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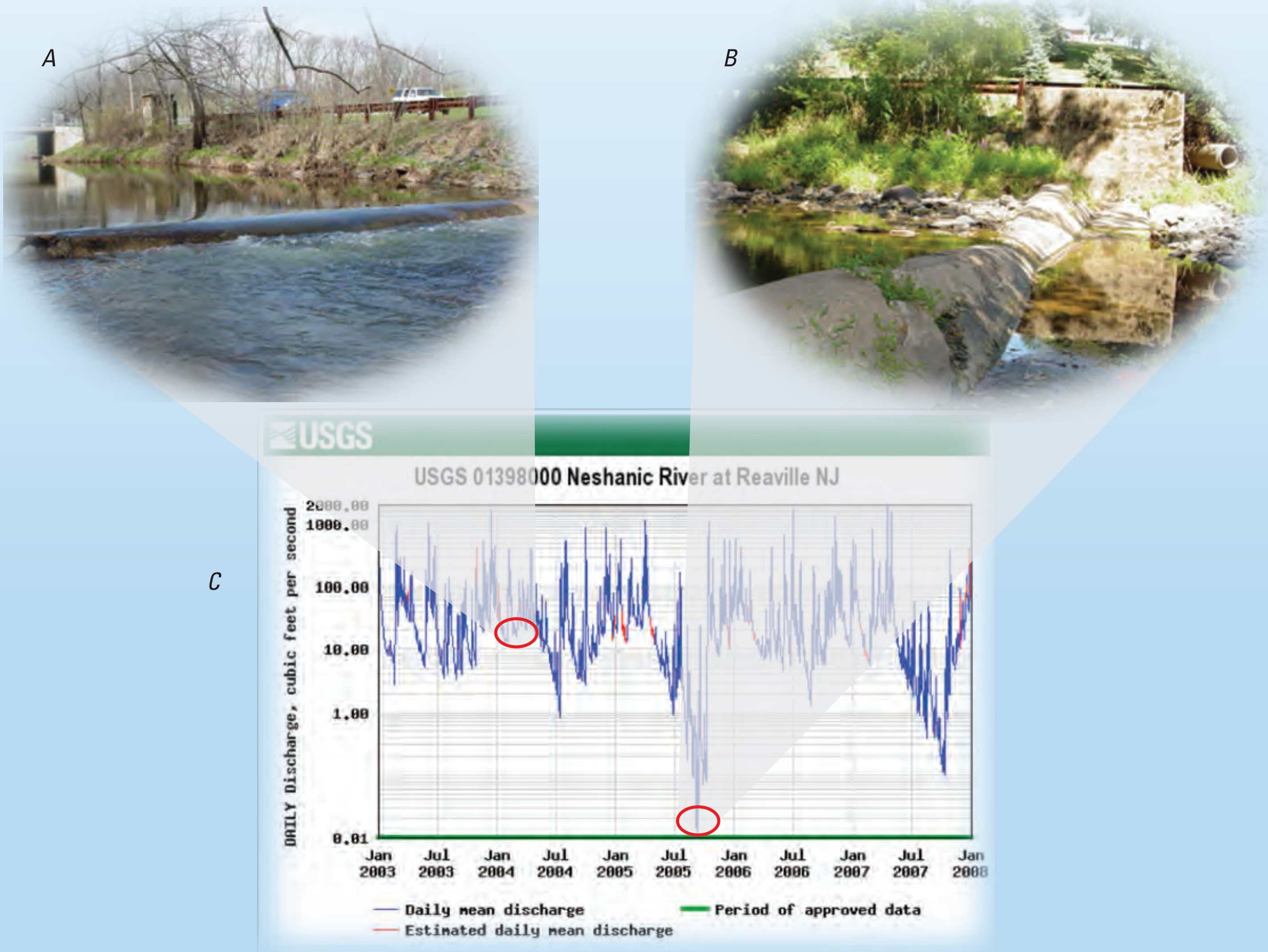
Regional Regression Equations for the Estimation of Selected Monthly Low-Flow Duration and Frequency Statistics at Ungaged Sites on Streams in New Jersey



Scientific Investigations Report 2014–5004

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

Cover: Photographs of base flow during *A*, April 2003 and *B*, September 2005 at U.S. Geological Survey streamflow-gaging station 01398000 Neshanic River at Reaville, New Jersey, and *C*, Hydrograph of daily mean flow at U.S. Geological Survey streamflow-gaging station 01398000 Neshanic River at Reaville, New Jersey, showing seasonal and annual variation from January 2003 through December 2007. (Photographs taken by U.S. Geological Survey field crews)

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U.S. Department of the Interior
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U.S. Department of the Interior
SALLY JEWELL, Secretary

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

U.S. Geological Survey, Reston, Virginia: 2014

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4. Flow-duration and low-flow frequency values computed from observed continuous-record streamflow-gaging station and partial-record gaging station data, estimates predicted using regression equations, and percent difference between the two values for the Coastal Plain region in New Jersey for the current land- and water-use conditions, water years 1989–2008.
5. Comparison of flow-duration and low-flow frequency values for continuous-record streamflow-gaging stations and partial-record stations in the non-coastal region in New Jersey between the baseline and current (water years 1989–2008) land- and water-use conditions.
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Figures

Tables

Conversion Factors

Inch/Pound to SI

Multiply	By	To obtain
	Length	
inch (in)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
square foot (ft^2)	0.0929	square meter (m^2)
square mile (mi^2)	2.590	square kilometer (km^2)
	Flow rate	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).

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

Elevation, as used in this report, refers to distance above the vertical datum.

Acronyms

ANNIE	USGS Interactive Hydrologic Analyses and Data Management computer program
APRAVPRE	Average April precipitation (1971-2000), in inches
DEM	Digital elevation model
DRNAREA	GIS-determined drainage area
ERHI	Ecologically Relevant Hydrologic Indices
GIS	Geographic Information System
HIP	Hydroecological Integrity Assessment Process
IOWDM	USGS Input and Output for a Watershed Data Management file computer program
JUNAVPRE	Average June precipitation (1971-2000), in inches
M7D10Y	The 7-day mean streamflow for a set period (typically yearly or monthly) that has an average recurrence interval of 10 years
MLE	Maximum-likelihood estimation
MOVE.1	Maintenance of Variance Extension, type 1
NJDEP	New Jersey Department of Environmental Protection
NJHIP	New Jersey Hydroecological Integrity Assessment Process
NLCD	National Land Cover Data
NRCS	Natural Resources Conservation Service
OLS	Ordinary-least-squares regression
PERMSSUR	Average soil permeability
PRISM	Parameter-elevation Regressions on Independent Slopes Model
SSURGO	NRCS Soil Survey Geographic database
STORAGE	GIS-determined percent of water and wetland land use
StreamStats	USGS Web-based Application (*http://water.usgs.gov/osw/streamstats/*)
SWSTAT	USGS Surface-Water Statistics computer program
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey

Regional Regression Equations for the Estimation of Selected Monthly Low-Flow Duration and Frequency Statistics at Ungaged Sites on Streams in New Jersey

By Kara M. Watson and Amy R. McHugh

Abstract

Regional regression equations were developed for estimating monthly flow-duration and monthly low-flow frequency statistics for ungaged streams in Coastal Plain and non-coastal regions of New Jersey for baseline and current land- and water-use conditions. The equations were developed to estimate 87 different streamflow statistics, which include the monthly 99-, 90-, 85-, 75-, 50-, and 25-percentile flow-durations of the minimum 1-day daily flow; the August–September 99-, 90-, and 75-percentile minimum 1-day daily flow; and the monthly 7-day, 10-year (M7D10Y) low-flow frequency. These 87 streamflow statistics were computed for 41 continuous-record streamflow-gaging stations (streamgages) with 20 or more years of record and 167 low-flow partial-record stations in New Jersey with 10 or more streamflow measurements.

The regression analyses used to develop equations to estimate selected streamflow statistics were performed by testing the relation between flow-duration statistics and low-flow frequency statistics for 32 basin characteristics (physical characteristics, land use, surficial geology, and climate) at the 41 streamgages and 167 low-flow partial-record stations. The regression analyses determined drainage area, soil permeability, average April precipitation, average June precipitation, and percent storage (water bodies and wetlands) were the significant explanatory variables for estimating the selected flow-duration and low-flow frequency statistics.

Streamflow estimates were computed for two land- and water-use conditions in New Jersey— land- and water-use during the baseline period of record (defined as the years a streamgage had little to no change in development and water use) and current land- and water-use conditions (1989–2008)—for each selected station using data collected through water year 2008. The baseline period of record is representative of a period when the basin was unaffected by change in development. The current period is representative of the increased development of the last 20 years (1989–2008). The two different land- and water-use conditions were used as surrogates for development to determine whether there have been changes in low-flow statistics as a result of changes in development over time. The State was divided into two low-flow regression regions, the Coastal Plain and the non-coastal region, in order to improve the accuracy of the regression equations. The left-censored parametric survival regression method was used for the analyses to account for streamgages and partial-record stations that had zero flow values for some of the statistics. The average standard error of estimate for the 348 regression equations ranged from 16 to 340 percent. These regression equations and basin characteristics are presented in the U.S. Geological Survey (USGS) StreamStats Web-based geographic information system application. This tool allows users to click on an ungaged site on a stream in New Jersey and get the estimated flow-duration and low-flow frequency statistics. Additionally, the user can click on a streamgage or partial-record station and get the “at-site” streamflow statistics.

The low-flow characteristics of a stream ultimately affect the use of the stream by humans. Specific information on the low-flow characteristics of streams is essential to water managers who deal with problems related to municipal and industrial water supply, fish and wildlife conservation, and dilution of wastewater.

Introduction

The demands for water use for domestic, agriculture, and recreation purposes in New Jersey have increased as the population has grown from about 5 million people in 1950 to 8,790,000 people in 2010 (U.S. Census, 2013). As a result, the New Jersey Department of Environmental Protection (NJDEP) is interested in developing tools to help water-resource managers allocate water resources to meet demands.

The NJDEP and the U.S. Geological Survey (USGS), through cooperative agreements, have been developing tools to assess the changes in stream biota owing to groundwater and surface-water withdrawals. The New Jersey Hydroecological Integrity Assessment Process (HIP) (Kennen and others, 2007) is the present approach; using this method, the status of aquatic biota in a stream is assessed on the basis of selected statistics for streamflow. The greater the differences between (1) the statistical values under current conditions (water years 1989–2008) of land and water use and (2) the statistical values under baseline conditions (little to no change in development and water use), the more likely it is that the biota in a stream under current conditions of land and water use are different from the biota that would have occurred under baseline conditions. The 171 streamflow statistics calculated by using the New Jersey Hydroecological Assessment Tool (Kennen and others, 2007) are useful in assessing stream biota; however, 12 low-flow statistics (medians of minimum daily flows, by month) have been identified as the most useful in assessing the current status of stream biota (Jeff Hoffman, NJDEP, written commun., 2008).

The magnitude and frequency of low streamflow in New Jersey is used for a number of watershed management and planning purposes. Low-flow statistics are used by water-supply planners and regulatory agencies for reservoir design and for permitting purposes. The issues of minimum passing flows and reservoir safe yields are concerns for water-suppliers across New Jersey and low-flow statistics are used to determine the amount of water available for storage. The NJDEP uses low-flow statistics for allocating surface-water withdrawals and for setting waste-load allocation limits for municipal and industrial facilities that discharge to surface water. The statistics are critical for studies of total maximum daily loads and studies of the effect of point and nonpoint sources of contamination on the chemical and biological qualities of streams.

For this study, regional regression equations were developed for estimating selected low-flow statistics for land- and water-use conditions during a baseline period and during the current period. The baseline period of record for a streamgage consists of the years in which data were collected and during which little to no change in development and water use occurred. The baseline period of record for streamgages was previously determined by Esralew and Baker (2008). Current land- and water-use conditions are defined as occurring during water years 1989–2008. Those 20 years are representative of increased development in New Jersey. This analysis was conducted for the two regions for the State because the nature of surface and near-surface geologic materials in the non-coastal region and Coastal Plain represent differences great enough to affect streamflow (Newell and others, 1998). All low-flow regional regression equations and basin characteristics are available on StreamStats, which is a Web application.

Purpose and Scope

This report presents techniques for estimating low-flow duration and frequency statistics for rural and urban, unregulated or slightly regulated, streams in New Jersey. The development of regional regression equations through the use of left-censored parametric survival techniques is described, and the relation of the basin characteristics (physical characteristics, land use, surficial geology, and climate) to low-flow duration and frequency statistics is presented. Low-flow statistics and basin characteristics for 41 continuous-record streamflow-gaging stations (hereafter called streamgage) and 167 low-flow partial record stations with 10 or more streamflow measurements were used to develop regional regression equations to estimate low-flow duration and frequency statistics. The equations were calculated by using streamflow data for the period of record through September 2008 (water year[1] 2008).

Regression equations for estimating the selected low-flow statistics are presented for baseline and current (water years 1989–2008) land- and water-use conditions.

Low-flow duration statistics are presented for the monthly 99-, 90-, 85-, 75-, 50-, and 25-percentile flow durations of the minimum 1-day daily flow and the August–September 99-, 90-, and 75-percentile flow durations of the minimum 1-day daily flow. The low-flow frequency statistics are presented for the monthly 7-day, 10-year low-flows.

Description of Study Area

New Jersey is located in the North Atlantic slope adjacent to the Atlantic Ocean. New Jersey lies within four major physiographic provinces (fig. 1). The Piedmont, New England (Highlands), and Valley and Ridge Physiographic Provinces encompass northern New Jersey above the Fall Line. The Coastal Plain Physiographic Province encompasses southern New Jersey below the Fall Line. For this report the Piedmont, New England (Highlands), and Valley and Ridge Physiographic Provinces are grouped together under the classification of non-coastal region. The Valley and Ridge Physiographic Province in the non-coastal region covers the northwestern part of the State. Faulted and folded sedimentary layers of sandstone, shale, and limestone underlie the area (New Jersey Department of Environmental Protection and Energy, 1992). Alternating belts of erosion-resistant sandstone and less-resistant eroded shale and limestone create long, parallel, northeast-southwest trending ridges and valleys that are characteristic of the province. The New England (Highlands) Physiographic Province is underlain predominantly by granite, gneiss, and small amounts of marble of Precambrian age. These rocks are resistant to erosion and create hilly uplands dissected by the steep-sided valleys of major streams. The Piedmont Physiographic Province is a broad lowland that contains ridges underlain by interbedded sandstone, shale, conglomerate, basalt, and diabase. The Coastal Plain region is mainly flat and is underlain by unconsolidated layers of sand, silt, and clay (New Jersey Department of Environmental Protection and Energy, 1992).

The non-coastal region and the Coastal Plain Physiographic Province are separated by the western limit of the Coastal Plain sediments or the Fall Line. The Fall Line is a low, east-facing largely buried cliff extending more or less

[1] The water year is the 12-month period, October 1 through September 30, designated by the calendar year in which it ends.

Figure 1. Study area and physiographic provinces in New Jersey and surrounding states.

parallel to the Atlantic coastline from New Jersey to the Carolinas (Newell and others, 1998). The Fall Line is the western limit of the coastal sediments separating the hard Paleozoic metamorphic rocks of the Piedmont Physiographic Province to the west from softer, more gently dipping Mesozoic and Tertiary sedimentary rocks of the Coastal Plain to the east. This erosional scarp, in many ways, affects the behavior of streamflow owing to the nature of the underlying geology; for example, whether a stream channel is steeply sloped with swift-moving waters or is more gently sloped with typically lower stream velocities is, to varying degrees, dependent on the underlying geology and streambed material.

Previous Studies

During 2003–13, a series of surface-water studies of stream characteristics and stream classification was conducted for New Jersey. The first study by Watson and others (2005) evaluated trends in streamflow and the relation between those trends and land-use patterns. Annual streamflow variability and trends in 1-, 7-, and 30-day low and high flows were evaluated for 111 streamgages (including 41 used in this study) and 500 low-flow partial-record stations (including 141 used in this study). Significant relations were found between high flows and streams that are regulated and high flows and development in the drainage basin. The study also demonstrated that the relation between low-flow trends and development was not as strong as that for the high-flow trends. Streamflow variability was found to be significantly greater at streamgages located in the non-coastal region than in the Coastal Plain.

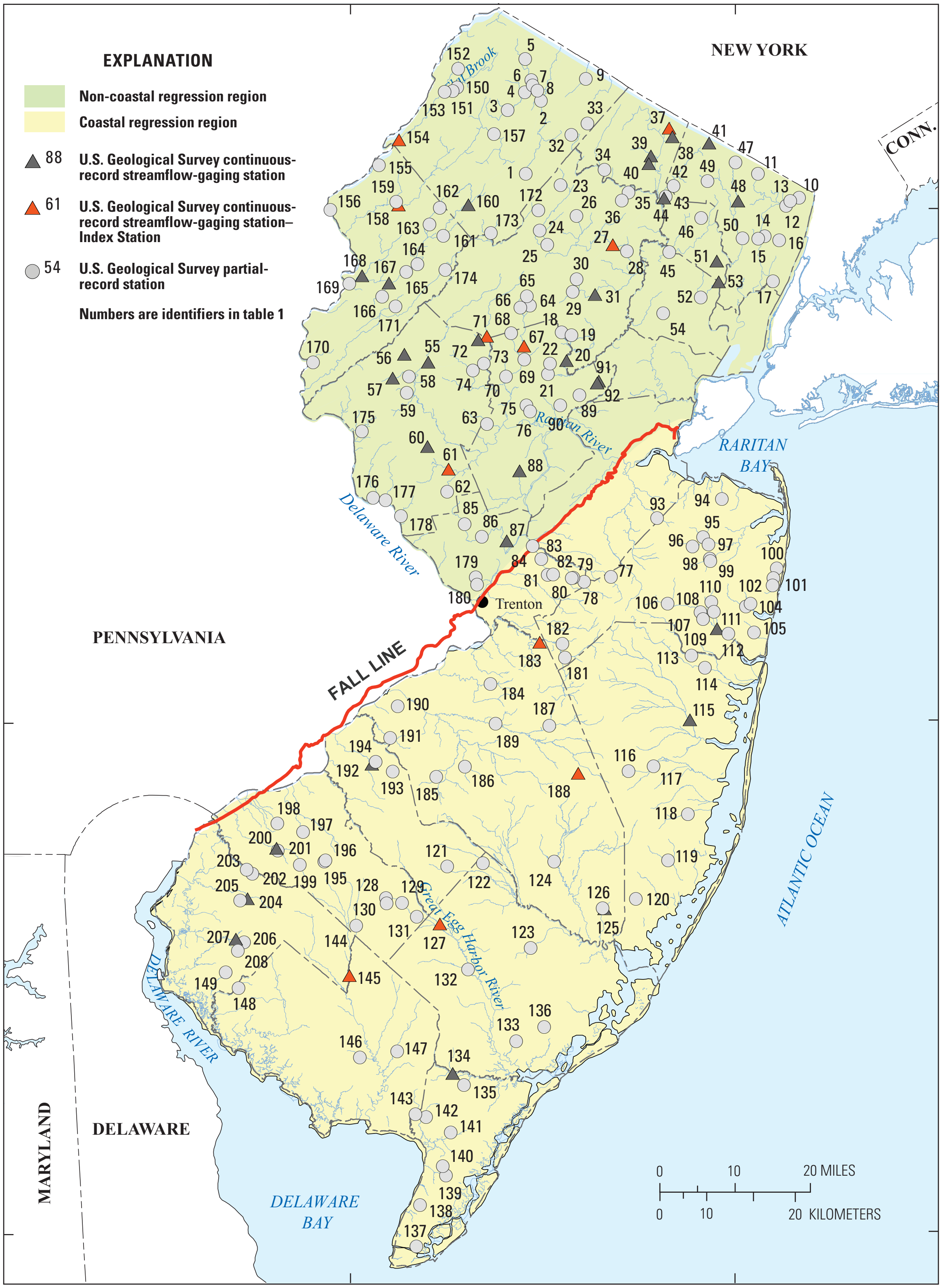
The second study, conducted by Henriksen and others (2006), adapted the stream classification and Ecologically Relevant Hydrologic Indices (ERHI) determination procedure from the national HIP. This process was applied to hydrologic conditions that are present in New Jersey streams and was used to develop the tool NJHIP. NJHIP involved development of new stream classifications for New Jersey streams and subsequent identification of sets of primary and surrogate ERHIs for each stream class. In order to classify streams in New Jersey, a preliminary baseline period of record was identified as the period during which streamflow was least affected by human activity. This baseline was selected on the basis of the history of the streamgage, such as visual interpretation of anomalies in hydrographs, and trends in streamflow data reported in previous studies (J.G. Kennen, U.S. Geological Survey, written commun., 2006). Those baseline periods for 95 streamgages are listed in Henriksen and others (2006).

The third study in the series, conducted by Esralew and Baker (2008), describes the analytical determination of baseline periods of record for 85 streamgages in New Jersey with 10 or more years of continuous streamflow data. Methods of utilizing historical information about streamflow, impervious surface, and double-mass-curve analysis to assign baseline periods to drainage basins were determined. A preliminary baseline period of record was determined for each streamgage as the period during which the streamflow was least regulated or did not have any known major groundwater or surface-water withdrawals or diversions affecting the drainage basin. Analysis of change in impervious-surface data was used to assess the point at which substantial development had occurred in a basin and to define the end of the preliminary baseline period. Impervious-surface data were used as a surrogate to population density values. There have been no previous low-flow regionalization studies in New Jersey. However, this report is the fourth in a series of reports presenting the analyses of stream characteristics and stream classification in order to expand the understanding of sustainability for New Jersey streams.

