LOW-FLOW CHARACTERISTICS AND PROFILES FOR SELECTED STREAMS IN THE ROANOKE RIVER BASIN, NORTH CAROLINA

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations Report 96-4154

Prepared in cooperation with the

DIVISION OF ENVIRONMENTAL MANAGEMENT
of the
NORTH CAROLINA DEPARTMENT OF ENVIRONMENT, HEALTH, AND NATURAL RESOURCES

GLOSSARY

Base flow. The contribution of flow to a stream from ground water or spring effluent.

Climatic year. A continuous 12-month period during which a complete annual cycle occurs. In low-flow analyses, the climatic year typically is from April 1 through March 31, designated by the calendar year in which the climatic year begins. The year begins and ends during the period of increased flows so that all flows during a single dry season are included in annual values for that year.

Continuous-record gaging station. A site on a stream where continuous records of gage height are collected and discharge records are computed.

Drainage area. The drainage area of a stream at a specified location is that area, measured in a horizontal plane, which is enclosed by a drainage divide.

Gage height. The water-surface elevation referenced to some arbitrary gage datum, often used interchangeably with the term "stage."

Low flow. Base flow or sustained fair weather flow.

Partial-record gaging station. A site on a stream where periodic discharge measure-ments are collected, usually for a period of years. The data collected at partial-record stations are often correlated with data at nearby continuous-record stations to estimate low-flow characteristics at the partial-record stations.

Recurrence interval. The average interval of time within which the magnitude of an extreme event will be equaled or exceeded once. The primary recurrence intervals used in this report are 2 years and 10 years. For example, if the 7-day, 10-year low-flow discharge is 5 ft^3/s, then the average discharge for a 7-day consecutive period would be 5 ft^3/s *or lower* on average 1 time in 10 years, 5 times in 50 years, or 10 times in 100 years.

Unit flow. Value of flow expressed in units of volume per time per square-mile drainage area. In this report, unit flows are expressed in cubic feet per second per square mile [$(ft^3/s)/mi^2$].

Water year. The 12-month period October 1 through September 30, designated by the calendar year in which the period ends. Average discharge and flow-duration data are computed using the water-year time frame.

Zero-flow day. Day in which no flow occurred at a continuous-record gaging station as evidenced by a daily mean discharge of zero.

Low-flow Characteristics and Profiles for Selected Streams in the Roanoke River Basin, North Carolina

By J. Curtis Weaver

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The Division of Environmental Management of the
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U.S. DEPARTMENT OF THE INTERIOR
BRUCE BABBITT, Secretary

U.S. GEOLOGICAL SURVEY
Gordon P. Eaton, Director

For addtional information write to:

District Chief
U.S. Geological Survey
3916 Sunset Ridge Road
Raleigh, NC 27607

Copies of this report can be purchased from:

U.S. Geological Survey
Branch of Information Services
Box 25286
Federal Center
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Multiply	By	To obtain
	Length	
inch (in.)	25.4	millimeter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
	Area	
acre	4,047	square meter
acre	0.4047	hectare
square mile (mi^2)	2.590	square kilometer
	Flow	
gallon per minute (gal/min)	0.06309	liter per second
million gallon per day (Mgal/d)	0.04381	cubic meter per second
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
cubic foot per second per square mile [(ft^3/s)/mi^2]	0.01093	cubic meter per second per square kilometer

Temperature: In this report, temperature is given in degrees Fahrenheit (°F), which can be converted to degrees Celsius (°C) by using the following equation:

°C = (°F-32)/1.8

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)—a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.

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By J. Curtis Weaver

ABSTRACT

An understanding of the magnitude and frequency of low-flow discharges is an important part of protecting surface-water resources and planning for municipal and industrial economic expansion. Low-flow characteristics are summarized for 22 continuous-record gaging stations in North Carolina (19 sites) and Virginia (3 sites) and 60 partial-record gaging stations in the North Carolina Roanoke River Basin. Records of discharge collected through the 1994 water year are used. Flow characteristics included in the summary are (1) average annual unit flow, (2) 7Q10 low-flow discharge, the minimum average discharge for a 7-consecutive-day period occurring, on average, once in 10 years; (3) 30Q2 low-flow discharge; (4) W7Q10 low-flow discharge, similar to 7Q10 discharge except that flow during November through March only is considered; and (5) 7Q2 low-flow discharge. The potential for sustaining base flows is moderate to high in the western part of the basin as well as in the eastern and western fringes of the Piedmont and Coastal Plain physiographic provinces, respectively. Areas of low potential for sustaining base flow exist in the central part of the basin (between eastern Caswell County and western Warren County), where soils have low infiltration rates, and in lower regions of the Coastal Plain, where small streams tend to have zero flow during prolonged drought.

Drainage area and low-flow discharge profiles are presented for 10 streams in the Roanoke River Basin in North Carolina and reflect a wide range in basin size, characteristics, and streamflow conditions. The selected streams are Town Fork Creek, Hogans Creek, Mayo River, Buffalo Creek, Smith River, Country Line Creek, Dan River, Marlowe Creek, Hyco River, and Roanoke River. The drainage-area profiles show the increases in drainage areas as streams travel their course in the basin. At the mouths of streams profiled, the drainage areas range from 22 miles to about 9,700 miles. Low-flow discharges for each stream include 7Q10, 30Q2, W7Q10, and 7Q2 discharges in a continuous profile with contributions from major tributaries included.

INTRODUCTION

The need for better understanding of low-flow hydrology and for improved techniques in determining low-flow characteristics of streams has become more critical as demands for sustained, high-quality water supplies and effective waste assimilation have increased. The simultaneous occurrence of higher demands and recent droughts in North Carolina have increased awareness of the importance of determining low-flow characteristics.

Low flow is defined as base flow, or sustained fair weather flow, and is composed largely of ground-water discharge from aquifers into streams. Discharges from aquifers have large spatial and temporal variations which are highly dependent on topographic, geologic, and climatic conditions in the drainage basin. The high variability of such conditions across North Carolina—and sometimes even within a drainage basin or along the same stream—results in a complex low-flow hydrology. Moreover, withdrawals, point-source discharges, impoundments, and development in the drainage basin complicate the characterization of low-flow hydrology. Low flows in North Carolina typically occur at the conclusion of the growing season in late summer and early autumn, following maximum use of ground water by crops and other plants. The moderation of temperatures also causes a reduction in human consumption of water supplies, which in turn places less demand on withdrawals from streams and reservoirs.

An understanding of low-flow characteristics is crucial in the evaluation of water-supply potential and reservoir-release requirements, the determination of allowable wastewater discharges into streams, and the maintenance of aquatic habitats in streams. Where sufficient records of discharge are available at continuous- and partial-record sites, application of statistical techniques, such as those described by Riggs (1972), form the basis for determining low-flow characteristics. However, the number of sites for which sufficient record exists to determine low-flow characteristics is far outnumbered by those locations where little or no record is available for developing estimates.

Low-flow characteristics are defined by a set of discharges that are statistically derived values having an associated duration and recurrence interval (or probability of occurrence). For example, the 7-day, 10-year low-flow discharge (hereafter referred to as 7Q10 discharge) is the annual lowest mean streamflow over a 7-consecutive-day period which, on average, will be exceeded in 9 out of 10 years—or stated another way, the probability is 10 percent (the inverse of the recurrence interval) that the lowest average 7-consecutive-day flow in any year will be less than the 7Q10 discharge (Giese and Mason, 1993). If the 7Q10 discharge is 5 ft^3/s, then the annual minimum average discharge for a 7-consecutive-day period would be 5 ft^3/s or lower an average of 1 time in 10 years, 5 times in 50 years, or 10 times in 100 years.

In North Carolina, other low-flow statistics used by State regulatory agencies in determining permitting limits for withdrawals from and discharges into streams include the 30Q2, W7Q10, and 7Q2 discharges. The W7Q10 discharge, or "winter 7Q10," is defined in a similar manner as the 7Q10 discharge except flow in the months of November through March only is considered in the analysis.

In 1991, the Division of Environmental Management (DEM) of the North Carolina Department of Environmental, Health, and Natural Resources (DEHNR), began using a basinwide approach in its assessment and management of water quality and, in particular, permitting of point-source discharges. This approach is being applied sequentially to each of the 17 major river basins in the State (fig. 1) so that all discharges in a basin are permitted simultaneously. The process is repeated for each basin at 5-year intervals. In conjunction with the basinwide approach, the U.S. Geological Survey (USGS), in cooperation with the DEM, began a study to define low-flow characteristics in the Roanoke River Basin in North Carolina for use in permitting point-source discharges.

Purpose and Scope

This report presents low-flow characteristics for streams in the Roanoke River Basin in North Carolina. Low-flow characteristics at existing stream gaging stations are summarized, and drainage area and low-flow discharge profiles for selected streams in the Roanoke River Basin are presented. Descriptions of a number of basin characteristics (impoundments, diversions, climate, geology, soils, and land use) and their effects on low flows are included in the report.

Low-flow characteristics are summarized for 22 continuous-record gaging stations (including three on the Dan and Hyco Rivers in Virginia) and for 60 partial-record gaging stations; statistics include the average annual unit flow and the 7Q10, 30Q2, W7Q10, and 7Q2 discharges. The period of record varies from site to site; in this report, records of discharge collected through the 1994 water year were used in the analyses. The number of zero-flow days and discharge measurements for continuous- and partial-record stations, respectively, are included in the summary.

Drainage area and low-flow discharge profiles are presented for 10 selected streams and tributaries in the Roanoke River Basin in North Carolina. The streams drain areas which reflect a wide range of basin size, characteristics, and streamflow conditions. The selected streams included are Town Fork Creek, Hogans Creek, Mayo River, Buffalo Creek, Smith River, Country Line Creek, Dan River, Marlowe Creek, Hyco River, and Roanoke River. Discharge profiles show the relation of 7Q10, 30Q2, W7Q10, and 7Q2 discharges to river mileage.

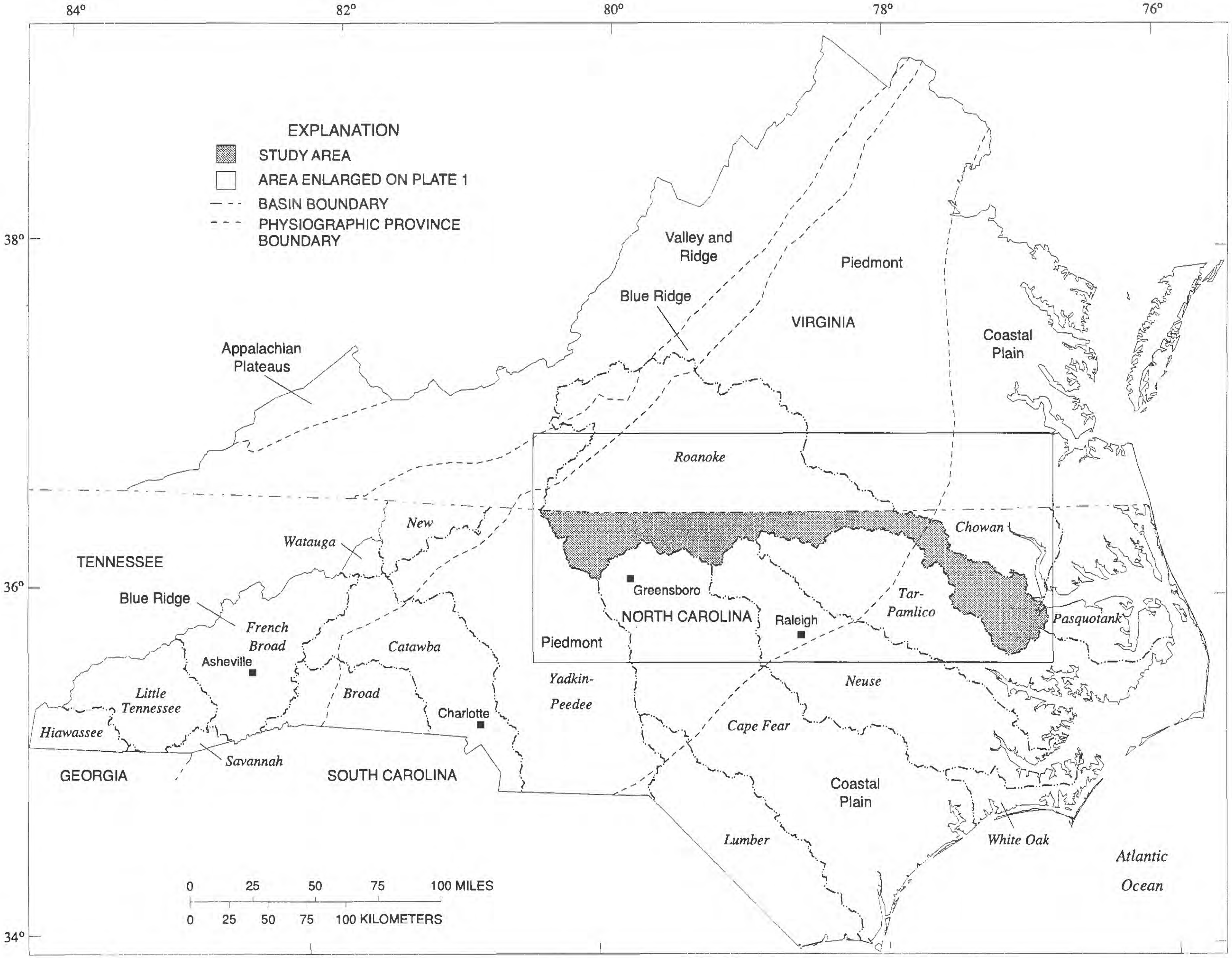

Figure 1. Locations of the major river basins in North Carolina, the Roanoke River Basin study area, and physiographic provinces in North Carolina and Virginia.

Previous Low-flow Studies

Prior to World War II, low-flow characteristics of North Carolina streams were determined only for sites operated as continuous-record gaging stations. With the economic expansion after World War II, the USGS began to receive an increasing number of requests for hydrologic information at sites where no data had been collected (Yonts, 1972). Thus, the USGS expanded its data-collection programs in the late 1940's to include partial-record sites where discharge measurements were made on a periodic basis. Discharge measurements made under conditions of base flow along with observations of zero flow became the foundation of data used in the initial assessments of low-flow characteristics in North Carolina. With data available from the partial-record sites network, the USGS began to respond to requests for low-flow characteristics on a site-specific basis, including ungaged sites.

Estimates of low-flow discharges continue to be provided upon request to government agencies and private corporations. These data are used in assessing the capacity of streams to receive wastewater discharges and to allow withdrawals for water supply. Data are generally provided on a site-specific basis without consideration of previously estimated low-flow statistics upstream or downstream from the request site. In some instances, this has led to inconsistencies in estimates of low-flow discharges for adjacent sites.

Only a limited number of studies have been conducted to investigate low flows for streams in North Carolina. Goddard (1963) presented low-flow characteristics for many continuous-record gaging stations in North Carolina along with drainage area and 7Q10 discharge profiles developed for selected mainstem rivers. Yonts (1972) reported base-flow measurements made at over 2,200 continuous-record and partial-record gaging stations throughout the State.

Giese and Mason (1993) evaluated low-flow characteristics at 518 continuous- and partial-record gaging stations having drainage areas between 1 and 400 mi^2 and having streamflows unaffected by regulation or diversions. Sites were characterized on the basis of similarity in ranges of low-flow discharges and potential to sustain base flow. Ten hydrologic areas (HA) were delineated and regression equations, which related low flows to basin characteristics, were derived to determine flow characteristics at ungaged sites (fig. 2). Equations for only four of the 10 areas—HA10, representing the mountains and western Piedmont; HA3, the Sand Hills; and HA5 and HA9, the eastern and central Piedmont—had standard errors that were considered small enough to permit use of the equations in estimating low-flow characteristics at the ungaged sites. The large standard errors computed for equations in the remaining hydrologic areas reflect the complex relation between low-flow hydrology and geologic, topographic, and climatic factors. High standard errors for low-flow regression equations

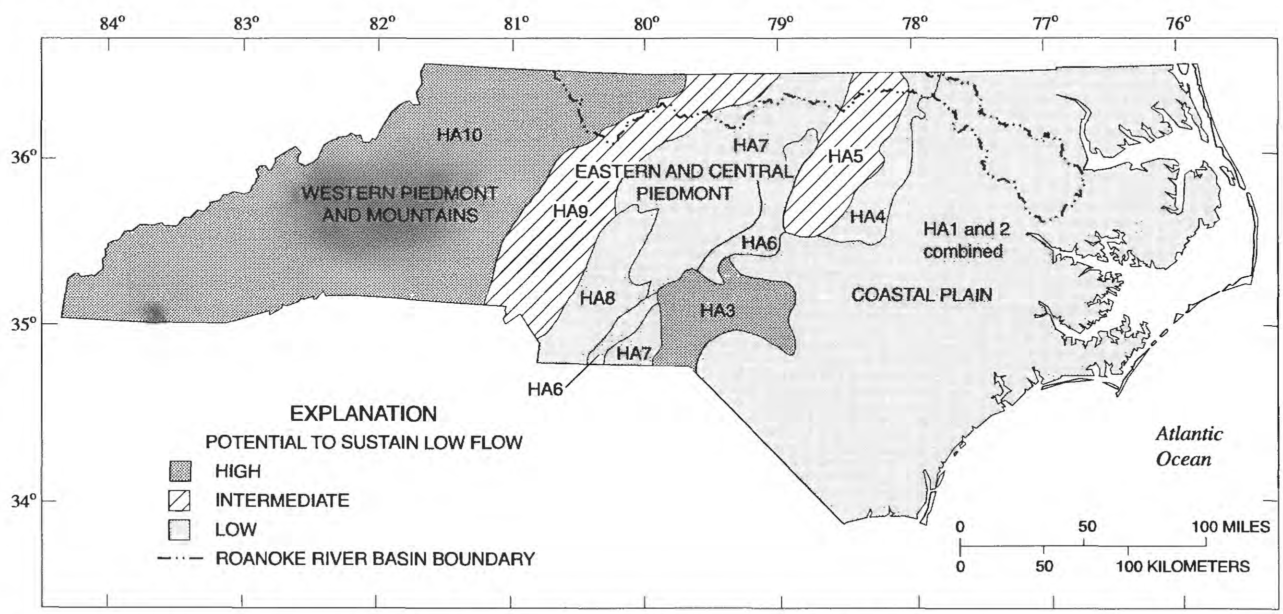

Figure 2. Areas of similar potential to sustain low flows in North Carolina (modified from Giese and Mason, 1993).

also were reported in a 1970 comprehensive study of low flows in which 47 USGS districts participated (each district being representative of the State in which it is located) (Riggs, 1973). Some districts reported standard errors well in excess of 100 percent while others were unable to derive useful low-flow relations.

Evett (1994) investigated the effects of urbanization and land-use changes on low flows. Negative trends in low flows were detected from data at selected urban and rural continuous-record gaging stations in the Asheville, Charlotte, Greensboro, and Raleigh municipalities (fig. 1). However, while the conclusions tended to support the investigation's hypothesis of decreasing low flows with increasing urbanization, the results were considered statistically inconclusive.

DESCRIPTION OF ROANOKE RIVER BASIN

The Roanoke River Basin drains an area of about 9,700 mi^2 in parts of North Carolina and Virginia (Seaber and others, 1987). Approximately 36 percent of the basin is in North Carolina (fig. 1). The headwaters of the river are in the mountainous region of southwestern Virginia, and the river flows in a general southeastern direction through the two States before entering the Albemarle Sound. The nature of the drainage system of the Roanoke River Basin varies greatly from the headwaters to the mouth.

Ground elevations in the Roanoke River Basin in North Carolina decrease from west to east. Average elevations range from approximately 1,000 ft above sea level in Stokes County north of the Dan River to sea level at the mouth of the Roanoke River (Stuckey, 1965). The highest elevation in the basin in North Carolina is nearly 2,570 ft above sea level near the drainage area divide west of Danbury in Stokes County (plate 1 at the back of the report).

The Roanoke River Basin in North Carolina includes parts of seven of the 10 hydrologic areas identified by Giese and Mason (1993). The western areas of the basin are in HA10 (fig. 2), where base flows are generally sustained primarily because of the large degree of topographic relief which exists in the western Piedmont and Blue Ridge Provinces. The areas of the basin falling within HA9, HA7, HA5, and HA4 in the central and eastern Piedmont have intermediate or low potential for sustaining base flow. Giese and Mason reported a correlation between the potential to sustain base flow and well yields reported by Daniel (1989), who related rock type to well yields. Thus, these hydrologic areas were delineated on the basis of geology. The eastern areas of the Roanoke River Basin in the Coastal Plain fall within HA1 and HA2 and have low potential to sustain base flow in streams. Low topographic relief results in low hydraulic gradients in the water table, with little potential to move water towards streams. A comparison of sites having sustained base flows versus those not having sustained base flows can be seen in the flow-duration curves for two sites in the study area (fig. 3). Base flows for the gaging station on the Dan River near Francisco (site 4; plate 1) are much higher than those at the gaging station on Hyco Creek near Leasburg (site 97). During the 1950-94 water years, flows at site 4 were 65 ft^3/s or greater 95 percent of the time, whereas flows at site 97 were greater than 0.1 ft^3/s.

Drainage System

The Roanoke River Basin consists of seven subbasins, units 03010101 to 03010107, as defined in the system of hydrologic units in the USGS National Water Data Network (Seaber and others, 1987) (fig. 4; table 1). In this report, the study area for the Roanoke River Basin is defined as the parts of units 03010102 (Middle Roanoke), 03010103 (Upper Dan), 03010104 (Lower Dan), and 03010106 (Roanoke Rapids) lying in North Carolina, and all of unit 03010107 (Lower Roanoke) (fig. 4). Gaging stations and measurements from streams in these areas are used to determine the low-flow characteristics presented in this report

Major Rivers and Tributaries

The Dan River, the largest tributary to the Roanoke River, begins in the eastern fringe of the Blue Ridge physiographic province in Virginia and flows in a south-southeasterly direction into the Piedmont Province of North Carolina (plate 1). The river makes an abrupt 90-degree turn in Stokes County and flows in a north-east direction into Rockingham County where it crosses back into Virginia. Southeast of Danville, the Dan River re-enters North Carolina for a brief stretch before returning to Virginia, where it eventually merges with the Roanoke River in John H. Kerr Reservoir. Much of the terrain in the Dan River Basin is characterized by the rolling and hilly topography. The total length of the Dan River is nearly 200 mi with

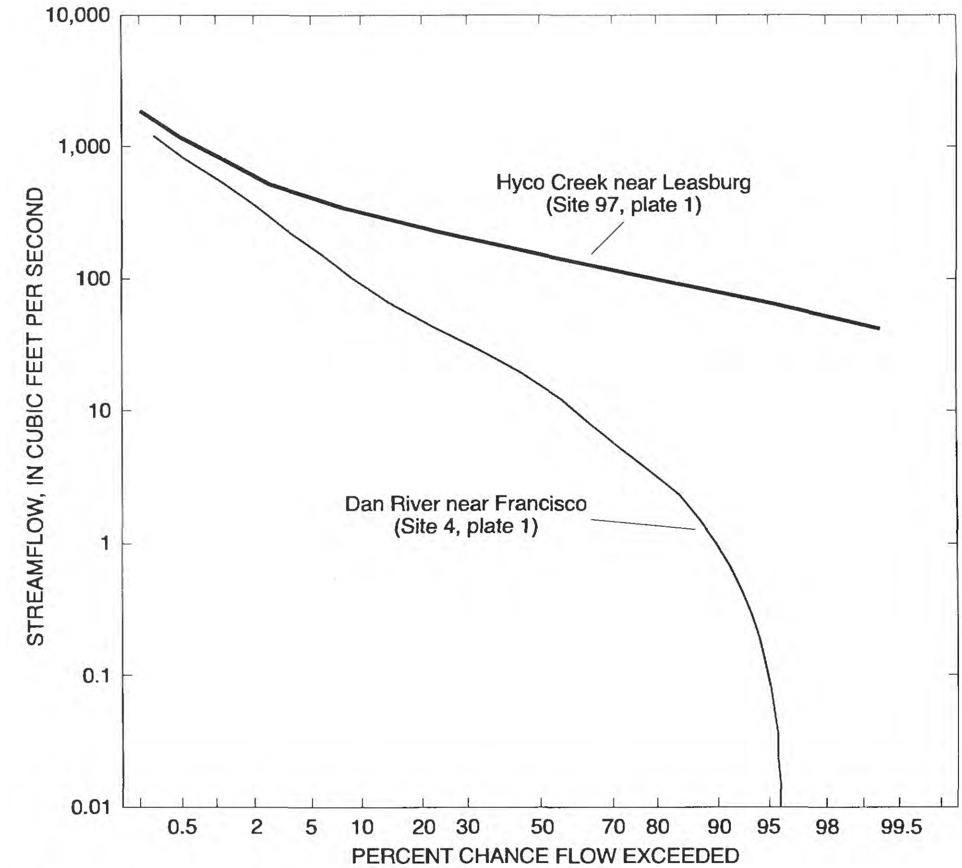

Figure 3. Flow-duration curves for (A) the Dan River near Francisco, N.C. (site 4), and (B) Hyco Creek near Leasburg, N.C. (site 97).

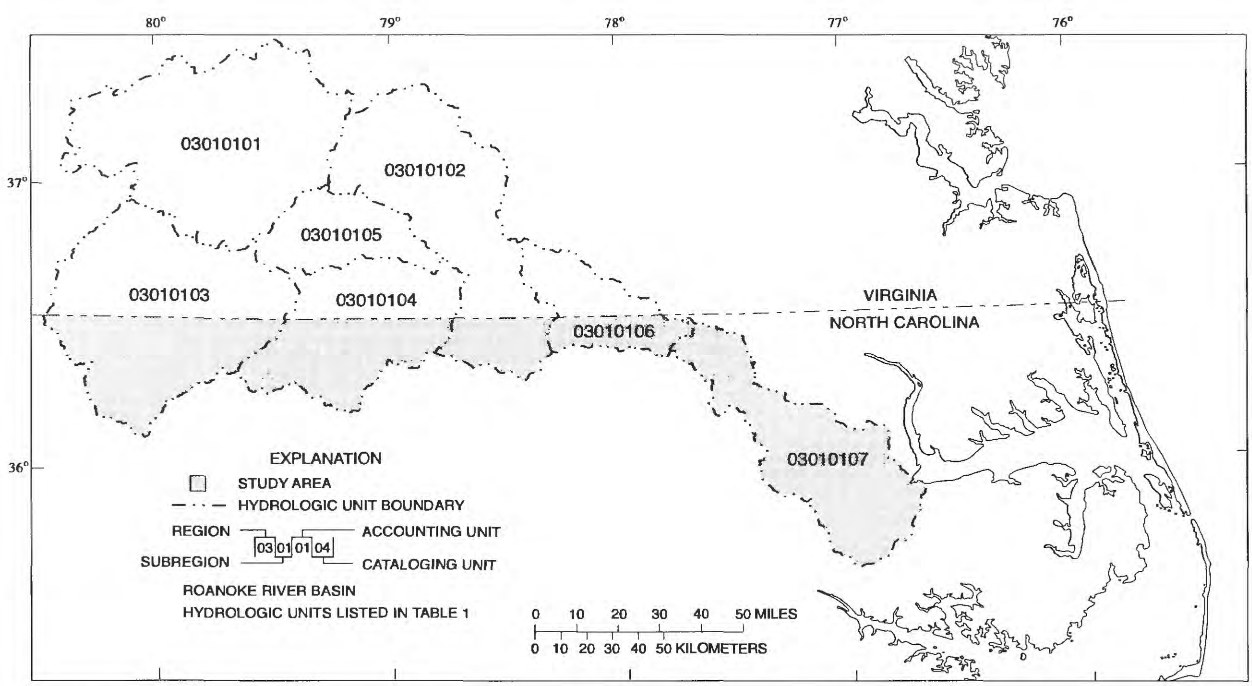

Figure 4. Hydrologic units in the Roanoke River Basin, North Carolina and Virginia.

