In Cooperation with the
NEW HAMPSHIRE DEPARTMENT OF ENVIRONMENTAL SERVICES

Development of Regression Equations to Estimate Flow Durations and Low-Flow-Frequency Statistics in New Hampshire Streams

Water-Resources Investigations Report 02-4298

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

Cover photograph shows a stream-gaging station on the East Branch Pemigewasset River in Lincoln, New Hampshire. (Photograph is by Sanborn L. Ward, U.S. Geological Survey)

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By Robert H. Flynn

U.S. GEOLOGICAL SURVEY

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CONVERSION FACTORS

Multiply	By	To obtain
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
square mile (mi^2)	2.590	square kilometer (km^2)
cubic feet per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)

Temperature in degrees Fahrenheit (°F) can be converted to degrees Celsius (°C) as follows:

$$°C = 5/9\ (°F - 32).$$

VERTICAL DATUM

Vertical Datum: 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.

ABBREVIATIONS

Organizations

CSRC	Complex Systems Research Center at the UNH
MassGIS	Massachusetts office of GIS
MEGIS	Maine office of GIS
NRCS	Natural Resources Conservation Service
NHDES	New Hampshire Department of Environmental Services
UNH	University of New Hampshire
USGS	U.S. Geological Survey

Basin Characteristics

ABT	Average mean annual basin temperature, in Fahrenheit
BS	Average basin slope, in percent
C	Coniferous trees in the drainage basin, in percent
CD	Mixed coniferous/deciduous trees in the drainage basin, in percent
DA	Drainage area, in square miles
MxBE	Maximum basin elevation, in feet
SBT	Average mean summer basin temperature, in Fahrenheit
SGP	Average summer gage precipitation, in inches
SpGP	Average spring gage precipitation, in inches
WCP	Average winter basin centroid precipitation, in inches

Miscellaneous

7Q2	7-day, 2-year Low-Flow Frequency
7Q10	7-day, 10-year Low-Flow Frequency
ADAPS	Automatic data processing system
AML	Arc Macro Language
APE	Average prediction error
BCF	Bias correction factor
DEM	Digital elevation model of topography
DLG	Digital line graph of hydrography
fal	Fall
FORTRAN	Formula Translation
GIS	Geographic information system
GLS	Generalized-least-squares regression analysis
GLSNET	Generalized-least-squares network computer software
GRID	Raster based dataset
HUC	Hydrologic unit code
IOWDM	Input Output Watershed Data Management
MRLC	Multi-resolution land cover
MSE	Mean square error of regression
NLCD	National land cover dataset
OLS	Ordinary-least-squares regression analysis
Por	Period-of-record
PRESS	Predicted residual sum of squares
PRISM	Parameter-elevation regressions on independent slopes model
R^2adj	Adjusted R-squared
ref.	Reference

SAS	Statitical analysis system computer software
Ser	Standard error of estimate
spr	Spring
STATSGO	State soil geographic database
sum	Summer
SWSTAT	Surface Water statistics program
VIF	Variance inflation factor
win	Winter
WLS	Weighted-least-squares regression analysis

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ABSTRACT

Regression equations and basin-characteristic digital datasets were developed to help water-resource managers estimate surface-water resources during periods of low flow in New Hampshire. The regression equations were developed to estimate statistics for the seasonal and annual low-flow-frequency and seasonal period-of-record and period-of-record flow durations. Because streamflow is maintained by ground-water discharge during periods of low flow, these equations also will aid in the assessment of ground-water availability. Ultimately, the equations and datasets developed herein can be combined with data on water withdrawals, discharges, and interbasin transfers in a geographic information system (GIS) to allow assessments of water use and water availability in any drainage basin in the State of New Hampshire.

Regression equations developed in this study provide estimates of the seasonal (spring, summer, fall, and winter) and annual 7-day 2-year (7Q2) and 7-day 10-year (7Q10) low-flow-frequency values, as well as seasonal period-of-record and period-of-record flow durations (60-, 70-, 80-, 90-, 95-, and 98-percent exceedences) for ungaged reaches of unregulated New Hampshire streams. Regression equations were developed using seasonal and annual low-flow statistics from 58 to 60 continuous-record stream-gaging stations in New Hampshire and nearby areas in neighboring states, and measurements of various characteristics of the drainage basins that contribute flow to those stations.

The estimating equations for the seasonal and annual 7Q2 and 7Q10 values were developed using generalized-least-squares (GLS) regression analyses. The GLS equations developed for these flow statistics gave average prediction errors that ranged from 11 to 61 percent.

The estimating equations for flow-duration exceedence frequency values were developed using ordinary-least-squares (OLS) regression analysis. The OLS equations developed for these flow statistics gave average prediction errors ranging from 14 to 79 percent.

A total of 93 measurable drainage-basin characteristics were selected as possible predictor variables. Of these 93 variables, the following 10 were determined to be statistically significant predictors for at least one of the dependent variables: drainage area, average basin slope, maximum basin elevation, average summer gage precipitation for 1961-90, average spring gage precipitation for 1961-90, average mean annual basin temperature for 1961-90, average mean summer basin temperature for 1961-90, average winter basin-centroid precipitation for 1961-90, percent of the basin that is coniferous, and percent of the basin that is mixed coniferous and deciduous. These 10 basin characteristics were selected because they were statistically significant based on several statistical parameters that evaluated which combination of characteristics contributed the most to the predictive accuracy of the regression-equation models. A GIS is required to measure the values of the predictor variables for the equations developed in this study.

INTRODUCTION

New Hampshire is the fastest growing State in the northeastern United States. Its population has grown by approximately 141,000 people or 11.4 percent from 1990 to 2000, and another 215,000 people are expected to be living in the State by the year 2025 (New Hampshire State Data Center, 2001, accessed April 2002, at URL: http://www.state.nh.us/osp/sdc/sdc.html). Because of the increasing population, especially along the seacoast and south-central areas of the State, New Hampshire needs to develop tools to characterize and manage water resources as future dry periods and droughts may have a major effect on crop yields, drinking-water supplies, aquatic habitats, and hydroelectric power generation. The State has enacted legislation to develop rules and procedures to ensure that acceptable instream flows in designated streams are maintained when demand exceeds supply. These rules, referred to as the Instream Flow Rules, are the key streamflow-protection measures provided under the Rivers Management and Protection Act (RSA 483). The instream-flow rules would require the quantification and protection of minimum flows in designated stream reaches on a seasonal basis such that the naturally occurring seasonal variations are accounted for in river flows.

Knowledge of water-availability statistics is required for Federal, State, local, and private entities to make sound decisions regarding water-resource planning, regulatory activities, and management. The U.S. Geological Survey (USGS), in cooperation with the New Hampshire Department of Environmental Services (NHDES), developed datasets, hydrologic statistical relations, a geographic information system (GIS) of data coverages, and water-use datasets for all of New Hampshire to better understand water availability. This information provides the basis for sustainable water management for the benefit of water users and the environment. Such information is especially critical for the management of water quality through the regulation of wastewater discharges to receiving waters and for estimating surface-water availability for domestic, agricultural, industrial, and recreational purposes.

The most widely used measures of water availability are statistics indicating the probabilities or frequencies of occurrence of low streamflows, specifically (1) the frequencies of minimums of streamflow averaged over consecutive-day periods of various lengths, and (2) the streamflows that are exceeded with various frequencies. Since streamflows are measured only at specific stream reaches (streamgaging stations), a means of determining the critical low-flow statistics at ungaged reaches is required. Equations were developed by the USGS for estimating those statistics at any unregulated stream reach in New Hampshire on the basis of characteristics of the drainage basin that provide flow to that reach. Because typical streamflows in humid climate regions, such as New Hampshire, can vary widely for a season and systematically throughout the year, separate estimating equations were developed seasonally, as well as annually.

The estimation equations developed in this study were incorporated into a GIS to produce a “point-and-click” tool for rapidly estimating the low-flow and flow-duration statistics for any unregulated stream reach in the State. Determination of the regression equation independent variables requires the use of a GIS to measure the value of these variables. Development of this tool provides a capability that was previously defined as a priority by the New Hampshire Basin Planning Program Advisory Workshop (New Hampshire Department of Environmental Services, 1996).

Purpose and Scope

This report describes the results of this study to determine the seasonal and annual 7-day, 2-year low-flow (7Q2) and 7-day, 10-year low-flow (7Q10) statistics and seasonal period-of-record and period-of-record streamflow-duration quantiles for the 60-, 70-, 80-, 90-, 95-, and 98-percent exceedences for gaged and ungaged drainage basins throughout New Hampshire from regression analyses relating basin and climatic characteristics to streamflow statistics. In addition, this report describes how the methods used to determine the flow statistics were developed and evaluated. Statistical methods are presented for estimating low-flow and flow-duration statistics for streams with natural flow conditions (unregulated) in locations where no streamflow data are available (ungaged sites), as well as for locations where data are available (gaged sites). An evaluation of the accuracy of the equations and limitations for their use also is provided along with an example application.

Previous Studies

Previous studies used regression analysis to regionalize low-flow-frequency statistics in New England. These include studies for central New England (Wandle and Randall, 1994), Maine (Parker, 1977), and Massachusetts (Vogel and Kroll, 1990; Risley, 1994; Ries and Friesz, 2000) and New Hampshire (Dingman and Lawlor, 1995). Studies in New England that regionalized flow-duration statistics include New Hampshire (Dingman, 1978) and Massachusetts (Fennessey and Vogel, 1990; Ries, 1994a, 1994b; and Ries and Friesz, 2000).

Description of Study Area

New Hampshire encompasses an area of 8,973 mi^2 of which 309 mi^2 is surface-water bodies. The State can be divided into three broad physical environments: mountains, lowlands and foothills, and coastal plain. New Hampshire is in the Seaboard Lowland, New England Upland, and White Mountain sections of the New England Physiographic Province (Fenneman, 1938). The southeastern part of the State primarily is coastal plain, the central region primarily is lowland and foothills, and the northern part primarily is mountainous. Elevation and surface irregularity gradually increase from south to north. Precipitation is evenly distributed throughout the year and ranges from an annual precipitation of approximately 35 in. in the Connecticut and Merrimack River valleys to approximately 90 in. on the summit of Mt. Washington. Typically, statewide, the driest month is February. The wettest months are November and December in the area south of the White Mountains, and June, July, and August in the area north of the White Mountains (Hammond, 1989). Average annual runoff ranges from 18 in. in parts of the Connecticut River valley and seacoast area to about 42 in. in the White Mountains. Runoff varies seasonally and geographically. The high flows typically occur during March, April, and May, and are caused by the melting snowpack and concurrent precipitation (U.S. Geological Survey, 1987). Annual snowfall ranges from about 50 in. along the coast to approximately 100 in. in the White Mountains (Hammond, 1989).

New Hampshire is in the glaciated Appalachian ground-water region. The bedrock consists of metasedimentary rock in about two-thirds of the State and intrusive rock in approximately the other third of the State (Billings, 1956). The two principal types of aquifers in New Hampshire are glacial deposits, which are primarily stratified drift, and crystalline bedrock. The areas of stratified-drift deposits are primarily the valleys of the major streams. The lowlands and foothills region of New Hampshire has thick layers of till on the slopes and large areal distributions of stratified drift along the streams. Other stratified-drift deposits in New Hampshire include areas of fine- and coarse-grained marine clays and sands along the seacoast, areas of outwash sands and gravels, and areas of fine- and coarse-grained glacial-lake deposits (Medalie and Moore, 1995) throughout the State. Till, the most extensive glacial deposit in New Hampshire, is either buried beneath stratified-drift deposits in valleys or lowlands or overlays the bedrock in upland areas (Flanagan and others, 1999).

Soils generally inherit the texture and drainage characteristics of their underlying surficial geologic deposits or parent materials. The soil hydrologic group classifications, which were obtained from the U.S. Department of Agriculture's State Soil Geographic (STATSGO) soils database (U.S. Geological Survey, 1997; and Schwartz and Alexander, 1995), indicate that soils in New Hampshire are predominantly grouped into two soil hydrologic classifications. These two classifications include soils with moderate infiltration rates (deep and moderately deep soils, moderately well and well-drained soils with moderately course textures) and soils with slow infiltration rates (soils with layers impeding downward flow of water or soils with moderately fine textures). Soils with moderate infiltration rates occur in areas of high slope, such as the White Mountains, and in areas of stratified-drift deposits. Soils with slow infiltration rates are in areas where glacial till is most commonly found at the surface. The different STATSGO soils classifications are a reflection of the properties of the soils, which affect the residence time and amount of precipitation percolating into the soil surface (Flanagan and others, 1999).

Three general land-use categories are defined by the New Hampshire Division of Forests and Lands (1997, accessed April 2002, at URL http://www.nhdfl.org/info_plan_bureau/fi&p_foreststatistics.htm). These include forest land, farm land, and other nonforest land. According to the New Hampshire Division of Forests and Lands, New Hampshire is the second most forested state in the United States (Maine is the most forested).

Forest land is categorized as either timberland or noncommercial. Timberland is physically capable of growing timber crops and is potentially available for harvesting. Noncommercial forest land includes reserved forest lands, unproductive forests, and urban forests. As of 1997, forest land occupied 84 percent of New Hampshire. Farm land occupied 3 percent of New Hampshire, and other nonforest land (includes urbanized and industrial areas) occupied 13 percent (New Hampshire Division of Forests and Lands, 1997, accessed April 2002, at URL: http://www.nhdfl.org/info_plan_bureau/fi&p_foreststatistics.htm).

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The author thanks Gary Tasker of the U.S. Geological Survey for sharing his extensive experience with weighted-least-squares (WLS) and generalized-least-squares (GLS) regression methods, and with the computer software program generalized-least-squares NETwork (GLSNET). In addition, Dr. S.L. Dingman of the University of New Hampshire reviewed this study and made many valuable comments.

LOW-FLOW FREQUENCY AND FLOW-DURATION ESTIMATING METHODS AT STREAM-GAGING STATIONS

The adequacy of a stream or river to supply the water needed for various uses, both seasonally and annually, commonly is evaluated by a statistical analysis of the historical data from a stream-gaging station. The results of this statistical analysis are then used to predict the probability of occurrence of low streamflow over an annual or seasonal period. The daily-mean flows for all of the complete climatic years of record through 1999 were used to determine annual low-flow-frequency statistics at each station. The season for the *n*-day low flow typically is the climatic year that begins on April 1 and ends on March 31 of the following year.

Daily-mean flows through water year 1999 were used to determine the period-of-record flow-duration statistics for each of the stream-gaging stations evaluated in this study. The water year begins on October 1 and ends on September 30 of the following year. The daily-mean flows through water year 1999 were used for flow-duration quantiles in this study as these data are a period-of-record statistic, and the extent of the data available at the beginning of this study were through water year 1999. The seasonal periods for the low-flow-frequency and period-of-record flow-duration statistics as defined by the NHDES for the purpose of managing water resources are: winter (January 1 to March 15), spring (March 16 to May 31), summer (June 1 to October 31), and fall (November 1 to December 31).

Streamflow Database

Daily-streamflow data were downloaded using the USGS database software ADAPS (Automatic DAta Processing System). The input streamflow data were formatted, managed, and displayed using the USGS computer software programs IOWDM (Input Output Drainage basin Data Management) (Lumb and others, 1990) and ANNIE (Flynn and others, 1995). The computer program Surface Water Statistics (SWSTAT) (A.M. Lumb, W.O. Thomas, Jr., and K.M. Flynn, U.S. Geological Survey, written commun., 1997) was used to perform statistical analyses for the determination of the seasonal and annual low-flow-frequency statistics at the USGS stream-gaging stations. SWSTAT ranks the seasonal and annual series of minimum mean *n*-day flows and then fits them to a log-Pearson Type III distribution. A resulting line-of-fit then is plotted through the values. The seasonal and annual series were then checked for trends. The program SWSTAT requires daily time-step data for the determination of duration statistics; however, the seasonal period-of-record duration statistics could not be determined with this software for the winter and spring seasons as SWSTAT will not provide percentile flows for periods that have less than a whole month. The determination of the seasonal and period-of-record flow durations was accomplished using a FORTRAN computer program (E.M. Boehmler, U.S. Geological Survey, written commun., 2000) in which the Weibull (1939) formula was applied for determining the plotting position by ranking each seasonal and annual minimum flow among observed seasonal and annual flow minima into a recurrence interval. Ranks were assigned on the basis of the ascending order of discharge and the plotting position was computed.

Trends in the data, at each of the stream-gaging stations selected for low-flow analysis, were analyzed using Kendall's Tau, a statistic that indicates a monotonically increasing or decreasing trend in the time-series data (Helsel and Hirsch, 2000). The Kendall's Tau statistic was calculated using SWSTAT and indicated that at several sites, a trend in the time series existed. If changes in the drainage basin or human activities caused a trend in the time series, these data were either excluded, adjusted for the trend, or only part of the record would have been used in the frequency analysis (Ruhl and Martin, 1991). Plots of the 7-day (7Q) low flow with time were made for those stations that indicated a trend in the annual series data. Beginning in the mid- to early-1960s, a consistent increasing pattern is apparent in the plots of 7Q low flow for those sites in which Kendalls' Tau indicated a trend. In the early- to mid-1960s, New Hampshire experienced a period of drought statewide. As this drought is coincident with the trends in the annual series data, the trends were determined to be a result of climatic variability rather than the result of changes in the drainage basin or effects of human activities.

On the basis of the streamflow-durations and 7Q low-flow statistics, low-flow-frequency curves were developed for the period of unregulated streamflow record for each of the continuous-record stream-gaging stations with 10 or more years of record of unregulated flow. Any flow data collected after a stream became regulated were not used in the analysis.

Flow-Duration Statistics

Streamflow commonly is presented as a flow duration, in which a streamflow for a certain time increment (typically daily) is described as a percentage of time that the flow is equaled or exceeded for a given period of time. This period of time for a stream-gaging station duration typically is the period-of-record. For example, the 95-percent flow duration is a streamflow that is equaled or exceeded 95-percent of the time for a given period. Flow-duration statistics are points along a flow-duration curve and reflect only the period for which they are calculated. When the period-of-record used to compute the statistics is sufficiently long (typically at least 10 years), however, the statistics are an indicator of probable future conditions (Searcy, 1959).

The duration statistics used in this study were the 60-, 70-, 80-, 90-, 95-, and 98-percent exceedence quantiles on the flow-duration curve. The statistics were determined at each station for the period-of-record through water year 1999, or for a season as defined by NHDES and through water year 1999. The flow-duration statistics can be determined using USGS software, commercially available statistical software, or as in the case of this study, with a program written in a computer language such as FORTRAN. Flow-duration curves can be used to characterize the variations at a stream-gaging station. A flow-duration curve is a cumulative-frequency curve representing the percentage of time that daily flows were equaled or exceeded during a given period of time. To construct flow-duration curves, all of the mean daily discharges for the period-of-record must be ranked from largest to smallest, without consideration to the sequence of occurrence of flows. For each value, the probability of that value being equaled or exceeded then is determined and discharges are plotted against their associated exceedence probabilities. A curve is drawn through the plotted discharges and represents the percentage of time that streamflows are equaled or exceeded during a selected period (Searcy, 1959). The discharges associated with specified exceedence quantiles provide quantitative information about streamflow availability at that station.

Typical applications of streamflow-duration quantiles are for river and reservoir sedimentation studies, assessment of instream flows, hydropower-feasibility studies, water-quality and wasteload-allocation studies, and analysis of water-supply systems.

Low-Flow-Frequency Statistics

Low-flow-frequency statistics typically are based on the D-day, Y-year frequency statistic of daily-mean flow. This statistic is the minimum consecutive D-day mean streamflow expected to occur once in any Y-years or that has a probability of $1/Y$ of not being exceeded in any given year or season. For example, the annual 7Q10 low flow is the annual minimum average flow for 7 consecutive days that is expected to not be exceeded in 1 of 10 years, or that has a 0.10 probability of not being exceeded in a given year. Some typical applications of low-flow-frequency statistics are for management of water supplies, water-quality management, and design of wastewater-treatment facilities. The 7Q10 is used by many State and local agencies to regulate discharges into surface waters.

Low-flow-frequency statistics typically are determined for stream-gaging stations using annual series of selected low-flow statistics based on the lowest mean discharge for some number of consecutive days. Any combination of number of days of mean minimum flow and years of recurrence may be used in determining the low-flow statistics. The annual series for the determination of low flow was based on a climatic water year from April 1 to March 31. The low-flow statistic used in this study was the 7-day low flow (7Q), which is the lowest mean discharge for 7 consecutive days in a climatic year, from April 1 through March 31, or in a season as defined by NHDES. In New Hampshire, the minimum 7Q mean discharge for most streams occurs in August or September, although it may occur in the winter during long periods of prolonged subfreezing weather. The use of the time period of a climatic year rather than a water year to determine the annual series of low-flow statistics allows for an analysis with an uninterrupted low-flow period. Values for selected recurrence intervals were obtained from a frequency analysis, which was used to fit the annual and seasonal series of 7-day minimum mean flow data to a particular probability distribution. The recurrence interval for an individual 7-day minimum mean flow is typically determined by fitting the 7-day minimum mean flows to a log-Pearson Type III distribution (Riggs, 1982). A study estimating low-flow statistics in Massachusetts (Ries and Friesz, 2000) used this method although other researchers have occasionally employed other distributions (Vogel and Kroll, 1989). The log-Pearson Type III distribution relates the mean, standard deviation, and skewness of the logarithm of a flow statistic, Y_g, to the logarithm of the value of that flow statistic with a particular exceedence or non-exceedence probability p, Y_{pg}. The following equation describes the log Pearson Type III analysis:

$$Log(Y_{pg}) = E[\log(Y_g)] + K\{SK[\log(Y_g)],\ p\} * S([\log(Y_g)]), \quad (1)$$

where

$Log(Y_{pg})$ is the logarithm of the Y-year low flow with a particular exceedence or nonexceedence probability,

$E[\log(Y_g)]$ is the mean of the logarithm of the low flows,

$S[\log(Y_g)]$ is the standard deviation of the logarithm of the low flows, and

$K\{SK[\log(Y_g)],p\}$ is a frequency factor that is a function of skewness of the logarithms of low-flow and exceedence probability.

An extensive treatment on the use of this distribution in the determination of flood-flow-frequency distributions is presented in a report by the U.S. Interagency Advisory Committee on Water Data (1982). A determination of the data fit to the distribution, and the eventual low-flow frequency values to be used, are based on the individual judgement of the hydrologist. The flow statistics (Y_{pg}) determined for this report are the seasonal and annual 7Q2 and 7Q10 low flows. These values are commonly expressed as the minimum 7-day mean discharge with an average recurrence interval of 2 and 10 years, respectively, or having a 50- and 10-percent chance, respectively, of not being equaled or exceeded in any given year.

For this study, SWSTAT (Lumb and others, 1990) was used to determine the annual and seasonal series of minimum mean low flows. SWSTAT ranked the minimum mean low flows and fit them to a log-Pearson Type III distribution, plotting the resulting line of fit through the seasonal and annual values.

LOW-FLOW-FREQUENCY AND FLOW-DURATION ESTIMATING METHODS AT UNGAGED STREAM SITES

Low-flow and duration-streamflow statistics for streams with no available data (ungaged streams) can be estimated by several methods. These methods include (1) a drainage-area ratio relation, (2) a correlation of measured streamflows with concurrent daily-mean streamflows from nearby continuous-record stream-gaging stations, or (3) a regression equation relating streamflow statistics to drainage-basin characteristics. The basic aspects of these approaches are described in the following sections.

Drainage-Area Ratio Approach

The drainage-area ratio method is most appropriate for use when the ungaged site is on the same stream as a stream-gaging station. If the site is upstream or downstream of a station, then a drainage-area ratio relation may be used to determine the statistic of interest. The accuracy of the drainage-area ratio method is dependent on how close the two sites (gaged and ungaged) are to one another, similarities in drainage area, and other physical and climatic characteristics of the drainage basins (Ries and Friesz, 2000). Ries and Friesz determined that in Massachusetts, the recommended ratio of the drainage area, at the point of interest on a stream, to the drainage area of the station for use of the drainage-area ratio method is between 0.3 and 1.5 (Ries and Friesz, 2000). Outside these ratios, regression equations are recommended. The drainage-area ratio method is used to estimate low-flow statistics at an ungaged site on the basis of low-flow values from stream-gaging stations on the same stream. The low-flow values are transferred from a gaged site to the ungaged site using the following formula:

$$Y_{pu} = Y_{pg}(A / Ag)^n , \qquad (2)$$

where

Y_{pu} is the discharge value at the specific ungaged site;

Y_{pg} is the discharge statistic of interest at the USGS stream-gaging station;

A and Ag are the drainage areas at the specific site and the USGS stream-gaging station, respectively; and

n is an exponent that can be computed by analyzing low-flow characteristics at paired long-term continuous-record stream-gaging stations.

Alternatively, if stream-gaging stations are located upstream and downstream of an ungaged stream location, n can be derived directly from equation 2 to determine the discharge value at the specific site.

Concurrent-Flow Approach

In this method, a number of discrete measurements of discharge are made at the ungaged stream reach of interest. These flows are then related to concurrent flows at a nearby stream-gaging station by regression analysis to determine the flow statistic of interest at the ungaged reach. A correlation of measured streamflows with concurrent daily mean streamflows from a nearby continuous station requires numerous measurements of streamflow in order to establish a relation between low flows at the stream-gaging stations and a partial-record location. According to Riggs (1982), 8 to 10 measurements from separate hydrograph recessions, and in more than 1 year, should minimize errors and provide adequate data to define a relation with concurrent flows at a long-record station. The regression-equation coefficient of determination (R^2) should be at least 0.70 and the two basins should be similar in size, geology, topography, and climate (Riggs, 1982; S.L. Dingman, University of New Hampshire, written commun., 2002).

The concurrent-flow method is appropriate for establishing low-flow statistics for the design of water withdrawal or wastewater-discharge facilities at a specific site. This method is not practical for routine planning purposes (S.L. Dingman, University of New Hampshire, written commun., 2002) or regional investigations.

Regression-Equation Approach

Regression equations that relate streamflow statistics at stream-gaging stations to basin and climatic characteristics can be used to estimate streamflow statistics for most ungaged sites. The estimating equations developed for seasonal and annual low-flow and seasonal period-of-record and period-of-record durations in this study were based on multiple-linear-regression analysis using records from 58 to 60 continuous-record stream-gaging stations. Multiple-linear regression is a method of demonstrating that a response (dependent) variable, *Y*, varies with a set of independent variables, X_1 to X_n. The variability that the response variable exhibits has two components—a systematic and a random part. The systematic variation of *Y* can be modeled as a function of the *X* variables. The random part accounts for the model not exactly describing the behavior of the response. The least-squares method is used to estimate the parameters of the model, based on observed values of these variables, by minimizing the sum of squared differences between the actual *Y* values and the values of *Y* predicted by the regression equation (Freund and Littell, 2000).

In multiple-linear-regression analysis, one or more climatic or physical characteristics (independent or predictor variables) of the drainage area above the station site are statistically related to a streamflow statistic (dependent variable) for a group of stream-gaging stations, resulting in an equation that can be used to estimate the statistic for a site for which no streamflow data are available (ungaged). The equations determined by multiple-linear-regression analysis take the following form:

$$Y_{pg} = b_0 + b_1 X_{1g} + b_2 X_{2g} + \ldots + b_n X_{ng} + E_g \,, \qquad (3)$$

where

- Y_{pg} is the estimate of the dependent variable for site *g*,
- X_{1g} to X_{ng} are the independent variables for site *g*,
- b_0 to b_n are the regression-model coefficients (unknown parameters), and
- E_g is the residual error or difference between the observed and the estimated value of the dependent variable for site *g*.

Assumptions for use of the regression analysis are that (1) the regression equation adequately describes the relation between the dependent and independent variables, (2) the mean of the residual error is zero, (3) the variance of the residual error is constant and independent of the values of X_n, (4) the residual errors are normally distributed, and (5) the residual errors are independent of one another (Helsel and Hirsch, 2000).

As the streamflow and basin characteristics used in a hydrologic regression typically are log-normally distributed, transformation of the variables to logarithms is usually necessary to satisfy regression assumption 2 (Ries and Friesz, 2000).

Using logarithms of the independent and dependent variables in equation 3, the model takes the following linear form (Ries and Friesz, 2000):

$$Log Y_{pg} = b_0 + b_1 \log X_{1g} + b_2 \log X_{2g} + \ldots + b_n \log X_{ng} + E_g, \qquad (4)$$

and a least-squares solution can be used to determine the coefficients of b_0 to b_n.

When base 10 logarithms are used in the transformations, and equation 4 is converted back to its original units, the resulting equation takes the form

$$Y_{pg} = 10^{b0}(X_{1g}^{b1})(X_{2g}^{b2})..(X_{ng}^{bn})10^{E_g} \,, \qquad (5)$$

where in equations 4 and 5

- E_g is the residual error (difference between the observed and the estimated value of the dependent variable) and the optimal value for E_g would be zero.

Equation 4 provides an unbiased estimate of the mean response of the dependent variable. Estimates of the base 10 logarithm of the dependent variable are obtained with equation 4, although estimates in their original units are desired. Equation 5 is the result of a retransformation back to its original units of equation 4. Although equation 5 produces estimates in the desired units, it predicts the median rather than the mean response of the dependent variable and so the estimate is biased. In the case of streamflow, the median tends to be lower than the mean (Ries and Friesz, 2000). Bias correction factors (BCF) have been proposed to correct the problem of bias in retransformed logarithmic equations and these have been used in this study. A more thorough discussion of BCF's is provided in the section "Regression Equation Development."

