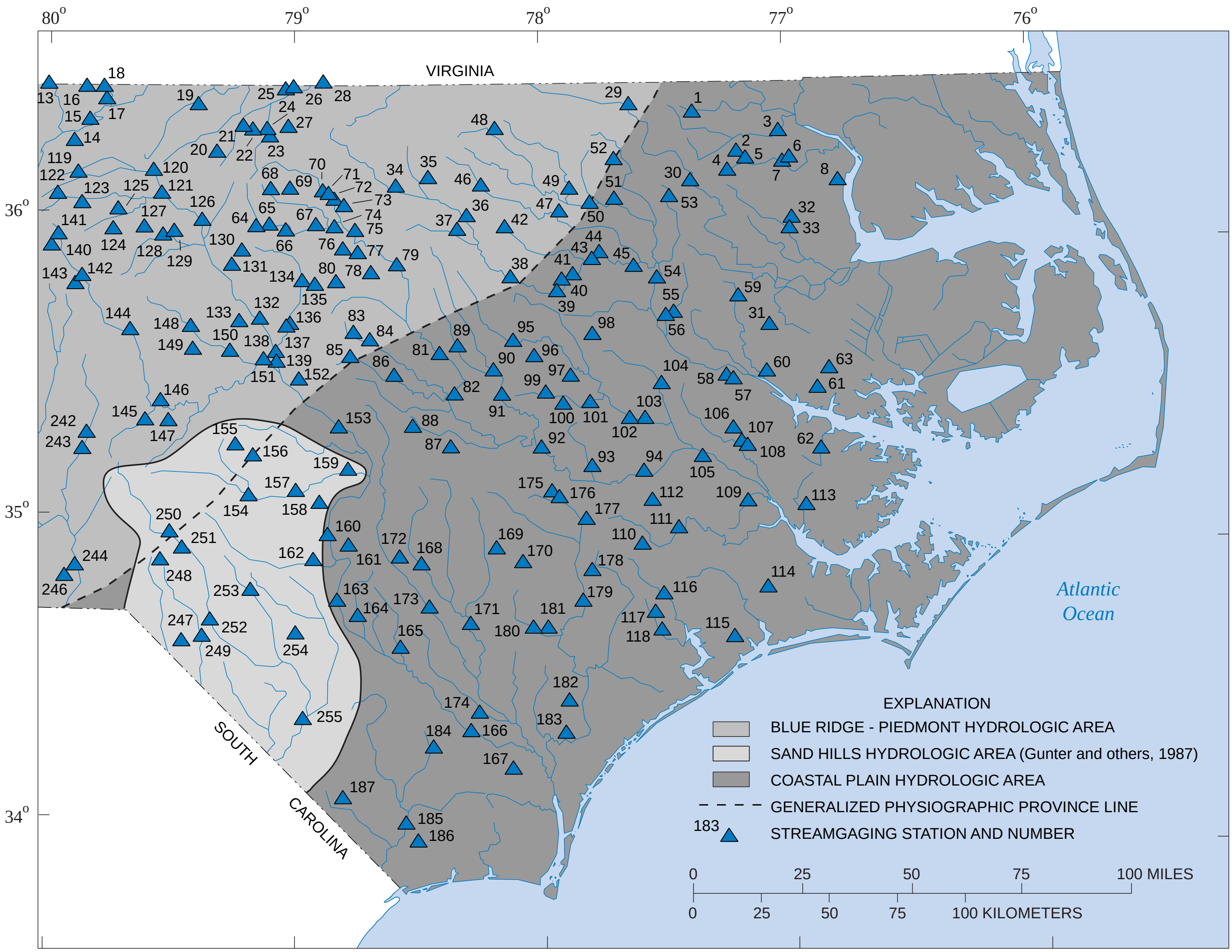


Figure 1. Locations of gaged rural sites in North Carolina.


80°
79°
78°
77°
76°
36°
35°
34°
VIRGINIA
SOUTH
CAROLINA
Atlantic
Ocean
EXPLANATION
BLUE RIDGE - PIEDMONT HYDROLOGIC AREA
SAND HILLS HYDROLOGIC AREA (Gunter and others, 1987)
COASTAL PLAIN HYDROLOGIC AREA
GENERALIZED PHYSIOGRAPHIC PROVINCE LINE
183
STREAMGAGING STATION AND NUMBER
0 25 50 75 100 MILES
0 25 50 75 100 KILOMETERS

office staff in collecting, processing, and storing the peak-flow data necessary for the completion of this report.

BASIN CHARACTERISTICS

The annual peak-flow data that were used in this study were collected at gages in rural basins from all areas of the State, representing the wide range of physical and climatic conditions that occur in North Carolina. Eight parameters that characterize the size, shape, relief, and climate of rural basins in North Carolina were computed and compiled for each site used in the study. Physical basin characteristics include drainage area (DA), channel length (L), channel slope (CSLOPE), basin slope (BSLOPE), and basin shape (SHAPE) (table 3). The primary climatic characteristics relevant to flood frequency in each basin are the intensity, duration, and amount of storm rainfall, as well as other meteorologic inputs that control evaporation and transpiration. Lichty and Liscum (1978) suggested the use of a regional climate factor, CF_t, where t = 2-, 25-, and 100-year recurrence intervals, that integrates long-term rainfall and pan evaporation information and represents the effect of these climatic influences on flood frequency. In this study, a refined version of CF_t, as developed and described by Lichty and Karlinger (1990), was used to characterize climatic effects of flood frequency. Climate factors, CF_t, for each site were computed by using a computer algorithm that used the maps of climate factor isolines presented in Lichty and Karlinger (1990) and the latitude and longitude of a site to interpolate values for the three climate factors, CF_2, CF_{25}, and CF_{100}.

The hydrologic area for each site was determined by examining drainage boundary maps. The appropriate integer value for each site was then assigned to the region variable (REG) (table 3).

Table 3. Basin characteristics that were used in the North Carolina flood-frequency regionalization study

[mi^2, square mile; mi, mile; ft/mi, foot per mile; ----, a dimensionless characteristic]

Basin characteristic	Unit of measure	Definition
Physical characteristics		
DA	mi^2	Drainage area, measured area contained within basin divides.
L	mi	Channel length, measured from gage site upstream along main channel to basin divide.
CSLOPE	ft/mi	Channel slope, computed between points at 10- and 85-percent of the length, measured from the gage site.
BSLOPE	ft/mi	Basin slope, mean value of slope measured along several flow paths from basin divide to channel.
SHAPE	----	Shape, computed by dividing drainage area by the square of channel length (DA/L^2).
Climatic characteristics		
CF_2	----	2-year recurrence interval climate factor
CF_{25}	----	25-year recurrence interval climate factor
CF_{100}	----	100-year recurrence interval climate factor
Regional identifiers		
BRP	----	1, if site is in Blue Ridge-Piedmont; 0, if not.
CP	----	1, if site is in Coastal Plain; 0, if not.
SH	----	1, if site is in Sand Hills; 0, if not.
REG	----	1, if site is in Blue Ridge-Piedmont; 2, if site is in Coastal Plain; 3, if site is in Sandhills.

Other than drainage area, the physical basin characteristics selected for use in this study were not readily available for most of the basins in the study. In previous studies, drainage area was the primary explanatory variable; thus, there was no prior need to measure or compute the other characteristics. As a result, the other physical basin characteristics had to be computed and compiled. Because of the large number of sites involved and the need for consistent, unbiased methodology in making measurements and computations, a geographic information system (GIS) was used to compute the required physical basin characteristics.

In order to use GIS to develop basin characteristics, a digital elevation model (DEM) was created by combining individual data sets. These data sets included the U.S. Environmental Protection Agency River File 3 (McKay and others, 1994), USGS digital line graph contour lines (U.S. Geological Survey, 1989), and the National Oceanic and Atmospheric Administration shoreline data set (National Oceanic and Atmospheric Administration, 1999). Known drainage basin boundaries were overlain onto the DEM, and a combination of computer and visual interpolation techniques were used to define boundaries between the 366 gage sites and the known drainage boundaries.

Once the DEM was constructed and basin boundaries were delineated for all sites, a set of computer algorithms was developed to automatically compute drainage area, L, CSLOPE, BSLOPE, and SHAPE. Although GIS-computed drainage area was computed, the values used for DA were the drainage areas compiled from site records that were hand-computed and checked when the sites were established. The percent difference between GIS-computed drainage area and DA was automatically computed and used to verify the delineation of basin boundaries and the automated computations. Sites with greater than 10-percent difference between the computed drainage area and DA were flagged and re-examined. Errors in boundary delineation were corrected by comparing USGS 7.5-minute topographic maps with the original hand-delineated basin boundary and by using manual techniques to match the GIS basin boundary to the original. After adjusting basin boundaries, basin characteristics were recomputed and rechecked until satisfactory results were obtained. Several sites with drainage areas less than about 1 square mile (mi^2) did not meet the criteria of less that 10-percent difference between computed drainage area and DA because the resolution of the GIS data and computational methods were about one-tenth of a square mile. These sites were examined manually to determine if the automated delineation of basin boundaries was consistent with the hand-drawn boundaries; if not, the boundaries were adjusted accordingly and basin characteristics were recomputed.

ESTIMATION OF FLOOD MAGNITUDE AND FREQUENCY AT GAGED SITES

Flood-frequency estimates for a given stream site are typically presented as a set of exceedance probabilities or, alternatively, recurrence intervals along with the associated discharges. Exceedance probability is defined as the probability of exceeding a specified discharge in a 1-year period and is expressed as decimal fractions less than 1.0 or as percentages less than 100. A discharge with an exceedance probability of 0.10 has a 10-percent chance of being exceeded in any given year. Recurrence interval is defined as the number of years, on average, during which the specified discharge is expected to be exceeded one time and is expressed as number of years. A discharge with a 10-year recurrence interval is one that, on average, will be exceeded once every 10 years. Recurrence interval and exceedance probability are the mathematical inverses of one another; thus, a discharge with an exceedance probability of 0.10 has a recurrence interval of 1/0.10 or 10 years. Conversely, a discharge with a recurrence interval of 10 years has an exceedance probability of one-tenth or 0.10. It is important to remember that recurrence intervals, regardless of length, always refer to the average number of occurrences over a long period of time; for example, a 10-year flood discharge is one that might occur about 10 times in a 100-year period, rather than exactly once every 10 years.

Flood-frequency estimates for gaged sites are computed by fitting the series of annual peak flows to some known statistical distribution. For the purposes of this study, estimates of flood-flow frequency are computed by fitting the logarithms (base 10) of the annual peak flows to a log-Pearson Type III distribution, following the guidelines and using the computational methods described in Bulletin 17B of the Hydrology Subcommittee of the Interagency Advisory Committee on Water Data (1982). The equation for fitting the log-Pearson Type III distribution to an observed series of annual peak flows is as follows:

$$LogQ_t = \bar{X} + KS , \tag{1}$$

where

Q_t is the t-year recurrence interval discharge in cubic feet per second,

X is the mean of the log-transformed annual peak flows,

K is a factor dependent on recurrence interval and the skew coefficient of the log-transformed annual peak flows, and

S is the standard deviation of the log-transformed annual peak flows.

Values for K for a wide range of recurrence intervals and skew coefficients are published in Appendix 3 of Bulletin 17B (Hydrology Subcommittee of the Interagency Advisory Committee on Water Data, 1982).

Fitting the log-Pearson Type III distribution to the general case of a long, well-distributed series of annual peak flows is fairly straightforward. Often, however, a series of peak flows may include low or high outliers, which are extremely low or high peak flows that depart significantly from the trend in the data. The gage record also may frequently include information about maximum peak flows that occurred outside of the period of regularly collected, or systematic, record. Such peak flows, known as historic peaks, are often the maximum peak flows known to have occurred during an extended period of time, longer than the period of collected record. The interpretation of outliers and historic peak information in the fitting process can greatly affect the final flood-frequency estimate. Bulletin 17B (Hydrology Subcommittee of the Interagency Advisory Committee on Water Data, 1982) provides guidelines for detecting and interpreting these data points and provides computational methods for making appropriate corrections to the distribution to account for their presence. In some cases, high or low outliers are excluded from the record, so that the number of systematic peaks may not be equal to the number of years in the period of record.

Statistical measures, such as mean, standard deviation, or skew coefficient, can be described in terms of the sample, or computed, measure and the population, or true, measure. In terms of annual peak flows, the period of collected record can be thought of as a sample, or small portion, of the entire record, or population. Statistical measures computed from the sample record are estimates of what the measure would be if the entire population were known and used to compute the given measure. The accuracy of these estimates depends on the nature of the specific measure and the given sample of the population.

Skew coefficient measures the symmetry of the distribution of a set of peak flows about the median of the distribution. A peak-flow distribution with the mean equal to the median is said to have zero skew. A positively skewed distribution has a mean that exceeds the median typically as a result of one or more extremely high peak flows. A negatively skewed distribution has a mean that is less than the median typically because of one or more extremely low peak flows.

The computed skew coefficient for the peak-flow record of a given station is very sensitive to extreme events; therefore, the sample skew coefficient for short records may not provide an accurate estimate of the population skew. This is problematic because the *K*-factor in equation 1 for a given recurrence interval is dependent only on skew coefficient; therefore, an inaccurate skew coefficient will result in a flood-frequency estimate that is not representative of the true, or population, value.

A more accurate estimate of skew coefficient at a site can be obtained by using a weighted average of the sample skew coefficient estimate with a generalized, or regional, skew coefficient. A generalized skew coefficient is obtained by combining skew estimates from nearby, similar sites. A nationwide generalized skew study was conducted for the study documented in Bulletin 17B (Hydrology Subcommittee of the Interagency Advisory Committee on Water Data, 1982). Skew coefficients for long-term gage sites from all over the Nation were computed and used to produce a map of isolines of generalized skew. Gunter and others (1987) used this nationwide generalized skew in their flood-frequency computations. In addition, the USGS in North Carolina has computed other unpublished flood-frequency estimates by using the nationwide generalized skew.

During preliminary computations of flood-frequency estimates for inclusion in the regression analyses, a number of inconsistencies were noted between the computed values of sample skew coefficients at long-term gaging sites in North Carolina and the values obtained from the national generalized skew study. Inconsistencies at long-term sites are of concern because if generalized skew coefficients for a region are accurate estimates of the population skew, then the computed values of sample skew at long-term sites should approach the generalized values. Instead, it was noted that while sample skew coefficients at long-term North Carolina sites were somewhat consistent among themselves, they did not agree with the generalized values obtained from the nationwide generalized skew study. This anecdotal evidence, when considered along with the age and lack of resolution of the national study, was deemed sufficient cause to develop new generalized skew estimates for rural gaging sites in North Carolina.

Bulletin 17B (Hydrology Subcommittee of the Interagency Advisory Committee on Water Data, 1982) describes three methods for performing generalized skew studies using skew coefficients computed from long-term gaging stations—(1) plot computed skew coefficients on a map and construct skew isolines, (2) use regression techniques to develop a skew prediction equation that would relate station skew coefficients to some set of basin characteristics, or (3) use the arithmetic mean of computed skew coefficients from long-term sites in the area. For the purposes of this report, a modification of the second method initially was decided to be the most likely method to produce satisfactory results. However, rather than using ordinary least-squares regression, a weighted least-squares regression technique was used to determine the relation between the sample skew coefficient and selected basin characteristics. Sample skew estimates were weighted according to their respective record length; sites with long records were assigned greater weight than those with short records. The use of this regression technique in this study made it possible for data from all 347 sites with unregulated flows to be used in developing the estimate.

Multiple regression analysis, using ordinary least-squares regression, was used to determine the best set of basin characteristics to use as explanatory, or independent, variables in the weighted least-squares predictive model. Initial analyses were somewhat disappointing; no combination of basin characteristics accounted for a significant amount of the variance in computed skew. Lacking any significant statewide relationship between sample skew and basin characteristics, three location variables—BRP, CP, and SH, one for each of the three hydrologic areas, Blue Ridge-Piedmont, Coastal Plain, and Sand Hills—were added to the analysis. For a given site, the location variable representing the region of the site was set at 1, and the other two location variables were set at 0 (table 3). When these variables were added to the multiple regression analysis, results were only marginally better. None of the exploratory multiple regression models yielded significant relations between sample skew and the basin characteristics.

Given the lack of satisfactory results in this attempt to develop predictive equations relating skew to some set of basin characteristics, it was decided to apply a modified version of the third method in Bulletin 17B (Hydrology Subcommittee of the Interagency Advisory Committee on Water Data, 1982). However, instead of using an arithmetic mean of computed skews from long-term sites as an estimate of generalized skews, weighted regional average skews were used. Weights were assigned, according to record length, to the computed skews from each site, and a weighted average for each hydrologic area was computed. Inspection of the initial results revealed no significant difference between the weighted average skew estimates for the Blue Ridge-Piedmont hydrologic area or the Coastal Plain hydrologic area. As a result, these two areas were combined in the computation, and two weighted regional average skew values, along with the mean square error associated with each estimate, were determined for use as generalized skew values for sites in North Carolina—one for sites in the Sand Hills hydrologic area and the other for sites in the remainder of the State (table 4).

Table 4. Generalized skew coefficient and associated mean square error for rural North Carolina gaging sites

Hydrologic area	Generalized skew coefficient	Mean square error
Blue Ridge-Piedmont and Coastal Plain	0.195	0.038
Sand Hills	0.252	0.062

As described previously, a weighted skew coefficient is used in order to improve the accuracy of the skew coefficient used to fit peak-flow records to a log-Pearson Type III distribution. The weighted skew coefficient for a given site is computed as the weighted average of the generalized skew coefficient and the site's computed skew coefficient, with weights assigned according to the mean square error of each component skew value. Flood-frequency estimates for all sites with unregulated flow records were computed by using the weighted skew method. Flood-frequency estimates for sites with regulated flow record were computed by fitting the recorded regulated peak flows to the log-Pearson Type III distribution. Computed sample skew coefficients for the regulated flow record were used because regulated peak-flow records typically are not representative of regional or generalized conditions. Although flood-frequency estimates for regulated sites are presented in this report, more detailed, site-specific analyses of flood frequency at many regulated sites are available from the U.S. Army Corps of Engineers.

ESTIMATION OF FLOOD MAGNITUDE AND FREQUENCY AT UNGAGED SITES

Two regional analyses were used to develop methods for estimating flood discharges for ungaged rural basins in North Carolina. The first analysis, a traditional regional regression, required the use of generalized least-squares regression to define a set of predictive equations that relate peak discharges for the 2-, 5-, 10-, 25-, 50-, 100-, 200-, and 500-year recurrence intervals to selected basin characteristics for unregulated rural basins in each of three hydrologic areas of North Carolina (fig. 1). The second analysis, the region-of-influence method, required the development of a computer application to derive, for any given ungaged rural site in the Blue Ridge-Piedmont or Coastal Plain hydrologic areas, unique predictive relations between the 2-, 5-, 10-, 25-, 50-, 100-, 200-, and 500-year recurrence interval discharges and selected basin characteristics. Just as in the traditional regional regression, generalized least-squares regression is used to develop these predictive relations; however, in the region-of-influence analysis, regression techniques are applied to only a selected subset of gaged sites, rather than the entire data base of gaged sites.

Regional Regression Analysis

Ordinary least-squares regression with flood discharge as the dependent variable was used in exploratory analyses to determine the best regression models for all combinations of the eight basin characteristics that were used as explanatory variables. An additional goal of the exploratory analysis was to determine if the subdivision of the State into three hydrologic areas is supported by current data.

Initially, the regionalization scheme used by Gunter and others (1987), which divided the State into the Blue Ridge-Piedmont, Coastal Plain, and Sand Hills hydrologic areas, was assumed to still be valid. Multiple regression analysis, using Mallow's Cp (Stedinger and Tasker, 1985), adjusted coefficient of determination, and hydrologic judgment as criteria, resulted in one-variable and two-variable models relating flood discharge to basin characteristics for each of the three hydrologic areas. The most significant one-variable models for all three regions included drainage area only. The most significant two-variable models included drainage area and the 25-year climate factor for the Blue Ridge-Piedmont and Sand Hills hydrologic areas; while the best two-variable models for Coastal Plain sites consisted of drainage area and channel length.

