Prepared in cooperation with the South Carolina Department of Health and Environmental Control

Low-Flow Frequency and Flow Duration of Selected South Carolina Streams in the Pee Dee River Basin through March 2007

Open-File Report 2009–1171

U.S. Department of the Interior
U.S. Geological Survey

Cover. Little Pee Dee River at Galivants Ferry, South Carolina. Timbers are remnants from the old ferry back in the 1800s. Photo by John W. Erbland, USGS, September 2007.

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U.S. Department of the Interior
KEN SALAZAR, Secretary

U.S. Geological Survey
Suzette M. Kimball, Acting Director

U.S. Geological Survey, Reston, Virginia: 2009

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Conversion Factors and Datums

Multiply	By	To obtain
	Length	
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
square mile (mi^2)	2.590	square kilometer (km^2)
	Volume	
cubic foot (ft^3)	0.02832	cubic meter (m^3)
	Flow rate	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
million gallons per day (Mgal/d)	0.04381	cubic meter per second (m^3/s)

Vertical coordinate information is referenced to the National Geodetic Vertical Datum of 1929 (NGVD 29).

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Acronyms and Abbreviations Used in the Report

CR	continuous record
HUC	hydrologic unit code
loratio	ratio of the 10 percentile to the 50 percentile of the average 7-day flows
MOVE.1	Maintenance of Variance Extension, Type 1
NWIS	National Water Information System
PR	partial record
QAQC	quality assurance and quality control
SCDHEC	South Carolina Department of Health and Environmental Control
TMDL	total maximum daily load
USGS	U.S. Geological Survey
WWQMS	Watershed Water Quality Management Strategy
7Q2	annual minimum 7-day average streamflow with a 2-year recurrence interval
7Q10	annual minimum 7-day average streamflow with a 10-year recurrence interval

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Abstract

Part of the mission of the South Carolina Department of Health and Environmental Control and the South Carolina Department of Natural Resources is to protect and preserve South Carolina's water resources. Doing so requires an ongoing understanding of streamflow characteristics of the rivers and streams in South Carolina. A particular need is information concerning the low-flow characteristics of streams; this information is especially important for effectively managing the State's water resources during critical flow periods such as the severe drought that occurred between 1998 and 2002 and the most recent drought that occurred between 2006 and 2009.

In 2008, the U.S. Geological Survey, in cooperation with the South Carolina Department of Health and Environmental Control, initiated a study to update low-flow statistics at continuous-record streamgaging stations operated by the U.S. Geological Survey in South Carolina. Under this agreement, the low-flow characteristics at continuous-record streamgaging stations will be updated in a systematic manner during the monitoring and assessment of the eight major basins in South Carolina as defined and grouped according to the South Carolina Department of Health and Environmental Control's Watershed Water Quality Management Strategy.

Depending on the length of record available at the continuous-record streamgaging stations, low-flow frequency characteristics are estimated for annual minimum 1-, 3-, 7-, 14-, 30-, 60-, and 90-day average flows with recurrence intervals of 2, 5, l0, 20, 30, and 50 years. Low-flow statistics are presented for 17 streamgaging stations in the Pee Dee River basin. In addition, daily flow durations for the 5-, 10-, 25-, 50-, 75-, 90-, and 95-percent probability of exceedance also are presented for the stations. The low-flow characteristics were computed from records available through March 31, 2007.

The last systematic update of low-flow characteristics in South Carolina occurred more than 20 years ago and included data through March 1987. Of the 17 streamgaging stations included in this study, 15 had low-flow characteristics that were published in previous U.S. Geological Survey reports. A comparison of the low-flow characteristic for the minimum average flow for a 7-consecutive-day period with a 10-year recurrence interval from this study with the most recently published values indicated that 10 of the 15 streamgaging stations had values that were within ±25 percent of each other. Nine of the 15 streamgaging stations had negative percentage differences indicating the low-flow statistic had decreased since the previous study, 4 streamgaging stations had positive percent differences indicating that the low-flow statistic had increased since the previous study, and 2 streamgaging stations had a zero percent difference indicating no change since the previous study. The low-flow characteristics are influenced by length of record, hydrologic regime under which the record was collected, techniques used to do the analysis, and other changes that may have occurred in the watershed.

Introduction

South Carolina State agencies, such as the South Carolina Department of Health and Environmental Control (SCDHEC) and the South Carolina Department of Natural Resources, currently use low-flow statistics for many applications, including determining waste-load allocations for point sources, development of total maximum daily loads (TMDLs) for streams, determining the quantity of water that can be safely withdrawn from a particular stream, and preparing the State Water Plan. In addition, low-flow statistics are useful for improving the general level of understanding of natural and regulated stream systems. The two most recent droughts in South Carolina, during 1998–2002 and 2006–2009, have heightened the awareness of the importance of having up-to-date statistics for making such critical decisions.

It is critical to effectively measure and document base-flow data for use in updating low-flow characteristics on a regular basis, preferably about every 10 years, because of the importance of the applications previously mentioned. Low-flow characteristics, as defined in this report, are minimum average-streamflow rates over designated time periods (Riggs, 1972) and flow-duration estimates, which define the percentage of time that specified flows were equaled or exceeded during a given period (Searcy, 1959). Low-flow characteristics in South Carolina have not been updated in a systematic way since 1987. In 2008, the U.S. Geological Survey (USGS), in cooperation with the SCDHEC, initiated a study to update low-flow characteristics at continuous-record streamgaging stations operated by the USGS in South Carolina. The investigation coincides with the SCDHEC Watershed Water Quality Management Strategy (WWQMS) for monitoring and assessment of the eight major basins in South Carolina (fig. 1), which is done every 5 years (South Carolina Department of Health and Environmental Control, 2009). The low-flow characteristics are scheduled by the SCDHEC to be updated during the monitoring year of the WWQMS schedule, and the updated values are scheduled to be available during the following year (table 1).

Table 1. South Carolina Department of Health and Environmental Control (SCDHEC) schedule for basin data analysis and statistics availability.

SCDHEC basin name (fig. 1)	Data analysis year[1]	Low-flow information available year[1]
Pee Dee	2009	2010
Broad	2010	2011
Savannah and Salkehatchie	2011	2012
Saluda and Edisto	2012	2013
Catawba-Wateree and Santee	2013	2014

[1]The year is the Federal fiscal year, which begins in October and ends in September, and is designated by the calendar year in which it ends. For example, Year 2009 is the 12-month period from October 1, 2008 through September 30, 2009.

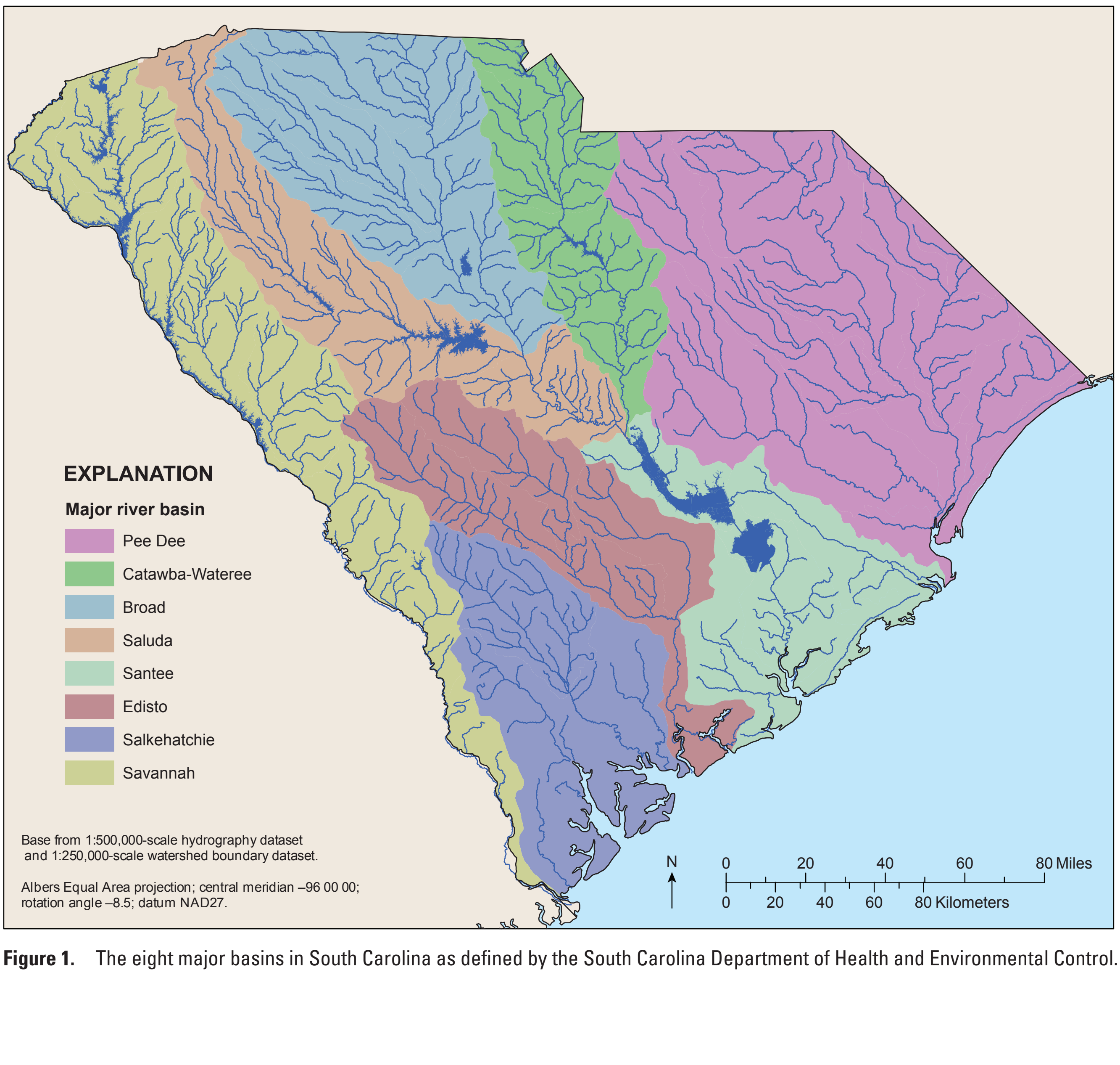


Figure 1. The eight major basins in South Carolina as defined by the South Carolina Department of Health and Environmental Control.

Purpose and Scope

The purpose of this report is to present updated low-flow characteristics at continuous-record (CR) streamgaging stations in the Pee Dee River basin of South Carolina. Depending on the length of record available at the CR streamgaging stations, the report presents estimates of annual minimum 1-, 3-, 7-, 14-, 30-, 60-, and 90-day average flows with recurrence intervals of 2, 5, l0, 20, 30, and 50 years. Low-flow statistics are presented for 18 CR streamgaging stations. In addition, daily flow durations for the 5-, 10-, 25-, 50-, 75-, 90-, and 95-percent probabilities of exceedance also are presented for these streamgaging stations (tables 2 and 3 at end of report).

The scope of this report includes both unregulated and regulated streams in the Pee Dee River basin of South Carolina, with the exception of tidally influenced streams. In order for the low-flow characteristics for CR streamgaging stations included in the previous study (Zalants, 1991b) to be updated, at least 3 years of additional streamflow data had to be collected after 1987. For new CR streamgaging stations that began collecting data after 1987, at least 5 years of data had to be available.

The daily mean streamflow data for this study were collected through March 2007, which is the 2006 climatic year. A climatic year is the 12-month period from April 1 through March 31 and is designated by the year in which it begins. For example, the 2006 climatic year is the period from April 1, 2006 through March 31, 2007. The climatic year encompasses the low-water period of the hydrologic cycle and is used to prevent the annual low-flow cycle from being artificially placed in separate years (Straub, 2001).