Table 1. Code, name, and drainage area of each U.S.Geological Survey hydrologic unit in the Roanoke River Basin within North Carolina and Virginia

[USGS, U.S. Geological Survey; mi^2, square mile; N/A, not applicable.]

USGS hydrologic unit code (fig. 4)	Name	Drainage area within (mi^2):[1]		
		North Carolina	Virginia	Hydrologic unit
03010101	Upper Roanoke [River]	N/A	2,192	2,192
03010102	Middle Roanoke [River]	299	1,473	1,772
03010103	Upper Dan [River]	914	1,140	2,054
03010104	Lower Dan [River]	717	534	1,251
03010105	Banister [River][2]	N/A	597	597
03010106	Roanoke Rapids	254	337	591
03010107	Lower Roanoke [River]	1,319	N/A	1,319
	Totals	3,503 (36%)	6,273 (64%)	9,776

[1]Drainage areas computed using USGS ARC/INFO Geographic Information System coverages.

[2]The Banister River is a tributary of the Dan River at John H. Kerr Reservoir in Virginia.

a little more than 120 mi, or 60 percent of its total length, in North Carolina.

The drainage area of the Dan River at its mouth is about 3,900 mi^2, or about 40 percent of the entire Roanoke River Basin. Portions of hydrologic units 03010103 and 03010104 within North Carolina (fig. 4) occupy nearly 1,630 mi^2 of the Dan River Basin. Along the 120-mi length of the Dan River in North Carolina, the drainage area increases from nearly 71 mi^2 at the discontinued USGS gaging station near Asbury (site 1; plate 1) to 2,310 mi^2 at the partial-record station near Milton (site 80; plate 1). North Carolina tributaries draining to the Dan River include Town Fork Creek, Belews Creek, Hogans Creek, Mayo River, Buffalo Creek, Smith River, Wolf Island Creek, Country Line Creek, and Hyco River.

The Roanoke River is nearly 385 mi long, with much of its length lying in Virginia (plate 1). The river enters North Carolina in Warren County at Lake Gaston and Roanoke Rapids Lake, two large reservoirs which are impoundments of the Roanoke River. Downstream from Roanoke Rapids Lake, the Roanoke River reverts back to a riverine reach for its final 140-mi meander towards the Albemarle Sound in Bertie County. The topography of the basin downstream from Roanoke Rapids Lake is characterized by a gradual transition from gentle, rolling hills with little relief to nearly level land surfaces found in the Coastal Plain.

The drainage area of the Roanoke River at the USGS continuous-record gaging station (site 181; plate 1) downstream from the dam at Roanoke Rapids Lake is 8,384 mi^2. This accounts for nearly 86 percent of the entire Roanoke River Basin. The 140-mi stretch between the dam at Roanoke Rapids Lake and the mouth accounts for over 36 percent of the total length of the river, yet the drainage area only increases by 14 percent. This characteristic is reflected in the narrow shape of hydrologic unit 03010107 downstream from Roanoke Rapids Lake (fig. 4). Major tributaries to the Roanoke River in North Carolina include Chockoyotte Creek, Quankey Creek, Occoneechee Creek, Gumberry Swamp, Conoconnara Swamp, Kehukee Swamp, and Conoho Creek. The Cashie River, the largest tributary, which drains nearly 305 mi^2 of hydrologic unit 03010107, merges with the Roanoke River in the delta area immediately upstream from the Albemarle Sound (plate 1).

Major Flow Modifications

Previous discussions have alluded to the complex nature of low-flow hydrology due to geologic, topographic, and climatic factors. An additional complexity in the determination of low-flow characteristics results from the existence of major flow modifications. These modifications can be classified into two general categories—impoundments and diversions of flow. The ongoing addition and, in some instances, removal of these modifications results in continual changes to the low-flow characteristics.

Impoundments

Impoundments result from the construction of dams on streams, for use in storing water for a variety of purposes including supply, recreation, irrigation, and cooling water. The effects of impoundments on downstream low-flow characteristics vary because of changes in streamflow patterns that result from storage, diversions of water (for supply purposes) that commonly occur within the impoundments, and to a smaller extent, evaporation from the impoundments. Post-impoundment flow durations for downstream flows, particularly below major impoundments, adjust in response to changes in flows relative to pre-impoundment conditions.

Approximately 360 impoundments with dams having structural heights exceeding 15 ft were identified in the study area (North Carolina Department of Environment, Health, and Natural Resources, unpub. data, 1993). Many are privately owned impoundments having relatively small surface areas at the spillway level and serve as farm ponds, which provide irrigation and sediment reduction, or as recreational facilities at campgrounds and park facilities. Four of the impoundments have very large surface areas: Belews Lake (4,030 acres) (North Carolina Department of Environment, Health, and Natural Resources, 1992) in Stokes, Forsyth, and Rockingham Counties; Hyco Lake and Afterbay Reservoir (4,400 acres) in Caswell and Person Counties; Mayo Lake (2,800 acres) in Person County; and Roanoke Rapids Lake (4,890 acres) in Halifax and Northampton Counties (immediately downstream from Lake Gaston and John H. Kerr Reservoir in Virginia). These lakes, owned by utility companies, are used primarily for power production and cooling water. The effect of these impoundments on downstream flows is determined by the minimum flow releases at the dams.

Diversions

Diversions, occurring as withdrawals or point-source discharges, have the effect of immediately altering downstream low flows by an amount equal to the diversion rate. Withdrawals are commonly made by municipalities and by some major industries. Additionally, some withdrawals are made by farms for agricultural and livestock operations. The State of North Carolina requires registration of withdrawals equal to or exceeding 1 Mgal/d (approximately 1.5 ft^3/s). Within the study area, a total of 24 registered withdrawals were identified (North Carolina Department of Environment, Health, and Natural Resources, written commun., 1996). Knowledge of low-flow characteristics is important when withdrawals are being made because decreased flows downstream from the withdrawals must be sufficient to sustain downstream uses during drought conditions, including the assimilation of treated effluent.

Point-source discharges into streams are permitted through the issuance of National Pollution Discharge Elimination System (NPDES) permits. In North Carolina as well as other States, permits that set limits for discharges of treated effluent are based, in part, on the 7Q10 discharge. In a similar manner to withdrawals, flows upstream from the discharge point must be sufficient to assimilate the treated effluent while maintaining other uses of the stream. The DEM has issued 366 NPDES permits for point-source discharges within the study area (North Carolina Department of Environment, Health, and Natural Resources, 1996). Seventeen permit holders (eight municipal, nine industrial) are designated by the DEM as major dischargers.

Data describing major withdrawals and point-source discharges in the study area were obtained from the different State agencies which monitor flow diversions. For selected facilities, average surface-water withdrawals and return point-source discharges reported for 1995 were compiled into a summary that lists the magnitudes of streamflow changes in the affected streams (table 2). In most instances, point-source discharges were paired with a corresponding surface-water withdrawal on the same stream, often a short distance upstream from the discharge point. For each facility, the NPDES permit number and permitted flow rate assigned to the permit also are listed.

Some of the facilities which discharge into streams do not obtain water through surface-water withdrawals. In these cases, withdrawals are made from ground-water wells (primarily in the Coastal Plain) or are transferred from other facilities. An additional form of withdrawal listed with the State agencies is that made by large mining operations, which remove ground water from mining pits and discharge it into nearby streams. In the study area, withdrawals by three mining operations in Caswell, Rockingham, and Vance Counties were registered with the State. These are not listed in table 2 because withdrawal and return discharge rates are not documented.

Also not listed in table 2 are withdrawals and return discharges for a number of utility companies which use impoundments as sources of water for electric power production and cooling purposes. Water-use records obtained by the USGS in 1990 indicate that withdrawal and return discharge amounts exceed 750 Mgal/d (nearly 1,200 ft^3/s). Most of the water removed from these lakes by utility companies is returned to the impoundments. A small percentage of the water, usually 1 to 2 percent, is consumed in the production and cooling process. However, this loss is often replaced by water obtained from other sources, thereby giving the appearance of no net loss in water quantity (W. L. Yonts, North Carolina Department of Environment, Health, and Natural Resources, oral commun., 1996).

Table 2. Summary of selected flow modifications by surface-water withdrawals and return (point-source) discharges to streams in the Roanoke River Basin study area for 1995

[Mgal/d, million gallons per day (1 Mgal/d is equivalent to approximately 1.5 cubic feet per second); N/A, not applicable; N/D, not documented. For streams profiled in this report, river miles are listed in parentheses beside stream names.]

County	Facility name	Purpose	Source of withdrawal	Average withdrawal (Mgal/d)	Destination of return discharge	Average return discharge (Mgal/d)	NPDES permit number	Permitted NPDES discharge (Mgal/d)
Rockingham	Town of Mayodan	Public water supply	Mayo River (mile 2.5)	1.6	Mayo River (mile 0.6)	1.2	NC0021873	3.0
Rockingham	Town of Madison	Public water supply	Dan River (mile 105.3)	0.5	Dan River (mile 105.0)	0.4	NC0021075	0.775
Rockingham	City of Eden	Public water supply	Dan River (mile 86.0)	10.0	Dan River (mile 84 5)	6.6	NC0025071	13.5
Rockingham	Fieldcrest Cannon (Eden)	Industrial / water supply	Smith River (mile 1.5)	1.3	Dan River (mile 81.7)	0.16	NC0001643	0.5
Rockingham	Duke Power	Thermal electric power	Dan River (mile 83.5)	[1]70.1	Dan River (mile 83.5)	70.1	NC0003468	N/D[2]
Rockingham	Miller Brewing (Eden)	Industrial	Transfer from City of Eden	N/A	Dan River (mile 82.0)	2.4	NC0029980	5.2
Person	City of Roxboro	Public water supply	Isaac Walton Lake[3]	4.4	Marlowe Creek (mile 5.6)	2.9	NC0021024	5.0
Person	Cogentrix (Roxboro)	Thermal electric power	Transfer from City of Roxboro	N/A	Unnamed tributary to Mitchell Creek	0.06	NC0065081	N/D[2]
Person	Carolina Power and Light	Thermal electric power	Mayo Lake - Mayo River	3.3	Mayo Lake	10.7	NC0038377	21.0
Vance	Kerr Lake Regional Water System	Public water supply	John H. Kerr Reservoir[4]	5.0	Nutbush Creek (City of Henderson)	2.7	NC0020559	4.14
Halifax	Roanoke Rapids Sanitary District	Public water supply	Roanoke Rapids Lake[5]	5.0	Roanoke River (mile 126.8)	[6]6.0	NC0024201	8.34
Halifax	Champion International (Roanoke Rapids)	Industrial	Roanoke River (mile 130.0)	27.0	Roanoke River (mile 129.9)	17.9	NC0000752	28.0
Halifax	Town of Weldon	Public water supply	Roanoke River (mile 132.0)	3.4	Roanoke River (mile 124.5)	0.7	NC0025271	1.2
Martin	Alamac Knit Fabrics (Hamilton)	Industrial	Ground-water wells	N/A	Roanoke River (mile 56.5)	1.1	NC0001961	1.5
Martin	Town of Williamston	Public water supply	Ground-water wells	N/A	Roanoke River (mile 34.2)	1.1	NC0020044	2.0
Washington	Weyerhaeuser (Plymouth)	Industrial	Ground-water wells	N/A	Welch Creek	69.9	NC0000680	82.5
Bertie	Town of Windsor	Public water supply	Ground-water wells	N/A	Unnamed tributary to Cashie River	0.4	NC0026751	1.15

[1]Flows reported for 1990 (USGS 1990 water-use files).

[2]No permit limits established; flow is monitored.

[3]Isaac Walton Lake (Satterfield and Story Creeks) serves as normal withdrawal source; Lake Roxboro (South Hyco Creek) serves as an emergency source.

[4]Withdrawals redistributed as follows: 3.0 Mgal/d to Henderson (Roanoke River Basin), 1.5 Mgal/d to Oxford (Tar River Basin), and 0.5 Mgal/d to Warren County (Tar River Basin). Water received by Oxford and Warren Counties treated and released into the Tar River Basin.

[5]One intake used daily; a second is available for emergency use.

[6]Roanoke Rapids Sanitary District receives and treats wastewater from nearby small municipalities and entities; thus, average return discharge is higher than average withdrawal.

The average withdrawal and return discharge shown in table 2 for one utility company in Rockingham County using the Dan River as a source indicates identical withdrawal and return discharge quantities.

Climate

The climate in the study area, as throughout most of North Carolina, consists of long, hot, humid summers and short, mild winters with brief periods of more moderate, pleasant conditions during the spring and autumn seasons. The average annual temperature (1961-90) in the study area ranges from about 55°F near the western edge of the Roanoke River Basin to 60°F in the area near the mouth of the Roanoke River (fig. 5A). Records collected by the National Weather Service at selected observation stations in and near the study area indicate the average temperature ranges from a minimum of about 40°F in January to a maximum of about 78°F in July (National Oceanic and Atmospheric Administration, 1992). In some areas of the basin, particularly the Piedmont and Coastal Plain physiographic provinces, temperature extremes in the summer reach levels exceeding 90°F for long periods of consecutive days.

Average annual precipitation (1961-90) at selected observation stations in and surrounding the study area ranges from nearly 52 in. in the foothills region of the western Piedmont Province to 44 in. in the central and eastern Piedmont Province (fig. 5B). In the Coastal Plain province, average annual precipitation increases to between 44 and 48 in. On a monthly basis, the highest amounts occur during July, while the lowest amounts occur in January or February. Most rainfall occurring during the warmer months comes from isolated, convective-type storms which arise in the late afternoons and evenings as a result of daytime heating. Rainfall occurring during cooler months is from more organized frontal storms which cover broad areas of the region. The higher temperatures and more abundant moisture in the Coastal Plain reflect the moderating effects exerted by the Atlantic Ocean on the climate in that region (Kopec and Clay, 1975).

Since 1900, there have been seven major droughts in North Carolina, some of which have resulted in low flows in the Roanoke River Basin (Zembrzuski and others, 1991). The drought of longest duration affecting streams in the study area occurred during 1966-71 where low flows having a recurrence interval between 40 and 60 years were observed across the State. At the USGS gaging station at Flat River at Bahama (station 02085500) in Durham County, the lowest daily mean discharge (0.27 ft^3/s on the 24th) and instantaneous discharge (0.23 ft^3/s on the 26th) for the period of record (July 1925 to September 1994) occurred during September 1968 (U.S. Geological Survey, 1961-94, published annually). While not within the study area, much of the drainage basin for this site lies in the lower half of Person County immediately adjacent to the study area (plate 1). Hence, flow conditions at the Flat River gaging station are a good index of flow conditions occurring in the region. The drought of the longest duration (1950-57) among the seven major droughts in North Carolina, where low flows had recurrence intervals of about 30 years, did not severely affect flows in the study area where the recurrence interval of the low flows was less than 10 years.

Geology and Soils

The geology of the study area varies greatly from the western edge in Surry and Stokes Counties to the mouth of the Roanoke River in Bertie County (fig. 6A). Most of the study area within the Piedmont physiographic province is underlain by belts of metamorphic and metavolcanic rocks dating from the late Proterozoic and early Paleozoic periods (North Carolina Department of Natural Resources and Community Development, 1985). Underlying rocks include granite, granitic gneiss, schist, slate, and phyllite (fig. 6A). The noted exception is the Triassic basin across parts of Stokes and Rockingham Counties that is underlain by basalt and sedimentary rocks, which include sandstone, siltstone, and shale.

Downstream from Roanoke Rapids Lake, the Roanoke River enters the Coastal Plain where surface features are initially dissected and rolling with a gradual change from well-drained and flat to gently rolling surfaces. In the Coastal Plain, most of the basin is underlain by unconsolidated materials which date to the Tertiary and Cretaceous ages and are composed of alternating layers of sand, silt, and clay. A small segment of the basin, lying along the easternmost fringes of the Coastal Plain near the mouth of the Roanoke River, is underlain by sediments dating to the Quaternary age and includes layers of sand, silt, and clay.

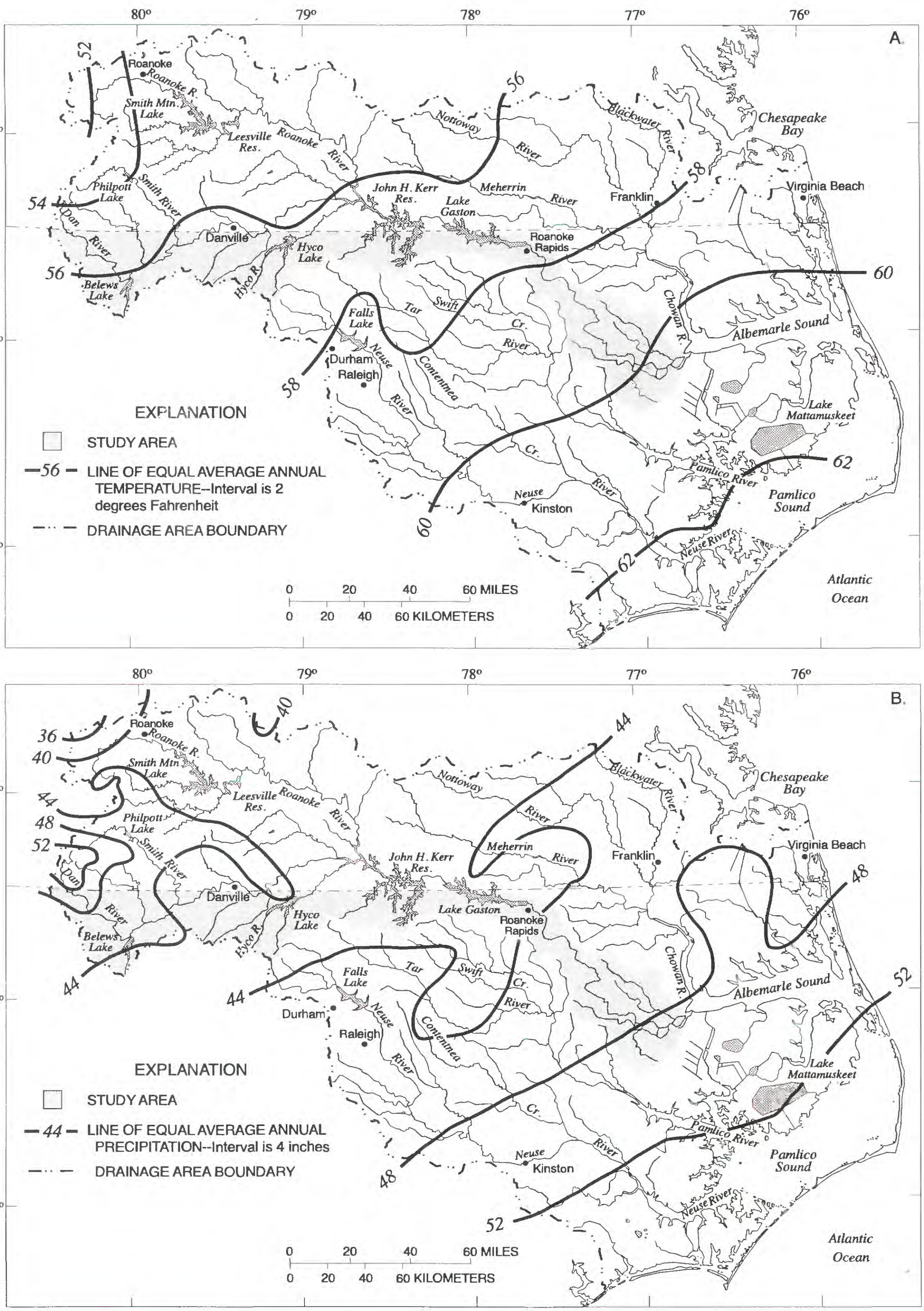

Figure 5. Average annual (A) temperature and (B) precipitation in the Roanoke River Basin, North Carolina and Virginia, 1961-90.

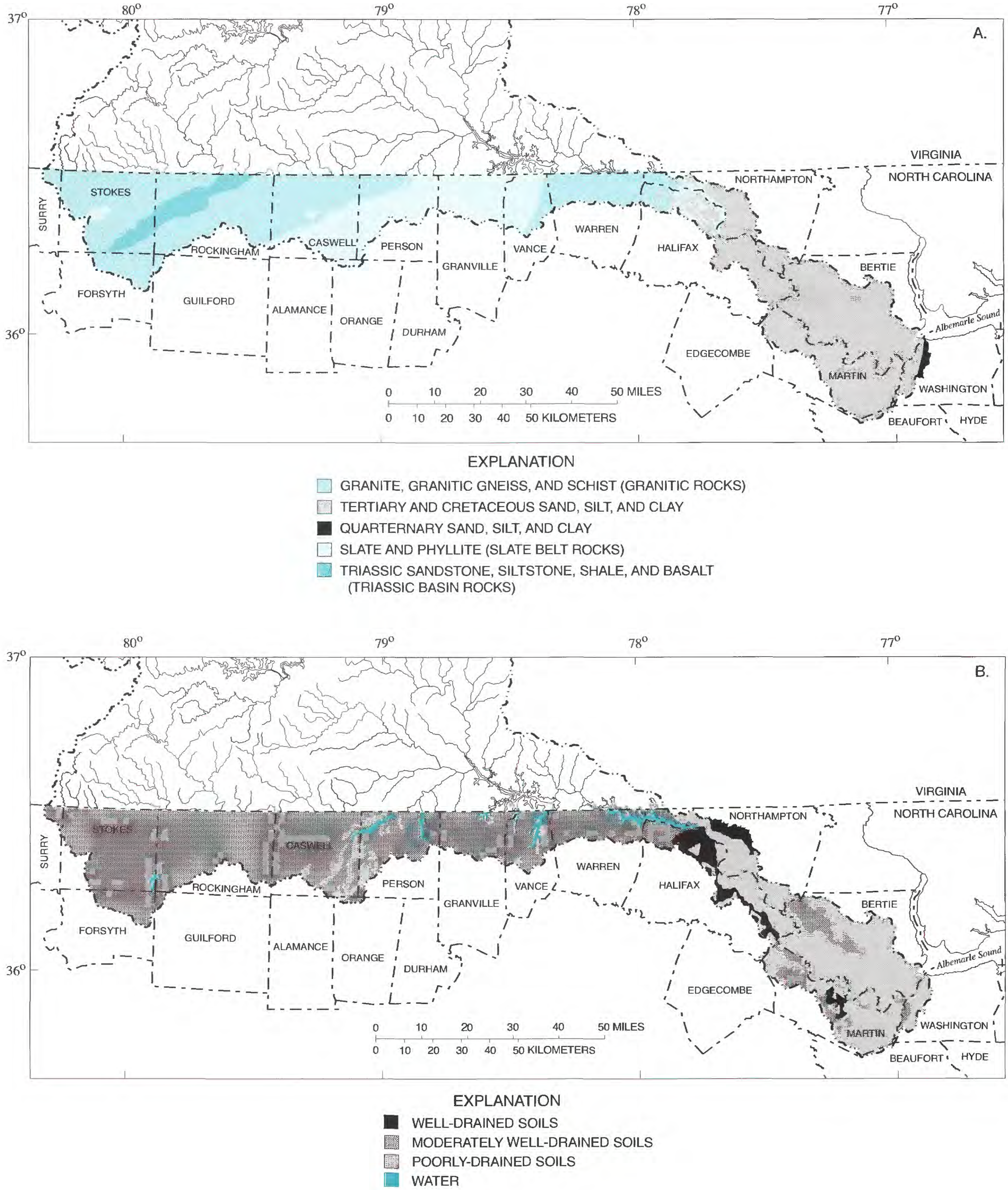

Figure 6. (A) Geology and (B) generalized soil infiltration groups in the Roanoke River Basin study area, North Carolina.

The effects of geology on low-flow characteristics cannot be determined solely on the identification of the geologic unit underneath a given area of interest. The geology indirectly affects the potential for sustained base flow through the soils, or overburden, into which the underlying rock units are transposed through the processes of physical and chemical weathering. The extent of fractures in the underlying rocks may also be regarded as an indicator of the potential to sustain base flow. Because the fractures act as conduits of water, a rock unit having an abundance of fractures will have a higher degree of storage capacity than a unit having a smaller number of fractures.

Daniel (1989) related well yields to geologic, topographic, and well-construction factors using data from over 6,200 wells drilled in the Blue Ridge, Piedmont, and western edge of the Coastal Plain physiographic provinces. To establish some indicator of water-bearing potential, Daniel categorized rock units using a classification scheme based on origin, composition, and texture. In the Roanoke River Basin study area, there is a high degree of variability of hydrogeologic units identified by Daniel (1989). Nearly 57 percent of the study area falling within the Piedmont Province is underlain by hydrogeologic units which have average well yields nearly equal to or exceeding the overall average yield of 18.2 gal/min determined by Daniel. Some of the predominant units having average yields that exceed the overall average are felsic gneiss (30.1 percent), felsic metaigneous (10.6 percent), and schist (8.8 percent). No comparisons were made for the part of the study area within the Coastal Plain because of differences in the extent of Coastal Plain regions covered by each investigation. However, well yields are generally higher in the Coastal Plain than in the Piedmont and Blue Ridge Provinces due in part to the greater saturated thicknesses of the overburden (C.C. Daniel, III, U.S. Geological Survey, oral commun., 1996).

Soil surveys conducted by the U.S. Department of Agriculture in the counties lying within the basin have resulted in the identification of numerous soil types (U.S. Department of Agriculture, 1910-92). Within the Piedmont Province, soils of the Cecil series tend to be the predominant type. These soils are characterized as being deep, well-drained, and moderately permeable soils derived from the weathering of mica gneiss, mica schist, and gneiss (U.S. Department of Agriculture, 1992). Of the soils identified in the Coastal Plain, the soils of the Norfolk series occupy the higher percentages of area in those counties within the basin. The Norfolk soils consist of sandy loams which are well drained and formed from loamy marine sediments (U.S. Department of Agriculture, 1990). The only exception is in Bertie County where soils in the Leaf series occupy the highest percentage of all soil series identified in the survey. Soils in the Leaf series are poorly drained and formed from clayey marine sediments (U.S. Department of Agriculture, 1990).

Data compiled from Tant and others (1974) indicate that most of the Piedmont Province in the study area (62 percent) is covered by soils identified as being moderately well drained (table 3; fig. 6B). Exceptions to this include some areas of Caswell and Person Counties where soils are poorly drained. The infiltration group and associated minimum infiltration rate of soil provide an indicator of the water storage within the overburden (Musgrave and Holtan, 1964). Because base flow is defined as sustained flow from ground water or spring effluent with no surface-runoff component, the streams in the study area covered by moderately well-drained soils will, assuming all other factors are equal, have a high potential for

Table 3. Soil infiltration groups in the Roanoke River Basin study area in North Carolina (compiled from Musgrave and Holtan (1964) and Tant and others (1974); adapted from McMahon and Lloyd (1995))

[mi^2, square mile. Soil characteristics and minimum infiltration rates for soils falling within one infiltration group are described in table footnotes. Sections of the study area not included are those covered by water bodies (approx. 50 mi^2) and those with unknown soil infiltration groups (approx. 8 mi^2).]