Methods for Dataset Development

All active and inactive streamgages in New Jersey with at least 20 years of record and minimally affected by changes in regulation or diversion were initially selected for evaluation in the regional regression analyses. New Jersey has an extensive partial-record-station network with more than 600 active and inactive stations. The initial partial-record stations considered for this analysis were used in the streamflow characteristics study by Watson and others (2005). From this network of 600 partial-record stations, 507 potential stations were evaluated for possible use in the regional regression analyses. Partial-record stations were considered if they had 10 or more streamflow measurements. Additionally, the potential streamgages and partial-record stations were reviewed to eliminate data affected by regulated streamflow, water withdrawals, diversions, flood control, and wastewater discharge, which would have biased the computation of selected low-flow duration and frequency statistics. Decisions on inclusion or exclusion of data for streamgages and partial-record stations were made using hydrologic judgment according to available information regarding the occurrence, timing, and extent of regulations or diversions upstream from the site. No explicit decision criteria were used.

This evaluation resulted in the selection of 41 streamgages and 167 partial-record stations in New Jersey for use in the regression analysis [(table 1, fig 2) table 1 in back of report]. Of these streamgages and partial-record stations, 86 were used for both the baseline and current condition analyses. The 86 streamgages and partial-record stations showed minimal change in land- and water-use conditions over the entire period of record. A summary of the number of streamgages and partial-record stations used in the two regions and land- and water-use conditions are listed in table 2.



Base from U.S. Geological Survey digital line graph files, 1:24,000,
Universal Transverse Mercator projection, Zone 18, NAD83

Figure 2. Location of regression regions and continuous-record streamflow-gaging stations and partial-record gaging stations in New Jersey with data analyzed for selected low-flow duration and frequency statistics and characteristics. Reference numbers shown above are used to describe the stations listed in table 1.

Table 2. Number of continuous-record streamflow-gaging stations and partial-record stations used in the low-flow regional regression analysis.

Period[1]	Low-flow regression region	Continuous-record stream-flow-gaging station	Partial-record station
Baseline land and water use	Non-coastal	29	58
	Coastal Plain	12	45
Current land and water use	Non-coastal	18	59
	Coastal Plain	10	63

[1] Current period refers to the period of record 1989–2008. Baseline period refers to the preliminary baseline period of record as determined by Esralew and Baker (2008).

Continuous-Record Streamflow-Gaging Station Network

Streamgages generally record flow data at regular 15-minute intervals throughout the day. The 15-minute interval data are then used to compute daily mean-flow values. The statistics computed from the daily mean flow at the streamgages were used as a basis for estimating low-flow statistics at the 167 partial-record stations.

Flow duration and frequency statistics in this report were computed from continuous records of streamflow collected at 41 active and inactive streamgages across New Jersey that have 20 or more years of records and minimal changes in regulated streamflow, withdrawals, and wastewater discharges. Statistics for streamgages and partial-record stations downstream from water-supply and flood-control reservoirs were not determined in the analysis. Statistics were calculated only for months within complete water years with no missing values. Minimum daily flows were calculated for each month within the period of record from records of daily flows if there were no missing values for that month.

Three exceptions were made to the guideline established for using streamgages with 20 or more years of record. The streamgages Saddle River at Ridgewood, NJ (station 01390500, map identifier 48; fig. 2), Upper Cold Brook near Pottersville, NJ (station 01399510, map identifier 72; fig. 2), and Stony Brook at Watchung, NJ (station 01403540, map identifier 92; fig. 2) have periods of record of slightly less than 20 years. The periods of record for these stations follow the preliminary baseline periods from Esralew and Baker (2008), which have been shortened as a result of regulation, channel alteration, or groundwater withdrawals within the drainage basins.

Estimation of Low-Flow Statistics at Partial-Record Gaging Stations

Streamflow data used in this report were collected at 167 active and inactive low-flow partial-record stations in New Jersey. A partial-record station is a site on a stream where discrete streamflow measurements of one of more hydrologic conditions, such as base-flow discharge, are made over a period of time without continuous data being recorded or computed. Partial-record stations with 10 or more streamflow measurements were used in the data analysis. Partial-record stations were excluded from the statistical analyses because of flow alteration (water withdrawals, diversions, reservoir operations, or point discharges) in the upstream basins, too few base-flow measurements for statistical analysis, or poor correlation with index stations using the Maintenance of Variance Extension, type 1 (MOVE.1) method of correlation analysis (Hirsch, 1982).

Streamflow measurements are periodically made at low-flow partial-record stations, water-quality sampling sites, and miscellaneous sites which have been established for special USGS studies during base-flow conditions. These base-flow measurements can be used to estimate low-flow statistics at the site by relating the measurements to concurrent daily mean flow at an index station. An index station is a continuous-record streamgage on an unregulated stream with 20 or more years of record. From 1959 through 2008, base-flow measurements were made at more than 600 partial-record stations in New Jersey. Typically, 10 to 12 base-flow measurements made over a 5 to 6 water-year period can provide an adequate amount of data to establish a relation between base-flow conditions at an index station and those at the partial-record station. An example of the output of the program used to generate the MOVE.1 relation between base-flow measurements and concurrent daily mean flow at an index station is shown in figure 3. The program also generates plots of residuals in relation to month, year, and flow for a cursory visual assessment for possible trends in the data.

Through the use of MOVE.1 technique, low-flow characteristics can be transferred from a streamgage to a partial-record station. The flows are transformed to base 10 logarithms to make the distribution of data more symmetrical and the relation more linear. The relation is defined by the line of correlation determined from the MOVE.1 analysis. The correlation coefficient and standard error of estimate are used as measures of accuracy (fig. 4). For the non-coastal region, partial-record sites were eliminated from the study if the correlation coefficients were less than 0.8; for the Coastal Plain, the cut-off was 0.7. Coastal Plain correlations were given more leniency as the base-flow relations generally show more scatter because of greater variation in the timing of the of base-flow recessions. For both regions, partial-record sites were eliminated if there was considerable extrapolation from the lowest measured flow to the estimated annual 7-day, 10-year flow (M7D10Y).

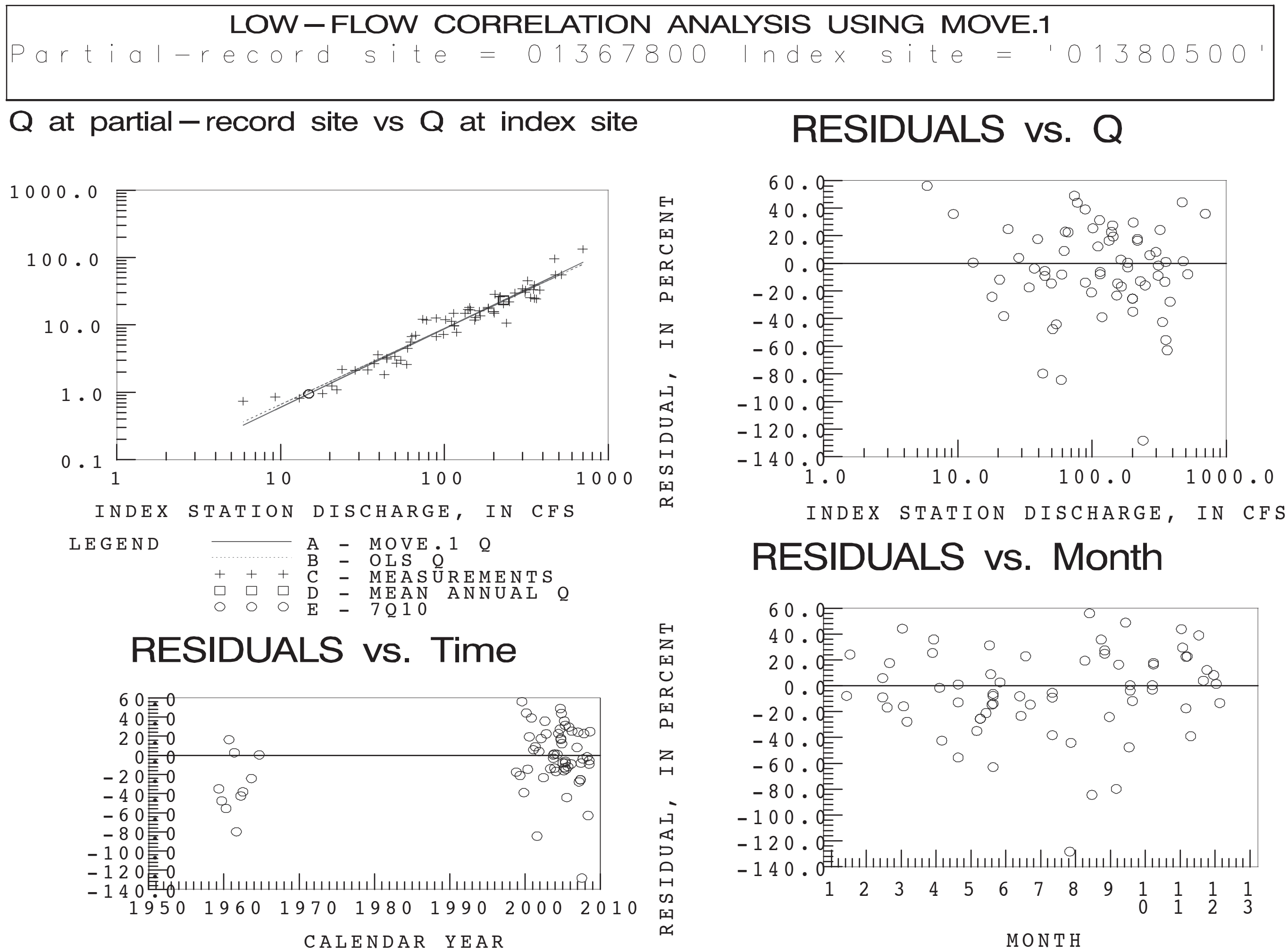


Figure 3. Example of plots generated by the Maintenance of Variance Extension Type 1 (MOVE.1) correlation analysis program to evaluate the relation between base-flow measurements at a low-flow partial-record station and daily mean flow at an index station in New Jersey. (Q, flow in cubic feet per second; residuals, difference between predicted values and the actual values for the dependent variable; MOVE.1 Q, relation between daily mean flow at a streamflow-gaging station and instantaneous flow at the partial-record site; CFS, cubic feet per second; OLS, ordinary least squares; 7Q10, 7-day 10-year flow)

Daily mean flows from at least three index stations correlated with measurements at each partial-record station. The index stations were selected on the basis of their proximity to the partial-record station within the same region (Coastal Plain and non-coastal region) and similarities of basin characteristics. A weighted mean of all the estimates is computed on the basis of the inversed squares of the standard error of estimate of the M7D10Y low-flow frequency statistic. The standard error of estimate of low-flow characteristics at partial-record stations is computed by using the standard errors of estimate of the MOVE.1 line and the time-sampling errors computed for the index stations (Telis, 1991).

Index stations used in the MOVE.1 regression have a baseline period that includes the assumed "drier" era (pre-1970) through the end of the study period (2008). In using index stations with the most robust baseline period, it is inferred that the relation (equation) between the two sites is most likely not different for the two periods of record, and only one equation is needed per partial-record station. Otherwise, not only would two equations be necessary, but sufficient data during both periods at the partial-record station would also be required. To check the assumption that the relation remained the same over time, a Kendall Tau trend test was applied to the residuals of the MOVE.1 correlations. A resulting p-value of less than 0.05 for the partial-record stations indicated that a trend may be present, and those stations were eliminated from the study.

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                                U. S. GEOLOGICAL SURVEY                            14:13 Monday, April 2, 2012   3
                    SUMMARY OF MOVE1 LOW-FLOW CORRELATIONS RUN BY THE NEW JERSEY DISTRICT
                                 PROVISIONAL RESULTS SUBJECT TO REVISION

-------------------------------------- Sta=01367800 Name=Papakating Creek at Pellettown NJ ----------------------------------------

INDEX                    INDEX    PARTIAL        Q1          Q7         Q710        WIN        Q30        Q30        WIN
STATION          USED       DA         DA       .10         .10          .DA       .Q710        .5        .10       Q305

01380500            1   116.00      15.80      0.80        0.94       0.0598       3.12       1.87       1.36       7.13
01384500            1    19.10      15.80      0.39        0.54       0.0343       2.38       1.27       0.88       6.75
01440000            1    64.00      15.80      0.71        0.81       0.0515       1.93       1.36       1.07       4.63
01443500            1   126.00      15.80      0.62        0.94       0.0593       1.70       1.54       1.21       3.93
Wgtd. Mean          0        .      15.80      0.66        0.84       0.0532       2.22       1.52       1.16       5.35

INDEX         WIN.                   HAR        DURA       DURA        DURA   PERCENT   PERCENT    PERCENT     CORRE       NO
STATION      Q3010        QAVG      MEAN         .25        .50         .75      PRED      GAGE        EST     LATION     MEAS

01380500      5.56       23.22      8.34       31.24      14.70        6.57      34.4      11.5       37.2       0.97     67.0
01384500      4.71       22.48      5.20       28.32      15.34        6.31      44.6      18.9       47.8       0.95     65.0
01440000      3.22       21.34      6.56       27.94      12.79        4.92      32.6       6.6       33.6       0.97     69.0
01443500      2.75       17.70      6.33       24.14      11.29        4.68      32.0       6.5       33.0       0.97     71.0
Wgtd. Mean    3.88       20.86      6.72       27.64      13.19        5.46         .         .       36.5         .      68.5

INDEX              BEGIN           END    YRS                       CONS       KEN      KEN             DATE
STATION             YEAR          YEAR     DV        POWER          TANT       TAU     PROB              RUN

01380500            1959          2008     64     1.17E+00      4.10E-02      0.03    0.689       2010-11-19
01384500            1959          2008     61     8.29E-01      1.23E+00      0.11    0.187       2010-11-19
01440000            1959          2008     78     1.20E+00      7.50E-02      0.00    0.959       2010-11-19
01443500            1959          2008     80     1.18E+00      3.50E-02     -0.04    0.585       2010-11-19
Wgtd. Mean             .             .      .            .             .         .        .       2012-04-02


                    Note: Weights for all Wgtd. Means were computed using inversed squares of
                     the standard error of estimate for the 7Q10 only, not for each low flow.
                       The PERCENT GAGE, PERCENT PRED, and PERCENT EST were computed using
                                           methods in WRIR 90-4087
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Figure 4. Example of summary statistics estimated by use of the Maintenance of Variance Extension Type 1 (MOVE.1) correlation program for Papakating Creek at Pellettown, N.J. (site 01367800), and the weighted mean of the estimates based on the standard error of estimation. (sta, station number; Wgtd., weighted; ".", no value calculated; INDEX DA, index station drainage area in square miles; PARTIAL DA, partial-record station drainage area in square miles; Q1.10, 1-day 10-year flow; Q7.10, 7-day 10-year flow; Q710.DA, 7-day 10-year flow per square mile; WIN.Q710, winter 7-day 10-year flow; Q30.5; 30-day 5-year flow; WIN.Q305, winter 30-day 5-year flow; WIN.Q3010, winter 30-day 10-year flow; QAVG, mean daily flow; HAR MEAN, harmonic mean; DURA.25, 25-percent flow duration; DURA.50, 50-percent flow duration; DURA.75, 75-percent flow duration; PERCENT PRED, standard error of prediction; PERCENT GAGE; time sampling error; PERCENT EST, standard error of the estimate; CORRELATION, correlation coefficient; NO MEAS, number of base-flow measurements; BEGIN YEAR, first year of base-flow measurements; END YEAR, last year of base-flow measurements; YRS DV, number of years of daily flow at index site; POWER, slope of the line; CONSTANT, intercept of the line; KEN TAU, Kendall tau coefficient; KEN PROB, probability; WRIR 90–4087, U.S. Geological Survey Water-Resources Investigations Report 90–4087, Telis (1991).)

Selected Flow Statistics and Methods of Statistical Analysis

Equations relating low-flow statistics to basin characteristics, including land use, can be used for sites along a stream where no streamgage is present (ungaged sites) for both baseline and current land- and water-use conditions. Baseline conditions are those that occurred during the preliminary baseline period of record established by Esralew and Baker (2008). Current conditions are those that occurred during water years 1989–2008.

All equations, basin characteristics, and low-flow statistics at streamgages and partial-record stations are included in the StreamStats application.

Flow-Duration Analysis

A flow-duration curve is a cumulative frequency curve that shows the percentage of time specified flows are equaled or exceeded for a given period of time. In this analysis the 99-percentile flow duration is the minimum 1-day daily flow, by month, that is exceeded 99-percent of the time. Flow-durations were computed for the 99-, 90-, 85-, 75-, 50-, and 25-percentiles by using each month's minimum 1-day daily flow and for the 99-, 90-, and 75-percentiles of the minimum 1-day daily flow for August through September for each streamgage for each of the two land- and water-use conditions, baseline and current.

The flow-duration curve is useful for analyzing the availability and variability of streamflow. The flow-duration curve, when based on many years of record, indicates the probable future behavior of a stream, assuming the basin will not be substantially altered by human activities (Searcy, 1959). The shape of the flow-duration curve generally is indicative of hydrologic conditions in the drainage basin. A curve with a steep slope is indicative of a basin with highly variable flow with more of the streamflow coming from direct runoff than base flow. A hydrograph separation computer program such as HYSEP can be used to separate a streamflow hydrograph into base flow and surface-water runoff components (Sloto and Crouse, 1996). A streamgage on a stream that drains an area with steep topography and shallow soils generally will have a flow-duration curve with a steep slope. Steep flow-duration curves represent drainage basins characterized by an absence of sustained base flow. A flat flow-duration curve is generally typical of a stream that drains an area with flat topography and land areas classified as wetlands and (or) soils with high permeability (infiltration), such as the coastal sands. An appreciable part of streamflow in these drainage basins is contributed by groundwater discharge which results in a sustained base flow (Watson and others, 2005). Examples of flow-duration curves for the April and September minimum 1-day daily flow during the baseline and current land- and water-use conditions for the non-coastal region and Coastal Plain regions of the State are shown in figures 5 and 6. The Flat Brook at Flatbrookville, NJ, streamgage (station 01440000, map identifier 154, fig. 2) is located in the non-coastal region (fig. 5). The Great Egg Harbor River at Folsom, NJ, streamgage (station 01411000, map identifier 127; fig. 2) is located in the Coastal Plain region (fig. 6). The flow-duration curve for the Flat Brook streamgage has a much steeper slope, indicating a sustained lower component of base flow for the total streamflow than for the Great Egg Harbor River streamgage, which has a flatter curve indicating the basins ability to sustain base flow (higher base-flow component).

Flow durations can be computed by using statistical software packages. The USGS computer program Surface Water Time Series Statistics (SWSTAT; Flynn and others, 1995) was used in this study to compute the 99-, 90-, 85-, 75-, 50-, and 25-percentile of minimum 1-day daily flows, by month, and the 99-, 90-, and 75-percentile August–September minimum 1-day daily flow for the streamgages. Flow durations were computed for the two flow conditions, baseline and current land and water uses (1989–2008), with data collected through water year 2008. Daily streamflow data from all complete months during the period of record were used for the analysis. The USGS has established standard methods for estimating low-flow duration and frequency statistics for streamgages (Riggs, 1972). In this study, the USGS computer programs Input and Output for Watershed Data Management files (IOWDM), Interactive Hydrologic Analyses and Data Management (ANNIE), and Surface-Water Statistics (SWSTAT) (*http://water.usgs.gov/software/surface_water.html*) were used to format daily mean streamflow data and to compute flow duration and low-flow frequency values (Lumb and others, 1990; Flynn and others, 1995).

Low-Flow Frequency Analysis

A log-Pearson Type III frequency distribution was used in this study because, in general it fits the distribution of the streamflow well. Fitting the distribution requires calculating the mean, standard deviation, and skew coefficient of the logarithms of the *n*-day flows. Estimates of the *n*-day non-exceedance flows for a specified recurrence interval *t* are computed by using the following equation (Interagency Advisory Committee on Water Data, 1982):

$$\log Q_t = X + K_t S \quad , \tag{1}$$

where

Q_t is *n*-day flow;
t is recurrence interval, in years;
X is mean of the base 10 logarithms of the annual (monthly) *n*-day flows;
K_t is frequency factor that is a function of the recurrence interval and the coefficient of skew; and
S is standard deviation of the logarithms of the annual (monthly) *n*-day flows.

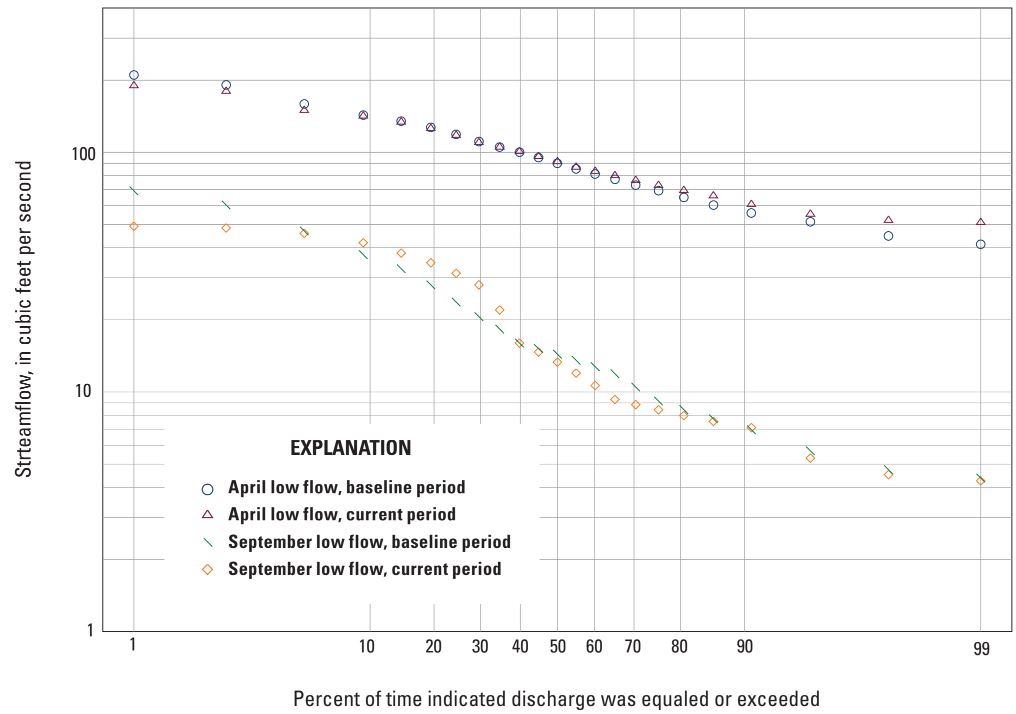

Figure 5. Flow-duration curves for April and September minumum 1-day flow for Flat Brook near Flatbrookville, N.J., (01440000) in the non-coastal regression region. Current period refers to the period of record 1989–2008. Baseline period refers to the preliminary baseline period of record as determined by Esralew and Baker (2008).