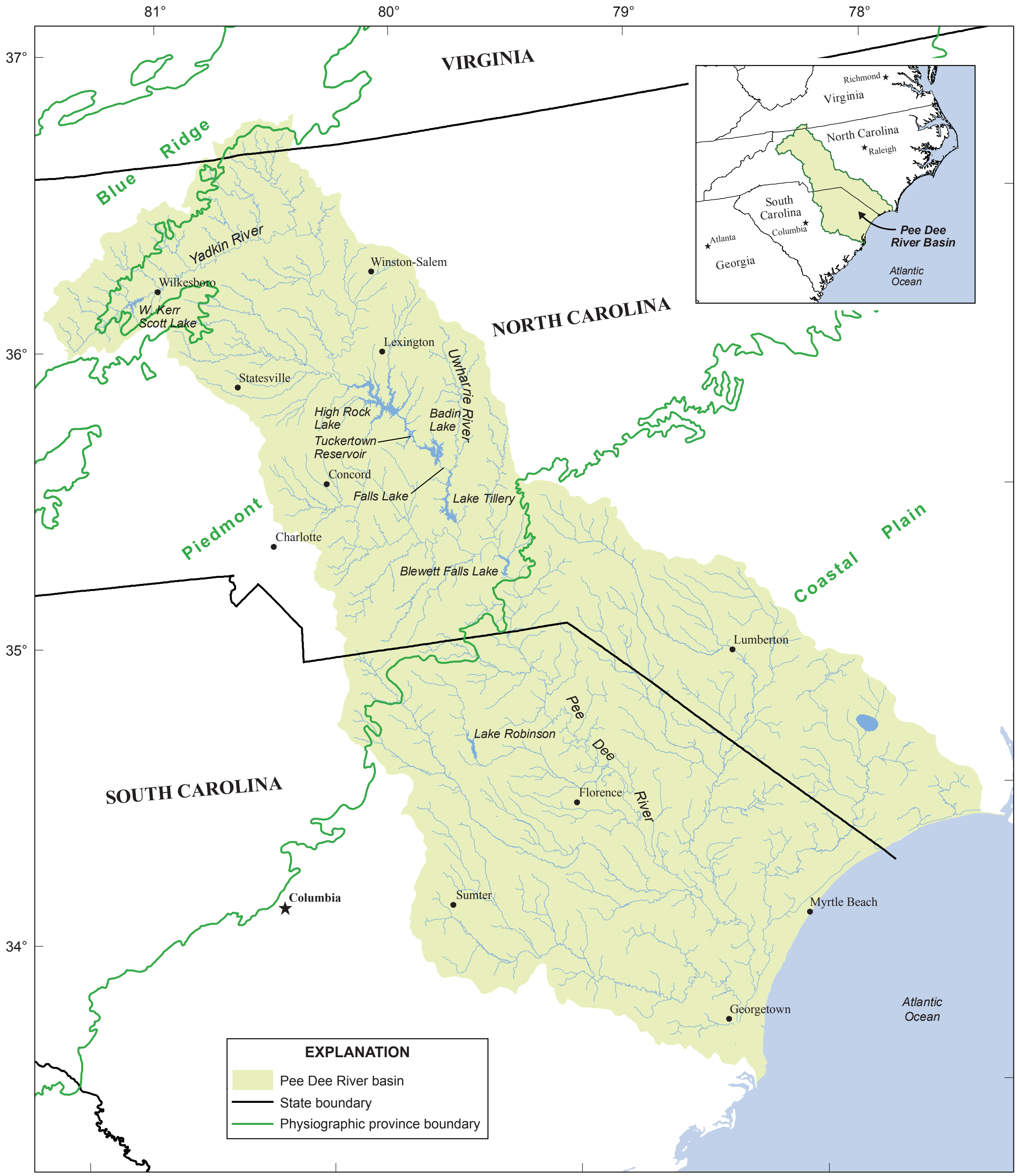
Previous Studies

Previous reports by Stallings (1967), Johnson and others (1968), Bloxham and others (1970), Bloxham (1976, 1979, and 1981), Barker (1986), and Zalants (1991a, b) described the low-flow frequency and flow-duration streamflows for CR streamgaging stations in South Carolina. Stallings (1968) presented low-flow statistics for 61 CR streamgaging stations and 83 other sites where flow was measured during the 1954 drought. Johnson and others (1968) focused on the low-flow characteristics of streams in Pickens County. Low-flow streamflow measurements from 1945 through 1967 were presented for 32 partial-record (PR) stations. Those stations were correlated with four index streamgaging stations to estimate annual minimum 7-day average streamflow with 2- and 10-year recurrence intervals (7Q2 and 7Q10, respectively). Bloxham and others (1970) presented magnitude and frequency of low-flow streamflows for nine CR streamgaging stations in Spartanburg County, and streamflow measurements were presented for 63 sites. At 35 of the 63 sites, correlation methods were used with index streamgaging stations to estimate the 7Q2 and 7Q10. Bloxham (1976) used 6 index streamgaging stations from the upper Coastal Plain to estimate the 7Q2 and 7Q10 at 54 PR stations and miscellaneous-measurement sites. Bloxham (1979) used data through the 1976 climatic year to compute low-flow frequency and flow-duration estimates at 71 CR streamgaging stations in South Carolina. Bloxham (1981) estimated the 7Q2 and 7Q10 at 130 PR stations in the Piedmont and lower Coastal Plain of South Carolina. Barker (1986) detailed the establishment of 361 PR stations with measurements made from August 1980 through July 1986. Zalants (1991a) provided estimates of the 7Q2 and 7Q10 at 564 low-flow PR stations and 27 CR streamgaging stations on streams in the Blue Ridge, Piedmont, and upper Coastal Plain Physiographic Provinces in South Carolina and in parts of North Carolina and Georgia. Zalants (1991b) provided estimates of annual minimum 1-, 3-, 7-, 14-, 30-, 60-, and 90-day average streamflows with recurrence intervals of 2 to 50 years, depending on the length of record, for 55 CR streamgaging stations in South Carolina for which at least 5 years of unregulated daily mean streamflow data were available through the 1986 climatic year.

Description of Study Area

The study area for this report is the Pee Dee River basin of South Carolina, which includes parts of the Piedmont, and upper and lower Coastal Plain Physiographic Provinces (fig. 2). The headwaters of the Pee Dee River basin begin in the Blue Ridge Physiographic Province of North Carolina and Virginia. Above the confluence with the Uwharrie River in North Carolina, the stream is known as the Yadkin River, and below as the Pee Dee River, or the Great Pee Dee River (Conrads and Roehl, 2007). While there are no reservoirs on the Pee Dee River in South Carolina, there are seven impoundments in North Carolina beginning with the W. Kerr Scott Lake west of Wilkesboro, NC. Farther downstream, a series of five reservoirs impound 50 miles of the river as follows: High Rock Lake, Tuckertown Reservoir, Badin Lake, Falls Lake, and Lake Tillery. The last impoundment on the Pee Dee River in North Carolina is Blewett Falls Lake, which is located approximately 15 miles upstream from where the river crosses into South Carolina. The watershed above Blewett Falls Lake drains approximately 6,800 square miles (mi^2).

Within South Carolina, the Pee Dee River basin watershed encompasses approximately 8,100 mi^2 (Eidson and others, 2005) (fig. 3; table 4). The South Carolina portion of the Pee Dee River basin has five major rivers: the Pee Dee, Little Pee Dee, Lynches, Black, and Waccamaw Rivers. The topographic relief is low, and Lake Robinson, which is located on Black Creek, is the only major reservoir in the Pee Dee River basin in South Carolina. Lake Robinson was completed in 1959 and has 31,000 acre-feet of storage (Moody and others, 1986).



Base from 1:100,000-scale national hydrography dataset and 1:250,000-scale watershed boundary dataset.
Albers Equal Area projection; central meridian –96 00 00; datum NAD83.

Figure 2. The Yadkin–Pee Dee River basin in North Carolina and the Pee Dee River basin in South Carolina.

Figure 3. The Pee Dee River basin in South Carolina along with streamgaging stations, physiographic provinces, and 8-digit hydrologic unit code boundaries.

Table 4. Eight-digit hydrologic unit code subbasins, subbasin name, drainage area in South Carolina, and number of U.S. Geological Survey continuous-record streamgaging stations analyzed per subbasin for the Pee Dee River basin of South Carolina.

[HUC, hydrologic unit code; USGS, U.S. Geological Survey; subbasins in bold text are wholly contained within South Carolina]

Eight-digit (subbasin) HUC number (fig. 3)	Subbasin name	Drainage area in South Carolina, in square miles	USGS continuous-record streamgaging stations analyzed
03040104	Upper Pee Dee	6.9	0
03040105	Rocky	0.9	0
03040201	Middle Pee Dee	2,047	7
03040202	Lynches	1,387	4
03040203	Lumber	122	0
03040204	Little Pee Dee	975	2
03040205	**Black**	**2,061**	**3**
03040206	Waccamaw	599	1
03040207	**Lower Pee Dee**	**570**	**0**
03040208	Coastal	344	0
	Total	8,113	17

Low-Flow Characteristics

Hydrologic information on the availability of streamflow under low-flow conditions is essential for the effective management of water resources. Low-flow characteristics defining the magnitude and frequency of such low-flow events are provided as a minimum average streamflow over some designated time period. For example, one of the most common low-flow characteristics is the annual minimum 7-day average streamflow with a 10-year recurrence interval (7Q10). In terms of probability of occurrence, there is a 1/10 or 10-percent probability that the annual minimum 7-day average flow in any 1 year will be less than the estimated 7Q10 value (Riggs, 1985).

Analysis Approach

The CR streamgaging stations included in this study were analyzed based on four categories of stations: (1) long-term record stations; (2) shorter-term record stations that had more than 10 years of record and for which a suitable long-term index station was available that could be used to extend the record at the shorter-term station; (3) stations that had between 5 and 10 years of record, which could be analyzed for a limited set of low-flow characteristics using techniques typically used in analyzing PR stations; and (4) regulated stations.

Typically, low-flow characteristics are computed at CR streamgaging stations if at least 10 years of record are available; however, computing the low-flow characteristics from long-term records is better because the long-term records are considered to be more representative due to the amount of data that typically covers a broader range of hydrologic conditions. Thus, long-term streamgaging data are better suited for trend assessments and statistical estimates. The USGS uses a value of 30 years of streamflow record to designate long-term streamgages (U.S. Geological Survey, 2009).

A second category of stations included in this study are CR streamgaging stations that have greater than 10 years of continuous-flow record, but for which record lengths are shorter than another CR streamgaging station that has a long-term record and is highly correlated with the shorter-term record. If the amount of concurrent records at the two stations is sufficient, improved low-flow characteristics may be obtained at the shorter-term streamgaging station by using record-extension techniques. This approach is often beneficial if the streamflow data at a shorter-term streamgaging station were collected during an unusually dry, wet, or otherwise unrepresentative period. As a result, the record-extension techniques allow for a more representative range of low-flow conditions at the site. This report presents selected low-flow characteristics for four CR streamgaging stations where record-extension techniques were used (table 5).

When limited streamflow data are collected on a systematic basis over a period of years for use in hydrologic analyses, the site where the data are collected is called a partial-record (PR) station. For low-flow analyses, typically 10 to 20 base-flow measurements are made over a period of about 2 years. Then, mathematical or graphical techniques can be used to correlate the base-flow measurements with concurrent daily mean flows at a CR streamgaging station (index station) (Riggs, 1972; Zalants, 1991a). Riggs (1972) noted that such a relation can be used to define a limited set of low-flow characteristics at the PR station but should not be used to define an entire frequency curve because to do so would imply a greater accuracy than is warranted. Consequently, often only the annual minimum 7-day average low-flow characteristics with 2- and 10-year recurrence intervals (7Q2 and 7Q10, respectively) are estimated at PR stations (U.S. Geological Survey, 1979).

Only CR streamgaging stations are included in the current study. However, as with PR stations, similar techniques can be used to correlate daily mean flows at CR streamgaging stations that have more than 5 years of CR streamgaging data but less than 10 years of CR data. In this report, such CR streamgaging stations represent a third category of stations that were analyzed. Similar to analyses at PR stations, only the 7Q2 and 7Q10 low-flow characteristics were estimated at these CR streamgaging stations. This report presents selected low-flow characteristics for two streamgaging stations that had between 5 and 10 years of CR streamgaging record available (table 5).