Ordinary-least-squares regression-analysis methods assume that all measured dependent variable (Y_{pg}) values contain the same amount of information. This is generally not the case for streamflow statistics as (1) Y_{pg} estimates are more precise for stations with long records than for those with short records, and (2) Y_{pg} values are spatially correlated, so there is some duplication of the information in the records at the various stream-gaging stations. Generalized-least-squares methods were developed to account for these effects. Tasker and Stedinger (1989) demonstrated that

GLS analysis generally provides the most accurate results for hydrologic regressions as a result of streamflow data being correlated spatially and in time. Generalized-least-squares methods generally provide more accurate estimates of regression coefficients when compared to OLS methods when sites have different record lengths and an unbiased model-error estimator. Weighted-least-squares (WLS) analysis can compensate for differences in record length, but, unlike GLS, it does not compensate for cross-correlation among the stream-gaging stations used in the analysis. For the WLS analysis, the correct weights are inversely proportional to the variance (modeling and sampling error of the streamflow statistics) of the observed values about the regression line (G.D. Tasker, U.S. Geological Survey, written commun., 2001) and directly proportional to the years of record. The weight given to each station in a GLS regression analysis is adjusted to compensate for differences in record length among the stations and for spatial correlation. Model precision increases with decreasing standard error of estimate and increasing cross correlation, when GLS methods are used instead of WLS methods (Stedinger and Tasker, 1985).

Because of its advantages, GLS was used to develop the estimation equations for the seasonal and annual 7Q10 and 7Q2 low-flow values, respectively. However, GLS was developed specifically for use with flow-frequency statistics (7Q10 and 7Q2), which are typically based on annual time periods, and requires substantial modification for use with duration statistics, which are typically based on the entire period of record (Ries, 1994b). Thus, GLS methods were not used for the duration statistics. Although WLS methods were tested for the seasonal period-of-record and period-of-record 60-, 70-, 80-, 90-, 95- and 98-percent-duration statistics, the resulting estimation equations did not differ significantly from those developed using OLS methods. The OLS equations were used for estimation.

Vogel and Kroll (1990) compared results from GLS and OLS regression analysis using Massachusetts data, and found the equation parameters to be similar, but with slightly lower prediction errors for GLS than for OLS. Stedinger and Tasker (1985) showed that differences between GLS-generated equations and WLS-generated equations were small and decreased with increasing standard error of estimate and decreasing interstation correlation (K.G. Ries, U.S. Geological Survey, written commun. 2000).

DEVELOPMENT OF REGRESSION MODEL FOR ESTIMATION OF LOW-FLOW-FREQUENCY AND FLOW-DURATION STATISTICS

Using active and discontinued stream-gaging stations, a database containing a representative set of drainage basins for the low-flow analysis was developed for estimating low-flow frequency and flow-duration statistics. These statistics were developed using the following criteria: (1) a minimum of 10 years of continuous-record data, as less than 10 years may not provide a sufficient sampling of the variation that may exist in the population, and (2) no substantial effects of regulation, diversion, or augmentation on streamflow. Continuous-record stream-gaging stations on streams with major streamflow regulation were eliminated if records had not been collected when the streamflow was unregulated as reservoir regulation at continuous stream-gaging stations typically increases low flows and reduces high flows (Ruhl and Martin, 1991). Continuous-record sites where data were collected during unregulated and regulated streamflow periods were retained for the study, but only the data collected during periods of unregulated streamflow were used to determine low-flow characteristics.

Data from 60 stream-gaging stations at unregulated sites in New Hampshire, Vermont, Maine, and Massachusetts were used in this study. All of these streamflows were unregulated for the period utilized in the analyses. Available records through year 1999 were used to compute the streamflow statistics for the stations. Lengths of record ranged from 10 to 95 years. Not all of the stations in Vermont, Massachusetts, and Maine that meet the criteria listed above were selected for use in this study. In Vermont, only those stations in the Connecticut River Basin were included. In Maine and Massachusetts, only those stations within 25 mi of the New Hampshire border were included. The names and descriptions of the stream-gaging stations are shown in table 1. The locations of the stream-gaging stations, streams, and associated drainage basins are shown on figure 1. The locations of the stream-gaging stations, New Hampshire towns and associated drainage basins are shown on figure 2.

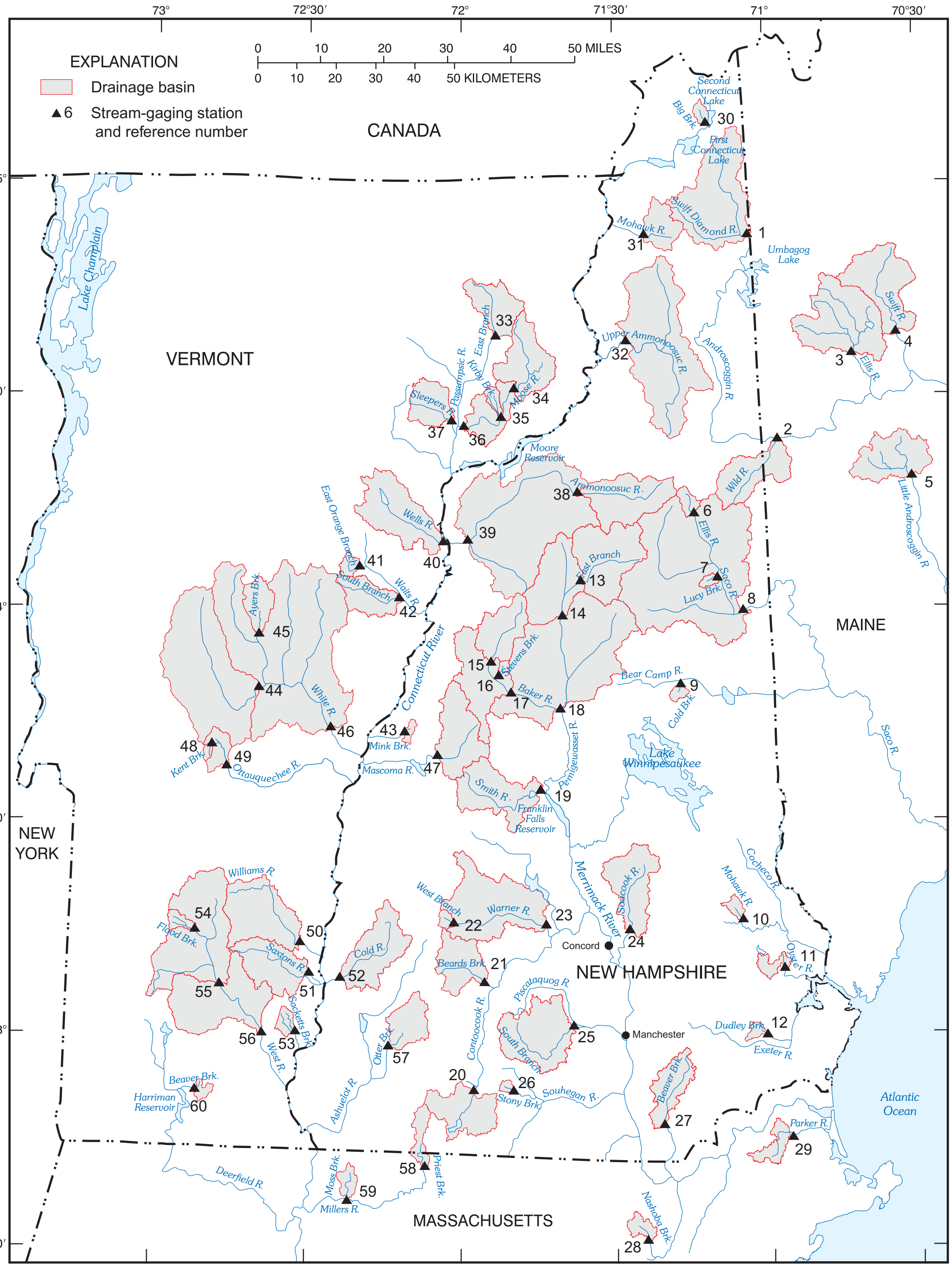
Table 1. Descriptions of stream-gaging stations used to develop the regression analysis for New Hampshire streams

[No., number; fig., figure; mi^2, square miles; present in period of record refers to data through water year 1999]

Stream-gaging station reference No. (fig. 1)	Stream-gaging station No.	Latitude (decimal degrees)	Longitude (decimal degrees)	River name	Location (fig. 2)	Period of record, year	Drainage area (mi^2)
1	1052500	44.8778	71.0569	Diamond River	Wentworth Location, N.H.	1941-present	153
2	1054200	44.3908	70.9797	Wild River	Gilead, Maine	1964-present	69.9
3	1054300	44.5936	70.7336	Ellis River	South Andover, Maine	1963-82	130
4	1055000	44.6422	70.5881	Swift River	near Roxbury, Maine	1929-present	96.8
5	1057000	44.3033	70.5394	Little Androscoggin River	near South Paris, Maine	1913-24, 1931-99	74.1
6	1064300	44.2200	71.2500	Ellis River	near Jackson, N.H.	1963-present	10.5
7	1064400	44.0694	71.1750	Lucy Brook	near North Conway, N.H.	1964-92	4.68
8	1064500	43.9908	71.0914	Saco River	near Conway, N.H.	1903-12, 1929-present	385
9	1064800	43.8158	71.2975	Cold Brook	South Tamworth, N.H.	1964-73	5.41
10	1072850	43.2631	71.0972	Mohawk River	Center Strafford, N.H.	1964-77,	7.47
11	1073000	43.1486	70.9656	Oyster River	Durham, N.H.	1934-present	12.2
12	1073600	42.9936	71.0233	Dudley Brook	Exeter, N.H.	1962-85	5.85
13	1074500	44.0600	71.6200	East Branch Pemigewasset	near Lincoln, N.H.	1928-53	106
14	1075000	43.9761	71.6800	Pemigewasset River	Woodstock, N.H.	1940-77	195
15	1075500	43.8680	71.9097	Baker River	Wentworth, N.H.	1940-52	57.8
16	1075800	43.8367	71.8853	Stevens Brook	Wentworth, N.H.	1963-98	3.29
17	1076000	43.7961	71.8450	Baker River	Rumney, N.H.	1929-75	143
18	1076500	43.7592	71.6861	Pemigewasset River	Plymouth, N.H.	1903-present	623
19	1078000	43.5675	71.7483	Smith River	near Bristol, N.H.	1918-present	86.0
20	1082000	42.8625	71.9597	Contoocook River	Peterborough, N.H.	1945-77	67.0
21	1084500	43.1142	71.9267	Beards Brook	Hillsboro, N.H.	1945-70	55.3
22	1085800	43.2592	72.0264	West Branch Warner River	near Bradford, N.H.	1962-present	5.91
23	1086000	43.2517	71.7317	Warner River	Davisville, N.H.	1940-78	146
24	1089000	43.2394	71.4622	Soucook River	near Concord, N.H.	1952-87, 1988-present	77.8
25	1091000	43.0136	71.6419	South Branch Piscataquog River	near Goffstown, N.H.	1940-78	103
26	1093800	42.8600	71.8333	Stony Brook Tributary	near Temple, N.H.	1964-present	3.62
27	10965852	42.7831	71.3539	Beaver Brook	North Pelham, N.H.	1986-present	47.8
28	1097300	42.5108	71.4069	Nashoba Brook	near Acton, Mass.	1963-present	12.8
29	1101000	42.7528	70.9461	Parker River	Byfield, Mass.	1945-present	21.2
30	1127880	45.1350	71.2064	Big Brook	Pittsburg, N.H.	1965-83	6.50

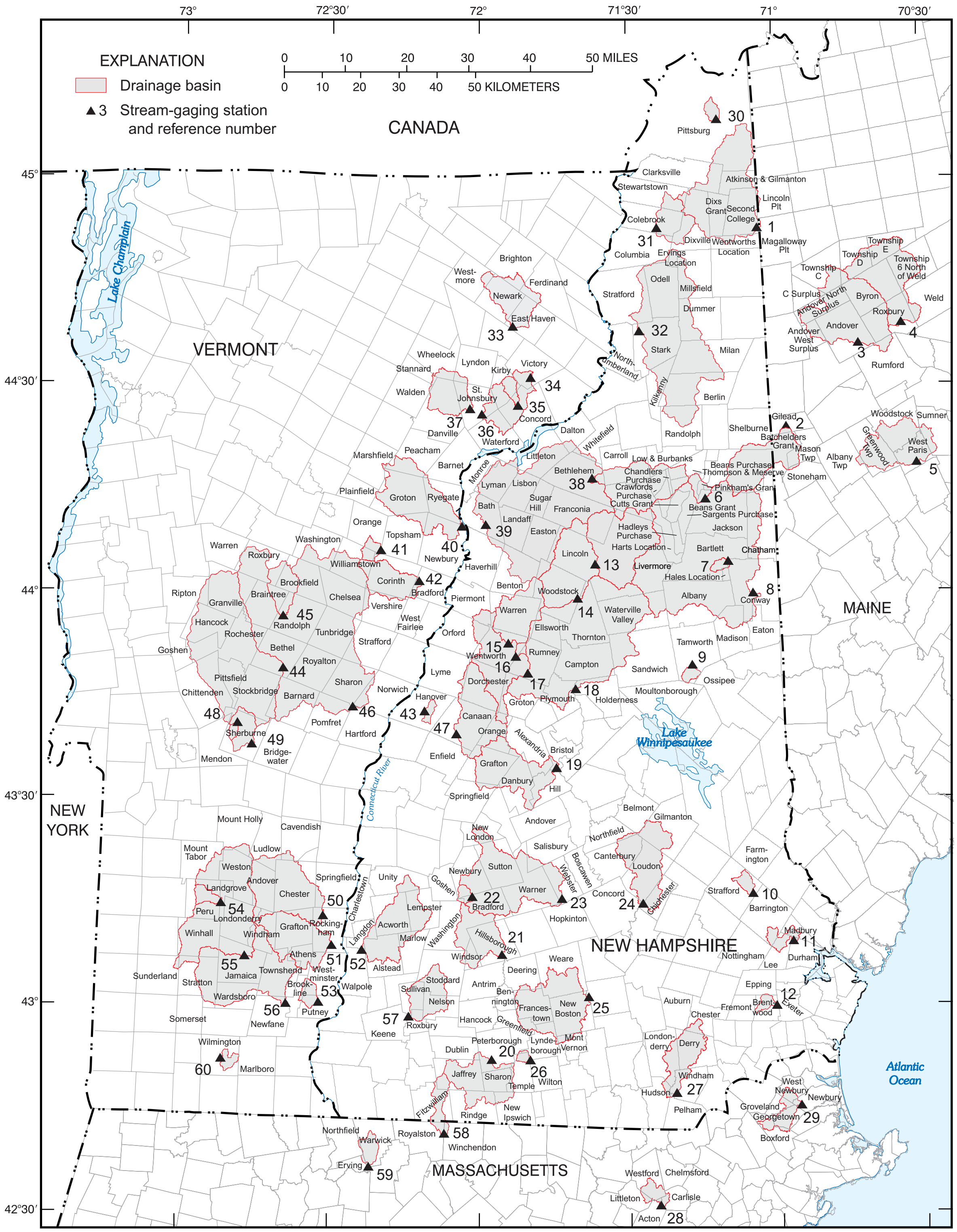
Table 1. Descriptions of stream-gaging stations used to develop the regression analysis for New Hampshire streams--Continued

Stream-gaging station reference No. (fig. 1)	Stream-gaging station No.	Latitude (decimal degrees)	Longitude (decimal degrees)	River name	Location (fig. 2)	Period of record, year	Drainage area (mi^2)
31	1129440	44.8744	71.4106	Mohawk River	near Colebrook, N.H.	1986-present	35.3
32	1130000	44.6250	71.4694	Upper Ammonoosuc River	near Groveton, N.H.	1940-80, 1982-present	230
33	1133000	44.6339	71.8981	East Branch Passumpsic	East Haven, Vt.	1939-45, 1948-79	51.3
34	1134500	44.5117	71.8369	Moose River	Victory, Vt.	1947-present	75.2
35	1134800	44.4419	71.8792	Kirby Brook	Concord, Vt.	1963-74	8.13
36	1135000	44.4228	72.0006	Moose River	St. Johnsbury, Vt.	1928-83	129
37	1135300	44.4344	72.0394	Sleepers River (W-5)	St. Johnsbury, Vt.	1989-present	42.5
38	1137500	44.2689	71.6311	Ammonoosuc River	Bethlehem Junction, N.H.	1939-present	88.2
39	1138000	44.1539	71.9861	Ammonoosuc River	Bath, N.H.	1935-80	396
40	1139000	44.1508	72.0653	Wells River	Wells River, Vt.	1940-present	98.7
41	1139800	44.0928	72.3361	East Orange Branch	East Orange, Vt.	1958-present	8.79
42	1140000	44.0181	72.2083	South Branch Waits River	near Bradford, Vt.	1940-51	43.8
43	1141800	43.7022	72.1875	Mink Brook	Etna, N.H.	1962-98	4.75
44	1142000	43.8125	72.6569	White River	Bethel, Vt.	1931-55	239
45	1142500	43.9344	72.6583	Ayers Brook	Randolph, Vt.	1939-75, 76-present	30.5
46	1144000	43.7142	72.4186	White River	West Hartford, Vt.	1915-present	689
47	1145000	43.6500	72.0806	Mascoma River	West Canaan, N.H.	1939-78	80.4
48	1150800	43.6733	72.8092	Kent Brook	Sherburne, Vt.	1964-74	3.26
49	1150900	43.6222	72.7594	Ottauquechee River	West Bridgewater, Vt.	1984-present	23.3
50	1153500	43.2086	72.5181	Williams River	Brockways Mills, Vt.	1940-84	102
51	1154000	43.1372	72.4881	Saxtons River	Saxtons River, Vt.	1940-82	72.1
52	1155000	43.1317	72.3897	Cold River	Drewsville, N.H.	1940-78	83.3
53	1155200	42.9992	72.5331	Sacketts Brook	Putney, Vt.	1963-74	10.1
54	1155300	43.2364	72.8564	Flood Brook	Londonderry, Vt.	1963-74	9.28
55	1155500	43.1089	72.7758	West River	Jamaica, Vt.	1946-60	177
56	1156000	42.9958	72.6389	West River	Newfane, Vt.	1919-23, 1928-60	306
57	1158500	42.9653	72.2333	Otter Brook	Keene, N.H.	1924-58	41.9
58	1162500	42.6825	72.1156	Priest Brook	Winchendon, Mass.	1963-present	19.0
59	1165500	42.6028	72.3600	Moss Brook	Wendell Depot, Mass.	1909-10, 1916-82	12.2
60	1167800	42.8606	72.8511	Beaver Brook	Wilmington, Vt.	1963-77	6.36



Base from U.S. Geological Survey
Digital line graphs, 1:24,000 or
1:25,000 scale, 1983

Figure 1. Location of streams, drainage basins, and stream-gaging stations in the study area that were used to develop the equations for estimating low-flow statistics for New Hampshire streams.



Base from U.S. Geological Survey
Digital line graphs, 1:24,000 or
1:25,000 scale, 1983

Figure 2. Location of towns, drainage basins, and stream-gaging stations in the study area. (For detailed information on stream-gaging stations, refer to table 1.)

Drainage-Basin Characteristics

The values of 93 physical and climatic (seasonal and annual) drainage-basin characteristic candidate explanatory variables (independent variables) were determined for each of the 60 unregulated stream-gaging stations (Appendix 1). The values for most of the basin characteristics were determined with a GIS. Ten of the 93 basin characteristics were determined to be the most statistically significant in explaining a significant amount of the variability of the dependent (response) variable. The following independent variables were used in the analyses:

- Drainage area, in square miles, is the area measured in a horizontal plane that is enclosed by a drainage divide.
- Average basin slope, in percent, is the average slope of the drainage basin measured using a Digital-Elevation Model (DEM) with the computer software Arc-INFO (Environmental Systems Research Institute, Inc., 1994).
- Maximum basin elevation, in feet, is the maximum elevation in the drainage basin derived from the intersection of basin polygon coverages and DEMs.
- Annual and summer mean basinwide average temperature, in degrees Fahrenheit, is the basinwide average temperature from 2-kilometer-grid Parameter-elevation regressions on Independent Slopes Model (PRISM) (Daly, 2000) data for 1961-90.
- Coniferous, in percent, is National Land Cover Dataset (NLCD) data (U.S. Geological Survey, 2000; and Vogelman and others, 2001) representing the percent of the basin that is coniferous and is defined as areas dominated by trees, where 75 percent or more of the tree species maintain their leaves all year.
- Summer and spring gage precipitation, in inches, is the seasonal precipitation determined at the stream-gaging station from 2-kilometer-grid PRISM data for 1961-90.
- Mixed Coniferous/Deciduous, in percent, is the NLCD data (U.S. Geological Survey, 2000; and Vogelman and others, 2001) representing the percent of the basin that is mixed coniferous and deciduous and defined as areas dominated by trees, where neither deciduous nor coniferous trees represent more than 75 percent of the cover present.
- Winter basin-centroid precipitation, in inches, is the seasonal precipitation determined at the centroid of the basin from 2-kilometer-grid PRISM data for 1961-90.

The measured basin characteristics for the stream-gaging stations used in the regression analyses are provided in table 2. All of the basin characteristics were measured in a GIS using available and created data layers. The digital data layers, which were important in the determination of other basin characteristics, include but are not limited to (1) drainage subbasins at 1:24000 scale created by the Natural Resources Conservation Service (NRCS) as 12-digit Hydrologic Unit Codes (HUCS) (Natural Resources Conservation Service, written commun., 2001), (2) centerline hydrography for New Hampshire at 1:24000 and 1:25000 scale developed by Complex Systems Research Center (CSRC) at the University of New Hampshire (UNH) (Fay Rubin, Complex Systems Research Center, University of New Hampshire, written commun., 2000), and (3) USGS DEMs at 1:24000 scale from the USGS National Elevation Dataset (U.S. Geological Survey, 2001).

The basin characteristics obtained for this study were delineated using scripts written in the computer programming language Avenue or Arc Macro Language (AML). Some of the basin characteristics tested for inclusion in the regression equations (see Appendix 1 for complete list and explanation) were obtained with the USGS drainage-basin-characteristics determination program BasinSoft (Harvey and Eash, 1995). The BasinSoft program, written in AML, uses digital cartographic data layers to quantify 27 selected morphometric basin characteristics. BasinSoft uses four source-data layers; three coverages representing the drainage-basin divide, hydrography, and hypsography; and a lattice-elevation model of the drainage basin (Harvey and Eash, 1995). The basin characteristics determined with BasinSoft were basin length, basin perimeter, basin relief, basin azimuth, effective basin width, shape factor, compactness ratio, relative relief, main channel length, main channel slope, main channel sinuosity ratio, stream density, main channel slope proportion, ruggedness number, and slope ratio. A requirement of BasinSoft is that the

Table 2. Basin characteristics for stream-gaging stations used in the regression analyses

[No., number; fig., figure; mi^2, square miles; ft, foot; in., inches; °F, degrees Fahrenheit; NLCD, National Land Cover Dataset]

Stream-gaging station reference No. (fig. 1)	Stream-gaging station No.	Basin characteristics									
		Drainage area (mi^2)	Percent average basin slope	Maximum basin elevation (ft)	Average summer gage precipitation (in.)	Average spring gage precipitation (in.)	Average winter basin centroid precipitation (in.)	Average mean annual basin temperature (°F)	Average mean summer basin temperature (°F)	Percent coniferous (NLCD)	Percent mixed coniferous and deciduous (NLCD)
		Basin-characteristic abbreviations									
		DA	BS	MxBE	SGP	SpGP	WCP	ABT	SBT	C	CD
1	1052500	153	18.0	3,620	17.9	7.48	7.46	37.0	54.4	20.0	30.2
2	1054200	69.9	25.9	4,830	19.9	9.09	8.74	40.7	57.3	31.5	30.5
3	1054300	130	15.9	3,780	17.7	8.72	6.91	40.0	57.2	22.9	26.9
4	1055000	96.8	18.5	3,770	18.1	8.70	7.34	38.9	56.2	36.6	13.5
5	1057000	74.1	14.2	2,400	18.3	9.13	7.56	42.6	59.5	17.1	22.3
6	1064300	10.5	38.1	6,280	22.4	10.6	15.1	36.8	52.9	56.2	20.7
7	1064400	4.68	27.5	3,180	20.3	10.3	10.3	41.7	58.1	45.2	36.5
8	1064500	385	23.1	6,280	19.1	9.86	9.41	40.5	56.9	31.1	34.0
9	1064800	5.41	25.6	2,680	21.2	11.0	12.2	41.6	58.1	19.9	39.8
10	1072850	7.47	8.85	1,130	17.9	9.63	8.52	45.4	61.5	19.1	46.1
11	1073000	12.2	4.51	386	16.9	9.21	7.83	46.8	62.6	17.7	33.2
12	1073600	5.85	3.19	260	17.4	9.39	8.31	46.9	62.6	20.6	20.3
13	1074500	106	30.5	5,230	22.0	10.0	9.98	39.3	55.4	55.0	31.6
14	1075000	195	28.4	5,250	19.6	9.80	8.37	40.3	56.4	40.7	32.9
15	1075500	57.8	19.7	4,810	17.7	7.60	5.93	42.2	58.5	18.1	38.2
16	1075800	3.29	23.5	3,270	17.8	8.44	7.01	42.9	59.2	30.7	41.0
17	1076000	143	17.5	4,810	18.2	9.02	5.79	42.5	58.9	13.8	36.3
18	1076500	623	22.3	5,250	17.4	8.50	8.92	41.7	57.9	25.7	35.9
19	1078000	86.0	13.9	2,820	18.4	9.19	7.78	43.1	59.4	23.9	30.9
20	1082000	67.0	8.45	3,120	18.1	9.25	8.33	44.4	59.9	22.6	28.2
21	1084500	55.3	12.3	2,450	17.5	9.27	8.64	45.1	61.1	21.3	26.3
22	1085800	5.91	17.4	2,480	18.3	9.51	7.95	44.6	60.7	7.18	10.7
23	1086000	146	12.9	2,690	17.0	8.60	8.31	44.4	60.7	22.5	29.8
24	1089000	77.8	7.80	1,490	16.5	7.83	6.71	44.5	60.9	17.4	29.7
25	1091000	103	9.96	2,030	17.0	8.72	8.23	44.8	60.7	26.7	26.6
26	1093800	3.62	16.8	2,270	18.9	9.92	9.15	44.6	60.1	13.2	27.2
27	10965852	47.8	5.55	637	17.4	9.07	8.13	46.8	62.8	10.4	12.9
28	1097300	12.8	4.86	462	17.6	9.37	8.82	48.3	64.1	5.19	19.2
29	1101000	21.2	5.24	358	17.6	9.69	9.02	48.7	64.4	3.07	14.5
30	1127880	6.50	13.2	3,190	23.1	8.82	7.28	36.1	53.8	9.30	33.9

Table 2. Basin characteristics for stream-gaging stations used in the regression analyses--Continued

[No., number; fig., figure; mi^2, square miles; ft, foot; in., inches; ° F, degrees Fahrenheit; NLCD, National Land Cover Dataset]

Stream-gaging station reference No. (fig. 1)	Stream-gaging station No.	Drainage area (mi^2)	Percent average basin slope	Maximum basin elevation (ft)	Average summer gage precipitation (in.)	Average spring gage precipitation (in.)	Average winter basin centroid precipitation (in.)	Average mean annual basin temperature (° F)	Average mean summer basin temperature (° F)	Percent coniferous (NLCD)	Percent mixed coniferous and deciduous (NLCD)
		DA	BS	MxBE	SGP	SpGP	WCP	ABT	SBT	C	CD
31	1129440	35.3	15.0	3,460	21.1	8.23	7.03	37.8	54.9	18.7	34.1
32	1130000	230	17.1	4,160	19.1	7.68	6.28	40.0	56.9	20.6	31.5
33	1133000	51.3	15.3	3,320	20.9	8.13	6.42	39.2	56.6	12.1	27.1
34	1134500	75.2	14.8	3,430	20.2	8.07	7.11	40.1	57.2	14.3	25.1
35	1134800	8.13	15.2	2,550	18.8	7.38	6.36	41.3	58.4	20.9	36.2
36	1135000	129	15.1	3,430	18.2	7.34	6.40	40.8	58.0	15.1	30.6
37	1135300	42.5	13.6	2,570	18.3	7.40	6.20	40.0	57.3	15.1	32.5
38	1137500	88.2	21.7	6,290	19.8	8.09	10.3	39.3	55.5	37.1	29.1
39	1138000	396	17.4	6,290	17.4	6.93	6.04	41.4	58.0	24.1	37.9
40	1139000	98.7	13.6	3,370	17.4	6.83	5.79	41.0	57.9	13.0	29.8
41	1139800	8.79	23.4	2,420	19.7	8.31	6.46	40.6	57.1	5.76	26.1
42	1140000	43.8	17.8	2,390	18.3	7.42	6.12	41.3	58.3	13.0	30.5
43	1141800	4.75	15.2	2,300	18.4	8.33	6.97	43.3	59.7	19.1	18.0
44	1142000	239	25.5	3,770	17.2	8.25	7.80	41.9	58.4	13.5	23.0
45	1142500	30.5	18.2	2,330	17.0	8.11	6.75	41.9	58.4	10.0	25.1
46	1144000	689	21.5	3,770	16.7	7.81	6.85	42.0	58.6	13.9	23.1
47	1145000	80.4	12.1	3,220	17.6	8.19	6.57	42.9	59.2	24.0	26.1
48	1150800	3.26	22.6	3,920	22.7	10.5	9.19	41.5	57.4	12.9	9.05
49	1150900	23.3	25.1	4,200	21.0	10.8	8.56	41.3	57.5	13.7	6.21
50	1153500	102	18.3	2,890	17.5	8.70	7.72	43.0	59.5	17.3	21.2
51	1154000	72.1	19.2	2,890	17.9	8.94	8.19	42.6	58.9	20.0	23.7
52	1155000	83.3	13.1	2,160	16.8	8.29	6.91	44.5	60.8	24.0	26.9
53	1155200	10.1	16.2	1,670	17.4	8.70	7.91	43.9	60.3	11.7	16.0
54	1155300	9.28	15.0	3,370	20.2	9.98	9.09	42.1	57.7	17.6	13.2
55	1155500	177	14.3	3,890	19.1	9.43	8.39	41.7	57.6	21.1	16.8
56	1156000	306	16.2	3,950	17.9	9.13	8.29	41.7	57.6	20.8	18.1
57	1158500	41.9	13.2	2,150	17.7	8.76	7.76	43.9	59.8	18.6	21.3
58	1162500	19.0	7.00	1,890	17.7	8.86	8.05	44.1	59.9	22.2	30.2
59	1165500	12.2	10.6	1,620	18.2	9.17	7.85	44.8	61.0	39.9	27.7
60	1167800	6.36	15.0	2,420	21.8	11.5	9.92	42.6	58.6	20.9	20.1

main channel must be extended to the drainage-basin divide. The USGS computer software program GIS Weasel (Viger and others, 2000), a graphical-user interface for a GIS, was utilized for this task in conjunction with DEMs of the drainage basins.