The validity of the regionalization scheme was examined by performing additional ordinary least-squares regression analyses by using the two-variable models determined previously and comparing the coefficients and intercepts for each region's model to those for the rest of the State. In each case, the coefficients and intercepts for each region's model differed from those of the model using the remaining sites in the State. Additionally, a further test was conducted by introducing the location variable (table 3) for each region into the regression model. Each of these variables was set either at 1, if the site was in a particular region, or 0, if not. A five-variable ordinary least-squares regression model, including all available sites and using (1) drainage area, (2) climate factor, (3) location variable, (4) the product of the location variable with drainage area, and (5) the product of the location variable with climate factor as explanatory variables, was constructed for each recurrence interval discharge in each of the three hydrologic area. For a given region's model, a significant coefficient for the location variable indicates a difference in the intercept between sites in that region and sites in the rest of the State; a significant coefficient for either of the terms that are products of a location variable and another variable indicates a difference in the coefficients of the basin characteristic in that term between sites in that region and the rest of the State. In this particular test, a 95-percent confidence level was defined as significant. All three regional models had significant coefficients for at least one of the location variables or location variable product terms. Given the results of these regression tests, the regionalization scheme used by Gunter and others (1987) was accepted.

Ordinary least-squares regression is an appropriate and efficient regression model for use when flow estimates that are used as response variables are independent of each other (no correlation exists between pairs of sites) and when the reliability and variability of flow estimates that are used as response variables are approximately equal. The flow estimates that were used in this regression were generated from peak-flow records at gaging stations in all parts of North Carolina with periods of record ranging from

10 to 101 years. Records from gaging stations on the same stream within the same basin or even in adjacent basins may be highly correlated because the peak flows resulted from the same rainfall events, similar antecedent conditions, and similar basin characteristics. However, records from other sites, in basins remote from each other, have varying degrees of correlation. In general, correlation between pairs of sites can be described as a function of distance between sites. Additionally, the reliability of flow estimates that were used as response variables in this regression is, in general, a function of record length and, as such, cannot be considered equal for all sites in the regression. Variability of the flow estimates, characterized by the standard deviation of the peak-flow record that was used to compute the flow estimate, depends in large part on characteristics of the basin and also cannot be considered equal for all sites used in the regression. For these reasons, ordinary least-squares regression was used only as an exploratory technique in this analysis to identify the best potential regression models and to evaluate the proposed regionalization scheme. The final regression equations were developed by using generalized least-squares regression techniques.

Generalized least-squares regression, as described by Stedinger and Tasker (1985), is a regression technique that takes into account the correlation between, as well as differences in the variability and reliability of, the flow estimates used as dependent, or response, variables. These factors are accounted for in generalized least-squares regression by assigning different weights to each observation of the response variable used in the regression, based on its contribution to the total variance of the sample-flow statistic used as the response variable. In contrast, ordinary least-squares regression assumes equal reliability and variability in flow estimates at all sites and no cross-correlation between flow records at all sites, so that each flow estimate has equal variance and is assigned equal weight in the regression.

The use of generalized least-squares regression techniques to model the relations between peak discharges and basin characteristics of North Carolina rural basins requires estimates of the cross-correlation coefficients and standard deviation of the peak-flow records that were used to compute peak discharges for the selected recurrence intervals. For each of the three hydrologic areas, a scatter-plot of sample correlation coefficients versus distance between sites was constructed for site pairs with long periods (at least 30 years) of concurrent record. A graphical ‘best-fit’ line to these points was used to define the relation between cross-correlation coefficient and distance between sites. This relation was then used to populate a cross-correlation matrix for the sites contained in each area. Variability of each peak-flow estimate is measured by the standard deviation of the peak-flow record used to compute that estimate. For each hydrologic area, a generalized least-squares regression of the sample standard deviations against drainage area was used to obtain estimates of the standard deviations of the peak-flow records at each site. These regression estimates of the standard deviations were used to assign weights to flow estimates because they are independent of the sample standard deviation estimates used to compute the flow estimate. Finally, length of record at each peak-flow site was used as a direct measure of the relative reliability of the flow estimates computed from those records.

Generalized least-squares regression was used to evaluate the 1- and 2-variable models suggested by preliminary ordinary least-squares regression for each of the three hydrologic areas in North Carolina. The final regression models in all of the regions relate peak discharge to drainage area for each recurrence interval (table 5). The 2-variable model for each region was tested by using generalized least-squares regression, and in each case, the addition of a second variable did not substantially improve the predictive ability of the model.

Table 5. North Carolina rural flood-frequency equations

[DA, drainage area, in square miles. Result will be in cubic feet per second]

Rural flood recurrence interval (years)	Hydrologic area		
	Blue Ridge-Piedmont	Coastal Plain	Sand Hills
2	139 DA $^{0.698}$	61.9 DA $^{0.677}$	33.7 DA $^{0.711}$
5	248 DA $^{0.672}$	121 DA $^{0.642}$	56.1 DA $^{0.700}$
10	342 DA $^{0.657}$	174 DA $^{0.623}$	73.9 DA $^{0.696}$
25	490 DA $^{0.640}$	261 DA $^{0.601}$	100 DA $^{0.692}$
50	622 DA $^{0.629}$	340 DA $^{0.586}$	122 DA $^{0.690}$
100	774 DA $^{0.618}$	435 DA $^{0.573}$	147 DA $^{0.688}$
200	949 DA $^{0.608}$	548 DA $^{0.560}$	175 DA $^{0.686}$
500	1,220 DA $^{0.596}$	727 DA $^{0.544}$	216 DA $^{0.683}$

Uncertainty in a flow estimate that was predicted for an ungaged site by using the regression equations can be measured by the standard error of prediction, S_p, which is computed as the square root of the mean square error of prediction, MSEp. The MSEp is the sum of two components—the mean square error resulting from the model, γ^2, and the sampling mean square error, $MSE_{s,i}$, which results from estimating model parameters from samples of the population. The mean square model error, γ^2, is a characteristic of the model and is a constant for all sites. The mean square sample error, $MSE_{s,i}$, for a given site, however, depends on the values of the explanatory variables (DA) used to develop the flow estimate at that site. The standard error of prediction for a site, i, is computed as:

$$S_{p,\,i} = (\gamma^2 + MSE_{s,\,i})^{\frac{1}{2}} \quad , \qquad (2)$$

and, therefore, varies from site to site. If the values of the explanatory variables for the gage sites used in the regression are assumed to be a representative sample of all sites in the region, then the average accuracy of prediction for the regression model can be determined by computing the average standard error of prediction:

$$S_p = \left\{ \gamma^2 + \frac{1}{n} \sum_{i=1}^{n} MSE_{s,\,i} \right\}^{\frac{1}{2}} \quad . \qquad (3)$$

The standard error of the model ($SE_{(model)}$) can be converted from log (base 10) units to percent error by using the transformation formula,

$$\%SE_{(model)} = 100(10^{2.3026(\gamma^2)} - 1)^{\frac{1}{2}} \quad . \qquad (4)$$

Similarly, the average standard error of prediction can be transformed from log (base 10) units to percent error by substituting ${S_p}^2$ for γ^2 in equation 4. Computation of $S_{p,i}$ for a given ungaged site, i, involves fairly complex matrix algebra. Computational procedures and the required matrices are provided in the Appendix.

The standard errors of the model, which measure how well the regression model fits the data used to construct it, ranged from about 34 percent to just over 50 percent. This error term is comparable to errors often cited and referred to as 'model error' or 'standard error of estimate' in earlier studies in which ordinary least-squares regression was used to develop predictive equations. The average standard errors of prediction, which provide a better overall measure of a model's predictive ability, ranged from about 38 percent to about 56 percent (table 6). Another measure of predictive ability is equivalent years of record (Hardison, 1971). Equivalent years of record are the number of years of peak-flow record needed to provide an estimate by using log-Pearson Type III techniques that would be equal in accuracy to an estimate made by using regional methods (table 6).

Table 6. Average predictive errors, in percent, and equivalent years of record associated with North Carolina rural flood-frequency equations

Rural flood recurrence interval (years)	Hydrologic area					
	Blue Ridge-Piedmont		Coastal Plain		Sand Hills	
	Average error of prediction	Equivalent years of record	Average error of prediction	Equivalent years of record	Average error of prediction	Equivalent years of record
2	43.9	1.8	38.6	2.8	38.2	2.1
5	43.9	2.7	38.0	4.3	41.9	2.8
10	44.5	3.7	38.8	5.8	44.1	3.6
25	45.8	5.0	40.7	7.7	47.0	4.7
50	47.2	5.9	42.3	8.9	49.1	5.4
100	48.7	6.8	44.3	9.9	51.1	6.1
200	50.4	7.6	46.3	11	53.3	6.8
500	52.6	8.4	49.1	12	56.1	7.5

Region-of-Influence Analysis

The region-of-influence method (Tasker and Slade, 1994) estimates flood discharges at ungaged basins by deriving, for a given ungaged rural site, regression relations between the flood discharges and basin characteristics of a unique subset of gaged sites. This unique subset of gaged sites for a given ungaged site, first suggested by Acreman and Wiltshire (1987), was described by Burn (1990a, b) as the region of influence for an ungaged site, hence the name of the method. The unique subset of gaged sites is defined as the N ‘nearest’ gages to the ungaged site, where distance between sites *i* and *j* is defined by the Euclidean distance metric:

$$d_{ij} = \left(\sum_{k=1}^{p} \left(\frac{x_{ik} - x_{jk}}{sd(X_k)} \right)^2 \right)^{\frac{1}{2}} , \qquad (5)$$

where

d_{ij} is the distance between sites *i* and *j* in terms of basin characteristics,

p is the number of basin characteristics used to calculate d_{ij},

X_k is the *k*th basin characteristic,

$sd(X_k)$ is the sample standard deviation for X_k, and

x_{ik} is the value of X_k at the *i*th site.

This distance metric is directly analogous to the more familiar equation for distance, *D*, between two points, (x_1, y_1) and (x_2, y_2) in a 2-dimensional rectangular coordinate system:

$$D = [(x_2 - x_1)^2 + (y_2 - y_1)^2]^{\frac{1}{2}} , \qquad (6)$$

where the only difference is the use of sample standard deviation to standardize the different basin characteristics and the slight notational difference of using an additional subscript *k* rather than changing variable symbols (x, y).

The distances, d_{ij}’s, between a given ungaged site and all the gaged sites are computed and ranked; the N gaging stations with the smallest d_{ij} compose the region of influence for that gaging station. Once determined, generalized least-squares regression techniques are used to develop the unique predictive relations between flood discharge and basin characteristics and estimates of the selected recurrence interval discharge at the ungaged site computed.

The number, *p*, and identity of the basin characteristics that are used to compute d_{ij} and the number of gaged sites, N, that compose the region of influence are specific to a given set of flood-discharge estimates and basin characteristics. In order to adapt the region-of-influence method to that data set, these parameters must be determined. In addition to these parameters, the set of basin characteristics also must be chosen for use as explanatory variables in the generalized least-squares regression models developed for each region. There is a subtle but important distinction between the two sets of basin characteristics—the first is used to define a region of influence; the second serves as variables in the unique predictive equations that are developed for that region of influence. These two sets of characteristics need not be identical but are in some cases. In other cases, such as in North Carolina, the set of characteristics used as variables is a subset of the set of characteristics used to define the region of influence.

Selection of the number of gaged sites, N, and the number and identity of the basin characteristics that will define the region of influence for North Carolina was done by trial and error, using a computed root mean square error (RMSE) as the criterion. RMSE was computed by removing one site at a time from the data base and using the remaining sites to compute an estimate of the flow characteristic. Once completed for every site, the RMSE was computed as the square root of the arithmetic mean of the differences between the estimated and computed values at each site. The results of the exploratory multiple regression analyses performed as part of the traditional regional regression analysis were used to provide some insight in selecting initial sets of basin characteristics. The strong evidence for using separate hydrologic areas in the traditional regression analysis led to the decision to restrict a site’s region of influence to its hydrologic area. As a result, 15 sites in the Sand Hills region (fig. 1) were not enough to support a valid region-of-influence analysis. For any ungaged site identified as a Sand Hills site, the same set of 15 sites would compose the region of influence, and the unique predictive equation developed would be the same equation developed by using traditional regional regression techniques, as described in previous sections of this report.

Combinations of defining variables that were tested include DA and CF_{25}; DA and REG; DA, CF_{25}, and REG; and DA, CF_{25}, L, and REG. Each set of defining variables was tested by using values of 25, 30, and 35 for N. For all variable combinations, N = 30 provided the best results; and the combination of variables that minimized RMSE for all recurrence intervals was DA, CF_{25}, and REG. For these initial tests, DA and CF_{25} were used as explanatory variables in the unique regression relations. Subsequent testing, after the defining variables and N were determined, indicated that CF_{25} was not significant as an explanatory variable. As a result, only DA is used as an explanatory variable in the final version of the region-of-influence method.

After determining the best combination of variables to define the region of influence and the optimal value for N, the computer application for the region of influence was completed. Equation 5 is used to determine the region of influence for an ungaged site, given the required input variables. Unique predictive equations for the ungaged site are then developed, using a generalized least-squares regression of the sites within the region of influence, and the predicted flood-discharge estimates are computed. In addition, because generalized least-squares regression was used to develop the predictive equations, $S_{p,i}$, the site-specific standard error of prediction is computed for each estimated recurrence interval discharge.

Comparison of Results

Application of the regional regression equations requires one less variable than application of the region-of-influence method. However, the additional variable, latitude and longitude of the ungaged site, is simple to determine, so that the variable requirements of the methods are nearly equal. The regional regression equations are easily evaluated manually, the region-of-influence method, however, is computationally intensive but is made simpler by the use of a computer application that performs the complex computations.

The average RMSE was computed for each area and recurrence interval (table 7), providing a measure of the predictive ability of the model or method. Average RMSE was computed as the square root of the arithmetic mean of the differences between the flood-frequency estimate determined using the log-Pearson Type III and the flood-frequency estimate computed using either the regression equations or the region-of-influence method. RMSE for the region-of-influence method is slightly less than for the traditional regression equations in all cases except for the 200- and 500-year discharges in the Coastal Plain hydrologic area. A site-specific comparison of predictive error also is possible by using $S_{p,i}$. As discussed previously, the region-of-influence method reports the site-specific standard error of prediction, $S_{p,i}$. The $S_{p,i}$ is not typically computed when evaluating the traditional regression equations manually because of the complexity of the computations involved. Automation of the equations eliminates this concern, and the $S_{p,i}$ is reported along with the flood-discharge estimate for any given site, allowing for comparison of predictive results on a site-by-site basis.

Table 7. Root mean square error, in percent, for the regional regression and region-of-influence methods, presented by hydrologic area and recurrence interval

[n.a., not applicable]

Recurrence interval	Hydrologic area					
	Blue Ridge-Piedmont		Coastal Plain		Sand Hills	
	Regional regression	Region of influence	Regional regression	Region of influence	Regional regression	Region of influence
2	46.5	45.9	39.6	36.4	36.5	n.a.
5	48.1	46.5	40.8	38.3	40.8	n.a.
10	50.2	48.0	43.4	41.5	44.1	n.a.
25	53.4	50.6	47.9	46.6	48.3	n.a.
50	56.1	52.7	51.5	50.8	51.4	n.a.
100	58.8	55.0	55.3	55.0	54.4	n.a.
200	61.7	57.4	59.2	59.4	57.5	n.a.
500	65.5	60.7	64.4	65.1	61.5	n.a.

In general, little difference was found in the ease of application or in average predictive abilities between the regional regression equations and the region-of-influence method. The region-of-influence method is a new technique and is still being improved. As a result, the region-of-influence method is considered a secondary or alternative method of determining flood-frequency estimates for ungaged rural sites in North Carolina.

Use of Computer Software

As part of the study described by this report, a computer software package was developed that computes (1) estimates of flood-frequency discharges using the region-of-influence method at ungaged rural sites in the Blue Ridge-Piedmont or Coastal Plain hydrologic areas of North Carolina, (2) estimates of flood-frequency discharges using the regional regression equations for ungaged rural sites in each of the three hydrologic areas of North Carolina, and (3) the associated site-specific errors of prediction, $S_{p,i}$, for each method. The complexity of the computations required for the region-of-influence method requires the use of the software for practical application of the method. The regional regression equations can be evaluated manually, but the software allows for easy evaluation of the complex computation of the $S_{p,i}$ for the regional regression method.

The computer software package includes an executable program file and four supporting data files. All five files are required for execution of the computer software. The software package and instructions for down loading, installation, and execution of the program currently are available at the North Carolina District home page on the World Wide Web at URL <http://sgi1dncrlg.er.usgs.gov/ncfloodfreq/>.

APPLICATION OF METHODS

The methods presented in this report can be used to estimate the 2-, 5-, 10-, 25-, 50-, 100-, 200-, and 500-year recurrence interval flood discharges at gaged and ungaged, unregulated, rural sites in North Carolina. Use of either the regional regression equations or the region-of-influence method requires estimates of the input variables. To apply these methods, first locate the ungaged site on a map and identify in which hydrologic area the site is located. An estimate of the latitude and longitude of the site is required for the region-of-influence method. Next, delineate the drainage boundaries of the ungaged site and measure the drainage area contained within those boundaries. The corresponding regression equations (table 5) can then be applied to determine an estimate of the flood discharges for the recurrence interval of interest. Alternatively, the region-of-influence computer application can be initiated; it will query the user for an output file name, an identifier for the site of interest, the hydrologic area for the site, the drainage area of the site, and the latitude and longitude of the site. With this information, the computer application computes the climate factor, defines a region of influence, and produces the desired flood-discharge estimates, along with the standard error of prediction, $S_{p,i}$, specific to the ungaged site.

The computer application contains the regression equations and can be used to apply either method. Use of the computer application to evaluate the regression equation provides an automated computation of $S_{p,i}$ for the regression equations as well as for the region-of-influence method. If evaluated manually, $S_{p,i}$ can be computed only by using the rather complex computational procedures described previously and outlined in detail in the Appendix. Although average standard errors of prediction (table 6) give an idea of the relative accuracy of the methods; $S_{p,i}$ is the more precise measure of the accuracy of a specific prediction.

Flood-frequency estimates at gaged sites and ungaged sites on the same stream as a gaged site can be improved by combining the estimate determined by regional methods with the estimate determined by fitting the log-Pearson Type III distribution to the peak-flow record at the gaged site. At a gaged site, the best estimate of flood frequency can be determined by

$$Q_t(w) = \frac{Q_t(g)N + Q_t(r)EY}{N + EY}, \qquad (7)$$

where

$Q_t(w)$ is the weighted discharge for recurrence interval t;

$Q_t(g)$ is the discharge for recurrence interval t determined using peak-flow record from the gaged site;

$Q_t(r)$ is the discharge for recurrence interval t determined using regional methods;

N is the number of systematic peaks in the gaged sites record; and

EY is the equivalent years of record from table 6.

Flood estimates at an ungaged site that is on the same stream as a gaged site can be determined by using a combination of the regional estimate and the log-Pearson Type III estimate from the nearby gaged site. In order to make the appropriate adjustment, first compute the ratio,

$$R = \frac{Q_t(w)}{Q_t(r)}, \qquad (8)$$

for the gaged site by using $Q_t(w)$ and $Q_t(r)$ as defined in the preceding paragraph. Next, a correction factor, R', is computed as follows:

$$R' = R - \frac{\Delta DA(R-1)}{0.5DA_g}, \qquad (9)$$

where ΔDA is the difference between the drainage areas of the gaged and ungaged sites, and DA_g is the drainage area of the ungaged site. If $\Delta DA/DA_g$ is less than 0.5, then the corrected discharge for the ungaged site, Q_t(corr), can be computed by multiplying the correction factor, R', by the regional estimate for the ungaged site, $Q_t(r)$. If $\Delta DA/DA_g$ is greater than 0.5, use the results of the regional methods without correction.

At times, flood-frequency estimates may be desired for an ungaged site that is between two gaged sites on the same stream. In this case, select the gaged site for which $\Delta DA/DA_g$ is less than 0.5, compute R', and apply as described above. If $\Delta DA/DA_g$ is less than 0.5 for both gaged sites, compute R' for each. If both correction factors are greater than 1.0, use the larger R'; if both correction factors are less than 1.0, use the smaller R'. If one correction factor is greater than 1.0 and the other smaller than 1.0, an average of the two correction factors should be used.