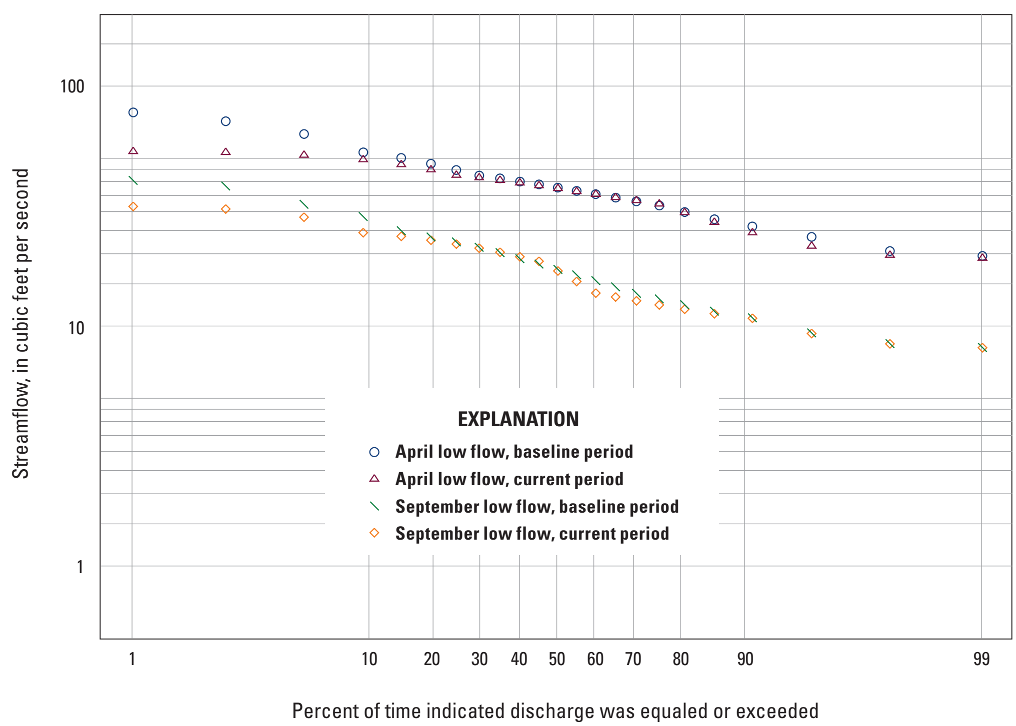

Figure 6. Flow-duration curves for April and September minumum 1-day flow for Great Egg Harbor River at Folsom, N.J., (01411000) in the Coastal Plain regression region. Current period refers to the period of record 1989–2008. Baseline period refers to the preliminary base-line period of record as determined by Esralew and Baker (2008).

For this study, low-flow frequency statistics were computed for the minimum average 7-day flows for a 10-year period (M7D10Y) per month (example, January M7D10Y). In terms of probability of occurrence, there is a one-tenth or 10-percent probability that the monthly minimum 7-day average flow in any single month will be less than the estimated monthly M7D10Y value for a specific location (Riggs, 1985). A 10-year recurrence interval does not imply that the value will have a non-exceedance every 10 years; it does indicate, however, that the average time between recurrences is equal to 10 years. Consequently, an observed interval between a non-exceedance of the M7D10Y may be as short as 1 year or may be considerably longer than 10 years (Guimaraes and Feaster, 2010). The log-Pearson Type III frequency curves were examined for each streamgage by using the USGS computer program SWSTAT (Flynn, and others, 1995).

Selection of Basin Characteristics

Low-flow characteristics of streams are related to the physical characteristics, land-use, surficial geology, and climate of drainage basins. In most studies, drainage area is a significant variable in explaining low-flow variability (Funkhouser and others, 2008; Eash and Barnes, 2012). Additional basin characteristics were examined to quantify their relation to low-flow statistics by using ordinary least squares regression (OLS). The basin characteristics were derived by using geographic information system (GIS) techniques to ensure consistency and reproducibility. Basin characteristics evaluated for each streamgage and partial-record station considered for use in the regression analysis are listed in table 3, along with the data source used to measure the characteristic. The GIS computed values for drainage-basin areas agree closely with previously published values for drainage areas. The original set of variables regressed against low-flow duration and frequency data included

1. Physical characteristics,
2. Land use/land cover (NJDEP, 2007),
3. Precipitation data (PRISM Climate Group, 2006),
4. Soil characteristics from Soil Survey Geographic Data base (SSURGO) (Natural Resources Conservation Service, 2007),
5. Surficial geology (Soller and Reheis, 2004; NJDEP, 1992), and
6. 2000 Census data, (U.S. Census Bureau, 2007).

From the initial OLS regression analysis, those basin characteristics that were found to relate to low-flow duration and frequencies with statistical significance at the 95-percent confidence interval are

- drainage area,
- soil permeability,
- average monthly precipitation—April,
- average monthly precipitation— June, and
- percentage of storage (water bodies and wetland area).

A description of each of these variables is presented in the following section, “Explanatory Variable Selection Methods.” These are the variables that were used in the determination of the final regression equations for each of the two flow conditions, baseline and current, using the left-censored parametric survival method. The multiple regression iterations were performed by using the statistical software package S-Plus (TIBCO Software, Inc., 2008).

Explanatory Variable Selection Methods

Flow characteristics of streams are directly related to the surficial geology, and physical, land-use, and climate characteristics of the associated basin—drainage area, soil permeability, average April precipitation, and average June precipitation. Characteristics of the drainage basin were selected for use as potential explanatory variables in the regression analyses on the basis of their theoretical relation to flows and the ability to measure the basin characteristics by using digital datasets and GIS technology. The drainage basin characteristics for the streamgages and partial-record stations used in the regression analyses are listed for the baseline and current land- and water-use conditions in tables 4 and 5 (tables 4 and 5 in back of report), respectively.

The methods discussed in the following paragraphs describe the work required, and datasets used, to determine the basin-characteristic values for the low-flow duration and frequency analysis. Drainage basin boundaries are needed before any other basin characteristic can be calculated. For each streamgage, coordinates of the site location and a 10-meter resolution Digital Elevation Model (DEM) coverage for New Jersey from the National Elevation Dataset (U.S. Geological Survey, 1999b were used to create the drainage basin boundary. The DEM is a digital cartographic/geographic dataset of elevations derived from contour lines and aerial photography by using USGS 7.5-minute topographic quadrangle maps. All elevation data presented in this report are referenced to the North American Vertical Datum of 1988. The 10-meter DEM uses the same sources as were used for the historical elevation data, which are manually derived from 7.5-minute quadrangle maps, but the 10-meter DEM also contains updated point data that provide refined elevation values. The vertical accuracy of the 10-meter DEM is considered to be +/- 7 to 15 meters.

The DEM can be inaccurate in geographically flat areas, such as the coastal areas of New Jersey. To improve the DEM used for this study a process was performed to conform the stream boundaries from the National Hydrography Dataset

Table 3. Basin characteristics tested for significance in the regression analysis.

[NJDEP, New Jersey Department of Environmental Protection]

Physical characteristics (U.S. Geological Survey, 1999a and 1999b)
Drainage area (square miles)
Channel slope–10–85 method (feet per mile)
Sum of streams (miles/or feet)
Basin average elevation (feet, NAVD 88)
Land-use characteristics (New Jersey Department of Environmental Protection, 2007 and Yang and others, 2003)
Forest (percent)
Storage–total of water and wetland land use type (percent)
Urban (percent)
Wetland (percent)
Census (Theobaud, 2001 and U.S. Census Bureau, 2007)
Population density, 2000 (people per square mile)
Precipitation, drainage basin average (PRISM Climate Group, 2006)
Precipitation 1971–2000, basin average, Mean annual (inches)
Precipitation 1971–2000, January basin average, Mean monthly (inches)
Precipitation 1971–2000, February basin average, Mean monthly (inches)
Precipitation 1971–2000, March basin average, Mean monthly (inches)
Precipitation 1971–2000, April basin average, Mean monthly (inches)
Precipitation 1971–2000, May basin average, Mean monthly (inches)
Precipitation 1971–2000, June basin average, Mean monthly (inches)
Precipitation 1971–2000, July basin average, Mean monthly (inches)
Precipitation 1971–2000, August basin average, Mean monthly (inches)
Precipitation 1971–2000, September basin average, Mean monthly (inches)
Precipitation 1971–2000, October basin average, Mean monthly (inches)
Precipitation 1971–2000, November basin average, Mean monthly (inches)
Precipitation 1971–2000, December basin average, Mean monthly (inches)
Soil characteristics SSURGO (Natural Resources Conservation Service, 2007)
Soil permeability (inches/hour)
Soil thickness (feet)
Available water capacity (inches)
Clay (percent)
Soil errodibility factor, rock fragments free
Surficial geology (New Jersey Department of Environmental Protection, 1992)
Glacial extent (percent)
Alluvial extent (percent)
Surfical geology units ability to support low flows- High (NJDEP)
Surfical geology units ability to support low flows- Medium (NJDEP)
Surfical geology units ability to support low flows- Low (NJDEP)

(U.S. Geological Survey, 1999a) and the Hydrologic Unit Code-14 (NJDEP, 2006) to the DEM. This process was developed by using the ArcHydro Tools (Environmental Systems Research Institute, Inc., 2007) by Peter Steeves (USGS, written commun., 2002). The result is a conditioned DEM, which was used for drainage-basin delineation.

Land use

The land uses for drainage basins entirely within New Jersey were derived from a GIS dataset developed from 2002 digital infrared aerial photography, the NJDEP 2002 Land use/Land cover by Watershed Management Area (New Jersey Department of Environmental Protection, 2007), through use of the Anderson method of classification (Anderson and others, 1976). Land uses for drainage basins extending outside of New Jersey were derived from the 2001 National Land Cover Data (NLCD) dataset (Yang and others, 2003). The land-use coverage divides the land area into a series of polygon segments that are assigned a single land-use classification, as in Level 1 classifications in the Anderson system (Anderson and others, 1976). Level 1 classification consists of the major land-use categories, including agriculture, urban, wetland, forested, barren, and water body areas. Each polygon segment is assumed to be uniform in land-use category.

Anderson Level 1 land-use classifications used for basin characteristics in this study are forest, urban, water bodies, and wetlands. Land use categorized as storage is the percentage of water bodies and wetland land-use areas in a drainage basin. The urban land-use category is a composite of residential, commercial, and industrial uses. A raster dataset of the land-use coverage was created for data processing. For each site the 2002 land-use dataset and (or) 2001 NLCD dataset was overlaid on the drainage basin polygon and clipped to the basin boundary. Percentages of each land-use type were calculated as the sum of the areas of the selected land-use type divided by the total area of the drainage basin.

Precipitation

The precipitation basin characteristic datasets are taken from monthly precipitation data from 1971–2000, using the Parametric-elevation Regressions on Independent Slopes Model (PRISM) (PRISM Climate Group, 2006). PRISM is a unique knowledge-based system that uses point measurements of precipitation, temperature, and other climatic factors to produce continuous, digital grid estimates from a 10-meter cell size grid of monthly, yearly, and event-based climatic parameters in association with a GIS. The average monthly precipitation data and average annual precipitation, in inches, were used in this analysis. The average monthly precipitation data were more significant in the analysis than the average annual precipitation. All months were tested in the regression analyses; however, only average April and June precipitation were significant explanatory variables in the regression equations. April was a significant variable for the Coastal Plain region for the baseline and current land- and water-use conditions, and June was significant for the non-coastal region for both conditions.

Soil Characteristics

The soil characteristics used in this study are from the Soil Survey Geographic Database (SSURGO), developed by the U.S. Department of Agriculture (USDA), Natural Resources Conservation Service (NRCS). This data base provides the physical properties of soils layers across the United States. Soil characteristics analyzed in this study were soil permeability, soil thickness, available water capacity, percentage of clay in the soil layer, and the soil erodibility factor. Soil permeability is the rate of water transport for the soil layer or horizon, expressed in inches per hour (in/hr). The soil thickness, measured in feet, is the depth between the upper and lower boundaries of the soil layer or horizon. The available water capacity, measured in inches, is the average water capacity for the uppermost soil layer. A soil erodibility factor quantifies the susceptibility of soil particles to detach and move by water.

Regional Regression Analyses to Estimate Selected Low-Flow Duration and Frequency Statistics for Ungaged Streams

Regression analyses provide a mathematical equation for estimating a response variable—streamflow statistic—from one or more explanatory variable(s)—basin characteristics. The low-flow statistic for a selected duration and frequency is expressed as a function of basin characteristics. The dataset values for the monthly minimum 1-day daily flow and the monthly M7D10Y include many zero flows. In order to handle this in the regression analysis, a left-censored parametric survival regression analysis, also referred to as Tobit regression, was used to develop the regression equations for estimating the selected streamflow statistics. Estimates of zero flow computed from observed streamflow data are often considered to be censored data (Eash and Barnes, 2012), and the use of multiple-linear regression is not appropriate for the censored data.

Definition of Low-Flow Regression Regions

In a regional regression study, subdividing a large study area into sub-regions that are relatively homogeneous in terms of low-flow hydrology typically helps to reduce error in the regression equations. Low-flow regions have not been determined for New Jersey in previous studies. For this analysis, the State was subdivided into two low-flow regression regions on the basis of similar geological and physical basin characteristics, base-flow characteristics, the physiographic map (Parker and others, 1964), and typical hydrologic response to storms. The low-flow regression regions for New Jersey are the non-coastal region and the Coastal Plain. The two low-flow regression regions are shown in fig 2.

The non-coastal region comprises Valley and Ridge, New England, and Piedmont Physiographic Provinces, in northern New Jersey (fig 1). The southern extent of the region is the Fall Line. The Fall Line is a natural junction, running parallel to the east coast of the United States, between the hard rocks of the Appalachians and the softer, sandy Coastal Plain soils, along which rivers form falls and rapids (Newell and others, 1998). In the non-coastal region the geology is more variable and consists of rocky areas with little or no sediment cover, minimal groundwater storage, and small contributions to the base flow; thick glacial deposits and (or) carbonate rock are present that can store large amounts of groundwater where the groundwater contribution to base flow is large (Watt, 2000).

The Coastal Plain consists of the streams tributary to the Raritan River east of the Fall Line, the Raritan Bay, the Atlantic Ocean, and Delaware River south of Trenton, NJ. The area is underlain by deposits of sand, silt, and clay. Areas with greater sand deposits generally have higher base flows as the sand can store more groundwater which contributes to the streamflow (Watt, 2000).

Development of Regional Regression Equations

Streamflow information at ungaged sites is critical for water-resource managers of Federal, State, county, city, and town agencies; non-governmental and private organizations; and the public dealing with water-resources issues. Flow-duration and low-flow frequency statistics for streams at ungaged sites can be estimated by using a regression equation relating streamflow statistics to basin characteristics.

Equation development was done in two phases. In the first phase flow-duration and low-flow frequency statistics (response variables) were related to basin characteristics (explanatory variables) by using the OLS regression method. OLS, commonly referred to as linear regression, is used to describe the co-variation between some variable of interest and one or more other variables (Helsel and Hirsch, 2002). The regression iterations using OLS (such as best subset, stepwise, forward, and backward selection) were performed by using the statistical software package Minitab (Minitab, 2006). These steps were performed to identify those explanatory variables that were significant at the 95-percent confidence interval.

It may be inferred that information from the index station flows is simply duplicated in using partial-record stations in the regionalization process. However, the estimated flows can add value by representing a wider array of basin characteristics. Also, it can be argued that the estimated flows at the partial-record sites are not as accurate as flow data for the long-term continuous gages depending on the range, quality, timing, and correlation of base-flow measurements at the partial-record sites. To account for this in the regionalization analysis, partial-record sites are assigned a weight that is based on the inverse of the weighted-mean of the standard error of estimate of the M7D10Y low-flow frequency statistic (“PERCENT EST” column of the MOVE.1 output in fig. 4). The weight for a streamgage is the inverse of the time sampling error of the M7D10Y low flow frequency statistic (“PERCENT GAGE” column of the MOVE.1 output in fig 4).

The left-censored parametric survival regression analyses method was used for the second phase of the study to derive the final regression equations that best fit the data. Regression analysis was performed by using the explanatory variables obtained from the OLS method that were determined to be significant. If an observed streamflow value, or response variable, is known to be less than a certain threshold, then the data are said to be left-censored. Because of the uncertainty in measuring daily mean flows and estimating low-flow durations and frequencies less than 0.05 cubic foot per second (ft^3/s), a censoring threshold set at 0.05 ft^3/s was used to develop the left-censored regression equations for this study. Tests were run to determine the value to set as the threshold. The estimated statistic results were identical using the threshold of 0.15, 0.1, and 0.05 ft^3/s. All input statistics having a streamflow value of 0 ft^3/s or a flow value between 0 and 0.05 ft^3/s were censored to have a value of 0.05 ft^3/s. Censoring and coding data as “less than” a threshold, allows the use of a log transformation on the data (D.L. Lorenz, USGS, written commun., 2011) and, therefore, allows all of the data to be used to develop the equations. Censored and uncensored response data can be included together in a censored-regression analysis. The left-censored parametric survival regression analyses were performed by using the USGS computer-program-library version 4.0 for S-Plus for windows (Lorenz and others, 2011) in TIBCO Spotfire S-Plus (TIBCO Software Inc., 2008). Censored regression is similar to multiple-linear regression, except that the regression coefficients are fit by maximum-likelihood estimation (MLE) (Helsel and Hirsch, 2002). MLE assumes that residuals are normally distributed around the regression line for the estimation of the slope and the intercept, and the range of predicted values has a constant variance (Eash and Barnes, 2012). It has been shown that censored regression estimates are slightly biased (Cohn, 1988); therefore, an adjustment is made in these estimates using an adjusted maximum-likelihood computation. An adjusted maximum-likelihood estimation computation has been implemented in the USGS computer-program-library, which is recommended for data that have log-normal distribution. An adjusted MLE is described further by Cohn (1988) and Helsel (2005).

Regression analyses provide a mathematical equation for estimating a response variable, streamflow statistic, from one or more explanatory variable(s), basin characteristics. The low-flow statistic for a selected duration and frequency statistic is expressed as a function of basin characteristics. Upon the development of regression equations, measurements of the basin characteristics at ungaged stream locations can be used to estimate the streamflow statistic. The general form of the mathematical model used is

$$\log_{10}Q_u = b_0 + b_1\log_{10}X_1 + b_2\log_{10}X_2 + b_3\log_{10}X_3 \ldots b_n\log_{10}X_n \ldots, \qquad (2)$$

where

Q_u is the response variable (estimated streamflow statistic) for the ungaged site "u";

b_0 is the regression equation coefficient, or intercept, determined in the analysis;

$X_1, X_2, X_3,\ldots X_n$ are explanatory variables (basin characteristics); and

$b_1, b_2, b_3,\ldots b_n$ are the fitting coefficients.

Linear regression analysis is based on the following assumptions: (1) the mean of the residuals (e_i) is zero, (2) the variance of the residuals is constant, (3) the residuals are normally distributed, and (4) the residuals are independent of each other. In addition to these assumptions, the selected explanatory variables (x) should have a good physical basis as predictors of the streamflow statistic. The plus and minus terms of the equation should make hydrological sense. For example, a variable such as drainage area would have a positive coefficient because an increase in drainage area would result in an increase in the streamflow statistic. The explanatory variables (basin characteristic) in the equation also should not be highly correlated with each other.

After the coefficients have been determined through regression analysis, the equation is transformed back to its original units, ft^3/s, in a form that can be used to estimate a specific streamflow statistic at an ungaged site. The retransformed equation has the following form:

$$Q_u = EXP^{b_0} x_1^{b_1} x_2^{b_2} x_3^{b_3} \ldots x_n^{b_n} \quad , \qquad (3)$$

where

Q_u is the response variable (estimated streamflow statistic) for the ungaged site "u";

b_0 is the regression equation coefficient, or intercept, determined in the analysis;

$x_1, x_2, x_3,\ldots x_n$ are explanatory variables (basin characteristics); and

$b_1, b_2, b_3,\ldots b_n$ are the fitting coefficients.