The centerline hydrography data layer for New Hampshire was developed from digital line graph (DLG) datasets (Fay Rubin, Complex Systems Research Center, University of New Hampshire, written commun., 2000). There was a stream-density inconsistency in many USGS topographic quadrangles in the western part of the State. USGS quadrangles at a scale of 1:25,000 have a much greater stream density than the 1:24,000-scale quadrangles. Because of this density difference, CSRC developed a threshold value to delineate the 1:25,000-scale quadrangles to match the drainage density of the 1:24,000-scale quadrangles. Centerline data for Vermont river basins also have a drainage-density inconsistency in many quadrangles in the eastern part of that State. Centerline hydrography for Vermont was developed by the USGS from 1:25,000- and 1:24,000-scale quadrangles and the threshold value, as determined by CSRC, was used for the 1:25,000-scale quadrangles. Centerline data for Massachusetts also were developed by the USGS (Peter Steeves, U.S. Geological Survey, written commun., 2001). Stream data for Maine were obtained from the Maine GIS (MEGIS) web site (Maine office of GIS, 2000) and used to create centerline data.

Precipitation, temperature, and snowfall data were acquired from PRISM datasets. PRISM is an analytical tool that uses point data, DEMs, and other spatial datasets to generate gridded estimates of annual, monthly, and event-based climatic parameters such as precipitation (Daly, 2000). The PRISM data contain polygon coverages of average monthly and annual climatological data for 1961-90. PRISM-derived raster data are the underlying datasets from which the polygons and vectors for the data layers were created. The PRISM data incorporate topographic effects on precipitation and include coastal and lake effects on precipitation.

Soils characteristics for each drainage basin were obtained from the STATSGO (State Soil Geographic) soil characteristics for the conterminous United States (U.S. Geological Survey, 1997, and Schwartz and Alexander, 1995). Forest characteristics for each drainage basin were obtained from the Forest Land Distribution Data for the United States (U.S. Forest Service, 1992).

The delineation of sand and gravel deposits in New Hampshire was based upon the USGS ground-water-availability maps for New Hampshire (Cotton; 1974, 1975, 1976a and b; and 1977a, b, and c) published at a scale of 1:125,000 (Fay Rubin, written commun., 2000). The sand and gravel deposits in Vermont were based upon the Aggregate Sand, Gravel and Stone Resources maps as digitized by the Vermont Agency of Natural Resources (VNR) and available on the Vermont Geographic Information System (VtGIS) Web site (Vermont Geographic Information System, 2000). In addition, sand- and gravel-deposit maps for Massachusetts were acquired from the Massachusetts Geographic Information System (MassGIS) Web site (Massachusetts Geographic Information System, 2000) and for Maine this information was acquired from the Maine office of GIS Web site (Maine office of GIS, 2000). The data from these maps were included in the database.

Regression Analysis

A large number of drainage-basin characteristics (93) were analyzed as potential independent variables in the seasonal and annual low-flow frequency and seasonal period-of-record and period-of-record flow-duration regression equations. Consequently, an automated procedure was required that would aid in the selection of an appropriate subset of independent variables to determine the dependent variable in each of the final regression models. A variable-selection algorithm also was required to assist in determining the combination of independent variables that provided the best estimates of the dependent variable in the regression equations. To accomplish this, a stepwise-regression procedure was used within the SAS (Statistical Analysis System) program, version 8.1 (SAS Institute, Inc., 1994) to specify which predictor variables were to be included in the regression equations. The stepwise method is a modification of the forward-selection method, in which variables already in the model do not necessarily remain in the model. Variables are added one at a time to the model and the F-statistic (mean square for the model divided by the mean square for error) must be significant at a predefined level. In this study, the significance level was set at 0.05. After each variable was added to a model, the stepwise method assessed all of the variables already included in the model and deleted any variable that did not produce an *F*-statistic significant at the selected confidence level. Only after the statistical significance of each independent variable was determined, and those that were statistically insignificant at the specified significance level of 5 percent were eliminated, could another variable be added to the model. The regression models tested were logarithmic and all statistical tests were done on the logarithms of the dependent and predictor variables.

After the statistically significant independent variables (at the 95-percent confidence level) were determined for each of the period-of-record and seasonal period-of-record flow durations, and seasonal and annual low-flow-frequency statistics, an all-possible-regression algorithm called RSQUARE was run in SAS. The RSQUARE method is a useful linear-regression tool for exploratory model building as it assists in finding subsets of independent variables that best predict a dependent variable in a given sample (SAS Institute, Inc., 1994). This algorithm examines all of the possible combinations of the independent variables and ranks them according to decreasing order of R^2 (fraction of the variance explained by the regression) magnitude for the given sample. Using this output of ranked R^2, the best combination of independent variables was selected for further testing for inclusion in the final regression equations. The test included using minimization of Mallow's *Cp* statistic (Cavalieri and others, 2000; Ries and Friesz, 2000) as a selection criterion. The flow-duration subsets were further analyzed using OLS regression analyses to select a final model for each streamflow statistic. The final regression models were selected based upon the following statistical parameters:

- Mallow's *Cp* statistic is a measure of the total squared error for a subset model containing *n* independent variables (Freund and Littell, 2000). Mallow's *Cp* is an indicator of model bias (Cavalieri and others, 2000). Models with a large *Cp* are biased in that they contain predictors that are not important in the population;
- Mean Square Error (MSE) is the precision of the biased estimate determined as the square of the bias plus the variance (Freund and Littell, 2000), also known as the sample model error variance of the estimates for the stream-gaging stations included in the analysis (Ries and Friesz, 2000);
- Adjusted *R* Squared (R^2adj) is an alternative to *R*-Square in which the percentage of variation in the dependent variable can be explained by the variation of the independent variables in the model. In contrast to R^2, R^2adj is adjusted for the number of parameters in the model (number of stations and number of independent variables in the regression analysis) (Freund and Littell, 2000);
- Predicted REsidual Sum of Squares (PRESS) statistic is the sum of squares of residuals using models obtained by estimating the equation with all other observations (Freund and Littell, 2000) and is an estimate of the prediction error sum of squares. The PRESS statistic measures how well the regression model predicts the i^{th} observation as though it were a new observation (Cavalieri and others, 2000).

In addition to the above listed statistical parameters for selection of the best combination of independent variables to be included in the final regression models for the seasonal and annual low-flow-frequency and seasonal period-of-record and period-of-record flow-duration regression equations, independent variables were selected on the basis of whether they (1) made "hydrologic sense," (2) explained a significant amount of the variability of the dependent (response) variable (low-flow-discharge statistic), and (3) could be easily measured using a GIS.

Regression equations were developed using SAS software version 8.1, (SAS Institute, Inc., 1994) for the seasonal and annual low-flow-frequency and seasonal period-of-record and period-of-record flow durations. The independent variables selected for the final models were statistically significant at the 95-percent confidence level based on a *p*-value of the test *F*-statistic less than alpha = 0.05 (Cavalieri and others, 2000). According to McCuen and others (1996), whereas a 5-percent level of significance sometimes is used to select independent variables for a regression model to ensure a reasonable level of accuracy and rational coefficients for the independent variables in the regression equation, it is preferable to select only those variables that are easily measured. When stepwise-regression analysis is used to select variables for a set of equations for different return periods, the same independent variables should be used in all of the equations. This redundancy may cause some equations in the set to be less accurate than would otherwise be possible, but it is desirable to ensure consistency across the set of equations (McCuen, 1996). In three of the regression equations, one of the independent variables in the regression equations had a level of significance slightly greater than 5 percent. As the estimate of the independent variables maintained at least a 10 percent level of significance, the variables were not removed from the regression equations. In addition to statistical criteria, all of the regression coefficients should make hydrologic sense.

Diagnostic checks were done to test for model adequacy and violations of the assumptions for regression analysis. Regression-equation independent variables that are highly intercorrelated result in a significant duplication of the information contained in those variables and the prediction equations are likely to be unreliable. To test for this condition, known as multicollinearity, variance inflation factors (VIF) are computed for each variable. VIFs express the ratio of the actual variance of the coefficient of the predictor variable to its variance if it were independent of the other predictor variables (Cavalieri and others, 2000) and are a measure of how multicollinearity increases the instability or variance of the linear-regression coefficient estimates (Freund and Littell, 2000). VIF values are computed as the inverse of the correlation matrix of the predictor variables; a value exceeding 10 indicates that a predictor variable is so highly correlated to other predictor variables that it is an unreliable predictor and should not be included in the estimation equation as the equation may be unstable. None of the predictor variables retained in the prediction models for this study had VIF values greater than 10.

Regression residuals dependence was evaluated using the Durbin-Watson statistic (Helsel and Hirsch, 2000). One of the assumptions of regression analysis is that the residuals are independent. The Durbin-Watson statistic evaluates whether or not there is auto-correlation in which the regression residuals are found to not be independent. If the model assumptions are valid, the residual values should be randomly scattered about a reference line at 0. Any patterns or trends in the residuals may indicate autocorrelation problems in the model.

Other diagnostic checks done to test for model adequacy and violations of the assumptions for regression analysis included identification of influential observations. Influential observations are data that substantially change the fit of the regression line. Three diagnostic statistics were determined to help in the identification of influential observations. These statistics were

1. Cook's D, which is a measure of the simultaneous change in the parameter estimates when an observation is deleted from the regression analysis. A value of Cook's D greater than 4 divided by *n*, where *n* is the sample size (Cavalieri and others, 2000) represents a suggested threshold for determining that an observation may have an adverse influence on the regression analysis results;
2. Rstudent residuals, a version of studentized residuals which are the ordinary residuals divided by their standard errors, are determined from the difference between the observed dependent variable and the predicted value of the independent variable excluding the i^{th} observation from the regression analysis (Freund and Littell, 2000); and
3. DFFITS, which measures the standardized difference between predicted values for the i^{th} observation (stream-gaging station flow statistic) obtained by the regression equation estimated by all observations and the regression equation estimated from all observations excluding the i^{th} observation (Freund and Littell, 2000).

In addition, plots were made of

4. The regression equation predicted values of the flow statistics in relation to the residuals to determine if there were any trends in the residuals;
5. Studentized residuals in relation to observation numbers (stream-gaging station reference numbers) to determine if there were any unusually large residuals; and
6. Studentized residuals in relation to normal quantiles to determine if the residuals were normally distributed. The normal quantile is the expected quantile if the residuals are normally distributed (Cavalieri and others, 2000).

No significant trends in the residuals or unusually large residuals were found and all of the residuals were normally distributed. In addition, the regression residuals for selected flow statistics were plotted at the centroid of their respective drainage basins to look for geographical biases and to determine whether New Hampshire should be divided into more than one hydrologic region (Hodgkins, 1999). There were no distinct patterns in the mapped residuals.

Regression-Equation Development

The final regression models for determining the period-of-record and seasonal period-of-record flow-durations for the 60-, 70-, 80-, 90-, 95-, and 98-percent exceedences were developed using OLS and, initially where applicable, WLS by use of the statistical analysis package SAS, version 8.1 (SAS Institute Inc., 1994). The GLS method was developed specifically for use with flow-frequency statistics analysis, and is not well suited for the development of equations to estimate period-of-record flow durations. OLS regression output was used to determine whether a WLS analysis would result in an improvement to the OLS regression equations. The WLS method can be used to account for differences in record length for these flow statistics. WLS is an improvement over OLS regression only if the correct weights can be determined where the correct weights are inversely proportional to the variance of the observed values about the regression line (G.D. Tasker, U.S. Geological Survey, written commun., 2001) and directly proportional to the years of record. Of the 30 duration-regression equations developed, only 7 of these equations had estimates of weights for a WLS regression analysis that indicated WLS would be an improvement over OLS regression analysis.

Weights were assigned to the stream-gaging station statistics, where appropriate, as the inverse of the variance of the observed values about the regression line. The differences between a WLS and an OLS analysis were small for the seven duration-regression equations. As the WLS-regression-equation results were not an improvement over OLS, the OLS-determined regression equations were used for all of the final duration-regression equations. Continuous-station database-determined values for the seasonal and period-of-record duration statistics and the OLS-regression predicted values are in Appendixes 2 through 6.

A GLS regression analysis using the computer program generalized-least-squares NETwork (GLSNET; Tasker and Stedinger, 1989) was undertaken to determine the annual- and seasonal-low-flow-frequency equations for estimating the 7Q2 and 7Q10 statistics. The final regression models selected by use of GLSNET were chosen from the proposed regression equation drainage-basin characteristics (candidate independent variables), which were common to both the 7Q2 and 7Q10 as screened by SAS using the RSQUARE algorithm. All of the regression models were run through the GLSNET program and a final model selection was made based on model error, PRESS, and physical reasoning. According to Tasker and Stedinger (1989), GLS analysis is more appropriate, and provides better results in hydrologic regressions, than OLS-regression analysis when the streamflow records at stream-gaging stations are of varying lengths and when concurrent flows at different stations are correlated. The continuous stream-gaging station database determined values for the seasonal and annual low-flow-frequency statistics and the GLS-regression-predicted values are in Appendix 7.

GLSNET allows for the weighting of the data to compensate for differences in record length among the stream-gaging stations, as does WLS, but the weight in the analysis also can be adjusted to compensate for spatial correlation between sites. Generalized-least-squares gives less weight to stream-gaging stations with short periods of record and to those stations with concurrent flows that are correlated with other sites. GLSNET requires annual series data for developing regression equations, therefore, GLSNET was not used in the development of the period-of-record flow-duration equations in this study.

The comparative advantages of using a GLS analysis to using an OLS analysis were not evaluated in this study. Studies by Vogel and Kroll (1989) and by Ries and Friesz (2000), however, did evaluate these two methods for regression analysis. Using GLS in a regression analysis to predict the 7Q10 low flows for Massachusetts streams, Vogel and Kroll (1989) found that the parameters of the regression equation were almost identical when either OLS or GLS regression analysis was used to develop the equation. In addition, Ries and Friesz (2000) found that the prediction errors when GLS was used were only slightly smaller than the errors produced when OLS was used. The GLS-developed regression equations for seasonal and annual low-flow-frequency statistics and the OLS-developed regression equations for period-of-record and seasonal period-of-record flow durations are presented in table 3 along with the number of stream-gaging stations used in the analysis and several measures of model adequacy.

Table 3. Summary of regression equations and measures of model adequacy for estimating flow duration and low-flow frequency statistics for selected New Hampshire stream-gaging stations

[**Statistic**, Pwinxx, Psprxx, Psumxx, Pfallxx are the xx-percent duration flow for winter (win), spring (spr), summer (sum), and fall (fall); Pporxx is the xx-percent duration flow for the period-of-record (por); **7Qt**, 7-day, t-year or season low flow. All flows are in cubic feet per second (ft^3/s); *, multiply by; **BCF**, Bias correction factor (Duan's (1983) formula for ordinary-least-squares regression and Ferguson's formula for generalized-least-squares regression); **DA**, drainage area (square miles); **BS**, average basin slope (percent); **MxBE**, maximum basin elevation (foot); **ABT**, average mean annual basin temperature (degrees Fahrenheit); **SBT**, average mean summer basin temperature (degrees Fahrenheit); **C**, percent of basin containing coniferous trees (percent); **CD**, percent of basin containing mixed coniferous and deciduous trees (percent); **SGP**, average summer gage precipitation (inches); **WCP**, average winter basin centroid precipitation (inches); **SpGP**, average spring gage precipitation (inches); **R^2adj**, Coefficient of determination which explains the percentage of variation in the dependent variable; **Ser**, Average Standard Error of Estimate (McCuen, 1996); **Percent Ser**, Average Standard Error of Estimate, in percent of predicted value (Aitcheson and Brown, 1957); **APE**, Average Prediction Error of Model (G.D. Tasker, U.S. Geological Survey, written commun., 2002); **Percent APE**, Average Prediction Error, in percent of predicted value (Aitcheson and Brown, 1957); **APE plus and APE minus,** 68 percent probability that the true flow will be within these 2 percentages based on the predicted flow; 7Q2, 7-day, 2-year low-flow; 7Q10, 7-day, 10-year low-flow; --, no data]

Statistic	BCF	Regression equation	No. of stream-gaging stations	R^2adj	Ser		APE			
				Percent	Log 10 units	Percent	Log 10 units	Percent	Plus	Minus
		Flow Duration - Ordinary-least-squares regression equations								
Pwin60 =	1.01935	$* 10^{-0.74691} * (DA)^{1.05501} * (C)^{-0.31447} * (WCP)^{1.04311}$	60	98.1	0.088	20.5	0.091	21.2	23.3	-18.9
Pwin70 =	1.01824	$* 10^{-0.85475} * (DA)^{1.06248} * (C)^{-0.32065} * (WCP)^{1.085}$	60	98.2	.086	20.0	.089	20.7	22.7	-18.5
Pwin80 =	1.01431	$* 10^{-0.88606} * (DA)^{1.0528} * (C)^{-0.28824} * (WCP)^{1.00598}$	59	98.5	.076	17.6	.079	18.2	19.8	-16.5
Pwin90 =	1.01631	$* 10^{-1.04824} * (DA)^{1.06566} * (C)^{-0.23842} * (WCP)^{0.9677}$	59	98.4	.080	18.7	.083	19.3	21.0	-17.4
Pwin95 =	1.01942	$* 10^{-1.17324} * (DA)^{1.06732} * (C)^{-0.21459} * (WCP)^{0.95736}$	58	98.1	.086	20.1	.089	20.7	22.8	-18.6
Pwin98 =	1.03264	$* 10^{-1.22564} * (DA)^{1.05571} * (C)^{-0.15768} * (WCP)^{0.83447}$	58	96.8	.112	26.2	.116	27.1	30.5	-23.4
Pspr60 =	1.00679	$* 10^{0.000678} * (DA)^{1.01298} * (BS)^{0.31101}$	58	99.3	.052	11.9	.053	12.2	12.9	-11.5
Pspr70 =	1.00596	$* 10^{-0.0748} * (DA)^{1.01608} * (BS)^{0.28206}$	58	99.4	.048	11.2	.049	11.4	12.1	-10.8
Pspr80 =	1.00668	$* 10^{-0.0203} * (DA)^{1.01729} * (BS)^{0.23293} * (CD)^{-0.08555}$	58	99.3	.052	12.0	.053	12.4	13.1	-11.6
Pspr90 =	1.00811	$* 10^{-0.04102} * (DA)^{1.01595} * (BS)^{0.15284} * (CD)^{-0.11743}$	58	99.2	.057	13.2	.059	13.7	14.6	-12.7
Pspr95 =	1.00936	$* 10^{-0.0632} * (DA)^{1.01597} * (BS)^{0.099718} * (CD)^{-0.15498}$	58	99.0	.062	14.3	.064	14.8	15.9	-13.7
Pspr98 =	1.01373	$* 10^{-0.10609} * (DA)^{1.02007} * (BS)^{0.11425} * (CD)^{-0.24025}$	58	98.5	.075	17.5	.078	18.1	19.6	-16.4
Psum60 =	1.05101	$* 10^{11.8078} * (DA)^{1.18298} * (SBT)^{-9.04402} * (C)^{-0.1922} * (SGP)^{2.86063}$	60	96.3	.148	35.1	.154	36.7	42.7	-29.9
Psum70 =	1.06039	$* 10^{14.0257} * (DA)^{1.19901} * (SBT)^{-10.3043} * (C)^{-0.20291} * (SGP)^{2.77037}$	60	95.9	.160	38.2	.167	39.9	46.8	-31.9
Psum80 =	1.07543	$* 10^{14.0788} * (DA)^{1.2123} * (SBT)^{-10.5568} * (SGP)^{2.76521}$	60	95.3	.179	42.9	.184	44.5	52.9	-34.6
Psum90 =	1.09816	$* 10^{17.8757} * (DA)^{1.2409} * (SBT)^{-12.691} * (SGP)^{2.58347}$	60	94.5	.201	48.9	.208	50.7	61.3	-38.0
Psum95 =	1.12433	$* 10^{19.5562} * (DA)^{1.28282} * (SBT)^{-13.8734} * (SGP)^{2.7607}$	60	93.9	.223	54.9	.230	57.0	69.9	-41.2
Psum98 =	1.13959	$* 10^{24.8367} * (DA)^{1.25479} * (SBT)^{-16.1965} * (SGP)^{1.78959}$	58	92.7	.237	58.8	.244	61.0	75.5	-43.0
Pfall60 =	1.02332	$* 10^{-0.70158} * (DA)^{0.94819} * (MxBE)^{0.24926} * (C)^{-0.08028}$	60	97.6	.097	22.5	.100	23.3	25.9	-20.5
Pfall70 =	1.02860	$* 10^{-1.02695} * (DA)^{0.95106} * (MxBE)^{0.32968} * (C)^{-0.12032}$	60	97.2	.107	25.0	.111	25.9	29.0	-22.5

Table 3. Summary of regression equations and measures of model adequacy for estimating flow duration and low-flow frequency statistics for selected New Hampshire stream-gaging stations--Continued

[**Statistic**, Pwinxx, Psprxx, Psumxx, Pfallxx are the xx-percent duration flow for winter (win), spring (spr), summer (sum), and fall (fall); Pporxx is the xx-percent duration flow for the period-of-record (por); **7Qt**, 7-day, t-year or season low flow. All flows are in cubic feet per second (ft^3/s); *, multiply by; **BCF**, Bias correction factor (Duan's (1983) formula for ordinary-least-squares regression and Ferguson's formula for generalized-least-squares regression); **DA**, drainage area (square miles); **BS**, average basin slope (percent); **MxBE**, maximum basin elevation (foot); **ABT**, average mean annual basin temperature (degrees Fahrenheit); **SBT**, average mean summer basin temperature (degrees Fahrenheit); **C**, percent of basin containing coniferous trees (percent); **CD**, percent of basin containing mixed coniferous and deciduous trees (percent); **SGP**, average summer gage precipitation (inches); **WCP**, average winter basin centroid precipitation (inches); **SpGP**, average spring gage precipitation (inches); **R^2adj**, Coefficient of determination which explains the percentage of variation in the dependent variable; **Ser**, Average Standard Error of Estimate (McCuen, 1996); **Percent Ser**, Average Standard Error of Estimate, in percent of predicted value (Aitcheson and Brown, 1957); **APE**, Average Prediction Error of Model (G.D. Tasker, U.S. Geological Survey, written commun., 2002); **Percent APE**, Average Prediction Error, in percent of predicted value (Aitcheson and Brown, 1957); **APE plus and APE minus,** 68 percent probability that the true flow will be within these 2 percentages based on the predicted flow; 7Q2, 7-day, 2-year low-flow; 7Q10, 7-day, 10-year low-flow; --, no data]

Statistic	BCF	Regression equation	No. of stream-gaging stations	R^2adj	Ser		APE			
				Percent	Log 10 units	Percent	Log 10 units	Percent	Plus	Minus
		Flow Duration - Ordinary-least-squares regression equations--Continued								
Pfall80 =	1.03285	$* 10^{-1.43202} * (DA)^{0.94519} * (MxBE)^{0.4377} * (C)^{-0.16618}$	60	97.0	0.115	26.9	0.118	27.8	31.3	-23.9
Pfall90 =	1.04291	$* 10^{-1.90346} * (DA)^{0.95483} * (MxBE)^{0.54551} * (C)^{-0.21994}$	60	96.4	.130	30.5	.134	31.6	36.1	-26.5
Pfall95 =	1.06287	$* 10^{-2.34912} * (DA)^{0.98509} * (MxBE)^{0.63994} * (C)^{-0.26681}$	60	95.3	.156	37.0	.161	38.3	44.8	-30.9
Pfall98 =	1.10999	$* 10^{-2.93315} * (DA)^{1.02072} * (MxBE)^{0.76078} * (C)^{-0.29871}$	60	93.2	.201	48.8	.207	50.6	61.2	-38.0
Ppor60 =	1.01422	$* 10^{-3.53416} * (DA)^{1.08542} * (SGP)^{2.54435}$	59	98.6	.076	17.5	.077	18.0	19.5	-16.3
Ppor70 =	1.01800	$* 10^{-1.65947} * (DA)^{1.09815} * (ABT)^{-1.29046} * (SGP)^{2.59298}$	59	98.4	.086	19.9	.088	20.6	22.6	-18.4
Ppor80 =	1.03216	$* 10^{0.14014} * (DA)^{1.14248} * (ABT)^{-2.7358} * (SGP)^{2.83256}$	59	97.4	.115	27.0	.119	28.0	31.6	-24.0
Ppor90 =	1.05674	$* 10^{2.94244} * (DA)^{1.19434} * (ABT)^{-4.72162} * (SGP)^{2.92621}$	59	96.0	.153	36.3	.158	37.5	43.8	-30.4
Ppor95 =	1.07750	$* 10^{5.05371} * (DA)^{1.23203} * (ABT)^{-6.13047} * (SGP)^{2.89144}$	59	95.2	.177	42.6	.183	44.1	52.4	-34.4
Ppor98 =	1.11561	$* 10^{6.24458} * (DA)^{1.28081} * (ABT)^{-7.19399} * (SGP)^{3.13133}$	59	93.8	.214	52.4	.221	54.3	66.3	-39.9
		Low-Flow Frequency - Generalized-least-squares regression equations								
7Q2 win =	1.01469	$* 10^{-0.86255} * (DA)^{1.05538} * (C)^{-0.22494} * (WCP)^{0.88402}$	59	97.2	--	--	.074	17.2	18.6	-15.7
7Q10 win =	1.02279	$* 10^{-1.24495} * (DA)^{1.08506} * (C)^{-0.20848} * (WCP)^{0.9756}$	59	96.3	--	--	.092	21.5	23.7	-19.1
7Q2 spr =	1.01039	$* 10^{-0.93746} * (DA)^{1.04219} * (SpGP)^{0.93329} * (C)^{-0.12319}$	58	99.3	--	--	.062	14.5	15.5	-13.4
7Q10 spr =	1.01307	$* 10^{-1.35488} * (DA)^{1.06065} * (SpGP)^{1.08213} * (C)^{-0.12298}$	58	97.6	--	--	.070	16.2	17.5	-14.9
7Q2 sum =	1.14416	$* 10^{14.00639} * (DA)^{1.22668} * (SBT)^{-10.70843} * (SGP)^{2.88837}$	60	91.5	--	--	.225	55.6	68.0	-40.5
7Q10 sum =	1.27148	$* 10^{18.56974} * (DA)^{1.36816} * (SBT)^{-14.06792} * (SGP)^{3.55322}$	60	87.1	--	--	.301	78.5	100.0	-50.0
7Q2 fal =	1.02686	$* 10^{-1.3758} * (DA)^{0.96049} * (MxBE)^{0.39654} * (C)^{-0.12046}$	60	98.1	--	--	.100	23.3	25.9	-20.6
7Q10 fal =	1.06484	$* 10^{-2.55435} * (DA)^{0.97395} * (MxBE)^{0.68011} * (C)^{-0.22167}$	60	90.8	--	--	.154	36.6	42.5	-29.8
7Q2 yr =	1.14477	$* 10^{3.77893} * (DA)^{1.24597} * (ABT)^{-5.77815} * (SGP)^{3.39819}$	60	91.6	--	--	.226	55.7	68.2	-40.5
7Q10 yr =	1.27688	$* 10^{5.33462} * (DA)^{1.39481} * (ABT)^{-7.67405} * (SGP)^{4.16826}$	60	87.6	--	--	.304	79.4	101.2	-50.3

The adequacy of the determined regression equations in table 3 were measured using the following statistics:

1. The adjusted *R*-squared (R^2adj), also called the coefficient of determination, in which the percentage of variation in the dependent variable can be explained by the variation of the independent variables in the model and is adjusted for the number of parameters in the model (number of stream-gaging stations and number of independent variables in the regression analysis) (Freund and Littell, 2000);
2. The standard error of the estimate (*Ser*, in percent), is a measure of the average precision with which the regression equations estimate streamflow statistics for stream-gaging stations used to develop regression equations (Ries and Friesz, 2000). The standard error of estimate is a measure of the deviation of the observed data from the corresponding predictive data values and is similar to standard deviation for a normal distribution. Approximately 68 percent of the observed data should be contained within ±one standard error of the regression line; and
3. The Average Prediction Error (APE), which is an overall measure of how accurately the regression model can predict streamflow statistics for ungaged sites where the average is taken from prediction sites with *X* variables identical to the observed data. Average Prediction Error represents an estimate of the average squared-model error for the *n* sites plus an estimate of the average squared error as a result of estimating the true model parameters from a sample of data.

The number of stream-gaging stations used in the regression analysis ranged from 58 to 60. The values of adjusted R^2 for each regression equation in the seasonal ($Pwin_{xx}$, $Pspr_{xx}$, $Psum_{xx}$, and $Pfal_{xx}$,) and period-of-record flow-duration ($Ppor_{xx}$) equations ranged from 92.7 to 99.4 percent (table 3). The adjusted *R*-squared for the seasonal and annual low-flow equations (7Q2, 7Q10) ranged from 87.1 to 99.3 percent (table 3). In some instances, stream-gaging stations were removed from the analyses as there were outliers that affected the fit of the regression line. Stations for those statistics with studentized residuals that were greater than an absolute value of 3.0 were removed from the analyses as studentized residuals of this magnitude rarely occur by chance alone (Cavalieri and others, 2000). The stations that were removed for selected low-flow and flow-duration statistics were station reference numbers 12 and 16 (table 1; Dudley Brook in Exeter, N.H., and Stevens Brook in Wentworth, N.H., respectively).

The GLS method allows the weight given to each site in the regression analyses to be adjusted for cross correlation among the concurrent streamflows of the sites and for differences in record lengths. For GLS regression, the variance of the errors for an observation is estimated as a function of the error in the regression model and the error in the estimate of the true value of the observed streamflow statistic. The error in the observed streamflow statistic is estimated as a function of the record length, variance of the annual events, and cross correlation between observations. As a result, it would be inappropriate to use the equally weighted residuals in a GLS regression to calculate a measure of predictive accuracy (G.D. Tasker, written commun., 2001). Instead, the APE is used as a measure of the predictive accuracy of the GLS and OLS regression equations in table 3.