A fourth category of stations included in this study are CR streamgaging stations on regulated streams. If an assessment of the daily mean flow at a regulated station indicates that the pattern of regulation has been relatively consistent, and if the logarithms of the N-day flows are consistent with a Pearson Type III distribution, low-flow characteristics can be computed for that period using similar techniques for the unregulated streamgaging stations (Riggs, 1972). The techniques used for estimating low-flow characteristics at PR sites are only applicable to unregulated stream characteristics and, therefore, will not be applied to regulated streams. In addition, the low-flow characteristics for regulated streams are relevant to similar future regulation patterns and would not be applicable if the future regulation patterns were significantly altered. This report presents selected low-flow characteristics for four regulated CR streamgaging stations (fig. 3; table 5).

Table 5. Streamgaging stations included in the Pee Dee River basin low-flow characteristics update.

[mi^2, square miles; MOVE.1, Maintenance of Variance Extension, Type 1]

Streamgaging station number (fig. 3)	Station name	Period of record	Number of climatic years of record	Drainage area (mi^2)	Remarks
02110500	Waccamaw River near Longs, SC	Mar. 1950–Mar. 2007	57	1,110	
02129590	Whites Creek near Wallace, SC	Oct. 1979–Sept. 1995	15	26.4	
02130561	Pee Dee River near Bennettsville, SC	Nov. 1990–Mar. 2007	16	7,600	Regulated (record extended using MOVE.1)
02130900	Black Creek near McBee, SC	Oct. 1959–Mar. 2007	47	108	
02130910	Black Creek near Hartsville, SC	Oct. 1960–Mar. 2007	46	173	Regulated
02130980	Black Creek near Quinby, SC	Oct. 2001–Mar. 2007	5	438	Analyzed as partial-record station (some regulation)
02131000	Pee Dee River at Peedee, SC	Oct. 1938–Mar. 2007	68	8,830	Regulated
02131150	Catfish Canal at Sellers, SC	Nov. 1966–Sept. 1992	25	27.4	
02131309	Fork Creek at Jefferson, SC	Aug. 1976–Sept. 1997	20	24.3	
02131472	Hanging Rock Creek near Kershaw, SC	Oct. 1980–Nov. 2003	22	23.9	
02131500	Lynches River near Bishopville, SC	Oct. 1942–Sept. 1971, Feb. 2002–Mar. 2007	33	675	
02132000	Lynches River at Effingham, SC	Oct. 1929–Mar. 2007	77	1,030	
02132500	Little Pee Dee River near Dillon, SC	Apr. 1939–Sept. 1971	32	524	Record extended using MOVE.1
02135000	Little Pee Dee River at Galivants Ferry, SC	Jan. 1942–Mar. 2007	65	2,790	
02135300	Scape Ore Swamp near Bishopville, SC	July 1968–Sept. 2003	34	96.0	
02135500	Black River near Gable, SC	June 1951–June 1966, Apr. 1972–Sept. 1992	36	401	
02136000	Black River at Kingstree, SC	Oct. 1929–Mar. 2007	77	1,252	

Quality Assurance and Quality Control

For this study, a quality assurance and quality control (QAQC) analysis was done on the annual minimum 7-day average streamflow data for the CR streamgaging stations that had a minimum of 10 years of record. The data at each station were reviewed for homogeneity, which implies relatively stable watershed conditions during the period of record. The Kendall's tau test was used to assess the homogeneity of the record at each station (Helsel and Hirsch, 1992). If a trend was indicated, additional assessments were used to determine if the trend may have been caused by a short-term condition. For example, if the record at a station happened to begin or end under extreme conditions (excessively wet or dry), the test might indicate a trend, but an additional analysis excluding the extreme events might indicate no trend. Trends in unregulated stations may result from changes in climatic cycles, land use, groundwater pumpage, or other practices that might affect the groundwater levels. For stations downstream from a major source of regulation, such as a dam, the data were assessed for gross trends, which may indicate a long-term change in the pattern of regulation (William Kirby, U.S. Geological Survey, written commun., June 6, 2005). Additionally, some investigations have shown that progressive urbanization can lead to a reduction in low flows (U.S. Environmental Protection Agency, 2009). Final decisions to include or exclude data from a specific streamgaging station were made using hydrologic judgment based on the results from the QAQC analyses along with any other available information.

The QAQC analyses included the use of several computer programs developed using the commercial statistical software SAS® (SAS Institute, Inc., 1989). The components of the QAQC reviews that were done for the CR streamgaging stations are as follows.

- The Kendall's tau test to check for trends in the annual minimum 7-day average flow data over time.
- Plot of the annual minimum 7-day average flow against climatic year, which is used along with the Kendall's tau results to assess potential trends.
- Plot of a relation of the ratio of the 10 percentile to the 50 percentile of the average 7-day flows (loratio) against climatic year, which is useful for graphically assessing potential trends.
- Plot of a relation of the 50 percentile of the average 7-day flow against climatic year. This plot is useful for assessing potential changes in the median average 7-day flow over time.
- Plot of the relation of the cumulative loratio against climatic year. A significant change in the slope of this relation would indicate a change in flow patterns.
- Plot of the relation of the cumulative 50 percentile of the average 7-day flow against climatic year. A significant change in the slope of this relation would indicate changes in the median average 7-day flow patterns.

Results from Quality Assurance and Quality Control Analyses

For streamgaging station 02130910, Black Creek near Hartsville, SC, a trend was observed in the complete dataset (1961–2006). The plotted data indicate that the regulation pattern seems to have changed around 1980 (fig. 4). A Kendall's tau test on data from 1981 through 2006 shows no trend in the data; therefore, the low-flow characteristics were computed for streamgaging station 02130910 for data from April 1, 1981, through March 31, 2007. Streamgaging station 02136361, Turkey Creek near Maryville, SC, was omitted from the low-flow analysis because the channel has experienced substantial modifications that have altered the flow characteristics. Streamgaging station 02131010, Pee Dee River below Peedee, SC, also was omitted because it is located only 4 miles downstream from streamgaging station 02131000, Pee Dee River at Peedee, SC (drainage area is 8,830 mi^2). The drainage area at streamgaging station 02131010 is 8,850 mi^2, which is only 0.23 percent greater than the drainage area at streamgaging station 02131000. In addition, the period of record at streamgaging station 02131000 began in 1938; whereas, the period of record at streamgaging station 02131010 began in 1996. Consequently, the low-flow characteristics at streamgaging station 02131000 should be representative of the low-flow characteristics at streamgaging station 02131010.

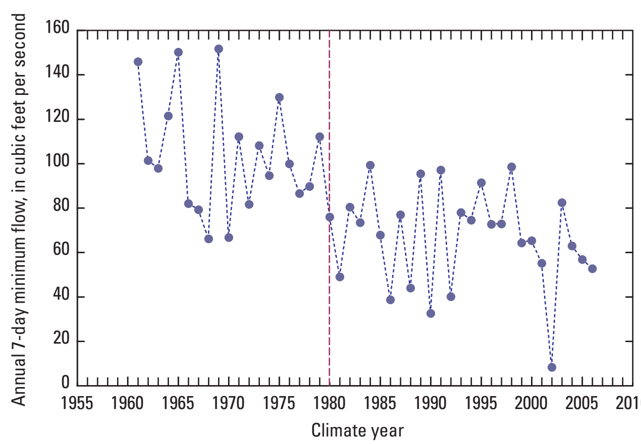


Figure 4. Annual minimum 7-day average streamflow at U.S. Geological Survey streamgaging station 02130910, Black Creek near Hartsville, South Carolina.

Diversions

Diversions on natural streams occur for a variety of reasons. Some diversions are the result of water-supply withdrawals, manufacturing, return point-source discharges, and agricultural needs, such as irrigation. Diversions by manufacturers are sometimes confined to short distances along rivers. Water may be taken from the river channel, passed through the manufacturing plant for use in processing, cooling, dilution of wastes, or other uses and then returned to the river. Consequently, in many cases, consumptive losses from diversions by manufacturers may be negligible (Ries, 1994). As this suggests, the effects of diversions to the streamflow regime of a river are variable and depend not only on where the diversions occur, but also on the final fate of the diverted water.

Ries (1994) noted that water diverted from a stream or adjacent aquifer for municipal supplies which is then returned to the basin as effluent from individual septic systems or from waste-water treatment plants within the basin generally causes little loss of water to the basin; however, such diversions may affect the temporal pattern of streamflows. Diversions from one basin to another reduce streamflow in the donor basin and increase it in the receiving basin. Diversions between subbasins of a larger basin can substantially affect streamflows in the subbasins, but if consumptive losses are negligible, streamflows for the larger basin may be nearly unaffected.

As this diversion information indicates, a proper accounting of all diversions in a basin is typically difficult; therefore, most USGS low-flow analyses are made on the data as measured at the streamgaging station without adjustments for diversions. For this study, diversion data, where available, were obtained from the SCDHEC and assessed to determine significance. Diversions upstream from a streamgaging station were considered significant if the average annual diversion equaled or exceeded 10 percent of the mean 1-day annual minimum flow for the period of record. This comparison assumes that the diversion and streamflow data are of similar quality and were measured with the same frequency and based on concurrent periods of record. If these conditions did not exist, assessments were still made and comments regarding the diversions were included in tables 2 and 3, but no adjustments were made to the low-flow estimates.

Frequency Analysis

Low-flow frequency statistics at CR streamgaging stations are often computed by fitting a series of annual minimum *N*-day average flows to some known statistical distribution, where *N* can equal any number from 1 to 365. Low-flow frequency statistics for this study were computed by fitting logarithms (base 10) of the annual minimum 1-, 3-, 7-, 14-, 30-, 60-, and 90-day average flows to a Pearson Type III distribution, which also is often referred to as a log-Pearson Type III distribution. Fitting the distribution requires calculating the mean, standard deviation, and skew coefficient of the logarithms of the *N*-day flows. Estimates of the *N*-day non-exceedance flows for a specified recurrence interval *T* are computed using the following equation:

$$\log Q_T = \bar{X} + KS \qquad (1),$$

where

Q_T is the *N*-day low flow, in cubic feet per second, and *T* is the recurrence interval, in years;

$\bar{X}$ is the mean of the logarithms of the annual minimum *N*-day average flows;

K is a frequency factor that is a function of the recurrence interval and the coefficient of skew; and

S is the standard deviation of the logarithms of the annual minimum *N*-day average flows.

Low-flow estimates typically are presented as a set of non-exceedance probabilities or, alternatively, recurrence intervals along with their associated flows. The non-exceedance probability is defined as the probability that a value will have a non-exceedance in a 1-year period and is expressed as decimal fractions less than 1.0 or as percentages less than 100. Recurrence interval is defined as the average interval of years (often referred to as the return period) during which a given flow will be less than a given value once. A flow with a non-exceedance probability of 0.10 has a 10-percent chance of being less than a specified value in any given year. Recurrence interval and non-exceedance probability are the mathematical inverses of one another; therefore, a flow with a non-exceedance probability of 0.10 has a recurrence interval of 1 divided 0.10 or 10 years. It should be emphasized that recurrence intervals, regardless of length, always refer to an average number of occurrences over a period of time. A 10-year recurrence interval does not imply that the value will have a non-exceedance every 10 years; it does indicate, however, that the average time between recurrences is equal to 10 years. Consequently, an observed interval between a non-exceedance of the 7Q10 may be as short as 1 year or may be considerably longer than 10 years.

For this study, recurrence intervals for low-flow frequency characteristics are provided based on period of record. The following criteria were established for extending frequency curves:

1. Curves for streamgaging stations with 10 or more years of annual low-flow streamflow record, but less than 20 years of record, were extended to a recurrence interval of 20 years;

2. Curves for streamgaging stations with 20 or more years of record, but less than 30 years of record, were extended to a recurrence interval of 30 years; and

3. Curves for streamgaging stations with 30 or more years of record were extended to a recurrence interval of 50 years. No data were compiled for recurrence intervals greater than 50 years.

An example of the log-Pearson type III curve-fitting procedure is illustrated in figure 5.