Multiple-regression analysis was used in a forward-stepwise procedure to include or exclude explanatory variables (basin characteristics) in the final model. The variables included in the final equations are those that are significant at a prescribed confidence level, that is, those variables that when included in the regression equation account for a sufficiently large portion of the total variance so that the relation is unlikely to have resulted from chance alone. The basin characteristics used in developing the low-flow duration and frequency regression equations for the two regions and two land- and water-use conditions are drainage area, percentage of storage (Coastal Plain), average April precipitation for 1971–2000 (Coastal Plain), average June precipitation for 1971–2000 (non-coastal region), and soil permeability (non-coastal region) (table 6). A value of "1" was added to the percentage of storage and soil permeability explanatory variables to assure no values would be equal to zero.

After regression analyses were performed, the residuals were examined to assess goodness of fit and determine whether regional trends existed. Final left-censored parametric survival regression models were selected primarily on the basis of minimizing values of the standard error of estimate. Coefficient of determination (R^2) is not determined when

Table 6. Significant basin characteristics for each regression equation by region and for baseline and current land- and water-use conditions.

[--, not applicable]

Coastal Plain regression region		Non-coastal regression region	
Baseline	**Current**	**Baseline**	**Current**
Drainage area	Drainage area	Drainage area	Drainage area
Average April precipitation	Average April precipitation	Average June precipitation	Average June precipitation
Soil permeability	Soil permeability	Soil permeability	Soil permeability
Percent storage	Percent storage	--	--

using the left-censored regression analyses, so this information could not be used to assess the equations. The best-fit equations are listed in tables 7–10 (tables 7–10 in back of report).

Final Regression Equations

The final regression equations were developed by using a left-censored parametric survival regression method for the 99-, 90-, 85-, 75-, 50-, and 25-percentile flow-durations of monthly minimum 1-day daily flow; the 99-, 90-, and 75-percentile August–September minimum 1-day daily flow; and the monthly 7-day, 10-year (M7D10Y) low-flow frequency statistic. The equations were developed separately for the baseline and current (water years1989–2008) land- and water-use conditions, and for non-coastal and Coastal Plain regions (tables 7–10). StreamStats variable names are used for the response and explanatory variables in the final regression equations; definitions of the variables and the units of measure are listed in table 3. The left-censored parametric survival regression analyses were done by using USGS computer-program-library for S-Plus for windows (Lorenz and others, 2011) in TIBCO Spotfire S-Plus (TIBCO Software Inc., 2008). This procedure in S-Plus uses the adjusted MLE or a method that involves applying a small constant value (for this study 0.05 ft^3/s was used) to all response variables in a dataset (Kroll and Stedinger, 1999), which is preferred for data that has log-normal distribution.

Drainage area (DRNAREA) generally is the most significant explanatory variable in all regional streamflow regression equations, whether for low-, peak-, annual mean, monthly mean, or median flow statistics. It is a significant variable at the 95-percent confidence interval in almost all equations in this study. Some equations, such as the June 99-percentile flow duration use drainage area as the only explanatory variable; however, the equation is not statistically significant. For the equations that estimate very low flows, often no significant explanatory variables were found. The equations that are not statistically significant are designated as such in tables 7–10.

Of the 174 flow statistics for both periods in the non-coastal region, 24 had no significant explanatory variables, and 71 had drainage area as the only significant variable. Most of the monthly 99-percentile flow durations could not be explained, as well as some of the lower flow durations of the summer months and M7D10Ys. Most low-flow statistics during summer months (generally June through October) for the M7D10Ys and the 90- through 50-percentile flow durations were explained only by drainage area.

For the Coastal Plain, 10 of 87 flow statistics had no significant explanatory variable for the baseline period. As in the non-coastal region, most of the monthly 99-percentile flow durations and the summer M7D10Ys could not be explained. For the current period in the Coastal Plain, drainage area was a significant variable for all 87 statistics. For both periods in the Coastal Plain, 50 of the 174 flow statistics could be explained by drainage area only. Statistics that had drainage area as the only significant explanatory variable generally were associated with the lower-flow months of June through October for M7D10Ys and flow durations at the 99, 90, 85, 75, and 50th percentiles.

Soil Permeability (PERMSSUR) was a significant explanatory variable for the winter and spring low-flow statistics in the non-coastal region for both periods. It was also a significant variable for just a few months of the 90-percentile flow durations for the baseline Coastal Plain region. For the other relatively higher Coastal Plain flows, percent storage (STORAGE) proved to be a significant variable. The regression equations containing the percent storage variable has a negative sign. Water bodies and wetlands (storage) contribute direct runoff during storms because water bodies and wetlands have high water tables; however, during low-flow conditions water bodies and wetlands don't contribute flow to the streams. Both regions had a significant precipitation variable in many of the equations. For the Coastal Plain region the variable is the average April precipitation (PRECIP_4), and for the non-coastal region it is the average June precipitation (PRECIP_6). The two regression regions not only have different geomorphic characteristics, but also coincide closely with the two climate divisions (not shown) within the State. Northern New Jersey has a continental climate with nearly 4 inches more of precipitation annually (from 1971–2000) than southern New Jersey, which has a subtropical climate (Office of New Jersey State Climatologist, 2013). The timing of the precipitation coupled with the different effects of surficial geology of the two regions proved to have a direct effect on base flow.

The percent of the standard error of estimate decreased as the number of significant explanatory variables increased for each every region and period, as shown in figure 7. Although using drainage area as the only variable may produce a fair estimate of flow, there is considerable improvement to the estimate when just one additional variable is added. The equations for which not even drainage area was a significant variable are not included in figure 7. The standard error of estimate for those equations ranged from 340 to 83.0 percent.

GIS software was required to measure the basin characteristics included as explanatory variables in the final regression equations. The performance metrics in tables 7–10 indicate the predictive accuracy of the final regression equations.

The standard errors of estimate for all of the regression equations ranged from 16 to 340 percent (tables 7–10). The standard errors of estimate for the flow-duration regression equations for the non-coastal region baseline period ranged from 16 to 340 percent and for the non-coastal region current period from 19.1 to 306 percent. The standard error of estimate for the Coastal Plain baseline period ranged from 29.7 to 217 percent and for the current period from 22.9 to 126 percent (table 11). The standard error of estimate for the low-flow frequency (monthly M7D10Y) regression equations ranged from 23 to 163 percent. For the non-coastal region baseline period, the standard error of the estimate ranged from 23.2 to 131 percent, and for the non-coastal region current period, it ranged from 26.1 to 163 percent. The standard error

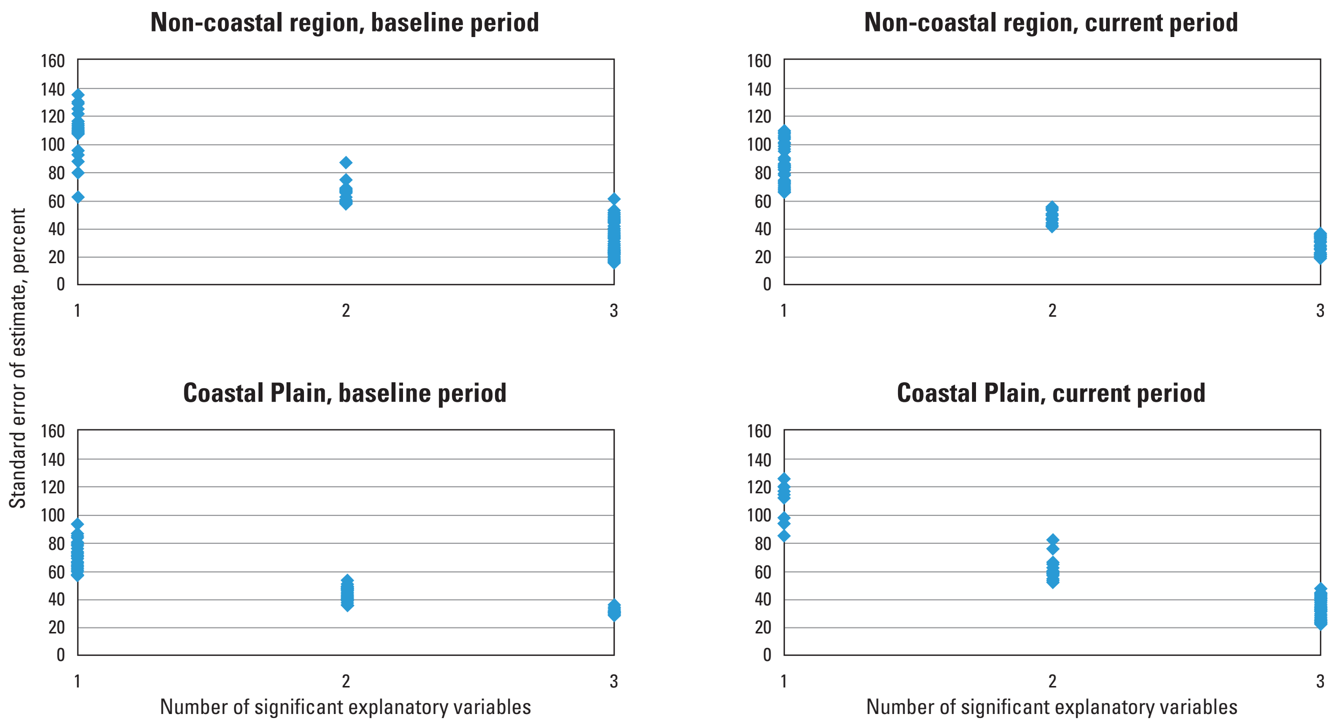

Figure 7. Standard error of estimate in relation to the number of significant explanatory variables used in regional regression equations for selected low-flow statistics in the non-coastal and Coastal Plain regression regions in New Jersey, during the baseline and current (1989–2008) land- and water-use conditions.

Table 11. Range of values of the standard error of estimate for the low-flow duration regression equations.

Period[1]	Low-flow regression region	Flow-duration statistics Standard error of estimate	
		Minumum	Maximum
Baseline	Non-coastal	16	339.55
Baseline	Coastal Plain	29.73	217.05
Current	Non-coastal	19.07	306.44
Current	Coastal Plain	22.89	126.39

[1] Current period refers to the period of record 1989–2008. Baseline period refers to the preliminary baseline period of record as determined by Esralew and Baker (2008).

Table 12. Range of values of the standard error of estimate for the low-flow frequency regression equations.

Period[1]	Low-flow regression region	Low-flow frequency statistics Standard error of estimate	
		Minumum	Maximum
Baseline	Non-coastal	23.2	131
Baseline	Coastal Plain	35.8	135
Current	Non-coastal	26.1	163
Current	Coastal Plain	29.7	63.5

[1] Current period refers to the period of record 1989–2008. Baseline period refers to the preliminary baseline period of record as determined by Esralew and Baker (2008).

of the estimate for the Coastal Plain baseline period ranged from 35.8 to 136 percent and for the Coastal Plain current period from 29.7 to 63.5 percent (table 12). The flow-duration statistics for the monthly 99-percent (the lowest streamflow) have the greatest inexplicable variability and high standard errors, ranging from 38.3 to 340 percent. The 25-percentile flow durations for all 12 months of the year could be quantified regionally with the most confidence because regression equations for both regions and periods resulted in at least two explanatory variables. The range of standard error of estimates was 16.0 to 55.4 percent for the 25-percentile flow durations. The M7D10Y low-flow statistics for summer months July through October, generally the lower-flow months, have high standard errors, ranging from 45.3 to 163 percent. The standard error of estimate is generally lower for the Coastal Plain equations, with the current time period having the lowest range of 22.9 to 126 percent (table 10). Although, the average standard errors of the estimate are high for the low-flow statistics, they are similar to those for regional regression equations used to estimate low-flow statistics in Connecticut (Ahearn, 2010) and Massachusetts (Ries and Friesz, 2000). Generally, high average standard errors of the estimate for the low-flow equations are common in state-wide studies throughout the United States.

The standard error of estimate output from the left-censored regression analysis is the “Scale.” The “Scale” is the equivalent of the residual standard error in an OLS model. The “Scale” is a biased estimate of the standard error; to determine the unbiased estimate, use the following equation (D.L. Lorenz, USGS, written commun., 2011):

$$\sqrt{\frac{n}{(n-p)}} \quad , \tag{4}$$

where

- n is the number of observations in the analysis and,
- p is the number of parameters that were estimated—number of explanatory variables, plus 1 for the intercept.

The output of this equation is the model “Scale,” which is the standard error of estimate in log space. This value is converted to standard error in percent by using the following equation found in the USGS Office of Surface Water technical guidance at *http://water.usgs.gov/usgs/osw/swstats/variance-percent_to_log.pdf* :

$$SEpct = \sqrt{EXP\left(\sigma^2\right) - 1} \quad , \tag{5}$$

where

- $SEpct$ is the standard error in percent, and
- σ is the scale.

The relations of observed to predicted streamflows for selected streamflow statistics are presented in figures 8–11. The plots are organized by the regression region and the flow-duration statistic. The baseline period of record and current period of record are displayed together on each figure and labeled A and B, respectively, for comparison. The uncertainty of the regression estimates can be seen graphically as the greater scatter of observed in relation to predicted values along the 1:1 line. Generally, the greatest error was found in predicting flows less than 1 ft^3/s; the predicted flow was most often higher than the observed flow. Also, at the lower flow durations (99-percentile flow duration of the monthly minimum 1-day flows) (figs. 8 and 9), a clear wider spread of the data is evident than at the higher flow duration (for example at the 50-percentile flow duration of the monthly minimum 1-day flow, where 50-percent of the time the flow is equal or exceeded) (figs. 10 and 11). This is evident in the higher average standard error of estimate, ranging from 38.3-to 340-percent, for the monthly minimum 1-day 99-percentile flow durations, whereas for the 50-percentile flow durations the range of the standard error of estimate was 17.8 to 84.3 percent. The increasing ability to more accurately estimate the higher durations of the monthly 1-day minimum flow is indicated by the statistics in table 13. The 25-percentile flow duration had the smallest range of the standard error of estimate; it is the only statistic for which there were at least two explanatory variables for all monthly flows for all equations for the two regions and both land- and water-use conditions. The observed, predicted, and percent difference statistic values for each of the regions and both land- and water-use conditions are in appendixes 1–4.

Plots showing a greater scatter of data points are generally found in all studies that developed regional regression equations for estimating low flows. The relation between data points in the non-coastal region and the Coastal Plain for the two example statistics can be observed in figures 8–11. For the 99- and 50-percentile of the minimum 1-day flow, the data for the current land- and water-use condition in the Coastal Plain region show a tighter scatter along the 1:1 line than for the baseline land- and water-use condition (figs. 9 and 11). The opposite is true for the non-coastal region; the baseline land- and water-use condition shows a tighter scatter along the 1:1 line than does the current condition for the 99 and 50 percentiles of the minimum 1-day flow (figs. 8 and 10). The relation between data points in the non-coastal region and the Coastal Plain as a percent difference between the observed and predicted selected streamflow statistics is presented geographically in figures 12–15. Positive percent differences indicate that the predicted flow statistic is higher than the observed. As seen in the figures 12–15, the predicted flow statistics are consistently and considerably over-estimated in the unglaciated Piedmont Physiographic Province of the State. During the development of this study, it was assumed that surficial geology variables would significantly explain the difference in flows between the glaciated and unglaciated parts of the non-coastal region. This assumption has been proven wrong, and perhaps a third region, the unglaciated Piedmont Physiographic Province, for the regression analysis could have been defined.

A comparison was made of the observed monthly low-flow duration and frequency statistics between the baseline and current land- and water-use conditions for the two regions. The medians of the percent differences between the observed baseline statistic value and the observed current statistic value were analyzed. In the non-coastal region, the median values of the percent differences were generally positive, indicating that the observed baseline monthly streamflow statistics are lower than the observed current monthly streamflow statistics. In the Coastal Plain, the median values of the percent differences were generally negative, indicating the observed baseline monthly streamflow statistics are higher than the observed current monthly streamflow statistics, with the summer months having the greatest median percent differences. The results of

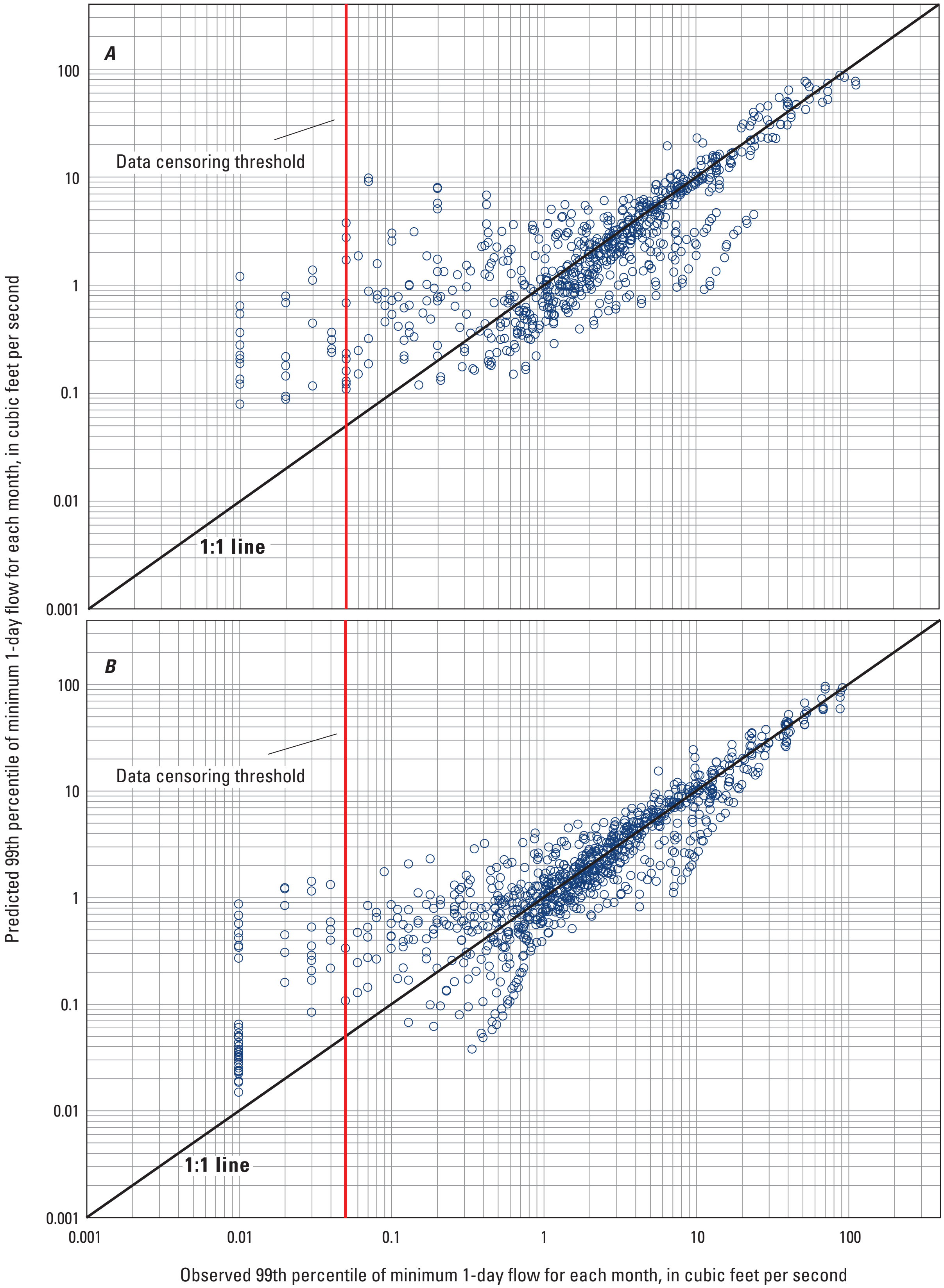

Figure 8. Relation of the 99th percentile of minimum 1-day flow for each month computed from observed streamflow to those predicted using the regression equations for the Coastal Plain regression region in New Jersey for *A*, baseline period of record from Esralew and Baker (2008) and *B*, current period of record (1989–2008).