The *Ser* was determined for the seasonal and period-of-record flow-duration regression equations by use of the following equation used by McCuen and others (1996):

$$Ser = [Sum(\log(Y_{pg}) - \log(Q_{pg}))^2 / \; n - q]^{0.5} , \quad (6)$$

where

Y_{pg} is the predicted discharge from the regression equation,

Q_{pg} is the observed discharge (estimated flow statistic),

n is the number of stream-gaging stations used to develop the regression equation, and

q is the number of regression coefficients.

The APE of the regression model is a measure of how well the regression equations will estimate flows when applied to ungaged drainage basins. The APE also can be used as an approximate standard error of prediction for individual sites. The probability that the true value of a duration or low flow at a site is between the positive percent, APE plus, and the negative percent, APE minus (table 3), is 68 percent. For example, in table 3, there is a 68-percent probability that the actual annual 7Q2 low flow at an ungaged site is between

+68.2 and –40.5 percent of the computed annual 7Q2 low flow. The APE was determined for the GLS-determined seasonal and annual low-flow-frequency regression equations by taking the square root of the sum of the average squared-model error for the *n* sites and the average squared-model error as a result of estimating true model parameters from a sample of data. The APE was calculated for the OLS-determined seasonal period-of-record and period-of-record flow-durations regression equations by use of the following equation (G.D. Tasker, written commun., 2001):

$$APE = [(Ser)^2(1 + (p/\ n))]^{0.5}, \qquad (7)$$

where

- *Ser* is the standard error of the estimate as determined in equation 6,
- *p* is the number of parameters estimated (1 + number of independent variables in the regression equation), and
- *n* is the number of stream-gaging stations used to develop the regression equation.

Various BCFs have been proposed to correct the problem of bias in retransformed logarithmic equations. Duan’s smearing estimate (Duan, 1983) was used as the BCF for the seasonal and period-of-record duration equations in this study by replacing the error term, E_g, in equation 4, with the mean error of the retransformed residuals. This BCF does not require normally distributed regression residuals (Ries and Friesz, 2000). As a result of the equal weighting of the residual errors in the GLS regression, the BCFs for the seasonal and annual low-flow-frequency statistics could not be determined using Duan’s smearing estimate (G.D. Tasker, oral commun., 2001). The BCFs for the seasonal and annual low-flow-frequency statistics were determined using the Ferguson formula in which the error term in equation 4 was replaced by the value of $exp^{(.5*(S^2)*5.302)}$, where *S* is the prediction error in log 10 units (Helsel and Hirsch, 2000).

Prediction Interval

Prediction intervals indicate the uncertainty associated with the use of the regression equations and can be calculated at any percent-confidence level for estimates obtained from the regression equations. The following equations illustrate the calculations necessary to determine the *n*-percent prediction interval. This interval is an assurance of *n*-percent that the true value of the streamflow statistic for an ungaged site will be within the prediction interval. The 100 (1-alpha) prediction interval for the true value of a streamflow statistic obtained for an ungaged site, and corrected for bias, can be obtained by use of the following equation (Tasker and Driver, 1988):

$$/\ T(Q/\ BCF) < Q < T(Q/\ BCF, \qquad (8)$$

where

- *Q* is the streamflow statistic for the site, and
- *BCF* is the bias correction factor for the equation.

T is computed in equation 8 as:

$$T = 10^{[t(alpha/\ 2,\ n-p)Si]}, \qquad (9)$$

where

- $t_{(alpha/2,n-p)}$ is the critical value from the student’s *t*-distribution at a particular *alpha* level divided by 2. This value may be obtained in many statistics textbooks; *Alpha* equals 0.05 for a 95-percent prediction interval; therefore, *alpha* divided by 2 equals 0.025;
- *n* is the degrees of freedom with *n* stream-gaging stations used in the regression analysis;
- *p* is the parameters in the equation, where *p* is the number of basin characteristics plus one; and
- S_i is the standard error of prediction and is computed from the following equation:

$$S_i = [ModelErrorVariance + X_i U X_i']^{0.5} , \quad (10)$$

where

X_i is a row vector for the study site, *i*, containing a one and the logarithm base 10 of the basin characteristics used in the regression equation (table 3). For example, for the period-of-record 70-, 80-, 90-, 95-, and 98-percent duration, the row vector, X_i, would be determined using the values of 1, $\log_{10}(DA)$, $\log_{10}(ABT)$, and $\log_{10}(SGP)$;

U is the covariance matrix for the seasonal and annual regression coefficients; and

X_i' is the matrix algebra transpose of X_i (Ludwig and Tasker, 1993 and Ries and Friesz, 2000). The values of *BCF*, $t_{(alpha/2,n-p)}$, Model Error Variance and *U* needed to determine the 90- and 95-percent prediction intervals for the regression-equation estimates are presented in table 4 (back of report).

Computation Example

The following example illustrates the calculations necessary to determine the 90- and 95-percent prediction intervals for the period-of-record 90-percent-duration low flow (*Ppor90*) for the Oyster River stream-gaging station in Durham, N.H. (station number 01073000; reference number 11, figs. 1 and 2). The prediction intervals are an assurance of 90 and 95 percent, respectively, that the true value of the streamflow statistic for an ungaged site will be within the calculated prediction interval for the *Ppor90* (period-of-record 90-percent duration low flow). Values for the drainage area, annual basinwide average temperature, and summer gage precipitation are 12.2 mi^2, 46.8 degrees Fahrenheit, and 16.9 in., respectively. Substituting these values into equation 11 to predict the annual *Ppor90* (90-percent duration low flow) yields

$$Ppor90 = 1.057(10)^{2.942}(12.2)^{1.194}(46.8)^{-4.722}(16.9)^{2.926}, \; and \; Ppor90 = 0.93 ft^3/s \quad (11)$$

The X_i vector for the *Ppor90* (period-of-record 90-percent duration low flow) determination of the prediction interval is shown in the following equation:

$$X_i = \{1, \log 10(12.21), \log 10(46.785), \log 10(16.89)\} \quad (12)$$

The regression model-error variance (γ^2) for the *Ppor90* (period-of-record 90-percent-duration low flow) from table 4 (back of report) is 0.023303 and the covariance matrix, *U*, for the *Ppor90* is

7.716369611	-0.075018343	-2.99107807	-2.154006464
-0.075018343	0.001780933	0.026410295	0.023009859
-2.99107807	0.026410295	1.25772585	0.712752485
-2.154006464	0.023009859	0.712752485	0.755032635

Using matrix algebra, the product of $X_i U X_i'$ is obtained by multiplying the transpose of X_i (X_i') by the matrices of the covariance matrix (*U*) and X_i. In this example, the value of $X_i U X_i'$ is 0.00188156.

The standard error of prediction computed from equation 10 is

$$S_i = [0.023303 + 0.00188156]^{0.5} = 0.158696 ,$$

and *T* from equation 9 is

$$T = 10^{(2.005)(0.158696)} = 2.0806 ,$$

where the critical value from the student's *t*-distribution for the 95-percent prediction interval is

$t_{(alpha/2,n-p)}$ is 2.005 (table 4, back of report); and

S_i is 0.158696.

The 95-percent prediction interval can now be determined by use of equation 8 as

$$1/2.0806)*(0.93/1.0567) < Ppor90 < (0.93/1.0567)*(2.0806) \; or \; 0.423 < Ppor90 < 1.83 .$$

Furthermore, the 90-percent prediction interval would be calculated as

$$T = 10^{(1.674)(0.158696)} = 1.8435,$$

where the critical value from the student's *t*-distribution for the 90-percent prediction interval

$t_{(alpha/2,n-p)}$ is 1.674 (table 4, back of report); and

S_i is 0.158696.

The 90-percent prediction interval can now be determined by use of equation 8 as

$$/ \ 1.8435)*(0.93/ \ 1.0567) < Ppor90 < (0.93/ \ 1.0567)* (1.8435) \ \ or \ \ 0.477 < Ppor90 < 1.62 \ .$$

The regression-equation estimate of the *Ppor90* (period-of-record 90-percent-duration low flow) for the Oyster River stream-gaging station in Durham, N.H. (station number 01073000; reference number 11, figs. 1 and 2), is 0.93 ft^3/s. From these calculations of prediction intervals, there is a 95-percent probability that the true value of the *Ppor90* is between 0.423 and 1.83 ft^3/s and a 90-percent probability that the true value of *Ppor90* is between 0.477 and 1.62 ft^3/s.

PHYSICAL BASIS FOR REGRESSION RELATIONS

Recharge to a drainage basin is primarily a function of precipitation, whereas storage, and discharge from the basin are controlled primarily by the physical characteristics of the basin (Hayes, 1991). Ground-water discharge maintains streams during periods of base flow and low-flow conditions. These streams are commonly referred to as gaining streams. The influence of the basin and climatological characteristics on ground-water discharge to a stream can be investigated with regression analysis of the streamflow data. Some of the primary basin and climatological characteristics that affect low-flow characteristics are drainage area, slope, land use, and precipitation. Low-flow discharge values generally increase with increasing drainage-basin size; however, topography, geology, and climate have a strong influence on low flows such that minor differences in basin characteristics may cause substantial differences in low-flow discharge (Hayes, 1991). Low-flow characteristics typically relate to drainage basin size better than any other basin or climatological characteristic when a basin is homogeneous with respect to topography, geology, and climate (Hayes, 1991). Drainage area is physically related to the magnitude of low-flow quantiles in the humid region of New Hampshire and Vermont where most streams are gaining streams and large basins generally have greater storage and natural flow regulation (Dingman and Lawlor, 1995).

The percent of the drainage basin with coniferous trees and the percent of the basin with mixed coniferous and deciduous trees were statistically significant basin characteristics in this study. These two drainage-basin characteristics reflect the effect of interception, evapotranspiration, infiltration, and runoff rates on seasonal and annual low flow and are inversely related to flow. The statistical significance of these two basin characteristics supports the concept that evapotranspiration and interception reduce low flows by capturing ground water that would have otherwise discharged to streams (Dunne and Leopold, 1978). Evapotranspiration results in a major loss of water from drainage basins. It dominates the water balance and controls soil moisture content, ground-water recharge, and streamflow. More than two-thirds of the precipitation falling on the conterminous United States is returned to the atmosphere through evaporation from plants and free-water surfaces (Dunne and Leopold, 1978). According to Dunne and Leopold (1978), coniferous trees intercept slightly more rainfall than deciduous trees because coniferous trees have greater masses of foliage and branches throughout the year than deciduous trees, and because their needles can hold more interception storage than broad leaves. Over the long term, canopy interception was determined to be greater under conifers than under broad-leaf hardwoods. Dunne and Leopold (1978) presumed that this is a result of the high density of conifers in New Hampshire and possibly because of more frequent occurrence of light rains and snows, which are more fully intercepted in coniferous forests.

For the winter (January 1–March 15) period-of-record flow durations and winter low-flow-frequency statistics, the basin characteristics of average winter basin-centroid precipitation, percent of basin containing coniferous trees, and drainage area were statistically significant. From November or December through March, flows generally decrease as a result of the accumulation and storage of precipitation within the snowpack (Hammond and Cotton, 1985). The regression results, however, suggest that precipitation has a direct relation and strong influence on low flows even during the winter, which may include snowpack, as precipitation is a measure of water available to become runoff. In addition, precipitation was highly correlated with drainage-basin elevation (Dingman, 1981) in New Hampshire. Because of this relation, much of the variability in low flow between basins can be explained by differences in either precipitation or elevation, as both are representative of water input or availability in the basin.

The basin characteristic of average drainage-basin slope was statistically significant for the spring (March 16–May 31) period-of-record flow durations, along with the basin characteristics of percent of basin containing mixed coniferous and deciduous trees and drainage-basin area. In addition, the basin characteristics of average spring-gage precipitation, percent of basin containing coniferous trees, and drainage-basin area, were statistically significant for the spring low-flow-frequency statistics. Basin slope is related to several factors that influence low flow. Generally, the steeper the basin slope, the less overburden is available to store precipitation. Runoff is more rapid and there is less time for infiltration (Hayes, 1991). Runoff varies seasonally and geographically. The high spring flows occurring during March, April and May are a result of the melting snowpack and concurrent precipitation. In general, flows are greatest in March and April in the streams in southern New Hampshire and are greatest in April and May in the streams in central and northern New Hampshire (Hammond and Cotton, 1985). The physical explanation for the regression relation appears to be that average basin slope has a direct relation and strong influence on spring flow durations as this basin characteristic is related to infiltration and runoff. Spring precipitation has a direct relation and strong influence on spring low flows and it is an index of water availability.

For the summer (June 1–October 31) period-of-record flow durations and summer low-flow-frequency statistics, the basin characteristics of average mean-summer-basin temperature, average summer-gage precipitation, drainage area, and percent coniferous trees (for the 60- and 70-percent duration exceedences) were statistically significant. In New Hampshire and Vermont, the climatic characteristic of basin temperature reflects, to a large degree, the basin elevation. Average basin temperature affects the rate of evaporation in a particular basin and is inversely related to flow. For the summer growing season, water requirements for transpiration increase dramatically and warm temperatures increase evaporation from free-water surfaces. Summer precipitation has a direct relation and strong effect on summer low flows and is an index of water availability. Precipitation during the summer recharges soil moisture and replaces water evaporated from the surfaces of ponds and lakes. Streamflow decreases progressively from June through August and as the transpiration decreases during September, streamflow increases once again (Hammond and Cotton, 1985).

For the fall (November 1–December 31) period-of-record flow durations and fall low-flow-frequency statistics, maximum basin elevation, drainage area, and percent of the drainage basin containing coniferous trees were found to be statistically significant. In the fall, following the first killing frost, growth of vegetation ceases, which greatly reduces the demands on soil moisture and more water is available for runoff or ground-water recharge (Hammond and Cotton, 1985). Maximum basin elevation appears to affect low flow as precipitation and streamflow are highly correlated with basin elevation; therefore, drainage-basin elevation serves as a measure of water available to become runoff. A previous study in New Hampshire found strong relations between various streamflows, including low flows, and drainage-basin elevation (Dingman, 1981). Dingman and Lawlor (1995) found that there is less flow variability (relatively high low flows) at high elevations, which is thought to be the result of large and more frequent precipitation inputs at high elevations.

For the period-of-record flow durations and annual low-flow-frequency statistics, the basin characteristics of average mean-annual basin temperature (degrees Fahrenheit), drainage area, and average summer-gage precipitation were found to be statistically significant. These characteristics are similar to the basin characteristics found to be significant for the summer period-of-record flow durations and low-flow-frequency statistics. The summer period, as defined in this report, is 5 months long and begins on June 1. In New Hampshire and Vermont, average mean-annual basin temperature reflects the basin elevation and affects the rate of evaporation in a particular basin. Average mean-annual basin temperature is inversely related to flow. Average summer-gage precipitation has a direct relation and strong effect on annual low-flows and period-of-record flow durations and is an index of water availability.

A previous study in New Hampshire (Dingman, 1978) found that the period-of-record flow duration for the 95-percent exceedence was related to drainage area and mean basin elevation. The mean basin elevation in Dingman's study was determined for 53 basins in New Hampshire using an empirical equation developed from area-elevation curves prepared for 29 New Hampshire basins. The importance of elevation as an influence on low-flow rates is explained by Dingman (1978) as being the result of low temperatures and evapotranspiration rates, as well as greater and long-lasting snowpack at high elevations. These factors hold moisture in the drainage basin and result in a more even streamflow throughout the year. Dingman (1978) found that the average location of the mean basin elevation was 0.324 of the distance between the minimum and maximum basin elevation. For this report, mean basin elevation as determined from DEMs within a GIS, was not statistically significant for use as an independent variable in the regression equations developed for the 60 drainage basins. Dingman and Lawlor (1995) found that the annual 7Q10, for 46 gages in New Hampshire and Vermont, is related to drainage area, mean basin elevation, and fraction of basin covered with coarse-grained stratified drift in contact with streams. In that study, Dingman and Lawlor derived the independent variable of fraction of basin covered with coarse-grained stratified drift in contact with streams from ground-water-availability maps published at a scale of 1:126,720 by the USGS and the Vermont Department of Water for Vermont (Hodges, 1967a, b, c and d; and 1968a, b, c and d) and by the USGS for New Hampshire at a scale of 1:125,000 (Cotton, 1974, 1975, 1976a and b; and 1977a, b and c). For this report, the independent variable of fraction of basin covered with coarse-grained stratified drift in contact with streams was determined from digitized GIS coverages of the same ground-water availability maps for New Hampshire used by Dingman and Lawlor (1995), which were published at a scale of 1:125,000 by Cotton (1974, 1975, 1976a and b; and 1977a, b and c). The digitized sand- and gravel-deposit coverages for Vermont used for this report, however, were based upon the Sand and Gravel Resource maps as digitized by the VNR. This dataset was compiled in 1993 by the VNR and is available on the VtGIS web site (Vermont Geographic Information System, 2000). The Sand and Gravel Resource maps are based upon USGS, surficial geology, and environmental geology studies. In addition, sand- and gravel-deposit coverages were obtained for the stations in Maine (Maine Office of Geographic Information System, 2000) and Massachusetts (Massachusetts Geographic Information System, 2000). For this report, fraction of basin covered with coarse-grained stratified drift in contact with streams was determined within a GIS and was not statistically significant as a variable to be used in the equations. Differences between the Vermont sand and gravel coverages of 1967 and 1968, and the Vermont sand and gravel deposit coverage of 1993, may explain why this variable was not statistically significant in this study.

The percent difference between the streamflow statistics and the predicted values (in Appendixes 2-7) was determined to assess if there was an apparent physical reason (for example, the prolonged drought of the 1960s) for the large percent differences (prediction errors) at individual stream-gaging stations. No physical reason was apparent in order to differentiate model error from sampling error for the seasonal, annual, or period-of-record regression equations. The prediction error, or variance of prediction, for an ungaged site is the sum of the model error and the sampling error. Some combinations of basin characteristics are better than others at explaining the variation in the regression equations for each statistic, which is apparent in the equation results. For each statistic, there was no specific region of stream-gaging stations with a large percent-prediction error, nor was there a specific season or seasons (as compared to other seasons for each station) with a large percent-prediction error. No station had a large percent-prediction error for all seasons and annual period or period-of-record.

LIMITATIONS ON THE USE OF REGRESSION EQUATIONS

Use of the regression equations presented in this report is limited in determining low-flow-frequency and flow-durations statistics by the range of the basin-characteristic data used to develop the equations and by the accuracy of the estimates. These equations should be used with caution for the determination of streamflow statistics at ungaged sites for which the basin characteristics are outside the range of those used to develop the regression equations. The ranges of the basin-characteristic data used to develop the flow-duration and low-flow-regression equations can be found in table 5, and the accuracy of the estimates when basin characteristics are within the ranges of those sites used in the regression analysis can be found in table 3. The use of these regression equations requires that the physical and climatic basin characteristics be determined within a GIS using the same datasets (Appendix 1) that were used to develop the equations outlined in this report.

A GIS application is being developed (2002) that will provide streamflow statistics from a database for stream-gaging stations and for ungaged sites. The necessary basin characteristics for a user-selected site will be determined from digital map data by use of ArcView GIS (Environmental Systems Research Institute, Inc., 1996) to solve the regression equations. The output will include a map of the drainage-basin boundary determined for the site, the values of the GIS-measured basin characteristics, the estimated streamflow statistics, and prediction intervals for the estimates. This GIS application is based on a similar application that was developed for the State of Massachusetts by the USGS, MassGIS, and Syncline, Inc. (Ries and others, 2000).

Table 5. Ranges of basin characteristics used to develop the flow duration and low-flow-frequency regression equations for New Hampshire streams

[PRISM, Parameter-elevation regressions on independent slopes model dataset; NLCD, National Land Cover Dataset]

Basin characteristic	Basin characteristic abbreviation	Minimum	Mean	Maximum
Drainage area (square miles)	DA	3.26	97.2	689
Average basin slope (percent)	BS	3.19	16.5	38.1
Maximum basin elevation (feet)	MxBE	260	3,120	6,290
Average summer gage precipitation (inches; PRISM)	SGP	16.5	18.7	23.1
Average spring gage precipitation (inches; PRISM)	SpGP	6.83	8.85	11.5
Average winter basin centroid precipitation (inches; PRISM)	WCP	5.79	7.96	15.1
Average mean annual basin temperature (degrees Fahrenheit) (PRISM)	ABT	36.0	42.3	48.7
Average mean summer basin temperature (degrees Fahrenheit) (PRISM)	SBT	52.9	58.7	64.4
Percent coniferous (percent; NLCD)	C	3.07	20.9	56.2
Percent mixed coniferous/deciduous (percent; NLCD)	CD	6.21	26.6	46.1

SUMMARY AND CONCLUSIONS

In cooperation with the New Hampshire Department of Environmental Services, the U.S. Geological Survey has developed datasets, hydrologic statistical relations, and a geographic information system (GIS) of data coverages for the entire State of New Hampshire. These streamflow datasets will aid in the management of water resources in a sustainable manner for the benefit of water users and the environment. This report describes methods used to determine streamflow and drainage-basin characteristics and statistical-prediction relations used in the estimation of seasonal and annual low-flow-frequency statistics and seasonal period-of-record and period-of-record duration quantiles for any gaged or ungaged stream in New Hampshire. These data also can be used to assess regional hydrologic conditions for administering New Hampshire water-resource programs.

Regression equations were developed to estimate the seasonal and annual 7-day 2-year (7Q2) and 7-day 10-year (7Q10) low-flow-frequency values, as well as seasonal and period-of-record flow durations for the 60-, 70-, 80-, 90-, 95-, and 98-percent exceedences for New Hampshire streams. Seasonal and annual low-flow frequency and period-of-record and seasonal period-of-record flow-duration characteristics were determined using from 58 to 60 continuous-record stream-gaging stations in New Hampshire and its neighboring States. Streamflow statistics and physical and climatic basin characteristics are presented in the report. All climatic and physical basin characteristics were determined from digital databases using GIS computer software.

The regression equations for determining the period-of-record and seasonal period-of-record flow durations for the 60-, 70-, 80-, 90-, 95-, and 98-percent exceedences were developed using ordinary-least-squares regression. Generalized-least-squares regression was used to develop the regression equations for the seasonal and annual 7Q10 and 7Q2 low flow. Standard errors of prediction ranged from 11 to 61 percent for the seasonal and period-of-record streamflow-duration quantiles. Standard errors of prediction ranged from 14 to 79 percent for the seasonal and annual low-flow-frequency statistics. The proportion of variation in the dependent variables that is explained by the independent variables (R^2adj) in the seasonal and period-of-record flow-duration equations ranged from 92.7 to 99.4 percent. The proportion of the variation in the dependent variable, which can be explained by the independent variables in the seasonal and annual low-flow equations (7Q2, 7Q10) ranged from 87.6 to 99.3 percent.

The equations developed for this study are not applicable for ungaged sites in which the basin characteristics are outside of the range of those used to develop the regression equations. If the equations are used to estimate streamflow statistics on a stream that has regulation, diversion, or augmentation of streamflow, then the user would need to adjust the estimates from these regression equations as required. To determine the regression-equation independent variables in this study, a GIS is required to measure the value of the variables.

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Table 4. Values required to determine the 90- and 95-percent prediction intervals for estimates obtained from regression equations using covariance matrices

[**Statistic**, **Pwinxx, Psprxx, Psumxx, Pfallxx** are the xx-percent duration flow for winter (win), spring (spr), summer (sum), and fall (fall); **Pporxx** is the xx-percent duration flow for the period-of-record (por); yr, year; **BCF**, Bias correction factor; **t90 and t95**, Critical value from the students t distribution for the 90- and 95-percent probability, respectively; γ^2, Regression model-error variance; **INTERCEPT**, y-axis intercept of regression equation; **DA**, drainage area (square miles); **C**, percent of basin containing coniferous trees (percent); **WCP**, average winter basin-centroid precipitation (inches); **BS**, average basin slope (percent); **CD**, percent of basin containing mixed coniferous and deciduous trees (percent); **SBT**, average mean summer basin temperature (degrees Fahrenheit); **SGP**, average summer gage precipitation (inches); **MxBE**, maximum basin elevation (foot); **ABT**, average mean annual basin temperature (degrees Fahrenheit); **SpGP**, average spring gage precipitation (inches); **7Qt**, 7-day, t-year or season low flow; --, no data]

Dependent variable	Prediction intervals			γ^2	Covariance matrix					
	BCF	t90	t95							
Pwin60	1.019354	1.6736	2.0042	0.007766		**INTERCEPT**	**DA**	**C**	**WCP**	
					INTERCEPT	0.021668437	-0.001318983	-0.00000542	-0.021723454	--
					DA	-0.001318983	0.000410263	-0.000371176	0.001261232	--
					C	-0.00000542	-0.000371176	0.003082219	-0.003689319	--
					WCP	-0.021723454	0.001261232	-0.003689319	0.027267918	--
Pwin70	1.018236	1.6736	2.0042	.007405		**INTERCEPT**	**DA**	**C**	**WCP**	
					INTERCEPT	0.020661551	-0.001257693	-0.00000517	-0.020714013	--
					DA	-0.001257693	0.000391199	-0.000353929	0.001202625	--
					C	-0.00000517	-0.000353929	0.002938995	-0.003517884	--
					WCP	-0.020714013	0.001202625	-0.003517884	0.026000837	--
Pwin80	1.014313	1.6743	2.0053	.005781		**INTERCEPT**	**DA**	**C**	**WCP**	
					INTERCEPT	0.016175026	-0.001004499	2.11897E-05	-0.016206276	--
					DA	-0.001004499	0.000316558	-0.000288698	0.000956737	--
					C	2.11897E-05	-0.000288698	0.002308028	-0.002766059	--
					WCP	-0.016206276	0.000956737	-0.002766059	0.020325627	--
Pwin90	1.016307	1.6743	2.0053	.00645		**INTERCEPT**	**DA**	**C**	**WCP**	
					INTERCEPT	0.018046596	-0.001120727	2.36415E-05	-0.018081462	--
					DA	-0.001120727	0.000353187	-0.000322102	0.001067439	--
					C	2.36415E-05	-0.000322102	0.002575084	-0.003086113	--
					WCP	-0.018081462	0.001067439	-0.003086113	0.022677452	--
Pwin95	1.019421	1.6749	2.0063	0.007448		**INTERCEPT**	**DA**	**C**	**WCP**	
					INTERCEPT	0.021887616	-0.001537871	0.000536894	-0.022273048	--
					DA	-0.001537871	0.000464481	-0.000490376	0.001556559	--
					C	0.000536894	-0.000490376	0.003221138	-0.004240935	--
					WCP	-0.022273048	0.001556559	-0.004240935	0.028038938	--

Table 4. Values required to determine the 90- and 95-percent prediction intervals for estimates obtained from regression equations using covariance matrices--Continued

[**Statistic**, **Pwinxx, Psprxx, Psumxx, Pfallxx** are the xx-percent duration flow for winter (win), spring (spr), summer (sum), and fall (fall); **Pporxx** is the xx-percent duration flow for the period-of-record (por); yr, year; **BCF**, Bias correction factor; **t90 and t95**, Critical value from the students t distribution for the 90- and 95-percent probability, respectively; γ^2, Regression model-error variance; **INTERCEPT**, y-axis intercept of regression equation; **DA**, drainage area (square miles); **C**, percent of basin containing coniferous trees (percent); **WCP**, average winter basin-centroid precipitation (inches); **BS**, average basin slope (percent); **CD**, percent of basin containing mixed coniferous and deciduous trees (percent); **SBT**, average mean summer basin temperature (degrees Fahrenheit); **SGP**, average summer gage precipitation (inches); **MxBE**, maximum basin elevation (foot); **ABT**, average mean annual basin temperature (degrees Fahrenheit); **SpGP**, average spring gage precipitation (inches); **7Qt**, 7-day, t-year or season low flow; --, no data]

Dependent variable	Prediction intervals			γ^2	Covariance matrix					
	BCF	t90	t95							
Pwin98	1.032644	1.6749	2.0063	.01251		**INTERCEPT**	**DA**	**C**	**WCP**	
					INTERCEPT	0.036764723	-0.002583168	0.000901824	-0.037412134	--
					DA	-0.002583168	0.000780191	-0.000823686	0.002614559	--
					C	0.000901824	-0.000823686	0.005410559	-0.007123516	--
					WCP	-0.037412134	0.002614559	-0.007123516	0.047097124	--
Pspr60	1.006795	1.6743	2.0053	.002661		**INTERCEPT**	**DA**	**BS**		
					INTERCEPT	0.001913132	-0.000144612	-0.001377297	--	--
					DA	-0.000144612	0.00012868	-0.000056948	--	--
					BS	-0.001377297	-0.000056948	0.001243766	--	--
Pspr70	1.00596	1.6743	2.0053	.002333		**INTERCEPT**	**DA**	**BS**		
					INTERCEPT	0.00167709	-0.00012677	-0.001207367	--	--
					DA	-0.00012677	0.000112804	-0.000049922	--	--
					BS	-0.001207367	-0.000049922	0.001090311	--	--
Pspr80	1.006677	1.6749	2.0063	.002679		**INTERCEPT**	**DA**	**BS**	**CD**	
					INTERCEPT	0.004885049	2.16E-06	-0.00140168	-0.002282139	--
					DA	2.16E-06	0.000136941	-0.000058085	-0.00011397	--
					BS	-0.00140168	-0.000058085	0.001252364	1.15E-05	--
					CD	-0.002282139	-0.00011397	1.15E-05	0.001760221	--
Pspr90	1.008106	1.6749	2.0063	.003269		**INTERCEPT**	**DA**	**BS**	**CD**	
					INTERCEPT	0.005961107	2.64E-06	-0.001710436	-0.002784839	--
					DA	2.64E-06	0.000167106	-0.000070879	-0.000139074	--
					BS	-0.001710436	-0.000070879	0.001528229	1.41E-05	--
					CD	-0.002784839	-0.000139074	1.41E-05	0.002147955	--
Pspr95	1.009355	1.6749	2.0063	0.003833		**INTERCEPT**	**DA**	**BS**	**CD**	
					INTERCEPT	0.006989577	3.09E-06	-0.002005538	-0.003265307	--
					DA	3.09E-06	0.000195937	-0.000083108	-0.000163069	--
					BS	-0.002005538	-0.000083108	0.001791895	1.65E-05	--
					CD	-0.003265307	-0.000163069	1.65E-05	0.002518542	--