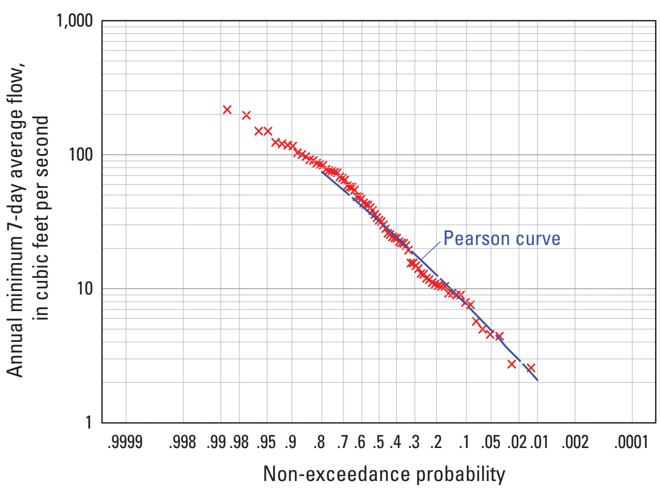


Figure 5. Low-flow frequency curve for the U.S. Geological Survey streamgaging station 02136000, Black River at Kingstree, South Carolina.

Conditional Probability Adjustment

Zero flows cannot be included in a log-Pearson Type III distribution because they cannot be transformed logarithmically. When zero flows are part of the *N*-day flows at a streamgaging station, a conditional probability adjustment can be made in order to estimate the low-flow characteristics (Jennings and Benson, 1969; Tasker, 1987). Additional information on the procedures and guidelines for the conditional probability adjustment can be found in Bulletin 17B of the Hydrology Subcommittee of the Interagency Advisory Committee on Water Data (1982) .

To calculate the adjusted probability, a log-Pearson Type III analysis is done using only the non-zero values. Then, the conditional probability adjustment is made using the following formula:

$$P_{adj} = \left(\frac{N}{n}\right)P_n - \frac{(N-n)}{n}, \qquad (2)$$

where

P_{adj} is the adjusted non-exceedance probability;
P_n is the non-exceedance probability for the non-zero values;
n is the number of non-zero values; and
N is the total number of values.

For this study, four streamgaging stations required conditional probability adjustments to adjust for zero flows: streamgaging station 02129590, Whites Creek near Wallace, SC; 02131150, Catfish Canal at Sellers, SC; 02131309, Fork Creek at Jefferson, SC; and 02135500, Black River near Gable, SC (table 6). The adjusted frequency curve for streamgaging station 02135500, Black River near Gable, SC, is shown in figure 6.

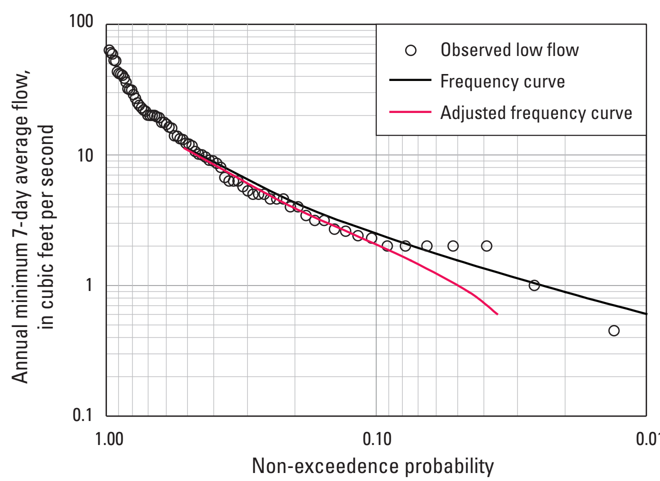


Figure 6. Conditional probability adjustment curve for U.S. Geological Survey streamgaging station 02135500, Black River near Gable, South Carolina.

Table 6. Streamgaging stations that were adjusted for zero flows, climatic years of record, and years of zero flows for the annual minimum 1-, 3-, 7-, 14-, 30-, and 60-day average streamflow for four U.S. Geological Survey streamgaging stations in the Pee Dee River basin of South Carolina.

[USGS, U.S. Geological Survey; NZ, no zero flows]

USGS streamgaging station number and name (fig. 3)	Climatic years of record	Years with N-day average zero flows					
		1	3	7	14	30	60
02129590, Whites Creek near Wallace, SC	1980–1994	1990	1990	1990	NZ	NZ	NZ
02131150, Catfish Canal at Sellers, SC	1967–1991	1978 1980 1983	1978 1980 1983	1978 1980 1983	1978 1980	1978 1980	NZ
02131309, Fork Creek at Jefferson, SC	1977–1996	1983 1986 1978 1988 1990	1983 1986 1988 1990	1983 1986 1988	1986	1986	NZ
02135500, Black River near Gable, SC	1930–2006	1954 1956 1957 1986	1954 1957 1986	1954 1957	1954	1954	1954

Record-Extension Technique

Streamflow characteristics often are needed to estimate probabilities of occurrences for periods much longer than the actual measured period of record. Consequently, short records that may have been collected during an unusually dry, wet, or otherwise unrepresentative period may not represent the fuller range of potential hydrologic regimes as would be desired. If a long-term streamgage is available that is significantly correlated with the short-term streamgage, record-extension techniques can be used to extend or augment the records at the short-term gage to better reflect a longer period.

If a linear relation between the logarithms of the N-day flows (where N is the number of days used to compute the annual minimum average flow) at a short-term gage are determined to be significantly correlated to a concurrent set of flows at a long-term, or index station, a mathematical record-extension method known as the Maintenance of Variance Extension, Type 1 (MOVE.1) method (Hirsch, 1982) can be used to extend the record at the short-term gage. The MOVE.1 relation maintains the mean and the variance of the data at the short-term record and, therefore, allows for the generation of a longer-term set of data that will possess the statistical characteristics of the actual measured data from the short-term record. The MOVE.1 equation is

$$Y_i = \bar{Y} + \frac{S_y}{S_x}(X_i - \bar{X}), \qquad (3)$$

where

Y_i is the logarithm of the estimated flow statistic or N-day flow for the short-record station;

$\bar{Y}$ is the mean of the logarithms of N-day flows for the concurrent period at the short-record station;

S_y is the standard deviation of the logarithms of N-day flows for the concurrent period at the short-record station;

S_x is the standard deviation of the logarithms of N-day flows for the concurrent period at the long-term or index station;

X_i is the logarithm of the flow statistic or observed N-day flow at the index station; and

$\bar{X}$ is the mean of the logarithms of the N-day flows for the concurrent period at the index station.

In order for an index station to be considered for this study, it had to have a minimum of 10 years of concurrent record with the short-term streamgaging station, had to have similar basin geology as the short-term streamgaging station, and the larger basin had to be less than 10 times the size of the smaller basin (Telis, 1991). A minimum correlation coefficient between concurrent flows has not been developed for the MOVE.1 technique; however, similar correlation studies have used values ranging from 0.70 to 0.80 (Hydrology Subcommittee of the Interagency Advisory Committee on Water Data, 1982; Stedinger and Thomas, 1985; Ries, 1994; Nielsen, 1999). In addition, if the record at the short-term station or the available index station included zero flows, record extensions were not done due to the lack of adequate testing of including such values in record-extension techniques (written commun., Julie Kiang, U.S. Geological Survey Office of Surface Water, January 26, 2010). A plot of the correlation of annual minimum 7-day average streamflow at stations 02132500, Little Pee Dee River near Dillon, SC, and 02135000, Little Pee Dee River at Galivants Ferry, SC, is shown in figure 7. The two short-term streamgaging stations for which record was extended are listed in table 7.

For gaging stations that have relatively long records, such as 30 years or more, record extensions may still be beneficial if an index station is available that has additional record collected under hydrologic conditions that are not included in the record being analyzed. Currently, there are no standard criteria for assessing when use of MOVE.1 is warranted with respect to improvement in the low-flow statistics at such stations. Therefore, for this investigation, an arbitrary criteria was set. If there was an average of 10 percent or more difference in the N-day low-flow statistics computed at the index station for the concurrent record as compared to those computed using the complete period of record at the index station, MOVE.1 was used to extend the record at the station of interest. Otherwise, no extension was done.

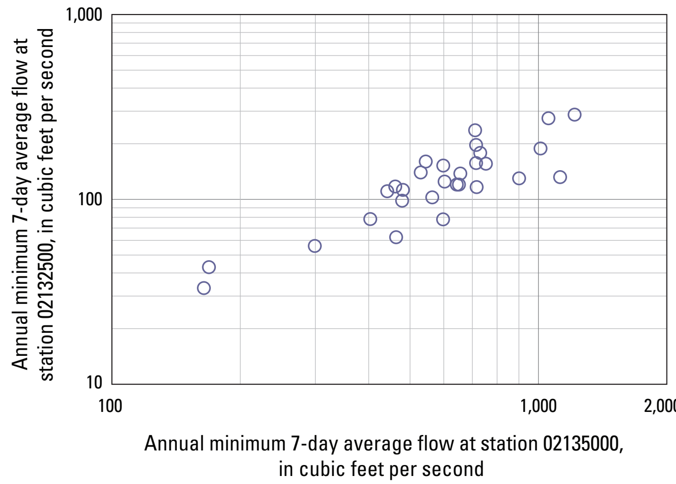


Figure 7. The correlation of annual minimum 7-day average flow at U.S. Geological Survey streamgaging stations 02132500, Little Pee Dee River near Dillon, South Carolina, and 02135000, Little Pee Dee River at Galivants Ferry, South Carolina, for the concurrent period of record.

Table 7. Short-term streamgaging stations for which record was extended, long-term index streamgaging stations, additional climatic years of record, and range of correlation coefficients for the various N-day periods assessed for gaging stations where record was extended using MOVE.1 for the Pee Dee River basin of South Carolina.

[USGS, U.S. Geological Survey; mi^2, square miles]

Short-term streamgaging station		Long-term (index) streamgaging station		Number of additional climatic years of record computed	Range of correlation coefficients
USGS streamgaging station number and name (and drainage area)	Period of record, years	USGS streamgaging station number and name (and drainage area)	Period of record, years		
02130561, Pee Dee River near Bennettsville, SC (7,600 mi^2)	Nov. 1990–Sept. 2007	02131000, Pee Dee River at Peedee, SC (8,830 mi^2)	Feb. 1939–Mar. 2007	52	0.93–0.96
02132500, Little Pee Dee River near Dillon, SC (524 mi^2)	Oct. 1939–Sept. 1971	02135000, Little Pee Dee River at Galivants Ferry, SC (2,790 mi^2)	Jan. 1942–Mar. 2007	36	0.83–0.92

Partial-Record Type Analysis

As previously discussed, when limited streamflow data are collected on a systematic basis over a period of years for use in hydrologic analyses, the site at which the data are collected is called a partial-record (PR) station (Zalants, 1991a). With respect to low-flow characteristics, once a sufficient number of base-flow measurements have been made over a reasonable period of time, techniques can be used to transfer low-flow characteristics from an index station to the PR station. If the relation between the flows at the PR station and the index station is linear, mathematical correlation methods such as MOVE.1 can be used (Hirsch, 1982). If the relation is nonlinear, then a graphical correlation described by Riggs (1972) can be used.

For this investigation, CR streamgaging stations that had record lengths greater than 5 years but less than 10 years were treated as PR stations and, hereafter, will be referred to in this report as PR stations. The MOVE.1 technique was used to establish a relation between the concurrent daily mean flows. In order to use daily mean flows that are representative of low-flow conditions, only concurrent flows that were less than or equal to the 90-percent flow duration at the index station were used in the MOVE.1 analysis. That relation was then used to transfer a limited set of low-flow characteristics from an appropriate index station to the PR station. Similar criteria as were described for extending the record at a short-term streamgaging station were used with the exception of the concurrent-record length. As recommended in the USGS Office of Surface Water Technical Memorandum No. 86.02 (U.S. Geological Survey, 1985), only the 7Q2 and 7Q10 statistics were estimated for the PR stations. Because of the limited records available at the PR stations, providing a broader set of statistics would imply an accuracy that is not warranted.