Well drained		Moderately well drained		Poorly drained	
Soil group	Area (mi^2)	Soil group	Area (mi^2)	Soil group	Area (mi^2)
A[1]	156	B[2]	1,452	B/D	710
		B/C	684	C[3]	111
		A/C	15	C/D	178
				D[4]	139

[1]Soil Group A - Deep sands, deep loesses, and aggregated soils having minimum infiltration rate of approximately 0.30 to 0.45 inches per hour.

[2]Soil Group B - Shallow loess and sandy loam soils having minimum infiltration rate of approximately 0.15 to 0.30 inches per hour.

[3]Soil Group C - Clay loams, shallow sandy loams, soils low in organic matter, and soils high in clay content, and having minimum infiltration rate of approximately 0.05 to 0.15 inches per hour.

[4]Soil Group D - Swelling soils, heavy plastic clays, and certain saline soils having minimum infiltration rate of approximately 0 to 0.05 inches per hour.

sustained flow during dry conditions. Streams in the areas covered by poorly drained soils would be expected to have low potential for sustained flows during dry periods. As discussed in more detail in later sections, a number of streams in southeastern Caswell County and northwestern Person County have little to no potential for sustained base flows. Other parts of the study area covered by poorly drained soils include most of the Coastal Plain, where swamp conditions are predominant. In all, nearly 33 percent of the study area has poorly drained soils. Well-drained soils in the study area (5 percent) are found in the eastern and western fringes of the Piedmont and Coastal Plain physiographic provinces, respectively. The existence of well-drained soils in this region reflects the transition from the Piedmont to the Coastal Plain Provinces where the interlocking and abutment of distinct geologic units likely results in highly permeable, unconsolidated material in the soil systems.

Land Use

Land-use information for the study area was obtained from the USGS geographic information retrieval and analysis system (GIRAS) (Mitchell and others, 1977). The GIRAS is the only land-use and land-cover data base in digital format that is available for all of the United States. Information in the data base was compiled from aerial photographs taken during the late-1970's and mid-1980's. For the study area, six categories of land use were identified from the data base (table 4).

Table 4. Areas and percentages of land-use categories in the Roanoke River Basin study area in North Carolina

[mi^2, square mile. Differences in total drainage area from those listed in other tables reflect differences in scale of map and accuracy of methods used by source to compute areas.]

Land-use category	Extent and percentage of study area covered by land-use category[1] (mi^2)	(percent)
Urban and developed	141	4.0
Agricultural	1,039	29.7
Forest	1,950	55.7
Water	65	1.9
Wetland and swamp	283	8.1
Other (includes rangeland, barren land, and areas where land use is unknown)	25	0.6
Totals	3,503	100.0

[1]From U.S. Geological Survey information retrieval and analysis system (GIRAS)

Land use within the Roanoke River Basin in North Carolina is mostly rural. Slightly more than 85 percent of the study area is classified as agricultural or forest cover (table 4). Four percent of the study area is urban with Roanoke Rapids in Halifax County being the largest municipality. Other smaller towns within the study area include, from west to east, Danbury in Stokes County, Wentworth in Rockingham County, Yanceyville in Caswell County, Roxboro in Person County, and Williamston in Martin County (plate 1). Water bodies such as Belews Lake, Hyco Lake and Afterbay Reservoir, Mayo and Roanoke Rapids Lakes, as well as the parts of John H. Kerr Reservoir and Lake Gaston within North Carolina account for less than 2 percent of the study area. Wetlands occupy nearly 8 percent of the study area and occur in the lower Roanoke River Basin (hydrologic unit 03010107) in the Coastal Plain. Within this hydrologic unit, wetlands occupy 21 percent of the total area (McMahon and Lloyd, 1995).

Land use in North Carolina has evolved considerably during the 10 to 15 years since the GIRAS data base was compiled. McMahon and Lloyd (1995) compared land-use data for several hydrologic units, including 03010107, with more recent land-use information developed from remotely sensed data from the Landsat Thematic Mapper sensor (Khorram and others, 1991). They observed several patterns in land-use change in their comparison, the most notable being increases in agricultural land use accompanied by decreases in percentages of forest. This pattern suggests the possibility of forest being converted to agricultural uses. In several of the hydrologic units, including 03010107, comparisons between percentages of urban land use appeared to remain relatively unchanged while percentages of wetlands were higher in the Landsat data base than in the GIRAS data base. The change in the percentage of wetlands likely reflects the methods and resolution of techniques used in compiling the information for each data base and not changes in the percentage of wetlands.

LOW-FLOW CHARACTERISTICS IN THE ROANOKE RIVER BASIN

Low-flow characteristics were determined for selected gaging stations in the Roanoke River Basin study area in North Carolina. Historical records of gage height and streamflow from 218 sites in North Carolina and three gaging stations on the Dan and Hyco Rivers in Virginia were compiled (plate 1). Streamflow records were examined (table 5, p. 39-53) for selection of sites where low-flow characteristics could be determined. Records of discharge collected through the 1994 water year were used. Of the total 221 sites, 22 were continuous-record gaging stations, 191 were partial-record gaging stations, and 8 were sites having a combination of continuous- and partial-record discharges. The period of record varies from site to site. The low-flow characteristics for selected sites in the Roanoke River Basin are presented in this section.

Continuous-record stations

Low-flow characteristics based on continuous records of discharge were developed for 22 sites. Daily mean discharges were compiled for 17 of the 22 continuous-record gaging stations and for 5 of the 8 combined sites that have both continuous- and partial-record discharges. Most of these sites were analyzed using frequency curves (Riggs, 1972); a small number required other graphical correlation techniques as explained below. The magnitude and frequency of low flows for the continuous-record gaging stations are shown in table 6. Not all sites having continuous records could be used to determine low-flow characteristics. A number of sites on the Roanoke River have only records of gage height or records of discharge which are insufficient for use in determining low-flow discharge estimates.

Estimates of low-flow discharges for continuous-record sites having more than 10 years of record were developed by using frequency curves (Riggs, 1972) (fig. 7). The curves depict the relation between recurrence interval and the lowest average annual discharge for a specified number of days at a gaging station. Frequency curves were developed for annual (climatic year) 7-day and 30-day lowest average discharges as well as for the winter (November through March) 7-day lowest average discharge, then fitted with the log-Pearson Type III frequency distribution. The computed log-Pearson distribution generally corresponds closely to the distribution of annual low flows for sites having long-term periods of record (fig. 7). The method of analysis for these sites is denoted as *LP* (table 6). For sites 113, 114, and 147, which have short-term records of 10 to 15 years, best-fit curves were developed graphically from the Weibull plots used in the log-Pearson analyses; the method of analysis for these sites is denoted as *G* (table 6). The method of analysis for continuous-record sites treated as partial-record sites is described in subsequent discussion below (denoted as *C* in table 6).

There are a total of seven gaging stations having daily mean discharge records on the Dan and Smith Rivers in North Carolina. A common base period, the 1950-93 climatic years (April 1, 1950, through March 31, 1994), was used to analyze data from sites 4, 50, and 57 and the two long-term continuous-record gaging stations on the Dan River in Virginia, sites 68 and 93 (table 6). Flows during this period reflect regulated flow from Philpott Lake in Virginia beginning in August 1950. At site 93 in Virginia on the Dan River, actual data collection began in November 1950. Thus, the period of analysis indicated for this site begins with the 1951 climatic year rather than 1950 (table 6).

For the gaging station on the Mayo River, site 38, low-flow characteristics presented in table 6 are based on discharges observed during the climatic years 1930-70. Because the Mayo River Basin is not affected by any known significant regulation or diversions, low-flow characteristics based on the actual period of record were assumed to represent a common base period. To check this assumption, annual minimum 7-day average discharges were estimated for the 1971-93 climatic years and combined with the observed annual values for the 1950-70 climatic years to develop low-flow characteristics based on the common base period. Estimates of 7Q10 and 7Q2 discharges developed for the extended record (1950-93) were found to be nearly identical to estimates based on the period of actual record (1930-70).

The common base period was not applied to the long-term gaging station Roanoke River at Roanoke Rapids (site 181) because additional regulation from Roanoke Rapids Lake began in 1965. Additionally, records at other gaging stations not having complete record during the common base period were not extended due to the effects of significant regulation at the short-term site or due to the occurrence of zero flows. Such factors may not be adequately reflected in correlation of annual minimum 7-day or 30-day discharges at the short-term station to those at the long-term continuous-record gaging station.

Low-flow characteristics developed for the long-term continuous-record gaging stations using the common base period reflect the effects of regulation from upstream impoundments. Streamflow in the upper

Table 6. Magnitude and frequency of annual low-flow characteristics at continuous-record streamflow gaging stations in the Roanoke River Basin study area, North Carolina

[mi^2, square mile; ft^3/s, cubic foot per second; PR, continuous-record gaging station having full period of record collected prior to 1950 or having less than 10 years of record of daily mean discharge, treated as a partial-record site where low-flow characteristics were developed using correlation techniques; R, regulated flow; C, estimates based on correlation techniques; LP, estimates based on log-Pearson frequency distribution; U, unregulated flow; <, less than; G, estimates based on best-fit curves developed graphically from the log-Pearson analyses.]

Site index no.	USGS downstream order number	Station name	Drainage area (mi^2)	Period of analysis, climatic years	Number of observed days of flow: Equal to zero flow	Number of observed days of flow: Less than or equal to 7Q10	Average annual unit flow [(ft^3/s)/mi^2]	Low-flow characteristics: 7Q10 (ft^3/s)	Low-flow characteristics: 30Q2 (ft^3/s)	Low-flow characteristics: W7Q10 (ft^3/s)	Low-flow characteristics: 7Q2 (ft^3/s)	Flow	Method of analysis
1	02068000	Dan River near Asbury, N.C.	71.4	PR	0	18	1.3	23	54	43	44	R	C
4	02068500	Dan River near Francisco, N.C.	129	1950-93	0	53	1.4	38	85	68	70	R	LP
28	02069000	Dan River at Pine Hall, N.C.	501	PR	0	5	1.3	80	190	165	160	R	C
38	02070500	Mayo River near Price, N.C.	242	1930-70	0	67	1.3	65	130	115	110	U	LP
50	02071000	Dan River near Wentworth, N.C.	1,035	1950-93	0	83	1.2	175	415	360	340	R	LP
56	02071500	Dan River at Eden, N.C.	1,133	PR	0	33	1.1	190	440	375	360	R	C
57	02074000	Smith River at Eden, N.C.	538	1950-93	0	765	1.2	175	290	215	250	R	LP
64	02074218	Dan River near Mayfield, N.C.	1,760	PR	0	7	1.2	375	750	650	640	R	C
68	02075000	Dan River at Danville, Va.	2,050	1950-93	0	102	1.1	425	810	700	685	R	LP
75	02075160	Moon Creek near Yanceyville, N.C.	32.8	1962-73	0	24	0.8	0.4	3.0	3.0	1.5	U	LP
93	02075500	Dan River at Paces, Va.	2,550	1951-93	0	98	1.1	460	920	810	750	R	LP
97	02077200	Hyco Creek near Leasburg, N.C.	45.9	1965-93	456	456	1.0	0	0.5	1.8	0.2	U	LP
111	02077230	South Hyco Creek near Hesters Store, N.C.	31.7	PR	15	15	0.9	0	1.4	0.8	0.5	U	C
113	02077240	Double Creek near Roseville, N.C.	7.47	1965-74, 1977-81	10	58	1.0	< 0.1	0.6	0.6	0.5	U	G
114	02077250	South Hyco Creek near Roseville, N.C.	56.5	1967-77	98	98	1.1	0	2.5	1.5	1.0	U	G
131	02077300	Hyco River at McGehees Mill, N.C.[1]	198	PR	0	27	0.7	3.0	9.2	3.8	7.0	R	G
132	02077303	Hyco River below Afterbay dam near McGehees Mill, N.C.	202	1974-86, 1989-93	0	64	0.9	2.4	12.8	6.1	10.0	R	LP
140	02077500	Hyco River near Denniston, Va.	289	1974-93	0	45	0.9	10.4	24.9	18.0	21.0	R	LP
147	02077670	Mayo Creek near Bethel Hill, N.C.	53.5	1984-94	0	6	0.7	1.0	2.9	2.0	2.5	R	G
181	02080500	Roanoke River at Roanoke Rapids, N.C.	8,384	1964-93	0	177	1.0	1,100	2,400	1,100	1,800	R	LP
194	02081000	Roanoke River near Scotland Neck, N.C.	8,671	PR	0	12	0.8	1,120	2,500	1,120	1,880	R	C
212	0208111310	Cashie River near Windsor, N.C.	108	PR	211	211	1.0	0	1.5	0.2	0.2	U	G

[1]Site now inundated by impoundment. Low-flow characteristics represent regulated flow from Hyco Lake.

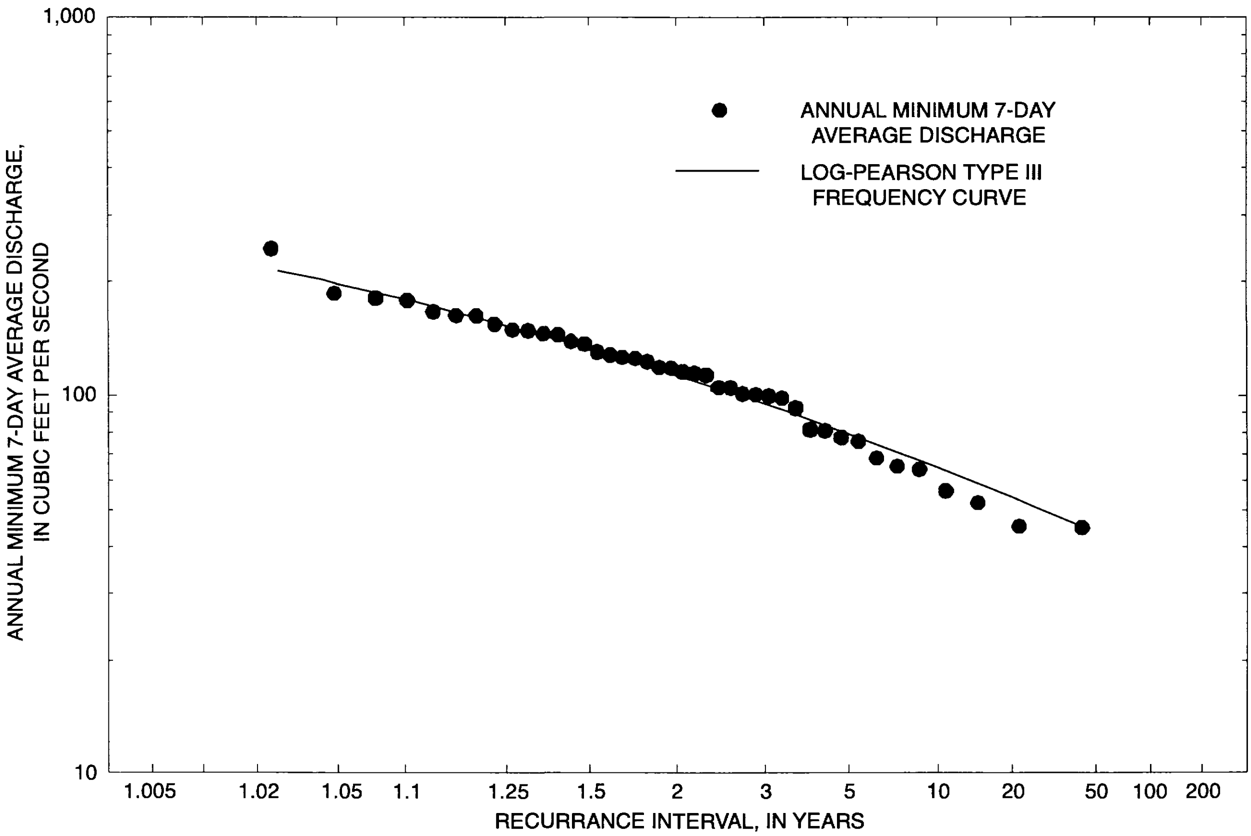

Figure 7. Low-flow frequency curve of annual minimum 7-day discharges using log-Pearson Type III frequency distribution at Mayo River near Price, N.C. (site 38; plate 1).

reaches of the Dan River has been regulated by Talbott and Townes Reservoirs (drainage areas of 20.2 mi^2 and 32.9 mi^2, respectively) in Virginia since 1938. The drainage basin upstream from Townes Reservoir is 26 percent of the basin at Dan River near Francisco (site 4; 129 mi^2) and 7 percent of the basin at Dan River at Pine Hall (site 28; 501 mi^2). Thus, the effects of regulation on the Dan River, while significant in the upper reaches, rapidly diminish as the drainage area increases. The effects of regulation on streamflow in the Dan River become more significant at the confluence of the Dan and Smith Rivers. Philpott Lake in Virginia drains 216 mi^2 of the Smith River Basin, which is 40 percent of the basin at the gaging station at Smith River at Eden (site 57). However, just downstream from the confluence of the Dan and Smith Rivers where the drainage area is nearly 1,680 mi^2, less than 15 percent of the total basin is upstream from Townes Reservoir and Philpott Lake. Table 6 indicates for each site whether flows are regulated (*R*) or unregulated (*U*) by upstream impoundments. Low-flow characteristics for the regulated sites can be considered valid as long as the current pattern of regulation continues to exist.

Eight continuous-record sites having less than 10 years of record or with full periods of record collected prior to 1950 were treated as partial-record stations for the analyses of low-flow characteristics. Daily mean discharges at these sites were correlated with concurrent flows at nearby long-term continuous-record gaging stations where low-flow characteristics had been developed. Correlations at sites 28, 64, and 111 having less than 10 years record provided a strong relation for determining low-flow characteristics. Streamflow data for sites 1 and 56 on the Dan River and site 194 on the Roanoke River were collected entirely or almost entirely before 1950. Low-flow characteristics at these sites were determined by correlating, for the period of record, daily mean discharges with flows at nearby long-term continuous-record gaging stations. For these six sites, the method of analysis is denoted by *C* (table 6).

At sites 131 and 212, having less than 10 years of record, correlations with concurrent flows at nearby long-term continuous-record gaging stations were poor and did not provide a relation from which low-flow characteristics could be determined. Thus, low-flow characteristics were derived from graphical interpretation of the Weibull probability plots used in the log-Pearson frequency analyses using available record. Because this approach is the same as that used for sites having 10 to 15 years of record where best-fit curves were developed graphically, the method of analysis for sites 131 and 212 also is denoted by *G*.

Partial-record stations

Using the techniques discussed by Riggs (1972), low-flow characteristics were determined for 58 of the 191 sites in the Roanoke River Basin study area identified as having partial-record data and for 2 of the 8 combined sites that have both continuous- and partial-record discharges (table 7, p. 54-56). Sites having 10 or more discharge measurements were included in the analyses of low-flow characteristics, as well as sites where low-flow characteristics have been previously published or for which knowledge of low-flow discharges were necessary in the development of discharge profiles.

Discharge measurements of base flow at the partial-record stations were correlated with concurrent flows at nearby index sites, typically continuous-record gaging stations where low-flow characteristics had been determined (fig. 8). Index sites for possible use in the correlation analysis of concurrent flows were selected using several factors including proximity of the partial-record and index sites as well as similarity in some basin characteristics such as drainage area and topography.

Defining the relation between concurrent flows is usually based on either statistical techniques or graphical interpretation whereby visually-fitted lines are drawn among the concurrent flows (Riggs, 1972). In this investigation, graphical interpretation was used to establish the relation between the concurrent flows. Ordinary least squares regression techniques were applied to a small number of sites; however, the nonlinear relation exhibited in many of the correlations indicated that visually-fit lines would more adequately describe the relations between concurrent flows.

At most partial-record sites, correlations of the discharge measurements with concurrent flows at multiple index sites yielded several relations from which estimates of low-flow discharges could be determined. From each relation, estimates of low-flow discharges were derived from the individual correlation plot. Thus, to determine overall estimates of low-flow discharges (7Q10, 30Q2, W7Q10, and 7Q2) for each partial-record station, individual estimates derived from each correlation were averaged. However, individually derived estimates from poor correlations where visually-fit lines could not be established or otherwise were deemed suspect were not included in the average for overall estimates.

Low-flow characteristics for the partial-record sites reflect unregulated conditions with the exception of two sites (table 7). Low-flow discharges shown for sites 80 and 195 on the Dan and Roanoke Rivers, respectively, reflect regulated conditions from upstream impoundments (table 7). Thus, estimates for these two sites can only be considered valid as long as the pattern of regulation observed during the years in which discharge measurements were obtained continues to exist.

Occurrence of zero or minimal 7Q10 discharge

Estimated 7Q10 discharges at 30 of the 82 sites were determined to be zero (tables 6, 7). However, when arranged in order of ascending drainage area, there was no clear indication of a maximum drainage area below which 7Q10 discharges are generally zero. In addition to the sites having zero 7Q10 discharge,

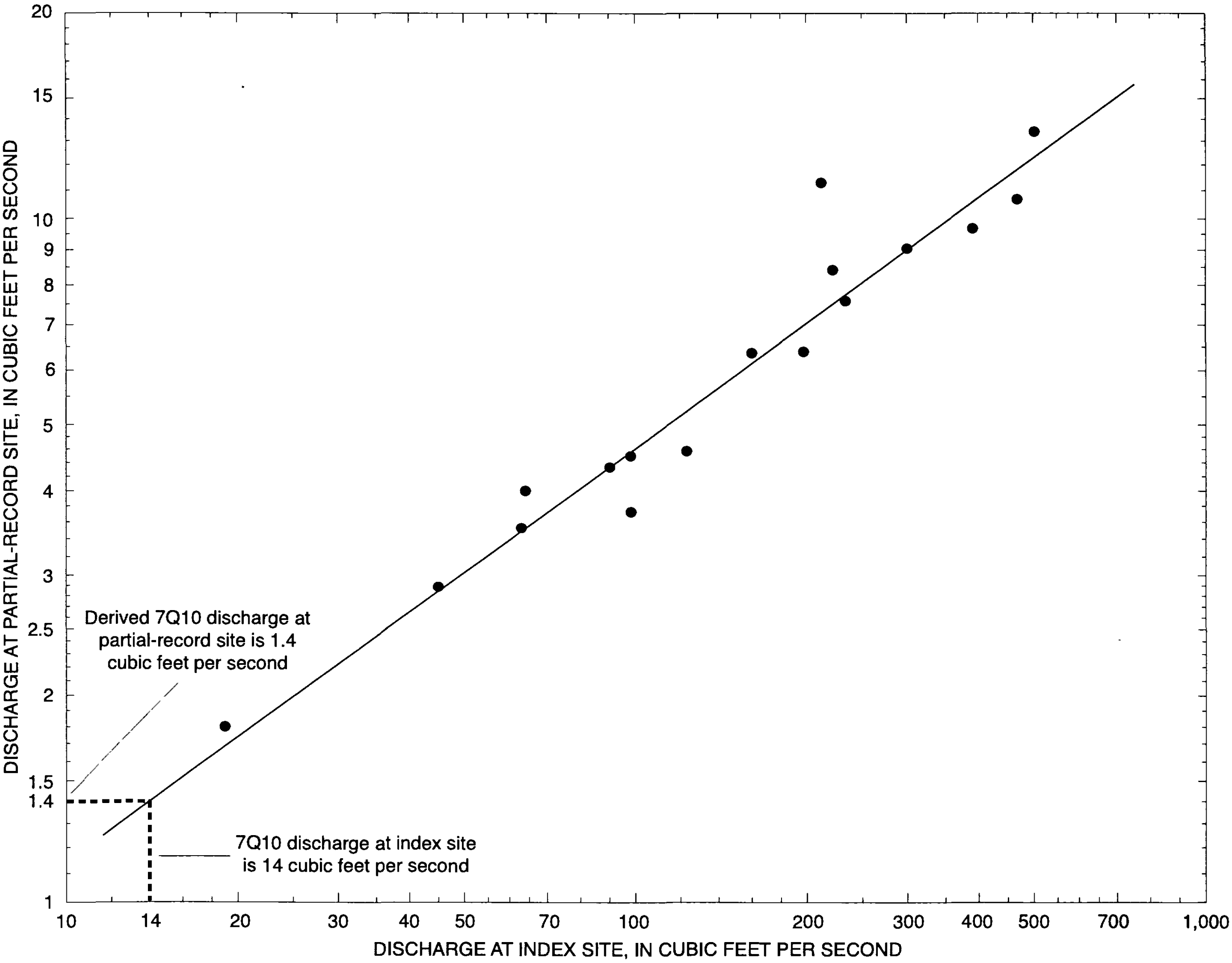

Figure 8. Correlation of concurrent discharge at the partial-record station at Sixpound Creek near Oakville, N.C., and at the index station at Fishing Creek near Enfield, N.C.

nine sites have minimal 7Q10 discharges reported to be less than 0.1 ft^3/s (tables 6, 7). The sites having zero or minimal 7Q10 discharges were combined and plotted on a map to determine what other factors, if any, may account for the low potential to sustain base flow.

Estimates of zero or minimal 7Q10 discharges occur in two general sections of the study area. Zero or minimal 7Q10 discharges occur at numerous sites between eastern Caswell and western Warren County (plate 1) and are primarily the result of soils having low infiltration rates. Much of the water that comes in contact with the soils in this area enters the streams as overland runoff and does not infiltrate into the surficial aquifers for later release during drought conditions. In eastern Caswell County and western Person County, many soils are identified as having poor drainage (fig. 6B). Correspondingly, many of the sites in the lower half of the Country Line Creek Basin in Caswell

County, as well as those in the upper reaches of Hyco Creek Basin, have estimates of zero or minimal 7Q10 discharge. Soils in much of the area between eastern Person County and western Warren County, while identified as moderately well drained, consist of those in the B/C infiltration group (table 3) which include soils having high clay content.

Sites on tributaries in the lower portions of the Coastal Plain physiographic province (plate 1) are also likely to have zero or minimal 7Q10 discharges as a result of the land-surface slope, which has little or no relief. The existence of little or no relief in the basin results in streams that have very little slope for moving flow in the downstream direction. This observation is consistent with the conclusions reached by Giese and Mason (1993) in which streams in the Coastal Plain have very low potential for sustained base flow.

DISCHARGE PROFILES FOR SELECTED STREAMS IN THE ROANOKE RIVER BASIN

Discharge profiles of low flows were developed for the Dan and Roanoke Rivers and selected tributaries of these rivers. The tributaries, which cover a range of basin size and characteristics, include Town Fork Creek in Stokes and Forsyth Counties; Hogans Creek, Buffalo Creek, Mayo River, and Smith River in Rockingham County; Country Line Creek in Caswell County; Marlowe Creek in Person County; and Hyco Creek/River in Caswell and Person Counties (plate 1). Drainage-area profiles also were developed for each of these streams to document the relation between basin size and low-flow characteristics.

River miles shown on the profiles were determined by using the Environmental Protection Agency's River Reach Files (T.R. Bondelid and others, 1990), which are Geographical Information Software System coverages of rivers and streams. The coverages, digitized from 1:100,000-scale USGS topographic maps, provide a very comprehensive depiction of the hydrology in a given area. River mileages computed for each stream begin at zero at the mouth and increase upstream towards the headwaters.