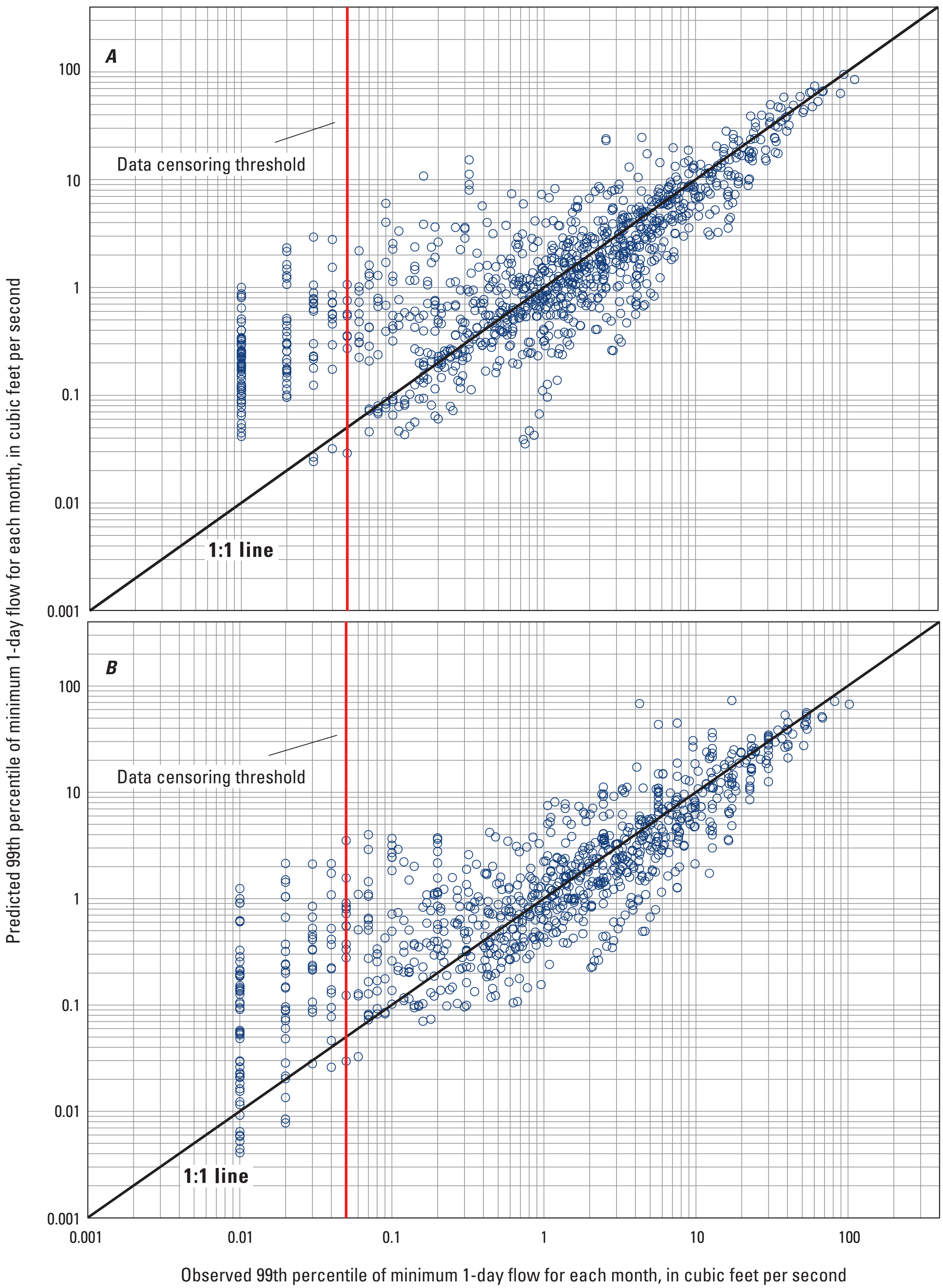

Figure 9. Relation of the 99th percentile of minimum 1-day flow for each month computed from observed streamflow to those predicted using the regression equations for the non-coastal regression region in New Jersey for *A*, baseline period of record from Esralew and Baker (2008) and *B*, current period of record (1989–2008).

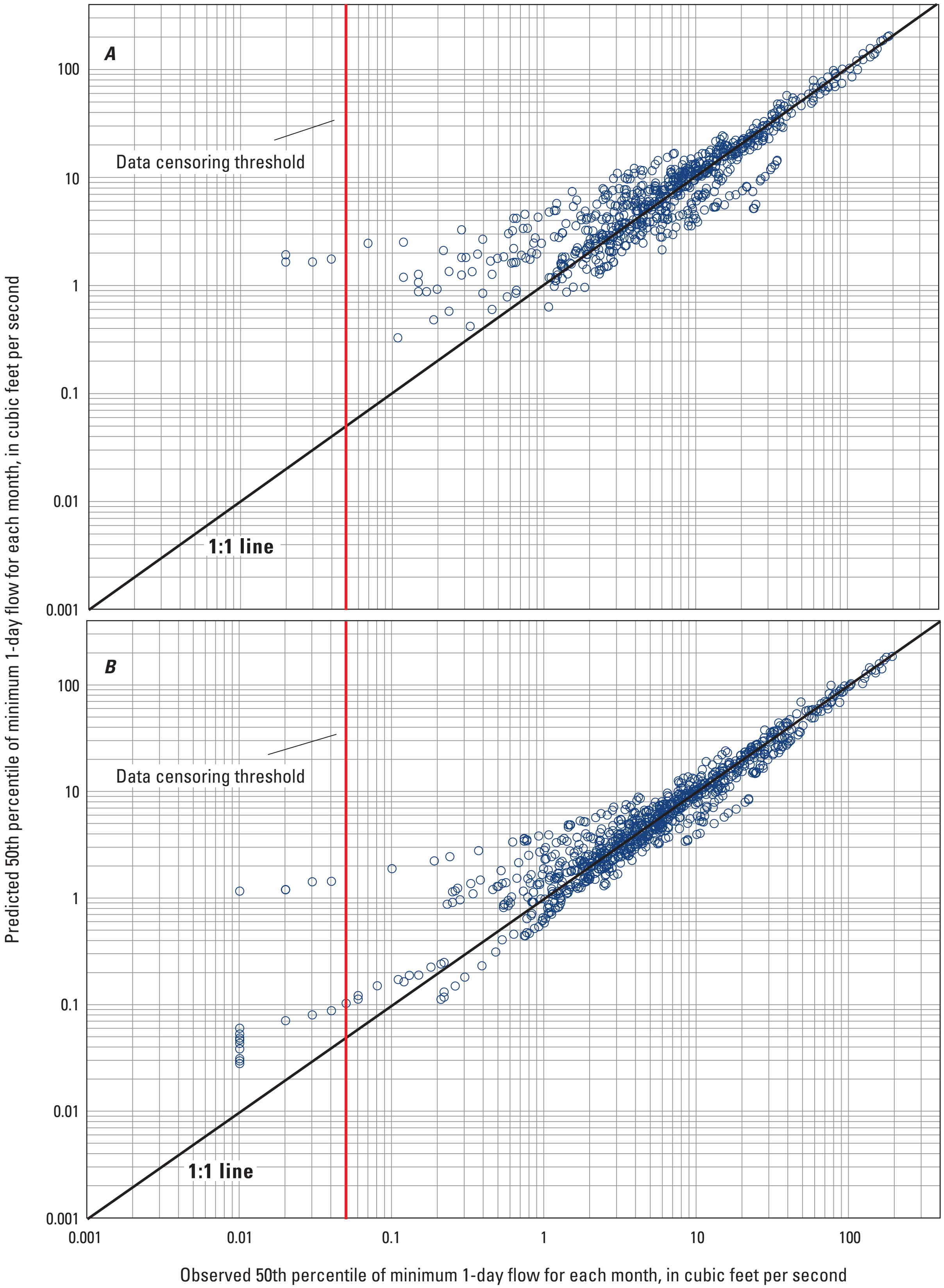

Figure 10. Relation of the 50th percentile of minimum 1-day flow for each month computed from observed streamflow to those predicted using the regression equations for the Coastal Plain regression region in New Jersey for *A*, baseline period of record from Esralew and Baker (2008) and *B*, current period of record (1989–2008).

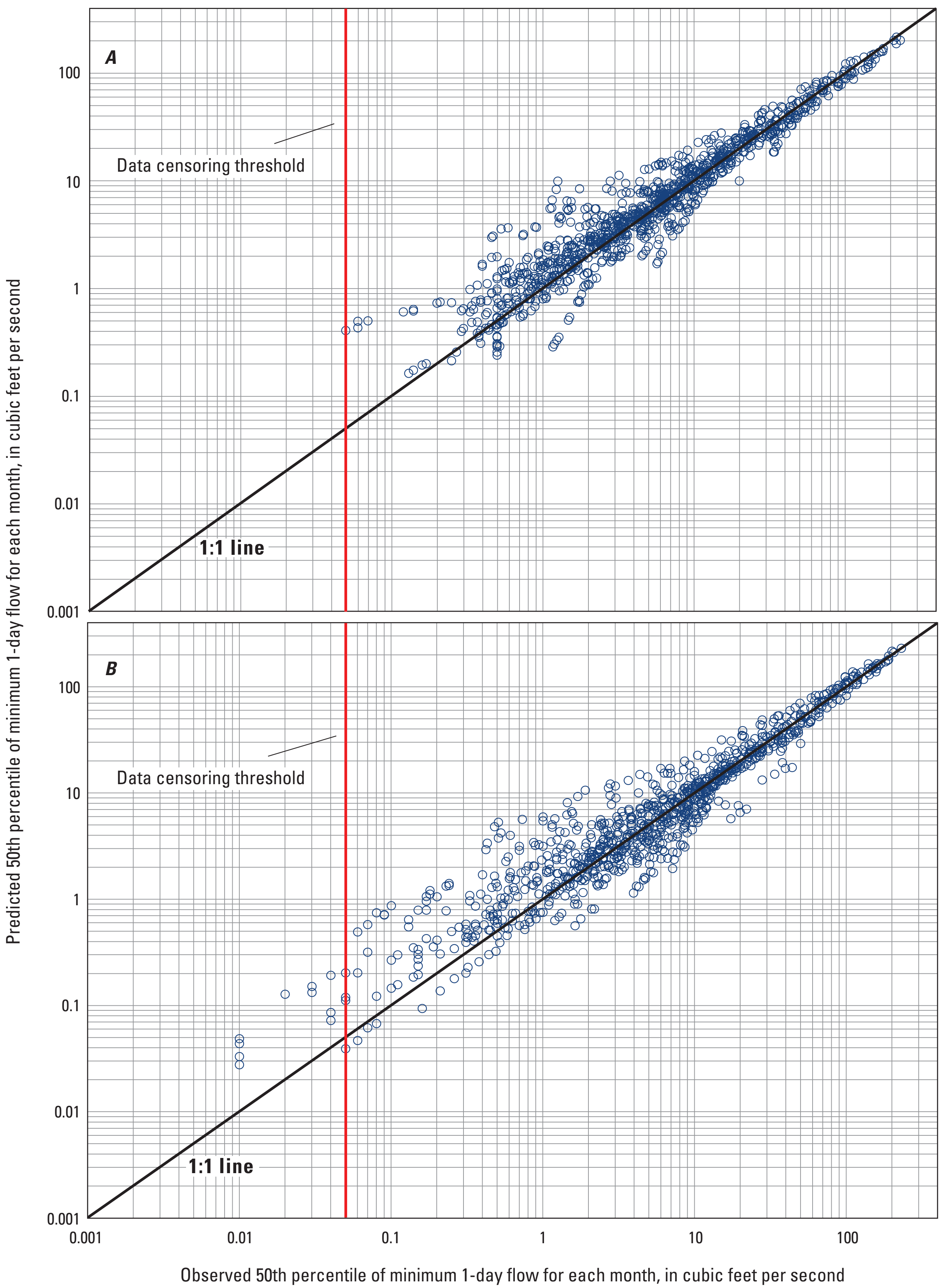

Figure 11. Relation of the 50th percentile of minimum 1-day flow for each month computed from observed streamflow to those predicted using the regression equations for the non-coastal regression region in New Jersey for *A*, baseline period of record from Esralew and Baker (2008) and *B*, current period of record (1989–2008).

Table 13. Summary of the standard error of estimates and number of explanatory variables for regression equations of selected low-flow statistics, for both the non-coastal region and Coastal Plain, and both baseline and current (1989–2008) land- and water-use conditions.

[--, no change; M7D10Y, lowest 7 consecutive days streamflow for a set period (monthly) that has an average reccurence interval of 10 years]

Regression statistic	Range of the standard error of estimate of the regression equations				Count of regression equations with the given number of significant explanatory variables			
Durations of monthly 1-day minimum flows	maximum	percent change	minimum	percent change	0	1	2	3
99	340	--	38.3	--	27	16	6	3
90	142	-58	28.9	-25	4	19	14	15
85	122	-14	25.6	-11	2	15	13	18
75	106	-13	22.3	-13	0	15	13	24
50	84.3	-20	17.8	-20	0	8	8	32
25	55.4	-34	16.0	-10	0	0	10	38
M7D10Y	163	--	23.2	--	4	11	13	20

the comparison between the observed statistics for the baseline and current land- and water-use conditions are in appendixes 5 and 6. Some of the factors that can contribute to changes in streamflow are an increase or decrease in impervious cover, water use, and wastewater sewers and treatment facilities. Another contributing factor could be the observed increase in annual precipitation (1971–2000) in the non-coastal region compared to that in the Coastal Plain (Office of New Jersey State Climatologist, 2013).

This example computation is provided for Toms River near Toms River, NJ (station number 01408500, map identifier 115) (fig. 2 and table 1). The values of the explanatory variables used in the regression equation for the June 90-percent flow duration of the minimum 1-day flow for the current land- and water-use condition are a drainage area (DRNAREA) of 123.74 mi^2, April precipitation (PRECIP_4) of 3.95 inches, and a percent storage (STORAGE) of 24.56 (table 5). The streamgage is located in the Coastal Plain region. By using the appropriate regional regression equation from table 11, the June 90-percent flow duration of the minimum 1-day flow is

$$\begin{aligned}\text{June } Q_{90} &= (0.00001)*(\text{DRNAREA})^{1.12}*(\text{PRECIP\_4})^{9.38}*\\ &\quad(\text{STORAGE}+1)^{-0.610}\\ &= (0.0000068)*(123.74)^{1.12}*(3.95)^{9.38}*\\ &\quad(24.56+1)^{-0.610}\\ &= (0.0000068)*(220.60)*(394530.66)*\\ &\quad(0.1385)\\ &= 81.97 \text{ ft}^3/\text{s} .\end{aligned}$$

Use of Regression Equations

The equations for the current period are to be used to estimate current low-flow statistics. The equations for the baseline period are assumed to produce estimated statistics for basins unaffected by increased development. Both types of equations can be used to determine how the conditions have changed from unaffected to the developed basin.

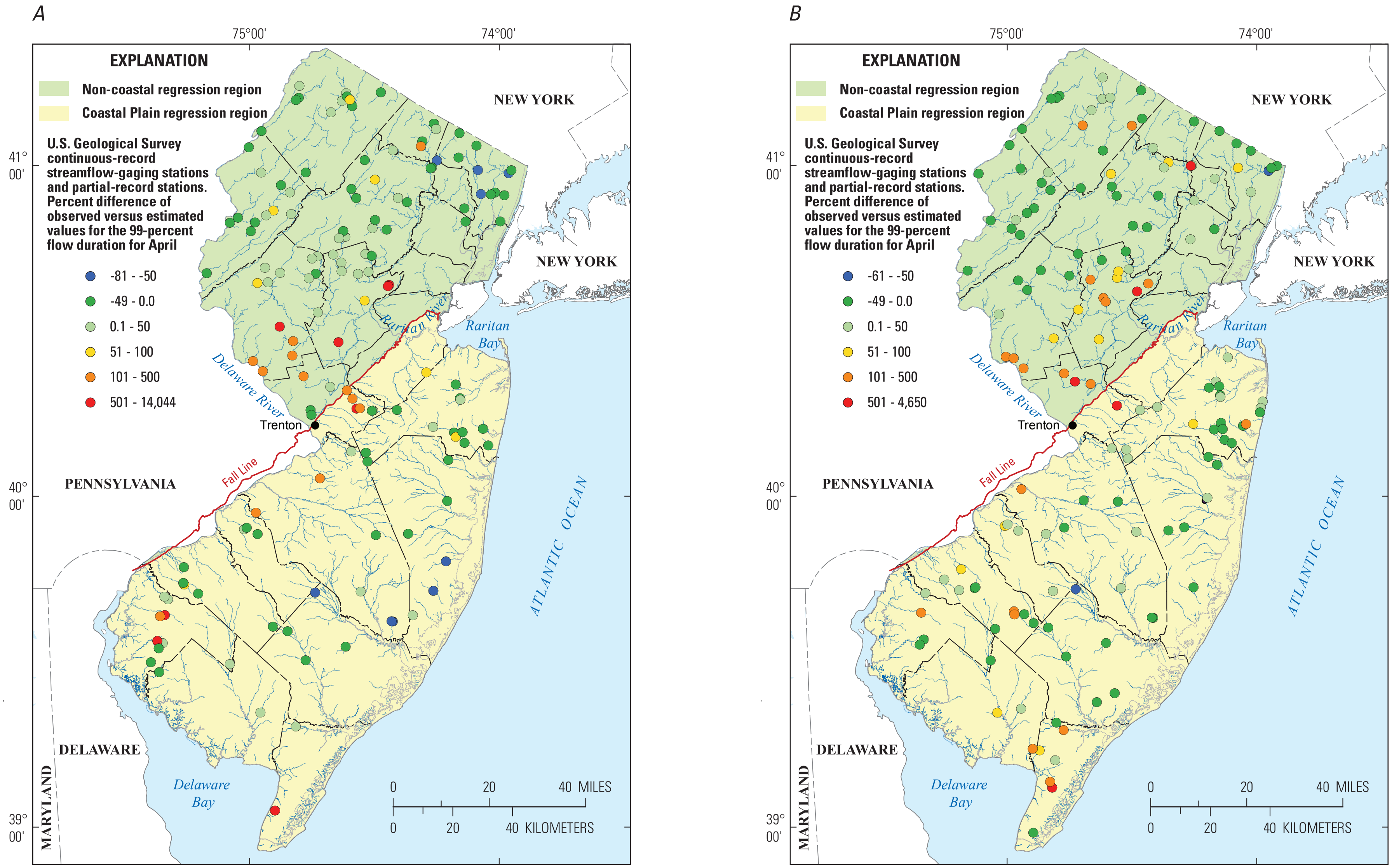

Figure 12. Percent difference between the observed and predicted values for the 99-percent flow duration for the April minimum 1-day flow for *A*, the baseline period of record from Esralew and Baker (2008) and *B*, the current period of record (1998–2008) at U.S. Geological Survey continuous-record streamflow-gaging stations and partial-record stations in New Jersey.

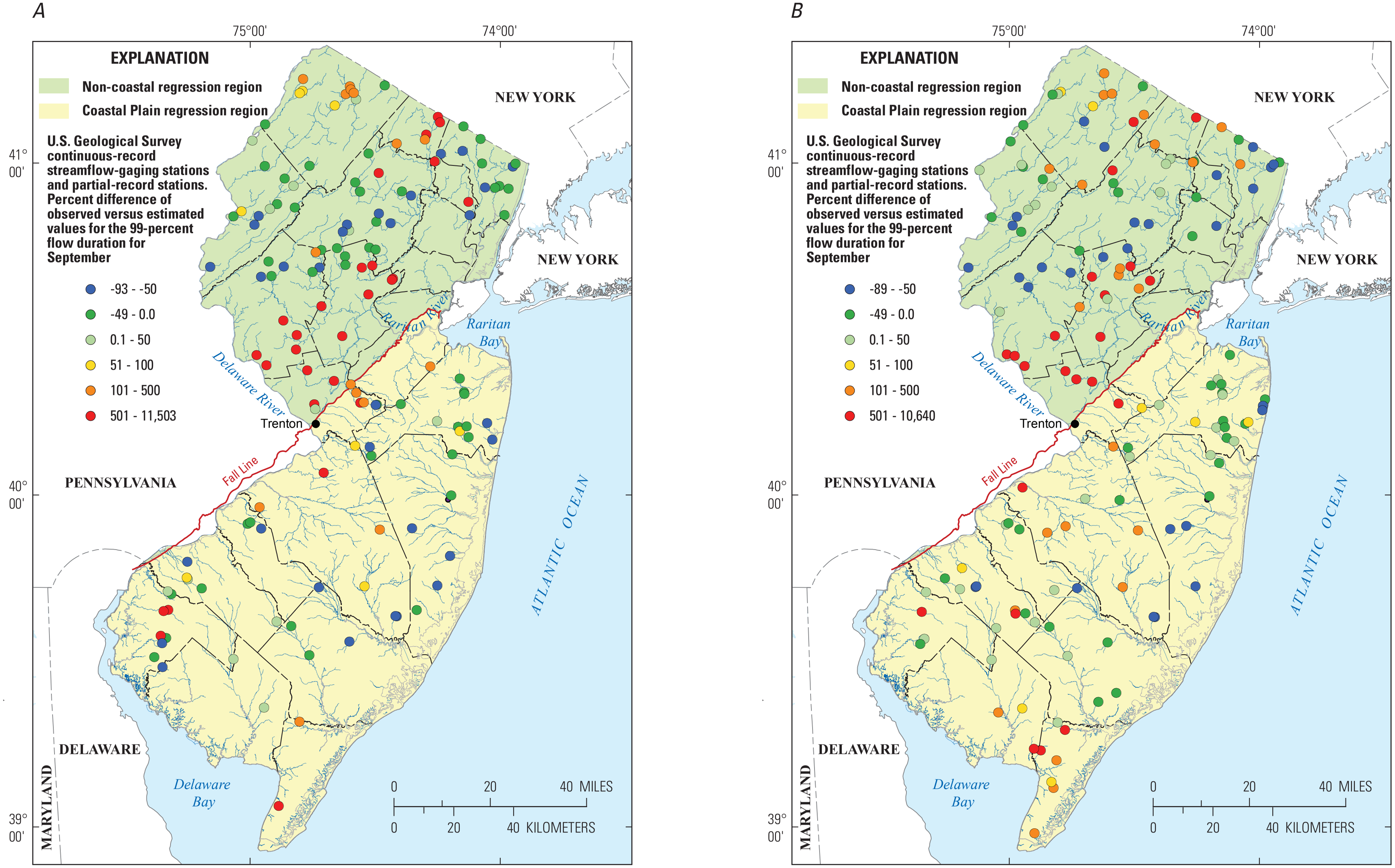

Figure 13. Percent difference between the observed and predicted values for the 99-percent flow duration for the September minimum 1-day flow for *A*, the baseline period of record from Esralew and Baker (2008) and *B*, the current period of record (1998–2008) at U.S. Geological Survey continuous-record streamflow-gaging stations and partial-record stations in New Jersey.