The same MOVE.1 equation (equation 3) as described previously is used to transfer the low-flow characteristic from the index station to the PR station. The difference is that now X_i is the low-flow characteristic computed from the index or long-term streamgaging station, and Y_i is the low-flow characteristic estimated at the PR station (fig. 8). Only one CR streamgaging stations in the Pee Dee River basin had greater than 5 years of record but less than 10 years of record for which record extension was appropriate: 02130980, Black Creek near Quinby, SC (table 8). As previously stated, only the 7Q2 and 7Q10 streamflows were estimated. Streamgaging station 02130980, Black Creek near Quinby, SC, was correlated with two streamgaging stations: 02130900, Black Creek near McBee, SC, and 02130910, Black Creek near Hartsville, SC. The correlation coefficient was slightly higher with streamgaging station 02130910 than with station 02130900, but the index station 02130900 was selected because it has a longer period of record and because streamgaging station 02130910 is located about 1,000 ft downstream from Lake Robinson dam. The dam causes the flow at streamgaging station 02130910 to be highly regulated, and regulation patterns seem to have changed for this station around 1980. Using data from 1980 therefore reduces the period of record, reducing the reliability of the low-flow streamflow estimates.

Table 8. Long-term index streamgaging stations, short-term streamgaging stations analyzed as partial-record stations, the 7-day, 2- and 10-year low flows, climatic years of record, additional climatic years of record at the index station, and correlation coefficients.

[7Q2, 7-day, 2-year recurrence interval flow; 7Q10, 7-day, 10-year recurrence interval flow; ft^3/s, cubic feet per second]

Station number and name of short-term streamgaging stations analyzed as partial-record station	Climatic years of record	7Q2 (ft^3/s)	7Q10 (ft^3/s)	Index station number and name	Climatic years of record	7Q2 (ft^3/s)	7Q10 (ft^3/s)	Additional years of record at index station	Correlation coefficient
02130980, Black Creek near Quinby, SC	5	212	112	02130900, Black Creek near McBee, SC	47	37	20	43	0.74

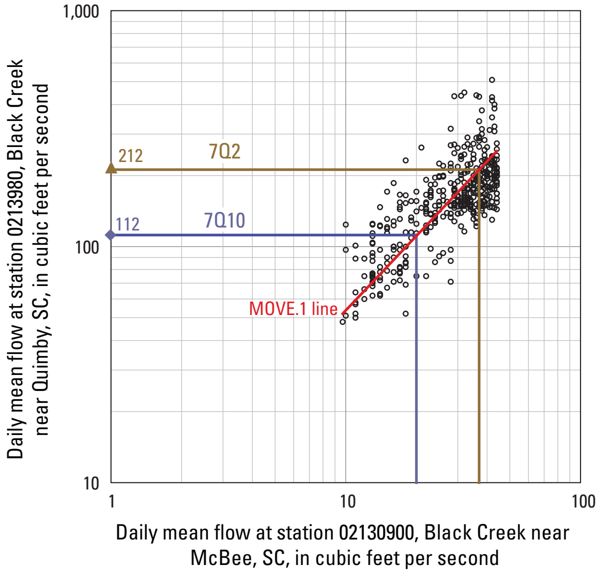


Figure 8. Relation between concurrent daily mean flow at U.S. Geological Survey streamgaging stations 02130900, Black Creek near McBee, South Carolina, and 02130980, Black Creek near Quinby, South Carolina, using a MOVE.1 correlation.

Flow-Duration Analysis

Flow durations represent the percentage of time that a specified streamflow is equaled or exceeded during a given period (Searcy, 1959). Flow durations are computed by sorting the daily mean flows for the period of record from the largest value to the smallest value and assigning each streamflow value a rank, starting from 1 to the largest value. The frequencies of exceedance are then computed using the Weibull formula for computing plotting position (Helsel and Hirsch, 1992):

$$P = 100 * [M / (n + 1)], \tag{4}$$

where

P is the probability that a given flow will be equaled or exceeded (percent of time),

M is the ranked position (dimensionless), and

n is the number of events for the period of record (dimensionless).

Flow durations are a summary of the past hydrologic events. Yet, if the streamflow during the period on which the duration curve is based is a sufficiently long period of record, the statistics can often be used as an indicator of probable future conditions (Searcy, 1959). In order to compare flow durations at different streamgaging stations or in different basins, flow-duration estimates can be normalized by drainage area to represent a streamflow per unit area. Again, it should be noted that the most useful comparisons will be those based on similar lengths of record from similar hydrologic periods.

Flow durations for this report are presented in tabular form for the 5-, 10-, 25-, 50-, 75-, 90-, and 95-percent exceedances (tables 2 and 3). To be consistent with the low-flow characteristics, flow durations were computed using daily mean flows through March 2007.

For streamgaging stations where record-extension techniques were used to extend a short-term record based on a relation with a long-term record (table 7), daily mean flows were extended using MOVE.1. Limited sensitivity test indicated doing so was appropriate for flows between the 5- to 95-percent duration values (written commun., Julie Kiang, U.S. Geological Survey Office of Surface Water, January 26, 2010). The flow durations were computed by combining the measured data with the synthesized data generated from the record extension.

Considerations for Accuracy of Low-Flow Characteristics

With respect to streamflow statistics, the period of collected record can be thought of as a sample, or small portion, of the population, which represents all possible measurements. Statistics allow for making inferences about the characteristics of the population based on samples from that population. For example, statistical measures, such as mean, standard deviation, or skew coefficient, can be described in terms of the sample and then used to make inferences about the population from which the sample was obtained. Statistical measures computed from the sample record are estimates of what the measure would be if the entire population were known and used to compute the given measure. Consequently, the accuracy of low-flow characteristics at streamgaging stations is related to the lengths of records (samples from the population) upon which the characteristics are based. The longer the period of record at a streamgaging station that covers a broad range of hydrologic conditions, the more accurate or reflective of long-term conditions the low-flow characteristics will be.

The streamflow characteristics for short records are much more sensitive to extreme hydrologic events than those for long-term records. As a result, streamflow characteristics, whether high or low, from one 10-year period may differ significantly from another 10-year period. Thus, a long-term record is always more desirable when computing streamflow statistics. To test the effect of record length and hydrologic conditions on low-flow characteristics, the 7Q10 for streamgaging station 02132000, Lynches River at Effingham, SC, was computed beginning with the first 10 years of record (April 1930–March 1940) and then updated on a 5-year basis through climatic year 2006. Figure 9 shows the annual minimum 7-day average flow by climatic year for the period of record along with the computed 7Q10 estimates. The figure shows that the 7Q10 for the first 10 years of record was 143 cubic feet per second (ft^3/s). By climatic year 1950, the 7Q10 had increased to 152 ft^3/s due to the addition of records collected during a period when streamflow was fairly well sustained. Then with the drought of the 1950s, the 7Q10 decreased to 138 ft^3/s in 1955. The 1960s and 1970s tended to be a relatively wet period, and the 7Q10 generally increased during that time. Lastly, the drought of 1998–2002 had a substantial effect on the 7Q10, with the value decreasing to 131 ft^3/s in climatic year 2006. The difference between the highest and lowest 7Q10 computed in this analysis is 14 percent.

To show the effect of how the 7Q10 can be influenced under a different set of hydrologic conditions and the significant influence that period of record can have on streamflow characteristics, a similar analysis was done using a synthesized record of annual minimum 7-day average flows. The synthesized flows were generated by reversing the annual minimum 7-day average flows from streamgaging station 02132000. Under these conditions, the streamflow record begins in a significant dry period. As can be seen in figure 10, the 7Q10 computed from the first 10 years of record is 89.9 ft^3/s, which is 63 percent of the 7Q10 based on the first 10 years of record from the measured data at station 02132000. Because the synthesized record began in a period that was the driest based on the next 68 years of record, the 7Q10 shows a pattern of continuing to increase until again, a value of 131 ft^3/s was obtained in climatic year 2006. The difference between the highest and lowest 7Q10 computed in this analysis is 32 percent. This percent difference emphasizes that although the 7Q10 value at the end of the record was the same for both the measured data and the synthesized data; the intermittent values were sometimes significantly different based on a rearrangement of the hydrologic conditions (starting in a significant drought as opposed to starting in a relatively wet period). Thus, as the length of record at a streamgaging station increases, the low-flow characteristics are moving toward the values that would be expected to be obtained from the population. As the period of record increases, the streamflow statistics tend to be less influenced by extreme conditions, whether they are wet or dry.

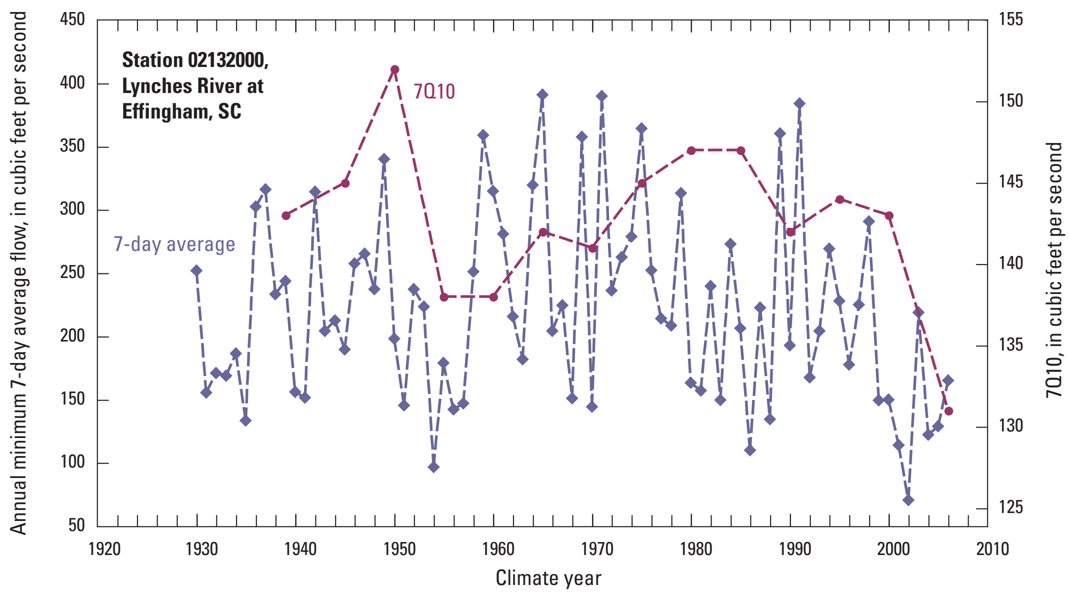


Figure 9. Annual minimum 7-day average flows and 7Q10 estimates at streamgaging station 02132000, Lynches River at Effingham, South Carolina.

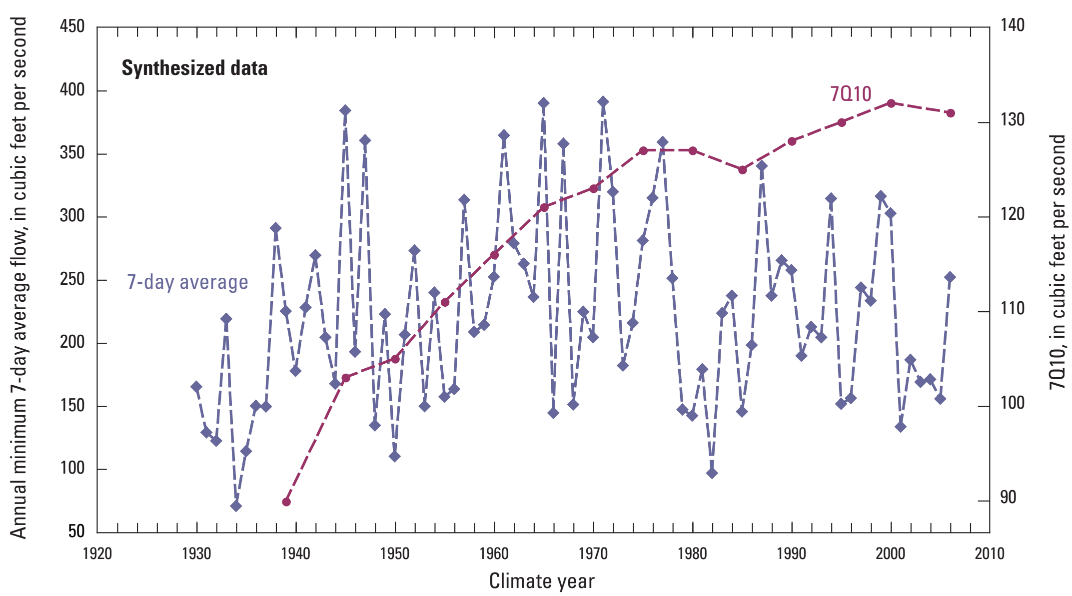


Figure 10. Annual minimum 7-day average flows and 7Q10 estimates from a synthesized dataset.