If the drainage basin for an ungaged site lies within more than one hydrologic area, the computed discharge should be adjusted according to the proportion of the total drainage area that lies within each hydrologic area. The adjusted discharge can be determined by the equation:

$$Q_t(\text{adjusted}) = Q_t(HA1)x\frac{DA_1}{DA_{\text{total}}} + Q_t(HA2)x\frac{DA_2}{DA_{\text{total}}}, \qquad (10)$$

where Q_t(adjusted) is the adjusted discharge for the t-year recurrence interval; $Q_t(HA1)$ and $Q_t(HA2)$ are the discharges computed as if the entire drainage area were within the hydrologic areas, $HA1$ and $HA2$; DA_1 and DA_2 are portions of the total drainage area found in the respective hydrologic drainage areas; and DA_{total} is the total drainage area.

SUMMARY

Accurate and reliable estimates of the magnitude and frequency of floods are critical for such activities as bridge design, flood-plain delineation and management, water-supply management, and management of water-control structures, among others. Recognizing the need for accurate estimates of flood frequency at ungaged rural basins, the U.S. Geological Survey, in cooperation with the North Carolina Department of Transportation, conducted a study to further define the relation between flood discharges of selected recurrence intervals and selected physical and climatic characteristics of rural North Carolina basins. This study includes the development of two methods for regionalizing, or extending in space, flood-frequency estimates at gaged sites. In the first method, traditional regional regression analysis, a generalized least-squares regression analysis is used to develop a set of predictive equations for each of three hydrologic areas in North Carolina—the Blue Ridge-Piedmont, the Coastal Plain, and the Sand Hills. In the second method, the region-of-influence method, flood-frequency estimates for ungaged sites are predicted interactively, based on data from a subset of gaged sites with basin characteristics similar to those of the ungaged site. This report documents the development of both methods, using a data base of flood-discharge estimates and basin characteristics for 317 rural North Carolina gaged sites.

An initial set of 366 gaged sites was determined to have some annual peak-flow record; basin characteristics data were computed and compiled for all of these sites by using a GIS. While the development of the basin characteristics was ongoing, flow records were examined to determine which sites had flows that were affected by regulation or channelization. Of the 366 original sites, 19 sites had only regulated record and 27 sites had periods of unregulated flow record prior to regulation. After basin characteristics were developed and flow records were examined, preliminary computations of flood-frequency estimates

were begun. Results of these preliminary computations indicated the need for a generalized skew study for North Carolina basins to replace outdated generalized skews that were based on a nationwide study. After the generalized skew study, flood-frequency estimates for all sites with 10 or more years of record were computed. Flood-frequency estimates were computed for 317 rural, unregulated sites and for 42 rural, regulated sites. The sites with regulated record were excluded from further analysis.

Basin characteristics data and flood-frequency estimates for the 317 rural, unregulated sites were merged to form the data base that was used to develop the regional regression equations and the region-of-influence method. Of the 317 total sites, 222 were located in the Blue Ridge-Piedmont hydrologic area, 80 were located in the Coastal Plain hydrologic area, and 15 were located in the Sand Hills hydrologic area. Preliminary multiple regression analyses, using ordinary least-squares regression, were conducted to confirm the validity of the regionalization scheme and to identify the best combination of explanatory variables for inclusion in the generalized least-squares analysis.

Generalized least-squares analysis was used to develop a set of equations for each region that relates the 2-, 5-, 10-, 25-, 50-, 100-, 200-, and 500-year recurrence interval flood discharges to drainage area. Model error and error of prediction for the equations ranged from about 40 percent for the lower recurrence interval equations to more than 50 percent for the 500-year equations.

The region-of-influence method was adapted to the available flood-frequency and basin characteristics data for North Carolina. The drainage area, hydrologic area, and latitude and longitude of an ungaged site in either the Blue Ridge-Piedmont or Coastal Plain hydrologic areas of North Carolina are required to predict the 2-, 5-, 10-, 25-, 50-, 100-, 200-, and 500-year recurrence interval flood discharges for a specified ungaged site. The Sand Hills hydrologic area did not have a sufficient number of sites to apply the region-of-influence method. Because of the complexity of the computations involved in the region-of-influence method, a computer application is required for the practical use of the method.

A brief comparison of the regional regression and region-of-influence methods, based on ease of application and RMSE of prediction, resulted in neither method being clearly superior. Both require hydrologic area and drainage area as input variables; the region-of-influence method additionally requires latitude and longitude, but these coordinates are fairly simple to determine. The RMSE were, in general, lower for the region-of-influence method, but only slightly. The region-of-influence method is newly developed and still being refined. As a result, the regional regression equations are considered to be the primary method of estimating magnitude and frequency of floods for rural ungaged sites in North Carolina. The region-of-influence method can be considered an alternative method.

A computer application is available that automates the complex computations required by the region-of-influence method. This computer application includes the option to compute flood-frequency estimates using the predictive equations developed by the traditional regional regression analysis. The computer application also computes site-specific error of prediction for each method.

REFERENCES

Acreman, M.C., and Wiltshire, S.E., 1987, Identification of regions for regional flood frequency analysis [abs.], EOS, v. 68, no. 44.

Burn, D.H., 1990a, An appraisal of the “region of influence” approach to flood frequency analysis: Hydrological Sciences Journal, v. 35, no. 24, p. 149–165.

———1990b, Evaluation of regional flood frequency analysis with a region of influence approach: Water Resources Research, v. 26, no. 10, p. 2257–2265.

Gunter, H.C., Mason, R.R., and Stamey, T.C., 1987, Magnitude and frequency of floods in rural and urban basins of North Carolina: U.S. Geological Survey Water-Resources Investigations Report 87–4096, 52 p.

Hardison, C.H., 1971, Prediction error of regression estimates of streamflow characteristics at ungaged sites: U.S. Geological Survey Professional Paper 750–C, p. C228–C236.

Hodge, S.A., and Tasker, G.D., 1995, Magnitude and frequency of floods in Arkansas: U.S. Geological Survey Water-Resources Investigations Report 95–4224, 52 p.

Hydrology Subcommittee of the Interagency Advisory Committee on Water Data, 1982, Guidelines for determining flood frequency: U.S. Geological Survey Bulletin 17B, Office of Water Data Collection, Reston, Va., 183 p.

Lichty, R.W., and Karlinger, M.R., 1990, Climate factor for small-basin flood frequency: American Water Resources Association, Water Resources Bulletin, v. 26, no. 4, p. 577–586.

Lichty, R.W., and Liscum, F., 1978, A rainfall-runoff modeling procedure for improving estimates of T-year annual floods for small drainage basins: U.S. Geological Survey Water-Resources Investigations 78–7, 44 p.

McKay, L., Hanson, S., Horn, R., Dulaney, R., Cahoon, A., Olsen, M., and Dewald, T., 1994, The U.S. EPA Reach File Version 3.0 Alpha Release (RF3-Alpha) Technical Reference: U.S. Environmental Protection Agency, Washington, D.C.

National Oceanic and Atmospheric Administration, 1999, NOAA's medium resolution digital vector shoreline, accessed March 17, 1999, at URL http://seaserver.nos.noaa.gov/projects/shoreline.html.

Stedinger, J.R., and Tasker, G.D., 1985, Regional hydrologic analysis 1—Ordinary, weighted, and generalized least square compared: American Geophysical Union, Water-Resources Research, v. 21, no. 9, p. 1421–1432.

Tasker, G.D., and Slade, R.M., 1994, An interactive regional regression approach to estimating flood quantiles, *in* Fontane, D.G., and Tuvel, H.N., eds., Proceedings of the Twenty-First Annual Conference, Water policy and management, solving the problems, May 23–26, 1994: Denver, Colo., Denver Society of American Society of Civil Engineers, p. 782–785.

Tasker, G.D., and Stedinger, J.R., 1989, An operational GLS model for hydrologic regression: Journal of Hydrology, v. 111, p. 361–375.

U.S. Geological Survey, 1989, Digital line graphs from 1:100,000-scale maps, National Mapping Program Technical Instructions Data Users Guide 2, 88 p.

Table 1. Map identification numbers and descriptions of gaged rural sites in North Carolina with annual peak-flow record

[nc, flood-frequency estimates were not computed because the site has less than 10 years of peak-flow record; *, duplicate map identification and station number for sites having separate period of regulated or channelized flows; r, site excluded from regional analysis because flows were affected by regulation or channelization]

Map identification number (fig. 1)	Station number	Station name	Latitude	Longitude	Period of record	Number of systematic peaks
1	02053110	Wildcat Swamp near Jackson	36°25'48"	77°22'24"	1953–71	19
2	02053170	Cutawhiskie Creek near Woodland	36°17'54"	77°11'58"	1953–71	19
3	02053200	Potecasi Creek near Union	36°22'14"	77°01'36"	1929–96	39
4[nc]	02053400	Ahoskie Creek near Rich Square	36°14'52"	77°14'12"	1965–73	9
5[nc]	02053450	Ahoskie Creek at Mintons Store	36°16'46"	77°09'28"	1965–73	9
6	02053500	Ahoskie Creek at Ahoskie	36°16'48"	77°00'00"	1940–63	13
6*[r]	02053500*	Ahoskie Creek at Ahoskie (channelized period)	36°16'48"	77°00'00"	1964–96	33
7	02053510	Ahoskie Creek tributary at Poortown	36°16'29"	77°00'38"	1964–73	10
8	02053550	Chinkapin Creek near Colerain	36°11'52"	76°47'14"	1953–71	19
9	02068500	Dan River near Francisco	36°30'53"	80°18'11"	1916–38	13
9*[r]	02068500*	Dan River near Francisco (regulated period)	36°30'53"	80°18'11"	1939–96	54
10	02068610	Hog Rock Creek near Moores Springs	36°23'53"	80°19'46"	1955–71	15
11	02068660	Little Snow Creek near Lawsonville	36°27'54"	80°10'28"	1954–71	18
12	02069030	Belews Creek near Kernersville	36°12'20"	80°04'25"	1954–71	17
13	02070500	Mayo River near Price	36°32'05"	79°59'30"	1930–96	45
14	02070810	Jacobs Creek near Wentworth	36°20'54"	79°53'14"	1954–73	18
15	02071000	Dan River near Wentworth	36°24'45"	79°49'35"	1908–96	57
16	02071410	Matrimony Creek near Leaksville	36°31'39"	79°50'08"	1958–73	15
17[nc]	02071500	Dan River at Leaksville	36°29'00"	79°46'00"	1930–49	9
18	02074000	Smith River at Eden	36°31'31"	79°45'57"	1940–49	10
18*[r]	02074000*	Smith River at Eden (regulated period)	36°31'31"	79°45'57"	1950–96	47
19	02075160	Moon Creek near Yanceyville	36°28'13"	79°23'00"	1954–89	21
20	02075230	South Country Line Creek near Hightowers	36°19'29"	79°18'20"	1954–76	23
21	02077200	Hyco Creek near Leasburg	36°23'57"	79°11'50"	1965–96	30
22	02077210	Kilgore Creek tributary near Leasburg	36°22'38"	79°09'57"	1954–71	13
23	02077240	Double Creek near Roseville	36°21'44"	79°05'48"	1965–82	16
24	02077250	South Hyco Creek near Roseville	36°23'09"	79°06'26"	1967–80	14
25[r, nc]	02077300	Hyco River at McGehees Mill	36°31'02"	79°01'42"	1965–73	9
26[r]	02077303	Hyco River below Afterbay Dam near McGehees Mill	36°31'24"	78°59'48"	1974–96	23
27	02077310	Storys Creek near Roxboro	36°23'48"	79°01'14"	1954–71	18
28[r]	02077670	Mayo Creek near Bethel Hill	36°32'26"	78°52'21"	1978–96	19
29	02080500	Roanoke River at Roanoke Rapids	36°27'37"	77°38'04"	1878–49	38
29*[r]	02080500*	Roanoke River at Roanoke Rapids (regulated period)	36°27'37"	77°38'04"	1956–96	41
30	02081000	Roanoke River near Scotland Neck	36°12'34"	77°23'03"	1940–49	10
31	02081060	Smithwick Creek tributary near Williamston	35°43'51"	77°04'42"	1953–71	19

Table 1. Map identification numbers and descriptions of gaged rural sites in North Carolina with annual peak-flow record—Continued

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Map identification number (fig. 1)	Station number	Station name	Latitude	Longitude	Period of record	Number of systematic peaks
32	02081110	White Oak Swamp near Windsor	36°04'46"	76°58'36"	1953–71	14
33[nc]	0208111310	Cashie River at Secondary Road 1257 near Windsor	36°02'51"	76°59'07"	1988–96	9
34	02081500	Tar River near Tar River	36°11'41"	78°35'00"	1940–96	57
35	02081710	Long Creek at Kittrell	36°13'30"	78°27'15"	1954–76	20
36	02081747	Tar River at U.S. 401 at Louisburg	36°05'34"	78°17'48"	1964–96	33
37	02081800	Cedar Creek near Louisburg	36°03'14"	78°20'24"	1935–75	22
38[nc]	02081935	Tar River at Spring Hope	35°55'42"	78°08'53"	1967–71	5
39	02082000	Tar River near Nashville	35°50'57"	77°55'51"	1919–70	42
40	02082500	Sapony Creek near Nashville	35°53'10"	77°54'40"	1951–70	20
41[r]	02082506	Tar River below Tar River Reservoir near Rocky Mount	35°53'58"	77°51'57"	1973–96	24
42	02082540	Wildcat Branch near Mapleville	36°03'29"	78°08'39"	1953–76	11
43[r]	02082585	Tar River at NC97 at Rocky Mount	35°57'15"	77°47'15"	1977–96	20
44	02082610	Tar River near Rocky Mount	35°58'38"	77°45'35"	1964–73	10
45	02082630	Harts Mill Run near Tarboro	35°55'40"	77°37'10"	1953–71	18
46[nc]	02082731	Devils Cradle Creek near Alert at Secondary Road 1412	36°12'03"	78°14'19"	1993–96	4
47	02082770	Swift Creek at Hilliardston	36°06'42"	77°55'16"	1924–96	33
48	02082835	Fishing Creek near Warrenton	36°23'00"	78°10'54"	1954–76	22
49	02082950	Little Fishing Creek near White Oak	36°11'08"	77°52'34"	1960–96	37
50[nc]	02082955	Fishing Creek near Glenview	36°08'44"	77°50'31"	1967–71	5
51	02083000	Fishing Creek near Enfield	36°09'03"	77°41'35"	1915–96	82
52	02083090	Beaverdam Swamp near Heathsville	36°16'49"	77°41'48"	1953–71	19
53	02083410	Deep Creek near Scotland Neck	36°09'26"	77°28'24"	1953–73	21
54	02083500	Tar River at Tarboro	35°53'38"	77°32'00"	1897–96	95
55	02083800	Conetoe Creek near Bethel	35°46'33"	77°27'45"	1957–96	40
56[nc]	02083833	Conetoe Creek (tributary 3) near Penny Hill	35°46'00"	77°29'26"	1993–96	4
57[nc]	02084160	Chicod Creek at Secondary Road 1760 near Simpson	35°33'47"	77°13'43"	1976–81	6
57*[r]	02084160*	Chicod Creek at Secondary Road 1760 near Simpson (channelized period)	35°33'47"	77°13'43"	1982–96	11
58[nc]	02084164	Juniper Branch at Secondary Road 1766 near Simpson	35°33'55"	77°14'43"	1976–78	3
58*[r,nc]	02084164*	Juniper Branch at Secondary Road 1766 near Simpson (channelized period)	35°33'55"	77°14'43"	1979–86	8
59	02084240	Collie Swamp near Everetts	35°49'34"	77°12'03"	1953–76	24
60	02084500	Herring Run near Washington	35°34'03"	77°01'09"	1946–80	30
61	02084520	Upper Goose Creek near Yeatsville	35°31'25"	76°53'23"	1953–73	21
62	02084540	Durham Creek at Edward	35°19'25"	76°52'26"	1966–92	27
63	02084570	Acre Swamp near Pinetown	35°35'02"	76°50'23"	1953–69	17
64[nc]	02084909	Sevenmile Creek near Efland	36°03'56"	79°08'39"	1988–96	9

Table 1. Map identification numbers and descriptions of gaged rural sites in North Carolina with annual peak-flow record—Continued

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Map identification number (fig. 1)	Station number	Station name	Latitude	Longitude	Period of record	Number of systematic peaks
65	02085000	Eno River at Hillsborough	36°04'18"	79°05'49"	1928–96	54
66	02085020	Stony Creek tributary near Hillsboro	36°03'01"	79°02'14"	1953–71	19
67	02085070	Eno River near Durham	36°04'20"	78°54'30"	1964–96	33
68	02085190	North Fork Little River tributary near Rougemont	36°11'41"	79°00'52"	1954–76	23
69	0208521324	Little River at Secondary Road 1461 near Orange Factory	36°08'30"	78°55'10"	1962–96	35
70	02085500	Flat River at Bahama	36°10'57"	78°52'44"	1926–96	71
71	02086000	Dial Creek near Bahama	36°10'36"	78°51'24"	1926–91	47
72[r]	02086500	Flat River at Dam near Bahama	36°08'55"	78°49'43"	1928–93	48
73	02086624	Knap Of Reeds Creek near Butner	36°07'40"	78°48'55"	1983–95	13
74[nc]	02086849	Ellerbe Creek near Gorman	36°03'33"	78°49'58"	1983–94	8
75	02087000	Neuse River near Northside	36°02'54"	78°44'59"	1928–80	53
76	0208700780	Little Lick Creek above Secondary Road 1814 near Oak Grove	35°59'11"	78°47'58"	1983–95	13
77	02087030	Lick Creek near Durham	35°58'50"	78°44'19"	1954–71	18
78	02087140	Lower Barton Creek tributary near Raleigh	35°54'44"	78°40'55"	1954–71	18
79	02087183	Neuse River near Falls	35°56'25"	78°34'56"	1945–80	21
79*[r]	02087183*	Neuse River near Falls (regulated period)	35°56'25"	78°34'56"	1981–96	16
80	02087240	Stirrup Iron Creek tributary near Nelson	35°53'06"	78°49'37"	1952–73	20
81	02087500	Neuse River near Clayton	35°38'50"	78°24'22"	1919–80	53
81*[r]	02087500*	Neuse River near Clayton (regulated period)	35°38'50"	78°24'22"	1981–96	16
82	02087570	Neuse River at Smithfield	35°30'46"	78°21'00"	1908–80	48
82*[r]	02087570*	Neuse River at Smithfield (regulated period)	35°30'46"	78°21'00"	1981–90	10
83	02087580	Swift Creek near Apex	35°43'00"	78°45'00"	1954–71	18
84[nc]	0208758850	Swift Creek near McCullars Crossroads	35°41'33"	78°41'34"	1992–96	5
85	02087910	Middle Creek near Holly Springs	35°39'28"	78°48'06"	1954–71	18
86	02088000	Middle Creek near Clayton	35°34'10"	78°35'30"	1940–96	56
87	02088140	Stone Creek near Newton Grove	35°20'24"	78°21'54"	1953–71	19
88	02088210	Hannah Creek near Benson	35°23'36"	78°31'48"	1953–71	19
89	02088420	Long Branch near Selma	35°38'11"	78°15'06"	1953–71	19
90	02088470	Little River near Kenly	35°35'20"	78°11'18"	1965–89	25
91	02088500	Little River near Princeton	35°30'40"	78°09'38"	1919–96	66
92	02089000	Neuse River near Goldsboro	35°20'14"	77°59'51"	1930–80	51
92*[r]	02089000*	Neuse River near Goldsboro (regulated period)	35°20'14"	77°59'51"	1984–96	13
93[nc]	0208925200	Bear Creek at Mays Store	35°16'28"	77°47'40"	1988–96	9
94	02089500	Neuse River at Kinston	35°15'29"	77°35'09"	1919–80	53
94*[r]	02089500*	Neuse River at Kinston (regulated period)	35°15'29"	77°35'09"	1981–96	16

Table 1. Map identification numbers and descriptions of gaged rural sites in North Carolina with annual peak-flow record—Continued