Table 4. Values required to determine the 90- and 95-percent prediction intervals for estimates obtained from regression equations using covariance matrices--Continued

[**Statistic**, **Pwinxx, Psprxx, Psumxx, Pfallxx** are the xx-percent duration flow for winter (win), spring (spr), summer (sum), and fall (fall); **Pporxx** is the xx-percent duration flow for the period-of-record (por); yr, year; **BCF**, Bias correction factor; **t90 and t95**, Critical value from the students t distribution for the 90- and 95-percent probability, respectively; γ^2, Regression model-error variance; **INTERCEPT**, y-axis intercept of regression equation; **DA**, drainage area (square miles); **C**, percent of basin containing coniferous trees (percent); **WCP**, average winter basin-centroid precipitation (inches); **BS**, average basin slope (percent); **CD**, percent of basin containing mixed coniferous and deciduous trees (percent); **SBT**, average mean summer basin temperature (degrees Fahrenheit); **SGP**, average summer gage precipitation (inches); **MxBE**, maximum basin elevation (foot); **ABT**, average mean annual basin temperature (degrees Fahrenheit); **SpGP**, average spring gage precipitation (inches); **7Qt**, 7-day, t-year or season low flow; --, no data]

Dependent variable	Prediction intervals			γ^2	Covariance matrix					
	BCF	t90	t95							
Pspr98	1.013731	1.6749	2.0063	.005676		**INTERCEPT**	**DA**	**CD**	**BS**	
					INTERCEPT	0.010349195	4.57E-06	-0.004834814	-0.002969522	--
					DA	4.57E-06	0.000290116	-0.00024145	-0.000123055	--
					CD	-0.004834814	-0.00024145	0.003729108	2.44E-05	--
					BS	-0.002969522	-0.000123055	2.44E-05	0.002653189	--
Psum60	1.051006	1.6743	2.0053	.021971		**INTERCEPT**	**DA**	**SBT**	**SGP**	**C**
					INTERCEPT	19.58794597	-0.115067517	-8.403905645	-3.482808145	-0.09728
					DA	-0.115067517	0.00176186	0.045801696	0.024934213	-0.00032
					SBT	-8.403905645	0.045801696	3.710973281	1.347015163	0.046829
					SGP	-3.482808145	0.024934213	1.347015163	0.832522923	0.003406
					C	-0.097277109	-0.000318047	0.04682937	0.003406156	0.008436
Psum70	1.060393	1.6743	2.0053	.02566		**INTERCEPT**	**DA**	**SBT**	**SGP**	**C**
					INTERCEPT	22.87705814	-0.134389092	-9.815048414	-4.06762427	-0.11361
					DA	-0.134389092	0.002057703	0.053492493	0.029121044	-0.00037
					SBT	-9.815048414	0.053492493	4.33410178	1.573199367	0.054693
					SGP	-4.06762427	0.029121044	1.573199367	0.972316104	0.003978
					C	-0.113611406	-0.000371452	0.054692729	0.003978101	0.009853
Psum80	1.075425	1.6736	2.0042	.031898		**INTERCEPT**	**DA**	**SBT**	**SGP**	
					INTERCEPT	26.80982005	-0.172382465	-11.41705975	-4.999413465	--
					DA	-0.172382465	0.002540508	0.069059284	0.036386595	--
					SBT	-11.41705975	0.069059284	5.010292749	1.928182757	--
					SGP	-4.999413465	0.036386595	1.928182757	1.206682671	--
Psum90	1.098157	1.6736	2.0042	0.040443		**INTERCEPT**	**DA**	**SBT**	**SGP**	
					INTERCEPT	33.99191053	-0.218562053	-14.4755792	-6.338707791	--
					DA	-0.218562053	0.003221086	0.087559595	0.046134211	--
					SBT	-14.4755792	0.087559595	6.35250153	2.444724196	--
					SGP	-6.338707791	0.046134211	2.444724196	1.529941243	--

Table 4. Values required to determine the 90- and 95-percent prediction intervals for estimates obtained from regression equations using covariance matrices--Continued

[**Statistic**, **Pwinxx, Psprxx, Psumxx, Pfallxx** are the xx-percent duration flow for winter (win), spring (spr), summer (sum), and fall (fall); **Pporxx** is the xx-percent duration flow for the period-of-record (por); yr, year; **BCF**, Bias correction factor; **t90 and t95**, Critical value from the students t distribution for the 90- and 95-percent probability, respectively; γ^2, Regression model-error variance; **INTERCEPT**, y-axis intercept of regression equation; **DA**, drainage area (square miles); **C**, percent of basin containing coniferous trees (percent); **WCP**, average winter basin-centroid precipitation (inches); **BS**, average basin slope (percent); **CD**, percent of basin containing mixed coniferous and deciduous trees (percent); **SBT**, average mean summer basin temperature (degrees Fahrenheit); **SGP**, average summer gage precipitation (inches); **MxBE**, maximum basin elevation (foot); **ABT**, average mean annual basin temperature (degrees Fahrenheit); **SpGP**, average spring gage precipitation (inches); **7Qt**, 7-day, t-year or season low flow; --, no data]

Dependent variable	Prediction intervals			γ^2	Covariance matrix					
	BCF	t90	t95							
Psum95	1.124327	1.6736	2.0042	.049707		**INTERCEPT**	**DA**	**SBT**	**SGP**	
					INTERCEPT	41.77809791	-0.268625879	-17.79135553	-7.790652264	--
					DA	-0.268625879	0.003958908	0.107615997	0.056701714	--
					SBT	-17.79135553	0.107615997	7.807605597	3.004712745	--
					SGP	-7.790652264	0.056701714	3.004712745	1.8803896	--
Psum98	1.139588	1.6749	2.0063	.055959		**INTERCEPT**	**DA**	**SBT**	**SGP**	
					INTERCEPT	50.41923124	-0.346921379	-21.35039966	-9.535775375	--
					DA	-0.346921379	0.005219042	0.136928842	0.07582904	--
					SBT	-21.35039966	0.136928842	9.319408794	3.663845042	--
					SGP	-9.535775375	0.07582904	3.663845042	2.311005002	--
Pfall60	1.023322	1.6736	2.0042	.009353		**INTERCEPT**	**DA**	**MxBE**	**C**	
					INTERCEPT	0.022240853	0.000709383	-0.006780383	-0.000016952	--
					DA	0.000709383	0.000493459	-0.00043416	-0.000015521	--
					MxBE	-0.006780383	-0.00043416	0.002706268	-0.001408558	--
					C	-0.000016952	-0.000015521	-0.001408558	0.003843776	--
Pfall70	1.028601	1.6736	2.0042	.011469		**INTERCEPT**	**DA**	**MxBE**	**C**	
					INTERCEPT	0.027274724	0.000869941	-0.008315018	-0.000020789	--
					DA	0.000869941	0.000605145	-0.000532425	-0.000019033	--
					MxBE	-0.008315018	-0.000532425	0.003318789	-0.001727364	--
					C	-0.000020789	-0.000019033	-0.001727364	0.004713755	--
Pfall80	1.032848	1.6736	2.0042	0.013144		**INTERCEPT**	**DA**	**C**	**MxBE**	
					INTERCEPT	0.031258058	0.000996991	-0.000023825	-0.009529383	--
					DA	0.000996991	0.000693524	-0.000021813	-0.000610183	--
					C	-0.000023825	-0.000021813	0.005402174	-0.001979636	--
					MxBE	-0.009529383	-0.000610183	-0.001979636	0.003803481	--

Table 4. Values required to determine the 90- and 95-percent prediction intervals for estimates obtained from regression equations using covariance matrices--Continued

[**Statistic**, **Pwinxx, Psprxx, Psumxx, Pfallxx** are the xx-percent duration flow for winter (win), spring (spr), summer (sum), and fall (fall); **Pporxx** is the xx-percent duration flow for the period-of-record (por); yr, year; **BCF**, Bias correction factor; **t90 and t95**, Critical value from the students t distribution for the 90- and 95-percent probability, respectively; γ^2, Regression model-error variance; **INTERCEPT**, y-axis intercept of regression equation; **DA**, drainage area (square miles); **C**, percent of basin containing coniferous trees (percent); **WCP**, average winter basin-centroid precipitation (inches); **BS**, average basin slope (percent); **CD**, percent of basin containing mixed coniferous and deciduous trees (percent); **SBT**, average mean summer basin temperature (degrees Fahrenheit); **SGP**, average summer gage precipitation (inches); **MxBE**, maximum basin elevation (foot); **ABT**, average mean annual basin temperature (degrees Fahrenheit); **SpGP**, average spring gage precipitation (inches); **7Qt**, 7-day, t-year or season low flow; --, no data]

Dependent variable	Prediction intervals			γ^2	Covariance matrix					
	BCF	t90	t95							
Pfall90	1.042913	1.6736	2.0042	.016801		**INTERCEPT**	**DA**	**MxBE**	**C**	
					INTERCEPT	0.039952885	0.001274317	-0.012180103	-0.000030453	--
					DA	0.001274317	0.000886436	-0.000779913	-0.000027881	--
					MxBE	-0.012180103	-0.000779913	0.004861468	-0.002530297	--
					C	-0.000030453	-0.000027881	-0.002530297	0.006904858	--
Pfall95	1.062871	1.6736	2.0042	.02419		**INTERCEPT**	**DA**	**C**	**MxBE**	
					INTERCEPT	0.057524796	0.001834781	-0.000043846	-0.017537104	--
					DA	0.001834781	0.001276305	-0.000040143	-0.001122931	--
					C	-0.000043846	-0.000040143	0.009941724	-0.003643162	--
					MxBE	-0.017537104	-0.001122931	-0.003643162	0.006999619	--
Pfall98	1.109987	1.6736	2.0042	.040357		**INTERCEPT**	**DA**	**MxBE**	**C**	
					INTERCEPT	0.095971514	0.003061058	-0.029258034	-0.000073151	--
					DA	0.003061058	0.002129324	-0.001873442	-0.000066973	--
					MxBE	-0.029258034	-0.001873442	0.011677816	-0.006078071	--
					C	-0.000073151	-0.000066973	-0.006078071	0.016586278	--
Ppor60	1.014225	1.6736	2.0042	.00571		**INTERCEPT**	**DA**	**SGP**		
					INTERCEPT	0.147769511	-0.002991755	-0.11245461	--	--
					DA	-0.002991755	0.00030048	0.001970721	--	--
					SGP	-0.11245461	0.001970721	0.086029866	--	--
Ppor70	1.017996	1.6742	2.0052	0.007314		**INTERCEPT**	**DA**	**SGP**	**ABT**	
					INTERCEPT	2.421815696	-0.023544829	-0.676044167	-0.93876268	--
					DA	-0.023544829	0.000558954	0.007221743	0.008288984	--
					SGP	-0.676044167	0.007221743	0.236970231	0.223700424	--
					ABT	-0.93876268	0.008288984	0.223700424	0.394742652	--

Table 4. Values required to determine the 90- and 95-percent prediction intervals for estimates obtained from regression equations using covariance matrices--Continued

[**Statistic**, **Pwinxx, Psprxx, Psumxx, Pfallxx** are the xx-percent duration flow for winter (win), spring (spr), summer (sum), and fall (fall); **Pporxx** is the xx-percent duration flow for the period-of-record (por); yr, year; **BCF**, Bias correction factor; **t90 and t95**, Critical value from the students t distribution for the 90- and 95-percent probability, respectively; γ^2, Regression model-error variance; **INTERCEPT**, y-axis intercept of regression equation; **DA**, drainage area (square miles); **C**, percent of basin containing coniferous trees (percent); **WCP**, average winter basin-centroid precipitation (inches); **BS**, average basin slope (percent); **CD**, percent of basin containing mixed coniferous and deciduous trees (percent); **SBT**, average mean summer basin temperature (degrees Fahrenheit); **SGP**, average summer gage precipitation (inches); **MxBE**, maximum basin elevation (foot); **ABT**, average mean annual basin temperature (degrees Fahrenheit); **SpGP**, average spring gage precipitation (inches); **7Qt**, 7-day, t-year or season low flow; --, no data]

Dependent variable	Prediction intervals			γ^2	Covariance matrix					
	BCF	t90	t95							
Ppor80	1.032156	1.6742	2.0052	.013318		**INTERCEPT**	**DA**	**SGP**	**ABT**	
					INTERCEPT	4.410041436	-0.042874307	-1.231052715	-1.709453913	--
					DA	-0.042874307	0.001017835	0.013150541	0.01509395	--
					SGP	-1.231052715	0.013150541	0.431514478	0.407350626	--
					ABT	-1.709453913	0.01509395	0.407350626	0.718812524	--
Ppor90	1.056736	1.6742	2.0052	.023303		**INTERCEPT**	**DA**	**ABT**	**SGP**	
					INTERCEPT	7.716369611	-0.075018343	-2.99107807	-2.154006464	--
					DA	-0.075018343	0.001780933	0.026410295	0.023009859	--
					ABT	-2.99107807	0.026410295	1.25772585	0.712752485	--
					SGP	-2.154006464	0.023009859	0.712752485	0.755032635	--
Ppor95	1.077499	1.6742	2.0052	.0314		**INTERCEPT**	**DA**	**ABT**	**SGP**	
					INTERCEPT	10.39753943	-0.101084606	-4.030373575	-2.902448726	--
					DA	-0.101084606	0.002399746	0.035586953	0.031004985	--
					ABT	-4.030373575	0.035586953	1.6947418	0.960409161	--
					SGP	-2.902448726	0.031004985	0.960409161	1.017380192	--
Ppor98	1.115612	1.6742	2.0052	.045694		**INTERCEPT**	**DA**	**ABT**	**SGP**	
					INTERCEPT	15.13106365	-0.147103805	-5.865218354	-4.223800901	--
					DA	-0.147103805	0.00349224	0.051788065	0.045120136	--
					ABT	-5.865218354	0.051788065	2.46628024	1.397639533	--
					SGP	-4.223800901	0.045120136	1.397639533	1.480546868	--
7Q2 win	1.01469	1.6743	2.0053	0.004834		**INTERCEPT**	**DA**	**C**	**WCP**	
					INTERCEPT	0.015723000	-0.001021200	0.000026303	-0.015265000	--
					DA	-0.001021200	0.000384760	-0.000238830	0.000690620	--
					C	0.000026303	-0.000238830	0.002158800	-0.002644100	--
					WCP	-0.015265000	0.000690620	-0.002644100	0.019591000	--

Table 4. Values required to determine the 90- and 95-percent prediction intervals for estimates obtained from regression equations using covariance matrices--Continued

[**Statistic**, **Pwinxx, Psprxx, Psumxx, Pfallxx** are the xx-percent duration flow for winter (win), spring (spr), summer (sum), and fall (fall); **Pporxx** is the xx-percent duration flow for the period-of-record (por); yr, year; **BCF**, Bias correction factor; **t90 and t95**, Critical value from the students t distribution for the 90- and 95-percent probability, respectively; γ^2, Regression model-error variance; **INTERCEPT**, y-axis intercept of regression equation; **DA**, drainage area (square miles); **C**, percent of basin containing coniferous trees (percent); **WCP**, average winter basin-centroid precipitation (inches); **BS**, average basin slope (percent); **CD**, percent of basin containing mixed coniferous and deciduous trees (percent); **SBT**, average mean summer basin temperature (degrees Fahrenheit); **SGP**, average summer gage precipitation (inches); **MxBE**, maximum basin elevation (foot); **ABT**, average mean annual basin temperature (degrees Fahrenheit); **SpGP**, average spring gage precipitation (inches); **7Qt**, 7-day, t-year or season low flow; --, no data]

Dependent variable	Prediction intervals			γ^2	Covariance matrix					
	BCF	t90	t95							
7Q10 win	1.02279	1.6743	2.0053	.007152		**INTERCEPT**	**DA**	**C**	**WCP**	
					INTERCEPT	0.028100	-0.001980	0.000241	-0.026700	--
					DA	-0.001980	0.000661	-0.000426	0.001410	--
					C	0.000241	-0.000426	0.003720	-0.004620	--
					WCP	-0.026700	0.001410	-0.004620	0.033300	--
7Q2 spr	1.01039	1.6749	2.0063	.003198		**INTERCEPT**	**DA**	**SpGP**	**C**	
					INTERCEPT	0.040400	-0.001910	-0.039400	0.000714	--
					DA	-0.001910	0.000352	0.001620	-0.000216	--
					SpGP	-0.039400	0.001620	0.041600	-0.002340	--
					C	0.000714	-0.000216	-0.002340	0.001490	--
7Q10 spr	1.01307	1.6749	2.0063	.003942		**INTERCEPT**	**DA**	**SpGP**	**C**	
					INTERCEPT	0.058900	-0.002630	-0.057400	0.000767	--
					DA	-0.002630	0.000485	0.002230	-0.000286	--
					SpGP	-0.057400	0.002230	0.060400	-0.003080	--
					C	0.000767	-0.000286	-0.003080	0.002120	--
7Q2 sum	1.14416	1.6736	2.0042	.04692		**INTERCEPT**	**DA**	**SBT**	**SGP**	
					INTERCEPT	41.510000	-0.263080	-17.762000	-7.626200	--
					DA	-0.263080	0.004223	0.105640	0.054523	--
					SBT	-17.762000	0.105640	7.837400	2.942600	--
					SGP	-7.626200	0.054523	2.942600	1.840200	--
7Q10 sum	1.27148	1.6736	2.0042	0.08371		**INTERCEPT**	**DA**	**SBT**	**SGP**	
					INTERCEPT	75.366000	-0.474830	-32.249000	-13.850000	--
					DA	-0.474830	0.007681	0.190570	0.098400	--
					SBT	-32.249000	0.190570	14.230000	5.343900	--
					SGP	-13.850000	0.098400	5.343900	3.342700	--

Table 4. Values required to determine the 90- and 95-percent prediction intervals for estimates obtained from regression equations using covariance matrices--Continued

[**Statistic**, **Pwinxx, Psprxx, Psumxx, Pfallxx** are the xx-percent duration flow for winter (win), spring (spr), summer (sum), and fall (fall); **Pporxx** is the xx-percent duration flow for the period-of-record (por); yr, year; **BCF**, Bias correction factor; **t90 and t95**, Critical value from the students t distribution for the 90- and 95-percent probability, respectively; γ^2, Regression model-error variance; **INTERCEPT**, y-axis intercept of regression equation; **DA**, drainage area (square miles); **C**, percent of basin containing coniferous trees (percent); **WCP**, average winter basin-centroid precipitation (inches); **BS**, average basin slope (percent); **CD**, percent of basin containing mixed coniferous and deciduous trees (percent); **SBT**, average mean summer basin temperature (degrees Fahrenheit); **SGP**, average summer gage precipitation (inches); **MxBE**, maximum basin elevation (foot); **ABT**, average mean annual basin temperature (degrees Fahrenheit); **SpGP**, average spring gage precipitation (inches); **7Qt**, 7-day, t-year or season low flow; --, no data]

Dependent variable	Prediction intervals			γ^2	Covariance matrix					
	BCF	t90	t95							
7Q2 fal	1.02686	1.6736	2.0042	.008773		**INTERCEPT**	**DA**	**C**	**MxBE**	
					INTERCEPT	0.038001	0.000603	0.000629	-0.011048	--
					DA	0.000603	0.000649	0.000007	-0.000498	--
					C	0.000629	0.000007	0.004086	-0.001690	--
					MxBE	-0.011048	-0.000498	-0.001690	0.003976	--
7Q10 fal	1.06484	1.6736	2.0042	.02083		**INTERCEPT**	**DA**	**C**	**MxBE**	
					INTERCEPT	0.093133	0.001350	0.000553	-0.026866	--
					DA	0.001350	0.001618	-0.000090	-0.001188	--
					C	0.000553	-0.000090	0.009953	-0.003765	--
					MxBE	-0.026866	-0.001188	-0.003765	0.009589	--
7Q2 yr	1.14477	1.6736	2.0042	.04709		**INTERCEPT**	**DA**	**ABT**	**SGP**	
					INTERCEPT	16.452000	-0.158580	-6.420100	-4.539000	--
					DA	-0.158580	0.003987	0.056970	0.046702	--
					ABT	-6.420100	0.056970	2.712600	1.512500	--
					SGP	-4.539000	0.046702	1.512500	1.580200	--
7Q10 yr	1.27688	1.6736	2.0042	.08516		**INTERCEPT**	**DA**	**ABT**	**SGP**	
					INTERCEPT	30.502000	-0.294480	-11.898000	-8.419400	--
					DA	-0.294480	0.007431	0.106100	0.086244	--
					ABT	-11.898000	0.106100	5.025000	2.804900	--
					SGP	-8.419400	0.086244	2.804900	2.932900	--

APPENDIXES 1-7

APPENDIX 1. BASIN CHARACTERISTICS TESTED FOR SIGNIFICANCE IN THE REGRESSION ANALYSIS

- **Total drainage area**, in square miles, is the area measured in a horizontal plane that is enclosed by a drainage divide.
- **Basin length**, in miles, is the length of the basin measured along a line areally centered through the drainage divide data layer from the basin outlet to where the main channel extended meets the basin divide.
- **Basin perimeter**, in miles, is the length as measured along the entire drainage-basin boundary.
- **Average basin slope**, in percent, is the average slope of the drainage basin measured using a Digital Elevation Model (DEM) in the computer software ARC-INFO.
- **Basin relief**, in feet, is the measured difference between the elevation of the highest grid cell and the elevation of the grid cell at the basin outlet. A lattice data layer, created using ARC-INFO, is used to determine the minimum and maximum land-surface elevation.
- **Basin azimuth**, in degrees, is the direction of a line projected from where the main channel meets the basin divide downslope to the basin outlet (clockwise from north = 0 degrees).
- **Basin azimuth**, in radians.
- **Basin azimuth region**: Four quadrants where 0-90 degrees = 1, 90-180 degrees = 2, 180-270 degrees = 3, and 270-360 degrees = 4.
- **Effective basin width**, in miles, is the ratio of the total drainage area to the basin length.
- **Shape factor**, dimensionless, is the ratio of basin length to the effective basin width.
- **Compactness ratio**, dimensionless, is the ratio of the perimeter of the basin to the circumference of a circle of equal area.
- **Relative relief**, in foot/mile, is the ratio of the basin relief to the basin perimeter.
- **Main channel length**, in miles, is measured along the main channel from the basin outlet to where the main channel meets the basin divide using centerlined hydrography.
- **Main channel slope**, in foot/mile, is the slope of the main channel based on the difference in streambed elevation at points 10 and 85 percent of the distance along the main channel from the basin outlet to the basin divide.
- **Main channel sinuosity ratio**, dimensionless, is the ratio of the main channel length to the basin length.
- **Stream density**, in miles per square mile, is the ratio of the main channel length to the drainage area.
- **Main channel slope proportion**, dimensionless, is the ratio of the main channel length to the square root of the main channel slope.
- **Ruggedness number**, in feet/mile, is the product of the stream density multiplied by the Basin Relief.
- **Slope ratio**, dimensionless, is the ratio of the main channel slope to the basin slope.
- **Minimum basin elevation**, in feet, is the minimum elevation in the drainage basin based on the intersection of the basin polygon coverages and the DEMs.
- **Maximum basin elevation**, in feet, is the maximum elevation in the drainage basin based on the intersection of the basin polygon coverages and the DEMs.
- **Mean basin elevation**, in feet, is mean basin elevation in the drainage basin based on the intersection of the basin polygon coverages and the DEMs.
- **Median basin elevation**, in feet, is the median basin elevation in the drainage basin based on the intersection of the basin polygon coverages and the DEMs.
- **Ground-water head**, in feet, is a surrogate for the effective head in the sand and gravel deposits determined by subtracting the minimum basin elevation from the mean basin elevation.

- **Basin elevation group**, either a 1 or a 2, is based on the median value of the mean basin elevations for all 60 basins used to develop the regression equations, which is 1,498 feet above mean sea level. A “1” indicates that the mean basin elevation is above this value and a “2” indicates that the mean basin elevation is below this value.
- **Standardized centroid latitude and longitude** is the latitude and longitude of the basin centroid, which was standardized by replacing the centroid latitude (and similarly centroid longitude) of each basin with (Latitude – mean (Latitude) divided by the Standard Deviation (Latitude). The standardized latitude and longitude are symmetrically distributed with a mean of zero and a standard deviation of one.
- **Centroid latitude and longitude**, in decimal degrees, is the latitude and longitude at the centroid of the drainage basin.
- **Significant sand and gravel deposits**, in square miles plus 0.01, is the total area of sand and gravel deposits in the basin plus 0.01.
- **Percent sand and gravel in basin**, in percent plus 0.01, is the percentage of the total drainage basin area, which has sand and gravel deposits, to the total drainage basin area plus 0.01.
- **Ratio of sand and gravel in basin in contact with stream network to total drainage basin area**, in percent plus 0.01, is the percent of drainage basin underlain by sand and gravel, which is in contact with the stream network (based on the intersection of stream centerline data and polygon coverages of sand and gravel deposits) as a percentage of the total drainage-basin area.
- **Minimum elevation of sand and gravel deposits**, in feet, is the minimum elevation of the sand and gravel deposits based upon DEMs and sand and gravel data.
- **Maximum elevation of sand and gravel deposits**, in feet, is the maximum elevation of the sand and gravel deposits based upon DEMs and sand and gravel data.
- **Mean elevation of sand and gravel deposits**, in feet, is the mean elevation of the sand and gravel deposits based upon DEMs and sand and gravel data.
- **Maximum sand and gravel deposit elevation above minimum basin elevation**, in feet plus 0.01, is the difference in elevation between the maximum and minimum sand and gravel deposit elevations as determined from DEMs and sand and gravel data (plus 0.01).
- **Mean sand and gravel deposit elevation above minimum basin elevation**, in feet plus 0.01, is the difference in elevation between the mean sand and gravel deposit elevation and the minimum basin elevation based upon DEMs and sand and gravel data (plus 0.01).
- **Mean sand and gravel deposit elevation above minimum basin elevation divided by drainage area**, in feet plus 0.01, is the difference in elevation between the mean sand and gravel deposit elevation and the minimum basin elevation divided by drainage area and based upon DEMs and sand and gravel data (plus 0.01).
- **Relief of sand and gravel deposits**, in feet plus 0.01, is the difference between the maximum sand and gravel elevation and minimum sand and gravel elevation based upon DEMs and sand and gravel data (plus 0.01).
- **Mean annual and seasonal precipitation**, in inches, at a stream-gaging station, is from PRISM average monthly and annual precipitation data from 1961 to 1990. It is based on 2-kilometer grid data. Five parameters were determined based on these data:
    - annual gage
    - winter gage (January 1 – March 15)
    - spring gage (March 16 – May 31)
    - summer gage (June 1 – October 31)
    - fall gage (November 1 – December 31)
- **Mean annual and seasonal precipitation**, in inches, at the centroid of the basin, is from PRISM average monthly and annual precipitation data from 1961 to 1990. It is based on 2-kilometer grid data. Five parameters were determined based on these data:
    - annual centroid
    - winter centroid (January 1 – March 15)
    - spring centroid (March 16 – May 31)

- summer centroid (June 1 – October 31)
- fall centroid (November 1 – December 31)

- **Mean annual and seasonal precipitation**, in inches, as a basin average for the drainage basin, is from PRISM average monthly and annual precipitation data from 1961 to 1990. It is based on 2-kilometer grid data. Five parameters were determined based on these data:
  - annual basin
  - winter basin (January 1 – March 15)
  - spring basin (March 16 – May 31)
  - summer basin (June 1 – October 31)
  - fall basin (November 1 – December 31)
- **Average mean, minimum, and maximum annual and seasonal basin temperature**, in degrees Fahrenheit, is based on monthly data acquired from PRISM for 1961-1990. It is based on 2-kilometer grid data. The temperature values for the entire month of March were used for each of the seasonal "half March" periods.
  - annual basin mean, minimum, maximum
  - winter basin mean, minimum, maximum (January 1 – March 31)
  - spring basin mean, minimum, maximum (March 1 – May 31)
  - summer basin mean, minimum, maximum (June 1 – October 31)
  - fall basin mean, minimum, maximum (November 1 – December 31)
- **Soil drainage**, in percent, is the percentage of drainage basin that is well drained as determined from STATSGO (State Soil Geographic) (Schwarz and Alexander, 1995; and U.S. Department of Agriculture, 1991) data.
- **Mean permeability**, in inches per hour, is the mean permeability in each basin as determined from STATSGO (Schwarz and Alexander, 1995, and U.S. Department of Agriculture, 1991) data.
- **32fday**, in days, is the seasonally and annually determined basinwide average number of days in which the temperature was a minimum of 32 degrees or less. The seasonal value for the month of March was determined by dividing the March value in half (assumes uniform distribution).
  - annual basinwide
  - winter basinwide (January 1 – March 15)
  - spring basinwide (March 16 – May 31)
  - summer basinwide (June 1 – October 31)
  - fall basinwide (November 1 – December 31)
- **Curve_25thquartile**, dimensionless, is the curvature of the basin based on a DEM for all of New Hampshire and Vermont and part of Maine and Massachusetts. The area encompasses all of the 60 basins used in this study. The curvature command was used in a grid of the DEM. A slope and a curvature grid were generated. The lowest 25 percent of slope and curvature grid cells were given a value of one while everything else was given a value of zero. These two grids were then cross-multiplied and a grid was produced that identifies those cells representing the lowest 25 percent of both slope and curvature. The curvature grid calculates the curvature of a surface at each cell center and the slope grid show the rate of maximum change in *Z* value from each cell. Slope is the first derivative of surface; curvature is the second derivative of surface. A negative value indicates that the surface (relative to a best fit plane) is concave at that cell. The basin characteristic is the lowest 25-percent quartile of curvature and slope relative to a best fit plane and indicates the smallest change in *Z* value from each cell (slope grid) and most curved cell surfaces (curvature grid). This grid was intersected with the basin grids to obtain percent flat and curved in each basin.
- **Curve cell_relief**, dimensionless, is the relief (maximum – minimum) of curvature of the basin grid surface at each cell center for each basin.
- **Profile curve** (mean, minimum, maximum), dimensionless, is the average curvature of the grid surface at each cell center in the direction of slope for each basin.
- **Total stream length**, in miles, is the total length of all streams in the basin.
- **Area of water bodies**, in square miles plus 0.01, is the total area of water bodies in the basin.