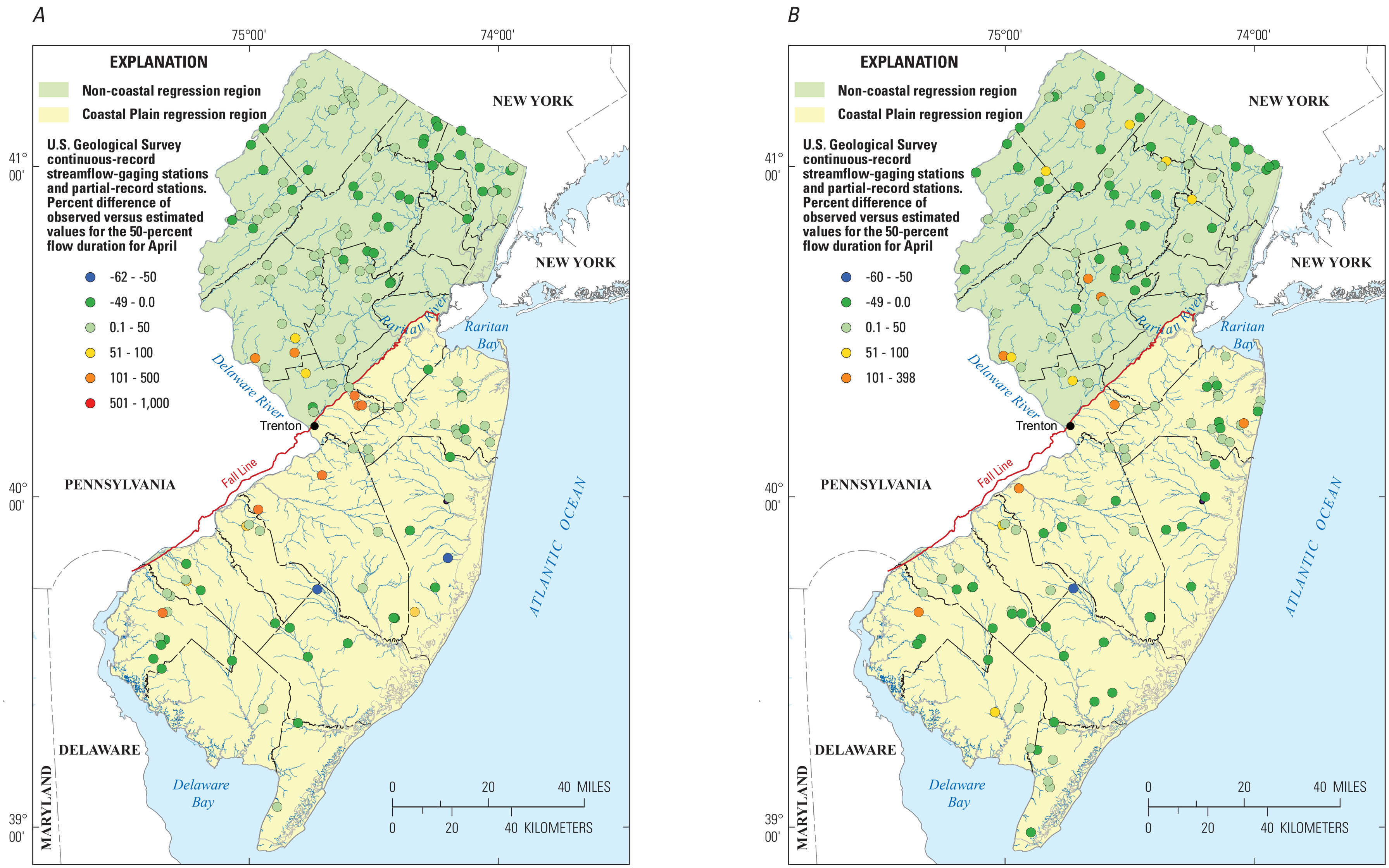

Figure 14. Percent difference between the observed and predicted values for the 50-percent flow duration for the April minimum 1-day flow, for *A*, the baseline period of record from Esralew and Baker (2008) and *B*, the current period of record (1998–2008) at U.S. Geological Survey continuous-record streamflow-gaging stations and partial-record stations in New Jersey.

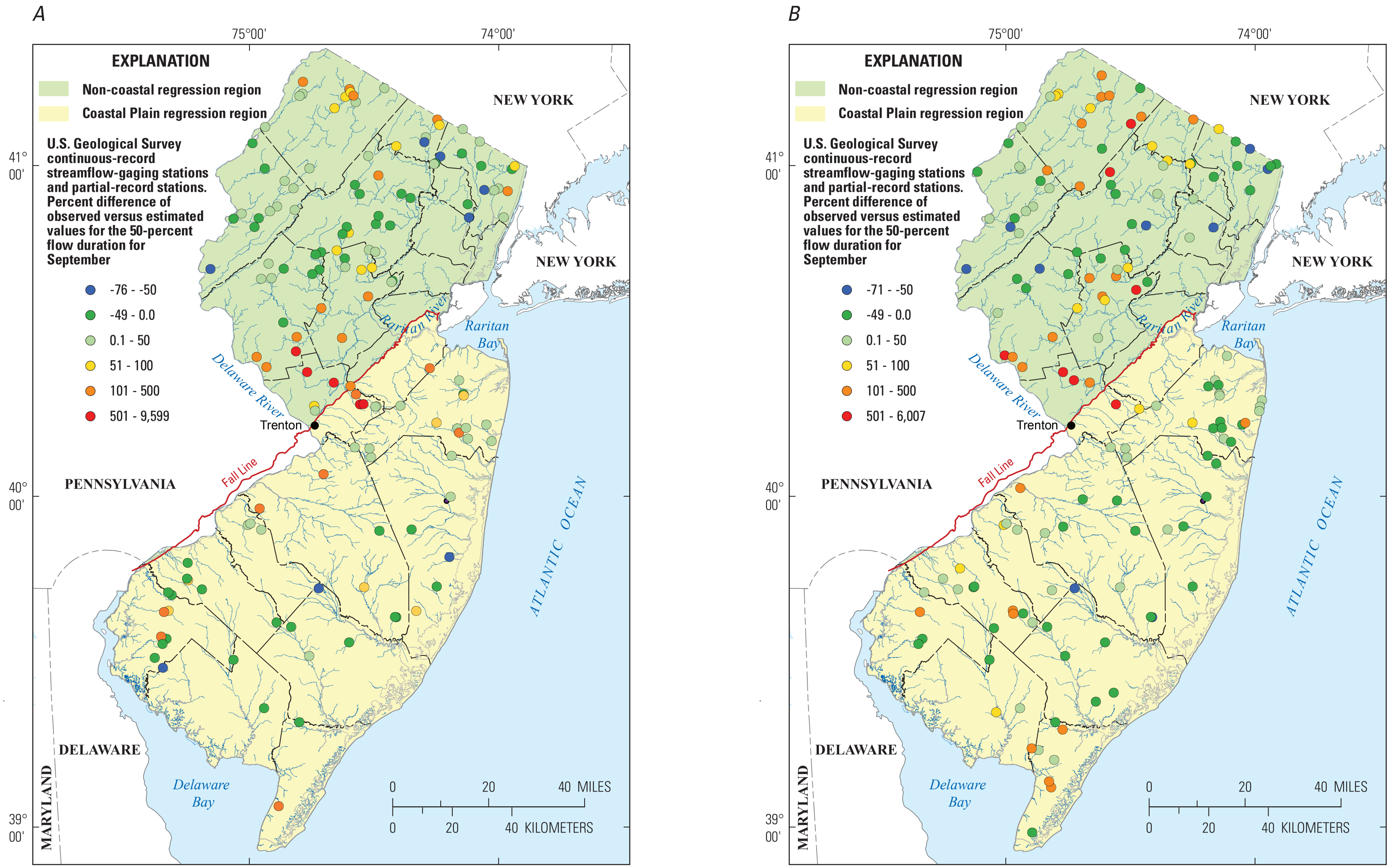

Figure 15. Percent difference between the observed and predicted values for the 50-percent flow duration for the September minimum 1-day flow, for *A*, the baseline period of record from Esralew and Baker (2008) and *B*, the current period of record (1998–2008) at U.S. Geological Survey continuous-record streamflow-gaging stations and partial-record stations in New Jersey.

Limitation of Regression Equations

The regional regression equations developed in this study apply only to stream sites in New Jersey where low flows are not significantly affected by regulation, water withdrawals, diversions, flood control, and wastewater discharge. Use of the regression equations presented in this report is limited in determining selected streamflow statistics for the baseline and the current (water years 1989–2008) land- and water-use conditions and for the Coastal Plain and non-coastal regions by the range of the basin-attribute data used to develop the equations and by the accuracy of the estimates. The acceptable range of basin-characteristic values used to develop each regional regression equation is shown as minimum and maximum values in table 14. The applicability of the regional regression equations is unknown when any characteristic value measured for an ungaged site is outside the acceptable range. A known anomaly in the results of the comparison between observed and predicted values, as seen in figures 12–15, would suggest the non-coastal region regression equations, in general, over-predicted the statistic estimates in the unglaciated Piedmont Physiographic Province area of the non-coastal region. The addition of a third regression region, the unglaciated Piedmont Physiographic Province, may improve the accuracy of the estimates.

The basin-characteristic measurements at ungaged sites need to be computed by using the same GIS datasets and measurement methods used in this study; the USGS StreamStats Web-based GIS tool includes the same GIS basin characteristic data layers and measurement methods as were used to develop the regression equations in this study.

The low-flow duration and frequency equations presented in this report are best used with caution for the determination of streamflow statistics at ungaged sites with basin-characteristic values approaching the minimum or maximum limits (table 14) because inconsistencies in the estimates may result. Regression equations used to determine flow-duration and low-flow frequency statistics for sites downstream from reservoirs do not produce acceptable results.

StreamStats

StreamStats is a USGS Web-based GIS tool (*http://water.usgs.gov/osw/streamstats/index.html*) that allows users to obtain streamflow statistics and basin characteristics for user-selected sites on streams. Users can select stream sites of interest from an interactive map and can obtain information for these sites. The GIS program determines the boundary of the drainage basin upstream from the stream site of interest, measures the basin characteristics of the drainage basin, and solves the regional regression equation to estimate the streamflow statistics for that site. The results are presented in a table with a map showing the drainage basin delineation as a polygon. This tool greatly reduces the effort needed in the past to delineate drainage basin boundaries. StreamStats reduces the duration of the process to only a few minutes.

The USGS Web application StreamStats was implemented for use in New Jersey in 2009. StreamStats can be used to estimate low-flow statistics at ungaged stream sites by use of two methods (Ries and others 2008). One method uses equations relating low-flow statistics at ungaged sites to selected basin characteristics. The second method estimates flow statistics for an ungaged site by using statistics for a nearby gaged site.

StreamStats allows users to estimate values of selected low-flow statistics at ungaged sites for both baseline and current land- and water-use conditions. The statistics for which values can be estimated are the 99-, 90-, 85-, 75-, 50-, and 25-percentile flow durations of monthly minimum 1-day flow; the 99-, 90-, and 75-percentile August–September minimum

Table 14. Ranges of values of basin characteristics used to develop the low-flow duration and frequency regional regression equations.

[mi², square mile; in/hr, inches per hour; in, inches; Min., minumum value; Max., maximum value; --, not applicable]

Period[1]	Low-flow regression region	Number of stations used	Drainage area (mi²)		Soil permeability (in/hr)		Average April precipitation (in)		Average June precipitation (in)		Percent storage	
			Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
Baseline	Non-coastal	87	0.6	159.88	0.43	6.99	--	--	3.79	4.81	--	--
Baseline	Coastal Plain	57	1.88	123.74	2.43	11.73	3.42	4.05	--	--	7.43	46.28
Current	Non-coastal	77	.35	159.88	0.38	6.73	--	--	3.79	4.76	--	--
Current	Coastal Plain	73	.35	123.74	--	--	3.37	4.11	--	--	5.2	55.9

[1] Current period refers to the period of record 1989–2008. Baseline period refers to the preliminary baseline period of record as determined by Esralew and Baker (2008).

1-day flow; and the monthly 7-day, 10-year (M7D10Y) low-flow frequency. The basin characteristics used in this study have been incorporated into StreamStats. These new basin characteristics are soil permeability, average June precipitation, and average April precipitation. The other basin characteristics used in the study for low-flow regression equations—percent storage and drainage area—were added to the StreamStats application from the peak flow study by Watson and Schopp, (2009).

Summary and Conclusions

The demands for water use for domestic, agriculture, and recreation purposes in New Jersey have increased as the population has grown from about 5 million in 1950 to nearly 9 million in 2010. The low-flow characteristics of a stream ultimately affect its use by humans. In response to the need to improve predictive methods for estimating low-flow duration and frequency statistics for stream sites in New Jersey, the U.S. Geological Survey in cooperation with the New Jersey Department of Environmental Protection, initiated a study to develop regression equations and expand the basin characteristics used in the regression equations.

Flow duration, low-flow frequency statistics, and basin characteristics were used to develop 348 regression equations to estimate the 99-, 90-, 85-, 75-, 50-, and 25-percentile flow-durations of monthly minimum 1-day flow; the 99-, 90-, and 75-percentile August–September minimum 1-day flow; and the monthly 7-day, 10-year (M7D10Y) low-flow frequency statistic for the baseline and current (water years 1989–2008) land- and water-use conditions in the Coastal Plain and non-coastal regions of New Jersey. These selected streamflow statistics were determined for 41 continuous-record steamflow-gaging stations (streamgages) and 167 partial-record stations in New Jersey.

Major components of the study included (1) computing 87 selected low-flow duration and frequency statistics at 41 streamgages and 167 partial-record stations in New Jersey using streamflow data collected through September 30, 2008; (2) measuring 32 basin characteristics for the streamgages and partial-record stations used in the analysis; and (3) developing 348 regional regression equations to estimate the selected low-flow duration and frequency statistics at ungaged sites on the basis of basin characteristics.

The State was divided into two low-flow regression regions, Coastal Plain region and non-coastal region, in order to refine the regression equations. The non-coastal region is north of the Fall Line and consists of approximately the northern half of the State; the Coastal Plain region lies south of the Fall Line and consists of approximately the southern half of the State. A left-censored parametric survival regression method was used for the analyses to account for streamgages and partial-record stations that had zero flow values for some of the statistics. Regression analyses were used to define the relations between low-flow statistics and basin characteristics.

Results of the analyses indicate that low-flow statistics at a site are related to the drainage area, plus a combination of either soil permeability, average monthly precipitation (April or June), and percentage of storage (water bodies and wetland area). The average standard error of estimate for the regression equations ranged from 16 to 340 percent. The monthly minimum 1-day 99-percentile flow durations are extremely low flows and have the greatest variability. The regression equations for this statistic have a high standard error of estimate, ranging from 38.3 to 340 percent; the results of most regression equations indicated that no explanatory variable was significant in predicting this flow duration. The M7D10Y regression equations for July through October also have a high standard error of estimate, ranging from 45.3 to 163 percent. Most of the summer flow frequencies and the 99- to 50-percentile flow durations could be explained only by drainage area in both regions and periods. The 25-percentile flow durations for all 12 months of the year could be quantified regionally with the most confidence because regression equations for both regions and periods resulted in at least two explanatory variables. The range of standard error of estimates was 16.0 to 55.4 percent for the 25-percentile flow durations.

The Coastal Plain regression equations for all statistics for the current land- and water-use condition generally performed best among the individual regions and period regressions, with the lowest range of standard errors of estimate ranging from 22.9 to 126 percent. All but one statistic (excluding the 99-percentile flow duration) for the Coastal Plain current period had at least two explanatory variables. It is assumed that the greater variation in the non-coastal plain region surficial geology adds to the difficulty in regionalizing low flows. Also, because the non-coastal region is more populated than the Coastal Plain, minimizing land- and water-use influences is more problematic, thereby introducing inconsistencies in flows that cannot be explained by basin characteristics.

The regression equations performed most poorly in the unglaciated Piedmont Physiographic Province in the non-coastal region, where estimated values of flow are considerably higher than observed values. Defining a third regression region may improve the estimates.

Reliable estimates of low-flow statistics are essential for the effective management of water resources related to water-supply planning and management, recreation, and wildlife conservation. The regression equations provided in this report for estimating flow-duration and low-flow frequency are applicable to streams in New Jersey that are not significantly affected by regulation, water withdrawals, diversions, flood control, and wastewater discharge. These estimating equations may be used by Federal, State, and local water managers in addressing numerous water issues. The regression equations and basin characteristics presented in this report are also available on the StreamStats web application.

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Table 1. Continuous-record streamflow-gaging stations and partial-record streamflow-gaging stations analyzed for low-flow characteristics.

[CR, continuous-record streamflow-gaging station; PR, partial-record gaging station; *, streamflow-gaging station is also an index station used in the analysis]

Map reference number (figure 2)	U.S. Geological Survey station number	U.S. Geological Survey station name	Station type	Period[1]	Low-flow regression region	Latitude (decimal degrees)	Longitude (decimal degrees)
1	01367625	Wallkill River at Sparta, NJ	PR	Current	Non-coastal	41.040	-74.630
2	01367750	Beaver Run near Hamburg, NJ	PR	Baseline	Non-coastal	41.181	-74.590
3	01367800	Papakating Creek at Pellettown, NJ	PR	Baseline, current	Non-coastal	41.163	-74.675
4	01367850	West Branch Papakating Creek at Mccoys Corner, NJ	PR	Baseline, current	Non-coastal	41.197	-74.632
5	01367875	Papakating Creek at Sussex, NJ	PR	Current	Non-coastal	41.262	-74.630
6	01367890	Clove Brook above Clove Acres Lake at Sussex, NJ	PR	Baseline	Non-coastal	41.220	-74.614
7	01367900	Clove Brook at Sussex, NJ	PR	Baseline	Non-coastal	41.211	-74.611
8	01367910	Papakating Creek at Sussex, NJ	PR	Baseline, current	Non-coastal	41.201	-74.599
9	01368950	Black Creek near Vernon, NJ	PR	Baseline, current	Non-coastal	41.223	-74.476
10	01376273	Sparkill Brook at Piermont Road at Northvale, NJ	PR	Current	Non-coastal	40.990	-73.935
11	01377370	Pascack Brook at Park Ridge, NJ	PR	Current	Non-coastal	41.037	-74.039
12	01378385	Tenakill Brook at Closter, NJ	PR	Baseline, current	Non-coastal	40.975	-73.968
13	01378410	Dwars Kill at Norwood, NJ	PR	Baseline, current	Non-coastal	40.983	-73.958
14	01378530	French Brook at New Bridge, NJ	PR	Baseline	Non-coastal	40.917	-74.023
15	01378560	Coles Brook at Hackensack, NJ	PR	Baseline, current	Non-coastal	40.911	-74.040
16	01378590	Metzer Brook at Englewood, NJ	PR	Baseline	Non-coastal	40.908	-73.987
17	01378615	Wolf Creek at Ridgefield, NJ	PR	Baseline	Non-coastal	40.829	-74.004
18	01378690	Passaic River near Bernardsville, NJ	PR	Baseline, current	Non-coastal	40.734	-74.541
19	01378800	Primrose Brook near New Vernon, NJ	PR	Baseline	Non-coastal	40.728	-74.516
20	01379000	Passaic River near Millington, NJ	CR	Baseline, current	Non-coastal	40.680	-74.529
21	01379100	Dead River at Martinsville Road, at Liberty Corner, NJ	PR	Current	Non-coastal	40.654	-74.576
22	01379150	Harrisons Brook at Liberty Corner, NJ	PR	Baseline, current	Non-coastal	40.674	-74.570
23	01379630	Russia Brook tributary at Milton, NJ	PR	Baseline	Non-coastal	41.018	-74.541
24	01379700	Rockaway River at Berkshire Valley, NJ	PR	Baseline, current	Non-coastal	40.931	-74.595
25	01379750	Rockaway River at Dover, NJ	PR	Baseline, current	Non-coastal	40.903	-74.576
26	01380050	Hibernia Brook at out of Lake Telemark, NJ	PR	Baseline	Non-coastal	40.959	-74.501
27	01380500 *	Rockaway River above Reservoir at Boonton, NJ	CR	Baseline, current	Non-coastal	40.903	-74.410
28	01381150	Crooked Brook near Boonton, NJ	PR	Baseline	Non-coastal	40.890	-74.374
29	01381400	Whippany River near Morristown, NJ	PR	Baseline, current	Non-coastal	40.812	-74.512
30	01381470	Jaquis Brook at Greystone Park State Hospital, NJ	PR	Baseline	Non-coastal	40.837	-74.502

Table 1. Continuous-record streamflow-gaging stations and partial-record streamflow-gaging stations analyzed for low-flow characteristics.—Continued

[CR, continuous-record streamflow-gaging station; PR, partial-record gaging station; *, streamflow-gaging station is also an index station used in the analysis]