Segments of the larger streams are located in both North Carolina and Virginia. The Dan, Mayo, Smith, Hyco, and Roanoke Rivers drain portions of both States. Discharge and drainage-area profiles for these streams do not show the entire reaches, only the segments of streams flowing through North Carolina. Profiles for the remaining mid-size to smaller streams—Town Fork, Hogans, Buffalo, Country Line, and Marlowe Creeks—show the entire reach from mouth to headwaters.

Discharge profiles are presented for the 7Q10, 30Q2, W7Q10, and 7Q2 discharges. Low-flow characteristics (tables 6, 7) for streams where profiles were developed serve as anchor points in the discharge profiles. It is these points which serve as a reference for computing other low-flow discharges at upstream and downstream locations. Low-flow discharges at the ungaged locations on the profile were determined by linear interpolation between the nearest upstream and downstream anchor points. Contributions of low flows from tributaries were estimated where the increase in drainage area from a tributary was 5 percent or greater of the drainage area immediately upstream from the tributary. The exception to this is in the profiles for Country Line Creek and Hyco River; sites within these basins exhibit unit low flows having a high degree of variability or, in the case of 7Q10 discharges, many zero values.

A small number of the discharge profiles are included which show actual measurements of discharge obtained synoptically at multiple points along streams. Streamflows on many small to mid-size streams in the Dan River Basin were measured on September 24, 1959; August 14, 1963; July 19, 1966; and September 10, 1968. The profiles of actual measurements provide a "snapshot" of the flow conditions on these dates which, for many streams, were at or near 7Q10 discharge conditions. Discharges at unmeasured locations between the measured points are linearly interpolated.

Changes in flow caused by impoundments and instream diversions or withdrawals (table 2) were not noted on the discharge profiles. Where a point-source discharge is occurring, the ratio of the discharge amount to the 7Q10 discharge generally is insignificant. Furthermore, and more importantly, a point-source discharge usually is preceded by a withdrawal at a nearby upstream location. Analysis of these withdrawals and associated major point-source discharges indicated that the ratio of net loss of flow (between withdrawal and discharge points) to 7Q10 discharge is essentially of no consequence.

Four major impoundments affect the low-flow patterns of streams in the study area. The impoundments, owned by regional utility companies, occur on

Belews, Hyco, and Mayo Creeks, and the Roanoke River (at Roanoke Rapids). The effect of required minimum flow releases from these impoundments varies from site to site. Low-flow characteristics at ungaged sites downstream from an impoundment are determined as the product of the estimated pre-impoundment low flows and the drainage area between the dam and site of interest plus the minimum flow from the impoundment. Discharge profiles presented in this report for the Hyco and Roanoke Rivers include regulated low flows downstream from impoundments. The low-flow characteristics determined for these reaches are based on records from the long-term continuous-record gaging stations (sites 132, 181) immediately downstream from each impoundment (table 6).

At Belews Creek, the impoundment is located about one-half mi upstream from the mouth where streamflow empties into the Dan River. Belews Creek drains nearly 73 mi^2 of the study area; the impoundment retains flow from about 70 mi^2 or 96 percent of the Belews Creek Basin. Thus, streamflow observed at the mouth consists mostly of the flow being released from the dam. No minimum flow is required by permit; however, minimal flow rates observed in operations of the impoundment are nearly 150 ft^3/s (Ken Broughton, Duke Power, 1996). Hyco Lake drains 202 mi^2 (site 132) of the Hyco River Basin which, at its mouth in Virginia, is about 425 mi^2 in size. Nearby, Mayo Lake drains about 54 mi^2 of the nearly 62 mi^2 Mayo Creek Basin. Permit-required minimum flow rates downstream from the Hyco and Mayo impoundments are 10 ft^3/s and 2 ft^3/s, respectively (Marshall Lundsford and Mark Frederick, Carolina Power and Light, 1996). Analyses of the post-impoundment record at the continuous-record gaging stations immediately downstream from the Hyco and Mayo dams reveal the low-flow 7Q10 discharges, 2.4 ft^3/s and 1.0 ft^3/s (sites 132, 147; table 6), respectively, to be less than the minimum flow releases.

The largest impoundment in the study area is on the Roanoke River at Roanoke Rapids Lake. Immediately upstream from the lake are two much larger impoundments, Lake Gaston and John H. Kerr Reservoir in Virginia. Consequently, the segment of the Roanoke River between Roanoke Rapids and its mouth is one of the most heavily regulated rivers in North Carolina. The Federal Energy Regulatory Agency license for Roanoke Rapids Lake specifies a minimum release which varies by season (Fransen, 1991). The minimum release is as follows: 2,000 ft^3/s during the months of May through September; 1,500 ft^3/s during the months of April and October; and 1,000 ft^3/s in the months of November through March. The regulated-flow 7Q10 discharge at the continuous-record gaging station downstream from Roanoke Rapids Lake (site 181; table 6) is 1,100 ft^3/s and is based on the daily mean discharges observed during the 1964-93 climatic years. While the minimum flow release from Roanoke Rapids Lake is less than the 7Q10 discharge during the winter months (November through March), the minimum flow releases during the warm-season months of April through September exceed the 7Q10 discharge.

Town Fork Creek

Town Fork Creek drains 135 mi^2 in portions of Stokes and Forsyth Counties in the westernmost part of the study area. The largest tributaries draining to Town Fork Creek are Buffalo (different from the Buffalo Creek of Rockingham County profiled in this report), Neatman, and Old Field Creeks (fig. 9A). Estimates of low-flow discharges shown on the profiles were based on the unit flows at the three partial-record stations in the basin (table 7); the 7Q10 discharge at the mouth is nearly 11 ft^3/s (fig. 9B). The potential for sustaining base flow in the Town Fork Creek Basin is high. Giese and Mason (1993) also identified this part of North Carolina as having a high potential to sustain base flows. Twenty-one NPDES permits are recorded for the Town Fork Creek Basin. Permitted flows for the 11 NPDES discharges (including two into Town Fork Creek) which must comply with wastewater-treatment standards compose nearly 9 percent of the 7Q10 discharge at the mouth. On September 24, 1959, and August 14, 1963, flows in the basin appear to have been at or somewhat higher than 30Q2 discharge conditions.

Hogans Creek

Hogans Creek drains over 24 mi^2 of Rockingham County southwest of Madison; its largest tributary is Little Hogans Creek (fig. 10A). Low-flow discharges for the entire reach were estimated using the unit low flows for the partial-record station (site 47) on Hogans Creek just above the mouth. The 7Q10 discharge at the mouth is 1.3 ft^3/s (fig. 10B). Total permitted flow for the three known NPDES discharges in the basin is nearly 10 percent of the 7Q10 discharge at the mouth.

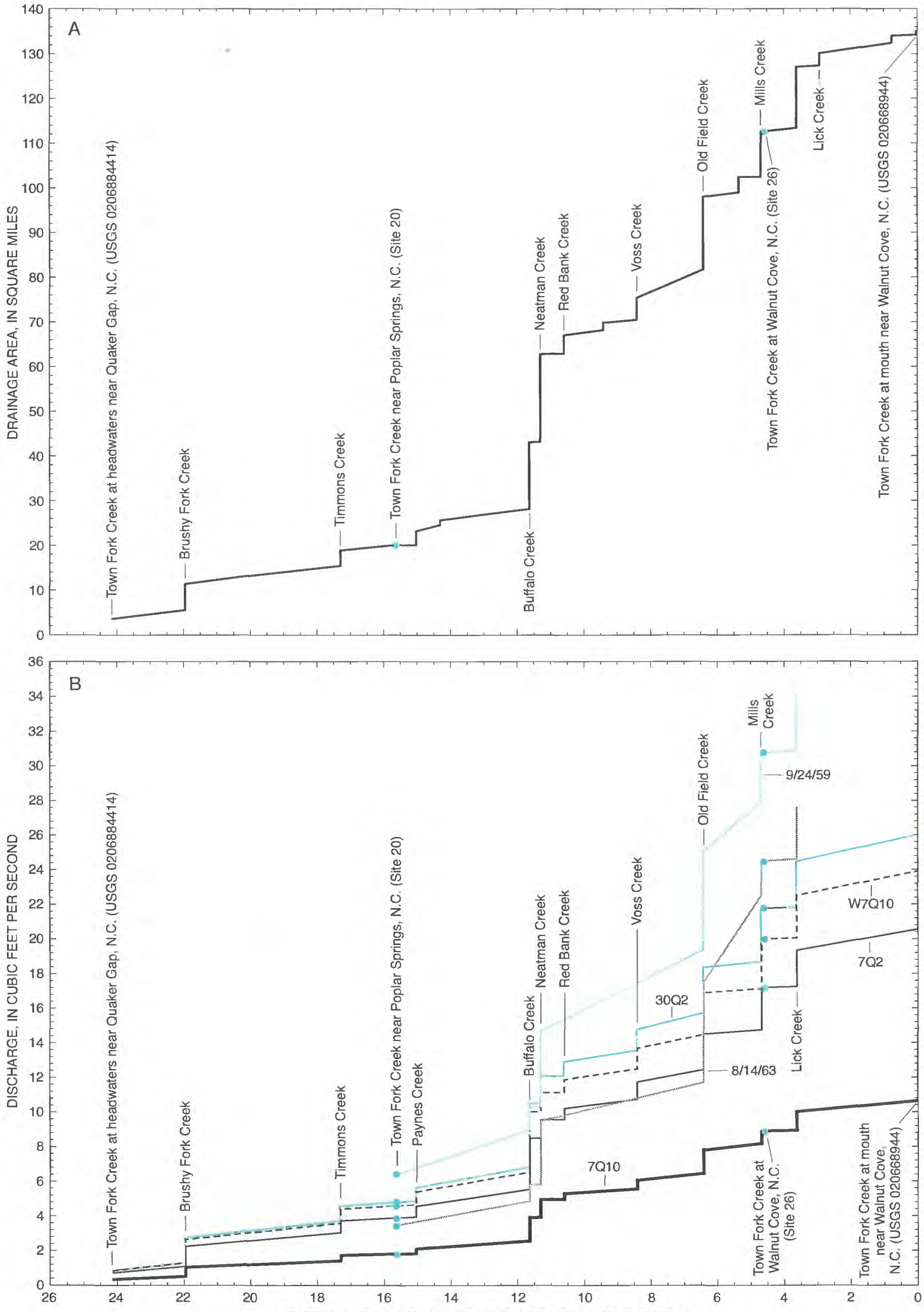

Figure 9. Relation of river miles to (A) drainage area and (B) low-flow discharge for Town Fork Creek.

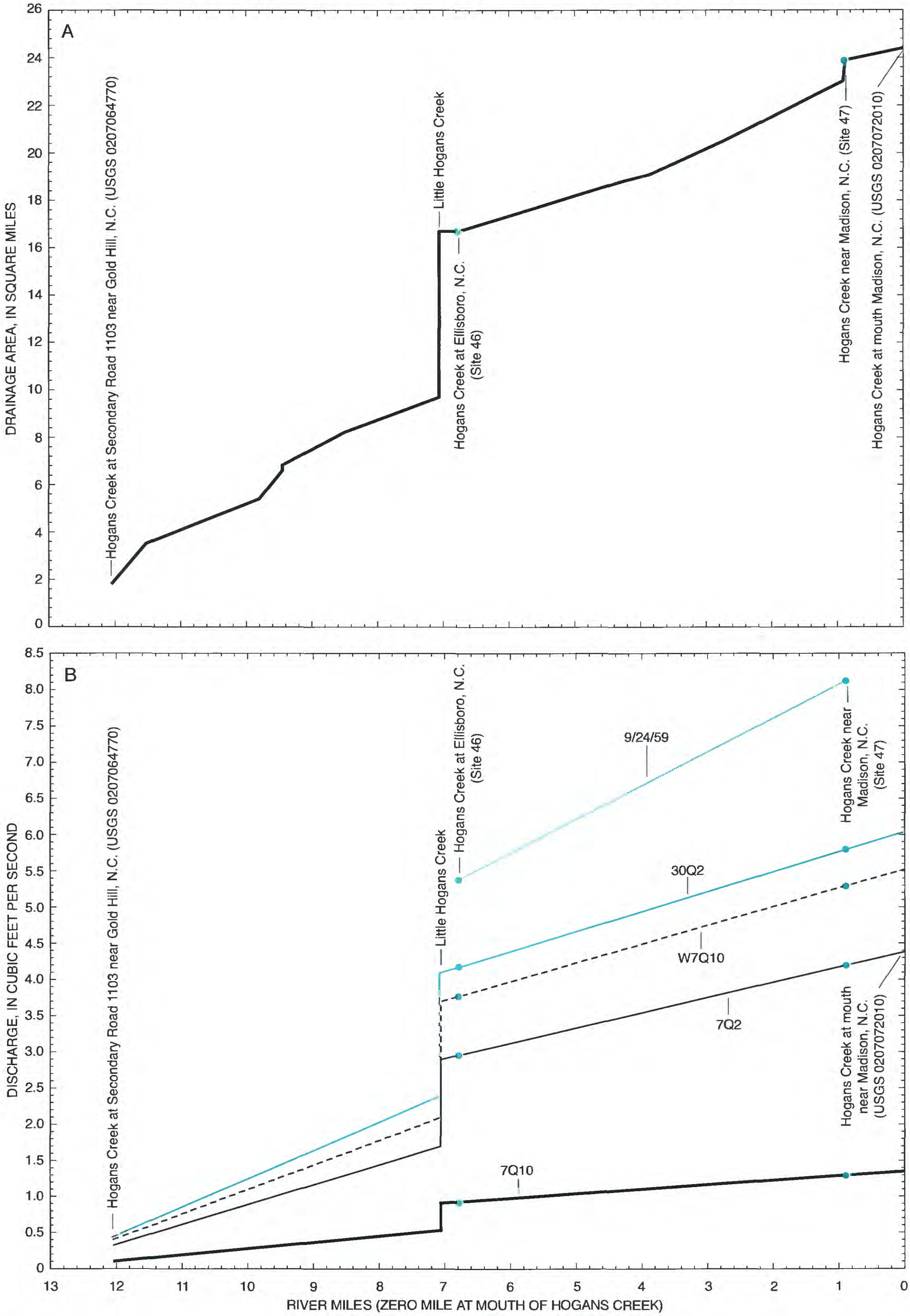

Figure 10. Relation of river miles to (A) drainage area and (B) low-flow discharge for Hogans Creek.

Buffalo Creek

Buffalo Creek drains nearly 22 mi^2 of Rockingham County just west of Eden; the largest tributary is Buffalo Creek Branch (fig. 11A). Miscellaneous measurements of discharge have been made at four sites in the Buffalo Creek Basin. However, none of the sites has a sufficient number of measurements for which concurrent discharges at nearby index stations are available for correlation analysis. Thus, estimates of low flow discharges shown on the profiles are based primarily on average unit flows from three nearby partial-record stations (sites 47, 49, 51) which drain basins similar in size and characteristics to Buffalo Creek. Although low-flow discharges shown on the profile for Buffalo Creek are considered ungaged estimates, favorable comparison of the unit low flows at the three nearby sites provides a basis upon which estimates can be determined for ungaged sites in the immediate vicinity. The estimate of 7Q10 discharge at the mouth is 1.1 ft^3/s (fig. 11B). Twelve NPDES permits have been assigned to facilities which discharge into streams in the Buffalo Creek Basin. Total permitted flow from the three facilities which must comply with wastewater-treatment standards is less than 3 percent of the 7Q10 discharge at the mouth of Buffalo Creek. Actual discharge measurements obtained at points along Buffalo Creek on August 14, 1963, indicate that flows were near 7Q10 discharge conditions (fig. 11B).

Mayo River and Smith River

Low-flow discharge profiles were developed for Mayo and Smith Rivers, the two largest tributaries of the Dan River in Rockingham County. At the mouths, the drainage areas of the Mayo and Smith Rivers are 297 mi^2 and 546 mi^2, respectively (fig. 12A and B). Much of the basins drained by each river lie in Virginia, and the rivers travel a short distance in North Carolina before emptying into the Dan River. The Mayo River is not known to be affected by any regulation or significant upstream diversions. However, the Smith River has been regulated by Philpott Lake in Virginia since 1950, the starting year of the common base period (1950-93 climatic years) chosen for the analysis of long-term continuous-record gaging stations in the Dan River Basin.

The Mayo and Smith Rivers near the State line between North Carolina and Virginia have unit low flows which are among the highest in the study area. The uppermost reaches of the basins drained by the two rivers have high annual precipitation compared with long-term averages of annual precipitation observed in other parts of the study area (fig. 5B). Additionally, a transition in the underlying geology from the Blue Ridge to the Piedmont physiographic province most likely results in a high degree of fissures and rock openings which, in turn, results in higher availability of water storage in surficial aquifers. Steep stream gradients in the upper ends of the Mayo and Smith River Basins also likely contribute to the high unit low flows. The 7Q10 discharges at the mouths of the Mayo and Smith Rivers are 80 ft^3/s and 178 ft^3/s, respectively (fig. 13A and B). Permitted flows from known NPDES permits in North Carolina for discharges into the Mayo River account for less than 3 percent of the estimated 7Q10 discharge at the mouth. No significant NPDES discharges exceeding 1 Mgal/d (1.5 ft^3/s) are known to exist on the reach of Smith River within North Carolina.

Country Line Creek

The Country Line Creek Basin drains 140 mi^2 in much of central Caswell County. The largest tributary is South Country Line Creek (fig. 14A). This part of the study area represents a region of rapid transition in potential to sustain base flow. In the western part of the Country Line Creek Basin, the potential to sustain flow is moderate but becomes very low in the eastern part of the basin. Two factors exist which may partially account for the reduction in base-flow potential. First, the basin contains soils having moderate to poor infiltration rates (fig. 6B). Because low flow is sustained base flow that, in turn, is derived from ground water stored in the surficial aquifers, soils having low infiltrations rates will not have water stored for later release during extended dry periods. Second, irrigation withdrawals also occur in Caswell County. Water-use records compiled in 1990 for the county indicate that an average of over 1.4 Mgal/d (2.2 ft^3/s) in irrigation withdrawals are made for agricultural purposes. Profiles of actual measurements made at a number of sites on July 19, 1966, and September 10, 1968, reveal a loss of water in the lower reaches of Country Line Creek. No specific information is available to attribute the loss of water on these dates to irrigation; however, irrigation withdrawals are known to have occurred in

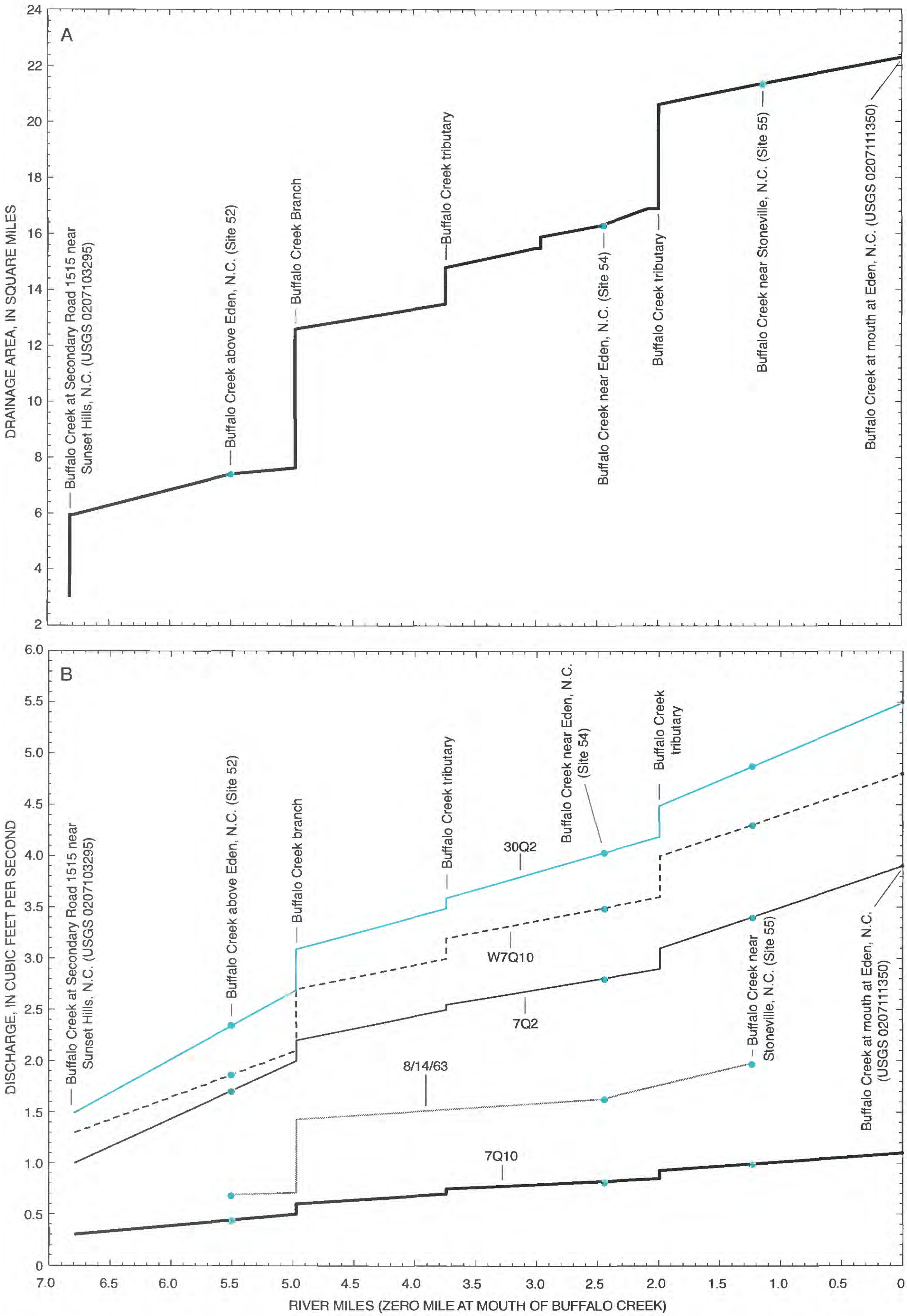

Figure 11. Relation of river miles to (A) drainage area and (B) low-flow discharge for Buffalo Creek.

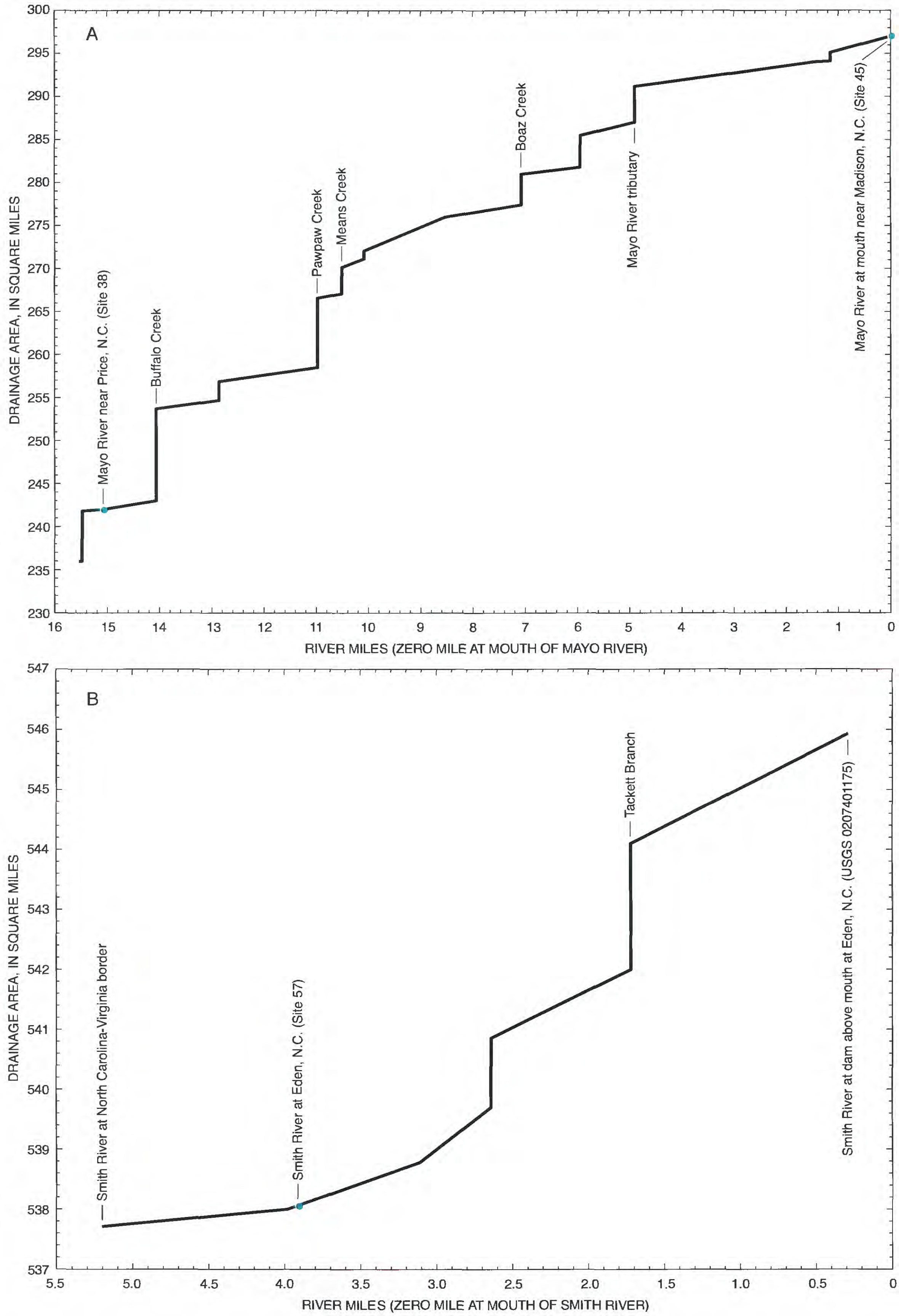

Figure 12. Relation of river miles to drainage area for (A) the Mayo River and (B) the Smith River.