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Map identification number (fig. 1)	Station number	Station name	Latitude	Longitude	Period of record	Number of systematic peaks
95	02090380	Contentnea Creek near Lucama	35°41'29"	78°06'38"	1965–76	12
95*[r]	02090380*	Contentnea Creek near Lucama (regulated period)	35°41'29"	78°06'38"	1977–96	20
96	02090560	Lee Swamp tributary near Lucama	35°38'21"	78°01'37"	1953–71	19
97	02090625	Turner Swamp near Eureka	35°34'14"	77°52'47"	1969–87	19
98	02090780	Whiteoak Swamp tributary near Wilson	35°42'24"	77°47'11"	1953–71	19
99	02090960	Nahunta Swamp near Pikeville	35°30'40"	77°58'56"	1953–73	19
100[nc]	0209096970	Moccasin Run near Patetown	35°28'46"	77°54'37"	1989–96	8
101	02091000	Nahunta Swamp near Shine	35°29'20"	77°48'22"	1955–96	42
102	02091430	Shepherd Run near Snow Hill	35°26'06"	77°38'42"	1953–71	19
103	02091500	Contentnea Creek at Hookerton	35°25'44"	77°34'59"	1928–96	68
104	02091700	Little Contentnea Creek near Farmville	35°32'40"	77°30'41"	1957–87	31
105	02091810	Halfmoon Creek near Fort Barnwell	35°17'58"	77°21'14"	1953–75	12
106	02091970	Creeping Swamp near Vanceboro	35°23'30"	77°13'46"	1972–85	14
107	02092000	Swift Creek near Vanceboro	35°20'42"	77°11'45"	1909–89	39
108	02092020	Palmetto Swamp near Vanceboro	35°20'18"	77°10'16"	1953–76	24
109	02092120	Bachelor Creek near New Bern	35°10'24"	77°06'14"	1953–71	19
110	02092290	Rattlesnake Branch near Comfort	35°00'31"	77°35'50"	1953–71	19
111	02092500	Trent River near Trenton	35°03'54"	77°27'24"	1928–96	45
112	02092520	Vine Swamp near Kinston	35°09'29"	77°33'16"	1953–71	19
113	02092620	Upper Broad Creek tributary near Grantsboro	35°08'06"	76°56'31"	1953–73	21
114	02092720	White Oak River at Belgrade	34°53'30"	77°14'02"	1953–73	21
115	02092780	Bell Swamp near Hubert	34°42'04"	77°14'01"	1953–70	18
116	02093000	New River near Gum Branch	34°50'56"	77°31'11"	1908–96	33
117	02093040	Southwest Creek tributary near Jacksonville	34°47'18"	77°33'08"	1954–73	19
118	02093070	Southwest Creek near Jacksonville	34°43'56"	77°32'02"	1953–73	20
119	02093290	Haw River near Summerfield	36°14'32"	79°52'20"	1954–71	18
120	02093500	Haw River near Benaja	36°15'06"	79°33'55"	1916–71	43
121[nc]	02093549	Haw River at Altamahaw	36°10'43"	79°30'09"	1968–73	6
122	02093800	Reedy Fork near Oak Ridge	36°10'22"	79°57'12"	1956–96	41
123	02094000	Horsepen Creek at Battle Ground	36°08'34"	79°51'40"	1926–59	30
124	02095000	South Buffalo Creek near Greensboro	36°03'36"	79°43'33"	1929–58	29
125	02095500	North Buffalo Creek near Greensboro	36°07'13"	79°42'30"	1929–90	62
126	02096500	Haw River at Haw River	36°05'13"	79°22'02"	1929–96	68
127	02096660	Rock Creek near Whitsett	36°04'49"	78°47'45"	1954–71	17
128	02096700	Big Alamance Creek near Elon College	36°02'21"	79°31'29"	1945–80	23

Table 1. Map identification numbers and descriptions of gaged rural sites in North Carolina with annual peak-flow record—Continued

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Map identification number (fig. 1)	Station number	Station name	Latitude	Longitude	Period of record	Number of systematic peaks
129	02096740	Gun Branch near Alamance	36°02'58"	79°28'35"	1954–73	19
130[nc]	02096846	Cane Creek near Orange Grove	35°59'13"	79°12'23"	1989–96	8
131	02096850	Cane Creek near Teer	35°56'34"	79°14'46"	1960–73	14
132	02096960	Haw River near Bynum	35°45'48"	79°08'02"	1908–96	69
133	02097010	Robeson Creek near Pittsboro	35°43'29"	79°12'33"	1954–76	23
134	02097314	New Hope Creek near Blands	35°53'05"	78°57'58"	1983–96	14
135	0209741955	Northeast Creek at Secondary Road 1100 near Genlee	35°52'20"	78°54'49"	1983–96	12
136	02097910	White Oak Creek near Wilsonville	35°44'47"	79°00'44"	1954–71	18
137	02098000	New Hope River near Pittsboro	35°44'12"	79°01'36"	1908–73	24
138[r]	02098198	Haw River below B. Everett Jordan Dam near Moncure	35°39'11"	79°04'03"	1980–92	13
139[nc]	02098200	Haw River near Haywood	35°39'01"	79°03'59"	1966–72	0
140	02098500	West Fork Deep River near High Point	36°00'15"	79°58'42"	1924–66	42
141	02099000	East Fork Deep River near High Point	36°02'15"	79°56'46"	1929–94	66
142	02099500	Deep River near Randleman	35°54'06"	79°51'05"	1929–96	66
143[nc]	02100000	Muddy Creek near Archdale	35°52'35"	79°52'43"	1935–41	7
144	02100500	Deep River at Ramseur	35°43'34"	79°39'20"	1901–96	73
145	02101000	Bear Creek at Robbins	35°26'03"	79°35'39"	1940–71	32
146	02101030	Falls Creek near Bennett	35°33'20"	79°29'56"	1954–73	20
147	02101480	Sugar Creek near Tramway	35°25'28"	79°14'50"	1954–73	20
148[nc]	0210166029	Rocky River near Crutchfield Crossroads	35°48'25"	79°31'41"	1988–96	9
149	02101800	Tick Creek near Mount Vernon Springs	35°39'37"	79°24'08"	1959–96	26
150	02101890	Bear Creek near Goldston	35°37'33"	79°17'54"	1952–71	19
151	02102000	Deep River at Moncure	35°37'38"	79°06'58"	1931–96	66
152[nc]	02102192	Buckhorn Creek near Corinth	35°33'34"	78°58'25"	1973–80	8
152*[r]	02102192*	Buckhorn Creek near Corinth (regulated period)	35°33'34"	78°58'25"	1981–96	16
153	02102500	Cape Fear River at Lillington	35°24'22"	78°48'48"	1924–80	57
153*[r]	02102500*	Cape Fear River at Lillington (regulated period)	35°24'22"	78°48'48"	1981–96	16
154	02102908	Flat Creek near Inverness	35°10'54"	79°10'40"	1969–96	28
155	02102910	Dunhams Creek tributary near Carthage	35°18'41"	79°22'53"	1954–71	18
156	02102930	Crane Creek near Vass	35°17'53"	79°16'19"	1954–71	18
157	02103000	Little River at Manchester	35°11'38"	78°59'14"	1939–50	11
158	02103390	South Prong Anderson Creek near Lillington	35°15'31"	78°55'27"	1953–71	19
159	02103500	Little River at Linden	35°15'46"	78°46'35"	1928–71	44
160	02104000	Cape Fear River at Fayetteville	35°02'49"	78°51'36"	1889–76	71
161	02104080	Reese Creek near Fayetteville	35°04'49"	78°47'45"	1953–71	17

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Map identification number (fig. 1)	Station number	Station name	Latitude	Longitude	Period of record	Number of systematic peaks
162	02104500	Rockfish Creek near Hope Mills	34°57'57"	78°55'04"	1939–54	16
163	02105500	Cape Fear River at William O. Huske Lock near Tarheel	34°50'05"	78°49'27"	1938–80	36
163*[r]	02105500*	Cape Fear River at William O. Huske Lock near Tarheel (regulated period)	34°50'05"	78°49'27"	1981–96	15
164	02105570	Browns Creek near Elizabethtown	34°36'32"	78°36'57"	1953–73	18
165	02105630	Turnbull Creek near Elizabethtown	34°41'32"	78°35'02"	1949–71	19
166	02105769	Cape Fear River at Lock 1 near Kelly	34°24'15"	78°17'38"	1970–80	11
166*[r]	02105769*	Cape Fear River at Lock 1 near Kelly (regulated period)	34°24'15"	78°17'38"	1981–96	16
167	02105900	Hood Creek near Leland	34°16'43"	78°07'34"	1953–96	24
168	02106000	Little Coharie Creek near Roseboro	34°57'13"	78°29'17"	1924–91	41
169	02106240	Turkey Creek near Turkey	35°00'11"	78°11'06"	1953–73	18
170	02106410	Stewarts Creek tributary near Warsaw	34°57'25"	78°04'42"	1955–71	16
171	02106500	Black River near Tomahawk	34°45'17"	78°17'21"	1928–96	45
172	02106910	Big Swamp near Roseboro	34°58'38"	78°34'07"	1953–73	20
173	02107000	South River near Parkersburg	34°48'45"	78°27'26"	1952–86	35
174	02107500	Colly Creek near Kelly	34°27'48"	78°15'26"	1908–71	21
175	02107590	Northeast Cape Fear River tributary near Mount Olive	35°11'06"	77°57'34"	1954–71	18
176	02107600	Northeast Cape Fear River near Seven Springs	35°10'20"	77°55'56"	1959–75	17
177	02107620	Mathews Creek near Pink Hill	35°05'49"	77°49'10"	1953–76	16
178	02107980	Limestone Creek near Beulaville	34°45'48"	77°48'15"	1953–71	19
179	02108000	Northeast Cape Fear River near Chinquapin	34°49'40"	77°50'00"	1941–96	56
180	02108500	Rockfish Creek near Wallace	34°44'32"	78°02'22"	1955–81	27
181	02108548	Little Rockfish Creek at Wallace	34°44'02"	77°58'03"	1977–92	16
182	02108610	Pike Creek near Burgaw	34°30'00"	77°53'58"	1953–71	18
183	02108630	Turkey Creek near Castle Hayne	34°23'47"	77°54'48"	1953–71	19
184	02108960	Buckhead Branch near Bolton	34°20'52"	78°26'19"	1953–71	19
185	02109500	Waccamaw River at Freeland	34°05'43"	78°32'55"	1940–96	57
186	02109640	Wet Ash Swamp near Ash	34°02'17"	78°30'14"	1953–71	18
187	02110020	Mill Branch near Tabor City	34°10'59"	78°48'08"	1953–71	18
188	02111000	Yadkin River at Patterson	35°59'29"	81°33'30"	1940–96	56
189	02111180	Elk Creek at Elkville	36°04'16"	81°24'13"	1940–96	31
190	02111340	South Prong Lewis Fork Creek near North Wilkesboro	36°11'23"	81°24'40"	1955–71	16
191	02111500	Reddies River at North Wilkesboro	36°10'29"	81°10'09"	1940–95	55
192	02112000	Yadkin River at Wilkesboro	36°09'09"	81°08'45"	1904–61	48
192*[r]	02112000*	Yadkin River at Wilkesboro (regulated period)	36°09'09"	81°08'45"	1962–96	35
193	02112120	Roaring River near Roaring River	36°14'59"	81°02'39"	1916–96	32

Table 1. Map identification numbers and descriptions of gaged rural sites in North Carolina with annual peak-flow record—Continued

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Map identification number (fig. 1)	Station number	Station name	Latitude	Longitude	Period of record	Number of systematic peaks
194	02112247	Elkin River at Elkin	36°15'12"	80°51'45"	1971–80	10
195[r]	02112250	Yadkin River at Elkin	36°14'30"	80°50'49"	1965–95	31
196	02112360	Mitchell River near State Road	36°18'42"	80°48'26"	1940–96	32
197	02112410	Fisher River near Bottom	36°26'35"	80°46'12"	1954–71	16
198	02112500	Fisher River near Dobson	36°23'05"	80°40'20"	1922–33	12
199	02113000	Fisher River near Copeland	36°21'26"	80°41'10"	1922–96	74
200[r]	02113500	Yadkin River at Siloam	35°16'55"	80°33'46"	1977–87	11
201	02113850	Ararat River at Ararat	36°24'16"	80°33'43"	1947–96	32
202	02114010	Ararat River at Dam near Pilot Mountain	36°22'00"	80°33'00"	1938–68	16
203	02114450	Little Yadkin River at Dalton	36°17'56"	80°25'53"	1961–96	36
204[r]	02115360	Yadkin River at Enon	36°07'55"	80°26'39"	1965–96	32
205	02115500	Forbush Creek near Yadkinville	36°08'13"	80°33'09"	1941–71	31
206	02115520	Logan Creek near Smithtown	36°12'50"	80°33'32"	1954–71	18
207	02115540	South Deep Creek near Yadkinville	36°08'00"	80°46'00"	1954–66	13
208[nc]	02115730	Mill Creek near Stanleyville	36°10'49"	80°16'19"	1965–72	6
209[nc]	02115740	Mill Creek near Oldtown	36°09'06"	80°19'03"	1965–72	6
210[nc]	02115810	Little Creek near Clemmons	36°02'19"	80°20'46"	1965–72	6
211	02115830	Smith Creek near Kernersville	36°06'19"	80°06'19"	1954–71	18
212	02115856	Salem Creek near Atwood	36°02'10"	80°18'35"	1972–82	11
213	02115860	Muddy Creek near Muddy Creek	36°00'01"	80°20'25"	1965–91	19
214	02115900	South Fork Muddy Creek near Clemmons	36°00'22"	80°18'07"	1965–91	19
215	02116500	Yadkin River at Yadkin College	35°51'23"	80°23'14"	1916–61	33
215*[r]	02116500*	Yadkin River at Yadkin College (regulated period)	35°51'23"	80°23'14"	1962–96	35
216	02117030	Humpy Creek near Fork	35°51'17"	80°26'24"	1969–83	15
217	02117410	McClelland Creek near Statesville	35°57'04"	80°56'46"	1954–76	22
218	02117500	Rocky Creek at Turnersburg	35°54'23"	80°48'34"	1941–71	31
219	02118000	South Yadkin River near Mocksville	35°50'41"	80°39'34"	1930–96	58
220	02118500	Hunting Creek near Harmony	36°00'00"	80°44'44"	1952–96	45
221	02119000	South Yadkin River at Cooleemee	35°48'10"	80°33'22"	1916–65	37
222[r]	02119400	Third Creek near Stony Point	35°52'04"	81°04'00"	1957–69	13
223	02120500	Third Creek at Cleveland	35°45'00"	80°41'00"	1916–54	14
223*[r]	02120500*	Third Creek at Cleveland (regulated period)	35°45'00"	80°41'00"	1955–71	17
224	02120780	Second Creek near Barber	35°43'05"	80°35'45"	1980–96	17
225	02120820	Deal Branch near Salisbury	35°44'43"	80°30'25"	1954–71	15
226	02121000	Yadkin River near Salisbury	35°43'30"	80°23'50"	1896–27	30

Table 1. Map identification numbers and descriptions of gaged rural sites in North Carolina with annual peak-flow record—Continued

[nc, flood-frequency estimates were not computed because the site has less than 10 years of peak-flow record; *, duplicate map identification and station number for sites having separate period of regulated or channelized flows; r, site excluded from regional analysis because flows were affected by regulation or channelization]

Map identification number (fig. 1)	Station number	Station name	Latitude	Longitude	Period of record	Number of systematic peaks
227	02121180	North Potts Creek at Linwood	35°45'28"	80°19'24"	1980–90	11
228	02121500	Abbotts Creek at Lexington	35°48'23"	80°14'05"	1941–95	23
229	02121940	Flat Swamp Creek near Lexington	35°43'59"	80°06'37"	1954–71	18
230[nc]	02122500	Yadkin River at High Rock	35°35'46"	80°13'59"	1916–27	8
230*[r]	02122500*	Yadkin River at High Rock (regulated period)	35°35'46"	80°13'59"	1942–61	19
231	02122560	Cabin Creek near Jackson Hill	35°34'57"	80°09'12"	1954–71	17
232	02122720	Beaverdam Creek tributary near Denton	35°31'57"	80°05'04"	1954–71	18
233	02123500	Uwharrie River near Eldorado	35°25'47"	80°01'05"	1928–71	32
234	02123567	Dutchmans Creek near Uwharrie	35°22'05"	80°01'49"	1982–95	12
235	02124060	North Prong Clarke Creek near Huntersville	35°25'13"	80°47'54"	1954–73	20
236	02124130	Mallard Creek near Charlotte	35°19'05"	80°44'16"	1954–71	18
237	02125000	Big Bear Creek near Richfield	35°20'02"	80°20'09"	1955–96	42
238	02125410	Chinkapin Creek near Monroe	35°02'48"	80°29'33"	1953–71	18
239	02126000	Rocky River near Norwood	35°08'54"	80°10'33"	1908–96	67
240	02127000	Brown Creek near Polkton	35°02'10"	80°08'42"	1908–71	36
241	02127390	Palmetto Branch at Ansonville	35°06'03"	80°07'11"	1953–71	17
242	02128000	Little River near Star	35°23'11"	79°49'56"	1955–96	41
243	02128260	Cheek Creek near Pekin	35°12'37"	79°50'49"	1954–71	18
244[r]	02129000	Pee Dee River near Rockingham	34°56'46"	79°52'11"	1928–96	69
245	02129440	South Fork Jones Creek near Morven	34°53'51"	80°00'24"	1954–71	18
246	02129530	Little Creek tributary near Pee Dee	34°55'07"	79°54'38"	1955–71	11
247	02132230	Bridge Creek tributary at Johns	34°42'12"	79°26'34"	1953–73	18
248[nc]	0213228795	Jordan Creek near Silver Hill	34°58'12"	79°31'35"	1985–93	9
249	02132320	Big Shoe Heel Creek near Laurinburg	34°45'01"	79°23'12"	1987–96	10
250	02133500	Drowning Creek near Hoffman	35°03'38"	79°29'39"	1940–96	57
251	02133590	Beaverdam Creek near Aberdeen	35°00'42"	79°26'50"	1953–71	18
252	02133624	Lumber River near Maxton	34°46'22"	79°19'55"	1987–96	10
253	02133960	Raft Swamp near Red Springs	34°52'16"	79°10'12"	1953–71	15
254	02134380	Tenmile Swamp near Lumberton	34°43'34"	78°59'31"	1953–73	18
255	02134500	Lumber River at Boardman	34°26'32"	78°57'38"	1901–96	67
256	02137000	Mill Creek at Old Fort	35°37'59"	82°11'14"	1940–75	15
257	02137727	Catawba River near Pleasant Gardens	35°41'09"	82°03'40"	1981–96	16
258	02138000	Catawba River near Marion	35°42'26"	82°02'00"	1916–81	40
259	02138500	Linville River near Nebo	35°47'41"	81°53'25"	1916–96	74
260	02138680	White Branch near Marion	35°38'46"	81°55'18"	1955–71	14

Table 1. Map identification numbers and descriptions of gaged rural sites in North Carolina with annual peak-flow record—Continued

[nc, flood-frequency estimates were not computed because the site has less than 10 years of peak-flow record; *, duplicate map identification and station number for sites having separate period of regulated or channelized flows; r, site excluded from regional analysis because flows were affected by regulation or channelization]