Map reference number (figure 2)	U.S. Geological Survey station number	U.S. Geological Survey station name	Station type	Period[1]	Low-flow regression region	Latitude (decimal degrees)	Longitude (decimal degrees)
31	01381500	Whippany River at Morristown, NJ	CR	Baseline, current	Non-coastal	40.807	-74.456
32	01382050	Pequannock River near Stockholm, NJ	PR	Current	Non-coastal	41.115	-74.514
33	01382090	Pacock Brook near Highland Lakes, NJ	PR	Current	Non-coastal	41.136	-74.473
34	01382360	Kanouse Brook at Newfoundland, NJ	PR	Baseline, current	Non-coastal	41.047	-74.430
35	01382550	Pequannock River tributary 1 at Kinnelon, NJ	PR	Current	Non-coastal	41.003	-74.369
36	01382700	Stone House Brook at Kinnelon, NJ	PR	Current	Non-coastal	40.988	-74.386
37	01384500 *	Ringwood Creek near Wanaque, NJ	CR	Baseline, current	Non-coastal	41.127	-74.264
38	01385000	Cupsaw Brook near Wanaque, NJ	CR	Baseline	Non-coastal	41.110	-74.256
39	01386000	West Brook near Wanaque, NJ	CR	Baseline	Non-coastal	41.073	-74.312
40	01386500	Blue Mine Brook near Wanaque, NJ	CR	Baseline	Non-coastal	41.059	-74.317
41	01387500	Ramapo River near Mahwah, NJ	CR	Baseline, current	Non-coastal	41.098	-74.163
42	01387930	Ramapo River tributary 5 at Oakland, NJ	PR	Baseline	Non-coastal	41.015	-74.254
43	01387980	Haycock Brook at Pompton Lakes, NJ	PR	Baseline, current	Non-coastal	40.994	-74.274
44	01388000	Ramapo River at Pompton Lakes, NJ	CR	Baseline, current	Non-coastal	40.992	-74.279
45	01389140	Deepavaal Brook at Two Bridges, NJ	PR	Current	Non-coastal	40.887	-74.266
46	01389765	Molly Ann Brook at North Haledon, NJ	PR	Current	Non-coastal	40.953	-74.185
47	01390450	Saddle River at Upper Saddle River, NJ	PR	Baseline, current	Non-coastal	41.059	-74.096
48	01390500	Saddle River at Ridgewood, NJ	CR	Baseline, current	Non-coastal	40.985	-74.091
49	01390700	Hohokus Brook at Wyckoff, NJ	PR	Baseline	Non-coastal	41.024	-74.168
50	01391485	Sprout Brook at Rochelle Park, NJ	PR	Baseline	Non-coastal	40.912	-74.080
51	01392000	Weasel Brook at Clifton, NJ	CR	Baseline	Non-coastal	40.870	-74.146
52	01392170	Third River at Bloomfield, NJ	PR	Current	Non-coastal	40.800	-74.188
53	01392210	Third River at Passaic, NJ	CR	Baseline	Non-coastal	40.830	-74.142
54	01393960	West Branch Rahway River at Northfield Avenue at West Orange, NJ	PR	Current	Non-coastal	40.770	-74.283
55	01396500	South Branch Raritan River near High Bridge, NJ	CR	Baseline, current	Non-coastal	40.678	-74.879
56	01396580	Spruce Run at Glen Gardner, NJ	CR	Baseline	Non-coastal	40.693	-74.940
57	01396660	Mulhockaway Creek at Van Syckel, NJ	CR	Baseline, current	Non-coastal	40.647	-74.969
58	01396700	Mulhockaway Creek near Clinton, NJ	PR	Baseline	Non-coastal	40.649	-74.928
59	01396865	Sidney Brook at Grandin, NJ	PR	Current	Non-coastal	40.619	-74.933
60	01397500	Walnut Brook near Flemington, NJ	CR	Baseline	Non-coastal	40.515	-74.881

Table 1. Continuous-record streamflow-gaging stations and partial-record streamflow-gaging stations analyzed for low-flow characteristics.—Continued

[CR, continuous-record streamflow-gaging station; PR, partial-record gaging station; *, streamflow-gaging station is also an index station used in the analysis]

Map reference number (figure 2)	U.S. Geological Survey station number	U.S. Geological Survey station name	Station type	Period[1]	Low-flow regression region	Latitude (decimal degrees)	Longitude (decimal degrees)
61	01398000 *	Neshanic River at Reaville, NJ	CR	Baseline, current	Non-coastal	40.472	-74.828
62	01398045	Back Brook tributary near Ringoes, NJ	PR	Baseline	Non-coastal	40.428	-74.831
63	01398107	Holland Brook at Readington, NJ	PR	Baseline, current	Non-coastal	40.558	-74.731
64	01398220	India Brook near Mendham, NJ	PR	Baseline	Non-coastal	40.786	-74.621
65	01398300	Dawsons Brook near Ironia, NJ	PR	Baseline	Non-coastal	40.804	-74.628
66	01398360	Burnett Brook near Chester, NJ	PR	Baseline	Non-coastal	40.783	-74.645
67	01398500 *	North Branch Raritan River near Far Hills, NJ	CR	Baseline, current	Non-coastal	40.708	-74.636
68	01398700	Peapack Brook at Gladstone, NJ	PR	Baseline	Non-coastal	40.733	-74.668
69	01398950	Mine Brook at Far Hills, NJ	PR	Baseline	Non-coastal	40.683	-74.635
70	01399100	Middle Brook at Burnt Mills, NJ	PR	Current	Non-coastal	40.649	-74.682
71	01399500 *	Lamington (Black) River near Pottersville, NJ	CR	Baseline, current	Non-coastal	40.728	-74.731
72	01399510	Upper Cold Brook near Pottersville, NJ	CR	Baseline	Non-coastal	40.721	-74.753
73	01399540	Cold Brook at Oldwick, NJ	PR	Baseline	Non-coastal	40.675	-74.738
74	01399570	Rockaway Creek at McCrea Mills, NJ	PR	Baseline, current	Non-coastal	40.662	-74.766
75	01400300	Peters Brook near Raritan, NJ	PR	Current	Non-coastal	40.594	-74.631
76	01400350	Macs Brook at Somerville, NJ	PR	Current	Non-coastal	40.582	-74.621
77	01400540	Millstone River near Manalapan, NJ	PR	Baseline, current	Coastal Plain	40.262	-74.420
78	01400589	Rocky Brook at Disbrow Hill Road at Etra, NJ	PR	Current	Coastal Plain	40.253	-74.488
79	01400593	Rocky Brook at Hightstown, NJ	PR	Baseline	Coastal Plain	40.261	-74.514
80	01400596	Peddie Brook at Hightstown, NJ	PR	Baseline	Coastal Plain	40.260	-74.519
81	01400750	Bear Brook near Hickory Corner, NJ	PR	Baseline, current	Coastal Plain	40.267	-74.579
82	01400770	Little Bear Brook at Hickory Corner, NJ	PR	Baseline	Coastal Plain	40.268	-74.566
83	01400800	Bear Brook near Grovers Mill, NJ	PR	Baseline	Coastal Plain	40.298	-74.595
84	01400810	Bear Brook at Princeton Junction, NJ	PR	Baseline	Non-coastal	40.323	-74.616
85	01400900	Stony Brook at Glenmoore, NJ	PR	Baseline, current	Non-coastal	40.365	-74.787
86	01400970	Honey Brook near Rosedale, NJ	PR	Current	Non-coastal	40.341	-74.744
87	01401000	Stony Brook at Princeton, NJ	CR	Baseline, current	Non-coastal	40.333	-74.682
88	01401650	Pike Run at Belle Mead, NJ	CR	Baseline, current	Non-coastal	40.468	-74.649
89	01403075	East Branch Middle Brook at Green Valley Road at Warrenville, NJ	PR	Current	Non-coastal	40.613	-74.496
90	01403100	East Branch Middle Brook at Martinsville, NJ	PR	Baseline	Non-coastal	40.594	-74.545

Table 1. Continuous-record streamflow-gaging stations and partial-record streamflow-gaging stations analyzed for low-flow characteristics.—Continued

[CR, continuous-record streamflow-gaging station; PR, partial-record gaging station; *, streamflow-gaging station is also an index station used in the analysis]

Map reference number (figure 2)	U.S. Geological Survey station number	U.S. Geological Survey station name	Station type	Period[1]	Low-flow regression region	Latitude (decimal degrees)	Longitude (decimal degrees)
91	01403535	East Branch Stony Brook at Best Lake at Watchung, NJ	CR	Baseline	Non-coastal	40.640	-74.448
92	01403540	Stony Brook at Watchung, NJ	CR	Baseline, current	Non-coastal	40.637	-74.452
93	01406000	Deep Run near Browntown, NJ	PR	Baseline	Coastal Plain	40.375	-74.303
94	01407065	Mahoras Brook at Hendrickson Corners, NJ	PR	Current	Coastal Plain	40.411	-74.139
95	01407250	Willow Brook at Holmdel, NJ	PR	Baseline, current	Coastal Plain	40.338	-74.187
96	01407290	Big Brook near Marlboro, NJ	PR	Current	Coastal Plain	40.320	-74.214
97	01407320	Big Brook at Cross Road near Vandenburg, NJ	PR	Current	Coastal Plain	40.323	-74.174
98	01407400	Yellow Brook at Colts Neck, NJ	PR	Baseline, current	Coastal Plain	40.296	-74.171
99	01407450	Mine Brook at Colts Neck, NJ	PR	Baseline, current	Coastal Plain	40.291	-74.169
100	01407618	Whale Pond Brook near Oakhurst, NJ	PR	Current	Coastal Plain	40.276	-74.003
101	01407628	Poplar Brook near Deal, NJ	PR	Current	Coastal Plain	40.257	-74.011
102	01407636	Harvey Brook at West Allenhurst, NJ	PR	Current	Coastal Plain	40.243	-74.014
103	01407700	Shark River at Glendola, NJ	PR	Baseline, current	Coastal Plain	40.203	-74.081
104	01407755	Jumping Brook above reservoir near Neptune City, NJ	PR	Current	Coastal Plain	40.208	-74.070
105	01407800	Wreck Pond Brook near Spring Lake, NJ	PR	Baseline	Coastal Plain	40.153	-74.061
106	01407830	Manasquan River near Georgia, NJ	PR	Baseline, current	Coastal Plain	40.210	-74.278
107	01407900	Manasquan River at West Farms, NJ	PR	Baseline, current	Coastal Plain	40.193	-74.195
108	01407970	Timber Swamp Brook near Farmingdale, NJ	PR	Baseline	Coastal Plain	40.179	-74.189
109	01408000	Manasquan River at Squankum, NJ	CR	Baseline, current	Coastal Plain	40.161	-74.155
110	01408009	Mingamahone Brook near Earle, NJ	PR	Current	Coastal Plain	40.213	-74.168
111	01408015	Mingamahone Brook at Farmingdale, NJ	PR	Baseline, current	Coastal Plain	40.194	-74.162
112	0140802850	Manasquan River at Golf Course Bridge near Allenwood, NJ	PR	Current	Coastal Plain	40.151	-74.126
113	01408100	North Branch Metedeconk River at Lakewood, NJ	PR	Baseline, current	Coastal Plain	40.110	-74.219
114	01408150	South Branch Metedeconk River near Lakewood, NJ	PR	Current	Coastal Plain	40.086	-74.186
115	01408500	Toms River near Toms River, NJ	CR	Baseline, current	Coastal Plain	39.986	-74.225
116	01408800	Webbs Mill Branch near Whiting, NJ	PR	Baseline, current	Coastal Plain	39.888	-74.379
117	01408830	Cedar Creek at Cedar Crest, NJ	PR	Current	Coastal Plain	39.897	-74.316
118	01409100	Oyster Creek near Waretown, NJ	PR	Baseline	Coastal Plain	39.804	-74.232
119	01409150	Mill Creek near Manahawkin, NJ	PR	Baseline, current	Coastal Plain	39.715	-74.282
120	01409300	Mill Branch near Tuckerton, NJ	PR	Baseline	Coastal Plain	39.641	-74.363

Table 1. Continuous-record streamflow-gaging stations and partial-record streamflow-gaging stations analyzed for low-flow characteristics.—Continued

[CR, continuous-record streamflow-gaging station; PR, partial-record gaging station; *, streamflow-gaging station is also an index station used in the analysis]

Map reference number (figure 2)	U.S. Geological Survey station number	U.S. Geological Survey station name	Station type	Period[1]	Low-flow regression region	Latitude (decimal degrees)	Longitude (decimal degrees)
121	0140940310	Wildcat Branch near Chesilhurst, NJ	PR	Current	Coastal Plain	39.706	-74.833
122	01409405	Clark Branch at U.S. Route 206 near Atsion, NJ	PR	Baseline, current	Coastal Plain	39.712	-74.744
123	01409575	Landing Creek at Philadelphia Avenue at Egg Harbor City, NJ	PR	Baseline, current	Coastal Plain	39.548	-74.626
124	01409780	Tulpehocken Creek near Jenkins, NJ	PR	Baseline, current	Coastal Plain	39.714	-74.566
125	01410150	East Branch Bass River near New Gretna, NJ	CR	Baseline, current	Coastal Plain	39.623	-74.442
126	01410200	West Branch Bass River near New Gretna, NJ	PR	Baseline, current	Coastal Plain	39.624	-74.446
127	01411000 *	Great Egg Harbor River at Folsom, NJ	CR	Baseline, current	Coastal Plain	39.595	-74.852
128	01411035	Hospitality Branch at Blue Bell Road near Cecil, NJ	PR	Current	Coastal Plain	39.644	-74.986
129	01411040	Hospitality Branch near Cecil, NJ	PR	Current	Coastal Plain	39.636	-74.946
130	01411042	Whitehall Branch near Cecil, NJ	PR	Current	Coastal Plain	39.635	-74.984
131	01411053	Hospitality Branch at Berryland, NJ	PR	Baseline, current	Coastal Plain	39.609	-74.909
132	01411140	Deep Run at Weymouth, NJ	PR	Baseline, current	Coastal Plain	39.507	-74.782
133	01411250	English Creek near Scullville, NJ	PR	Current	Coastal Plain	39.369	-74.663
134	01411300	Tuckahoe River at Head of River, NJ	CR	Baseline, current	Coastal Plain	39.307	-74.821
135	01411302	Mill Creek near Steelmantown, NJ	PR	Current	Coastal Plain	39.284	-74.792
136	01411305	Mill Branch near Northfield, NJ	PR	Current	Coastal Plain	39.396	-74.593
137	01411388	Mill Creek at Cold Spring, NJ	PR	Current	Coastal Plain	38.973	-74.911
138	01411404	Green Creek at Green Creek, NJ	PR	Baseline	Coastal Plain	39.053	-74.902
139	01411410	Bidwell Creek tributary near Cape May Court House, NJ	PR	Current	Coastal Plain	39.109	-74.838
140	01411418	Goshen Creek at Goshen, NJ	PR	Current	Coastal Plain	39.128	-74.846
141	01411428	Dennis Creek tributary 2 at Dennisville, NJ	PR	Current	Coastal Plain	39.193	-74.826
142	01411442	East Creek near Eldora, NJ	PR	Current	Coastal Plain	39.223	-74.886
143	01411445	West Creek near Eldora, NJ	PR	Current	Coastal Plain	39.228	-74.913
144	01411466	Indian Brook near Malaga, NJ	PR	Current	Coastal Plain	39.591	-75.060
145	01411500 *	Maurice River at Norma, NJ	CR	Baseline, current	Coastal Plain	39.496	-75.077
146	01411955	Gravelly Run at Laurel Lake, NJ	PR	Current	Coastal Plain	39.337	-75.051
147	01412100	Manumuskin River near Manumuskin, NJ	PR	Baseline, current	Coastal Plain	39.349	-74.958
148	01413050	Stow Creek at Jericho, NJ	PR	Baseline	Coastal Plain	39.471	-75.353
149	01413060	Canton Drain near Canton, NJ	PR	Baseline	Coastal Plain	39.501	-75.385
150	01439800	Big Flat Brook near Hainesville, NJ	PR	Baseline, current	Non-coastal	41.207	-74.804

Table 1. Continuous-record streamflow-gaging stations and partial-record streamflow-gaging stations analyzed for low-flow characteristics.—Continued

[CR, continuous-record streamflow-gaging station; PR, partial-record gaging station; *, streamflow-gaging station is also an index station used in the analysis]

Map reference number (figure 2)	U.S. Geological Survey station number	U.S. Geological Survey station name	Station type	Period[1]	Low-flow regression region	Latitude (decimal degrees)	Longitude (decimal degrees)
151	01439830	Big Flat Brook at Tuttles Corner, NJ	PR	Baseline, current	Non-coastal	41.200	-74.815
152	01439900	Little Flat Brook at Hainesville, NJ	PR	Baseline	Non-coastal	41.243	-74.801
153	01439920	Little Flat Brook at Peters Valley, NJ	PR	Current	Non-coastal	41.198	-74.836
154	01440000 *	Flat Brook near Flatbrookville, NJ	CR	Baseline, current	Non-coastal	41.107	-74.953
155	01440100	Vancampens Brook near Millbrook, NJ	PR	Baseline, current	Non-coastal	41.058	-75.003
156	01442760	Dunnfield Creek at Dunnfield, NJ	PR	Current	Non-coastal	40.971	-75.127
157	01443305	Paulins Kill tributary 2 at Ross Corner, NJ	PR	Current	Non-coastal	41.117	-74.711
158	01443500 *	Paulins Kill at Blairstown, NJ	CR	Baseline, current	Non-coastal	40.981	-74.954
159	01443510	Blair Creek at Blairstown, NJ	PR	Current	Non-coastal	40.987	-74.959
160	01445000	Pequest River at Huntsville, NJ	CR	Baseline	Non-coastal	40.981	-74.777
161	01445100	Pequest River at Long Bridge, NJ	PR	Baseline, current	Non-coastal	40.921	-74.840
162	01445160	Bear Brook at Dark Moon Road near Johnsonburg, NJ	PR	Current	Non-coastal	40.975	-74.849
163	01445200	Bear Creek near Johnsonburg, NJ	PR	Baseline, current	Non-coastal	40.943	-74.875
164	01445400	Pequest River at Great Meadows, NJ	PR	Baseline, current	Non-coastal	40.866	-74.905
165	01445430	Pequest River at Townsbury, NJ	PR	Baseline, current	Non-coastal	40.852	-74.934
166	01445490	Furnace Brook at Oxford, NJ	PR	Baseline, current	Non-coastal	40.804	-74.995
167	01445500	Pequest River at Pequest, NJ	CR	Baseline, current	Non-coastal	40.831	-74.979
168	01446000	Beaver Brook near Belvidere, NJ	CR	Baseline	Non-coastal	40.844	-75.047
169	01446400	Pequest River at Belvidere, NJ	PR	Baseline, current	Non-coastal	40.829	-75.079
170	01455100	Lopatcong Creek at Phillipsburg, NJ	PR	Baseline, current	Non-coastal	40.677	-75.170
171	01455135	Pohatcong Creek at Tunnel Hill Road near Washington, NJ	PR	Current	Non-coastal	40.785	-74.961
172	01455370	Weldon Brook at Hurdtown, NJ	PR	Current	Non-coastal	40.969	-74.598
173	01455780	Lubbers Run at Lockwood, NJ	PR	Current	Non-coastal	40.927	-74.719
174	01456100	Hatchery Brook at Hackettstown, NJ	PR	Baseline	Non-coastal	40.856	-74.835
175	01458570	Nishisakawick Creek near Frenchtown, NJ	PR	Current	Non-coastal	40.544	-75.046
176	01460880	Lockatong Creek at Raven Rock, NJ	PR	Current	Non-coastal	40.416	-75.018
177	01461300	Wickecheoke Creek at Stockton, NJ	PR	Baseline, current	Non-coastal	40.411	-74.987
178	01461900	Alexauken Creek near Lambertville, NJ	PR	Baseline, current	Non-coastal	40.381	-74.948
179	01463750	Shabakunk Creek at Ewingville, NJ	PR	Baseline	Non-coastal	40.263	-74.760
180	01463790	West Branch Shabakunk Creek near Ewingville, NJ	PR	Baseline	Non-coastal	40.249	-74.756

Table 1. Continuous-record streamflow-gaging stations and partial-record streamflow-gaging stations analyzed for low-flow characteristics.—Continued

[CR, continuous-record streamflow-gaging station; PR, partial-record gaging station; *, streamflow-gaging station is also an index station used in the analysis]

Map reference number (figure 2)	U.S. Geological Survey station number	U.S. Geological Survey station name	Station type	Period[1]	Low-flow regression region	Latitude (decimal degrees)	Longitude (decimal degrees)
181	01464460	Lahaway Creek near Hornerstown, NJ	PR	Baseline, current	Coastal Plain	40.107	-74.536
182	01464480	Miry Run at Holmes Mills ,NJ	PR	Baseline, current	Coastal Plain	40.134	-74.543
183	01464500 *	Crosswicks Creek at Extonville, NJ	CR	Baseline, current	Coastal Plain	40.137	-74.601
184	01464580	Assiscunk Creek at Columbus, NJ	PR	Baseline	Coastal Plain	40.057	-74.724
185	01465865	Barton Run at Tuckerton Road near Medford, NJ	PR	Current	Coastal Plain	39.879	-74.860
186	01465893	Little Creek at Chairville, NJ	PR	Current	Coastal Plain	39.898	-74.788
187	01465965	Ong Run at Browns Mills, NJ	PR	Current	Coastal Plain	39.976	-74.577
188	01466500 *	McDonalds Branch in Byrne State Forest, NJ	CR	Baseline, current	Coastal Plain	39.885	-74.506
189	0146700260	Indian Run at Birmingham, NJ	PR	Current	Coastal Plain	39.981	-74.711
190	01467027	Swede Run at U.S. Route 130 at Delran, NJ	PR	Current	Coastal Plain	40.015	-74.956
191	01467070	North Branch Pennsauken Creek at Maple Shade, NJ	PR	Baseline	Coastal Plain	39.953	-74.975
192	01467150	Cooper River at Haddonfield, NJ	CR	Baseline, current	Coastal Plain	39.903	-75.022
193	01467160	North Branch Cooper River near Marlton, NJ	PR	Baseline, current	Coastal Plain	39.889	-74.969
194	01467180	North Branch Cooper River at Ellisburg, NJ	PR	Baseline, current	Coastal Plain	39.908	-75.011
195	01475033	Plank Run at Glassboro, NJ	PR	Current	Coastal Plain	39.715	-75.140
196	0147503330	Plank Run at Pitman, NJ	PR	Current	Coastal Plain	39.717	-75.137
197	01475100	Edwards Run near Mantua, NJ	PR	Current	Coastal Plain	39.772	-75.193
198	01476600	Still Run near Mickleton, NJ	PR	Baseline	Coastal Plain	39.789	-75.257
199	01477100	Raccoon Creek near Mullica Hill, NJ	PR	Baseline, current	Coastal Plain	39.709	-75.201
200	01477118	South Branch Raccoon Creek near Mullica Hill, NJ	PR	Baseline	Coastal Plain	39.736	-75.256
201	01477120	Raccoon Creek near Swedesboro, NJ	CR	Baseline, current	Coastal Plain	39.741	-75.259
202	01477500	Oldmans Creek near Woodstown, NJ	PR	Baseline	Coastal Plain	39.691	-75.319
203	01477510	Oldmans Creek at Porches Mill, NJ	PR	Baseline, current	Coastal Plain	39.699	-75.333
204	01482500	Salem River at Woodstown, NJ	CR	Baseline	Coastal Plain	39.643	-75.331
205	01482510	Nichomus Run near Woodstown, NJ	PR	Baseline, current	Coastal Plain	39.639	-75.349
206	01482950	Cedar Brook near Alloway, NJ	PR	Baseline, current	Coastal Plain	39.559	-75.339
207	01483000	Alloway Creek at Alloway, NJ	CR	Baseline	Coastal Plain	39.565	-75.360
208	01483010	Deep Run near Alloway, NJ	PR	Baseline, current	Coastal Plain	39.543	-75.355

[1] Current period refers to the period of record 1989–2008. Baseline period refers to the preliminary baseline period of record as determined in SIR 2008–5077 by Esralew and Baker.