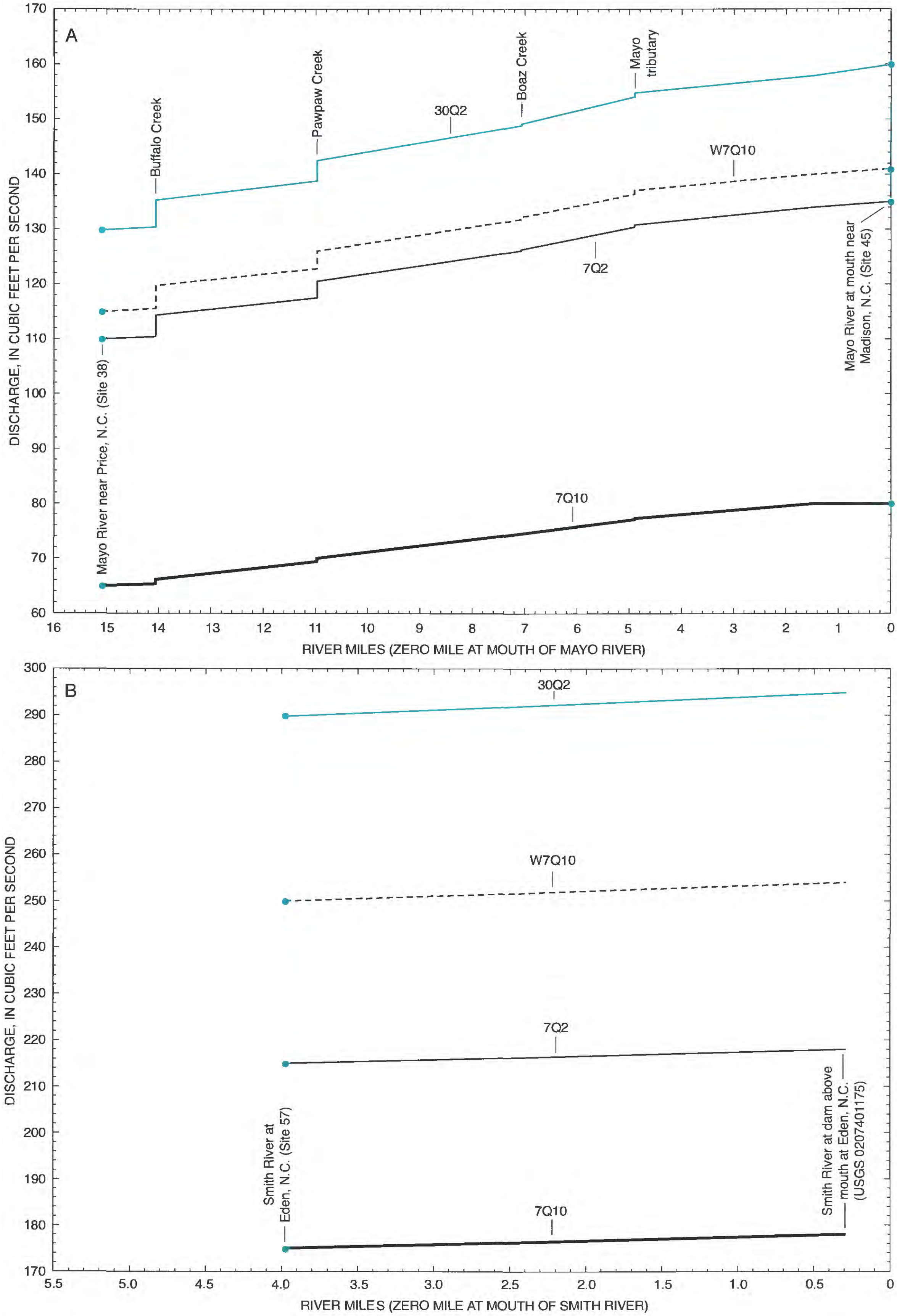

Figure 13. Relation of river miles to low-flow discharge for (A) the Mayo River and (B) the Smith River.

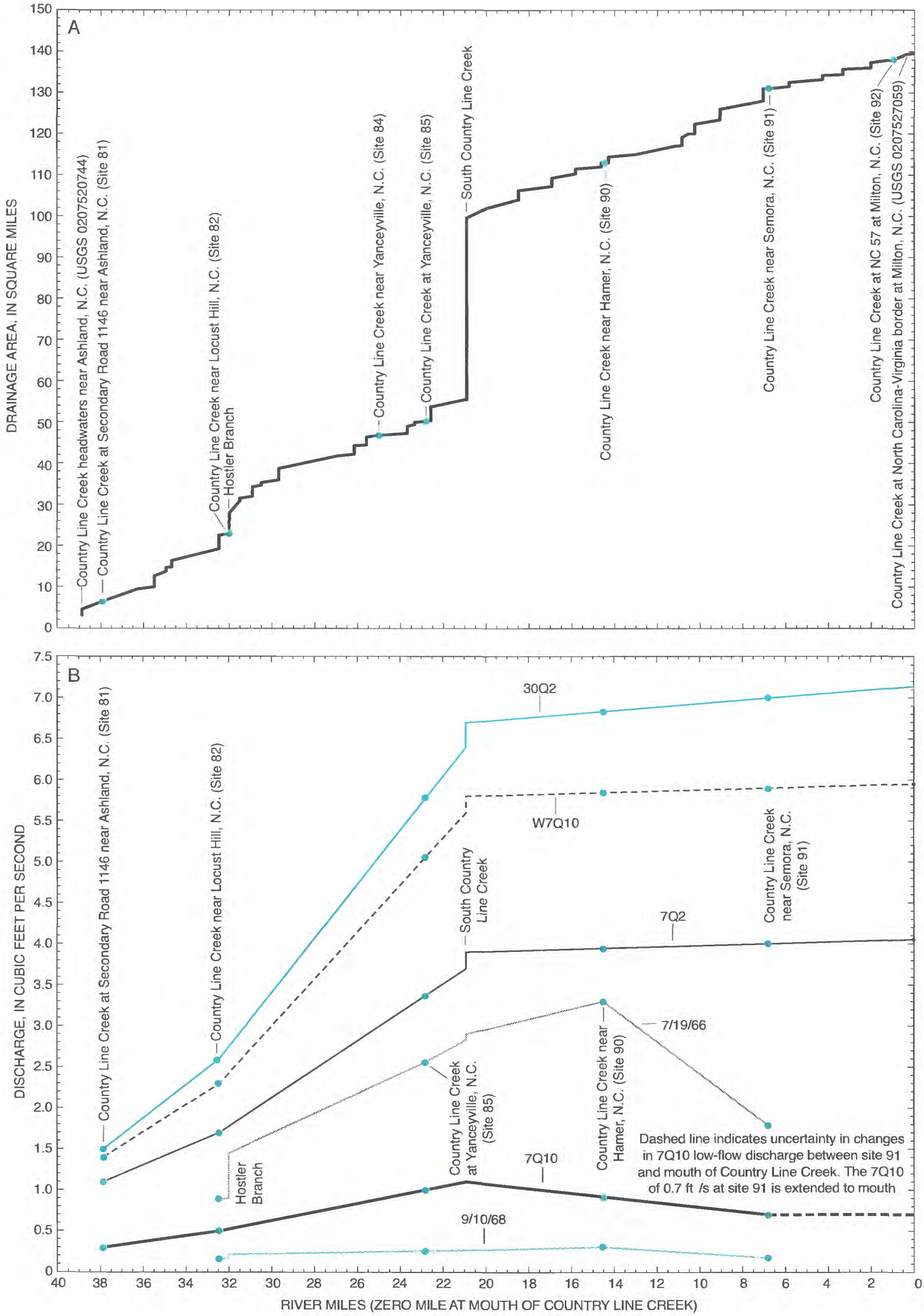

Figure 14. Relation of river miles to (A) drainage area and (B) low-flow discharge for Country Line Creek.

the Country Line Creek Basin. Given the size of the basin and its location in central Caswell County, it is likely that a significant percentage of the irrigation withdrawals are from Country Line Creek. The loss of water is also reflected in the decrease in 7Q10 discharge between South Country Line Creek and site 91 shown on the profile (fig. 14B). At least three NPDES permits are present in the basin, all of which must comply with wastewater-treatment standards. The total permitted flow from the three discharges is nearly 60 percent of the 7Q10 discharge at the mouth (0.7 ft^3/s) of County Line Creek (fig. 14B). The high percentage reflects low potential of base flow, particularly in the lower reaches of the basin.

Dan River

Profiles developed for the Dan River present the drainage areas and low-flow discharges for the reach of the river within North Carolina (fig. 15A and B). Continuous- and partial-records of discharge are available at nine gaging stations (including two in Virginia); low-flow estimates developed at these locations serve as the anchor points on the discharge profile. Unit low flows for the uppermost gaging station (site 1; table 6) reveal high potential to sustain base flow, similar to the high-unit low flows on the Mayo and Smith Rivers. Just downstream from Town Fork Creek in Stokes County, unit low flows are approximately 50 percent of the unit low flows further upstream in the basin; unit flows remain fairly constant as the Dan River continues its downstream course through North Carolina and into Virginia. A number of NPDES permits exist for discharges from municipal and utility facilities into the Dan River. The NPDES permit having the largest permitted flow is for a discharge of about 70 Mgal/d (110 ft^3/s) from a utility company. However, the same amount of flow is withdrawn just upstream from the discharge point resulting in no net loss in flow. The sum of the remaining permitted flows for known discharges into the Dan River is nearly 7 percent of the 7Q10 discharge at the gaging station on the Dan River at the State line (site 64) downstream from Eden (near Mayfield).

Marlowe Creek

Similar in size to the Buffalo Creek Basin, the Marlowe Creek Basin drains nearly 22 mi^2 of Person County and has the largest percentage of urban and developed land use among the streams profiled during this investigation (fig. 16A). Additionally, flows in the lower reaches of Marlowe Creek consist mostly of treated effluent released by a local municipal wastewater-treatment plant. Just upstream from the mouth, the 7Q10 discharge is 0.2 ft^3/s (site 137) under what would be considered natural-flow conditions. The permitted flow specified by the NPDES permit for release of the treated effluent is 5 Mgal/d, or nearly 7.7 ft^3/s. The average flow released into Marlowe Creek is approximately 2.9 Mgal/d, or about 5 ft^3/s (table 2) which is reflected on the profile (fig. 16B).

Hyco River

Profiles developed for Hyco River show drainage areas and low-flow discharges from the headwaters (where it is known as Hyco Creek) to the gaging station on Hyco River near Denniston, Virginia (site 140) (fig. 17A and B). The most prominent feature of the discharge profiles is the effect of Hyco Lake and Afterbay Reservoir on downstream flows. Hyco Lake is the largest of the two impoundments; however, downstream flows are regulated by Afterbay Reservoir, which is located immediately downstream from the dam on Hyco Lake. At the State line, Hyco River drains 277 mi^2 of Caswell and Person Counties, 202 mi^2 of which is drained by the impoundment. Not including those which drain directly into the lake, the largest tributary to Hyco River is Storys Creek, including the Marlowe Creek Basin. Upstream from the impoundment, low-flow discharges developed at the continuous- and partial-record gaging stations indicate that the potential to sustain base flow is extremely low. Estimates of zero 7Q10 discharges are numerous for streams in this area; unit flows for the remaining low-flow statistics shown on the profiles also reflect the low potential to sustain base flow. The Hyco Creek Basin (upstream from Hyco Lake) is underlain by soils similar to those found in the adjacent Country Line Creek Basin; these soils have low infiltration rates (fig. 6B). Downstream from the dam on Afterbay Reservoir, low flows are affected by the flows released from the lake. A very large withdrawal exceeding 1,100 Mgal/d is made by the utility company that owns the lake; however, nearly the same volume is returned to the lake. No other withdrawals and return discharges in North Carolina are known to exist for the reach of Hyco River profiled in this report.

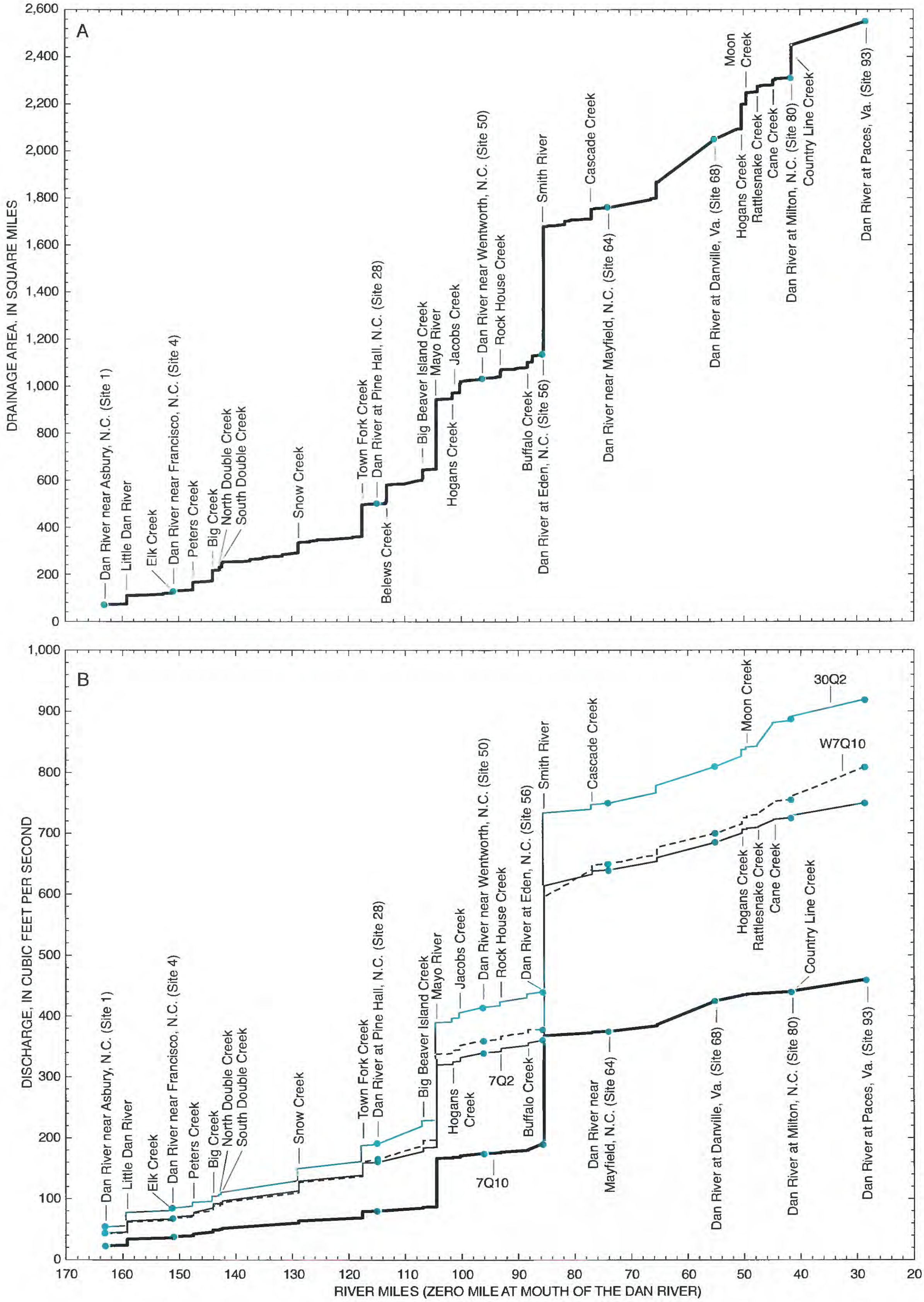

Figure 15. Relation of river miles to (A) drainage area and (B) low-flow discharge for the Dan River.

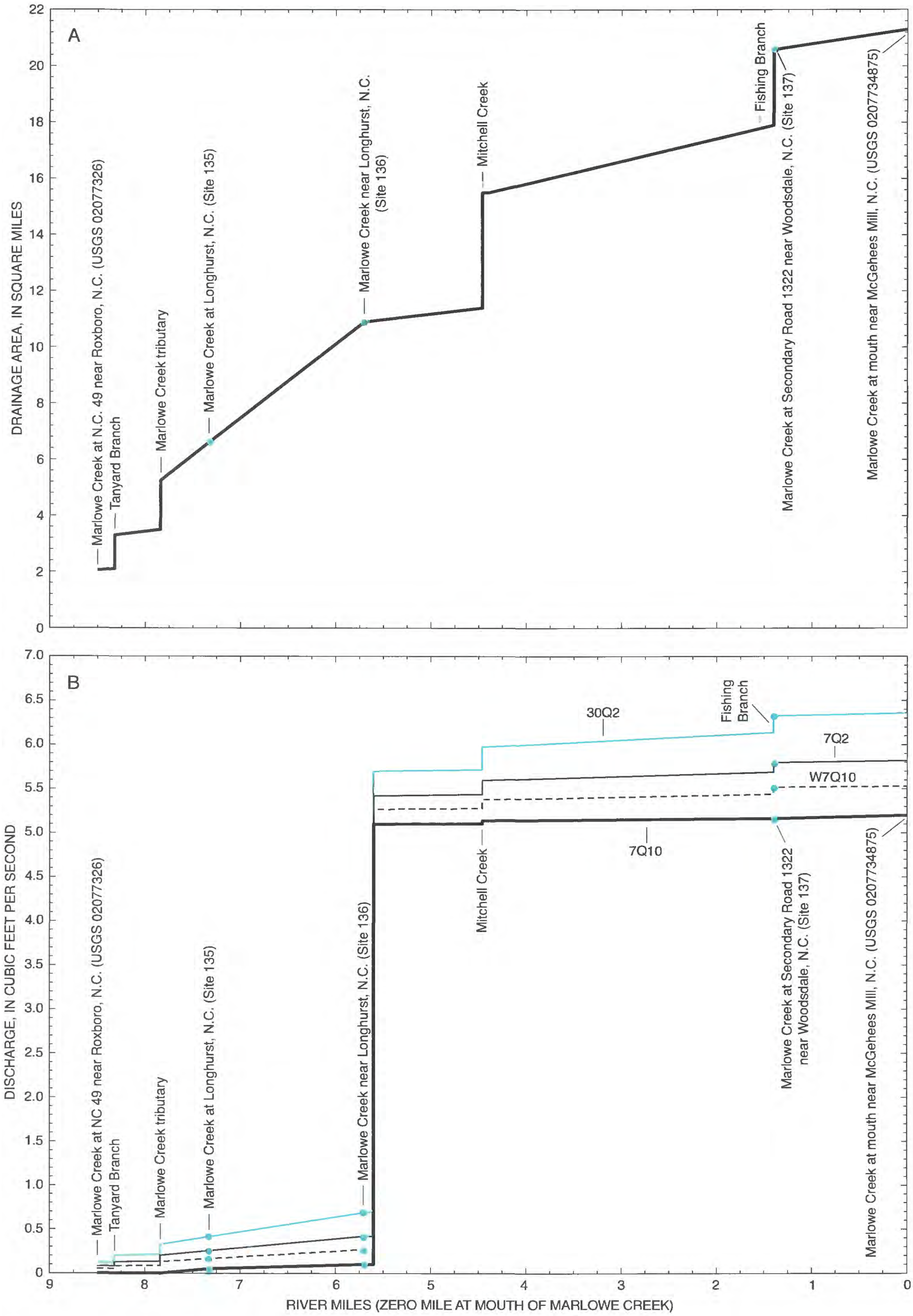

Figure 16. Relation of river miles to (A) drainage area and (B) low-flow discharge for Marlowe Creek.

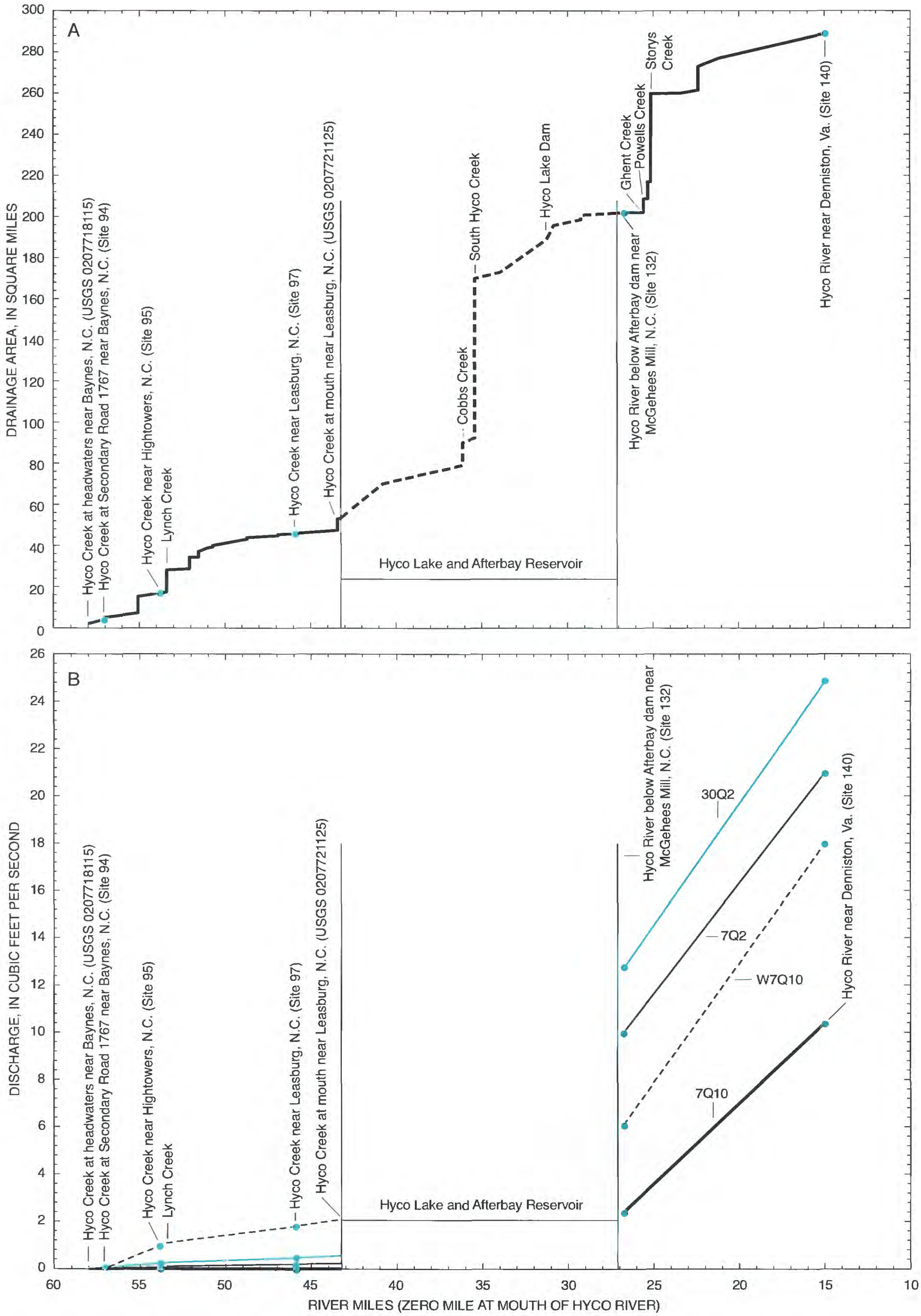

Figure 17. Relation of river miles to (A) drainage area and (B) low-flow discharge for the Hyco River.

Roanoke River

Drainage area and low-flow discharge profiles for the reach of the Roanoke River between Roanoke Rapids Lake and the mouth show the effects of the narrow basin shape and regulation. The basin between Roanoke Rapids Lake and the mouth is very narrow and varies in width from about 8 mi in the reaches downstream from the lake to about 25 mi in the vicinity of Williamston. The drainage-area profile reflects the narrow basin shape by the small increases in drainage area contributed by tributaries. The larger tributaries to the Roanoke occur in the lower reaches of the basin and include Conoho and Welch Creeks; the largest are Cashie and Middle Rivers which merge with the Roanoke River at its mouth (fig. 18A).

The discharge profile depicts low flows for the reach of the river between the gaging stations at Roanoke Rapids (site 181) and at Williamston (site 200) (fig. 18B). Average unit low flows for the regulated period for the gaging stations near Roanoke Rapids and Scotland Neck (sites 181, 194) were applied to the entire reach shown on the profile. The same average unit low flows also were applied to the sites near Oak City and at Williamston (sites 195, 200) in order to extend the profile.

Streamflow records for locations downstream from the gaging station near Oak City are either insufficient or unreliable for use in developing estimates of low flows. Additionally, much of the lower reaches is affected by tides from the Albemarle Sound, making any attempts at estimation subject to large errors. The discharge profiles depict a river with flows during extended dry conditions composed largely of releases from Roanoke Rapids Lake. The unit low flows for partial-record stations on tributaries in the vicinity of Roanoke Rapids show low to moderate potential for sustaining base flow. The transition of underlying geology from Piedmont to Coastal Plain physiographic-province terrain likely results in a soil overburden that has infiltration rates sufficient to allow storage of water in surficial aquifers. In the lower reaches of the basin, the potential for sustained base flow decreases significantly. Giese and Mason (1993) also described the Coastal Plain region as an area having low potential to sustain base flow.

Six NPDES permits exist for facilities which must comply with wastewater-treatment standards before discharging into the river. The largest permitted discharge is for nearly 83 Mgal/d (128 ft^3/s) into the Roanoke River near Plymouth. Because low-flow characteristics cannot be reliably estimated for the Roanoke River at its mouth due to lack of streamflow data and unknown effects of tides, the percentage of permitted flows to the 7Q10 discharge is unknown. However, the ratio of permitted flows in the entire river to the 7Q10 discharge at the gaging station at Roanoke Rapids (site 181) is about 18 percent. The percentage can be regarded as a reliable estimate of the maximum percentage expected at the mouth, because the 7Q10 discharge is not likely to be much higher than the 1,100 ft^3/s at site 181. While low-flow estimates on the Roanoke River would be expected to increase in the downstream direction, the existence of zero or minimal 7Q10 discharge contributions from tributaries plus the unknown effects from tides would limit the magnitude of flow increases.

SUMMARY

This report describes low-flow characteristics for the Roanoke River Basin in North Carolina through the 1994 water year and 1993 climatic year. Low-flow characteristics were summarized for a number of existing gaging stations in the study area, and drainage area and low-flow discharge profiles were developed for selected rivers and streams. Estimates of low flows presented in this report were prepared in cooperation with the North Carolina Division of Environmental Management (DEM) of the Department of Health, Environment, and Natural Resources. In 1991, the DEM began using a basinwide approach in its assessment of water-quality conditions in North Carolina; part of the assessment includes the simultaneous evaluation of National Pollution Discharge Elimination System (NPDES) permits for point-source discharges into streams within the basin. The Roanoke River Basin in North Carolina is one of 17 major river basins selected by the DEM for the purposes of conducting the basinwide assessments.

About 9,700 mi^2 in size, the Roanoke River Basin is located in parts of Virginia and North Carolina. Nearly 36 percent of the basin lies in North Carolina and is drained by the Dan and Roanoke Rivers. The western two-thirds of the study area, drained by the Dan River, is in the Blue Ridge and Piedmont physiographic provinces and is characterized by rolling and hilly topography. The Dan River flows into the Roanoke River in Virginia. The eastern one-third of the basin, drained by the Roanoke River, is in the Coastal

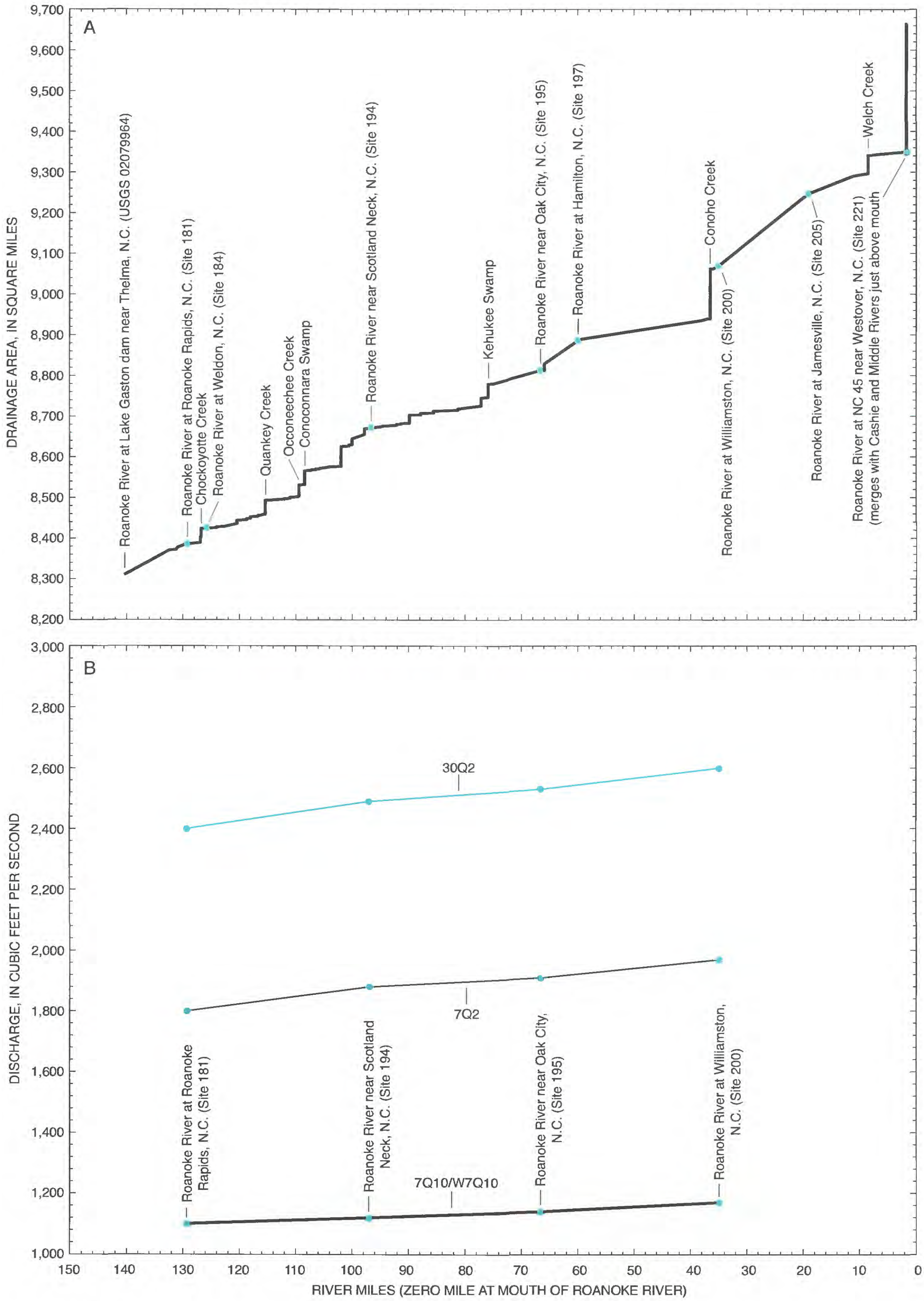

Figure 18. Relation of river miles to (A) drainage area and (B) low-flow discharge for the Roanoke River.