Map identification number (fig. 1)	Station number	Station name	Latitude	Longitude	Period of record	Number of systematic peaks
261	02140980	Carroll Creek near Collettsville	35°53'21"	81°44'18"	1955–71	17
262	02140991	Johns River at Arneys Store	35°50'01"	81°42'43"	1986–96	11
263	02141130	Zacks Fork Creek near Lenoir	35°55'32"	81°31'13"	1967–76	10
264	02141890	Duck Creek near Taylorsville	35°53'34"	81°18'09"	1954–71	18
265	02142000	Lower Little River near All Healing Springs	35°56'44"	81°14'13"	1954–95	42
266	02142480	Hagan Creek near Catawba	35°40'20"	81°08'12"	1954–71	15
267[r]	02142500	Catawba River at Catawba	35°43'00"	81°03'59"	1936–62	30
268	0214253830	Norwood Creek near Troutman	35°40'48"	80°56'44"	1984–96	13
269	02142900	Long Creek near Paw Creek	35°19'42"	80°54'35"	1966–96	31
270	02143000	Henry Fork near Henry River	35°41'03"	81°24'10"	1916–96	59
271	02143040	Jacob Fork at Ramsey	35°35'26"	81°34'02"	1962–96	35
272	02143310	Lithia Inn Branch near Lincolnton	35°27'47"	81°13'27"	1954–71	14
273	02143500	Indian Creek near Laboratory	35°25'20"	81°15'52"	1916–96	45
274	02144000	Long Creek near Bessemer City	35°18'23"	81°14'05"	1954–96	43
275	02145000	South Fork Catawba River at Lowell	35°17'10"	81°06'00"	1940–96	42
276	02146890	East Fork Twelve Mile Creek near Waxhaw	34°57'46"	80°42'40"	1954–72	18
277	02146900	Twelve Mile Creek near Waxhaw	34°57'08"	80°45'21"	1949–96	36
278[r]	02148500	Broad River near Chimney Rock	35°25'29"	82°10'54"	1928–58	31
279	02149000	Cove Creek near Lake Lure	35°25'24"	82°06'42"	1916–96	45
280	02150420	Camp Creek near Rutherfordton	35°27'47"	81°54'29"	1955–71	17
281	02151000	Second Broad River at Cliffside	35°14'08"	81°45'57"	1926–96	71
282	02151500	Broad River near Boiling Springs	35°12'39"	81°41'52"	1926–96	70
283	02152100	First Broad River near Casar	35°29'35"	81°40'56"	1960–96	36
284	02152420	Big Knob Creek near Fallston	35°29'34"	81°32'25"	1953–71	18
285	02152500	First Broad River near Lawndale	35°22'50"	81°32'40"	1916–80	41
286	02152610	Sugar Branch near Boiling Springs	35°15'00"	81°37'15"	1954–87	34
287	03160610	Old Field Creek near West Jefferson	36°21'29"	81°31'46"	1955–71	17
288	03161000	South Fork New River near Jefferson	36°23'35"	81°24'26"	1916–96	69
289	03162110	Buffalo Creek at Warrensville	36°27'22"	81°30'51"	1940–71	17
290	03162500	North Fork New River at Crumpler	36°31'04"	81°23'18"	1878–66	39
291	03162880	Vile Creek near Sparta	36°30'39"	81°06'16"	1955–71	17
292	03439000	French Broad River at Rosman	35°08'32"	82°49'28"	1908–96	62
293	03439500	French Broad at Calvert	35°08'55"	82°47'57"	1916–55	31
294	03440000	Catheys Creek near Brevard	35°12'40"	82°47'00"	1945–96	21
295	03441000	Davidson River near Brevard	35°16'23"	82°42'21"	1876–96	73

Table 1. Map identification numbers and descriptions of gaged rural sites in North Carolina with annual peak-flow record—Continued

[nc, flood-frequency estimates were not computed because the site has less than 10 years of peak-flow record; *, duplicate map identification and station number for sites having separate period of regulated or channelized flows; r, site excluded from regional analysis because flows were affected by regulation or channelization]

Map identification number (fig. 1)	Station number	Station name	Latitude	Longitude	Period of record	Number of systematic peaks
296	03441440	Little River above High Falls near Cedar Mountain	35°11'32"	82°36'49"	1963–90	28
297	03441500	Little River near Penrose	35°13'23"	82°38'07"	1916–73	13
298	03442000	Crab Creek near Penrose	35°14'02"	82°36'39"	1916–65	13
299	03443000	French Broad River at Blantyre	35°17'56"	82°37'26"	1875–96	76
300	03444000	Boylston Creek near Horseshoe	35°22'10"	82°33'50"	1943–73	13
301	03444500	South Fork Mills River at The Pink Beds	35°21'59"	82°44'20"	1927–73	31
302	03446000	Mills River near Mills River	35°23'55"	82°35'42"	1876–96	64
303	03446410	Laurel Branch near Edneyville	35°22'15"	82°24'10"	1955–70	12
304	03446500	Clear Creek near Hendersonville	35°21'14"	82°26'40"	1910–65	10
305	03447000	Mud Creek at Naples	35°22'52"	82°29'54"	1939–55	17
306	03447500	Cane Creek at Fletcher	35°26'08"	82°29'23"	1901–02; 1943–58	18
307	03448000	French Broad River at Bent Creek	35°30'07"	82°35'33"	1916–86	52
308	03448500	Hominy Creek at Candler	35°32'28"	82°40'35"	1940–78	35
309[nc]	0344894205	North Fork Swannanoa River near Walkertown	35°41'07"	82°19'58"	1990–96	7
310	03449000	North Fork Swannanoa River near Black Mountain	35°39'11"	82°21'04"	1926–52	27
310*[r,nc]	03449000*	North Fork Swannanoa River near Black Mountain (regulated period)	35°39'11"	82°21'04"	1953–57	5
311	03450000	Beetree Creek near Swannanoa	35°39'11"	82°24'20"	1927–96	61
312	03451000	Swannanoa River at Biltmore	35°34'06"	82°32'42"	1921–79	51
312*[r]	03451000*	Swannanoa River at Biltmore (regulated period)	35°34'06"	82°32'42"	1980–96	17
313	03451500	French Broad River at Asheville	35°36'33"	82°34'43"	1896–96	101
314	03452000	Sandymush Creek near Alexander	35°43'49"	82°40'11"	1940–55	13
315	03453000	Ivy Creek near Marshall	35°46'10"	82°37'16"	1876–96	42
316	03453500	French Broad River at Marshall	35°47'10"	82°39'39"	1916–96	54
317	03453880	Brush Creek at Walnut	35°50'40"	82°44'30"	1954–71	17
318	03454000	Big Laurel Creek near Stackhouse	35°55'12"	82°45'42"	1935–78	39
319	03454500	French Broad River at Hot Springs	35°53'23"	82°49'16"	1796–78	15
320	03455500	West Fork Pigeon River above Lake Logan near Hazelwood	35°23'46"	82°56'17"	1955–96	42
321[r,nc]	0345577330	West Fork Pigeon River near Retreat	35°25'36"	82°55'12"	1989–96	8
322[r]	03456100	West Fork Pigeon River at Bethel	35°27'48"	82°54'00"	1955–96	41
323	03456500	East Fork Pigeon River near Canton	35°27'42"	82°52'13"	1955–96	42
324	03456991	Pigeon River near Canton	35°31'19"	82°50'53"	1810–96	71
325	03457500	Allen Creek near Hazelwood	35°25'49"	83°00'30"	1950–73	24
326[nc]	03458500	Pigeon River nr Crabtree	35°34'37"	82°57'07"	1922–30	9
327	03459000	Jonathan Creek near Cove Creek	35°37'21"	83°00'25"	1931–73	43
328	03459500	Pigeon River near Hepco	35°38'05"	82°59'21"	1876–96	69

Table 1. Map identification numbers and descriptions of gaged rural sites in North Carolina with annual peak-flow record—Continued

[nc, flood-frequency estimates were not computed because the site has less than 10 years of peak-flow record; *, duplicate map identification and station number for sites having separate period of regulated or channelized flows; r, site excluded from regional analysis because flows were affected by regulation or channelization]

Map identification number (fig. 1)	Station number	Station name	Latitude	Longitude	Period of record	Number of systematic peaks
329	03460000	Cataloochee Creek near Cataloochee	35°40'02"	83°04'22"	1935–96	52
330	03461910	North Toe River at Newland	36°05'01"	81°55'45"	1955–73	19
331	03462000	North Toe River at Altapass	35°53'59"	82°01'50"	1935–78	24
332	03463300	South Toe River near Celo	35°49'53"	82°11'04"	1958–96	39
333	03463500	South Toe River at Newdale	35°54'22"	82°11'19"	1916–78	18
334	03463910	Phipps Creek near Burnsville	35°54'40"	82°22'10"	1957–73	14
335	03464000	Cane River near Sioux	36°00'52"	82°19'40"	1893–78	38
336	03464500	Nolichucky River at Poplar	36°04'29"	82°20'41"	1926–78	30
337	03478910	Cove Creek at Sherwood	36°15'50"	81°47'03"	1940–72	18
338	03479000	Watauga River near Sugar Grove	36°14'18"	81°49'22"	1916–96	57
339	03480540	Peavine Branch near Banner Elk	36°10'20"	81°54'42"	1953–72	11
340	03481000	Elk River near Elk Park	36°11'01"	81°57'45"	1935–78	21
341	03500000	Little Tennessee River near Prentiss	35°08'59"	83°22'47"	1899–96	52
342	03500240	Cartoogechaye Creek near Franklin	35°09'31"	83°23'40"	1949–96	35
343[r]	03500500	Cullasaja River at Highlands	35°04'14"	83°13'57"	1928–71	44
344	03501000	Cullasaja River at Cullasaja	35°09'59"	83°19'25"	1908–76	52
345	03501760	Coon Creek near Franklin	35°14'04"	83°20'28"	1957–73	17
346	03502000	Little Tennessee River at Iotla	35°13'59"	82°23'32"	1899–49	17
347	03503000	Little Tennessee River at Needmore	35°20'11"	83°31'37"	1899–96	51
348	03504000	Nantahala River near Rainbow Springs	35°07'37"	83°37'09"	1940–96	57
349[r]	03505500	Nantahala River at Nantahala	35°17'55"	83°39'21"	1943–82	39
350	03506500	Nantahala River at Almond	35°22'32"	83°33'59"	1923–41	17
351	03507000	Little Tennessee River at Judson	35°24'30"	83°33'26"	1897–44	48
352[nc]	03508000	Tuckasegee River at Tuckasegee	35°16'55"	83°07'37"	1840–40	6
352*[r]	03508000*	Tuckasegee River at Tuckasegee (regulated period)	35°16'55"	83°07'37"	1940–76	37
353	03509000	Scott Creek above Sylva	35°23'02"	83°12'51"	1929–95	48
354	03510500	Tuckasegee River At Dillsboro	35°22'00"	83°15'37"	1928–40	13
354*[r]	03510500*	Tuckasegee River at Dillsboro (regulated period)	35°22'00"	83°15'37"	1940–82	43
355	03511000	Oconaluftee River at Cherokee	35°29'04"	83°18'56"	1867–49	28
356	03512000	Oconaluftee River at Birdtown	35°27'41"	83°21'13"	1946–96	48
357	03513000	Tuckasegee River at Bryson City	35°25'40"	83°26'51"	1898–40	43
357*[r]	03513000*	Tuckasegee River at Bryson City (regulated period)	35°25'40"	83°26'51"	1940–95	55
358	03513410	Jenkins Branch tributary at Bryson City	35°24'50"	83°27'20"	1957–71	13
359	03513500	Noland Creek near Bryson City	35°29'05"	83°30'15"	1936–71	36
360	03514000	Hazel Creek at Proctor	35°28'38"	83°42'58"	1943–52	10

Table 1. Map identification numbers and descriptions of gaged rural sites in North Carolina with annual peak-flow record—Continued

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Map identification number (fig. 1)	Station number	Station name	Latitude	Longitude	Period of record	Number of systematic peaks
361[nc]	03515000	Little Tennessee River at Fontana Dam	35°26'45"	83°48'20"	1939–44	6
361*[r]	03515000*	Little Tennessee River at Fontana Dam (regulated period)	35°26'45"	83°48'20"	1945–54	10
362	03516000	Snowbird Creek near Robbinsville	35°18'40"	83°51'35"	1943–52	10
363	03546000	Shooting Creek near Hayesville	35°01'29"	83°42'27"	1923–55	13
364[r]	03547000	Hiwassee River below Chatuge Dam near Hayesville	35°01'45"	83°47'45"	1943–74	32
365	03548500	Hiwassee River above Murphy	35°04'49"	84°00'10"	1897–41	44
365*[r]	03548500*	Hiwassee River above Murphy (regulated period)	35°04'49"	84°00'10"	1941–96	55
366	03550000	Valley River at Tomotla	35°08'20"	83°58'50"	1898–96	86

Table 2. Recurrence interval discharges and basin characteristics for gaged rural sites in North Carolina

[Q, recurrence interval flood discharge for years indicated; DA, drainage area; L, channel length; CSLOPE, channel slope; BSLOPE, basin slope; SHAPE, basin shape; CF, climate factor for recurrence interval years indicated; REG, region; nc, flood-frequency estimates were not computed because the site has less than 10 years of peak-flow record; *, duplicate map identification number for sites having separate periods of regulated or channelized flows; r, site excluded from regional analysis because flows were affected by regulation or channelization; n.a., data not available]

Map identification number (fig. 1)	Q_2	Q_5	Q_{10}	Q_{25}	Q_{50}	Q_{100}	Q_{200}	Q_{500}	DA (mi^2)	L (mi)	CSLOPE (ft/mi)	BSLOPE (ft/mi)	SHAPE (DA/L^2)	CF_2	CF_{25}	CF_{100}	REG
1	51.6	99.6	143	211	274	347	433	568	0.7	1.17	8.61	4.33	0.53	2.24	2.89	3.08	2
2	331	641	918	1360	1770	2240	2800	3680	11.8	5.84	2.93	13.25	.33	2.25	2.90	3.09	2
3	1940	2950	3700	4750	5600	6510	7490	8900	225	30.86	3.18	16.19	.23	2.26	2.90	3.10	2
4[nc]	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	3.7	2.65	2.38	4.10	.58	2.25	2.90	3.09	2
5[nc]	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	24.0	8.03	2.18	9.79	.34	2.26	2.90	3.09	2
6	816	1380	1840	2510	3090	3740	4460	5540	63.3	18.55	2.34	8.23	.18	2.26	2.90	3.10	2
6*[r]	963	1340	1630	2070	2440	2860	3330	4040	63.3	18.55	2.34	8.23	.18	2.26	2.90	3.10	2
7	209	253	280	314	338	363	386	418	2.6	3.07	7.12	2.28	.25	2.26	2.90	3.10	2
8	221	427	611	906	1180	1490	1860	2450	8.9	4.96	6.71	1.53	.35	2.31	2.94	3.14	1
9	4630	7620	9990	13400	16400	19600	23200	28500	129	46.52	51.21	211.90	.06	2.07	2.77	2.95	1
9*[r]	4210	7370	9940	13700	17000	20600	24600	30500	129	46.52	51.21	211.90	.06	2.07	2.77	2.95	1
10	128	186	227	283	328	375	424	495	.3	1.96	393.39	225.04	.33	2.08	2.78	2.95	1
11	616	945	1190	1540	1820	2120	2450	2920	5.4	5.21	53.24	154.08	.20	2.08	2.77	2.95	1
12	884	1510	2020	2780	3430	4170	4990	6220	14.9	6.25	18.65	87.83	.37	2.11	2.80	2.97	1
13	7080	11800	15600	21200	26000	31300	37300	46100	261	36.02	21.01	145.96	.20	2.10	2.79	2.97	1
14	884	1560	2120	2980	3730	4580	5550	7020	16.2	7.98	40.33	137.37	.26	2.11	2.80	2.97	1
15	18100	25400	30500	37300	42700	48200	53900	62000	1035	97.48	23.62	148.17	.11	2.10	2.80	2.97	1
16	957	1640	2200	3040	3760	4570	5480	6850	12.0	9.17	30.50	138.34	.14	2.10	2.79	2.97	1
17[nc]	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	1150	116.76	20.23	154.63	.09	2.10	2.79	2.97	1
18	15000	24300	31500	42000	50700	60300	70900	86400	538	77.81	10.76	194.65	.09	2.10	2.79	2.97	1
18*[r]	10300	15300	19000	24100	28200	32500	37000	43500	538	77.81	10.76	194.65	.09	2.10	2.79	2.97	1
19	816	1640	2400	3630	4780	6150	7780	10400	29.9	8.97	20.81	117.88	.41	2.11	2.80	2.98	1
20	912	1380	1730	2220	2610	3040	3490	4150	7.1	4.32	40.20	103.92	.35	2.12	2.80	2.98	1
21	1850	3700	5390	8150	10700	13700	17300	23100	45.9	14.66	13.59	118.79	.22	2.12	2.80	2.98	1
22	44.5	77.8	106	147	184	225	272	343	.2	.39	19.18	66.32	.66	2.12	2.80	2.98	1
23	726	1270	1720	2400	2990	3660	4410	5560	7.5	4.39	53.25	94.67	.39	2.12	2.80	2.98	1
24	1960	3680	5190	7560	9700	12200	15100	19500	56.5	14.40	13.70	104.89	.27	2.12	2.80	2.98	1
25[r, nc]	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	191	30.26	6.66	108.97	.22	2.11	2.80	2.98	1
26[r]	4450	8400	10900	13700	15600	17100	18500	20100	202	32.72	6.28	108.48	.19	2.14	2.82	3.01	1
27	172	259	324	414	487	564	648	768	2.0	2.60	38.00	100.05	.28	2.16	2.83	3.01	1
28[r]	385	1010	1700	3030	4430	6280	8690	13000	53.5	16.06	13.21	108.45	.21	2.14	2.82	3.01	1
29	77700	105000	124000	149000	169000	188000	209000	237000	8386	280.12	4.03	159.83	.11	2.22	2.87	3.06	1
29*[r]	22800	29400	35100	43900	51600	60500	70800	87000	8386	280.12	4.03	159.83	.11	2.22	2.87	3.06	1
30	52000	78600	98500	126000	148000	172000	198000	235000	8671	311.75	3.83	155.40	.09	2.25	2.89	3.09	2
31	70.2	148	221	344	461	603	774	1050	.9	1.17	18.78	10.29	.38	2.29	2.92	3.12	2

Table 2. Recurrence interval discharges and basin characteristics for gaged rural sites in North Carolina—Continued

[Q, recurrence interval flood discharge for years indicated; DA, drainage area; L, channel length; CSLOPE, channel slope; BSLOPE, basin slope; SHAPE, basin shape; CF, climate factor for recurrence interval years indicated; REG, region; nc, flood-frequency estimates were not computed because the site has less than 10 years of peak-flow record; *, duplicate map identification number for sites having separate periods of regulated or channelized flows; r, site excluded from regional analysis because flows were affected by regulation or channelization; n.a., data not available]

Map identification number (fig. 1)	Q_2	Q_5	Q_{10}	Q_{25}	Q_{50}	Q_{100}	Q_{200}	Q_{500}	DA (mi^2)	L (mi)	CSLOPE (ft/mi)	BSLOPE (ft/mi)	SHAPE (DA/L^2)	CF_2	CF_{25}	CF_{100}	REG
32	638	1010	1290	1690	2020	2380	2780	3350	17.1	6.76	5.83	9.42	0.42	2.27	2.91	3.10	2
33[nc]	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	108	24.98	2.45	9.75	.19	2.36	2.98	3.16	2
34	4990	8160	10700	14300	17400	20700	24400	29900	167	30.12	11.33	77.62	.18	2.17	2.84	3.02	1
35	351	688	993	1480	1940	2470	3100	4090	3.3	5.41	35.92	104.99	.22	2.18	2.84	3.02	1
36	5910	9120	11500	15000	17800	20800	24000	28700	427	52.26	7.45	93.14	.16	2.19	2.85	3.03	1
37	1180	1980	2620	3570	4370	5260	6260	7740	47.8	14.33	14.77	93.74	.23	2.19	2.85	3.03	1
38[nc]	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	660	76.62	4.14	90.51	.11	2.21	2.87	3.05	1
39	6720	9720	11900	14800	17100	19600	22100	25800	701	87.60	4.17	88.94	.09	2.25	2.90	3.09	1
40	909	1620	2230	3150	3960	4880	5930	7530	64.8	19.85	4.83	44.34	.17	2.25	2.90	3.09	1
41[r]	7530	10000	11200	12400	13100	13700	14100	14600	777	95.12	3.81	84.58	.09	2.25	2.90	3.09	2
42	56.2	115	170	262	348	451	574	772	.3	.53	98.69	39.08	.76	2.20	2.86	3.04	2
43[r]	8570	11300	12400	13400	13900	14300	14500	14800	925	102.35	3.42	80.30	.09	2.25	2.90	3.09	2
44	7690	10100	11700	13800	15400	17000	18600	20800	930	104.89	3.71	79.30	.09	2.25	2.90	3.09	2
45	266	399	497	634	744	862	987	1170	8.6	5.49	10.82	37.10	.29	2.26	2.90	3.09	2
46[nc]	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	13.4	7.79	24.43	81.63	.22	2.18	2.85	3.03	2
47	1820	3000	3930	5280	6430	7690	9090	11200	166	40.80	5.81	87.37	.10	2.24	2.89	3.08	2
48	1160	2180	3070	4490	5760	7240	8960	11600	45.0	11.36	11.65	85.77	.36	2.17	2.84	3.02	2
49	2440	3990	5230	7020	8540	10200	12100	14800	177	30.93	6.85	76.60	.19	2.24	2.89	3.08	2
50[nc]	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	440	53.86	3.65	82.13	.16	2.24	2.89	3.08	2
51	4590	7460	9720	13000	15700	18800	22100	27000	526	57.85	3.97	77.03	.16	2.24	2.89	3.08	2
52	211	423	617	934	1230	1580	1990	2660	9.4	5.22	15.08	36.16	.37	2.23	2.88	3.07	2
53	387	809	1210	1880	2510	3280	4210	5710	11.7	5.95	4.60	10.38	.36	2.25	2.89	3.09	2
54	13900	20300	24900	31100	36100	41300	46900	54800	2183	148.95	2.63	66.04	.10	2.26	2.90	3.09	2
55	812	1250	1570	2030	2410	2810	3240	3870	78.1	16.59	2.14	8.86	.26	2.27	2.91	3.10	2
56[nc]	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	11.0	9.76	2.24	3.45	.13	2.26	2.91	3.10	2
57[nc]	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	45.0	10.82	3.64	12.34	.38	2.32	2.94	3.12	2
57*[r]	1460	2260	2690	3110	3370	3570	3740	3920	45.0	10.82	3.64	12.34	.38	2.32	2.94	3.12	2
58[nc]	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	7.5	4.90	9.66	13.23	.34	2.32	2.94	3.12	2
58*[r,nc]	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	7.5	4.90	9.66	13.23	.34	2.32	2.94	3.12	2
59	672	1160	1570	2180	2710	3310	3980	5000	29.0	9.75	3.43	16.82	.33	2.28	2.91	3.11	2
60	243	397	518	695	843	1010	1190	1450	9.6	4.76	8.21	8.18	.43	2.32	2.95	3.14	2
61	102	192	270	393	503	631	779	1010	1.5	2.37	5.55	3.21	.29	2.32	2.95	3.14	2
62	446	752	999	1360	1680	2030	2410	3000	26.0	9.15	2.07	16.80	.28	2.37	2.98	3.17	2
63	624	1150	1610	2330	2970	3710	4560	5880	32.2	7.85	3.90	5.16	.53	2.32	2.95	3.14	2
64[nc]	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	14.1	6.11	26.95	79.86	.38	2.15	2.82	2.99	1