Comparison with Previously Published Low-Flow Characteristics

The last systematic update of low-flow statistics in South Carolina included data though March 1987 (the 1986 climatic year). Since that time, several droughts have occurred, with the most severe drought occurring between 1998 and 2002 and the most recent drought occurring from 2006 to 2009 (South Carolina Department of Natural Resources, 2009). Less severe droughts were reported in 1988, 1990, 1993, and 1995 (Mizzell, 2008). At many stations, the 1998–2002 drought resulted in the lowest annual minimum 7-day average flow of record. However, that was not true at every station. For example, at streamgaging stations 02110500, Waccamaw River near Longs, SC, and 02136000, Black River near Kingstree, SC, the lowest annual minimum 7-day average flow occurred during the 1954 drought. It is worth noting that the 7Q10 flow estimates for the Waccamaw River station and two stations on the Black River increased from the estimates given in previous studies (table 9). Other factors that would influence the differences in the 7Q10 values are record extensions that were used in this study but were not part of the previous studies, whether the 7Q10 analyses were done mathematically or graphically (all were done mathematically in this study), and other changes in the watershed that were not substantial enough to indicate any trends in the data but could still have some influence on the low-flow characteristics.

Table 9. Differences between 7-day, 10-year low flows in this report and previously published 7-day, 10-year low flows for continuous-record streamgaging stations in the Pee Dee River basin of South Carolina.

[USGS, U.S. Geological Survey; ft^3/s, cubic feet per second; —, no miscellaneous estimate; ND, not determined]

USGS streamgaging station number and name	Previous estimate from Bloxham (1979), in ft^3/s	Previous estimate from Zalants (1991), in ft^3/s	Miscellaneous estimate, in ft^3/s (date)	Current (2007) estimate, in ft^3/s	Percent difference from most recent estimate to current estimate
02110500, Waccamaw River near Longs, SC	6.8	8.2	—	9.9	20.7
02129590, Whites Creek near Wallace, SC	ND	0.25	—	0.14	–44.0
02130561, Pee Dee River near Bennettsville, SC	ND	ND	—	1,010	ND
02130900, Black Creek near McBee, SC	22	23	—	20	–13.0
02130910, Black Creek near Hartsville, SC	67	ND	—	33	[1] –50.7
02130980, Black Creek near Quinby, SC	ND	ND	—	112	ND
02131000, Pee Dee River at Peedee, SC	1,500	ND	1,470 (July 5, 2005)	1,430	–2.7 ([2] –4.7)
02131150, Catfish Canal at Sellers, SC	0.05	0.02	—	0.0	–100
02131309, Fork Creek at Jefferson, SC	ND	0.0	—	0.0	0.0
02131472, Hanging Rock Creek near Kershaw, SC	ND	0.15	—	0.31	107
02131500, Lynches River near Bishopville, SC	140	ND	—	117	–16.4
02132000, Lynches River at Effingham, SC	132	140	—	131	–6.4
02132500, Little Pee Dee River near Dillon, SC	57	ND	—	49	–14.0
02135000, Little Pee Dee River at Galivants Ferry, SC	315	310	—	249	–19.7
02135300, Scape Ore Swamp near Bishopville, SC	6.7	6.6	—	6.5	–1.5
02135500, Black River near Gable, SC	0.41	1.2	—	1.0	–16.7
02136000, Black River at Kingstree, SC	5.7	7.0	—	7.6	8.6

[1] Part of the annual minimum 7-day average flows used in the Bloxham analysis were not used in the current estimate because the quality control and quality assurance checks indicated that the regulation patterns had substantially changed after about 1980.

[2] Percent difference between the current estimate and the estimate presented by Bloxham (1979).

Of the 17 streamgaging stations included in this study, 15 had low-flow characteristics that were previously published by Bloxham (1979) or Zalants (1991b). For those 15 streamgaging stations, the most recently published 7Q10 value was compared with the current value and a percent difference was computed as follows:

$$\text{Percent difference} = [(\text{current 7Q10} - \text{previous 7Q10}) / \text{previous 7Q10}] \times 100. \quad (5)$$

As computed, the percent difference indicates the percent of change from the previous 7Q10 estimate. The percent differences ranged from –100 to 107 percent with nine streamgaging stations having negative percent differences indicating that the 7Q10 had decreased, four streamgaging stations having positive percent differences indicating that the 7Q10 had increased, and two streamgaging stations having a zero percent difference indicating no change from the previously published value (table 9). All but 5 of the 15 streamgaging stations had percent differences that were within ±25 percent of the previous value. Streamgaging station 02131150 had the highest negative percent difference, which was –100 percent; however, that negative percent difference represented a change from 0.02 ft^3/s to 0.0 ft^3/s, which is difficult to distinguish in reality from a statistical and physical measure. Streamgaging station 02131472 had the highest positive percent difference (107 percent). The previously published 7Q10 was 0.15 ft^3/s, and the current 7Q10 is 0.31 ft^3/s, which is in the range of flows that tend to have a higher uncertainty with respect to physically measuring such values. Streamgaging station 02130910 had a percent difference of –50.7 percent. It was previously noted, however, that the QAQC analysis indicated a substantial difference in regulation patterns before and after about 1980. Consequently, for the current 7Q10 estimate at streamgaging station 02130910, the data prior to 1980 (fig. 4) were not included in the analysis; therefore, part of the difference between the current 7Q10 and the previous 7Q10 would be accounted for by the different periods of record used in the analysis.

Summary

This report, prepared in cooperation with the South Carolina Department of Health and Environmental Control, provides updated low-flow characteristics at continuous-record streamgaging stations operated by the U.S. Geological Survey in the Pee Dee River basin of South Carolina. The continuous-record streamgaging stations included in this study were analyzed based on four categories of stations: (1) long-term record stations; (2) short-term record stations that had more than 10 years of record and for which a suitable long-term index station was available that was used to extend the record at the short-term station; (3) stations that had between 5 and 10 years of record, which were analyzed for a limited set of low-flow characteristics using techniques typically used in analyzing partial-record stations; and (4) regulated stations. The Maintenance of Variance Extension, Type 1 method, was used for the record-extension analyses and the partial-record type analyses. Based on the length of record available at the continuous-record streamgaging stations, low-flow frequency characteristics were estimated for consecutive 1-, 3-, 7-, 14-, 30-, 60-, and 90-day average minimum flows with recurrence intervals of 2, 5, l0, 20, 30, and 50 years. Additionally, daily flow durations for the 5-, 10-, 25-, 50-, 75-, 90-, and 95-percent probability of exceedance also were computed for the stations.

To illustrate the effect of record length and hydrologic conditions on low-flow characteristics, the 7-day, 10-year low-flow characteristic (7Q10) was computed at a streamgaging station that had 77 climatic years of record available for analysis. The 7Q10 was computed using the first 10 years of record and recomputed with each additional 5 years of record. The highest and lowest 7Q10 estimates varied by about 14 percent. A synthesized record was then generated by reversing the order of the data from the actual streamgaging station, which caused the first 10 years of record to include the driest period during the complete 77 years of record. When the 7Q10 was computed using all 77 years of record, the 7Q10 estimate was exactly the same, as expected based on the analytical method. For the synthesized dataset, however, the percent difference between the highest and lowest 7Q10 was 32 percent.

Of the 17 streamgaging stations included in this study, 15 had low-flow characteristics that were published in previous U.S. Geological Survey reports. A comparison of the low-flow characteristic for the minimum average flow for a 7-consecutive-day period with a 10-year recurrence interval from this study with the most recently published values from previous studies indicated that 10 of the 15 streamgaging stations had values that were within ±25 percent of each other. Nine of the 15 streamgaging stations had negative percent differences, indicating that the low-flow statistic decreased since the previous study. Four streamgaging stations had positive percent differences, indicating that the low-flow statistic had increased since the previous study. Two streamgaging stations had a zero percent difference, indicating no change since the previous study. Low-flow characteristics are influenced by length of record, hydrologic regime under which the record was collected, techniques used to do the analysis, and other changes that may have occurred in the watershed.

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Tables 2 and 3

Table 2. Low-flow statistics for unregulated continuous-record gaging stations in South Carolina.

[lat, latitude; long, longitude; ft, feet; mi, mile; mi^2, square mile; SCDHEC, South Carolina Department of Health and Environmental Control; MOVE.1, Maintenance of Variance Extension, Type 1; ND, not determined; the station low-flow statistics are presented in the following pages in numerical order by station number]

STATION NUMBER AND NAME.—02110500 Waccamaw River near Longs, SC

LOCATION.--Lat 33º54’45’’, long 78º42’55’’, Horry County, Hydrologic Unit 03040206, on the upstream side of the upstream bridge on State Highway 9, 500 ft downstream from Buck Creek, 2.1 mi southeast of Longs, and at mile 85.4.

DRAINAGE AREA.—1,110 mi^2, approximately.

PERIOD OF RECORD.—March 1950 to September 2007.

PERIOD OF ANALYSIS.—April 1950 to March 2007.

REMARKS.—Based on review of withdrawal and discharge data provided by the SCDHEC, there is no significant regulation or diversion upstream in South Carolina. The potential exists for significant diversion upstream in North Carolina. However, adequate data are not available to quantify this diversion. No adjustment was made to data used in the frequency analysis.

MAGNITUDE AND FREQUENCY OF ANNUAL LOW FLOWS

Recurrence intervals (years)	Lowest average flow for indicated number of consecutive days (cubic feet per second)						
	1	3	7	14	30	60	90
2	36	36	39	44	61	109	186
5	15	15	16	18	24	38	63
10	8.4	9.2	9.9	11	14	21	34
20	5.1	5.9	6.5	7.3	9.1	13	19
30	3.9	4.6	5.1	5.8	7.1	9.4	14
50	2.8	3.5	3.9	4.5	5.5	6.8	9.8

DURATION OF DAILY FLOWS

Flow, in cubic feet per second, which was equaled or exceeded for indicated percentage of days							
Percent	5	10	25	50	75	90	95
Flow	4,360	3,120	1,680	713	195	56	30

STATION NUMBER AND NAME.—02129590 Whites Creek near Wallace, SC

LOCATION.—Lat 34º45’20”, Long 79º53’00”, Marlboro County, Hydrologic Unit 03040201, on the upstream side of bridge on U.S. Highway 1, 100 feet downstream from lake spillway and 2.9 miles northwest of Wallace, SC.

DRAINAGE AREA.—26.4 mi^2.

PERIOD OF RECORD.—October 1979 to September 1995.

PERIOD OF ANALYSIS.—April 1980 to March 1995.

REMARKS.—Based on review of withdrawal and discharge data provided by the SCDHEC, there are no significant diversions upstream. Some regulation upstream from some small reservoirs**.** No adjustment was made to data used in the frequency analysis.

MAGNITUDE AND FREQUENCY OF ANNUAL LOW FLOWS

Recurrence intervals (years)	Lowest average flow for indicated number of consecutive days (cubic feet per second)						
	1	3	7	14	30	60	90
2	1.3	1.3	1.7	2.0	4.1	6.5	8.2
5	0.20	0.26	0.43	0.68	2.0	4.0	5.3
10	0.04	0.07	0.14	0.36	1.3	3.0	4.1
20	0.0	.0	.0	0.20	0.87	2.4	3.4

DURATION OF DAILY FLOW

Flow, in cubic feet per second, which was equaled or exceeded for indicated percentage of days							
Percent	5	10	25	50	75	90	95
Flow	83	61	36	19	8.8	4.4	2.2

STATION NUMBER AND NAME.—02130900 Black Creek near McBee, SC

LOCATION.--Lat 34º30’50’’, long 80º11’00’’, Chesterfield County, Hydrologic Unit 03040201, near right bank, at downstream side of bridge on U.S. Highway 1, 0.2 mi upstream from Little Alligator Creek, 5.8 mi northeast of McBee, and at mile 59.1.