Plain physiographic province, characterized by a gradual transition from gentle, rolling hills with little relief to nearly level land surfaces.

Selected basin characteristics and their known effects on the low-flow characteristics are described in this report. An accounting of the flow modifications caused by impoundments and diversions from and into streams in the study area was made to determine the effects on low-flow characteristics. Nearly 360 impoundments having dams with structural heights exceeding 15 ft were identified in the investigation. Four are major impoundments: Belews Lake, Hyco Lake and Afterbay Reservoir, Mayo Lake, and Roanoke Rapids Lake. These impoundments affect low flows through the minimum releases maintained at each impoundment.

A total of 24 withdrawals exceeding Mgal/d are registered with the State of North Carolina; most are made by municipalities and major industries for water supply and manufacturing purposes. The State also permits 366 point-source discharges under the NPDES permitting system; 17 are deemed by the State as being major discharges. Many of the major withdrawals and return discharges can be paired resulting in negligible effects on low flows. Flow modifications having the most significant effects on low flows are likely those unknown withdrawals in small to mid-size basins which are not required to be registered with the State. Often made for irrigation purposes, the cumulative effect of multiple withdrawals, particularly in basins having low potential to sustain base flows, would be to further reduce the availability of flow for assimilating effluent from point-source discharges. In this report, low flows in the Country Line Creek Basin were determined to be partly affected by irrigation withdrawals known to occur, but in unknown specific amounts.

The variability of average rainfall amounts occurring in the Roanoke River Basin is partly reflected in the potential to sustain low flows in the study area. Higher rainfall amounts in the mountain and foothills regions of Virginia correspond to higher unit low flows at gaging stations in the western portions of the study area. Flows at the long-term continuous-record gaging station at Mayo River near Price (site 38) have high potential to sustain base flows. Similarly, flows observed at long-term gaging stations on the Dan and Smith Rivers have high unit low flows attributable to the higher rainfall amounts which occur within the basin, although some of the high unit flows are attributed to the effects of upstream regulation.

Available documentation of soils was examined to determine the effects on low flows in the study area. Soil infiltration groups, when mapped throughout the study area, correspond to the potential to sustain base flows. In eastern Caswell County and western Person County, the presence of soils classified as having low infiltration rates are reflected in the low potential to sustain base flows for streams in this area. The Country Line Creek Basin occupies this area; a number of sites in the lower half of the basin have zero or minimal 7Q10 discharges (defined as less than 0.1 ft^3/s). Many soils in the study area within the Coastal Plain are also classified as having low infiltration rates. Similarly, the potential for sustaining base flows at many of the gaging stations in this area is low.

Land use in the basin is mostly rural; over 85 percent is classified as agricultural or forest cover. Four percent is urban with Roanoke Rapids being the largest municipality in the study area. Data describing land use in the study area indicates that percentages for most categories have remained relatively unchanged since the mid-1970's. Examination of recent land-use data indicates exceptions to this in areas where agricultural land use has increased while forested land use has decreased. This suggests the possibility that changes in these categories are related. That is, forested areas are being converted to areas for agricultural use. The effects of land use on low flows in the study area are likely insignificant.

Records of surface-water data were identified and compiled for 218 sites in the study area and three sites on the Dan and Hyco Rivers in Virginia. Low-flow characteristics (7Q10, 30Q2, W7Q10, and 7Q2) were determined for 82 sites (22 continuous-record and 60 partial-record). For seven gaging stations having continuous records of daily mean discharge on the Dan and Smith Rivers, a common base period (1950-93 climatic years) was selected for use in determining low-flow characteristics. When unit low flows were plotted on a map of the study area, two general areas of zero or minimal 7Q10 discharges were recognized. A number of sites in eastern Caswell County and western Person County have zero or minimal 7Q10 discharges; as well as many of the sites in lower portions of the Coastal Plain. This poorly sustained base flow is reflective of soils having low infiltration rates; very little water is stored in the surficial aquifers in these areas which results in little to no water being available for release to streams during extended dry conditions.

Drainage area and low-flow discharge profiles were developed for 10 streams and rivers in the study area. Streams profiled in this report include the two mainstems, the Dan and Roanoke Rivers, along with selected tributaries to the Dan River. The selected tributaries include Town Fork Creek, Hogans Creek, Mayo River, Buffalo Creek, Smith River, Country Line Creek, Marlowe Creek, and Hyco River. Drainage-area profiles show increases in the basin size for reaches of the streams in North Carolina. The low-flow discharge profiles depict the 7Q10, 30Q2, W7Q10, and 7Q2 discharges. For a few streams, a profile of actual measurements obtained at multiple points on September 24, 1959; August 14, 1963; July 19, 1966; and September 10, 1968, provide a "snapshot" of actual flow conditions on these dates. For each stream, the percentage of total known permitted NPDES flows to 7Q10 discharge at the mouth or other identified location was determined.

Hogans, Buffalo, and Marlowe Creeks each drain basins less than 25 mi^2. The percentages of permitted flows to 7Q10 discharges at the mouths of Hogans and Buffalo Creeks are 10 and 3 percent, respectively. At Marlowe Creek, the 7Q10 discharges are composed mostly of point-source discharges upstream from site 137. Under what would be considered "natural-flow" conditions, the 7Q10 discharge at this site is 0.2 ft^3/s (table 7). However, the average flow from the point-source discharge is nearly 5 ft^3/s. The low-flow discharge profile shown for Marlowe Creek reflects the presence of the point-source discharge.

Town Fork and Country Line Creeks each drain nearly 140 mi^2 of the study area. The percentages of permitted flows to 7Q10 discharges are 9 and 60 percent, respectively. Eleven point-source discharges which must comply with water-quality standards exist in the Town Fork Creek Basin; however, the potential to sustain base flows in the basin is high, thereby offsetting the effect of the point-source discharges. The higher percentage in the Country Line Creek Basin is not reflective of numerous permitted discharges in the basin, but rather the low 7Q10 discharge determined at the mouth. The existence of soils having low infiltrations rates in combination with irrigation withdrawals in the lower portion of the Country Line Creek Basin result in loss of 7Q10 discharge (between sites 90 and 91).

The Mayo and Smith Rivers drain 297 mi^2 and 546 mi^2, respectively. Much of the basin drained by each river lies in the mountains and foothills regions of Virginia, where average rainfall amounts in combination with significant slopes in topography yield some of the highest unit low flows determined in the investigation. The Mayo River is unaffected by regulation, while the Smith River is affected by regulation from Philpott Lake in Virginia. On the Mayo River, the percentage of permitted flows (in North Carolina) to the 7Q10 discharge at the mouth is less than 3 percent. No known point-source discharges exist on the brief stretch of the Smith River in North Carolina prior to its convergence with the Dan River.

The Dan River drains nearly 3,900 mi^2 of Virginia and North Carolina which includes 1,630 mi^2 of the study area. Profiles for the river were limited to a 130-mi reach between the continuous-record gaging stations at the State line (site 1) and near Paces, Virginia (site 93). Unit low flows for the Dan River vary along the stretch of the river profiled in this report, with the highest values being reported in the uppermost reaches in Stokes County. The major withdrawals and point-source discharges do not have any significant effect on the Dan River; most withdrawals and discharges for a given facility occur within a short distance resulting in negligible losses of flow. The percentage of known permitted flows to the 7Q10 discharge at the gaging station near Mayfield (site 64) is nearly 7 percent.

Drainage area and low-flow profiles for the Roanoke River were limited to the reach of the river downstream from Roanoke Rapids Lake. Flow in the Roanoke River is heavily regulated by a series of lakes which occur along the North Carolina-Virginia State line. The drainage-area profile reflects the narrow shape of the Roanoke River Basin, varying in width from 8 mi in reaches downstream from Roanoke Rapids Lake to about 25 mi near Williamston. The low-flow discharge profiles were limited to the reach of the Roanoke River between Roanoke Rapids (site 181) and Williamston (site 200). Insufficient data in the lower reaches along with unknown effects of tides on low flows prevented development of low-flow discharges. The percentage of permitted NPDES flows to the 7Q10 discharge at the gaging station at Roanoke Rapids (site 181) is about 18 percent.

SELECTED REFERENCES

Barnes, C.R., 1986, Method for estimating low-flow statistics for ungaged streams in the lower Hudson River Basin, New York: U.S. Geological Survey Water-Resources Investigations Report 85-4070, 22 p.

Bingham, R.H., 1985, Low flows and flow duration of Tennessee streams through 1981: U.S. Geological Survey Water-Resources Investigations Report 84-4347, 325 p.

Bondelid, T.R., Hanson, S.A., and Taylor, P.L., 1990, Technical description of the Reach File: U.S. Environmental Protection Agency RF1/2/3 Draft, 17 p.

Carter, R.F., Hopkins, E.H., and Perlman, H.A., 1988, Low-flow profiles of the Upper Savannah and Ogeechee Rivers and tributaries in Georgia: U.S. Geological Survey Water-Resources Investigations Report 88-4047, 169 p.

Daniel, C.C., III, 1989, Statistical analysis relating well yield to construction practices and siting of wells in the Piedmont and Blue Ridge provinces of North Carolina: U.S. Geological Survey Water-Supply Paper 2341-A, 27 p.

Daniel, C.C., III, and Payne, R.A., 1990, Hydrogeologic unit map of the Piedmont and Blue Ridge Provinces of North Carolina: U.S. Geological Survey Water-Resources Investigations Paper 90-4035, 1 sheet, scale 1:500,000.

Evett, J.B., 1994, Effects of urbanization and land-use changes on low stream flow: Raleigh, University of North Carolina Water Resources Research Institute Report No. 284, 146 p.

Fenneman, N.M., 1938, Physiography of Eastern United States: New York, McGraw-Hill, 714 p.

Fransen, T., 1991, Hydrology for 1990, *in* Rulifson, R.A., and Manooch, C.S., III, eds., Roanoke River water flow committee report for 1990: National Ocean and Atmospheric Administration Technical Memorandum NMFS-SEFC-291, p. 139-162.

Giese, G.L., and Mason, R.R., Jr., 1993, Low-flow characteristics of streams in North Carolina: U.S. Geological Survey Water-Supply Paper 2403, 29 p.

Goddard, G.C., Jr., 1963, Water-supply characteristics of North Carolina streams: U.S. Geological Survey Water-Supply Paper 1761, 223 p.

Hale, T.W., Hopkins, E.H., and Carter, R.F., 1989, Effects of the 1988 drought on streamflow in Alabama, Georgia, North Carolina, South Carolina, Tennessee, and Virginia: U.S. Geological Survey Water-Resources Investigations Report 89-4212, 102 p.

Hayes, D.C., 1991, Low-flow characteristics of streams in Virginia: U.S. Geological Survey Water-Supply Paper 2374, 69 p.

Khorram, S., Chesire, H., Siderelis, K., and Nagy, Z., 1991, Mapping and GIS implementation of land use and land cover categories for the Albemarle-Pamlico drainage basin: Raleigh, N.C., Computer Graphics Center, North Carolina State University and the Center for Geographic Information and Analysis, North Carolina Department of Environment, Health, and Natural Resources, 53 p.

Kopec, R.J., and Clay, J.W., 1975, Climate and air quality, *in* North Carolina atlas: Portrait of a changing southern State, 1975: Chapel Hill, University of North Carolina Press, p. 92-111.

Langbein, W.B., and Iseri, K.T., 1960, General introduction and hydrologic definitions: U.S. Geological Survey Water-Supply Paper 1541-A, 29 p.

McMahon, G., and Lloyd, O.B., Jr., 1995, Water-quality assessment of the Albemarle-Pamlico drainage basin, North Carolina and Virginia—Environmental setting and water-quality issues: U.S. Geological Survey Open-File Report 95-136, 72 p.

Mitchell, W.B., Guptill, S.C., Anderson, K.E., Fegras, R.G., and Hallam, C.A., 1977, GIRAS—A geographic information and retrieval system for handling land use and land cover data: U.S. Geological Survey Professional Paper 1059, 16 p.

Musgrave, G.W., 1955, How much of the rain enters the soil?, *in* Water: The yearbook of agriculture 1955: U.S. Department of Agriculture, p. 151-159.

Musgrave, G.W., and Holtan, H.N., 1964, Infiltration, *in* Te Chow, Ven, ed., Handbook of applied hydrology—A compendium of water-resources technology: New York, McGraw-Hill Book Co., Section 12, p. 12-26.

Nelms, D.L., Harlow, G.E., Jr., and Hayes, D.C., 1995, Base-flow characteristics of streams in the Valley and Ridge, Blue Ridge, and Piedmont physiographic provinces of North Carolina: U.S. Geological Survey Open-File Report 95-298, 52 p.

National Oceanic and Atmospheric Administration, 1992, Climatological data annual summary: North Carolina: National Oceanic and Atmospheric Administration, issued annually.

North Carolina Department of Environment, Health, and Natural Resources: 1992, North Carolina lake assessment report: Division of Environmental Management, Water Quality Section, Report 92-02, 353 p.

——— 1996, Roanoke River Basin-wide water quality management plan: draft report, 300 p.

North Carolina Department of Natural Resources and Community Development, 1985, Geologic map of North Carolina: 1 sheet, scale 1:500,000.

Outlaw, G.S., and Weaver, J.D., 1996, Flow duration and low flows of Tennessee streams through 1992: U.S. Geological Survey Water-Resources Investigations Report 95-4293, 245 p.

Riggs, H.C., 1968, Frequency curves: U.S. Geological Survey Techniques of Water-Resources Investigations, book 4, chap. A2, 15 p.

——— 1972, Low-flow investigations: U.S. Geological Survey Techniques of Water-Resources Investigations, book 4, chap. B1, 15 p.

——— 1973, Regional analyses of streamflow characteristics: U.S. Geological Survey Techniques of Water-Resources Investigations, book 4, chap. B3, 15 p.

Seaber, P.R., Kapinos, F.P., and Knapp, G.L., 1987, Hydrologic unit maps: U.S. Geological Survey Water-Supply Paper 2294, 63 p.

Stedinger, J.R., and Thomas, W.O., Jr., 1985, Low-flow frequency estimation using base-flow measurements: U.S. Geological Survey Open-File Report 85-95, 22 p.

Strickland, A.G., and Bales, J.D., 1994, Simulation of unsteady flow in the Roanoke River from near Oak City to Williamston: U.S. Geological Survey Water-Supply Paper 2408-A, 34 p.

Stuckey, J.L., 1965, North Carolina: Its geology and mineral resources: Raleigh, Department of Conservation and Development, 550 p.

Tant, P.L., Byrd, H.J., and Horton, R.E., 1974, General soil map of North Carolina: U.S. Department of Agriculture, Soil Conservation Service map, 1 sheet, scale 1:1,000,000.

Telis, P.A., 1991, Low-flow and flow-duration characteristics of Mississippi streams: U.S. Geological Survey Water-Resources Investigations Report 90-4087, 214 p.

——— 1992, Techniques for estimating 7-day, 10-year low-flow characteristics for ungaged sites on streams in Mississippi: U.S. Geological Survey Water-Resources Investigations Report 91-4130, 143 p.

Terziotti, S., Schrader, T.P., and Treece, M.W., Jr., 1994, Estimated water use, by county, in North Carolina, 1990: U.S. Geological Survey Open-File Report 94-522, 102 p.

U.S. Department of Agriculture, 1910, Soil survey of Caswell County, North Carolina: Bureau of Soils, 28 p.

——— 1912, Soil survey of Granville County, North Carolina: Bureau of Soils, 44 p.

——— 1918, Soil survey of Halifax County, North Carolina: Bureau of Soils, 47 p.

——— 1925, Soil survey of Northampton County, North Carolina: Bureau of Chemistry and Soils, 48 p.

——— 1928, Soil survey of Martin County, North Carolina: Bureau of Chemistry and Soils, 32 p.

——— 1928, Soil survey of Person County, North Carolina: Bureau of Chemistry and Soils, 36 p.

——— 1940, Soil survey [of] Stokes County, North Carolina: Bureau of Plant Industry, 39 p.

——— 1942, Soil survey [of] Warren County, North Carolina: Bureau of Plant Industry, 37 p.

——— 1980, Soil survey of Vance County, North Carolina: Soil Conservation Service, 94 p.

——— 1990, Soil survey of Bertie County, North Carolina: Soil Conservation Service, 115 p.

——— 1992, Soil survey of Rockingham County, North Carolina: Soil Conservation Service, 152 p.

U.S. Geological Survey, 1961-94, Water resources data for North Carolina: U.S. Geological Survey Water-Data Report, issued annually.

——— 1974, Hydrologic unit map: State of North Carolina: 1 sheet, scale 1:500,000.

——— 1974, Hydrologic unit map: State of Virginia: 1 sheet, scale 1:500,000.

Yonts, W.L., 1972, Low-flow measurements of North Carolina streams: Raleigh, North Carolina Department of Water and Air Resources, 236 p.

Yonts, W.L., Giese, G.L., and Hubbard, E.F., 1973, Evaporation from Lake Michie, North Carolina 1961-71: U.S. Geological Survey Water-Resources Investigations 38-73, 27 p.

Zalants, M.G., 1991, Low-flow frequency and flow duration of selected South Carolina streams through 1987: U.S. Geological Survey Water-Resources Investigations Report 91-4170, 87 p.

Zembrzuski, T.J., Jr., Hill, C.L., Weaver, J.C., Coble, R.W., and Gunter, H.C., 1991, North Carolina floods and droughts, *in* National Water Summary 1988-89—Hydrologic events and floods and droughts: U.S. Geological Survey Water-Supply Paper 2375, p. 425-434.

Table 5. Summary of continuous- and partial-record gaging stations in the Roanoke River Basin study area in North Carolina where records of gage height and streamflow were collected

[mi^2, square mile; N/A, not applicable; SEO, sewage effluent outfall. Sites shaded in gray indicate those sites for which low-flow characteristics have been developed. Period of record for continuous-record sites (site type 1) shown in months and years; period of record for partial-record sites (site type 2) shown is water years in which discharge measurements were made.]

Site index no.	USGS downstream order number	Station name	Latitude	Longitude	County	USGS topographic quad name	Drainage area, (mi^2)	Tributary to	Hydrologic unit code	Site type	Period of record	Number of measurements for partial-record sites: Flow	Number of measurements for partial-record sites: Zero-flow
1	02068000	Dan River near Asbury	36°32'35"	80°24'42"	Stokes	Claudeville	71.4	Roanoke River	03010103	1	Sept 1924 - Sept 1926	N/A	N/A
2	02068012	Little Dan River above SEO near Asbury	36°32'52"	80°22'58"	Stokes	Claudeville	28.0	Dan River	03010103	2	1970, 1974	4	0
3	0206835750	Dan River at SR 1432 at Jessup Mill	36°31'33"	80°22'16"	Stokes	Stuart SE	110	Roanoke River	03010103	2	1970, 1974, 1976-81	21	0
4	02068500	Dan River near Francisco	36°30'53"	80°18'11"	Stokes	Stuart SE	129	Roanoke River	03010103	1	Sept 1924 - Sept 1926, Apr 1927 - Oct 1987, Dec 1991 - Sept 1994	N/A	N/A
5	02068504	Peters Creek near Lawsonville	36°29'12"	80°16'28"	Stokes	Hanging Rock	32.0	Dan River	03010103	2	1963	1	0
6	02068512	Big Creek near Francisco	36°28'17"	80°22'13"	Stokes	Hanging Rock	18.9	Dan River	03010103	2	1959, 1963	2	0
7	02068522	Pinch Gut Creek near Francisco	36°28'03"	80°22'18"	Stokes	Hanging Rock	11.2	Big Creek	03010103	2	1959, 1963	2	0
8	02068536	Dan River at NC 89 near Moores Springs	36°26'53"	80°17'07"	Stokes	Hanging Rock	172	Roanoke River	03010103	2	1970	3	0
9	02068537	Big Creek near Moores Springs	36°26'59"	80°17'15"	Stokes	Hanging Rock	44.6	Dan River	03010103	2	1955-56, 1963	3	0
10	02068552	North Double Creek near Vade Mecum	36°26'23"	80°18'41"	Stokes	Hanging Rock	12.4	Dan River	03010103	2	1959, 1963	2	0
11	02068574	North Double Creek near Moores Springs	36°25'55"	80°17'40"	Stokes	Hanging Rock	13.30	Dan River	03010103	2	1955-56, 1963	3	0
12	02068606	South Double Creek near Vade Mecum	36°25'39"	80°18'57"	Stokes	Hanging Rock	10.4	Dan River	03010103	2	1959, 1963	2	0
13	02068638	Dan River at Danbury	36°24'33"	80°11'52"	Stokes	Danbury	276	Roanoke River	03010103	2	1970	3	0
14	02068720	Snow Creek near Prestonville	36°27'44"	80°09'01"	Stokes	Danbury	22.7	Dan River	03010103	2	1955-56, 1964-68, 1970, 1980	19	0
15	0206872225	Snow Creek tributary near Prestonville	36°27'11"	80°08'51"	Stokes	Danbury	1.00	Snow Creek	03010103	2	1963	1	0
16	02068723	Snow Creek near Hartman	36°26'33"	80°08'29"	Stokes	Danbury	31.9	Dan River	03010103	2	1959, 1965	2	0
17	02068732	Snow Creek near Dillard	36°24'12"	80°08'28"	Stokes	Danbury	43.9	Dan River	03010103	2	1959, 1963	2	0

Table 5. Summary of continuous- and partial-record gaging stations in the Roanoke River Basin study area in North Carolina where records of gage height and streamflow were collected (Continued)

[mi^2, square mile; N/A, not applicable; SEO, sewage effluent outfall. Sites shaded in gray indicate those sites for which low-flow characteristics have been developed. Period of record for continuous-record sites (site type 1) shown in months and years; period of record for partial-record sites (site type 2) shown is water years in which discharge measurements were made.]

Site index no.	USGS downstream order number	Station name	Latitude	Longitude	County	USGS topographic quad name	Drainage area, (mi^2)	Tributary to	Hydrologic unit code	Site type	Period of record	Number of measurements for partial-record sites: Flow	Number of measurements for partial-record sites: Zero-flow
18	02068734	Dan River near Dodgetown	36°24'06"	80°08'21"	Stokes	Danbury	335	Roanoke River	03010103	2	1970	3	0
19	02068762	Dan River near Walnut Cove	36°19'36"	80°05'44"	Stokes	Belews Lake	355	Roanoke River	03010103	2	1970, 1974	5	0
20	02068856	Town Fork Creek near Poplar Springs	36°16'24"	80°16'27"	Stokes	King	20.1	Dan River	03010103	2	1959, 1963, 1981	3	0
21	02068891	Buffalo Creek at Germanton	36°15'51"	80°13'47"	Stokes	Walnut Cove	15.0	Town Fork Creek	03010103	2	1959, 1963	2	0
22	02068892	Neatmans Creek near Germanton	36°16'58"	80°15'26"	Stokes	King	17.0	Town Fork Creek	03010103	2	1959, 1963, 1981	3	0
23	02068904	Voss Creek near Walnut Cove	36°16'45"	80°11'31"	Stokes	Walnut Cove	4.89	Town Fork Creek	03010103	2	1970, 1973-74	5	0
24	02068911	Old Field Creek near Walnut Cove	36°16'37"	80°10'05"	Stokes	Walnut Cove	16.0	Town Fork Creek	03010103	2	1959, 1963, 1981	3	0
25	02068931	Mills Creek at Walnut Cove	36°17'39"	80°08'50"	Stokes	Walnut Cove	9.86	Town Fork Creek	03010103	2	1955-56, 1963	3	0
26	02068980	Town Fork Creek at Walnut Cove	36°17'29"	80°08'29"	Stokes	Walnut Cove	113	Dan River	03010103	2	1925, 1949-1957, 1959, 1961-63, 1966, 1970, 1973, 1974	39	0
27	02068988	Lick Creek at Walnut Cove	36°17'10"	80°08'13"	Stokes	Walnut Cove	13.5	Town Fork Creek	03010103	2	1959, 1963, 1981	3	0
28	02069000	Dan River at Pine Hall	36°19'09"	80°03'01"	Stokes	Belews Lake	501	Roanoke River	03010103	1	Oct 1923 - Mar 1926, Apr 1986 - Dec 1990, Feb 1991	N/A	N/A
										2	1975-77, 1979-81, 1983	33	0
29	02069032	Belews Creek at Belews Creek[1]	36°14'25"	80°04'10"	Forsyth	Belews Creek	22.8	Dan River	03010103	2	1959, 1963	2	0
30	02069034	East Belews Creek near Grims Crossroads	36°12'20"	80°02'57"	Forsyth	Belews Creek	5.52	Belews Creek	03010103	2	1959, 1963	2	0
31	02069036	East Belews Creek near Belews Creek[1]	36°14'20"	80°03'00"	Forsyth	Belews Creek	16.9	Belews Creek	03010103	2	1963	1	0

Table 5. Summary of continuous- and partial-record gaging stations in the Roanoke River Basin study area in North Carolina where records of gage height and streamflow were collected (Continued)

[mi^2, square mile; N/A, not applicable; SEO, sewage effluent outfall. Sites shaded in gray indicate those sites for which low-flow characteristics have been developed. Period of record for continuous-record sites (site type 1) shown in months and years; period of record for partial-record sites (site type 2) shown is water years in which discharge measurements were made.]