Table 2. Recurrence interval discharges and basin characteristics for gaged rural sites in North Carolina—Continued

[Q, recurrence interval flood discharge for years indicated; DA, drainage area; L, channel length; CSLOPE, channel slope; BSLOPE, basin slope; SHAPE, basin shape; CF, climate factor for recurrence interval years indicated; REG, region; nc, flood-frequency estimates were not computed because the site has less than 10 years of peak-flow record; *, duplicate map identification number for sites having separate periods of regulated or channelized flows; r, site excluded from regional analysis because flows were affected by regulation or channelization; n.a., data not available]

Map identification number (fig. 1)	Q_2	Q_5	Q_{10}	Q_{25}	Q_{50}	Q_{100}	Q_{200}	Q_{500}	DA (mi^2)	L (mi)	CSLOPE (ft/mi)	BSLOPE (ft/mi)	SHAPE (DA/L^2)	CF_2	CF_{25}	CF_{100}	REG
65	2760	4340	5550	7270	8690	10200	11900	14400	66.0	15.62	11.78	81.54	0.27	2.17	2.84	3.01	1
66	87.0	165	233	340	438	551	682	888	.8	1.11	126.53	135.53	.72	2.17	2.84	3.01	1
67	4760	8450	11500	16200	20300	25000	30300	38400	141	33.53	11.00	92.00	.13	2.17	2.84	3.01	1
68	157	274	371	517	644	787	949	1200	1.0	1.34	39.06	63.54	.52	2.17	2.84	3.01	1
69	3440	6160	8460	12000	15100	18600	22600	28800	78.2	18.92	15.26	76.96	.22	2.17	2.84	3.01	1
70	6770	10800	13800	18200	21900	25900	30200	36600	149	24.50	12.08	79.98	.25	2.17	2.84	3.01	1
71	338	606	833	1180	1490	1840	2240	2850	4.8	5.13	31.73	112.77	.18	2.17	2.84	3.01	1
72[r]	6650	10200	12400	15000	16800	18400	19900	21700	168	29.13	11.83	82.17	.20	2.17	2.84	3.01	1
73	2210	3970	5470	7760	9790	12100	14700	18800	43.0	14.25	17.05	85.63	.21	2.17	2.84	3.02	1
74[nc]	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	21.9	12.15	14.29	84.86	.15	2.17	2.84	3.01	1
75	8530	13300	16800	21900	26100	30600	35500	42600	535	47.55	9.18	83.44	.24	2.18	2.84	3.02	1
76	864	1330	1670	2160	2560	2980	3440	4110	10.1	5.01	16.67	91.21	.40	2.18	2.84	3.02	1
77	696	827	908	1010	1080	1150	1210	1300	13.8	7.04	15.49	100.58	.28	2.18	2.84	3.02	1
78	108	195	267	379	478	590	718	914	.7	1.06	98.62	100.04	.60	2.18	2.85	3.02	1
79	7020	9710	11600	14100	16000	18000	20100	23000	772	64.87	7.08	87.30	.18	2.19	2.85	3.03	1
79*[r]	4820	5900	6620	7540	8230	8930	9640	10600	772	64.87	7.08	87.30	.18	2.19	2.85	3.03	1
80	49.5	85.2	115	159	197	239	287	359	.3	.73	75.75	111.31	.48	2.18	2.84	3.02	1
81	9720	13200	15700	18800	21300	23800	26400	30000	1150	94.85	4.90	87.62	.13	2.25	2.88	3.05	1
81*[r]	7090	10000	12300	15600	18300	21300	24600	29600	1150	94.85	4.90	87.62	.13	2.25	2.88	3.05	1
82	8870	11500	13200	15400	17100	18700	20400	22800	1206	108.53	4.37	86.24	.10	2.26	2.88	3.05	1
82*[r]	7630	10300	11700	13000	13700	14300	14700	15200	1206	108.53	4.37	86.24	.10	2.26	2.88	3.05	1
83	1380	2100	2640	3380	3980	4630	5330	6330	19.5	7.18	21.38	89.93	.37	2.23	2.87	3.03	1
84[nc]	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	35.8	11.55	13.54	89.20	.27	2.24	2.87	3.04	1
85	536	980	1360	1950	2480	3090	3780	4850	8.2	6.53	23.77	82.99	.19	2.23	2.87	3.03	1
86	1410	2620	3660	5290	6750	8440	10400	13400	83.5	22.16	9.08	81.46	.17	2.25	2.88	3.04	1
87	580	1120	1610	2380	3100	3930	4910	6450	27.9	9.77	11.67	46.15	.29	2.26	2.88	3.05	2
88	140	297	447	701	944	1240	1600	2180	2.6	3.45	34.25	80.30	.23	2.26	2.88	3.04	2
89	483	1020	1540	2410	3230	4240	5450	7430	7.6	5.36	21.29	45.76	.27	2.25	2.89	3.06	2
90	1630	2620	3390	4510	5440	6460	7570	9220	191	39.18	5.87	56.06	.12	2.25	2.89	3.06	2
91	2290	3490	4380	5620	6630	7700	8860	10500	232	49.28	5.32	50.49	.09	2.26	2.89	3.06	2
92	12700	18400	22400	27900	32200	36800	41600	48400	2399	169.34	2.78	68.54	.08	2.31	2.93	3.09	2
92*[r]	10200	15700	19700	25100	29500	34000	38900	45700	2399	169.34	2.78	68.54	.08	2.31	2.93	3.09	2
93[nc]	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	.0	15.33	4.61	19.67	.25	2.32	2.93	3.10	2
94	13500	19800	24400	30600	35500	40800	46400	54300	2692	203.19	2.10	63.32	.07	2.33	2.94	3.11	2
94*[r]	10800	15700	18900	22800	25500	28200	30900	34200	2692	203.19	2.10	63.32	.07	2.33	2.94	3.11	2

Table 2. Recurrence interval discharges and basin characteristics for gaged rural sites in North Carolina—Continued

[Q, recurrence interval flood discharge for years indicated; DA, drainage area; L, channel length; CSLOPE, channel slope; BSLOPE, basin slope; SHAPE, basin shape; CF, climate factor for recurrence interval years indicated; REG, region; nc, flood-frequency estimates were not computed because the site has less than 10 years of peak-flow record; *, duplicate map identification number for sites having separate periods of regulated or channelized flows; r, site excluded from regional analysis because flows were affected by regulation or channelization; n.a., data not available]

Map identification number (fig. 1)	Q_2	Q_5	Q_{10}	Q_{25}	Q_{50}	Q_{100}	Q_{200}	Q_{500}	DA (mi^2)	L (mi)	CSLOPE (ft/mi)	BSLOPE (ft/mi)	SHAPE (DA/L^2)	CF_2	CF_{25}	CF_{100}	REG
95	1770	2870	3730	4980	6030	7180	8450	10300	161	28.02	6.14	55.52	0.20	2.25	2.90	3.09	2
95*[r]	2160	3250	3900	4620	5090	5520	5900	6350	161	28.02	6.14	55.52	.20	2.25	2.90	3.09	2
96	170	293	394	544	674	820	984	1230	2.8	3.74	11.87	30.38	.21	2.28	2.91	3.09	2
97	121	252	375	580	774	1010	1290	1740	2.1	2.12	15.71	20.07	.43	2.29	2.92	3.10	2
98	126	258	381	586	779	1010	1290	1730	2.6	2.51	17.67	8.17	.44	2.29	2.92	3.10	2
99	388	658	876	1200	1480	1790	2130	2650	18.6	10.51	7.48	38.55	.16	2.30	2.92	3.09	2
100[nc]	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	1.9	3.15	13.58	10.80	.23	2.30	2.92	3.10	2
101	1100	1750	2250	2970	3570	4220	4940	5990	80.4	22.82	4.03	28.29	.15	2.33	2.95	3.13	2
102	70.0	124	192	309	423	564	737	1020	1.5	2.11	43.56	39.01	.34	2.32	2.93	3.10	2
103	3960	6380	8280	11000	13300	15800	18500	22600	733	71.80	2.84	35.09	.14	2.32	2.93	3.11	2
104	1430	2150	2690	3430	4030	4680	5370	6360	93.3	18.49	3.08	17.46	.28	2.32	2.93	3.11	2
105	339	710	1060	1650	2210	2880	3700	5010	4.9	3.71	7.90	21.89	.35	2.33	2.94	3.11	2
106	502	1000	1460	2200	2890	3710	4680	6230	27.0	8.46	5.17	11.26	.41	2.33	2.94	3.12	2
107	1910	3090	4000	5320	6420	7630	8950	10900	182	27.24	2.11	9.57	.25	2.33	2.94	3.12	2
108	516	1140	1760	2840	3880	5170	6760	9390	24.0	6.29	3.48	16.11	.57	2.33	2.94	3.12	2
109	877	1600	2210	3160	4010	4980	6090	7800	33.6	8.56	2.56	6.86	.51	2.34	2.95	3.12	2
110	219	391	537	760	957	1180	1440	1830	2.5	3.23	5.47	11.12	.44	2.34	2.94	3.11	2
111	1770	2910	3820	5130	6250	7480	8840	10900	168	32.46	2.04	17.33	.16	2.34	2.94	3.11	2
112	229	434	614	898	1160	1450	1800	2340	6.3	3.77	11.66	7.75	.46	2.33	2.94	3.11	2
113	143	368	617	1090	1580	2230	3070	4550	3.3	3.60	5.93	2.05	.28	2.39	2.99	3.17	2
114	613	1310	1980	3120	4210	5550	7160	9810	53.3	15.10	2.22	5.60	.26	2.36	2.96	3.13	2
115	123	264	401	633	857	1130	1460	2010	4.9	2.55	10.28	15.94	.71	2.40	2.99	3.15	2
116	1580	2760	3750	5240	6530	8000	9650	12200	74.5	15.74	4.07	24.27	.33	2.35	2.95	3.11	2
117	108	214	309	464	607	776	975	1290	1.0	1.21	31.68	22.23	.38	2.35	2.95	3.11	2
118	772	1570	2320	3550	4700	6080	7720	10400	26.9	10.28	6.16	22.31	.25	2.40	2.97	3.11	2
119	467	757	984	1310	1590	1890	2230	2720	26.3	12.57	10.60	85.79	.17	2.11	2.80	2.97	1
120	1690	3030	4160	5910	7440	9190	11200	14300	168	32.93	6.66	89.48	.16	2.12	2.80	2.98	1
121[nc]	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	188	42.64	5.17	90.27	.10	2.12	2.81	2.98	1
122	888	1620	2260	3240	4110	5110	6250	8020	20.6	9.17	19.56	88.69	.25	2.11	2.80	2.97	1
123	669	1130	1510	2070	2550	3090	3690	4590	15.9	7.48	21.30	81.00	.29	2.12	2.80	2.98	1
124	1670	2910	3930	5470	6810	8320	10000	12600	33.6	13.47	12.21	74.59	.19	2.12	2.80	2.98	1
125	2120	3610	4820	6610	8160	9890	11800	14700	37.1	12.83	12.47	73.20	.23	2.12	2.80	2.98	1
126	11400	18200	23400	30900	37200	44000	51500	62400	606	52.96	6.84	85.86	.22	2.14	2.81	2.98	1
127	1250	2320	3250	4700	5990	7480	9200	11900	14.4	6.27	21.48	86.92	.37	2.17	2.84	3.02	1
128	3710	5330	6490	8050	9280	10600	11900	13900	116	20.29	12.27	88.54	.28	2.13	2.81	2.98	1

Table 2. Recurrence interval discharges and basin characteristics for gaged rural sites in North Carolina—Continued

[Q, recurrence interval flood discharge for years indicated; DA, drainage area; L, channel length; CSLOPE, channel slope; BSLOPE, basin slope; SHAPE, basin shape; CF, climate factor for recurrence interval years indicated; REG, region; nc, flood-frequency estimates were not computed because the site has less than 10 years of peak-flow record; *, duplicate map identification number for sites having separate periods of regulated or channelized flows; r, site excluded from regional analysis because flows were affected by regulation or channelization; n.a., data not available]

Map identification number (fig. 1)	Q_2	Q_5	Q_{10}	Q_{25}	Q_{50}	Q_{100}	Q_{200}	Q_{500}	DA (mi^2)	L (mi)	CSLOPE (ft/mi)	BSLOPE (ft/mi)	SHAPE (DA/L^2)	CF_2	CF_{25}	CF_{100}	REG
129	222	566	944	1650	2390	3360	4610	6800	5.0	4.16	22.72	65.39	0.22	2.13	2.81	2.98	1
130[nc]	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	7.5	4.66	25.70	94.32	.35	2.18	2.83	2.99	1
131	1810	2860	3660	4790	5730	6760	7870	9490	33.7	9.75	18.51	93.90	.35	2.18	2.83	2.99	1
132	25000	36600	45000	56500	65600	75300	85600	100000	1275	82.36	6.20	85.28	.19	2.21	2.85	3.01	1
133	175	312	429	607	763	942	1140	1460	1.1	1.93	40.95	95.44	.41	2.19	2.83	3.00	1
134	2320	4030	5450	7570	9410	11500	13800	17300	75.9	21.38	18.18	93.48	.17	2.21	2.85	3.01	1
135	1310	2260	3050	4240	5260	6420	7720	9700	21.1	8.79	11.61	78.16	.27	2.21	2.85	3.02	1
136	828	1250	1560	1980	2330	2700	3100	3670	23.6	11.69	16.49	90.08	.19	2.22	2.86	3.02	1
137	3860	5610	6860	8570	9930	11400	12900	15000	285	34.81	11.44	91.08	.23	2.22	2.86	3.02	1
138[r]	14800	17000	17600	18000	18200	18200	18300	18300	1689	91.01	6.68	87.29	.20	2.22	2.86	3.02	1
139[nc]	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	1689	91.01	6.68	87.29	.20	.00	.22	.86	1
140	1590	2600	3390	4540	5500	6570	7740	9480	32.1	9.71	15.85	66.01	.34	2.16	2.82	2.99	1
141	1640	2760	3650	4970	6100	7350	8740	10800	14.8	6.54	18.72	79.92	.34	2.12	2.80	2.98	1
142	4750	7280	9180	11900	14000	16400	18900	22500	125	23.34	10.90	83.89	.23	2.17	2.82	2.99	1
143[nc]	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	16.7	9.61	19.55	79.42	.18	2.17	2.82	2.99	1
144	12100	17400	21200	26300	30400	34600	39100	45400	349	45.45	8.79	94.27	.17	2.18	2.83	3.00	1
145	6470	11800	16300	23400	29600	36800	45100	57800	137	18.60	17.28	90.65	.40	2.20	2.84	3.01	1
146	520	860	1130	1520	1860	2230	2640	3250	3.0	2.38	36.12	70.12	.48	2.19	2.84	3.00	1
147	141	265	373	542	695	871	1080	1390	.9	1.60	68.37	91.52	.32	2.24	2.87	3.03	1
148[nc]	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	7.4	6.09	22.99	69.92	.21	2.18	2.83	3.00	1
149	1090	2040	2880	4190	5380	6750	8340	10800	15.5	8.06	24.42	85.61	.24	2.19	2.83	3.00	1
150	2920	4480	5650	7290	8630	10100	11600	13900	43.2	16.66	9.64	61.78	.15	2.19	2.83	3.00	1
151	22000	29700	35000	42000	47300	52800	58500	66300	1434	115.73	5.50	91.10	.11	2.23	2.86	3.02	1
152[nc]	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	76.3	15.61	9.64	103.60	.31	2.23	2.87	3.03	1
152*[r]	746	1470	2170	3380	4570	6070	7930	11100	76.3	15.61	9.64	103.60	.31	2.23	2.87	3.03	1
153	42400	57400	67700	81200	91600	102000	113000	128000	3464	119.72	6.22	93.60	.24	2.25	2.87	3.04	1
153*[r]	28700	36300	41100	46700	50800	54700	58600	63600	3464	119.72	6.22	93.60	.24	2.25	2.87	3.04	1
154	145	229	294	387	465	550	644	782	7.6	5.87	42.55	86.78	.22	2.25	2.87	3.03	3
155	91.8	168	235	341	436	546	675	877	2.2	2.10	63.92	88.21	.48	2.21	2.84	3.01	3
156	856	1480	2010	2810	3510	4300	5200	6590	32.4	11.10	17.11	86.34	.27	2.24	2.87	3.03	3
157	2770	3700	4340	5170	5810	6480	7160	8110	348	40.74	7.27	84.77	.21	2.25	2.87	3.03	3
158	121	199	262	355	434	523	623	772	7.6	4.37	17.00	77.76	.39	2.25	2.87	3.04	3
159	3600	5560	7070	9220	11000	13000	15100	18200	460	57.53	5.33	80.68	.14	2.26	2.88	3.04	3
160	46100	63500	75500	91400	104000	116000	130000	148000	4395	156.35	5.15	89.44	.18	2.26	2.88	3.04	2
161	175	319	442	631	799	991	1210	1550	7.9	4.81	7.27	23.11	.43	2.26	2.88	3.04	2

Table 2. Recurrence interval discharges and basin characteristics for gaged rural sites in North Carolina—Continued

[Q, recurrence interval flood discharge for years indicated; DA, drainage area; L, channel length; CSLOPE, channel slope; BSLOPE, basin slope; SHAPE, basin shape; CF, climate factor for recurrence interval years indicated; REG, region; nc, flood-frequency estimates were not computed because the site has less than 10 years of peak-flow record; *, duplicate map identification number for sites having separate periods of regulated or channelized flows; r, site excluded from regional analysis because flows were affected by regulation or channelization; n.a., data not available]