DRAINAGE AREA.—108 mi^2.

PERIOD OF RECORD.—October 1959 to September 2007.

PERIOD OF ANALYSIS.—April 1960 to March 2007.

REMARKS.—Based on review of withdrawal and discharge data provided by the SCDHEC, there are no significant diversions upstream. Infrequent fluctuations at low flow caused by small lakes upstream. No adjustment was made to data used in the frequency analysis.

MAGNITUDE AND FREQUENCY OF ANNUAL FLOWS

Recurrence intervals (years)	Lowest average flow for indicated number of consecutive days (cubic feet per second)						
	1	3	7	14	30	60	90
2	34	35	37	41	47	60	71
5	22	23	24	27	31	40	47
10	18	19	20	22	25	32	37
20	15	16	17	19	22	26	31
30	14	14	15	17	20	24	28
50	12	13	14	16	18	21	25

DURATION OF DAILY FLOW

Flow, in cubic feet per second, which was equaled or exceeded for indicated percentage of days							
Percent	5	10	25	50	75	90	95
Flow	340	269	192	126	72	44	34

STATION NUMBER AND NAME.—02131150 Catfish Canal at Sellers, SC

LOCATION.--Lat 34º17'04'', long 79º26'32'', Marion County, Hydrologic Unit 03040201, on right downstream wingwall of culvert on State Highway 38, 2.0 mi east of Sellers, 2.3 mi upstream from Stackhouse Creek, and at mile 25.6.

DRAINAGE AREA.—27.4 mi^2.

PERIOD OF RECORD.—November 1966 to September 1992.

PERIOD OF ANALYSIS.—April 1967 to March 1992.

REMARKS.—Some seasonal diversion for agricultural use in the upper reaches of the stream. Based on review of withdrawal and discharge data provided by the SCDHEC, there are no significant diversions upstream. However, adequate data are not available to quantify this diversion. No adjustment was made to data used in the frequency analysis.

MAGNITUDE AND FREQUENCY OF ANNUAL FLOWS

Recurrence intervals (years)	Lowest average flow for indicated number of consecutive days (cubic feet per second)						
	1	3	7	14	30	60	90
2	0.97	1.0	1.2	1.5	2.0	2.8	4.5
5	0.25	0.28	0.34	0.33	0.44	0.96	1.9
10	0.0	.0	.0	0.04	0.07	0.49	1.1
20	.0	.0	.0	.0	.0	0.26	0.65
30	.0	.0	.0.	.0	.0	0.18	0.48

DURATION OF DAILY FLOW

Flow, in cubic feet per second, which was equaled or exceeded for indicated percentage of days							
Percent	5	10	25	50	75	90	95
Flow	91	62	32	14	5.1	2.0	1.1

STATION NUMBER AND NAME.—02131309 Fork Creek at Jefferson, SC

LOCATION.--Lat 34º38’19’’, long 80º23’20’’, Chesterfield County, Hydrologic Unit 03040202, on upstream side, at center of span on State Highway 151 bridge, 1.0 mi south of intersection of State Highways 265 and 151, at Jefferson, SC.

DRAINAGE AREA.—24.3 mi^2.

PERIOD OF RECORD.— October 1976 to September 1997.

PERIOD OF ANALYSIS.—April 1977 to March 1997.

REMARKS.—Based on review of withdrawal and discharge data provided by the SCDHEC, there are no significant diversions upstream. No adjustment was made to data used in the frequency analysis.

MAGNITUDE AND FREQUENCY OF ANNUAL LOW FLOWS

Recurrence intervals (years)	Lowest average flow for indicated number of consecutive days (cubic feet per second)						
	1	3	7	14	30	60	90
2	0.36	0.46	0.50	0.73	1.5	2.9	3.5
5	0.0	.0	0.05	0.15	0.54	0.89	1.6
10	.0	.0	.0	0.05	0.26	0.41	1.0
20	.0	.0	.0	.0	.0	0.20	0.71
30	.0	.0	.0	.0	.0	0.13	0.57

DURATION OF DAILY FLOW

Flow, in cubic feet per second, which was equaled or exceeded for indicated percentage of days							
Percent	5	10	25	50	75	90	95
Flow	75	53	32	15	4.6	1.3	0.61

STATION NUMBER AND NAME.—02131472 Hanging Rock Creek near Kershaw, SC

LOCATION.--Lat 34º30'58'', long 80º34'59'', Lancaster County, Hydrologic Unit 03040202, on right downstream side of bridge on State Road 184, 2.1 miles south of Kershaw, and 4.0 miles upstream from mouth.

DRAINAGE AREA.—23.9 mi^2.

PERIOD OF RECORD.— October 1980 to September 2003.

PERIOD OF ANALYSIS.—April 1981 to March 2003.

REMARKS.—Some possible regulation by Kershaw City Reservoir located about 1 mile upstream. Based on review of withdrawal and discharge data provided by the SCDHEC, the potential exists for significant diversion upstream. However, adequate data are not available to quantify this diversion. No adjustments for diversion were made.

MAGNITUDE AND FREQUENCY OF ANNUAL LOW FLOWS

Recurrence intervals (years)	Lowest average flow for indicated number of consecutive days (cubic feet per second)						
	1	3	7	14	30	60	90
2	0.87	1.0	1.3	1.7	2.4	3.6	4.8
5	0.32	0.41	0.50	0.67	0.95	1.5	2.0
10	0.20	0.26	0.31	0.41	0.55	0.86	1.2
20	0.13	0.18	0.21	0.28	0.34	0.54	0.81
30	0.11	0.15	0.17	0.22	0.26	0.42	0.63

DURATION OF DAILY FLOW

Flow, in cubic feet per second, which was equaled or exceeded for indicated percentage of days							
Percent	5	10	25	50	75	90	95
Flow	75	50	26	13	4.7	1.6	0.76

STATION NUMBER AND NAME.—02131500 Lynches River near Bishopville, SC

LOCATION.-- Lat 34º15’00’’, long 80º12’50’’, Lee County, Hydrologic Unit 03040202, near center span on downstream side of bridge on U.S. Highway 15, 1.0 mile upstream from Seaboard Coast Line Railroad bridge, 2.9 miles northeast of Bishopville, SC, 3.0 miles downstream from Bells Branch and at mile 89.5.

DRAINAGE AREA.—675 mi^2.

PERIOD OF RECORD.— October 1942 to September 1971, February 2002 to March 2007.

PERIOD OF ANALYSIS.—April 1943 to March 1971, April 2002 to March 2007.

REMARKS.—Based on review of withdrawal and discharge data provided by the SCDHEC, there are no significant diversions upstream. No adjustment was made to data used in the frequency analysis.

MAGNITUDE AND FREQUENCY OF ANNUAL LOW FLOWS

Recurrence intervals (years)	Lowest average flow for indicated number of consecutive days (cubic feet per second)						
	1	3	7	14	30	60	90
2	198	200	211	218	240	284	319
5	132	134	143	151	170	201	223
10	98	101	109	121	139	163	180
20	74	77	85	99	116	134	148
30	62	65	72	88	105	120	132
50	51	54	61	77	94	106	117

DURATION OF DAILY FLOW

Flow, in cubic feet per second, which was equaled or exceeded for indicated percentage of days							
Percent	5	10	25	50	75	90	95
Flow	2,110	1,510	918	527	336	232	202

STATION NUMBER AND NAME.—02132000 Lynches River at Effingham, SC

LOCATION.-- Lat 34º03’15’’, long 79º45’15’’, Florence County, Hydrologic Unit 03040202, on left bank on downstream side of bridge on U.S. Highway 52, 75 feet upstream from Seaboard Coast Line Railroad bridge, 1.0 miles south of Effingham, SC, and at mile 43.4.

DRAINAGE AREA.—1,030 mi^2, approximately.

PERIOD OF RECORD.— October 1929 to September 2007.

PERIOD OF RECORD.—April 1930 to March 2007.

REMARKS.—Based on review of withdrawal and discharge data provided by the SCDHEC, there are no significant diversions upstream. No adjustment was made to data used in the frequency analysis.

MAGNITUDE AND FREQUENCY OF ANNUAL LOW FLOWS

Recurrence intervals (years)	Lowest average flow for indicated number of consecutive days (cubic feet per second)						
	1	3	7	14	30	60	90
2	201	204	213	228	260	311	357
5	148	150	156	167	184	216	246
10	125	127	131	140	152	177	200
20	108	109	113	120	129	150	169
30	99	101	104	110	118	136	153
50	91	92	95	100	107	123	138

DURATION OF DAILY FLOW

Flow, in cubic feet per second, which was equaled or exceeded for indicated percentage of days							
Percent	5	10	25	50	75	90	95
Flow	2,950	2,200	1,280	667	376	245	198

STATION NUMBER AND NAME.—02132500 Little Pee Dee River near Dillon, SC

LOCATION.—Lat 34º24'17'', long 79º20'25'', Dillon County, Hydrologic Unit 03040204, on downstream side of bridge on State Highway 9, 1.9 miles southeast of Dillon, SC, 3.1 miles upstream from Maple Swamp, and at mile 88.3.

DRAINAGE AREA.—524 mi^2, approximately.

PERIOD OF RECORD.—April 1939 to September 1971.

PERIOD OF ANALYSIS.—April 1939 to March 2007.

REMARKS.—Period of record was extended to include climatic years 1971 to 2006 by using streamgaging station 02135000, Little Pee Dee River near Galivants Ferry, SC, as an index station. The MOVE.1 technique was used to extend the record. Based on review of withdrawal and discharge data provided by the SCDHEC, there are no significant diversions upstream. No adjustment was made to data used in the frequency analysis.

MAGNITUDE AND FREQUENCY OF ANNUAL LOW FLOWS

Recurrence intervals (years)	Lowest average flow for indicated number of consecutive days (cubic feet per second)						
	1	3	7	14	30	60	90
2	96	100	108	119	146	190	230
5	56	59	66	71	87	114	140
10	40	43	49	53	64	84	104
20	30	33	38	40	48	63	80
30	26	28	32	34	41	53	68
50	22	24	27	29	34	44	58

DURATION OF DAILY FLOW

Flow, in cubic feet per second, which was equaled or exceeded for indicated percentage of days							
Percent	5	10	25	50	75	90	95
Flow	1,540	1,180	729	417	225	137	103

STATION NUMBER AND NAME.—02135000 Little Pee Dee River at Galivants Ferry, SC

LOCATION.— Lat 34º03'25'', long 79º14'50'', Horry-Marion County line, Hydrologic Unit, near left bank on downstream side of bridge on U.S. Highway 501, at Galivants Ferry, SC, 1.0 miles downstream from Lake Swamp, and at mile 41.7.

DRAINAGE AREA.—2,790 mi^2, approximately.

PERIOD OF RECORD.—January 1942 to September 2007.

PERIOD OF ANALYSIS.—April 1943 to March 2007.

REMARKS.—Based on review of withdrawal and discharge data provided by the SCDHEC, there are no significant diversions upstream in South Carolina. The potential exists for significant diversion upstream in North Carolina. However, adequate data are not available to quantify this diversion. No adjustment was made to data used in the frequency analysis.

MAGNITUDE AND FREQUENCY OF ANNUAL LOW FLOWS

Recurrence intervals (years)	Lowest average flow for indicated number of consecutive days (cubic feet per second)						
	1	3	7	14	30	60	90
2	498	505	523	556	660	841	990
5	312	317	328	345	400	494	589
10	237	241	249	260	297	357	430
20	185	189	195	202	228	266	325
30	161	164	169	175	196	223	276
50	138	141	145	149	166	185	231

DURATION OF DAILY FLOW

Flow, in cubic feet per second, which was equaled or exceeded for indicated percentage of days							
Percent	5	10	25	50	75	90	95
Flow	8,850	6,730	4,050	2,090	1,050	596	452

STATION NUMBER AND NAME.—02135300 Scape Ore Swamp near Bishopville, SC

LOCATION.--Lat 34º09’02’’, long 80º18’18’’, Lee County, Hydrologic Unit 03040205, on left bank, on downstream side of bridge on U.S. Highway 15, 0.1 mi downstream from Beaverdam Creek, 0.9 mi upstream from Seaboard Coast Line Railroad bridge, and 5.8 mi southwest of Bishopville.