Site index no.	USGS downstream order number	Station name	Latitude	Longitude	County	USGS topographic quad name	Drainage area, (mi^2)	Tributary to	Hydrologic unit code	Site type	Period of record	Number of measurements for partial-record sites: Flow	Number of measurements for partial-record sites: Zero-flow
32	02069037	Belews Creek near Walnut Cove[1]	36°15'56"	80°02'58"	Stokes	Belews Lake	41.9	Dan River	03010103	2	1955, 1959, 1963	3	0
33	02069044	West Belews Creek near Walnut Cove[1]	36°16'32"	80°04'02"	Stokes	Belews Lake	12.0	Belews Creek	03010103	2	1955, 1959, 1963	3	0
34	02069050	Belews Creek near Pine Hall	36°19'42"	80°01'42"	Rockingham	Belews Lake	72.2	Dan River	03010103	2	1953-60, 1962-63, 1966	26	0
35	02069222	Dan River at Madison Industrial Site	36°22'29"	79°59'33"	Rockingham	Ellisboro	603	Roanoke River	03010103	2	1970, 1974, 1976-77, 1979-81	17	0
36	02069410	Big Beaver Island Creek near Madison	36°22'59"	79°58'51"	Rockingham	Mayodan	23.8	Dan River	03010103	2	1953-59, 1961-63, 1966	29	0
37	02069476	Little Beaver Island Creek at Madison	36°22'58"	79°58'56"	Rockingham	Mayodan	14.3	Big Beaver Island Creek	03010103	2	1966	1	0
38	02070500	Mayo River near Price	36°32'02"	79°59'30"	Rockingham	Price	[2]242	Dan River	03010103	1	Aug 1929 - Oct 1971, Oct 1993 - Sept 1994	N/A	N/A
										2	1981, 1985-93	15	0
39	02070528	Pawpaw Creek near Stoneville	36°30'20"	79°57'50"	Rockingham	Price	7.61	Mayo River	03010103	2	1954, 1959, 1963	3	0
40	02070558	Boaz Creek near Stoneville	36°27'48"	79°55'18"	Rockingham	Mayodan	2.48	Mayo River	03010103	2	1970, 1973	6	0
41	02070559	Boaz Creek below SEO near Stoneville	36°27'26"	79°55'45"	Rockingham	Mayodan	3.00	Mayo River	03010103	2	1970, 1973	6	0
42	02070576	Mayo River tributary above SEO near Mayodan	36°27'00"	79°54'03"	Rockingham	Mayodan	1.16	Mayo River	03010103	2	1970, 1973	6	0
43	02070578	Mayo River tributary near Mayodan	36°26'24"	79°55'52"	Rockingham	Mayodan	4.10	Mayo River	03010103	2	1970, 1973	6	0
44	02070598	Mayo River at Mayodan	36°24'27"	79°57'58"	Rockingham	Mayodan	[2]294	Dan River	03010103	2	1970, 1973	5	0
45	02070608	Mayo River at mouth near Madison	36°23'32"	79°57'11"	Rockingham	Mayodan	[2]297	Dan River	03010103	2	1970	3	0
46	02070658	Hogans Creek at Ellisboro	36°20'16"	79°57'45"	Rockingham	Ellisboro	16.7	Dan River	03010103	2	1959, 1963	2	0
47	02070720	Hogans Creek near Madison	36°22'54"	79°54'30"	Rockingham	Mayodan	23.9	Dan River	03010103	2	1954, 1956-64, 1966	27	0
48	02070810	Jacobs Creek near Wentworth	36°20'54"	79°53'14"	Rockingham	Ellisboro	16.4	Dan River	03010103	2	1963	1	0
49	02070930	Jacobs Creek at NC 704 near Madison	36°22'46"	79°52'36"	Rockingham	Mayodan	36.2	Dan River	03010103	2	1954, 1959, 1963-67, 1969, 1970	13	0

Table 5. Summary of continuous- and partial-record gaging stations in the Roanoke River Basin study area in North Carolina where records of gage height and streamflow were collected (Continued)

[mi^2, square mile; N/A, not applicable; SEO, sewage effluent outfall. Sites shaded in gray indicate those sites for which low-flow characteristics have been developed. Period of record for continuous-record sites (site type 1) shown in months and years; period of record for partial-record sites (site type 2) shown is water years in which discharge measurements were made.]

Site index no.	USGS downstream order number	Station name	Latitude	Longitude	County	USGS topographic quad name	Drainage area, (mi^2)	Tributary to	Hydrologic unit code	Site type	Period of record	Number of measurements for partial-record sites: Flow	Number of measurements for partial-record sites: Zero-flow
50	02071000	Dan River near Wentworth	36°24'45"	79°49'35"	Rockingham	SW Eden	[2]1,035	Roanoke River	03010103	1	Dec 1939 - Oct 1994	N/A	N/A
51	02071003	Rock House Creek near Wentworth	36°23'48"	79°47'24"	Rockingham	Southwest Eden	18.4	Dan River	03010103	2	1954, 1959, 1963	3	0
52	02071033	Buffalo Creek above Eden	36°29'26"	79°51'17"	Rockingham	Southwest Eden	7.41	Dan River	03010103	2	1959, 1963, 1981	3	0
53	02071063	Buffalo Creek Branch near Stoneville	36°29'06"	79°52'18"	Rockingham	Southwest Eden	3.11	Buffalo Creek	03010103	2	1954, 1970, 1973, 1981	8	0
54	02071110	Buffalo Creek near Eden	36°28'41"	79°49'16"	Rockingham	Southwest Eden	16.3	Dan River	03010103	2	1954, 1963	3	0
55	02071113	Buffalo Creek near Stoneville	36°28'21"	79°48'26"	Rockingham	Southwest Eden	21.3	Dan River	03010103	2	1954, 1959, 1963, 1981	4	0
56	02071500	Dan River at Eden	36°29'09"	79°45'24"	Rockingham	Southwest Eden	1,133[a]	Roanoke River	03010103	1	Aug 1929 - Sept 1949	N/A	N/A
57	02074000	Smith River at Eden	36°31'31"	79°45'57"	Rockingham	Northwest Eden	538	Dan River	03010103	1	Oct 1939 - Sept 1994	N/A	N/A
58	02074018	Dan River near Eden	36°28'18"	79°44'52"	Rockingham	Southeast Eden	[2]1,682	Roanoke River	03010103	2	1970, 1973-74	6	0
59	02074021	Dan River below SEO near Eden	36°28'26"	79°44'11"	Rockingham	Southeast Eden	[2]1,683	Roanoke River	03010103	2	1970	3	0
60	02074056	Town Creek near Eden	36°28'44"	79°42'12"	Rockingham	Southeast Eden	12.3	Dan River	03010103	2	1954, 1959, 1963, 1981	4	0
61	02074062	Machine Creek at SR 1974 near Eden	36°28'38"	79°42'02"	Rockingham	Southeast Eden	2.28	Town Creek	03010103	2	1954, 1959, 1963, 1981	4	0
62	02074082	Dan River at NC 700 at Eden	36°29'55"	79°40'53"	Rockingham	Southeast Eden	[2]1,708	Roanoke River	03010103	2	1970, 1973	5	0
63	02074188	Mountain Run near Draper	36°32'00"	79°38'50"	Rockingham	Northeast Eden	7.30	Cascade Creek	03010103	2	1958, 1963	2	1
64	02074218	Dan River near Mayfield	36°32'29"	79°36'21"	Rockingham	Brosville	[2]1,760	Roanoke River	03010103	1	Sept 1976 - Nov 1984	N/A	N/A
										2	1968-72, 1974-75	25	0
65	02074282	Wolf Island Creek at Reidsville	36°22'20"	79°41'10"	Rockingham	Reidsville	3.71	Dan River	03010103	2	1954, 1970, 1973-74, 1976-81	19	0
66	02074292	Wolf Island Creek near Reidsville	36°23'28"	79°40'11"	Rockingham	Southeast Eden	7.10	Dan River	03010103	2	1970, 1973-74	8	0

Table 5. Summary of continuous- and partial-record gaging stations in the Roanoke River Basin study area in North Carolina where records of gage height and streamflow were collected (Continued)

[mi², square mile; N/A, not applicable; SEO, sewage effluent outfall. Sites shaded in gray indicate those sites for which low-flow characteristics have been developed. Period of record for continuous-record sites (site type 1) shown in months and years; period of record for partial-record sites (site type 2) shown is water years in which discharge measurements were made.]

Site index no.	USGS downstream order number	Station name	Latitude	Longitude	County	USGS topographic quad name	Drainage area, (mi²)	Tributary to	Hydrologic unit code	Site type	Period of record	Number of measurements for partial-record sites: Flow	Zero-flow
67	02074360	Wolf Island Creek near Pelham	36°31'54"	79°30'07"	Caswell	Brosville	68.7	Dan River	03010103	2	1954, 1956-64, 1966, 1968, 1970, 1974-79, 1981, 1983-84	59	0
68	02075000	Dan River at Danville (Va.)	36°35'15"	79°22'55"	Danville City	Danville	2,050	Roanoke River	03010104	1	Aug 1934 - Sept 1994	N/A	N/A
69	0207506085	Hogans Creek at Casville	36°23'56"	79°31'49"	Rockingham	Ruffin	40.3	Dan River	03010104	2	1959, 1963, 1968	3	0
70	02075082	Hogans Creek near Pelham	36°27'56"	79°27'50"	Caswell	Park Spring	79.2	Dan River	03010104	2	1966, 1968	2	0
71	02075090	Hogans Creek near Providence	36°30'54"	79°22'56"	Caswell	Danville	98.4	Dan River	03010104	2	1953-54, 1956-60, 1963, 1966, 1968, 1970	29	2
72	02075113	Moon Creek near Park Springs	36°26'19"	79°26'56"	Caswell	Park Spring	8.44	Dan River	03010104	2	1966, 1968	2	0
73	02075124	West Prong Moon Creek near Yanceyville	36°25'07"	79°24'50"	Caswell	Park Spring	4.97	Moon Creek	03010104	2	1959, 1963, 1966, 1968	4	0
74	02075142	East Prong Moon Creek near Yanceyville	36°24'52"	79°24'43"	Caswell	Park Spring	7.15	Moon Creek	03010104	2	1959, 1963, 1966, 1968	4	0
75	02075160	Moon Creek near Yanceyville	36°28'04"	79°23'05"	Caswell	Park Spring	32.8	Dan River	03010104	1	Oct 1961 - Dec 1974, May 1988 - Sept 1989	N/A	N/A
76	02075170	Moon Creek near Providence	36°29'23"	79°21'57"	Caswell	Yanceyville	41.2	Dan River	03010104	2	1954, 1956-64, 1966, 1968, 1970	31	1
77	02075183	North Fork Rattlesnake Creek near Purley	36°27'28"	79°19'36"	Caswell	Yanceyville	4.66	Rattlesnake Creek	03010104	2	1966, 1968	2	1
78	02075187	South Fork Rattlesnake Creek near Hamer	36°27'30"	79°17'45"	Caswell	Yanceyville	7.70	Rattlesnake Creek	03010104	2	1966, 1968	2	1
79	02075190	Rattlesnake Creek at Blanch	36°30'28"	79°17'37"	Caswell	Ringgold	23.7	Dan River	03010104	2	1954, 1959, 1961-64, 1966, 1968, 1970	14	1
80	02075198	Dan River at Milton	36°32'27"	79°12'53"	Caswell	Milton	[2]2,310	Roanoke River	03010104	2	1970, 1974, 1976-79	10	0
81	0207520780	Country Line Creek at SR 1146 near Ashland	36°18'47"	79°30'39"	Caswell	Williamsburg	6.58	Dan River	03010104	2	1974-81	17	0

Table 5. Summary of continuous- and partial-record gaging stations in the Roanoke River Basin study area in North Carolina where records of gage height and streamflow were collected (Continued)

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Site index no.	USGS downstream order number	Station name	Latitude	Longitude	County	USGS topographic quad name	Drainage area, (mi^2)	Tributary to	Hydrologic unit code	Site type	Period of record	Number of measurements for partial-record sites	
												Flow	Zero-flow
82	02075208	Country Line Creek near Locust Hill	36°21'20"	79°26'19"	Caswell	Cherry Grove	22.6	Dan River	03010104	2	1959, 1963, 1966, 1968	4	0
83	02075209	Hostler Branch at Locust Hill	36°21'58"	79°26'27"	Caswell	Cherry Grove	6.95	Country Line Creek	03010104	2	1966, 1968	2	0
84	02075217	Country Line Creek near Yanceyville	36°23'07"	79°21'31"	Caswell	Yanceyville	46.8	Dan River	03010104	2	1970, 1973-74	6	0
85	02075220	Country Line Creek at Yanceyville	36°23'30"	79°19'54"	Caswell	Yanceyville	50.3	Dan River	03010104	2	1954, 1956-62, 1966, 1970, 1973	23	0
86	02075230	South Country Line Creek near Hightowers	36°18'47"	79°18'36"	Caswell	Anderson	6.57	Country Line Creek	03010104	2	1953, 1959, 1963, 1966, 1968, 1970	6	5
87	02075240	South Country Line Creek near Topnot	36°20'44"	79°17'27"	Caswell	Anderson	16.4	Country Line Creek	03010104	2	1962-69	20	8
88	02075250	Penson Creek near Yanceyville	36°20'54"	79°17'34"	Caswell	Anderson	12.2	South Country Line Creek	03010104	2	1959, 1963-68, 1970	19	4
89	02075260	South Country Line Creek near Yanceyville	36°20'50"	79°17'24"	Caswell	Anderson	29.0	Country Line Creek	03010104	2	1949-53, 1956-60, 1962-66, 1968	33	4
90	02075268	Country Line Creek near Hamer	36°26'57"	79°15'12"	Caswell	Yanceyville	113	Dan River	03010104	2	1966, 1968	2	0
91	02075270	Country Line Creek near Semora	36°29'54"	79°12'25"	Caswell	Leasburg	131	Dan River	03010104	2	1954, 1956-68, 1970, 1973-74	38	1
92	0207527050	Country Line Creek at NC 57 at Milton	36°32'16"	79°12'04"	Caswell	Milton	138	Dan River	03010104	2	1974-84	35	0
93	02075500	Dan River at Paces (Va.)	36°38'32"	79°05'23"	Halifax (Va.)	Oak Level	2,550	Roanoke River	03010104	1	Nov 1950 - Sept 1994	N/A	N/A
94	0207718130	Hyco Creek at SR 1767 near Baynes	36°17'15"	79°15'43"	Caswell	Anderson	5.00	Dan River	03010104	2	1974-81	19	0
95	02077182	Hyco Creek near Hightowers	36°19'07"	79°13'35"	Caswell	Ridgeville	16.9	Dan River	03010104	2	1959, 1963, 1966, 1968	4	2
96	02077192	Panther Creek near Frogsboro	36°19'54"	79°12'31"	Caswell	Ridgeville	5.49	Hyco Creek	03010104	2	1966, 1968	2	0
97	02077200	Hyco Creek near Leasburg	36°23'57"	79°11'50"	Caswell	Leasburg	45.9	Dan River	03010104	1	Aug 1964 - Sept 1994	N/A	N/A
98	02077214	Reedy Fork Creek near Leasburg	36°25'06"	79°13'57"	Caswell	Leasburg	9.29	Hyco Creek	03010104	2	1964-66, 1968, 1970	9	6

Table 5. Summary of continuous- and partial-record gaging stations in the Roanoke River Basin study area in North Carolina where records of gage height and streamflow were collected (Continued)

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Site index no.	USGS downstream order number	Station name	Latitude	Longitude	County	USGS topographic quad name	Drainage area, (mi^2)	Tributary to	Hydrologic unit code	Site type	Period of record	Number of measurements for partial-record sites: Flow	Number of measurements for partial-record sites: Zero-flow
99	02077216	Reedy Fork Creek near Osmond[1]	36°26'58"	79°10'58"	Caswell	Leasburg	17.0	Hyco Creek	03010104	2	1959, 1963	2	1
100	02077217	Hyco Creek tributary 1 near Semora	36°28'45"	79°09'23"	Caswell	Leasburg	0.29	Hyco Creek	03010104	2	1965	1	0
101	02077218	Hyco Creek tributary 2 near Semora	36°28'51"	79°09'12"	Caswell	Leasburg	0.22	Hyco Creek	03010104	2	1965, 1964	2	1
102	02077219	Hyco Creek tributary 3 near Semora	36°28'33"	79°08'28"	Person	Leasburg	0.12	Hyco Creek	03010104	2	1965	1	1
103	02077222	Hyco Creek tributary 4 near Semora	36°28'35"	79°08'25"	Person	Leasburg	0.07	Hyco Creek	03010104	2	1965	1	1
104	02077223	Hyco Creek tributary 5 near Cunningham	36°28'46"	79°08'07"	Person	Leasburg	0.19	Hyco Creek	03010104	2	1965	1	1
105	02077224	Hyco Creek tributary 6 near Cunningham	36°28'53"	79°08'00"	Person	Leasburg	0.15	Hyco Creek	03010104	2	1965	1	1
106	02077225	Hyco Creek near Roxboro[1]	36°28'32"	79°06'59"	Person	Olive Hill	78.0	Dan River	03010104	2	1949-54, 1956-59, 1961-64	33	4
107	0207722510	Cobbs Creek near Leasburg	36°23'41"	79°08'51"	Caswell	Leasburg	1.23	Hyco Creek	03010104	2	1965-66, 1968	4	1
108	02077226	Cobbs Creek near Concord[1]	36°28'14"	79°06'42"	Person	Olive Hill	11.0	Hyco Creek	03010104	2	1964	5	0
109	02077227	South Hyco Creek near Gordonton	36°16'00"	79°08'50"	Person	Ridgeville	10.5	Hyco River	03010104	2	1968, 1976, 1978-81, 1983-84	24	2
110	02077228	South Hyco Creek near Ridgeville	36°18'33"	79°09'06"	Caswell	Ridgeville	19.0	Hyco River	03010104	2	1966	1	0
111	02077230	South Hyco Creek near Hesters Store	36°21'06"	79°08'29"	Person	Ridgeville	31.7	Hyco River	03010104	1	Jun 1964 - Sept 1967	N/A	N/A
										2	1968	1	1
112	02077238	Broachs Mill Creek near Hesters Store	36°19'53"	79°06'49"	Person	Hurdle Mills	3.72	South Hyco Creek	03010104	2	1964-65, 1968	6	1
113	02077240	Double Creek near Roseville	36°21'44"	79°05'48"	Person	Hurdle Mills	7.47	Mill Creek	03010104	1	Jun 1964 - Oct 1975, Mar 1977 - Dec 1982	N/A	N/A
114	02077250	South Hyco Creek near Roseville	36°23'09"	79°06'26"	Person	Olive Hill	56.5	Hyco River	03010104	1	Oct 1966 - Jul 1980, Sept 1980 - Oct 1980	N/A	N/A
115	02077251	Cub Creek at mouth near Longs Store	36°24'26"	79°06'35"	Person	Olive Hill	1.87	South Hyco Creek	03010104	2	1965-66	3	2

Table 5. Summary of continuous- and partial-record gaging stations in the Roanoke River Basin study area in North Carolina where records of gage height and streamflow were collected (Continued)

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Site index no.	USGS downstream order number	Station name	Latitude	Longitude	County	USGS topographic quad name	Drainage area, (mi^2)	Tributary to	Hydrologic unit code	Site type	Period of record	Number of measurements for partial-record sites: Flow	Number of measurements for partial-record sites: Zero-flow
116	02077252	South Hyco Creek near Longs Store[1]	36°25'08"	79°06'14"	Person	Olive Hill	61.9	Hyco River	03010104	2	1959, 1963	2	0
117	02077254	Richland Creek near Roseville	36°24'01"	79°04'42"	Person	Olive Hill	5.79	South Hyco Creek	03010104	2	1964-66, 1968, 1970	8	2
118	02077256	Richland Creek near Longs Store	36°25'04"	79°05'58"	Person	Olive Hill	7.96	South Hyco Creek	03010104	2	1959, 1963, 1965	4	0
119	02077258	Duck Creek near Concord	36°26'36"	79°05'05"	Person	Olive Hill	4.30	South Hyco Creek	03010104	2	1965	2	0
120	02077260	South Hyco Creek near Concord[1]	36°27'48"	79°05'34"	Person	Olive Hill	76.5	Hyco River	03010104	2	1953-54, 1956-64	28	1
121	02077261	Sargents Creek near Ceffo	36°27'06"	79°03'27"	Person	Olive Hill	1.77	Hyco River	03010104	2	1965-66, 1968	4	0
122	0207726250	Cane Creek near McGehees Mill	36°30'08"	79°05'53"	Person	Alton	3.05	Hyco River	03010104	2	1965	1	0
123	0207726275	Cane Creek tributary 4 near McGehees Mill	36°30'07"	79°05'53"	Person	Alton	0.06	Cane Creek	03010104	2	1965	1	1
124	0207726350	Cane Creek tributary 3 near McGehees Mill	36°30'49"	79°05'34"	Person	Alton	1.80	Cane Creek	03010104	2	1965	1	0
125	0207726365	Unnamed tributary to Cane Creek tributary 3 near McGehees Mill	36°30'48"	79°05'34"	Person	Alton	0.02	Cane Creek tributary 3	03010104	2	1965	1	1
126	0207726375	Unnamed tributary to Cane Creek tributary 3 near McGehees Mill	36°30'49"	79°05'26"	Person	Alton	0.02	Cane Creek tributary 3	03010104	2	1965	1	1
127	0207726410	Cane Creek tributary 2 near McGehees Mill	36°31'38"	79°04'05"	Person	Alton	0.69	Cane Creek	03010104	2	1965	1	0
128	0207726425	Unnamed tributary to Cane Creek tributary 2 near McGehees Mill	36°31'34"	79°04'11"	Person	Alton	0.48	Cane Creek tributary 2	03010104	2	1965	1	0
129	0207726450	Unnamed tributary to Cane Creek tributary 2 near McGehees Mill	36°31'32"	79°03'44"	Person	Alton	0.79	Cane Creek tributary 2	03010104	2	1965	1	0
130	02077279	Hyco River tributary near McGehees Mill	36°30'38"	7903'12"	Person	Alton	0.03	Hyco River	03010104	2	1965	1	1
131	02077300	Hyco River at McGehees Mill[1]	36°31'02"	79°01'42"	Person	Alton	198	Dan River	03010104	1	Sept 1964 - Sept 1973	N/A	N/A

Table 5. Summary of continuous- and partial-record gaging stations in the Roanoke River Basin study area in North Carolina where records of gage height and streamflow were collected (Continued)

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132	02077303	Hyco River below Afterbay dam near McGehees Mill	36°31'24"	78°59'48"	Person	Cluster Springs	202	Dan River	03010104	1	Oct 1973 - Sept 1987, Oct 1988 - Sept 1994	N/A	N/A
133	02077304	Ghents Creek near Ceffo	36°30'11"	79°00'45"	Person	Alton	5.24	Hyco River	03010104	2	1965	1	1
134	02077317	Satterfield Creek near Roxboro	36°24'07"	79°02'03"	Person	Olive Hill	2.49	Storys Creek	03010104	2	1963, 1965, 1968	3	0
135	02077331	Marlowe Creek at Longhurst	36°25'28"	78°58'05"	Person	Roxboro 15'	6.64	Storys Creek	03010104	2	1953, 1963, 1968, 1970	6	3
136	02077338	Marlowe Creek near Longhurst	36°26'33"	78°58'43"	Person	Roxboro 15'	10.9	Storys Creek	03010104	2	1954, 1957, 1970, 1973	8	0
137	02077348	Marlowe Creek at SR 1322 near Longhurst	36°28'59"	78°58'47"	Person	Roxboro	20.6	Storys Creek	03010104	2	1970, 1973-74, 1976, 1978, 1980-81, 1983-94	56	0
138	02077368	Hyco River near Bethel Hill	36°32'34"	78°57'48"	Person	Cluster Springs	264	Dan River	03010104	2	1970, 1973-74, 1976, 1978, 1980	9	0
139	02077374	Castle Creek at Woodsdale	36°29'28"	78°56'36"	Person	Roxboro 15'	4.30	Hyco River	03010104	2	1968	1	1
140	02077500	Hyco River near Denniston (Va.)	36°35'16"	78°53'56"	Halifax (Va.)	Cluster Springs	289	Dan River	03010104	1	Oct 1928 - Sept 1934, Oct 1950 - Sept 1994	N/A	N/A
141	02077627	Mayo Creek at Allensville	36°23'31"	78°53'31"	Person	Roxboro 15'	5.48	Hyco River	03010104	2	1966, 1968	2	2
142	02077629	Mayo Creek tributary near Allensville	36°23'55"	78°54'05"	Person	Roxboro 15'	0.68	Mayo Creek	03010104	2	1966, 1968, 1976, 1979	5	0
143	02077631	Mayo Creek near Allensville	36°24'37"	78°53'03"	Person	Roxboro 15'	8.06	Hyco River	03010104	2	1984	1	0
144	02077632	Mayo Creek near Gentrys Store[1]	36°26'21"	78°52'40"	Person	Roxboro 15'	16.8	Hyco River	03010104	2	1959, 1963, 1966, 1968, 1970	6	2
145	02077644	Mill Creek near Gentrys Store	36°26'57"	78°53'50"	Person	Roxboro 15'	8.81	Mayo Creek	03010104	2	1959, 1963, 1966, 1968	4	2
146	02077660	Mayo Creek near Woodsdale[1]	36°31'48"	78°52'42"	Person	Cluster Springs	52.7	Hyco River	03010104	1	Jun 1975 - Oct 1977	N/A	N/A
										2	1956-64, 1966, 1968	25	1
147	02077670	Mayo Creek near Bethel Hill	36°32'31"	78°52'19"	Person	Virgilina	53.5	Hyco River	03010104	1	Jul 1977 - Sept 1994	N/A	N/A
148	02077678	Big Blue Wing Creek near Dixons Store	36°32'23"	78°48'58"	Person	Virgilina	9.77	Hyco River	03010104	2	1966	1	1
149	02078200	Aarons Creek near Oak Hill	36°31'54"	78°44'22"	Granville	Nelson	27.6	Dan River	03010104	2	1956-64, 1966, 1969	24	3

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150	02078214	Wolfpit Run near Cornwall	36°32'20"	78°44'59"	Granville	Virgilina	1.95	Aarons Creek	03010104	2	1966	1	1
151	0207901030	Grassy Creek at SR 1325 near Oak Hill	36°25'35"	78°46'10"	Granville	Triple Springs	1.88	Roanoke River	03010102	2	1974, 1976, 1978, 1980	6	0
152	02079022	Grassy Creek at Cornwall	36°28'20"	78°39'52"	Granville	Satterwhite	20.9	Roanoke River	03010102	2	1966, 1969	2	1
153	02079032	Mountain Creek near Cornwall	36°27'53"	78°38'46"	Granville	Satterwhite	11.0	Grassy Creek	03010102	2	1966	1	1
154	02079100	Little Grassy Creek near Stovall	36°28'34"	78°36'16"	Granville	Stovall	22.9	Grassy Creek	03010102	2	1956-59, 1961-64, 1966, 1969	24	1
155	02079101	Grassy Creek at SR 1436 near Cornwall	36°29'22"	78°37'08"	Granville	Stovall	61.2	Roanoke River	03010102	2	1981, 1983-92	46	0
156	02079182	Little Johnson Creek near Cornwall	36°30'49"	78°40'17"	Granville	Nelson	14.3	Grassy Creek	03010102	2	1955-56	2	1
157	0207920210	Grassy Creek at SR 1443 near Bullock[1]	36°32'02"	78°35'53"	Granville	Clarksville South	103	Roanoke River	03010102	2	1974-76	7	1
158	0207920940	Gills Creek at SR 1430 near Stovall	36°26'10"	78°32'37"	Granville	Stovall	13.8	Island Creek	03010102	2	1974-76, 1978-81, 1983-89	43	2
159	02079210	Island Creek near Bullock	36°29'42"	78°30'16"	Granville	Stovall	33.1	Roanoke River	03010102	2	1963-70	15	1
160	02079237	Little Island Creek near Tungsten[1]	36°30'49"	78°27'27"	Vance	Tungsten	20.0	Island Creek	03010102	2	1966, 1968	2	0
161	02079239	Little Island Creek at mouth near Tungsten[1]	36°31'55"	78°27'37"	Vance	Tungsten	21.2	Island Creek	03010102	2	1966	1	1
162	0207923905	Island Creek near Townsville[1]	36°32'01"	78°27'31"	Vance	Tungsten	61.0	Roanoke River	03010102	2	1974-76	5	0
163	02079259	Nutbush Creek at SR 1310 near Henderson	36°20'26"	78°25'12"	Vance	Henderson	2.10	Roanoke River	03010102	2	1970, 1973-76, 1978, 1980	12	0
164	02079264	Nutbush Creek near Henderson	36°22'10"	78°24'31"	Vance	Henderson	6.00	Roanoke River	03010102	2	1970, 1973-74, 1976, 1978-79, 1981, 1983-94	63	0