Map identification number (fig. 1)	Q_2	Q_5	Q_{10}	Q_{25}	Q_{50}	Q_{100}	Q_{200}	Q_{500}	DA (mi^2)	L (mi)	CSLOPE (ft/mi)	BSLOPE (ft/mi)	SHAPE (DA/L^2)	CF_2	CF_{25}	CF_{100}	REG
162	2090	3600	4870	6790	8470	10400	12600	15900	284	39.33	5.14	66.05	0.18	2.29	2.89	3.05	3
163	36500	45500	51300	58500	63800	69100	74400	81500	4852	176.67	4.67	86.19	.16	2.30	2.90	3.05	2
163*[r]	28500	33500	36200	39100	41000	42700	44200	46100	4852	176.67	4.67	86.19	.16	2.30	2.90	3.05	2
164	148	386	651	1150	1680	2380	3280	4880	14.1	7.56	12.15	24.86	.30	2.31	2.90	3.05	2
165	494	1010	1490	2280	3020	3900	4960	6670	60.1	19.22	3.19	11.61	.16	2.32	2.90	3.05	2
166	32500	47400	58200	72900	84500	96900	110000	128000	5255	229.76	3.55	81.22	.10	2.38	2.95	3.09	2
166*[r]	25100	33900	39800	47400	53100	58800	64700	72600	5255	229.76	3.55	81.22	.10	2.38	2.95	3.09	2
167	652	1200	1670	2390	3040	3790	4640	5970	21.6	7.51	8.09	12.90	.38	2.39	2.95	3.09	2
168	862	1480	1990	2750	3400	4140	4960	6210	92.8	24.69	4.25	22.86	.16	2.29	2.89	3.04	2
169	392	761	1090	1620	2110	2680	3350	4410	15.7	5.78	6.99	19.12	.45	2.33	2.92	3.07	2
170	56.8	96.8	129	178	219	266	318	396	.5	.86	8.83	41.15	.58	2.33	2.92	3.07	2
171	4150	6870	9040	12200	14900	17900	21200	26100	676	52.96	2.15	31.48	.24	2.33	2.91	3.05	2
172	561	1120	1630	2460	3230	4140	5220	6950	32.3	11.64	7.19	23.35	.25	2.28	2.89	3.04	2
173	1970	2990	3750	4800	5660	6580	7570	8990	379	65.20	2.72	25.51	.09	2.32	2.90	3.05	2
174	488	732	912	1160	1360	1580	1810	2140	103	29.39	1.79	6.03	.12	2.38	2.95	3.09	2
175	30.8	68.4	106	170	232	310	405	562	.6	1.41	31.94	10.32	.33	2.32	2.93	3.09	2
176	939	1590	2110	2880	3550	4290	5110	6350	47.5	10.83	5.65	18.88	.41	2.32	2.93	3.09	2
177	140	311	480	774	1060	1420	1850	2580	8.6	4.84	19.02	36.42	.36	2.33	2.93	3.10	2
178	1080	2110	3040	4530	5900	7520	9420	12400	49.7	15.46	4.84	24.90	.22	2.38	2.95	3.09	2
179	4830	7620	9760	12800	15300	18100	21100	25400	599	47.76	2.47	26.63	.27	2.34	2.93	3.09	2
180	1510	2600	3490	4830	5980	7280	8730	10900	69.3	13.50	5.64	26.50	.37	2.37	2.94	3.08	2
181	279	345	387	439	478	516	554	605	7.8	5.35	4.79	12.77	.29	2.38	2.94	3.08	2
182	127	330	554	978	1430	2010	2770	4100	1.1	1.27	3.71	.81	.70	2.39	2.95	3.10	2
183	330	734	1140	1830	2520	3360	4400	6130	10.2	4.40	6.96	7.38	.49	2.40	2.96	3.10	2
184	410	700	936	1290	1590	1930	2300	2870	15.3	4.35	5.03	6.70	.75	2.32	2.91	3.06	2
185	3850	6080	7800	10300	12300	14500	16900	20400	680	38.60	.87	7.67	.47	2.33	2.92	3.07	2
186	415	795	1130	1670	2160	2730	3400	4440	16.0	5.02	4.36	.72	.66	2.35	2.93	3.08	2
187	149	322	490	776	1050	1390	1800	2470	3.8	3.57	9.32	17.28	.30	2.32	2.91	3.06	1
188	1400	2750	3970	5940	7760	9910	12400	16500	28.8	15.93	89.91	323.81	.12	2.15	2.78	2.94	1
189	4080	8160	11900	18000	23700	30400	38400	51200	48.1	20.64	48.76	314.89	.12	2.14	2.78	2.95	1
190	459	770	1020	1390	1710	2060	2450	3030	11.0	6.66	386.26	325.50	.26	2.11	2.77	2.95	1
191	3610	5980	7870	10600	13000	15500	18400	22700	89.2	20.61	32.65	265.44	.20	2.13	2.79	2.96	1
192	12800	21000	27400	36900	44800	53500	63200	77600	504	48.21	21.29	243.78	.22	2.13	2.79	2.96	1
192*[r]	7340	9530	11000	12700	14100	15400	16700	18500	504	48.21	21.29	243.78	.22	2.13	2.79	2.96	1
193	6200	12000	17100	25300	32800	41600	51800	67900	128	20.23	33.91	254.90	.31	2.09	2.77	2.95	1

Table 2. Recurrence interval discharges and basin characteristics for gaged rural sites in North Carolina—Continued

[Q, recurrence interval flood discharge for years indicated; DA, drainage area; L, channel length; CSLOPE, channel slope; BSLOPE, basin slope; SHAPE, basin shape; CF, climate factor for recurrence interval years indicated; REG, region; nc, flood-frequency estimates were not computed because the site has less than 10 years of peak-flow record; *, duplicate map identification number for sites having separate periods of regulated or channelized flows; r, site excluded from regional analysis because flows were affected by regulation or channelization; n.a., data not available]

Map identification number (fig. 1)	Q_2	Q_5	Q_{10}	Q_{25}	Q_{50}	Q_{100}	Q_{200}	Q_{500}	DA (mi^2)	L (mi)	CSLOPE (ft/mi)	BSLOPE (ft/mi)	SHAPE (DA/L^2)	CF_2	CF_{25}	CF_{100}	REG
194	3250	4640	5620	6950	7990	9080	10200	11800	35.5	14.74	32.24	168.32	0.16	2.08	2.77	2.95	1
195[r]	16200	21900	25000	28300	30400	32200	33800	35700	869	70.50	12.10	218.10	.17	2.08	2.77	2.95	1
196	3220	5280	6900	9260	11200	13400	15800	19400	78.8	22.18	31.52	281.93	.16	2.08	2.77	2.95	1
197	1800	2650	3260	4100	4770	5480	6240	7310	44.7	15.33	27.18	257.85	.21	2.08	2.77	2.95	1
198	4710	6530	7810	9500	10800	12200	13600	15600	109	27.61	14.56	202.20	.15	2.08	2.77	2.95	1
199	5490	9100	12000	16200	19800	23800	28200	34800	128	30.68	13.23	198.38	.13	2.08	2.77	2.95	1
200[r]	28000	35300	39200	43300	45800	48100	50100	52500	1226	93.13	6.98	208.67	.14	2.20	2.82	2.99	1
201	6690	11200	14900	20200	24800	29900	35600	44000	231	28.32	19.16	173.69	.29	2.08	2.77	2.95	1
202	7640	13100	17700	24400	30200	36700	44100	55100	287	31.47	17.57	165.49	.29	2.08	2.77	2.95	1
203	3220	5390	7130	9690	11900	14300	17000	21000	42.8	13.55	22.17	145.31	.25	2.09	2.78	2.95	1
204[r]	39200	53100	59000	63800	66100	67700	68800	69800	1694	110.42	5.25	193.78	.14	2.10	2.78	2.96	1
205	1150	1700	2100	2660	3100	3570	4070	4790	22.1	11.48	21.49	105.01	.17	2.09	2.78	2.96	1
206	215	356	469	635	775	930	1100	1360	.9	1.13	85.26	88.49	.64	2.09	2.78	2.95	1
207	1570	2900	4040	5820	7410	9240	11300	14600	19.5	8.29	38.11	134.61	.26	2.14	2.80	2.97	1
208[nc]	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	10.2	6.32	28.92	66.74	.28	2.10	2.79	2.97	1
209[nc]	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	27.8	10.14	19.34	69.36	.27	2.10	2.79	2.97	1
210[nc]	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	6.8	6.67	31.49	60.00	.16	2.12	2.80	2.98	1
211	210	400	568	835	1080	1360	1690	2210	2.2	1.69	47.86	66.44	.73	2.12	2.80	2.98	1
212	2650	3280	3680	4180	4550	4910	5280	5760	65.6	16.39	13.47	86.79	.24	2.12	2.80	2.98	1
213	4200	7030	9310	12700	15500	18700	22200	27500	186	25.82	10.45	90.93	.27	2.13	2.80	2.98	1
214	1240	1940	2480	3240	3860	4540	5280	6350	42.9	14.12	15.63	92.00	.21	2.12	2.80	2.98	1
215	30400	43700	53300	66300	76500	87300	98700	115000	2280	149.50	4.38	169.42	.10	2.15	2.80	2.98	1
215*[r]	32700	46400	54600	64100	70700	76700	82400	89400	2280	149.50	4.38	169.42	.10	2.15	2.80	2.98	1
216	93.0	180	258	383	498	632	789	1040	1.0	1.60	56.18	100.24	.40	2.15	2.80	2.98	1
217	225	315	379	463	529	597	669	768	1.6	2.80	78.01	132.30	.19	2.15	2.80	2.97	1
218	2640	4230	5470	7240	8710	10300	12100	14700	101	34.64	18.90	138.79	.08	2.15	2.80	2.97	1
219	4020	6590	8620	11600	14000	16800	19800	24300	306	48.80	11.36	120.89	.13	2.15	2.80	2.98	1
220	5040	7600	9490	12100	14200	16500	18900	22400	155	30.06	13.21	148.05	.17	2.15	2.80	2.97	1
221	6990	10200	12500	15600	18100	20800	23600	27600	569	56.83	10.23	125.33	.17	2.16	2.80	2.98	1
222[r]	63.2	68.3	70.9	73.6	75.3	76.9	78.2	79.9	4.8	4.56	29.75	52.42	.23	2.15	2.80	2.97	1
223	1430	2080	2550	3190	3700	4240	4810	5620	87.4	33.20	11.75	91.45	.08	2.16	2.80	2.98	1
223*[r]	1490	1830	2050	2310	2490	2680	2860	3100	87.4	33.20	11.75	91.45	.08	2.16	2.80	2.98	1
224	2770	4040	4970	6240	7240	8310	9440	11000	118	16.59	12.07	96.08	.43	2.16	2.81	2.98	1
225	557	1030	1450	2090	2670	3340	4100	5300	3.9	3.17	28.98	99.43	.36	2.16	2.81	2.98	1
226	53000	79300	98800	126000	147000	170000	195000	230000	3450	170.84	3.90	170.74	.12	2.16	2.81	2.98	1

Table 2. Recurrence interval discharges and basin characteristics for gaged rural sites in North Carolina—Continued

[Q, recurrence interval flood discharge for years indicated; DA, drainage area; L, channel length; CSLOPE, channel slope; BSLOPE, basin slope; SHAPE, basin shape; CF, climate factor for recurrence interval years indicated; REG, region; nc, flood-frequency estimates were not computed because the site has less than 10 years of peak-flow record; *, duplicate map identification number for sites having separate periods of regulated or channelized flows; r, site excluded from regional analysis because flows were affected by regulation or channelization; n.a., data not available]

Map identification number (fig. 1)	Q_2	Q_5	Q_{10}	Q_{25}	Q_{50}	Q_{100}	Q_{200}	Q_{500}	DA (mi^2)	L (mi)	CSLOPE (ft/mi)	BSLOPE (ft/mi)	SHAPE (DA/L^2)	CF_2	CF_{25}	CF_{100}	REG
227	565	933	1230	1650	2020	2420	2860	3520	9.6	5.98	17.12	96.67	0.27	2.15	2.81	2.98	1
228	4640	6530	7880	9660	11100	12500	14100	16200	174	29.85	9.77	97.43	.20	2.17	2.82	2.99	1
229	450	685	861	1110	1310	1520	1750	2090	6.6	6.14	16.73	89.50	.17	2.17	2.82	3.00	1
230[nc]	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	4000	186.48	3.43	160.97	.11	2.18	2.83	3.00	1
230*[r]	41300	51800	58000	65200	70200	74900	79400	85000	4000	186.48	3.43	160.97	.11	2.18	2.83	3.00	1
231	850	955	1020	1090	1140	1190	1240	1300	13.7	6.59	21.96	86.01	.31	2.19	2.83	3.00	1
232	400	717	987	1400	1760	2180	2650	3380	2.9	2.80	45.36	113.22	.37	2.19	2.83	3.00	1
233	7740	10600	12500	15000	17000	19000	21100	24000	342	51.53	6.63	131.78	.13	2.19	2.83	3.00	1
234	426	720	958	1310	1610	1950	2330	2900	3.4	4.41	72.33	173.68	.18	2.20	2.83	3.00	1
235	573	1080	1520	2220	2840	3570	4420	5740	3.6	3.55	35.95	95.22	.28	2.18	2.81	2.98	1
236	1680	2420	2960	3680	4260	4870	5510	6410	20.7	7.02	29.69	93.64	.42	2.18	2.81	2.99	1
237	4580	7000	8810	11300	13400	15600	18000	21400	55.6	14.09	21.06	90.60	.28	2.20	2.83	3.00	1
238	1390	2320	3050	4130	5050	6070	7200	8880	8.5	5.26	27.59	55.44	.28	2.22	2.83	3.00	1
239	32800	47100	57300	71000	81800	93200	105000	122000	1372	81.80	5.70	84.63	.21	2.23	2.85	3.01	1
240	2220	4140	5810	8440	10800	13500	16700	21700	110	26.68	7.72	83.54	.16	2.24	2.85	3.01	1
241	175	283	368	490	592	704	828	1010	.9	1.06	89.92	65.70	.73	2.24	2.85	3.01	1
242	4460	6340	7670	9460	10900	12300	13900	16000	106	29.55	12.14	108.15	.12	2.20	2.84	3.00	1
243	1030	1760	2350	3220	3980	4820	5760	7180	15.4	9.24	47.53	142.49	.18	2.20	2.84	3.01	1
244[r]	73500	106000	132000	170000	202000	237000	276000	335000	6863	255.33	4.59	134.56	.11	2.25	2.86	3.02	1
245	845	1220	1480	1850	2130	2430	2750	3200	16.7	5.91	33.41	75.65	.47	2.24	2.86	3.02	1
246	16.9	28.8	38.5	52.9	65.2	79.1	94.5	118	.1	1.03	114.65	86.40	.14	2.25	2.86	3.02	1
247	107	195	272	391	499	624	769	996	6.2	5.46	11.97	23.56	.19	2.26	2.87	3.03	3
248[nc]	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	.1	.37	119.76	58.22	1.45	2.25	2.86	3.03	3
249	361	527	649	816	950	1090	1250	1460	83.3	20.22	7.30	40.58	.20	2.29	2.89	3.04	3
250	1380	2450	3370	4800	6080	7550	9240	11900	183	26.23	10.26	76.68	.27	2.23	2.85	3.02	3
251	76.4	116	145	186	220	257	296	353	4.7	4.32	33.83	66.99	.24	2.25	2.86	3.03	3
252	1440	2190	2760	3560	4220	4940	5710	6830	365	64.79	4.11	63.07	.09	2.29	2.89	3.04	3
253	466	647	775	946	1080	1220	1370	1570	39.8	14.30	7.65	24.83	.21	2.28	2.88	3.04	3
254	230	344	429	547	643	746	858	1020	16.1	6.85	3.83	7.32	.36	2.30	2.89	3.05	3
255	4850	7590	9700	12700	15200	18000	21000	25400	1228	130.44	2.09	27.34	.07	2.31	2.90	3.05	3
256	1130	1820	2360	3150	3800	4530	5320	6490	20.7	8.95	268.53	407.99	.26	2.19	2.78	2.94	1
257	6250	9430	11800	15100	17700	20600	23600	28000	127	20.20	67.00	299.40	.31	2.18	2.78	2.94	1
258	7160	12600	17100	23900	29900	36700	44300	56000	172	23.12	52.06	299.74	.32	2.18	2.78	2.94	1
259	4620	8780	12500	18300	23600	29800	37000	48200	66.7	34.93	86.54	285.37	.05	2.17	2.78	2.94	1
260	57.1	93.3	122	163	198	236	279	341	0.5	1.07	526.60	243.48	.48	2.18	2.78	2.95	1

Table 2. Recurrence interval discharges and basin characteristics for gaged rural sites in North Carolina—Continued

[Q, recurrence interval flood discharge for years indicated; DA, drainage area; L, channel length; CSLOPE, channel slope; BSLOPE, basin slope; SHAPE, basin shape; CF, climate factor for recurrence interval years indicated; REG, region; nc, flood-frequency estimates were not computed because the site has less than 10 years of peak-flow record; *, duplicate map identification number for sites having separate periods of regulated or channelized flows; r, site excluded from regional analysis because flows were affected by regulation or channelization; n.a., data not available]

Map identification number (fig. 1)	Q_2	Q_5	Q_{10}	Q_{25}	Q_{50}	Q_{100}	Q_{200}	Q_{500}	DA (mi^2)	L (mi)	CSLOPE (ft/mi)	BSLOPE (ft/mi)	SHAPE (DA/L^2)	CF_2	CF_{25}	CF_{100}	REG
261	229	420	584	839	1070	1330	1630	2090	2.4	3.09	572.66	225.03	0.23	2.16	2.78	2.94	1
262	11900	21200	29000	40800	51200	63000	76400	96900	20.0	34.09	20.52	277.87	.17	2.17	2.78	2.95	1
263	448	776	1050	1450	1800	2200	2640	3320	9.1	6.71	31.80	227.46	.19	2.16	2.78	2.95	1
264	947	1560	2040	2750	3340	4000	4730	5810	18.4	9.83	44.78	189.99	.19	2.15	2.79	2.97	1
265	1510	2660	3620	5080	6350	7780	9410	11900	28.2	8.08	47.94	173.16	.43	2.15	2.79	2.97	1
266	855	1430	1900	2580	3160	3810	4530	5600	7.8	4.30	54.76	63.08	.44	2.17	2.80	2.97	1
267[r]	20500	39400	58400	92700	128000	174000	233000	338000	1535	99.51	5.45	174.39	.16	2.16	2.80	2.97	1
268	566	1010	1380	1950	2450	3020	3670	4660	7.2	4.34	31.23	139.86	.35	2.16	2.80	2.98	1
269	1330	2040	2580	3340	3960	4620	5340	6380	16.4	7.16	19.53	80.95	.31	2.18	2.81	2.98	1
270	4990	8530	11400	15700	19400	23600	28200	35200	83.2	30.41	35.01	165.65	.09	2.17	2.80	2.97	1
271	2280	3550	4510	5870	7000	8210	9520	11400	25.7	8.74	112.47	223.96	.33	2.18	2.79	2.95	1
272	199	413	614	950	1270	1650	2110	2850	1.0	1.49	81.90	43.94	.46	2.18	2.80	2.98	1
273	2110	3600	4830	6650	8220	9980	12000	14900	69.2	21.98	15.60	72.28	.14	2.18	2.80	2.98	1
274	1410	2360	3130	4250	5210	6280	7470	9250	31.8	10.79	20.61	79.15	.26	2.19	2.81	2.98	1
275	9470	14300	17900	22900	26900	31200	35900	42500	630	76.32	9.82	88.95	.11	2.18	2.81	2.98	1
276	2380	3210	3770	4510	5070	5640	6240	7050	41.8	9.79	12.37	65.58	.43	2.23	2.83	2.99	1
277	3130	4720	5910	7550	8880	10300	11800	14000	76.5	13.19	9.34	75.36	.44	2.23	2.83	2.99	1
278[r]	3020	7990	13100	22100	30900	41500	54300	74900	97.0	21.78	96.11	394.11	.20	2.19	2.78	2.94	1
279	3000	4740	6070	7970	9540	11300	13100	15800	79.0	19.99	22.73	295.91	.20	2.19	2.78	2.95	1
280	593	964	1260	1680	2030	2420	2850	3480	13.0	8.05	40.64	280.73	.20	2.19	2.79	2.95	1
281	4840	7610	9730	12700	15200	17900	20800	25100	220	42.35	15.04	212.62	.12	2.23	2.81	2.97	1
282	16900	25800	32600	42100	49800	58100	67000	80000	875	64.54	27.19	223.48	.21	2.23	2.81	2.97	1
283	3050	4880	6310	8370	10100	12000	14000	17000	60.5	20.27	25.87	305.26	.15	2.19	2.79	2.96	1
284	1070	1680	2150	2800	3350	3930	4570	5500	16.4	7.85	50.61	91.82	.25	2.19	2.79	2.96	1
285	7050	10300	12600	15800	18300	21000	23800	27800	200	40.97	13.36	212.84	.12	2.21	2.80	2.97	1
286	344	599	810	1130	1400	1720	2070	2600	1.4	2.29	72.02	100.64	.30	2.22	2.81	2.97	1
287	104	148	179	221	253	288	323	374	2.4	1.98	159.21	286.39	.58	2.10	2.76	2.93	1
288	5150	8910	12000	16700	20800	25400	30500	38400	205	66.19	10.53	314.07	.05	2.09	2.76	2.93	1
289	1170	1930	2530	3420	4170	5000	5920	7280	21.8	8.58	74.20	430.02	.29	2.09	2.75	2.92	1
290	5960	9660	12600	16800	20300	24200	28500	34900	277	41.20	19.42	386.04	.16	2.09	2.75	2.92	1
291	169	276	362	486	590	706	833	1020	3.5	2.32	219.54	266.66	.38	2.07	2.77	2.94	1
292	4150	6150	7620	9630	11200	13000	14800	17400	67.9	14.21	67.39	407.60	.34	2.27	2.80	2.95	1
293	4690	7180	9050	11700	13800	16100	18600	22200	103	19.57	79.36	373.79	.27	2.26	2.80	2.95	1
294	696	1250	1710	2430	3050	3770	4580	5830	11.7	4.85	205.76	446.05	.49	2.26	2.80	2.95	1
295	2740	4290	5490	7170	8570	10100	11700	14100	40.4	13.36	131.60	502.95	.22	2.25	2.80	2.95	1