- **Percent water bodies**, in percent plus 0.01, is the percent of each drainage basin that contains a body of water.
- **Area of sand and gravel in contact with the stream network**, in square feet plus 0.01, is the total area of sand and gravel in each drainage basin in contact with the stream network.
- **Ratio of sand and gravel deposits to streams which are in contact with the sand and gravel deposits in the basin**, in miles plus 0.01, is the ratio of the square miles of sand and gravel deposits to the miles of stream length in contact with the sand and gravel deposits plus 0.01.
- **Ratio of sand and gravel deposits to the total stream length in the basin**, in miles plus 0.01, is the ratio of the square miles of sand and gravel deposits to the miles of total stream length plus 0.01. The stream centerline data was intersected with the polygon coverages of sand and gravel deposits.
- **Annual snowfall**, in inches, is the mean annual basin average snowfall for each of the basins based on monthly data acquired from 2-kilometer PRISM grid data from 1961-1990.
- **Forest coverage**, in percent, is National Land Cover Dataset (NLCD) data used to determine the percent of the basin that is forested.
- **Deciduous forest**, in percent, is the percent of the basin that is deciduous. Defined in NLCD metadata as areas dominated by trees where 75 percent or more of the tree species shed foliage simultaneously in response to seasonal change.
- **Coniferous forest**, in percent, is the percent of the basin that is coniferous. Defined in NLCD metadata as areas dominated by trees where 75 percent or more of the tree species maintain their leaves all year. Canopy is never without green foliage.
- **Mixed Coniferous / Deciduous forest**, in percent, is the percent of the basin that is mixed coniferous and deciduous. Defined in NLCD metadata as areas dominated by trees where neither deciduous nor evergreen species represent more than 75 percent of the cover present.
- **Hypsometric curve area**, dimensionless, is the area under the curve for a hypsometric curve of the basin elevation. Elevation data was grouped in equal-area classifications to create a hypsometric curve and the area under the curve was determined by summing the products of elevation and basin area above a given maximum elevation for each of the particular equal area groupings.

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Appendix 2. Flow-duration statistics estimated using available data and regression equation predicted values for the period-of-record

[No., number; fig., figure; PORxx, period-of-record for percent streamflow duration, all values are in cubic feet per second; --, no data]

Streamgaging station reference No. (fig. 1)	Streamgaging station No.	Latitude (decimal degrees)	Longitude (decimal degrees)	River name	Location (fig. 2)	Period-of-record for percent streamflow duration											
						POR60		POR70		POR80		POR90		POR95		POR98	
						Database estimate	Predict value	Database estimate	Predict value	Database estimate	Predict value	Database estimate	Predict value	Database estimate	Predict value	Database estimate	Predict value
1	1052500	44.8778	71.0569	Diamond River	Wentworth Location, N.H.	122.01	106.79	93.00	93.40	71.99	80.69	51.00	68.64	38.00	61.14	27.00	53.93
2	1054200	44.3908	70.9797	Wild River	Gilead, Maine	58.00	60.23	44.00	46.35	33.00	34.57	21.00	23.59	16.00	17.77	12.00	13.99
3	1054300	44.5936	70.7336	Ellis River	South Andover, Maine	89.99	88.01	67.00	69.25	50.00	52.83	32.00	38.00	26.00	30.07	21.00	24.12
4	1055000	44.6422	70.5881	Swift River	near Roxbury, Maine	62.00	67.68	47.00	55.20	34.00	43.63	21.00	32.85	15.00	26.79	11.00	21.99
5	1057000	44.3033	70.5394	Little Androscoggin River	near South Paris, Maine	48.00	52.08	35.00	37.67	22.00	25.87	12.00	16.06	7.40	11.40	4.50	8.41
6	1064300	44.2200	71.2500	Ellis River	near Jackson, N.H.	15.00	10.36	13.00	8.92	10.00	7.28	8.30	5.56	6.80	4.48	5.20	3.68
7	1064400	44.0694	71.1750	Lucy Brook	near North Conway, N.H.	3.70	3.35	2.90	2.41	2.10	1.55	1.40	0.88	0.98	0.57	0.70	0.39
8	1064500	43.9908	71.0914	Saco River	near Conway, N.H.	370.00	346.44	299.99	272.99	244.01	218.50	183.99	163.29	151.01	131.86	123.99	112.10
9	1064800	43.8158	71.2975	Cold Brook	South Tamworth, N.H.	2.90	4.40	2.10	3.19	1.10	2.08	0.51	1.20	0.31	0.79	0.21	0.54
10	1072850	43.2631	71.0972	Mohawk River	Center Strafford, N.H.	3.50	4.08	2.10	2.63	0.93	1.48	0.38	0.71	0.19	0.42	0.08	0.26
11	1073000	43.1486	70.9656	Oyster River	Durham, N.H.	6.40	5.96	3.80	3.71	2.10	2.01	1.20	0.93	0.88	0.54	0.67	0.33
12	1073600	42.9936	71.0233	Dudley Brook	Exeter, N.H.	--	--	--	--	--	--	--	--	--	--	--	--
13	1074500	44.0600	71.6200	East Branch Pemigewasset	near Lincoln, N.H.	115.00	122.02	92.00	98.98	73.99	80.79	55.00	60.72	45.00	48.50	35.00	41.33
14	1075000	43.9761	71.6800	Pemigewasset River	Woodstock, N.H.	192.00	175.81	153.00	138.56	123.00	109.16	93.99	79.85	77.00	63.33	65.99	52.71
15	1075500	43.8681	71.9097	Baker River	Wentworth, N.H.	40.00	36.14	31.00	26.28	23.00	17.90	15.00	11.11	10.00	7.91	8.00	5.76
16	1075800	43.8367	71.8853	Stevens Brook	Wentworth, N.H.	1.10	1.65	0.73	1.13	0.35	0.67	0.16	0.35	0.10	0.22	0.05	0.14
17	1076000	43.7961	71.8450	Baker River	Rumney, N.H.	86.00	103.81	67.00	75.73	49.00	53.46	32.00	34.33	24.00	25.00	19.00	19.01
18	1076500	43.7592	71.6861	Pemigewasset River	Plymouth, N.H.	531.01	461.25	419.95	351.52	329.99	270.30	236.97	194.57	188.02	154.53	151.01	127.79
19	1078000	43.5675	71.7483	Smith River	near Bristol, N.H.	52.00	61.52	37.00	43.87	26.00	29.79	17.00	18.17	12.00	12.74	9.00	9.35
20	1082000	42.8625	71.9597	Contoocook River	Peterborough, N.H.	50.00	44.88	36.00	30.68	23.00	19.66	15.00	11.15	11.00	7.43	7.80	5.20

Appendix 2. Flow-duration statistics estimated using available data and regression equation predicted values for the period-of-record--Continued

Stream-gaging station reference No. (fig. 1)	Stream-gaging station No.	Latitude (decimal degrees)	Longitude (decimal degrees)	River name	Location (fig. 2)	Period-of-record for percent streamflow duration											
						POR60		POR70		POR80		POR90		POR95		POR98	
						Data-base estimate	Predict value	Data-base estimate	Predict value	Data-base estimate	Predict value	Data-base estimate	Predict value	Data-base estimate	Predict value	Data-base estimate	Predict value
21	1084500	43.1142	71.9267	Beards Brook	Hillsboro, N.H.	27.00	33.53	17.00	22.39	8.60	13.81	4.30	7.50	2.70	4.87	1.70	3.29
22	1085800	43.2592	72.0264	West Branch Warner River	near Bradford, N.H.	3.50	3.32	2.20	2.19	1.30	1.26	0.64	0.62	0.40	0.38	0.28	0.23
23	1086000	43.2517	71.7317	Warner River	Davisville, N.H.	77.00	89.05	51.00	61.21	32.00	39.93	18.00	23.39	12.00	16.07	7.70	11.48
24	1089000	43.2394	71.4622	Soucook River	near Concord, N.H.	45.00	41.62	30.00	28.33	19.00	17.84	11.00	10.08	8.00	6.77	5.50	4.65
25	1091000	43.0136	71.6419	South Branch Piscataquog River	near Goffstown, N.H.	60.01	61.32	36.00	41.57	22.00	26.43	12.00	14.99	8.30	10.06	5.70	7.01
26	1093800	42.8600	71.8333	Stony Brook Tributary	near Temple, N.H.	2.50	2.13	1.60	1.40	0.90	0.79	0.44	0.38	0.28	0.23	0.19	0.14
27	10965852	42.7831	71.3539	Beaver Brook	North Pelham, N.H.	33.00	28.26	22.00	17.94	13.00	10.40	5.80	5.20	3.00	3.18	1.90	2.05
28	1097300	42.5108	71.4069	Nashoba Brook	near Acton, Mass.	7.80	6.90	5.10	4.14	3.00	2.17	1.20	0.95	0.60	0.53	0.24	0.31
29	1101000	42.7528	70.9461	Parker River	Byfield, Mass.	15.00	11.99	8.60	7.16	4.10	3.79	1.40	1.68	0.56	0.94	0.27	0.56
30	1127880	45.1350	71.2064	Big Brook	Pittsburg, N.H.	5.90	6.67	4.60	5.86	3.60	4.85	2.54	3.77	1.90	3.06	1.50	2.53
31	1129440	44.8744	71.4106	Mohawk River	near Colebrook, N.H.	33.00	33.35	27.00	28.03	22.00	22.86	17.00	17.50	13.00	14.20	9.50	11.85
32	1130000	44.6250	71.4694	Upper Ammonoosuc River	near Groveton, N.H.	197.02	198.35	155.99	158.25	125.00	126.46	94.99	94.75	76.00	76.62	62.00	64.52
33	1133000	44.6339	71.8981	East Branch Passumpsic	East Haven, Vt.	53.00	48.71	45.00	39.23	38.00	30.79	30.00	22.33	26.00	17.47	22.00	14.25
34	1134500	44.5117	71.8369	Moose River	Victory, Vt	56.00	67.50	43.00	52.91	32.00	40.47	21.00	28.48	14.00	21.89	9.80	17.59
35	1134800	44.4419	71.8792	Kirby Brook	Concord, Vt.	3.80	5.04	2.90	3.69	2.00	2.42	1.00	1.42	0.68	0.97	0.48	0.67
36	1135000	44.4228	72.0006	Moose River	St. Johnsbury, Vt.	76.00	93.50	60.01	71.84	44.00	53.60	29.00	37.16	21.00	28.56	16.00	22.58
37	1135300	44.4344	72.0394	Sleepers River (W-5)	St. Johnsbury, Vt.	34.00	28.16	27.00	21.89	20.00	16.01	13.00	10.90	8.20	8.26	5.50	6.33
38	1137500	44.2689	71.6311	Ammonoosuc River	Bethlehem Junction, N.H.	88.00	76.37	71.01	61.55	58.00	48.63	46.00	35.90	38.00	28.60	33.00	23.57
39	1138000	44.1539	71.9861	Ammonoosuc River	Bath, N.H.	260.02	282.38	208.98	215.90	159.99	164.38	116.01	117.16	93.99	92.37	78.00	75.29
40	1139000	44.1508	72.0653	Wells River	Wells River, Vt.	65.99	62.13	52.00	47.22	41.00	34.23	29.00	23.12	23.00	17.52	18.00	13.47

Appendix 2. Flow-duration statistics estimated using available data and regression equation predicted values for the period-of-record--Continued

Stream-gaging station reference No. (fig. 1)	Stream-gaging station No.	Latitude (decimal degrees)	Longitude (decimal degrees)	River name	Location (fig. 2)	Period-of-record for percent streamflow duration											
						POR60		POR70		POR80		POR90		POR95		POR98	
						Data-base estimate	Predict value	Data-base estimate	Predict value	Data-base estimate	Predict value	Data-base estimate	Predict value	Data-base estimate	Predict value	Data-base estimate	Predict value
41	1139800	44.0928	72.3361	East Orange Branch	East Orange, Vt.	6.60	6.16	5.00	4.62	3.60	3.14	2.30	1.92	1.60	1.34	1.10	0.95
42	1140000	44.0181	72.2083	South Branch Waits River	near Bradford, Vt.	29.00	29.43	23.00	21.96	17.00	15.37	11.00	9.84	8.40	7.13	6.50	5.29
43	1141800	43.7022	72.1875	Mink Brook	Etna, N.H.	2.30	2.67	1.50	1.82	0.80	1.08	0.36	0.57	0.20	0.35	0.10	0.22
44	1142000	43.8125	72.6569	White River	Bethel, Vt.	203.00	157.85	151.98	118.02	110.00	86.07	76.00	58.31	58.00	44.37	46.80	34.73
45	1142500	43.9344	72.6583	Ayers Brook	Randolph, Vt.	21.00	16.26	16.00	11.80	11.00	7.81	6.80	4.73	4.70	3.32	3.30	2.34
46	1144000	43.7142	72.4186	White River	West Hartford, Vt.	500.03	462.84	380.01	349.18	274.98	264.15	189.02	187.61	148.01	148.22	118.00	120.98
47	1145000	43.6500	72.0806	Mascoma River	West Canaan, N.H.	40.00	51.47	30.00	36.83	21.00	24.86	13.00	15.20	8.70	10.72	6.20	7.80
48	1150800	43.6733	72.8092	Kent Brook	Sherburne, Vt.	3.50	3.03	2.70	2.20	2.10	1.44	1.40	0.81	1.00	0.53	0.79	0.36
49	1150900	43.6222	72.7594	Ottauquechee River	West Bridgewater, Vt.	25.00	20.92	20.00	15.62	15.00	11.00	10.00	6.93	7.30	4.89	5.20	3.64
50	1153500	43.2086	72.5181	Williams River	Brockways Mills, Vt.	53.00	65.68	38.00	47.01	26.00	31.92	17.00	19.67	12.00	13.96	8.90	10.24
51	1154000	43.1372	72.4881	Saxtons River	Saxtons River, Vt.	39.00	47.80	27.00	34.45	18.00	23.44	11.00	14.45	7.50	10.23	5.60	7.48
52	1155000	43.1317	72.3897	Cold River	Drewsville, N.H.	37.00	47.05	27.00	31.98	17.00	20.23	9.90	11.44	7.30	7.67	5.60	5.31
53	1155200	42.9992	72.5331	Sacketts Brook	Putney, Vt.	6.20	5.26	4.50	3.55	3.30	2.11	2.20	1.11	1.50	0.70	1.20	0.45
54	1155300	43.2364	72.8564	Flood Brook	Londonderry, Vt.	7.00	7.01	5.00	5.04	3.00	3.29	1.60	1.90	1.00	1.26	0.67	0.87
55	1155500	43.1089	72.7758	West River	Jamaica, Vt.	113.01	147.92	75.01	111.19	45.00	82.40	24.00	55.86	17.00	42.08	12.00	33.38
56	1156000	42.9958	72.6389	West River	Newfane, Vt.	190.02	229.37	135.99	173.04	89.99	129.46	54.00	89.72	39.00	69.11	29.00	55.48
57	1158500	42.9653	72.2333	Otter Brook	Keene, N.H.	26.00	25.35	17.00	17.44	11.00	11.06	6.90	6.24	4.80	4.15	2.80	2.85
58	1162500	42.6825	72.1156	Priest Brook	Winchendon, Mass.	12.00	10.83	7.90	7.35	4.50	4.48	2.10	2.41	1.20	1.55	0.70	1.02
59	1165500	42.6028	72.3600	Moss Brook	Wendell Depot, Mass.	7.40	7.23	4.80	4.78	3.00	2.81	1.70	1.43	1.20	0.88	0.89	0.56
60	1167800	42.8606	72.8511	Beaver Brook	Wilmington, Vt.	4.70	5.63	3.20	3.97	1.80	2.55	0.79	1.41	0.45	0.91	0.29	0.62

Appendix 3. Flow-duration statistics estimated using available data and regression equation predicted values for the winter season, January 1 to March 15

[No., number; fig., figure; WINxx, xx flow duration for winter; --, no data]

Stream-gaging station reference No. (fig. 1)	Stream-gaging station No.	Latitude (decimal degrees)	Longitude (decimal degrees)	River name	Location (fig. 2)	Flow-duration statistics for the winter season, January 1 to March 15											
						WIN60		WIN70		WIN80		WIN90		WIN95		WIN98	
						Data-base estimate	Predict value	Data-base estimate	Predict value	Data-base estimate	Predict value	Data-base estimate	Predict value	Data-base estimate	Predict value	Data-base estimate	Predict value
1	1052500	44.8778	71.0569	Diamond River	Wentworth Location, N.H.	85.00	116.61	73.99	100.75	65.00	83.63	54.00	66.15	48.35	52.78	41.00	41.40
2	1054200	44.3908	70.9797	Wild River	Gilead, Maine	53.00	52.25	46.00	45.06	39.00	37.76	32.00	30.07	22.95	24.18	17.00	19.27
3	1054300	44.5936	70.7336	Ellis River	South Andover, Maine	78.00	87.38	68.00	75.10	59.01	63.08	49.00	50.28	42.00	40.27	29.00	32.20
4	1055000	44.6422	70.5881	Swift River	near Roxbury, Maine	51.00	58.63	45.00	50.26	38.00	42.78	30.00	34.69	24.00	28.06	19.00	22.95
5	1057000	44.3033	70.5394	Little Androscoggin River	near South Paris, Maine	52.00	57.89	46.00	49.83	39.00	41.40	28.00	32.18	20.00	25.54	13.00	20.00
6	1064300	44.2200	71.2500	Ellis River	near Jackson, N.H.	9.30	10.40	8.20	9.02	6.90	7.51	5.60	5.88	4.47	4.76	3.20	3.74
7	1064400	44.0694	71.1750	Lucy Brook	near North Conway, N.H.	3.30	3.21	2.90	2.73	2.40	2.34	1.90	1.82	1.50	1.47	1.20	1.21
8	1064500	43.9908	71.0914	Saco River	near Conway, N.H.	319.01	342.95	284.97	300.43	254.98	246.13	219.99	199.63	188.02	160.82	153.99	124.41
9	1064800	43.8158	71.2975	Cold Brook	South Tamworth, N.H.	3.30	5.76	3.00	4.96	2.70	4.09	2.30	3.04	2.10	2.40	1.80	1.84
10	1072850	43.2631	71.0972	Mohawk River	Center Strafford, N.H.	6.70	5.64	5.80	4.79	4.80	4.04	3.10	3.05	2.60	2.42	2.50	1.93
11	1073000	43.1486	70.9656	Oyster River	Durham, N.H.	12.00	8.87	10.00	7.54	8.00	6.36	5.10	4.83	3.60	3.83	2.60	3.05
12	1073600	42.9936	71.0233	Dudley Brook	Exeter, N.H.	2.80	4.14	2.10	3.51	--	--	--	--	--	--	--	--
13	1074500	44.0600	71.6200	East Branch Pemigewasset	near Lincoln, N.H.	84.00	78.19	71.01	67.77	55.00	57.01	41.00	46.68	31.00	38.01	23.00	30.62
14	1075000	43.9761	71.6800	Pemigewasset River	Woodstock, N.H.	139.99	135.75	125.00	117.56	105.00	98.71	90.30	80.78	71.99	65.50	58.00	52.62
15	1075500	43.8681	71.9097	Baker River	Wentworth, N.H.	35.00	33.96	29.00	28.86	24.00	24.55	20.00	19.25	12.00	15.33	9.00	12.44
16	1075800	43.8367	71.8853	Stevens Brook	Wentworth, N.H.	1.20	1.67	1.00	1.39	0.83	1.22	0.60	0.94	--	--	--	--
17	1076000	43.7961	71.8450	Baker River	Rumney, N.H.	87.00	93.61	75.01	80.16	64.00	67.12	51.00	52.59	44.00	41.70	36.00	33.08
18	1076500	43.7592	71.6861	Pemigewasset River	Plymouth, N.H.	470.00	571.51	410.02	501.94	360.00	408.58	299.99	331.00	249.98	265.80	179.14	203.59
19	1078000	43.5675	71.7483	Smith River	near Bristol, N.H.	60.01	62.77	52.00	54.03	42.00	45.21	32.00	35.76	26.00	28.62	21.00	22.72
20	1082000	42.8625	71.9597	Contoocook River	Peterborough, N.H.	73.99	52.76	59.01	45.48	46.00	37.88	37.00	29.69	28.00	23.70	22.00	18.65

Appendix 3. Flow-duration statistics estimated using available data and regression equation predicted values for the winter season, January 1 to March 15--Continued

Stream-gaging station reference No. (fig. 1)	Stream-gaging station No.	Latitude (decimal degrees)	Longitude (decimal degrees)	River name	Location (fig. 2)	Flow-duration statistics for the winter season, January 1 to March 15											
						WIN60		WIN70		WIN80		WIN90		WIN95		WIN98	
						Data-base estimate	Predict value	Data-base estimate	Predict value	Data-base estimate	Predict value	Data-base estimate	Predict value	Data-base estimate	Predict value	Data-base estimate	Predict value
21	1084500	43.1142	71.9267	Beards Brook	Hillsboro, N.H.	43.00	45.64	38.00	39.36	32.00	32.68	23.00	25.45	17.85	20.27	14.14	15.87
22	1085800	43.2592	72.0264	West Branch Warner River	near Bradford, N.H.	4.50	5.56	3.90	4.73	3.10	3.90	2.10	2.81	1.70	2.17	1.10	1.66
23	1086000	43.2517	71.7317	Warner River	Davisville, N.H.	126.01	119.82	103.11	103.88	80.00	85.86	58.00	67.99	51.00	54.33	42.94	42.37
24	1089000	43.2394	71.4622	Soucook River	near Concord, N.H.	67.00	53.61	57.00	45.92	47.00	38.51	34.00	30.10	27.25	23.94	20.00	19.02
25	1091000	43.0136	71.6419	South Branch Piscataquog River	near Goffstown, N.H.	105.00	77.81	89.99	67.18	71.99	56.06	54.20	44.59	35.00	35.76	23.00	28.31
26	1093800	42.8600	71.8333	Stony Brook Tributary	near Temple, N.H.	3.60	3.18	3.00	2.70	2.40	2.25	1.80	1.65	1.20	1.29	0.93	1.01
27	10965852	42.7831	71.3539	Beaver Brook	North Pelham, N.H.	68.00	45.98	60.01	39.68	45.00	32.39	32.00	24.35	28.00	19.07	23.00	14.46
28	1097300	42.5108	71.4069	Nashoba Brook	near Acton, Mass.	17.00	15.47	14.00	13.33	10.00	10.70	6.74	7.62	5.00	5.85	3.50	4.29
29	1101000	42.7528	70.9461	Parker River	Byfield, Mass.	35.00	31.94	29.00	27.72	23.00	21.75	14.00	15.17	9.20	11.51	5.20	8.12
30	1127880	45.1350	71.2064	Big Brook	Pittsburg, N.H.	3.40	5.17	3.00	4.38	2.60	3.66	2.00	2.68	1.66	2.09	1.50	1.63
31	1129440	44.8744	71.4106	Mohawk River	near Colebrook, N.H.	26.00	23.82	23.00	20.31	21.00	17.15	19.00	13.30	15.00	10.57	12.00	8.47
32	1130000	44.6250	71.4694	Upper Ammonoosuc River	near Groveton, N.H.	150.00	148.94	134.99	128.13	115.00	107.47	93.99	86.14	73.99	68.95	57.00	55.09
33	1133000	44.6339	71.8981	East Branch Passumpsic	East Haven, Vt.	42.00	36.92	38.00	31.53	35.00	26.34	30.00	20.15	25.00	15.88	20.00	12.50
34	1134500	44.5117	71.8369	Moose River	Victory, Vt	45.00	58.36	40.00	50.17	34.00	41.63	27.60	32.14	22.00	25.42	15.00	19.84
35	1134800	44.4419	71.8792	Kirby Brook	Concord, Vt.	3.94	4.41	3.40	3.70	3.00	3.20	2.40	2.46	1.80	1.96	1.70	1.63
36	1135000	44.4228	72.0006	Moose River	St. Johnsbury, Vt.	65.00	90.89	55.00	78.06	46.00	65.10	38.00	50.96	30.00	40.43	20.00	31.88
37	1135300	44.4344	72.0394	Sleepers River (W-5)	St. Johnsbury, Vt.	33.00	27.25	28.00	23.18	24.00	19.59	20.00	15.14	16.99	11.99	14.83	9.62
38	1137500	44.2689	71.6311	Ammonoosuc River	Bethlehem Junction, N.H.	65.00	75.10	58.00	65.25	51.00	54.16	43.00	43.33	37.00	34.94	31.00	27.48
39	1138000	44.1539	71.9861	Ammonoosuc River	Bath, N.H.	219.99	241.45	190.02	207.99	154.99	174.97	120.01	142.57	94.99	114.67	80.00	92.29
40	1139000	44.1508	72.0653	Wells River	Wells River, Vt.	60.01	64.69	52.00	55.26	45.00	46.34	35.00	36.03	27.00	28.51	23.00	22.63

Appendix 3. Flow-duration statistics estimated using available data and regression equation predicted values for the winter season, January 1 to March 15--Continued

Stream-gaging station reference No. (fig. 1)	Stream-gaging station No.	Latitude (decimal degrees)	Longitude (decimal degrees)	River name	Location (fig. 2)	Flow-duration statistics for the winter season, January 1 to March 15: WIN60 Data-base estimate	WIN60 Predict value	WIN70 Data-base estimate	WIN70 Predict value	WIN80 Data-base estimate	WIN80 Predict value	WIN90 Data-base estimate	WIN90 Predict value	WIN95 Data-base estimate	WIN95 Predict value	WIN98 Data-base estimate	WIN98 Predict value
41	1139800	44.0928	72.3361	East Orange Branch	East Orange, Vt.	6.20	7.30	5.40	6.18	4.70	5.12	3.40	3.69	2.50	2.85	1.90	2.19
42	1140000	44.0181	72.2083	South Branch Waits River	near Bradford, Vt.	30.00	29.10	26.00	24.77	23.00	20.84	19.00	16.00	17.00	12.63	14.00	10.05
43	1141800	43.7022	72.1875	Mink Brook	Etna, N.H.	2.50	2.83	2.10	2.37	1.70	2.05	1.20	1.55	0.76	1.23	0.59	1.01
44	1142000	43.8125	72.6569	White River	Bethel, Vt.	229.99	221.93	199.99	193.22	159.99	157.10	120.01	122.36	94.15	96.75	81.00	73.44
45	1142500	43.9344	72.6583	Ayers Brook	Randolph, Vt.	23.00	23.88	19.00	20.39	16.00	16.94	12.00	12.72	10.00	9.97	8.60	7.75
46	1144000	43.7142	72.4186	White River	West Hartford, Vt.	540.01	586.44	470.00	511.74	390.03	416.46	299.99	330.85	239.99	262.51	199.99	200.33
47	1145000	43.6500	72.0806	Mascoma River	West Canaan, N.H.	42.00	49.05	36.00	41.91	30.00	35.56	23.00	28.29	19.00	22.68	16.00	18.40
48	1150800	43.6733	72.8092	Kent Brook	Sherburne, Vt.	3.40	2.87	3.00	2.44	2.50	2.04	2.08	1.49	1.70	1.17	1.60	0.91
49	1150900	43.6222	72.7594	Ottauquechee River	West Bridgewater, Vt.	23.00	20.83	20.00	17.89	17.00	14.77	15.00	11.13	14.00	8.76	12.00	6.76
50	1153500	43.2086	72.5181	Williams River	Brockways Mills, Vt.	73.00	82.82	60.39	71.51	50.00	59.14	38.00	46.15	31.00	36.66	23.00	28.54
51	1154000	43.1372	72.4881	Saxtons River	Saxtons River, Vt.	55.00	58.16	46.00	50.17	38.00	41.64	29.00	32.50	25.00	25.88	18.38	20.25
52	1155000	43.1317	72.3897	Cold River	Drewsville, N.H.	51.00	53.61	42.00	45.90	35.00	38.79	29.00	30.81	23.00	24.69	17.00	19.90
53	1155200	42.9992	72.5331	Sacketts Brook	Putney, Vt.	9.00	8.41	8.00	7.16	6.20	5.97	5.00	4.43	3.90	3.47	2.30	2.71
54	1155300	43.2364	72.8564	Flood Brook	Londonderry, Vt.	7.40	7.78	6.60	6.64	5.80	5.55	4.20	4.18	3.54	3.30	2.90	2.59
55	1155500	43.1089	72.7758	West River	Jamaica, Vt.	154.99	151.68	139.99	131.81	120.01	108.44	89.99	85.79	68.00	68.46	60.01	53.03
56	1156000	42.9958	72.6389	West River	Newfane, Vt.	239.99	267.44	209.99	233.26	169.98	190.93	137.59	152.03	112.41	121.44	89.47	93.49
57	1158500	42.9653	72.2333	Otter Brook	Keene, N.H.	35.00	31.74	29.00	27.22	21.00	22.75	15.00	17.61	11.00	13.99	8.00	11.04
58	1162500	42.6825	72.1156	Priest Brook	Winchendon, Mass.	18.00	13.57	15.00	11.57	12.00	9.78	9.50	7.55	6.00	6.01	3.80	4.82
59	1165500	42.6028	72.3600	Moss Brook	Wendell Depot, Mass.	11.00	6.89	8.60	5.83	7.00	5.05	4.60	3.99	3.30	3.22	2.40	2.69
60	1167800	42.8606	72.8511	Beaver Brook	Wilmington, Vt.	5.50	5.41	4.60	4.62	3.70	3.87	2.90	2.92	2.20	2.31	1.90	1.82