DRAINAGE AREA.— 96.0 mi^2.

PERIOD OF RECORD.—July 1968 to October 2003.

PERIOD OF ANALYSIS.—April 1969 to March 2003.

REMARKS.— Based on review of withdrawal and discharge data provided by the SCDHEC, there are no significant diversions upstream. No adjustment was made to data used in the frequency analysis.

MAGNITUDE AND FREQUENCY OF ANNUAL LOW FLOWS

Recurrence intervals (years)	Lowest average flow for indicated number of consecutive days (cubic feet per second)						
	1	3	7	14	30	60	90
2	12	12	13	14	18	26	32
5	7.5	7.7	8.2	9.2	11	16	20
10	5.9	6.1	6.5	7.3	8.5	12	15
20	4.8	5.0	5.3	6.0	6.8	9.3	12
30	4.4	4.6	4.8	5.4	6.1	8.1	11
50	3.8	4.0	4.2	4.8	5.3	7.1	9.7

DURATION OF DAILY FLOWS

Flow, in cubic feet per second, which was equaled or exceeded for indicated percentage of days							
Percent	5	10	25	50	75	90	95
Flow	260	199	129	72	31	17	12

STATION NUMBER AND NAME.—02135500 Black River near Gable, SC

LOCATION.-- Lat 33º54'00'', long 80º09'55'', Sumter County, Hydrologic Unit 03040205, near left bank on downstream side of McBride crossing on U.S. Highway 378, 1.0 mile downstream from Church Branch, 6.3 miles northwet of Gable, SC, and at mile 123.1.

DRAINAGE AREA.— 401 mi^2.

PERIOD OF RECORD.—June 1951 to June 1966, April 1972 to September 1992.

PERIOD OF ANALYSIS.—April 1952 to March 1966, April 1972 to March 1992.

REMARKS.—Based on review of withdrawal and discharge data provided by the SCDHEC, there are no significant diversions upstream. No adjustment was made to data used in the frequency analysis.

MAGNITUDE AND FREQUENCY OF ANNUAL LOW FLOWS

Recurrence intervals (years)	Lowest average flow for indicated number of consecutive days (cubic feet per second)						
	1	3	7	14	30	60	90
2	8.9	9.4	12	16	29	51	97
5	1.6	1.9	3.0	4.1	8.1	17	32
10	0.12	0.52	1.0	1.6	3.4	7.9	14
20	0.00	0.00	0.00	0.52	1.2	3.3	5.7
30	0.00	0.00	0.00	0.11	0.30	1.0	3.5
50	0.00	0.00	0.00	0.00	0.00	0.00	0.75

DURATION OF DAILY FLOW

Flow, in cubic feet per second, which was equaled or exceeded for indicated percentage of days							
Percent	5	10	25	50	75	90	95
Flow	1,240	867	456	241	89	25	11

STATION NUMBER AND NAME.—02136000 Black River at Kingstree, SC

LOCATION.--Lat 33º39’40’’, long 79º50’10’’, Williamsburg County, Hydrologic Unit 03040205, on left bank, at upstream side of bridge on U.S. Highway 52 at Kingstree, 1.0 mi downstream from Kingstree Swamp Canal, and at mile 86.7.

DRAINAGE AREA.—1,252 mi^2.

PERIOD OF RECORD.— October 1929 to September 2007. Gage-height records collected at same site since 1894 are contained in reports of National Weather Service.

PERIOD OF ANALYSIS.—April 1930 to March 2007.

REMARKS.—Based on review of withdrawal and discharge data provided by the SCDHEC, the potential exists for significant diversion upstream. However, adequate data are not available to quantify this diversion. No adjustments for diversion were made.

MAGNITUDE AND FREQUENCY OF ANNUAL LOW FLOWS

Recurrence intervals (years)	Lowest average flow for indicated number of consecutive days (cubic feet per second)						
	1	3	7	14	30	60	90
2	28	29	32	37	52	90	130
5	11	12	13	14	20	32	50
10	6.7	7.0	7.6	8.6	11	18	28
20	4.4	4.5	4.9	5.6	6.9	10	17
30	3.4	3.5	3.8	4.3	5.2	7.6	12
50	2.6	2.7	3.0	3.3	3.9	5.5	8.9

DURATION OF DAILY FLOWS

Flow, in cubic feet per second, which was equaled or exceeded for indicated percentage of days							
Percent	5	10	25	50	75	90	95
Flow	3,480	2,370	1,150	446	148	46	20

Table 3. Low-flow statistics for regulated continuous-record gaging stations in South Carolina.

[lat, latitude; long, longitude; mi^2, square mile; SCDHEC, South Carolina Department of Health and Environmental Control; the station low-flow statistics are presented in the following pages in numerical order by station number. At stations affected by regulation, low-flow statistics were calculated if the streamflow data showed no significant trend. Low-flow statistics presented for regulated streams are relevant provided future regulation patterns remain similar to historical data and would not be applicable if the future regulation patterns were significantly altered]

STATION NUMBER AND NAME.—02130561 Pee Dee River near Bennettsville, SC

LOCATION.— Lat 34º36’22’’, long 79º47’19’’, Marlboro County, Hydrologic Unit 03040201, inside the intake structure at Willamette Industries, 8.5 miles west of Bennettsville, SC.

DRAINAGE AREA.—7,600 mi^2, approximately.

PERIOD OF RECORD.—November 1990 to March 2007.

PERIOD OF ANALYSIS.—April 1939 to March 2007.

REMARKS.—Station is regulated by dams in North Carolina, but trend analysis indicates that regulation patterns have not changed through the period of record. Low-flow frequencies only apply if regulation patterns do not change in the future. Period of record was extended to include climatic years 1939 to 1990 by using streamgaging station 02131000, Pee Dee River at Peedee, SC, as an index station. The MOVE.1 technique was used to extend the record ; however, the correlation coefficient for the annual minimum 1- and 3-day averages was not sufficient enough to warrant record extensions. Therefore, the low-flow statistics for those averaging periods were computed from the measured data. Based on review of withdrawal and discharge data provided by the SCDHEC, there is no significant regulation or diversion upstream in South Carolina. The potential exists for significant diversion upstream in North Carolina. However, adequate data are not available to quantify this diversion. No adjustment was made to data used in the frequency analysis.

MAGNITUDE AND FREQUENCY OF ANNUAL LOW FLOWS

Recurrence intervals (years)	Lowest average flow for indicated number of consecutive days (cubic feet per second)						
	1	3	7	14	30	60	90
2	350	609	1,830	2,170	2,500	2,950	3,250
5	167	378	1,270	1,540	1,770	2,030	2,290
10	107	298	1,010	1,220	1,410	1,600	1,870
20	71	245	819	988	1,130	1,290	1,560
30	ND	ND	720	865	1,000	1,130	1,410
50	ND	ND	630	752	867	979	1,260

DURATION OF DAILY FLOW

Flow, in cubic feet per second, which was equaled or exceeded for indicated percentage of days							
Percent	5	10	25	50	75	90	95
Flow	24,700	17,500	9,790	5,290	3,050	1,840	1,270

STATION NUMBER AND NAME.—02130910 Black Creek near Hartsville, SC

LOCATION.— Lat 34º23’50’’, long 80º09’00’’, Darlington County, Hydrologic Unit 03040201, on right bank 59 feet upstream from bridge on State Road 23, 1,000 feet downstream from H.B. Robinson Steam Electric Plant, 2.1 miles upstream from Beaverdam Creek, 4.6 miles west of Hartsville, SC.

DRAINAGE AREA.—173 mi^2.

PERIOD OF RECORD.— October 1960 to September 2007.

PERIOD OF ANALYSIS.—April 1981 to March 2007.

REMARKS.—Station is regulated, but trend analysis indicates that regulation patterns have not changed from about 1980 through the period of record. Low-flow frequencies only apply if regulation patterns do not significantly change in the future. Based on review of withdrawal and discharge data provided by the SCDHEC, the potential exists for significant diversion upstream. However, adequate data are not available to quantify this diversion. No adjustments for diversion were made.

MAGNITUDE AND FREQUENCY OF ANNUAL LOW FLOWS

Recurrence intervals (years)	Lowest average flow for indicated number of consecutive days (cubic feet per second)						
	1	3	7	14	30	60	90
2	66	70	73	77	84	100	108
5	40	44	47	51	59	70	78
10	27	29	33	37	46	54	63
20	18	19	22	26	36	41	51
30	13	15	17	21	30	35	45
50	9.8	11	13	16	26	29	39

DURATION OF DAILY FLOW

Flow, in cubic feet per second, which was equaled or exceeded for indicated percentage of days							
Percent	5	10	25	50	75	90	95
Flow	415	335	242	169	111	80	67

STATION NUMBER AND NAME.—02130980 Black Creek near Quinby, SC

LOCATION.—Lat 34º14'37'', long 79º44'42'', Florence County, Hydrologic Unit 03040201, on the left downstream side of the bridge on State Highway 26, 2.1 miles northeast of Florence, SC.

DRAINAGE AREA.—438 mi^2.

PERIOD OF RECORD.— October 2001 to September 2007.

PERIOD OF ANALYSIS.— October 2001 to March 2007 (concurrent period of record with index station).

REMARKS.—Some regulation upstream. Because the period of analysis is more than 5 but less than 10 years, streamgaging station 02130980 was analyzed as if it was a partial-record station. Low-flow characteristics were estimated by using streamgaging station 02130900, Black Creek near McBee, SC, as an index station. Based on review of withdrawal and discharge data provided by the SCDHEC, the potential exists for significant diversion upstream. However, adequate data are not available to quantify this diversion. No adjustment was made to data used in the frequency analysis.

MAGNITUDE AND FREQUENCY OF ANNUAL LOW FLOWS

Low-flow characteristic	Flow (cubic feet per second)
7-day, 2-year	212
7-day, 10-year	112

STATION NUMBER AND NAME.—02131000 Pee Dee River at Peedee, SC

LOCATION.— Lat 34º12’15’’, long 79º32’55’’, Florence-Marlboro County line, Hydrologic Unit 03040201, at upstream side of upstream bridge on U.S. Highway 76 at Peedee, 0.2 mile downstream from Seaboard Coast Line Railroad bridge, 8.2 miles downstream from Black Creek, and at mile 100.2.

DRAINAGE AREA.—8,830 mi^2.

PERIOD OF RECORD.— October 1938 to September 2007.

PERIOD OF ANALYSIS.—April 1939 to March 2007.

REMARKS.—Station is regulated by dams in North Carolina, but trend analysis indicates that regulation patterns have not changed through the period of record. Low-flow frequencies only apply if regulation patterns do not change in the future. Based on review of withdrawal and discharge data provided by the SCDHEC, there is no significant regulation or diversion upstream in South Carolina. The potential exists for significant diversion upstream in North Carolina. However, adequate data are not available to quantify this diversion. No adjustment was made to data used in the frequency analysis.

MAGNITUDE AND FREQUENCY OF ANNUAL LOW FLOWS

Recurrence intervals (years)	Lowest average flow for indicated number of consecutive days (cubic feet per second)						
	1	3	7	14	30	60	90
2	1,490	1,880	2,590	2,990	3,350	3,920	4,250
5	1,080	1,330	1,800	2,080	2,330	2,720	3,030
10	910	1,100	1,440	1,640	1,840	2,160	2,490
20	787	925	1,170	1,310	1,460	1,750	2,090
30	726	841	1,030	1,140	1,280	1,540	1,900
50	666	759	903	984	1,100	1,340	1,700

DURATION OF DAILY FLOW

Flow, in cubic feet per second, which was equaled or exceeded for indicated percentage of days							
Percent	5	10	25	50	75	90	95
Flow	25,800	19,900	12,400	6,990	4,350	2,830	2,110

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