Table 2. Recurrence interval discharges and basin characteristics for gaged rural sites in North Carolina—Continued

[Q, recurrence interval flood discharge for years indicated; DA, drainage area; L, channel length; CSLOPE, channel slope; BSLOPE, basin slope; SHAPE, basin shape; CF, climate factor for recurrence interval years indicated; REG, region; nc, flood-frequency estimates were not computed because the site has less than 10 years of peak-flow record; *, duplicate map identification number for sites having separate periods of regulated or channelized flows; r, site excluded from regional analysis because flows were affected by regulation or channelization; n.a., data not available]

Map identification number (fig. 1)	Q_2	Q_5	Q_{10}	Q_{25}	Q_{50}	Q_{100}	Q_{200}	Q_{500}	DA (mi^2)	L (mi)	CSLOPE (ft/mi)	BSLOPE (ft/mi)	SHAPE (DA/L^2)	CF_2	CF_{25}	CF_{100}	REG
296	1510	2430	3140	4170	5030	5970	7000	8520	26.8	11.33	37.09	239.70	0.21	2.24	2.80	2.96	1
297	1670	2530	3180	4080	4810	5590	6430	7640	41.4	13.96	44.43	242.70	.22	2.24	2.80	2.96	1
298	561	938	1240	1690	2070	2490	2960	3660	10.9	4.91	338.78	285.36	.44	2.24	2.80	2.96	1
299	7050	10900	13900	18100	21600	25300	29400	35300	296	36.20	3.88	343.47	.23	2.24	2.80	2.95	1
300	482	717	890	1130	1320	1520	1740	2050	14.8	11.44	50.40	263.91	.11	2.23	2.79	2.95	1
301	663	1120	1500	2050	2530	3060	3650	4540	10.0	4.78	179.84	387.36	.45	2.25	2.79	2.95	1
302	2500	3850	4870	6300	7470	8730	10100	12100	66.7	27.47	50.49	440.37	.09	2.23	2.78	2.94	1
303	80.0	109	129	155	175	195	217	246	.6	.88	436.52	199.55	.72	2.24	2.80	2.96	1
304	1460	2420	3190	4310	5260	6320	7490	9230	42.2	13.01	24.24	226.31	.25	2.24	2.80	2.96	1
305	3270	6380	9170	13700	17800	22700	28400	37400	109	15.41	10.25	187.68	.46	2.23	2.79	2.95	1
306	1820	2940	3810	5070	6130	7290	8570	10400	63.1	15.97	28.17	307.71	.25	2.23	2.79	2.95	1
307	10700	15300	18700	23200	26800	30500	34400	40000	676	61.46	2.71	300.03	.18	2.23	2.78	2.94	1
308	2060	3630	4950	6950	8710	10700	13000	16400	79.8	13.83	57.53	415.17	.42	2.22	2.78	2.93	1
309[nc]	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	14.5	4.76	503.19	641.91	.66	2.19	2.78	2.94	1
310	1800	3120	4210	5840	7250	8850	10600	13400	23.8	7.84	282.05	600.92	.39	2.19	2.78	2.94	1
310*[r,nc]	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	23.8	7.84	282.05	600.92	.39	2.19	2.78	2.94	1
311	246	427	575	799	992	1210	1450	1820	5.5	3.89	574.31	591.79	.36	2.19	2.78	2.94	1
312	3090	5270	7060	9730	12000	14600	17500	21900	130	23.03	21.11	426.04	.24	2.21	2.78	2.94	1
312*[r]	2900	4940	6670	9370	11800	14600	17800	22900	130	23.03	21.11	426.04	.24	2.21	2.78	2.94	1
313	15000	22000	27200	34200	39900	45900	52300	61400	945	72.49	2.59	320.73	.18	2.20	2.78	2.94	1
314	2060	3080	3840	4890	5740	6650	7620	9010	79.5	19.44	34.12	403.22	.21	2.21	2.77	2.92	1
315	4100	6680	8720	11700	14200	16900	19900	24400	158	24.08	47.85	440.28	.27	2.21	2.77	2.92	1
316	19500	30200	38300	49600	58900	68900	79700	95300	1332	90.72	4.09	337.83	.16	2.21	2.77	2.92	1
317	624	940	1180	1500	1770	2050	2350	2780	8.0	5.34	142.20	400.62	.27	2.20	2.77	2.92	1
318	3350	5410	7020	9350	11300	13400	15800	19200	126	28.76	72.67	508.25	.15	2.20	2.76	2.92	1
319	23500	37200	47700	62800	75200	88800	104000	125000	1567	106.96	6.30	358.29	.14	2.20	2.77	2.92	1
320	4090	5820	7060	8720	10000	11400	12800	14900	27.6	10.24	259.95	565.57	.26	2.26	2.80	2.95	1
321[r,nc]	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	33.5	12.63	213.40	568.89	.21	2.26	2.79	2.95	1
322[r]	4400	6590	8210	10500	12300	14200	16300	19300	58.4	17.24	172.62	565.25	.19	2.25	2.79	2.95	1
323	4310	6990	9090	12100	14700	17500	20500	25100	51.5	19.40	155.96	569.36	.14	2.25	2.79	2.95	1
324	7740	11900	15000	19300	22900	26700	30800	36800	130	24.00	125.34	533.76	.22	2.22	2.77	2.93	1
325	764	1110	1370	1710	1990	2280	2590	3020	14.4	5.16	556.54	589.19	.54	2.26	2.80	2.95	1
326[nc]	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	243	35.84	79.37	478.74	.19	2.21	2.77	2.92	1
327	1930	2710	3250	3980	4550	5140	5760	6630	65.3	17.58	74.41	510.37	.21	2.21	2.77	2.92	1
328	11100	16900	21200	27200	32000	37200	42800	50800	350	42.50	51.32	482.01	.19	2.21	2.77	2.92	1

Table 2. Recurrence interval discharges and basin characteristics for gaged rural sites in North Carolina—Continued

[Q, recurrence interval flood discharge for years indicated; DA, drainage area; L, channel length; CSLOPE, channel slope; BSLOPE, basin slope; SHAPE, basin shape; CF, climate factor for recurrence interval years indicated; REG, region; nc, flood-frequency estimates were not computed because the site has less than 10 years of peak-flow record; *, duplicate map identification number for sites having separate periods of regulated or channelized flows; r, site excluded from regional analysis because flows were affected by regulation or channelization; n.a., data not available]

Map identification number (fig. 1)	Q_2	Q_5	Q_{10}	Q_{25}	Q_{50}	Q_{100}	Q_{200}	Q_{500}	DA (mi^2)	L (mi)	CSLOPE (ft/mi)	BSLOPE (ft/mi)	SHAPE (DA/L^2)	CF_2	CF_{25}	CF_{100}	REG
329	1880	2960	3790	4970	5940	7000	8140	9820	49.2	10.68	183.96	530.96	0.43	2.21	2.77	2.92	1
330	368	430	468	513	546	577	608	648	9.2	4.90	127.36	313.06	.39	2.16	2.77	2.94	1
331	2870	4550	5860	7720	9270	11000	12800	15500	104	37.92	34.80	410.63	.07	2.17	2.78	2.94	1
332	5440	9290	12400	17100	21200	25700	30800	38400	43.3	14.34	158.20	520.68	.21	2.18	2.78	2.94	1
333	5600	9430	12500	17100	21000	25400	30300	37600	60.8	27.05	50.38	484.24	.08	2.17	2.77	2.94	1
334	146	224	283	366	434	506	585	699	1.6	3.08	519.11	405.77	.17	2.17	2.77	2.93	1
335	5040	9150	12700	18100	23000	28500	34900	44700	157	39.09	34.98	531.07	.10	2.17	2.77	2.93	1
336	16200	26400	34400	46100	55900	66700	78600	96300	608	73.77	23.71	452.57	.11	2.17	2.77	2.93	1
337	1060	2050	2930	4350	5640	7160	8940	11700	23.1	9.70	118.81	398.27	.25	2.15	2.77	2.94	1
338	5990	10500	14200	19900	24900	30500	36800	46500	92.1	19.38	84.54	376.69	.24	2.15	2.77	2.94	1
339	15.7	23.5	29.2	37.1	43.5	50.3	57.6	68.1	.5	1.72	997.21	415.55	.18	2.16	2.77	2.94	1
340	2290	3770	4940	6660	8110	9710	11500	14100	42.0	11.66	104.61	406.56	.31	2.16	2.77	2.93	1
341	3350	5180	6560	8520	10100	11800	13700	16400	140	25.26	6.86	375.26	.23	2.28	2.80	2.95	1
342	1950	2860	3530	4430	5150	5920	6730	7880	57.1	16.11	31.33	436.73	.22	2.28	2.80	2.95	1
343[r]	975	1600	2160	3070	3920	4950	6200	8250	14.9	7.41	98.65	246.33	.26	2.28	2.81	2.95	1
344	2940	4610	5890	7710	9220	10900	12600	15200	86.5	20.22	123.81	435.46	.21	2.28	2.80	2.95	1
345	123	254	378	584	778	1010	1290	1740	1.6	2.64	491.80	467.80	.25	2.27	2.80	2.95	1
346	6190	8880	10800	13400	15500	17700	19900	23200	323	34.17	5.76	394.79	.28	2.24	2.80	2.96	1
347	9400	13500	16400	20400	23500	26700	30200	35000	436	52.12	6.48	408.05	.16	2.27	2.80	2.94	1
348	2500	3440	4100	4960	5630	6320	7040	8040	51.9	16.68	63.83	456.46	.19	2.28	2.80	2.95	1
349[r]	2800	4370	5530	7120	8390	9740	11200	13200	144	38.21	40.37	464.09	.10	2.27	2.80	2.95	1
350	5120	7330	8910	11000	12700	14500	16400	19000	174	49.80	42.39	475.41	.07	2.27	2.79	2.94	1
351	13600	21400	27400	36000	43000	50700	59100	71300	664	63.31	8.43	430.10	.17	2.27	2.79	2.94	1
352[nc]	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	143	21.61	112.60	411.88	.31	2.27	2.80	2.95	1
352*[r]	3940	7780	11500	18000	24400	32500	42600	59800	143	21.61	112.60	411.88	.31	2.27	2.80	2.95	1
353	1460	2070	2500	3080	3530	4000	4490	5180	51.0	15.75	167.42	520.46	.21	2.27	2.80	2.95	1
354	6860	9840	12000	14900	17100	19500	22100	25600	347	37.92	56.29	464.22	.24	2.27	2.80	2.95	1
354*[r]	7380	12900	17700	25600	32800	41400	51700	68300	347	37.92	56.29	464.22	.24	2.27	2.80	2.95	1
355	5340	7350	8750	10600	12000	13500	15000	17100	131	22.52	106.56	613.81	.26	2.27	2.80	2.94	1
356	8680	11500	13300	15700	17600	19400	21300	23900	184	26.94	85.10	589.97	.25	2.27	2.80	2.94	1
357	16700	26500	34100	44800	53700	63300	73800	89200	655	57.17	37.57	502.95	.20	2.27	2.79	2.94	1
357*[r]	16500	24200	29700	37300	43300	49600	56300	65800	655	57.17	37.57	502.95	.20	2.27	2.79	2.94	1
358	19.9	36.9	51.6	74.8	95.5	119	147	190	.5	1.78	595.52	474.30	.20	2.27	2.80	2.94	1
359	944	1290	1530	1850	2090	2340	2600	2960	13.8	8.53	346.36	601.47	.19	2.27	2.79	2.94	1
360	2310	3640	4660	6120	7320	8630	10100	12100	44.4	12.93	173.28	606.86	.26	2.26	2.79	2.93	1

Table 2. Recurrence interval discharges and basin characteristics for gaged rural sites in North Carolina—Continued

[Q, recurrence interval flood discharge for years indicated; DA, drainage area; L, channel length; CSLOPE, channel slope; BSLOPE, basin slope; SHAPE, basin shape; CF, climate factor for recurrence interval years indicated; REG, region; nc, flood-frequency estimates were not computed because the site has less than 10 years of peak-flow record; *, duplicate map identification number for sites having separate periods of regulated or channelized flows; r, site excluded from regional analysis because flows were affected by regulation or channelization; n.a., data not available]

Map identification number (fig. 1)	Q_2	Q_5	Q_{10}	Q_{25}	Q_{50}	Q_{100}	Q_{200}	Q_{500}	DA (mi^2)	L (mi)	CSLOPE (ft/mi)	BSLOPE (ft/mi)	SHAPE (DA/L^2)	CF_2	CF_{25}	CF_{100}	REG
361[nc]	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	1571	85.95	21.06	472.39	0.21	2.28	2.79	2.94	1
361*[r]	10800	17500	22400	29100	34500	40100	46100	54400	1571	85.95	21.06	472.39	.21	2.28	2.79	2.94	1
362	2930	4150	5010	6160	7070	8020	9010	10400	42.0	19.16	86.51	480.21	.11	2.29	2.80	2.95	1
363	1450	2420	3190	4330	5300	6380	7570	9360	37.6	7.91	150.30	474.21	.61	2.29	2.81	2.96	1
364[r]	1640	2090	2470	3070	3600	4220	4940	6070	190	26.23	50.04	384.09	.28	2.29	2.81	2.96	1
365	11200	15700	18900	23100	26400	29800	33400	38400	406	47.41	15.70	368.28	.18	2.31	2.81	2.96	1
365*[r]	8900	12500	14800	17400	19100	20800	22400	24400	406	47.41	15.70	368.28	.18	2.31	2.81	2.96	1
366	4210	6530	8290	10800	12800	15000	17400	20900	104	22.63	50.23	435.97	.20	2.31	2.81	2.95	1

APPENDIX

The value of the mean square error (MSE_s) at a specific site can be estimated as follows: Denote the column vector of *n* logarithms of observed peak-discharge characteristics at *n* sites in a region by *Y*. For example,

$$Y = \begin{bmatrix} \log Q_{50,\,1} \\ \log Q_{50,\,2} \\ \vdots \\ \log Q_{50,\,n} \end{bmatrix},$$

in which, $Q_{50,i,}$ represents the observed 50-year peak at the *i*th gaging station in the region. Further, let *X* represent a (*n* by *p*) matrix of *p*-1 basin characteristics augmented by a column of ones at *n* gaging stations and *B* represent a column vector of *p* regression coefficients.

For example,

$$X = \begin{bmatrix} 1 & \log(DA_1) & \log(IA_1) & \log(RQ50_1) \\ 1 & \log(DA_2) & \log(IA_2) & \log(RQ50_2) \\ & \vdots & \vdots & \vdots \\ 1 & \log(DA_n) & \log(IA_n) & \log(RQ50_n) \end{bmatrix} \text{ and } B = \begin{bmatrix} a \\ b_1 \\ b_2 \\ b_4 \end{bmatrix}.$$

The linear model can be written as

$$Y = XB.$$

The mean square sampling error, $MSE_{s,0}$, for an ungaged site with basin characteristics given by the row vector x_0=[1 log (DA_0) log (IA_0) log ($RQ50_0$)], for example, is calculated as

$$MSE_{s,0} = x_0\,\{X^T\Lambda^{-1}X\}^{-1}x_0^T\,,$$

in which Λ is the (*n* by *n*) covariance matrix associated with *Y*. The diagonal elements of Λ are model error variance, γ^2, plus the time-sampling error for each site *i* (*i*=1,2,3,...*n*), which is estimated as a function of a regional estimate of the standard deviation of annual peaks at site *i*, the recurrence interval of the dependent variable and the number of years of record at site *i*. The off-diagonal elements of Λ are the sample covariance of the estimated *t*-year peaks at sites *i* and *j*. These off-diagonal elements are estimated as a function of a regional estimate of the standard deviation of annual peaks at sites *i* and *j*, the recurrence interval of the dependent variable and the number of concurrent years of record at sites *i* and *j* (Tasker and Stedinger, 1989). The (*p* by *p*) matrix $\{X^T\Lambda^{-1}X\}^{-1}$ for each equation is given in Appendix table 1. The mean square error of a prediction, in log (base 10) units, at specific ungaged sites can be estimated as

$$MSE_{p,0} = (\gamma^2 + MSE_{s,0}).$$

The standard error of a prediction, $SE_{prediction,}$ in percent, can be calculated as

$$SE_{\text{prediction}} = 100\{e^{5.302\times(MSEp,\,0)} - 1\}^{0.5}\,.$$

Appendix Table 1. Matrix $\{X^T \Lambda^{-1} X\}^{-1}$ for the equations in table 5 (p. 11)

[These matrices can be used to compute the standard error of prediction and prediction intervals as explained in the text. Numbers are given in scientific notation, for example, 0.43958E–01 = 0.43958 x 10^{-1} = 0.043958]

Hydrologic area					
Blue Ridge-Piedmont		Coastal Plain		Sand Hills	
2-year recurrence interval					
0.15029E–02	–0.53920E–03	0.28189E–02	–0.90910E–03	0.96765E–02	–0.43179E–02
–0.53920E–03	0.26847E–03	–0.90910E–03	0.42844E–03	–0.43179E–02	0.24592E–02
5-year recurrence interval					
0.17447E–02	–0.60050E–03	0.33220E–02	–0.10290E–02	0.11983E–01	–0.52941E–02
–0.60050E–03	0.28874E–03	–0.10290E–02	0.45946E–03	–0.52941E–02	0.29971E–02
10-year recurrence interval					
0.20021E–02	–0.66987E–03	0.39046E–02	–0.11856E–02	0.13840E–01	–0.60545E–02
–0.66987E–03	0.31419E–03	–0.11856E–02	0.51365E–03	–0.60545E–02	0.34066E–02
25-year recurrence interval					
0.23859E–02	–0.77570E–03	0.47979E–02	–0.14331E–02	0.16439E–01	–0.71059E–02
–0.77570E–03	0.35450E–03	–0.14331E–02	0.60449E–03	–0.71059E–02	0.39674E–02
50-year recurrence interval					
0.26993E–02	–0.86340E–03	0.55348E–02	–0.16401E–02	0.18505E–01	–0.79370E–02
–0.86340E–03	0.38866E–03	–0.16401E–02	0.68241E–03	–0.79370E–02	0.44084E–02
100-year recurrence interval					
0.30284E–02	–0.95634E–03	0.63113E–02	–0.18599E–02	0.20648E–01	–0.87971E–02
–0.95634E–03	0.42534E–03	–0.18599E–02	0.76611E–03	–0.87971E–02	0.48635E–02
200-year recurrence interval					
0.33710E–02	–0.10538E–02	0.71209E–02	–0.20902E–02	0.22864E–01	–0.96843E–02
–0.10538E–02	0.46416E–03	–0.20902E–02	0.85453E–03	–0.96843E–02	0.53320E–02
500-year recurrence interval					
0.38420E–02	–0.11886E–02	0.82349E–02	–0.24083E–02	0.25894E–01	–0.10896E–01
–0.11886E–02	0.51827E–03	–0.24083E–02	0.97751E–03	–0.10896E–01	0.59708E–02