Appendix 4. Flow-duration statistics estimated using available data and regression equation predicted values for the spring season, March 16 to May 31

[No., number; fig., figure; SPRxx, xx flow duration for spring; --, no data]

Stream-gaging station reference No. (fig. 1)	Stream-gaging station No.	Latitude (decimal degrees)	Longitude (decimal degrees)	River name	Location (fig. 2)	Flow-duration statistics for the spring season, March 16 to May 31											
						SPR60		SPR70		SPR80		SPR90		SPR95		SPR98	
						Database estimate	Predict value	Database estimate	Predict value	Database estimate	Predict value	Database estimate	Predict value	Database estimate	Predict value	Database estimate	Predict value
1	1052500	44.8778	71.0569	Diamond River	Wentworth Location, N.H.	435.01	404.08	305.00	316.98	205.02	234.52	125.00	158.26	89.00	113.63	64.00	82.32
2	1054200	44.3908	70.9797	Wild River	Gilead, Maine	218.02	204.99	169.98	158.73	132.01	115.14	90.99	75.52	63.80	53.16	41.92	38.56
3	1054300	44.5936	70.7336	Ellis River	South Andover, Maine	357.03	331.45	272.02	260.82	199.99	196.05	134.99	134.15	98.99	97.38	57.64	71.07
4	1055000	44.6422	70.5881	Swift River	near Roxbury, Maine	257.45	256.44	192.00	200.75	136.99	158.85	88.00	109.84	59.01	81.18	42.00	62.90
5	1057000	44.3033	70.5394	Little Androscoggin River	near South Paris, Maine	183.02	180.27	142.00	142.09	107.99	109.10	71.99	75.87	55.00	55.81	43.00	41.23
6	1064300	44.2200	71.2500	Ellis River	near Jackson, N.H.	36.00	33.82	28.00	25.75	20.00	18.90	12.00	12.20	8.27	8.54	7.00	6.39
7	1064400	44.0694	71.1750	Lucy Brook	near North Conway, N.H.	13.00	13.50	10.00	10.35	7.70	7.34	5.30	4.78	3.70	3.33	2.90	2.36
8	1064500	43.9908	71.0914	Saco River	near Conway, N.H.	1349.90	1113.03	1059.99	869.41	781.09	629.78	517.96	414.61	350.99	292.51	270.02	211.33
9	1064800	43.8158	71.2975	Cold Brook	South Tamworth, N.H.	16.00	15.28	11.00	11.74	8.00	8.30	5.20	5.42	3.45	3.78	2.80	2.65
10	1072850	43.2631	71.0972	Mohawk River	Center Strafford, N.H.	14.00	15.24	11.00	12.09	8.40	8.90	6.10	6.30	4.27	4.62	2.30	3.16
11	1073000	43.1486	70.9656	Oyster River	Durham, N.H.	24.00	20.32	19.00	16.46	15.00	12.89	11.00	9.73	8.20	7.49	5.80	5.22
12	1073600	42.9936	71.0233	Dudley Brook	Exeter, N.H.	--	--	--	--	--	--	--	--	--	--	--	--
13	1074500	44.0600	71.6200	East Branch Pemigewasset	near Lincoln, N.H.	405.98	328.82	310.03	253.77	193.02	182.15	105.00	117.74	77.25	82.06	53.30	59.58
14	1075000	43.9761	71.6800	Pemigewasset River	Woodstock, N.H.	724.77	595.04	533.09	461.03	374.80	331.26	219.99	214.91	143.35	150.14	110.00	108.82
15	1075500	43.8681	71.9097	Baker River	Wentworth, N.H.	149.00	155.12	123.99	121.01	96.01	87.27	68.00	58.12	46.00	41.17	30.50	29.15
16	1075800	43.8367	71.8853	Stevens Brook	Wentworth, N.H.	--	--	--	--	--	--	--	--	--	--	--	--
17	1076000	43.7961	71.8450	Baker River	Rumney, N.H.	351.97	374.34	277.97	293.83	205.02	214.29	136.99	144.11	100.00	102.91	81.00	73.35
18	1076500	43.7592	71.6861	Pemigewasset River	Plymouth, N.H.	1949.84	1791.83	1549.89	1403.14	1189.87	1014.09	800.02	667.92	579.96	471.16	400.04	339.34
19	1078000	43.5675	71.7483	Smith River	near Bristol, N.H.	190.02	208.19	151.98	164.27	117.00	122.80	83.00	84.63	65.00	61.57	51.00	44.25
20	1082000	42.8625	71.9597	Contoocook River	Peterborough, N.H.	154.99	138.51	125.00	110.78	101.00	85.48	73.00	61.49	54.00	46.08	38.00	33.10

Appendix 4. Flow-duration statistics estimated using available data and regression equation predicted values for the spring season, March 16 to May 31--Continued

Stream-gaging station reference No. (fig. 1)	Stream-gaging station No.	Latitude (decimal degrees)	Longitude (decimal degrees)	River name	Location (fig. 2)	Flow-duration statistics for the spring season, March 16 to May 31: SPR60 Data-base estimate	SPR60 Predict value	SPR70 Data-base estimate	SPR70 Predict value	SPR80 Data-base estimate	SPR80 Predict value	SPR90 Data-base estimate	SPR90 Predict value	SPR95 Data-base estimate	SPR95 Predict value	SPR98 Data-base estimate	SPR98 Predict value
21	1084500	43.1142	71.9267	Beards Brook	Hillsboro, N.H.	121.00	128.48	93.00	101.58	70.00	77.39	50.00	54.14	39.00	39.87	29.00	28.95
22	1085800	43.2592	72.0264	West Branch Warner River	near Bradford, N.H.	13.00	14.82	11.00	11.52	8.40	9.30	5.80	6.53	4.50	4.88	3.10	3.81
23	1086000	43.2517	71.7317	Warner River	Davisville, N.H.	376.01	347.82	299.99	275.46	227.98	207.37	154.99	143.80	118.99	105.14	71.07	75.86
24	1089000	43.2394	71.4622	Soucook River	near Concord, N.H.	146.02	157.27	118.99	126.14	93.99	97.29	68.99	70.31	53.00	52.80	40.00	37.73
25	1091000	43.0136	71.6419	South Branch Piscataquog River	near Goffstown, N.H.	214.98	225.28	169.98	179.57	132.40	138.21	102.00	98.26	79.00	73.15	50.00	53.02
26	1093800	42.8600	71.8333	Stony Brook Tributary	near Temple, N.H.	8.20	8.93	6.30	6.94	4.90	5.17	3.50	3.54	2.70	2.56	2.11	1.84
27	10965852	42.7831	71.3539	Beaver Brook	North Pelham, N.H.	82.00	86.34	70.00	69.83	57.00	58.80	45.00	44.88	34.00	35.42	27.00	27.00
28	1097300	42.5108	71.4069	Nashoba Brook	near Acton, Mass.	23.00	21.76	19.00	17.60	14.73	14.39	11.00	10.98	8.60	8.59	6.66	6.28
29	1101000	42.7528	70.9461	Parker River	Byfield, Mass.	49.00	37.30	40.00	30.14	34.00	25.16	25.00	19.24	19.00	15.16	16.00	11.39
30	1127880	45.1350	71.2064	Big Brook	Pittsburg, N.H.	17.00	14.98	12.00	11.74	8.00	8.70	5.00	6.02	3.40	4.38	2.04	3.08
31	1129440	44.8744	71.4106	Mohawk River	near Colebrook, N.H.	71.99	86.50	60.01	67.91	49.00	50.08	35.00	34.23	28.00	24.70	21.00	17.56
32	1130000	44.6250	71.4694	Upper Ammonoosuc River	near Groveton, N.H.	679.05	603.12	526.02	474.42	380.01	350.79	249.98	237.24	150.00	170.53	110.00	123.22
33	1133000	44.6339	71.8981	East Branch Passumpsic	East Haven, Vt.	133.01	127.22	105.00	99.93	77.00	75.13	54.00	51.62	40.00	37.54	33.00	27.26
34	1134500	44.5117	71.8369	Moose River	Victory, Vt	180.01	185.26	138.01	145.84	101.00	110.62	70.00	76.37	48.00	55.80	35.00	40.83
35	1134800	44.4419	71.8792	Kirby Brook	Concord, Vt.	16.00	19.64	12.00	15.34	8.10	11.23	6.00	7.67	4.44	5.52	3.00	3.88
36	1135000	44.4228	72.0006	Moose River	St. Johnsbury, Vt.	297.03	322.58	225.01	254.21	166.00	189.45	105.00	129.64	70.00	93.90	50.00	67.73
37	1135300	44.4344	72.0394	Sleepers River (W-5)	St. Johnsbury, Vt.	82.00	101.42	65.99	79.89	54.00	59.45	41.00	41.00	33.00	29.80	21.99	21.25
38	1137500	44.2689	71.6311	Ammonoosuc River	Bethlehem Junction, N.H.	264.00	245.60	208.02	191.29	149.00	140.60	100.00	93.65	70.00	66.67	47.00	48.48
39	1138000	44.1539	71.9861	Ammonoosuc River	Bath, N.H.	968.05	1049.32	787.05	826.47	602.98	601.54	393.64	403.71	238.62	287.98	166.99	205.33
40	1139000	44.1508	72.0653	Wells River	Wells River, Vt.	206.02	238.04	166.19	188.01	131.01	141.11	96.01	97.49	71.99	71.08	56.00	51.25

Appendix 4. Flow-duration statistics estimated using available data and regression equation predicted values for the spring season, March 16 to May 31--Continued

Stream-gaging station reference No. (fig. 1)	Stream-gaging station No.	Latitude (decimal degrees)	Longitude (decimal degrees)	River name	Location (fig. 2)	Flow-duration statistics for the spring season, March 16 to May 31											
						SPR60		SPR70		SPR80		SPR90		SPR95		SPR98	
						Data-base estimate	Predict value	Data-base estimate	Predict value	Data-base estimate	Predict value	Data-base estimate	Predict value	Data-base estimate	Predict value	Data-base estimate	Predict value
41	1139800	44.0928	72.3361	East Orange Branch	East Orange, Vt.	24.00	24.31	20.00	18.76	15.00	13.83	10.00	9.22	7.00	6.56	5.00	4.78
42	1140000	44.0181	72.2083	South Branch Waits River	near Bradford, Vt.	107.99	113.62	92.00	88.82	75.01	65.61	54.00	44.38	40.00	31.87	28.00	22.95
43	1141800	43.7022	72.1875	Mink Brook	Etna, N.H.	9.50	11.39	7.50	8.88	5.60	6.90	3.60	4.82	2.70	3.56	1.90	2.65
44	1142000	43.8125	72.6569	White River	Bethel, Vt.	664.05	709.65	525.05	551.90	394.00	411.18	280.03	272.09	199.99	193.78	146.02	144.69
45	1142500	43.9344	72.6583	Ayers Brook	Randolph, Vt.	70.00	79.19	56.00	61.79	44.80	46.33	33.00	31.49	26.00	22.76	19.00	16.64
46	1144000	43.7142	72.4186	White River	West Hartford, Vt.	1710.02	1962.06	1399.91	1538.51	1109.94	1156.75	790.13	774.75	600.07	556.68	440.86	416.21
47	1145000	43.6500	72.0806	Mascoma River	West Canaan, N.H.	172.98	186.21	134.00	147.49	101.00	112.60	68.99	78.90	50.00	58.19	36.00	42.32
48	1150800	43.6733	72.8092	Kent Brook	Sherburne, Vt.	11.00	8.81	8.40	6.78	6.80	5.48	4.98	3.79	2.98	2.81	2.30	2.23
49	1150900	43.6222	72.7594	Ottauquechee River	West Bridgewater, Vt.	61.00	66.57	48.80	51.42	40.00	42.75	31.00	29.62	25.80	22.17	20.12	18.33
50	1153500	43.2086	72.5181	Williams River	Brockways Mills, Vt.	243.00	270.33	194.98	211.72	145.81	161.27	100.00	110.01	75.01	79.99	56.00	59.63
51	1154000	43.1372	72.4881	Saxtons River	Saxtons River, Vt.	166.00	192.49	132.01	150.39	100.00	113.15	68.00	76.65	51.00	55.36	39.00	40.85
52	1155000	43.1317	72.3897	Cold River	Drewsville, N.H.	163.00	198.22	129.99	156.63	97.99	118.78	68.00	82.58	51.00	60.56	38.00	43.99
53	1155200	42.9992	72.5331	Sacketts Brook	Putney, Vt.	26.00	25.08	21.00	19.57	17.00	15.32	12.00	10.68	9.60	7.89	7.50	5.96
54	1155300	43.2364	72.8564	Flood Brook	Londonderry, Vt.	26.00	22.39	20.00	17.51	15.00	13.98	9.60	9.86	6.93	7.37	5.20	5.65
55	1155500	43.1089	72.7758	West River	Jamaica, Vt.	443.81	437.79	338.92	345.90	247.63	272.26	169.98	190.68	122.86	141.70	100.00	107.64
56	1156000	42.9958	72.6389	West River	Newfane, Vt.	800.02	789.80	600.07	622.80	419.95	484.25	280.03	334.66	211.98	246.31	167.84	186.62
57	1158500	42.9653	72.2333	Otter Brook	Keene, N.H.	90.99	98.96	73.81	78.02	58.00	60.30	42.00	42.25	33.00	31.25	26.00	23.10
58	1162500	42.6825	72.1156	Priest Brook	Winchendon, Mass.	36.00	36.52	28.00	29.26	22.00	22.62	15.00	16.51	11.00	12.47	7.98	8.83
59	1165500	42.6028	72.3600	Moss Brook	Wendell Depot, Mass.	26.00	26.54	21.00	20.98	16.00	15.99	12.00	11.33	9.20	8.39	6.70	6.01
60	1167800	42.8606	72.8511	Beaver Brook	Wilmington, Vt.	17.00	15.25	13.00	11.91	10.00	9.17	6.20	6.39	4.48	4.71	3.10	3.48

Appendix 5. Flow-duration statistics estimated using available data and regression equation predicted values for the summer season, June 1 to October 31

[No, number; fig., figure; SUMxx, xx flow duration for summer; --, no data]

Stream-gaging station reference No. (fig. 1)	Stream-gaging station No.	Latitude (decimal degrees)	Longitude (decimal degrees)	River name	Location (fig. 2)	Flow-duration statistics for the summer season, June 1 to October 31											
						SUM60		SUM70		SUM80		SUM90		SUM95		SUM98	
						Database estimate	Predict value	Database estimate	Predict value	Database estimate	Predict value	Database estimate	Predict value	Database estimate	Predict value	Database estimate	Predict value
1	1052500	44.8778	71.0569	Diamond River	Wentworth Location, N.H.	92.00	112.49	71.01	98.60	52.00	79.72	36.00	69.03	28.00	61.87	20.00	58.78
2	1054200	44.3908	70.9797	Wild River	Gilead, Maine	34.00	34.84	27.00	27.85	21.00	24.10	16.00	17.91	13.00	14.89	10.00	11.54
3	1054300	44.5936	70.7336	Ellis River	South Andover, Maine	52.00	55.81	40.00	45.73	32.00	37.43	25.00	28.97	21.00	24.24	18.00	20.72
4	1055000	44.6422	70.5881	Swift River	near Roxbury, Maine	37.00	45.24	28.00	37.47	20.00	33.74	14.00	26.81	11.00	22.73	8.40	19.95
5	1057000	44.3033	70.5394	Little Androscoggin River	near South Paris, Maine	21.00	23.40	15.00	18.07	11.00	13.71	6.90	9.54	4.80	7.49	3.60	5.73
6	1064300	44.2200	71.2500	Ellis River	near Jackson, N.H.	15.00	9.47	13.00	7.98	12.00	7.72	9.60	6.30	8.30	5.43	7.00	4.75
7	1064400	44.0694	71.1750	Lucy Brook	near North Conway, N.H.	2.30	1.22	1.80	0.91	1.40	0.82	0.90	0.54	0.72	0.40	0.57	0.32
8	1064500	43.9908	71.0914	Saco River	near Conway, N.H.	270.02	248.83	223.98	206.86	186.98	183.01	150.00	145.90	128.00	130.43	107.99	101.73
9	1064800	43.8158	71.2975	Cold Brook	South Tamworth, N.H.	0.90	1.93	0.67	1.45	0.45	1.10	0.30	0.73	0.23	0.54	0.14	0.41
10	1072850	43.2631	71.0972	Mohawk River	Center Strafford, N.H.	0.71	1.05	0.48	0.75	0.31	0.56	0.14	0.34	0.08	0.23	0.04	0.18
11	1073000	43.1486	70.9656	Oyster River	Durham, N.H.	1.80	1.38	1.40	0.98	1.10	0.72	0.84	0.44	0.69	0.29	0.56	0.23
12	1073600	42.9936	71.0233	Dudley Brook	Exeter, N.H.	0.21	0.61	0.14	0.43	0.09	0.32	0.05	0.19	0.03	0.12	--	--
13	1074500	44.0600	71.6200	East Branch Pemigewasset	near Lincoln, N.H.	97.01	91.75	81.00	75.78	67.00	74.44	53.00	58.97	46.00	52.79	38.46	39.61
14	1075000	43.9761	71.6800	Pemigewasset River	Woodstock, N.H.	154.99	121.48	126.01	100.38	100.00	93.11	80.00	73.72	71.01	64.92	64.00	51.35
15	1075500	43.8681	71.9097	Baker River	Wentworth, N.H.	25.00	18.08	19.00	14.25	15.00	10.93	9.95	7.88	8.10	6.21	7.20	5.16
16	1075800	43.8367	71.8853	Stevens Brook	Wentworth, N.H.	0.30	0.51	0.20	0.37	0.14	0.31	0.09	0.20	0.05	0.14	--	--
17	1076000	43.7961	71.8450	Baker River	Rumney, N.H.	47.00	56.81	38.00	45.08	30.00	33.11	23.00	24.05	19.00	19.61	17.00	15.24
18	1076500	43.7592	71.6861	Pemigewasset River	Plymouth, N.H.	354.98	296.28	291.00	245.06	235.02	209.11	185.99	165.33	158.02	145.14	133.01	117.12
19	1078000	43.5675	71.7483	Smith River	near Bristol, N.H.	24.00	26.90	20.00	20.81	16.00	16.94	12.00	11.89	9.10	9.42	7.10	7.21
20	1082000	42.8625	71.9597	Contoocook River	Peterborough, N.H.	23.00	17.66	18.00	13.47	14.00	10.77	10.00	7.38	7.81	5.70	5.40	4.37

Appendix 5. Flow-duration statistics estimated using available data and regression equation predicted values for the summer season, June 1 to October 31--Continued

Stream-gaging station reference No. (fig. 1)	Stream-gaging station No.	Latitude (decimal degrees)	Longitude (decimal degrees)	River name	Location (fig. 2)	Flow-duration statistics for the summer season, June 1 to October 31											
						SUM60		SUM70		SUM80		SUM90		SUM95		SUM98	
						Data-base estimate	Predict value	Data-base estimate	Predict value	Data-base estimate	Predict value	Data-base estimate	Predict value	Data-base estimate	Predict value	Data-base estimate	Predict value
21	1084500	43.1142	71.9267	Beards Brook	Hillsboro, N.H.	7.20	10.89	5.30	8.11	3.80	6.37	2.60	4.19	1.70	3.12	1.10	2.38
22	1085800	43.2592	72.0264	West Branch Warner River	near Bradford, N.H.	1.10	1.16	0.79	0.84	0.58	0.52	0.37	0.32	0.28	0.22	0.21	0.17
23	1086000	43.2517	71.7317	Warner River	Davisville, N.H.	28.00	33.38	22.00	25.56	17.00	20.58	11.00	14.23	8.00	11.08	5.90	8.60
24	1089000	43.2394	71.4622	Soucook River	near Concord, N.H.	17.00	14.80	13.00	11.23	10.00	8.50	7.60	5.76	5.70	4.33	4.30	3.49
25	1091000	43.0136	71.6419	South Branch Piscataquog River	near Goffstown, N.H.	19.00	21.20	14.00	16.08	11.00	13.33	7.80	9.09	5.80	6.97	4.50	5.43
26	1093800	42.8600	71.8333	Stony Brook Tributary	near Temple, N.H.	0.79	0.69	0.56	0.50	0.40	0.35	0.26	0.22	0.19	0.15	0.13	0.12
27	10965852	42.7831	71.3539	Beaver Brook	North Pelham, N.H.	11.00	8.12	7.40	5.89	5.10	3.96	2.60	2.45	2.00	1.76	1.40	1.27
28	1097300	42.5108	71.4069	Nashoba Brook	near Acton, Mass.	2.50	1.66	1.70	1.15	1.00	0.66	0.50	0.38	0.26	0.25	0.13	0.18
29	1101000	42.7528	70.9461	Parker River	Byfield, Mass.	3.30	3.22	2.10	2.26	1.10	1.17	0.46	0.67	0.28	0.45	0.14	0.31
30	1127880	45.1350	71.2064	Big Brook	Pittsburg, N.H.	5.40	7.10	4.30	5.91	3.20	3.93	2.20	3.03	1.70	2.52	1.30	2.09
31	1129440	44.8744	71.4106	Mohawk River	near Colebrook, N.H.	24.00	29.72	20.00	24.78	17.00	19.32	12.00	15.24	9.65	13.08	7.98	10.75
32	1130000	44.6250	71.4694	Upper Ammonoosuc River	near Groveton, N.H.	149.00	146.49	123.00	121.30	102.00	98.01	79.00	76.98	67.00	67.33	56.00	53.25
33	1133000	44.6339	71.8981	East Branch Passumpsic	East Haven, Vt.	45.00	36.83	38.00	29.87	32.00	21.26	27.00	15.89	23.00	13.33	20.00	10.19
34	1134500	44.5117	71.8369	Moose River	Victory, Vt	36.00	46.33	27.00	37.37	20.00	27.57	13.00	20.51	10.00	17.17	7.96	13.12
35	1134800	44.4419	71.8792	Kirby Brook	Concord, Vt.	1.81	2.10	1.30	1.60	0.94	1.23	0.64	0.83	0.50	0.61	0.31	0.51
36	1135000	44.4228	72.0006	Moose River	St. Johnsbury, Vt.	47.00	57.68	36.00	46.58	28.00	34.90	20.00	26.14	16.00	21.65	13.00	17.47
37	1135300	44.4344	72.0394	Sleepers River (W-5)	St. Johnsbury, Vt.	20.00	17.41	16.00	14.02	11.00	10.39	7.60	7.73	5.70	6.20	4.10	5.30
38	1137500	44.2689	71.6311	Ammonoosuc River	Bethlehem Junction, N.H.	71.01	57.47	60.01	47.83	50.00	43.26	40.00	34.56	35.00	30.05	31.00	24.95
39	1138000	44.1539	71.9861	Ammonoosuc River	Bath, N.H.	181.01	173.82	149.00	142.62	120.01	119.28	94.99	92.85	82.00	79.85	70.00	65.07
40	1139000	44.1508	72.0653	Wells River	Wells River, Vt.	44.00	38.16	36.00	30.89	29.00	22.39	23.00	16.82	19.00	13.67	16.00	11.65

Appendix 5. Flow-duration statistics estimated using available data and regression equation predicted values for the summer season, June 1 to October 31--Continued

Stream-gaging station reference No. (fig. 1)	Stream-gaging station No.	Latitude (decimal degrees)	Longitude (decimal degrees)	River name	Location (fig. 2)	Flow-duration statistics for the summer season, June 1 to October 31											
						SUM60		SUM70		SUM80		SUM90		SUM95		SUM98	
						Data-base estimate	Predict value	Data-base estimate	Predict value	Data-base estimate	Predict value	Data-base estimate	Predict value	Data-base estimate	Predict value	Data-base estimate	Predict value
41	1139800	44.0928	72.3361	East Orange Branch	East Orange, Vt.	3.70	4.10	2.90	3.24	2.20	1.93	1.60	1.36	1.10	1.04	0.79	0.87
42	1140000	44.0181	72.2083	South Branch Waits River	near Bradford, Vt.	16.00	15.95	13.00	12.57	11.00	9.00	7.80	6.45	6.60	5.07	5.51	4.13
43	1141800	43.7022	72.1875	Mink Brook	Etna, N.H.	0.73	0.87	0.48	0.64	0.30	0.48	0.17	0.31	0.11	0.21	0.06	0.17
44	1142000	43.8125	72.6569	White River	Bethel, Vt.	108.99	97.30	89.00	79.15	71.01	58.41	55.00	44.33	47.00	36.97	41.00	30.52
45	1142500	43.9344	72.6583	Ayers Brook	Randolph, Vt.	8.40	8.55	8.40	6.75	6.20	4.55	4.40	3.26	3.40	2.48	2.40	2.19
46	1144000	43.7142	72.4186	White River	West Hartford, Vt.	270.02	299.23	223.00	246.70	179.02	185.34	140.99	144.30	118.99	124.48	100.00	101.40
47	1145000	43.6500	72.0806	Mascoma River	West Canaan, N.H.	20.00	22.76	15.00	17.74	12.00	14.45	8.10	10.28	6.30	8.09	5.10	6.51
48	1150800	43.6733	72.8092	Kent Brook	Sherburne, Vt.	2.00	1.57	1.60	1.19	1.30	0.82	1.00	0.54	0.79	0.40	0.58	0.30
49	1150900	43.6222	72.7594	Ottauquechee River	West Bridgewater, Vt.	15.00	12.53	12.00	9.83	9.50	7.07	6.80	5.00	5.30	3.99	4.30	3.00
50	1153500	43.2086	72.5181	Williams River	Brockways Mills, Vt.	24.00	30.12	20.00	23.51	16.00	17.95	11.00	12.73	9.00	10.05	7.30	7.99
51	1154000	43.1372	72.4881	Saxtons River	Saxtons River, Vt.	16.00	22.76	13.00	17.82	10.00	13.99	7.20	9.99	5.65	7.90	4.60	6.34
52	1155000	43.1317	72.3897	Cold River	Drewsville, N.H.	16.00	16.04	12.00	12.14	9.40	9.82	7.20	6.66	5.88	5.04	4.53	3.99
53	1155200	42.9992	72.5331	Sacketts Brook	Putney, Vt.	3.20	1.83	2.70	1.36	2.10	0.92	1.50	0.60	1.20	0.42	1.00	0.35
54	1155300	43.2364	72.8564	Flood Brook	Londonderry, Vt.	2.70	3.48	2.00	2.68	1.50	2.00	0.96	1.38	0.67	1.05	0.51	0.83
55	1155500	43.1089	72.7758	West River	Jamaica, Vt.	37.00	95.02	28.00	77.19	22.00	62.30	15.00	47.40	13.00	40.40	9.99	31.44
56	1156000	42.9958	72.6389	West River	Newfane, Vt.	80.00	152.86	64.00	125.94	50.00	102.04	36.00	79.68	29.00	68.74	24.00	55.81
57	1158500	42.9653	72.2333	Otter Brook	Keene, N.H.	11.00	9.98	8.40	7.61	6.60	5.82	4.44	3.97	3.00	3.00	2.00	2.40
58	1162500	42.6825	72.1156	Priest Brook	Winchendon, Mass.	3.90	3.75	2.70	2.81	1.90	2.20	1.10	1.46	0.72	1.07	0.45	0.87
59	1165500	42.6028	72.3600	Moss Brook	Wendell Depot, Mass.	2.80	1.85	2.10	1.34	1.60	1.17	1.20	0.73	0.90	0.52	0.70	0.40
60	1167800	42.8606	72.8511	Beaver Brook	Wilmington, Vt.	1.50	2.33	1.10	1.73	0.68	1.33	0.43	0.86	0.30	0.64	0.23	0.46

Appendix 6. Flow-duration statistics estimated using available data and regression equation predicted values for the fall season, November 1 to December 31

[No., number; fig., figure; FALxx, xx flow duration for fall]

Stream-gaging station reference No. (fig. 1)	Stream-gaging station No.	Latitude (decimal degrees)	Longitude (decimal degrees)	River name	Location (fig. 2)	Flow-duration statistics for the fall season, November 1 to December 31											
						FAL60		FAL70		FAL80		FAL90		FAL95		FAL98	
						Data-base estimate	Predict value	Data-base estimate	Predict value	Data-base estimate	Predict value	Data-base estimate	Predict value	Data-base estimate	Predict value	Data-base estimate	Predict value
1	1052500	44.8778	71.0569	Diamond River	Wentworth Location, N.H.	163.00	145.17	142.00	119.99	116.01	96.01	86.00	71.69	67.00	57.44	56.00	45.76
2	1054200	44.3908	70.9797	Wild River	Gilead, Maine	81.00	71.64	68.00	59.37	53.00	48.21	38.00	35.96	28.00	28.30	18.00	22.37
3	1054300	44.5936	70.7336	Ellis River	South Andover, Maine	127.00	125.02	110.00	103.08	89.99	82.43	60.01	61.29	41.00	48.76	28.00	38.66
4	1055000	44.6422	70.5881	Swift River	near Roxbury, Maine	90.99	90.65	77.00	73.27	62.00	57.43	42.00	41.51	31.00	32.01	22.00	24.73
5	1057000	44.3033	70.5394	Little Androscoggin River	near South Paris, Maine	67.00	66.88	54.00	53.71	41.00	41.58	26.04	29.74	17.00	22.59	10.00	16.77
6	1064300	44.2200	71.2500	Ellis River	near Jackson, N.H.	17.00	12.09	15.00	9.95	13.00	8.18	10.00	5.98	8.60	4.43	7.00	3.32
7	1064400	44.0694	71.1750	Lucy Brook	near North Conway, N.H.	5.50	4.83	4.60	3.79	3.90	2.94	2.40	2.00	1.60	1.37	1.02	0.93
8	1064500	43.9908	71.0914	Saco River	near Conway, N.H.	458.99	386.23	386.81	328.71	309.17	272.05	229.99	212.37	182.01	180.56	153.99	156.64
9	1064800	43.8158	71.2975	Cold Brook	South Tamworth, N.H.	5.34	5.67	4.20	4.53	3.40	3.58	2.40	2.50	1.36	1.76	1.00	1.20
10	1072850	43.2631	71.0972	Mohawk River	Center Strafford, N.H.	6.20	6.24	3.82	4.66	2.70	3.35	1.80	2.15	0.85	1.41	0.50	0.88
11	1073000	43.1486	70.9656	Oyster River	Durham, N.H.	9.89	7.64	7.00	5.26	4.50	3.37	2.80	1.94	1.90	1.17	1.30	0.65
12	1073600	42.9936	71.0233	Dudley Brook	Exeter, N.H.	2.50	3.41	1.60	2.26	1.00	1.38	0.52	0.75	0.37	0.43	0.23	0.22
13	1074500	44.0600	71.6200	East Branch Pemigewasset	near Lincoln, N.H.	139.99	103.76	115.00	84.72	89.99	67.47	68.00	49.46	55.00	38.69	45.00	30.79
14	1075000	43.9761	71.6800	Pemigewasset River	Woodstock, N.H.	251.19	189.28	208.69	156.78	169.98	126.21	129.99	94.62	110.00	76.50	84.37	62.84
15	1075500	43.8681	71.9097	Baker River	Wentworth, N.H.	52.00	62.49	42.00	52.91	33.00	44.11	24.00	33.83	16.00	27.17	11.66	21.70
16	1075800	43.8367	71.8853	Stevens Brook	Wentworth, N.H.	2.10	3.59	1.60	2.86	1.20	2.27	0.82	1.58	0.50	1.10	0.27	0.74
17	1076000	43.7961	71.8450	Baker River	Rumney, N.H.	115.00	150.62	94.99	129.24	78.00	108.49	60.01	85.13	46.00	71.14	34.00	59.19
18	1076500	43.7592	71.6861	Pemigewasset River	Plymouth, N.H.	679.99	591.51	560.02	500.67	451.96	408.80	348.74	317.68	274.85	271.83	219.99	236.16
19	1078000	43.5675	71.7483	Smith River	near Bristol, N.H.	70.00	78.00	57.00	62.63	45.00	48.54	32.00	34.74	26.00	26.50	22.00	19.95
20	1082000	42.8625	71.9597	Contoocook River	Peterborough, N.H.	56.00	63.39	43.00	51.39	33.00	40.43	23.00	29.28	17.00	22.43	12.00	16.97