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165	02079331	Flat Creek near Williamsboro	36°24'16"	78°27'05"	Vance	Townsville	13.0	Nutbush Creek	03010102	2	1966	1	1
166	0207966652	Smith Creek at SR 1224 near Ridgeway	36°27'12"	78°15'51"	Warren	Middleburg	2.56	Roanoke River	03010106	2	1973-76, 1979	12	0
167	02079693	Smith Creek near Oine	36°29'22"	78°15'31"	Warren	Middleburg	12.3	Roanoke River	03010106	2	1966, 1968	2	0
168	02079700	Smith Creek near Norlina	36°31'30"	78°14'23"	Warren	Bracey	31.5	Roanoke River	03010106	2	1954-63, 1966, 1969	22	0
169	02079712	Terrapin Creek at Oine	36°29'03"	78°12'53"	Warren	Warrenton	3.09	Blue Mud Creek	03010106	2	1970, 1974	4	0
170	02079714	Blue Mud Creek near Oine	36°31'54"	78°12'07"	Warren	Bracey	15.0	Smith Creek	03010106	2	1963, 1966	2	1
171	02079717	Smith Creek near Paschall	36°32'27"	78°11'43"	Warren	Bracey	52.9	Roanoke River	03010106	2	1954, 1961-62, 1966, 1973-74, 1976, 1979, 1981, 1983-94	63	1
172	02079731	Hawtree Creek near Oakville	36°29'55"	78°07'48"	Warren	Warrenton	15.3	Roanoke River	03010106	2	1966, 1968	2	0
173	02079734	Hawtree Creek near Paschall[1]	36°31'32"	78°07'46"	Warren	Bracey	25.9	Roanoke River	03010106	2	1954, 1961-62	3	0
174	02079749	Sixpound Creek near Church Hill	36°30'34"	78°04'50"	Warren	South Hill SE	9.58	Roanoke River	03010106	2	1966, 1969	2	0
175	02079750	Sixpound Creek near Oakville[1]	36°31'48"	78°04'22"	Warren	South Hill SE	12.1	Roanoke River	03010106	2	1954, 1956-62	17	0
176	02079776	Hubquarter Creek near Enterprise[1]	36°30'30"	77°59'30"	Warren	Gasburg	16.0	Roanoke River	03010106	2	1954, 1962	2	0
177	02079799	Big Stone House Creek near Vaughan	36°29'00"	77°58'06"	Warren	Littleton	10.2	Roanoke River	03010106	2	1966, 1969	2	0
178	02079800	Big Stone House Creek near Littleton[a]	36°29'16"	77°57'02"	Warren	Littleton	16.0	Roanoke River	03010106	2	1956-62	13	0

Table 5. Summary of continuous- and partial-record gaging stations in the Roanoke River Basin study area in North Carolina where records of gage height and streamflow were collected (Continued)

[mi^2, square mile; N/A, not applicable; SEO, sewage effluent outfall. Sites shaded in gray indicate those sites for which low-flow characteristics have been developed. Period of record for continuous-record sites (site type 1) shown in months and years; period of record for partial-record sites (site type 2) shown is water years in which discharge measurements were made.]

Site index no.	USGS downstream order number	Station name	Latitude	Longitude	County	USGS topographic quad name	Drainage area, (mi^2)	Tributary to	Hydrologic unit code	Site type	Period of record	Number of measurements for partial-record sites: Flow	Number of measurements for partial-record sites: Zero-flow
179	02079867	Big Stone House Creek near Enterprise[a]	36°30'00"	77°55'10"	Warren	Littleton	22.0	Roanoke River	03010106	2	1955	1	0
180	02080053	Deep Creek near Thelma	36°27'05"	77°46'58"	Halifax	Thelma	23.5	Roanoke River	03010106	2	1961-62, 1969	3	1
181	02080500	Roanoke River at Roanoke Rapids	36°27'37"	77°38'04"	Halifax	Roanoke Rapids	8,384	Roanoke River	03010107	1	Dec 1911 - Sept 1994	N/A	N/A
182	02080560	Chockoyotte Creek near Weldon	36°25'08"	77°36'49"	Halifax	Weldon	20.4	Roanoke River	03010107	2	1961-62, 1965-70	11	0
183	02080562	Chockoyotte Creek at Weldon	36°25'51"	77°36'29"	Halifax	Weldon	21.2	Roanoke River	03010107	2	1930, 1932, 1965	3	0
184	02080600	Roanoke River at Weldon	36°25'51"	77°35'28"	Halifax	Weldon	8,425	Roanoke River	03010107	1	Dec 1963 - Sept 1965, Feb 1968 - Oct 1968, Jan 1969 - Sept 1970	N/A	N/A
185	02080707	Quankey Creek at Pierces Crossroads	36°21'10"	77°38'38"	Halifax	Darlington	17.1	Roanoke River	03010107	2	1961-62, 1969	3	0
186	02080740	Quankey Creek near Halifax	36°19'42"	77°36'17"	Halifax	Halifax	31.7	Roanoke River	03010107	2	1959-68, 1970	21	0
187	02080742	Quankey Creek at Halifax	36°19'07"	77°35'43"	Halifax	Halifax	33.6	Roanoke River	03010107	2	1954, 1961-62, 1969, 1970, 1973-75	11	0
188	02080743	Quankey Creek below SEO at Halifax	36°19'37"	77°34'53"	Halifax	Halifax	33.0	Roanoke River	03010107	2	1970, 1973-74	6	0
189	02080794	Occoneechee Creek near Jackson	36°22'10"	77°31'25"	Northampton	Halifax	16.2	Roanoke River	03010107	2	1957, 1961	2	2
190	02080823	Gumberry Swamp near Pleasant Grove	36°26'05"	77°27'56"	Northampton	Jackson	7.48	Wheeler Creek	03010107	2	1961	1	0
191	02080870	Gumberry Swamp near Jackson	36°21'25"	77°28'01"	Northampton	Boones Crossroads	20.0	Roanoke River	03010107	2	1957, 1961, 1965-68	10	0
192	02080881	Lily Pond Creek below SEO near Jackson	36°22'23"	77°26'00"	Northampton	Boones Crossroads	1.60	Gumberry Swamp	03010107	2	1970, 1973-74	5	0

Table 5. Summary of continuous- and partial-record gaging stations in the Roanoke River Basin study area in North Carolina where records of gage height and streamflow were collected (Continued)

[mi^2, square mile; N/A, not applicable; SEO, sewage effluent outfall. Sites shaded in gray indicate those sites for which low-flow characteristics have been developed. Period of record for continuous-record sites (site type 1) shown in months and years; period of record for partial-record sites (site type 2) shown is water years in which discharge measurements were made.]

Site index no.	USGS downstream order number	Station name	Latitude	Longitude	County	USGS topographic quad name	Drainage area, (mi^2)	Tributary to	Hydrologic unit code	Site type	Period of record	Number of measurements for partial-record sites: Flow	Number of measurements for partial-record sites: Zero-flow
193	02080948	Bridgers Creek near Rich Square	36°15'23"	77°20'10"	Northampton	Rich Square	6.53	Roanoke River	03010107	2	1970, 1973	5	1
194	02081000	Roanoke River near Scotland Neck	36°12'34"	77°23'03"	Halifax	Scotland Neck	8,671	Atlantic Ocean	03010107	1	(discharge) Oct 1940 - Sept 1956 (gage height only) Oct 1985 - Sept 1994	N/A	N/A
										2	1983	1	0
195	02081022	Roanoke River near Oak City	36°00'50"	77°12'55"	Martin	Woodville	8,813	Atlantic Ocean	03010107	2	1969, 1972, 1983, 1986-87	8	0
										1	(gage height only) July 1987 - Sept 1994 (discharge)[3] Oct 1987 - Sept 1990	N/A	N/A
196	02081024	Indian Creek near Woodville	36°03'29"	77°10'40"	Bertie	Woodville	10.3	Roanoke River	03010107	2	1961	1	1
197	02081028	Roanoke River at Hamilton	35°56'50"	77°12'10"	Martin	Hamilton	8,886	Atlantic Ocean	03010107	1	(gage height only)[4] July 1987 - Sept 1994 (discharge)[3] Oct 1987 - Sept 1990	N/A	N/A
198	02081042	Etheridge Swamp at Oak City	35°58'27"	77°18'32"	Martin	Oak City	24.0	Conoho Creek	03010107	2	1959	1	1
199	02081050	Conoho Creek at Oak City	35°58'19"	77°17'55"	Martin	Oak City	40.0	Roanoke River	03010107	2	1959, 1964-66, 1968, 1970	8	4
200	02081054	Roanoke River at Williamston	35°51'40"	77°02'20"	Martin	Williamston	9,070	Atlantic Ocean	03010107	2	1983	1	0
										1	(gage height only) Dec 1985 - Sept 1994 (discharge)[3] Oct 1987 - Sept 1990	N/A	N/A

Table 5. Summary of continuous- and partial-record gaging stations in the Roanoke River Basin study area in North Carolina where records of gage height and streamflow were collected (Continued)

[mi^2, square mile; N/A, not applicable; SEO, sewage effluent outfall. Sites shaded in gray indicate those sites for which low-flow characteristics have been developed. Period of record for continuous-record sites (site type 1) shown in months and years; period of record for partial-record sites (site type 2) shown is water years in which discharge measurements were made.]

Site index no.	USGS downstream order number	Station name	Latitude	Longitude	County	USGS topographic quad name	Drainage area, (mi^2)	Tributary to	Hydrologic unit code	Site type	Period of record	Number of measurements for partial-record sites: Flow	Number of measurements for partial-record sites: Zero-flow
201	02081065	Smithwick Creek near Beargrass	35°45'58"	77°03'10"	Martin	Williamston	12.0	Sweetwater Creek	03010107	2	1959, 1965-68	7	2
202	02081071	Ready Branch above Dog Branch near Williamston	35°47'20"	77°03'40"	Martin	Williamston	9.60	Sweetwater Creek	03010107	2	1964	1	0
203	02081079	Dog Branch near Williamston	35°47'20"	77°03'40"	Martin	Williamston	6.00	Ready Branch	03010107	2	1964	1	0
204	02081080	Ready Branch near Williamston	35°47'20"	77°03'40"	Martin	Williamston	16.0	Sweetwater Creek	03010107	2	1949-54, 1957-59, 1963-64	25	2
205	02081094	Roanoke River at Jamesville	35°48'48"	76°53'37"	Martin	Jamesville	9,247	Atlantic Ocean	03010107	1	(gage height only) Oct 1990 - Sept 1993	N/A	N/A
206	02081096	Cashie River near Lewiston	36°08'43"	77°09'54"	Bertie	Kelford	19.2	Roanoke River	03010107	2	1961, 1974-76, 1978, 1981, 1983-84	18	8
207	02081098	Whatom Swamp near Rhodes	36°09'24"	77°08'45"	Bertie	Kelford	9.55	Cashie River	03010107	2	1961	1	1
208	02081101	Cashie River near Woodville	36°07'25"	77°07'18"	Bertie	Republican	38.6	Roanoke River	03010107	2	1961	1	1
209	02081102	Cashie River near Republican	36°05'43"	77°04'05"	Bertie	Republican	47.3	Roanoke River	03010107	2	1961	1	1
210	02081106	Connaritsa Swamp near Republican	36°06'26"	77°02'28"	Bertie	Republican	24.8	Cashie River	03010107	2	1961	1	1
211	02081110	Whiteoak Swamp near Windsor	36°04'46"	76°58'36"	Bertie	Windsor North	17.0	Cashie River	03010107	2	1957	1	1
212	0208111310	Cashie River near Windsor	36°02'51"	76°59'07"	Bertie	Windsor North	108	Roanoke River	03010107	1	Jun 1987 - Mar 1990, May 1990 - Sept 1994	N/A	N/A
213	02081117	Flat Swamp at Todds Crossroads	36°04'36"	76°52'17"	Bertie	Merry Hill	14.0	Hoggard Mill Creek	03010107	2	1961	1	1
214	0208112155	Cashie River above SEO at Windsor	35°59'40"	76°56'34"	Bertie	Windsor South	178	Roanoke River	03010107	2	1970, 1973-74	4	0
215	0208112253	Broad Branch at Windsor	35°58'56"	76°56'54"	Bertie	Windsor South	4.10	Cashie River	03010107	2	1970	1	1
216	02081123	Roquist Creek near Drew	36°00'37"	77°02'53"	Bertie	Republican	27.7	Cashie River	03010107	2	1961	1	1

Table 5. Summary of continuous- and partial-record gaging stations in the Roanoke River Basin study area in North Carolina where records of gage height and streamflow were collected (Continued)

[mi^2, square mile; N/A, not applicable; SEO, sewage effluent outfall. Sites shaded in gray indicate those sites for which low-flow characteristics have been developed. Period of record for continuous-record sites (site type 1) shown in months and years; period of record for partial-record sites (site type 2) shown is water years in which discharge measurements were made.]

Site index no.	USGS downstream order number	Station name	Latitude	Longitude	County	USGS topographic quad name	Drainage area, (mi^2)	Tributary to	Hydrologic unit code	Site type	Period of record	Number of measurements for partial-record sites: Flow	Number of measurements for partial-record sites: Zero-flow
217	02081130	Roquist Creek near Windsor	35°56'17"	76°56'42"	Bertie	Windsor South	60.1	Cashie River	03010107	2	1949-51, 1953-58, 1961	19	6
218	02081134	Cashie River at Sans Souci Ferry	35°54'42"	76°49'04"	Bertie	Woodard	293	Roanoke River	03010107	1	(gage height only) Oct 1990 - Sept 1993	N/A	N/A
219	02081137	Welch Creek near Hinson	35°46'06"	76°48'28"	Washington	Plymouth West	20.0	Roanoke River	03010107	2	1959	1	0
220	02081138	Welch Creek above SEO near Plymouth	35°49'45"	76°47'06"	Washington	Plymouth West	42.0	Roanoke River	03010107	2	1970	1	0
221	0208114150	Roanoke River at NC 45 near Westover	35°54'53"	76°43'23"	Bertie	Westover	9,665	Atlantic Ocean	03010107	1	(gage height only) Oct 1990 - Sept 1993	N/A	N/A

[1]Site inundated by impoundment.
[2]Drainage area revised from previously-published value.
[3]Simulated discharge data published in Strickland and Bales (1994).
[4]Operated as auxiliary gage for station 02081022.

Table 7. Magnitude and frequency of annual low-flow characteristics at partial-record streamflow gaging stations in the Roanoke River Basin study area, North Carolina

[mi^2, square mile; water years, annual periods from October 1 to September 30; $(ft^3/s)/mi^2$, cubic feet per second per square mile; N/A, not available.]

Site index no.	USGS downstream order number	Station name	Drainage area (mi^2)	Period of record, water years	Number of measurements: Flow	Number of measurements: Zero-flow	Average annual unit flow [$(ft^3/s)/mi^2$]	Low-flow characteristics in cubic feet per second: 7Q10	30Q2	W7Q10	7Q2
14	02068720	Snow Creek near Prestonville	22.7	1955-56, 1964-68, 1970, 1980	19	0	1.2	1.7	10.5	9.0	8.3
23	02068904	Voss Creek near Walnut Cove	4.89	1970, 1973-74	5	0	1.2	0.5	1.2	1.2	1.0
25	02068931	Mill Creek at Walnut Cove	9.86	1955-56, 1963	3	0	1.2	0.9	2.9	2.7	2.3
26	02068980	Town Fork Creek at Walnut Cove	113	1925, 1949-1957, 1959, 1961-63, 1966, 1970, 1973, 1974	39	0	1.2	8.9	21.8	20.0	17.2
33	02069044	West Belews Creek near Walnut Cove[1]	12.0	1955, 1959, 1963	3	0	1.2	1.2	2.5	2.3	2.0
36	02069410	Big Beaver Island Creek near Madison	23.8	1953-59, 1961-63, 1966	29	0	1.2	1.0	5.6	4.8	4.0
40	02070558	Boaz Creek near Stoneville	2.48	1970, 1973	6	0	1.2	< 0.1	0.2	0.3	0.1
42	02070576	Mayo River tributary above SEO near Mayodan	1.16	1970, 1973	6	0	1.2	< 0.1	0.2	0.2	0.1
47	02070720	Hogans Creek near Madison	23.9	1954, 1956-64, 1966	27	0	1.1	1.3	5.8	5.3	4.2
49	02070930	Jacobs Creek at NC 704 near Madison	36.2	1954, 1959, 1963-67, 1969, 1970	13	0	1.1	1.7	8.1	7.0	5.4
51	02071003	Rockhouse Creek near Wentworth	18.4	1954, 1959, 1963	3	0	1.0	0.9	5.0	4.2	3.6
65	02074282	Wolf Island Creek at Reidsville	3.71	1954, 1970, 1973-74, 1976-81	19	0	0.9	0.3	0.8	0.9	0.6
67	02074360	Wolf Island Creek near Pelham	68.7	1954, 1956-64, 1966, 1968, 1970, 1974-79, 1981, 1983-84	59	0	0.9	2.3	12.3	11.8	8.3
71	02075090	Hogans Creek near Providence	98.4	1953-54, 1956-60, 1963, 1966, 1968, 1970	29	2	0.9	1.2	10.4	9.5	6.0
73	02075124	West Prong Moon Creek near Yanceyville	4.97	1959, 1963, 1966, 1968	4	0	0.9	0	1.2	1.2	0.6
74	02075142	East Prong Moon Creek near Yanceyville	7.15	1959, 1963, 1966, 1968	4	0	0.9	0	1.4	1.4	0.4
80	02075198	Dan River at Milton	2,328	1970, 1974, 1976-79	10	0	1.1	440	885	755	725
81	0207520780	Country Line Creek at SR 1146 near Ashland	6.58	1974-81	17	0	0.9	0.3	1.5	1.4	1.1
82	02075208	Country Line Creek near Locust Hill	22.6	1959, 1963, 1966, 1968	4	0	0.9	0.5	2.6	2.3	1.7
86	02075230	South Country Line Creek near Hightowers	6.57	1953, 1959, 1963, 1966, 1968, 1970	6	5	0.9	[2]0	N/A[2]	N/A[2]	N/A[2]
87	02075240	South Country Line Creek near Topnot	16.4	1962-69	20	8	0.9	0	0.1	< 0.1	< 0.1
88	02075250	Penson Creek near Yanceyville	12.2	1959, 1963-68, 1970	19	4	0.9	0	0.1	< 0.1	< 0.1
89	02075260	South Country Line Creek near Yanceyville	29.0	1949-53, 1956-60, 1962-66, 1968	33	4	0.9	0	0.2	0.2	< 0.1
91	02075270	Country Line Creek near Semora	131	1954, 1956-68, 1970, 1973-74, 1974-84	[3]72	1	0.9	0.7	7.0	5.9	4.0
94	0207718130	Hyco Creek at SR 1767 near Baynes	5.00	1974-81	19	0	0.9	0	0.1	0	< 0.1

Table 7. Magnitude and frequency of annual low-flow characteristics at partial-record streamflow gaging stations in the Roanoke River Basin study area, North Carolina (Continued)

[mi^2, square mile; water years, annual periods from October 1 to September 30; $(ft^3/s)/mi^2$, cubic feet per second per square mile; N/A, not available.]

Site index no.	USGS downstream order number	Station name	Drainage area (mi^2)	Period of record, water years	Number of measurements		Average annual unit flow [$(ft^3/s)/mi^2$]	Low-flow characteristics in cubic feet per second			
					Flow	Zero-flow		7Q10	30Q2	W7Q10	7Q2
95	02077182	Hyco Creek near Hightowers	16.9	1959, 1963, 1966, 1968	4	2	0.9	[2]0	N/A[2]	N/A[2]	N/A[2]
98	02077214	Reedy Fork Creek near Leasburg	9.29	1964-66, 1968, 1970	9	6	0.9	0	< 0.1	0	< 0.1
106	02077225	Hyco Creek near Roxboro[1]	78.0	1949-54, 1956-59, 1961-64	33	4	0.9	0	1.4	0	< 0.1
107	0207722510	Cobbs Creek near Leasburg	1.23	1965-66, 1968	4	1	0.9	[2]0	N/A[2]	N/A[2]	N/A[2]
109	02077227	South Hyco Creek near Gordonton	10.5	1968, 1976, 1978-81, 1983-84	24	2	0.9	0	0.4	0.4	0.3
117	02077254	Richland Creek near Roseville	5.79	1964-66, 1968, 1970	8	2	0.9	0	< 0.1	< 0.1	< 0.1
120	02077260	South Hyco Creek near Concord[1]	76.5	1953-54, 1956-64	28	1	0.9	< 0.1	3.0	0.3	0.5
121	02077261	Sargents Creek near Ceffo	1.77	1965-66, 1968	4	0	0.9	0	0.2	0.2	0.2
135	02077331	Marlowe Creek at Longhurst	6.64	1953, 1963, 1968, 1970	6	3	0.9	< 0.1	0.4	0.2	0.3
136	02077338	Marlowe Creek near Longhurst	10.9	1954, 1957, 1970, 1973	8	0	0.9	0.1	0.7	0.3	0.4
137	02077348	Marlowe Creek at SR 1322 near Longhurst	20.6	1970, 1973-74, 1976, 1978, 1980-81, 1983-94	56	0	0.9	[4]0.2	1.4	0.5	0.8
144	02077632	Mayo Creek near Gentrys Store	16.8	1959, 1963, 1966, 1968, 1970	6	2	0.9	0	0.8	0.1	0.3
145	02077644	Mill Creek near Gentrys Store	8.81	1959, 1963, 1966, 1968	4	2	0.9	0	0.6	< 0.1	0.2
146	02077660	Mayo Creek near Woodsdale[1]	52.7	1956-64, 1966, 1968	25	1	0.8	0	2.0	0.2	0.7
149	02078200	Aarons Creek near Oak Hill	27.6	1956-64, 1966, 1969	24	3	0.8	0	0.2	0	< 0.1
154	02079100	Little Grassy Creek near Stovall	22.9	1956-59, 1961-64, 1966, 1969	24	1	0.9	0	0.5	< 0.1	0.2
155	02079101	Grassy Creek at SR 1436 near Cornwall	61.2	1981, 1983-92	46	0	0.8	< 0.1	1.8	0.2	0.8
158	0207920940	Gills Creek at SR 1430 near Stovall	13.8	1974-76, 1978-81, 1983-89	43	2	0.8	0	0.2	< 0.1	< 0.1
159	02079210	Island Creek near Bullock	33.1	1963-70	15	1	0.8	0	0.7	0.2	0.3
163	02079259	Nutbush Creek at SR 1310 near Henderson	2.10	1970, 1973-76, 1978, 1980	12	0	0.9	< 0.1	0.3	0.2	0.2
164	02079264	Nutbush Creek near Henderson	6.00	1970, 1973-74, 1976, 1978-79, 1981, 1983-94	63	0	0.9	< [4]0.1	0.5	0.4	0.4
166	0207966652	Smith Creek at SR 1224 near Ridgeway	2.56	1973-76, 1979	12	0	0.8	0	0.4	0.3	0.3
168	02079700	Smith Creek near Norlina	31.5	1954-63, 1966, 1969	22	0	0.8	< 0.1	6.5	3.2	4.3
171	02079717	Smith Creek near Paschall	52.9	1954, 1961-62, 1966, 1973-74, 1976, 1979, 1981, 1983-94	63	1	0.8	0.2	7.4	4.4	4.5
175	02079750	Sixpound Creek near Oakville	12.1	1954, 1956-62	17	0	0.9	1.8	4.1	3.4	3.4
178	02079800	Big Stone House Creek near Littleton[1]	16.0	1956-62	13	0	0.9	0.4	1.9	1.3	1.3
182	02080560	Chockoyotte Creek near Weldon	20.4	1961-62, 1965-70	11	0	1.0	0.4	1.4	1.0	0.9

Table 7. Magnitude and frequency of annual low-flow characteristics at partial-record streamflow gaging stations in the Roanoke River Basin study area, North Carolina (Continued)

[mi^2, square mile; water years, annual periods from October 1 to September 30; $(ft^3/s)/mi^2$, cubic feet per second per square mile; N/A, not available.]

Site index no.	USGS downstream order number	Station name	Drainage area (mi^2)	Period of record, water years	Number of measurements: Flow	Number of measurements: Zero-flow	Average annual unit flow [$(ft^3/s)/mi^2$]	Low-flow characteristics in cubic feet per second: 7Q10	30Q2	W7Q10	7Q2
186	02080740	Quankey Creek near Halifax	31.7	1959-68, 1970	21	0	1.0	1.7	3.8	2.8	2.8
191	02080870	Gumberry Swamp near Jackson	20.0	1957, 1961, 1965-68	10	0	1.0	1.6	2.6	2.2	2.2
195	02081022	Roanoke River near Oak City	8,813	1969, 1972, 1983, 1986-87	8	0	1.0	1,140	2,530	1,140	1,910
199	02081050	Conoho Creek at Oak City	40.0	1959, 1964-66, 1968, 1970	8	4	1.1	0	0	0	0
201	02081065	Smithwick Creek near Beargrass	12.0	1959, 1965-68	7	2	1.1	0	< 0.1	< 0.1	< 0.1
204	02081080	Ready Branch near Williamston	16.0	1949-54, 1957-59, 1963-64	25	2	1.1	0.5	1.5	0.7	1.1
206	02081096	Cashie River near Lewiston	19.2	1961, 1974-76, 1978, 1981, 1983-84	18	8	1.1	0	< 0.1	0	< 0.1
217	02081130	Roquist Creek near Windsor	60.1	1949-51, 1953-58, 1961	19	6	1.1	0	< 0.1	0	0

[1]Site now inundated by impoundment. Low-flow characteristics represent pre--impoundment conditions.

[2]Estimates for all low-flow characteristics cannot be determined based on available data; however, multiple observations of zero-flow discharge at site or zero-flow 7Q10 discharge at downstream site allow estimate of zero-flow 7Q10 at indicated site.

[3]Records of discharge measurements at site 91 were combined with measurements at USGS station 0207527050 (site 92, drainage area 138 mi^2) for determination of low-flow characteristics at site 91.

[4]Measurements made at this site include upstream point-source discharge; however, low-flow characteristics shown do not account for the effects of the point-source discharge.