Appendix 6. Flow-duration statistics estimated using available data and regression equation predicted values for the fall season, November 1 to December 31--Continued

Stream-gaging station reference No. (fig. 1)	Stream-gaging station No.	Latitude (decimal degrees)	Longitude (decimal degrees)	River name	Location (fig. 2)	Flow-duration statistics for the fall season, November 1 to December 31: FAL60 Data-base estimate	FAL60 Predict value	FAL70 Data-base estimate	FAL70 Predict value	FAL80 Data-base estimate	FAL80 Predict value	FAL90 Data-base estimate	FAL90 Predict value	FAL95 Data-base estimate	FAL95 Predict value	FAL98 Data-base estimate	FAL98 Predict value
21	1084500	43.1142	71.9267	Beards Brook	Hillsboro, N.H.	43.00	50.04	28.00	39.86	20.20	30.67	14.00	21.66	7.70	16.17	4.35	11.83
22	1085800	43.2592	72.0264	West Branch Warner River	near Bradford, N.H.	6.00	6.56	5.00	5.43	3.60	4.46	2.30	3.27	1.80	2.41	1.20	1.68
23	1086000	43.2517	71.7317	Warner River	Davisville, N.H.	105.00	127.87	77.00	102.69	58.00	79.15	41.00	56.84	31.00	43.98	19.00	33.61
24	1089000	43.2394	71.4622	Soucook River	near Concord, N.H.	65.99	62.12	51.00	47.99	35.00	35.26	20.00	23.95	15.00	17.41	9.74	12.22
25	1091000	43.0136	71.6419	South Branch Piscataquog River	near Goffstown, N.H.	80.00	84.41	62.99	65.74	42.00	48.87	28.00	33.61	20.00	24.85	14.00	18.03
26	1093800	42.8600	71.8333	Stony Brook Tributary	near Temple, N.H.	4.00	3.84	3.00	3.08	2.23	2.44	1.30	1.71	0.87	1.19	0.54	0.80
27	10965852	42.7831	71.3539	Beaver Brook	North Pelham, N.H.	50.00	32.97	37.00	24.25	26.00	16.68	18.00	10.58	13.00	7.16	11.00	4.53
28	1097300	42.5108	71.4069	Nashoba Brook	near Acton, Mass.	10.00	9.21	8.10	6.76	6.00	4.67	4.00	2.93	2.60	1.91	1.10	1.13
29	1101000	42.7528	70.9461	Parker River	Byfield, Mass.	20.00	14.59	15.00	10.73	10.00	7.37	5.80	4.65	3.10	3.08	1.30	1.84
30	1127880	45.1350	71.2064	Big Brook	Pittsburg, N.H.	8.00	7.49	6.80	6.26	5.90	5.22	4.70	3.88	4.07	2.90	3.70	2.08
31	1129440	44.8744	71.4106	Mohawk River	near Colebrook, N.H.	42.00	35.94	37.00	29.54	33.00	23.79	27.00	17.49	24.00	13.39	22.00	10.08
32	1130000	44.6250	71.4694	Upper Ammonoosuc River	near Groveton, N.H.	247.17	221.30	209.99	184.96	174.98	149.65	138.80	113.68	112.80	93.31	89.99	76.62
33	1133000	44.6339	71.8981	East Branch Passumpsic	East Haven, Vt.	62.00	52.60	55.00	43.91	49.00	35.84	42.00	26.95	36.00	21.21	31.00	16.34
34	1134500	44.5117	71.8369	Moose River	Victory, Vt.	76.00	75.15	64.00	62.56	53.00	50.75	39.00	38.11	31.00	30.21	25.00	23.56
35	1134800	44.4419	71.8792	Kirby Brook	Concord, Vt.	5.48	8.21	4.50	6.53	3.80	5.11	2.71	3.56	2.20	2.52	1.64	1.73
36	1135000	44.4228	72.0006	Moose River	St. Johnsbury, Vt.	105.00	124.89	88.00	103.90	71.99	83.81	56.00	63.06	46.00	50.68	38.00	40.22
37	1135300	44.4344	72.0394	Sleepers River (W-5)	St. Johnsbury, Vt.	40.94	40.53	36.40	32.84	31.00	25.84	26.00	18.64	21.00	14.10	18.00	10.38
38	1137500	44.2689	71.6311	Ammonoosuc River	Bethlehem Junction, N.H.	108.99	94.15	93.99	79.23	79.00	65.61	62.00	50.02	53.00	40.34	45.00	33.02
39	1138000	44.1539	71.9861	Ammonoosuc River	Bath, N.H.	334.97	405.20	280.03	348.45	234.21	291.76	180.01	230.99	139.99	198.93	120.01	174.18
40	1139000	44.1508	72.0653	Wells River	Wells River, Vt.	81.00	97.59	68.99	81.48	57.00	66.14	44.00	49.94	37.00	40.01	31.00	31.54

Appendix 6. Flow-duration statistics estimated using available data and regression equation predicted values for the fall season, November 1 to December 31--Continued

Stream-gaging station reference No. (fig. 1)	Stream-gaging station No.	Latitude (decimal degrees)	Longitude (decimal degrees)	River name	Location (fig. 2)	Flow-duration statistics for the fall season, November 1 to December 31											
						FAL60		FAL70		FAL80		FAL90		FAL95		FAL98	
						Data-base estimate	Predict value	Data-base estimate	Predict value	Data-base estimate	Predict value	Data-base estimate	Predict value	Data-base estimate	Predict value	Data-base estimate	Predict value
41	1139800	44.0928	72.3361	East Orange Branch	East Orange, Vt.	8.60	9.68	7.00	8.08	5.60	6.66	3.80	4.96	2.80	3.72	2.30	2.65
42	1140000	44.0181	72.2083	South Branch Waits River	near Bradford, Vt.	34.80	41.47	28.00	33.61	24.00	26.42	19.00	19.07	15.00	14.44	12.44	10.60
43	1141800	43.7022	72.1875	Mink Brook	Etna, N.H.	3.60	4.84	2.80	3.82	2.10	2.98	1.20	2.05	0.66	1.42	0.50	0.95
44	1142000	43.8125	72.6569	White River	Bethel, Vt.	249.98	231.80	219.99	195.52	181.01	159.57	129.99	122.75	109.24	101.95	89.00	83.97
45	1142500	43.9344	72.6583	Ayers Brook	Randolph, Vt.	25.00	29.81	20.00	24.34	17.00	19.35	12.00	14.08	9.60	10.65	7.40	7.76
46	1144000	43.7142	72.4186	White River	West Hartford, Vt.	617.59	629.84	505.01	532.33	400.04	431.26	312.03	334.69	260.02	286.64	203.56	244.95
47	1145000	43.6500	72.0806	Mascoma River	West Canaan, N.H.	55.00	75.62	45.00	61.35	36.00	48.24	26.00	34.99	20.00	26.96	15.00	20.57
48	1150800	43.6733	72.8092	Kent Brook	Sherburne, Vt.	5.58	4.00	4.46	3.35	3.80	2.82	3.30	2.09	2.80	1.54	2.30	1.09
49	1150900	43.6222	72.7594	Ottauquechee River	West Bridgewater, Vt.	34.00	26.07	28.80	22.02	24.00	18.42	19.00	14.01	17.00	10.95	15.00	8.40
50	1153500	43.2086	72.5181	Williams River	Brockways Mills, Vt.	68.00	94.89	52.00	77.37	40.00	60.95	29.00	44.58	24.00	34.77	18.00	26.69
51	1154000	43.1372	72.4881	Saxtons River	Saxtons River, Vt.	50.00	67.32	39.00	54.52	28.00	42.76	21.00	30.93	17.00	23.71	11.00	17.89
52	1155000	43.1317	72.3897	Cold River	Drewsville, N.H.	50.00	70.80	40.00	55.63	30.00	41.90	20.00	29.13	14.00	21.64	8.28	15.75
53	1155200	42.9992	72.5331	Sacketts Brook	Putney, Vt.	6.96	9.55	5.40	7.52	4.24	5.76	3.30	3.97	2.10	2.79	1.20	1.87
54	1155300	43.2364	72.8564	Flood Brook	Londonderry, Vt.	11.98	10.12	9.50	8.30	7.00	6.73	4.84	4.89	3.90	3.60	1.44	2.58
55	1155500	43.1089	72.7758	West River	Jamaica, Vt.	148.01	169.58	110.51	140.70	86.00	113.05	62.50	84.92	50.00	68.62	38.00	55.32
56	1156000	42.9958	72.6389	West River	Newfane, Vt.	245.81	285.57	204.08	237.80	166.99	190.95	125.00	144.58	106.00	119.06	83.00	98.11
57	1158500	42.9653	72.2333	Otter Brook	Keene, N.H.	30.00	37.60	23.00	29.77	16.00	22.77	10.00	15.93	7.30	11.73	4.97	8.39
58	1162500	42.6825	72.1156	Priest Brook	Winchendon, Mass.	18.00	16.99	14.00	13.19	10.00	9.91	6.37	6.72	3.69	4.73	2.00	3.22
59	1165500	42.6028	72.3600	Moss Brook	Wendell Depot, Mass.	9.00	10.24	7.00	7.66	5.00	5.52	3.50	3.55	2.50	2.37	1.70	1.53
60	1167800	42.8606	72.8511	Beaver Brook	Wilmington, Vt.	9.00	6.42	7.30	5.08	5.40	3.96	3.65	2.74	1.78	1.91	0.58	1.29

Appendix 7. Low-flow statistics estimated using available data and regression equation predicted values for annual and seasonal periods

[No., number; fig., figure; 7Q2, 7-day, 2-year low flow; 7Q10, 7-day, 10-year low flow, values are in cubic foot per second; yr, year; win, winter; spr, spring; sum, summer; fal, fall; --, no data]

Stream-gaging station reference No. (fig. 1)	Stream-gaging station No.	Latitude (decimal degrees)	Longitude (decimal degrees)	River name	Location (fig. 2)	7Q2 yr		7Q10 yr		7Q2 win	
						Database estimate	Predict value	Database estimate	Predict value	Database estimate	Predict value
1	1052500	44.8778	71.0569	Diamond River	Wentworth Location, N.H.	33.49	56.91	16.19	47.35	61.81	84.64
2	1054200	44.3908	70.9797	Wild River	Gilead, Maine	14.96	17.88	9.46	12.01	38.17	38.51
3	1054300	44.5936	70.7336	Ellis River	South Andover, Maine	22.26	28.60	14.29	19.84	63.08	64.97
4	1055000	44.6422	70.5881	Swift River	near Roxbury, Maine	12.53	25.41	7.13	18.18	38.35	45.02
5	1057000	44.3033	70.5394	Little Androscoggin River	near South Paris, Maine	6.92	11.19	2.49	6.53	44.41	41.35
6	1064300	44.2200	71.2500	Ellis River	near Jackson, N.H.	6.70	4.49	3.83	3.02	7.07	7.40
7	1064400	44.0694	71.1750	Lucy Brook	near North Conway, N.H.	1.00	0.57	0.56	0.25	2.35	2.38
8	1064500	43.9908	71.0914	Saco River	near Conway, N.H.	142.00	132.98	96.75	112.27	254.09	249.65
9	1064800	43.8158	71.2975	Cold Brook	South Tamworth, N.H.	0.34	0.80	0.14	0.37	2.29	3.86
10	1072850	43.2631	71.0972	Mohawk River	Center Strafford, N.H.	0.09	0.41	0.01	0.15	3.89	3.98
11	1073000	43.1486	70.9656	Oyster River	Durham, N.H.	0.90	0.52	0.51	0.18	6.99	6.31
12	1073600	42.9936	71.0233	Dudley Brook	Exeter, N.H.	0.05	0.22	0.01	0.07	--	--
13	1074500	44.0600	71.6200	East Branch Pemigewasset	near Lincoln, N.H.	47.36	51.02	26.71	41.91	66.41	59.32
14	1075000	43.9761	71.6800	Pemigewasset River	Woodstock, N.H.	73.81	63.91	56.04	50.23	112.72	103.11
15	1075500	43.8681	71.9097	Baker River	Wentworth, N.H.	9.99	7.57	6.05	4.20	28.55	25.32
16	1075800	43.8367	71.8853	Stevens Brook	Wentworth, N.H.	0.08	0.20	0.02	0.07	0.86	1.27
17	1076000	43.7961	71.8450	Baker River	Rumney, N.H.	21.62	24.65	14.88	15.76	66.36	68.45
18	1076500	43.7592	71.6861	Pemigewasset River	Plymouth, N.H.	179.36	151.12	118.40	121.23	363.84	412.65
19	1078000	43.5675	71.7483	Smith River	near Bristol, N.H.	10.94	12.60	6.16	7.35	42.73	45.99
20	1082000	42.8625	71.9597	Contoocook River	Peterborough, N.H.	10.84	7.34	6.31	3.85	51.87	38.03
21	1084500	43.1142	71.9267	Beards Brook	Hillsboro, N.H.	2.44	4.74	0.95	2.29	29.50	32.54
22	1085800	43.2592	72.0264	West Branch Warner River	near Bradford, N.H.	0.41	0.36	0.18	0.13	3.03	3.64
23	1086000	43.2517	71.7317	Warner River	Davisville, N.H.	11.34	15.54	5.28	8.70	88.86	86.40
24	1089000	43.2394	71.4622	Soucook River	near Concord, N.H.	6.67	6.39	3.58	3.18	44.95	39.06
25	1091000	43.0136	71.6419	South Branch Piscataquog River	near Goffstown, N.H.	8.67	9.71	4.33	5.10	70.89	57.04
26	1093800	42.8600	71.8333	Stony Brook Tributary	near Temple, N.H.	0.28	0.22	0.11	0.08	2.28	2.15
27	10965852	42.7831	71.3539	Beaver Brook	North Pelham, N.H.	3.48	3.12	1.37	1.37	40.24	31.03
28	1097300	42.5108	71.4069	Nashoba Brook	near Acton, Mass.	0.65	0.52	0.12	0.18	9.52	9.68
29	1101000	42.7528	70.9461	Parker River	Byfield, Mass.	0.71	0.93	0.15	0.34	20.88	19.01
30	1127880	45.1350	71.2064	Big Brook	Pittsburg, N.H.	1.62	3.08	1.12	2.05	2.34	3.52

Appendix 7. Low-flow statistics estimated using available data and regression equation predicted values for annual and seasonal periods--Continued

Stream-gaging station reference No. (fig. 1)	Stream-gaging station No.	Latitude (decimal degrees)	Longitude (decimal degrees)	River name	Location (fig. 2)	7Q2 yr		7Q10 yr		7Q2 win	
						Database estimate	Predict value	Database estimate	Predict value	Database estimate	Predict value
31	1129440	44.8744	71.4106	Mohawk River	near Colebrook, N.H.	12.76	14.22	7.38	10.37	19.47	17.34
32	1130000	44.6250	71.4694	Upper Ammonoosuc River	near Groveton, N.H.	70.49	76.32	49.14	61.37	113.14	111.41
33	1133000	44.6339	71.8981	East Branch Passumpsic	East Haven, Vt.	24.34	17.70	17.57	12.63	34.39	26.23
34	1134500	44.5117	71.8369	Moose River	Victory, Vt.	11.06	22.10	5.92	15.54	34.63	41.41
35	1134800	44.4419	71.8792	Kirby Brook	Concord, Vt.	0.71	0.93	0.13	0.42	2.79	3.29
36	1135000	44.4228	72.0006	Moose River	St. Johnsbury, Vt.	16.46	27.75	10.12	18.93	48.38	65.91
37	1135300	44.4344	72.0394	Sleepers River (W-5)	St. Johnsbury, Vt.	8.39	7.86	4.08	4.73	25.75	19.85
38	1137500	44.2689	71.6311	Ammonoosuc River	Bethlehem Junction, N.H.	36.22	28.45	27.56	20.99	50.90	54.74
39	1138000	44.1539	71.9861	Ammonoosuc River	Bath, N.H.	84.97	89.55	63.60	68.05	167.91	184.31
40	1139000	44.1508	72.0653	Wells River	Wells River, Vt.	21.84	16.59	13.94	10.41	45.13	47.03
41	1139800	44.0928	72.3361	East Orange Branch	East Orange, Vt.	1.60	1.30	0.60	0.64	4.96	4.84
42	1140000	44.0181	72.2083	South Branch Waits River	near Bradford, Vt.	6.27	6.88	4.72	3.92	23.45	20.96
43	1141800	43.7022	72.1875	Mink Brook	Etna, N.H.	0.18	0.34	0.04	0.13	1.68	2.06
44	1142000	43.8125	72.6569	White River	Bethel, Vt.	54.63	42.60	35.64	29.06	156.21	154.46
45	1142500	43.9344	72.6583	Ayers Brook	Randolph, Vt.	4.73	3.08	2.00	1.52	16.77	16.54
46	1144000	43.7142	72.4186	White River	West Hartford, Vt.	141.78	142.49	89.81	110.80	384.08	417.75
47	1145000	43.6500	72.0806	Mascoma River	West Canaan, N.H.	7.64	10.36	4.38	5.85	31.16	36.92
48	1150800	43.6733	72.8092	Kent Brook	Sherburne, Vt.	0.93	0.55	0.51	0.25	2.36	1.94
49	1150900	43.6222	72.7594	Ottauquechee River	West Bridgewater, Vt.	6.78	5.01	3.88	2.89	15.80	14.28
50	1153500	43.2086	72.5181	Williams River	Brockways Mills, Vt.	10.98	13.49	5.98	7.82	49.79	59.01
51	1154000	43.1372	72.4881	Saxtons River	Saxtons River, Vt.	6.93	9.93	3.87	5.65	39.03	41.59
52	1155000	43.1317	72.3897	Cold River	Drewsville, N.H.	6.90	7.32	4.18	3.72	37.02	40.03
53	1155200	42.9992	72.5331	Sacketts Brook	Putney, Vt.	1.76	0.66	0.90	0.26	6.15	5.76
54	1155300	43.2364	72.8564	Flood Brook	Londonderry, Vt.	0.78	1.26	0.34	0.59	5.22	5.40
55	1155500	43.1089	72.7758	West River	Jamaica, Vt.	10.52	42.32	7.18	30.05	101.95	108.62
56	1156000	42.9958	72.6389	West River	Newfane, Vt.	31.11	67.95	18.93	49.95	162.56	191.58
57	1158500	42.9653	72.2333	Otter Brook	Keene, N.H.	4.53	4.01	1.84	1.96	21.11	22.73
58	1162500	42.6825	72.1156	Priest Brook	Winchendon, Mass.	1.28	1.49	0.42	0.64	12.14	9.82
59	1165500	42.6028	72.3600	Moss Brook	Wendell Depot, Mass.	1.19	0.86	0.62	0.34	6.78	5.27
60	1167800	42.8606	72.8511	Beaver Brook	Wilmington, Vt.	0.52	0.94	0.16	0.43	3.83	3.77

Appendix 7. Low-flow statistics estimated using available data and regression equation predicted values for annual and seasonal periods--Continued

Stream-gaging station reference No. (fig. 1)	7Q10 win		7Q2 spr		7Q10 spr		7Q2 sum		7Q10 sum		7Q2 fal		7Q10 fal	
	Database estimate	Predict value	Database estimate	Predict value	Database estimate	Predict value	Database estimate	Predict value	Database estimate	Predict value	Database estimate	Predict value	Database estimate	Predict value
1	42.13	51.85	82.31	99.64	48.51	56.60	34.08	60.06	16.14	50.07	106.06	97.26	62.78	53.97
2	21.23	23.56	53.82	50.05	25.79	28.86	15.13	18.05	9.39	12.16	54.24	48.69	25.50	27.70
3	32.94	39.43	89.99	95.97	40.36	55.61	22.26	27.89	14.29	19.03	87.45	83.67	41.42	46.26
4	22.81	27.44	52.44	66.21	27.37	38.15	12.52	25.18	7.12	17.79	59.34	59.29	29.10	31.11
5	16.75	24.76	55.44	57.62	26.53	33.27	7.05	10.11	2.68	5.71	41.13	42.07	15.03	20.90
6	3.93	4.54	8.55	7.44	4.49	4.24	9.04	5.78	6.40	4.20	12.37	8.15	7.30	4.60
7	1.26	1.37	3.70	3.23	1.77	1.81	0.98	0.59	0.54	0.26	3.49	2.94	1.23	1.38
8	167.04	161.75	335.32	320.15	207.31	192.78	144.64	139.93	97.37	119.48	317.01	278.83	171.22	175.12
9	1.76	2.24	3.29	4.39	2.09	2.48	0.34	0.80	0.14	0.37	2.64	3.48	1.02	1.70
10	2.42	2.26	4.61	5.46	1.90	3.05	0.09	0.40	0.01	0.14	2.24	3.40	0.50	1.31
11	3.09	3.60	9.12	8.83	4.75	4.94	0.90	0.51	0.51	0.18	4.67	3.59	1.61	1.03
12	--	--	--	--	--	--	0.05	0.22	0.01	0.07	1.07	1.49	0.26	0.37
13	32.67	37.54	69.19	78.85	37.99	46.47	50.83	57.07	35.03	48.66	86.59	70.13	49.06	38.78
14	72.19	65.05	137.38	151.29	81.35	89.88	75.77	70.80	57.11	57.30	163.36	130.55	98.30	75.13
15	14.00	14.73	37.08	37.17	19.14	20.79	10.04	8.02	6.01	4.52	33.62	43.31	15.16	25.98
16	0.32	0.69	--	--	--	--	0.08	0.22	0.02	0.08	1.14	2.22	0.38	1.09
17	40.85	40.64	94.57	115.75	54.66	67.51	21.62	24.68	14.88	15.75	74.04	106.70	38.51	66.54
18	223.93	269.03	495.56	471.02	269.25	279.90	180.97	158.74	119.80	128.28	466.50	421.54	255.04	258.13
19	22.61	27.89	61.03	64.93	33.17	37.63	11.01	12.53	6.21	7.30	42.57	49.65	21.37	25.01
20	27.19	23.01	66.62	50.70	38.80	29.28	10.84	7.91	6.31	4.26	34.54	40.92	15.34	21.26
21	14.61	19.63	38.42	41.93	20.73	24.14	2.44	4.63	0.95	2.22	21.17	31.18	5.50	15.17
22	1.51	2.00	4.45	4.77	2.09	2.64	0.40	0.37	0.18	0.14	3.74	4.17	1.46	2.20
23	44.98	53.49	117.07	106.71	58.11	61.84	11.35	15.14	5.28	8.39	59.27	81.55	19.58	41.07
24	18.63	23.18	58.12	52.42	30.71	29.61	6.67	6.17	3.58	3.03	33.89	36.43	10.99	15.81
25	33.75	35.02	84.77	73.55	45.24	42.44	8.67	9.76	4.33	5.13	43.46	51.06	16.67	23.21
26	1.15	1.19	3.13	2.76	1.72	1.53	0.27	0.25	0.11	0.09	2.42	2.34	0.79	1.13
27	23.16	18.31	39.24	38.53	24.10	22.04	3.48	2.86	1.37	1.22	26.35	17.31	10.71	6.17
28	4.00	5.47	10.51	10.93	5.75	6.13	0.65	0.47	0.12	0.16	5.94	4.66	1.73	1.60
29	7.82	10.84	24.08	20.43	12.53	11.63	0.71	0.83	0.15	0.29	9.35	7.31	2.18	2.48
30	1.48	1.93	3.05	4.75	1.55	2.61	1.96	2.92	1.14	1.91	5.40	4.89	3.83	2.71
31	13.72	10.11	24.12	23.83	14.71	13.36	12.90	14.53	7.43	10.65	29.52	23.55	22.48	12.72
32	69.64	68.04	147.64	156.10	78.97	89.69	73.28	74.39	50.14	59.04	173.02	151.89	104.35	87.87
33	23.45	15.22	40.69	36.76	25.94	20.72	25.13	15.98	17.68	11.04	46.64	35.03	31.99	19.66
34	19.30	24.59	45.63	53.27	24.52	30.21	11.09	20.71	5.92	14.26	50.41	50.19	27.62	28.11
35	1.72	1.82	3.98	4.60	2.39	2.47	0.71	0.88	0.13	0.40	3.69	5.03	1.77	2.42

Appendix 7. Low-flow statistics estimated using available data and regression equation predicted values for annual and seasonal periods--Continued

Stream-gaging station reference No. (fig. 1)	7Q10 win		7Q2 spr		7Q10 spr		7Q2 sum		7Q10 sum		7Q2 fal		7Q10 fal	
	Database estimate	Predict value	Database estimate	Predict value	Database estimate	Predict value	Database estimate	Predict value	Database estimate	Predict value	Database estimate	Predict value	Database estimate	Predict value
36	26.33	39.44	67.90	85.07	33.97	48.04	16.66	26.04	10.12	17.32	70.06	83.78	42.45	47.00
37	17.07	11.46	27.89	26.94	17.63	14.92	8.39	7.64	4.08	4.53	27.20	25.70	18.95	13.08
38	34.58	34.33	64.02	56.05	37.64	31.89	38.47	32.64	27.82	25.06	75.34	66.28	48.81	40.09
39	93.01	114.29	234.10	244.92	114.97	140.00	87.16	89.95	63.79	67.90	224.02	295.67	128.81	190.67
40	25.96	27.59	66.28	61.28	32.74	34.06	22.14	16.55	14.01	10.31	56.99	65.46	32.79	36.94
41	2.28	2.64	6.98	6.54	3.23	3.58	1.60	1.40	0.60	0.71	6.05	6.21	2.59	3.35
42	14.63	12.07	28.16	28.39	16.40	15.74	6.27	6.61	4.72	3.71	23.20	26.19	12.51	13.27
43	0.74	1.13	2.56	2.97	1.19	1.61	0.18	0.34	0.04	0.13	2.21	2.91	0.72	1.36
44	100.82	95.67	218.38	183.03	125.32	106.36	54.76	43.61	36.05	29.75	164.11	159.60	93.01	93.79
45	9.39	9.46	25.05	21.82	13.59	12.18	4.83	3.29	2.01	1.66	17.87	18.87	8.41	9.70
46	231.85	263.94	582.88	521.70	330.95	306.67	140.21	139.93	89.71	107.13	418.88	438.88	219.91	260.92
47	17.39	22.00	46.91	54.34	25.94	30.92	7.64	10.63	4.38	6.04	35.37	49.03	16.27	25.60
48	1.62	1.07	3.26	2.61	1.78	1.45	0.93	0.60	0.51	0.28	3.27	2.63	2.32	1.48
49	12.10	8.33	20.26	20.63	12.38	11.95	6.78	5.24	3.81	3.09	19.79	17.71	13.69	10.39
50	24.82	35.75	75.26	76.92	38.00	44.36	10.91	13.23	5.96	7.60	41.77	61.53	19.56	32.31
51	17.95	25.13	55.14	53.78	29.22	30.94	6.90	10.30	3.87	5.92	32.54	43.22	13.86	22.26
52	16.22	23.99	51.65	57.00	28.59	32.51	6.90	7.16	4.18	3.60	30.57	43.31	12.15	20.21
53	2.78	3.24	9.60	7.27	5.23	4.02	1.76	0.66	0.90	0.26	4.32	5.64	1.67	2.56
54	2.91	3.10	7.02	7.16	4.10	4.03	0.78	1.46	0.34	0.73	6.52	6.52	1.97	3.46
55	54.38	67.62	131.38	143.65	91.17	84.70	10.52	47.01	7.18	34.45	86.53	114.75	39.11	64.71
56	94.53	121.05	221.13	246.31	136.54	146.00	31.11	77.02	18.93	58.57	157.42	195.14	82.83	111.58
57	8.06	13.43	31.41	30.25	19.52	17.18	4.67	4.23	1.87	2.11	15.99	23.02	5.56	10.91
58	5.29	5.70	12.60	13.14	6.47	7.37	1.28	1.59	0.42	0.70	11.11	10.03	3.17	4.45
59	2.80	3.05	9.88	7.96	5.18	4.45	1.18	0.84	0.62	0.34	5.37	5.74	2.23	2.28
60	1.79	2.16	4.91	5.41	2.21	3.09	0.52	0.97	0.16	0.46	5.63	3.89	1.45	1.84

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