Table 4. Values of basin characteristics for contiuous-record streamflow-gaging stations and partial-record stations in New Jersey used in the regression analysis for the baseline land- and water-use conditions.

[PR, Partial-record station; CR, continuous-record streamflow-gaging station; mi², square miles; in/hr, inches per hour; in, inches; --, not applicable]

U.S. Geological Survey station number	Low-flow regression region	Station type	Baseline period of record[1]	Basin characteristics				
				Drainage area (mi²)	Soil permeability (in/hr)	Average April precipitation (in)	Average June precipitation (in)	Percent storage
01367750	non-Coastal	PR	1922–2008	5.60	1.92	--	4.57	--
01367800	non-Coastal	PR	1922–2008	15.76	2.79	--	4.46	--
01367850	non-Coastal	PR	1922–2008	11.16	0.82	--	4.52	--
01367890	non-Coastal	PR	1922–2008	19.05	1.59	--	4.50	--
01367900	non-Coastal	PR	1922–2008	19.61	1.57	--	4.50	--
01367910	non-Coastal	PR	1922–2008	59.27	2.23	--	4.51	--
01368950	non-Coastal	PR	1922–2008	17.23	2.42	--	4.63	--
01378385	non-Coastal	PR	1922–2008	8.65	4.48	--	3.90	--
01378410	non-Coastal	PR	1922–2008	3.15	4.34	--	3.91	--
01378530	non-Coastal	PR	1922–2008	0.60	2.21	--	3.87	--
01378560	non-Coastal	PR	1922–2008	6.62	2.51	--	3.86	--
01378590	non-Coastal	PR	1922–2008	1.57	4.97	--	3.88	--
01378615	non-Coastal	PR	1922–2008	1.75	1.71	--	3.84	--
01378690	non-Coastal	PR	1922–2008	8.80	4.80	--	4.36	--
01378800	non-Coastal	PR	1922–2008	4.91	3.46	--	4.26	--
01379000	non-Coastal	CR	1921–1979	54.18	3.22	--	4.21	--
01379150	non-Coastal	PR	1922–2008	3.73	1.34	--	4.15	--
01379630	non-Coastal	PR	1922–2008	1.63	1.80	--	4.81	--
01379700	non-Coastal	PR	1922–2008	24.44	2.86	--	4.76	--
01379750	non-Coastal	PR	1922–2008	30.82	3.12	--	4.74	--
01380050	non-Coastal	PR	1922–2008	2.65	1.80	--	4.73	--
01380500	non-Coastal	CR	1938–2008	117.34	3.15	--	4.61	--
01381150	non-Coastal	PR	1922–2008	7.89	2.45	--	4.31	--
01381400	non-Coastal	PR	1922–2008	13.94	4.80	--	4.42	--
01381470	non-Coastal	PR	1922–2008	1.42	4.85	--	4.40	--
01381500	non-Coastal	CR	1922–1970	29.67	4.79	--	4.38	--
01382360	non-Coastal	PR	1922–2008	3.85	0.65	--	4.65	--
01384500	non-Coastal	CR	1935–2008	17.97	2.16	--	4.39	--
01385000	non-Coastal	CR	1935–1958	4.23	1.80	--	4.28	--
01386000	non-Coastal	CR	1935–1978	11.83	1.63	--	4.52	--
01386500	non-Coastal	CR	1935–1958	1.00	1.80	--	4.44	--
01387500	non-Coastal	CR	1923–1979	120.70	2.99	--	4.46	--
01387930	non-Coastal	PR	1922–2008	0.86	3.43	--	4.36	--
01387980	non-Coastal	PR	1922–2008	4.11	0.60	--	4.32	--
01388000	non-Coastal	CR	1922–1953	159.88	2.89	--	4.44	--
01390450	non-Coastal	PR	1922–2008	10.95	2.28	--	4.29	--
01390500	non-Coastal	CR	1955–1964	21.69	2.64	--	4.27	--
01390700	non-Coastal	PR	1922–2008	5.31	4.12	--	4.41	--
01391485	non-Coastal	PR	1922–2008	5.62	4.73	--	4.02	--
01392000	non-Coastal	CR	1937–1951	4.05	0.43	--	4.14	--

Table 4. Values of basin characteristics for contiuous-record streamflow-gaging stations and partial-record stations in New Jersey used in the regression analysis for the baseline land- and water-use conditions.—Continued

[PR, Partial-record station; CR, continuous-record streamflow-gaging station; mi^2, square miles; in/hr, inches per hour; in, inches; --, not applicable]

U.S. Geological Survey station number	Low-flow regression region	Station type	Baseline period of record[1]	Basin characteristics				
				Drainage area (mi^2)	Soil permeability (in/hr)	Average April precipitation (in)	Average June precipitation (in)	Percent storage
01392210	non-Coastal	CR	1977–1997	11.92	0.56	--	4.10	--
01396500	non-Coastal	CR	1919–1970	66.30	3.79	--	4.73	--
01396580	non-Coastal	CR	1978–2005	11.48	4.85	--	4.62	--
01396660	non-Coastal	CR	1977–2008	11.74	5.11	--	4.49	--
01396700	non-Coastal	PR	1922–2008	20.49	4.67	--	4.47	--
01397500	non-Coastal	CR	1936–1961	2.23	1.18	--	4.21	--
01398000	non-Coastal	CR	1931–2008	25.46	2.07	--	4.09	--
01398045	non-Coastal	PR	1922–2008	1.97	1.35	--	3.98	--
01398107	non-Coastal	PR	1922–2008	9.02	2.05	--	4.14	--
01398220	non-Coastal	PR	1922–2008	4.37	4.64	--	4.57	--
01398300	non-Coastal	PR	1922–2008	1.03	4.85	--	4.59	--
01398360	non-Coastal	PR	1922–2008	6.65	4.87	--	4.60	--
01398500	non-Coastal	CR	1922–2008	26.45	4.36	--	4.52	--
01398700	non-Coastal	PR	1922–2008	4.24	4.76	--	4.60	--
01398950	non-Coastal	PR	1922–2008	7.75	4.41	--	4.27	--
01399500	non-Coastal	CR	1922–2008	32.21	5.10	--	4.70	--
01399510	non-Coastal	CR	1982–1996	2.19	4.85	--	4.71	--
01399540	non-Coastal	PR	1922–2008	5.32	4.03	--	4.41	--
01399570	non-Coastal	PR	1922–2008	16.93	4.69	--	4.54	--
01400540	Coastal Plain	PR	1925–2008	7.37	5.22	3.92	--	19.62
01400593	Coastal Plain	PR	1925–2008	9.53	6.30	3.92	--	25.95
01400596	Coastal Plain	PR	1925–2008	3.09	7.98	3.91	--	22.88
01400750	Coastal Plain	PR	1925–2008	3.41	8.05	3.91	--	33.81
01400770	Coastal Plain	PR	1925–2008	1.88	8.05	3.92	--	21.84
01400800	Coastal Plain	PR	1925–2008	9.61	6.82	3.91	--	23.30
01400810	non-Coastal	PR	1922–2008	12.30	6.99	--	3.86	--
01400900	non-Coastal	PR	1922–2008	16.94	1.18	--	3.96	--
01401000	non-Coastal	CR	1954–1980	44.44	1.57	--	3.89	--
01401650	non-Coastal	CR	1980–2008	5.29	2.01	--	3.79	--
01403100	non-Coastal	PR	1922–2008	8.47	1.32	--	3.90	--
01403535	non-Coastal	CR	1980–2000	1.52	1.02	--	4.00	--
01403540	non-Coastal	CR	1975–1991	5.49	1.02	--	4.00	--
01406000	Coastal Plain	PR	1925–2008	7.97	7.52	3.88	--	33.19
01407250	Coastal Plain	PR	1925–2008	6.87	6.52	3.89	--	16.25
01407400	Coastal Plain	PR	1925–2008	9.72	6.25	3.88	--	15.80
01407450	Coastal Plain	PR	1925–2008	5.46	8.23	3.91	--	36.06
01407700	Coastal Plain	PR	1925–2008	9.47	11.06	4.02	--	38.12
01407800	Coastal Plain	PR	1925–2008	7.05	10.05	4.05	--	17.38
01407830	Coastal Plain	PR	1925–2008	10.69	5.67	3.91	--	22.75
01407900	Coastal Plain	PR	1925–2008	33.60	6.66	3.92	--	25.12

Table 4. Values of basin characteristics for contiuous-record streamflow-gaging stations and partial-record stations in New Jersey used in the regression analysis for the baseline land- and water-use conditions.—Continued

[PR, Partial-record station; CR, continuous-record streamflow-gaging station; mi², square miles; in/hr, inches per hour; in, inches; --, not applicable]

U.S. Geological Survey station number	Low-flow regression region	Station type	Baseline period of record[1]	Basin characteristics				
				Drainage area (mi²)	Soil permeability (in/hr)	Average April precipitation (in)	Average June precipitation (in)	Percent storage
01407970	Coastal Plain	PR	1925–2008	3.38	9.12	3.96	--	45.67
01408000	Coastal Plain	CR	1932–1989	44.04	7.39	3.93	--	30.64
01408015	Coastal Plain	PR	1925–2008	6.18	11.59	3.98	--	46.28
01408100	Coastal Plain	PR	1925–2008	19.31	10.63	3.95	--	34.70
01408500	Coastal Plain	CR	1929–1966	123.74	10.82	3.95	--	24.56
01408800	Coastal Plain	PR	1925–2008	2.91	10.13	3.90	--	7.43
01409100	Coastal Plain	PR	1925–2008	10.03	9.31	3.98	--	20.46
01409150	Coastal Plain	PR	1925–2008	10.36	9.94	3.97	--	9.22
01409300	Coastal Plain	PR	1925–2008	4.90	9.41	3.96	--	9.39
01409405	Coastal Plain	PR	1925–2008	7.08	9.91	3.88	--	19.43
01409575	Coastal Plain	PR	1925–2008	4.83	8.91	3.81	--	34.96
01409780	Coastal Plain	PR	1925–2008	21.90	11.07	3.84	--	38.52
01410150	Coastal Plain	CR	1978–2008	8.15	9.72	3.93	--	15.12
01410200	Coastal Plain	PR	1925–2008	5.63	11.58	3.91	--	15.41
01411000	Coastal Plain	CR	1925–2008	56.95	8.67	3.84	--	25.63
01411053	Coastal Plain	PR	1925–2008	20.12	8.86	3.81	--	16.54
01411140	Coastal Plain	PR	1925–2008	19.96	8.99	3.87	--	33.52
01411300	Coastal Plain	CR	1970–2008	30.77	7.67	3.73	--	22.95
01411404	Coastal Plain	PR	1925–2008	2.52	6.68	3.42	--	44.98
01411500	Coastal Plain	CR	1933–2008	112.25	8.14	3.78	--	19.38
01412100	Coastal Plain	PR	1925–2008	32.26	6.98	3.75	--	16.26
01413050	Coastal Plain	PR	1925–2008	8.19	4.83	3.63	--	9.73
01413060	Coastal Plain	PR	1925–2008	2.48	8.58	3.64	--	18.37
01439800	non-Coastal	PR	1922–2008	23.75	1.62	--	4.43	--
01439830	non-Coastal	PR	1922–2008	29.31	1.72	--	4.42	--
01439900	non-Coastal	PR	1922–2008	8.38	3.35	--	4.37	--
01440000	non-Coastal	CR	1924–2008	65.02	2.81	--	4.41	--
01440100	non-Coastal	PR	1922–2008	7.66	0.65	--	4.54	--
01443500	non-Coastal	CR	1922–2008	126.03	2.53	--	4.48	--
01445000	non-Coastal	CR	1940–1962	30.95	3.32	--	4.52	--
01445100	non-Coastal	PR	1922–2008	48.39	3.92	--	4.53	--
01445200	non-Coastal	PR	1922–2008	12.86	2.87	--	4.53	--
01445400	non-Coastal	PR	1922–2008	90.34	3.73	--	4.55	--
01445430	non-Coastal	PR	1922–2008	92.44	3.69	--	4.55	--
01445490	non-Coastal	PR	1922–2008	4.28	2.13	--	4.55	--
01445500	non-Coastal	CR	1922–1958	106.02	3.48	--	4.55	--
01446000	non-Coastal	CR	1923–1961	36.62	1.78	--	4.52	--
01446400	non-Coastal	PR	1922–2008	156.58	3.23	--	4.54	--
01455100	non-Coastal	PR	1922–2008	14.19	2.59	--	4.26	--
01456100	non-Coastal	PR	1922–2008	1.82	3.30	--	4.63	--

Table 4. Values of basin characteristics for contiuous-record streamflow-gaging stations and partial-record stations in New Jersey used in the regression analysis for the baseline land- and water-use conditions.—Continued

[PR, Partial-record station; CR, continuous-record streamflow-gaging station; mi^2, square miles; in/hr, inches per hour; in, inches; --, not applicable]

U.S. Geological Survey station number	Low-flow regression region	Station type	Baseline period of record[1]	Basin characteristics				
				Drainage area (mi^2)	Soil permeability (in/hr)	Average April precipitation (in)	Average June precipitation (in)	Percent storage
01461300	non-Coastal	PR	1922–2008	26.54	1.20	--	4.17	--
01461900	non-Coastal	PR	1922–2008	14.88	1.78	--	4.03	--
01463750	non-Coastal	PR	1922–2008	4.97	1.98	--	3.87	--
01463790	non-Coastal	PR	1922–2008	4.56	2.08	--	3.90	--
01464460	Coastal Plain	PR	1925–2008	21.45	8.66	3.87	--	23.68
01464480	Coastal Plain	PR	1925–2008	3.14	5.22	3.87	--	15.37
01464500	Coastal Plain	CR	1940–2008	81.53	7.44	3.83	--	28.87
01464580	Coastal Plain	PR	1925–2008	8.23	5.46	3.76	--	44.96
01466500	Coastal Plain	CR	1954–2008	2.34	11.73	3.81	--	11.59
01467070	Coastal Plain	PR	1925–2008	13.13	5.16	3.90	--	18.91
01467150	Coastal Plain	CR	1988–2008	17.08	5.32	3.87	--	11.07
01467160	Coastal Plain	PR	1925–2008	5.32	3.82	3.87	--	16.49
01467180	Coastal Plain	PR	1925–2008	10.61	4.18	3.88	--	14.12
01476600	Coastal Plain	PR	1925–2008	3.99	4.41	3.74	--	10.29
01477100	Coastal Plain	PR	1925–2008	10.11	6.96	3.79	--	13.60
01477118	Coastal Plain	PR	1925–2008	8.28	3.99	3.76	--	14.63
01477120	Coastal Plain	CR	1966–2008	25.94	5.43	3.77	--	12.62
01477500	Coastal Plain	PR	1925–2008	18.50	5.76	3.76	--	15.47
01477510	Coastal Plain	PR	1925–2008	20.99	5.60	3.75	--	14.79
01482500	Coastal Plain	CR	1940–1983	14.58	4.28	3.74	--	11.86
01482510	Coastal Plain	PR	1925–2008	3.75	2.43	3.72	--	17.90
01482950	Coastal Plain	PR	1925–2008	3.77	8.09	3.69	--	17.96
01483000	Coastal Plain	CR	1953–1973	20.32	4.61	3.71	--	16.72
01483010	Coastal Plain	PR	1925–2008	5.29	7.67	3.66	--	14.32

[1]Baseline period of record is given in water years, the 12-month period from October 1 through September 30, with the water year designated by the calendar year in which it ends. The baseline period refers to the preliminary baseline period of record as determined by Esralew and Baker (2008).

Table 5. Values of basin characteristics for contiuous-record streamflow-gaging stations and partial-record stations in New Jersey used in the regression analysis for the current (1989–2008) land- and water-use conditions.

[PR, partial-record station; CR, continuous-record streamflow-gaging station; mi^2, square miles; in/hr, inches per hour; in, inches; --, not applicable]

U.S. Geological Survey station number	Low-flow regression region	Station type	Current period of record	Basin characteristics				
				Drainage area (mi^2)	Soil permeability (in/hr)	Average April precipitation (in)	Average June precipitation (in)	Percent storage
01367625	Non-coastal	PR	1989–2008	6.89	1.56	--	4.63	--
01367800	Non-coastal	PR	1989–2008	15.76	2.79	--	4.46	--
01367850	Non-coastal	PR	1989–2008	11.16	0.82	--	4.52	--
01367875	Non-coastal	PR	1989–2008	8.54	1.19	--	4.48	--
01367910	Non-coastal	PR	1989–2008	59.27	2.23	--	4.51	--
01368950	Non-coastal	PR	1989–2008	17.23	2.42	--	4.63	--
01376273	Non-coastal	PR	1989–2008	0.46	2.38	--	3.93	--
01377370	Non-coastal	PR	1989–2008	13.01	3.83	--	4.25	--
01378385	Non-coastal	PR	1989–2008	8.65	4.48	--	3.90	--
01378410	Non-coastal	PR	1989–2008	3.15	4.34	--	3.91	--
01378560	Non-coastal	PR	1989–2008	6.62	2.51	--	3.86	--
01378690	Non-coastal	PR	1989–2008	8.80	4.80	--	4.36	--
01379000	Non-coastal	CR	1989–2008	54.18	3.22	--	4.21	--
01379100	Non-coastal	PR	1989–2008	7.56	1.06	--	4.10	--
01379150	Non-coastal	PR	1989–2008	3.73	1.34	--	4.15	--
01379700	Non-coastal	PR	1989–2008	24.44	2.86	--	4.76	--
01379750	Non-coastal	PR	1989–2008	30.82	3.12	--	4.74	--
01380500	Non-coastal	CR	1989–2008	117.34	3.15	--	4.61	--
01381400	Non-coastal	PR	1989–2008	13.94	4.80	--	4.42	--
01381500	Non-coastal	CR	1989–2008	29.67	4.79	--	4.38	--
01382050	Non-coastal	PR	1989–2008	5.41	2.89	--	4.68	--
01382090	Non-coastal	PR	1989–2008	2.55	1.80	--	4.71	--
01382360	Non-coastal	PR	1989–2008	3.85	0.65	--	4.65	--
01382550	Non-coastal	PR	1989–2008	1.20	1.80	--	4.53	--
01382700	Non-coastal	PR	1989–2008	3.46	1.80	--	4.59	--
01384500	Non-coastal	CR	1989–2008	17.97	2.16	--	4.39	--
01387500	Non-coastal	CR	1989–2008	120.70	2.99	--	4.46	--
01387980	Non-coastal	PR	1989–2008	4.11	0.60	--	4.32	--
01388000	Non-coastal	CR	1989–2008	159.88	2.89	--	4.44	--
01389140	Non-coastal	PR	1989–2008	7.64	2.50	--	4.31	--
01389765	Non-coastal	PR	1989–2008	4.01	0.86	--	4.39	--
01390450	Non-coastal	PR	1989–2008	10.95	2.28	--	4.29	--
01390500	Non-coastal	CR	1989–2008	21.69	2.64	--	4.27	--
01392170	Non-coastal	PR	1989–2008	7.73	0.48	--	4.15	--
01393960	Non-coastal	PR	1989–2008	3.94	0.38	--	4.18	--
01396500	Non-coastal	CR	1989–2008	66.30	3.79	--	4.73	--
01396660	Non-coastal	CR	1989–2008	11.74	5.11	--	4.49	--
01396865	Non-coastal	PR	1989–2008	4.71	5.72	--	4.41	--

Table 5. Values of basin characteristics for contiuous-record streamflow-gaging stations and partial-record stations in New Jersey used in the regression analysis for the current (1989–2008) land- and water-use conditions.—Continued

[PR, partial-record station; CR, continuous-record streamflow-gaging station; mi², square miles; in/hr, inches per hour; in, inches; --, not applicable]

U.S. Geological Survey station number	Low-flow regression region	Station type	Current period of record	Basin characteristics				
				Drainage area (mi²)	Soil permeability (in/hr)	Average April precipitation (in)	Average June precipitation (in)	Percent storage
01398000	Non-coastal	CR	1989–2008	25.46	2.07	--	4.09	--
01398107	Non-coastal	PR	1989–2008	9.02	2.05	--	4.14	--
01398500	Non-coastal	CR	1989–2008	26.45	4.36	--	4.52	--
01399100	Non-coastal	PR	1989–2008	6.67	3.99	--	4.22	--
01399500	Non-coastal	CR	1989–2008	32.21	5.10	--	4.70	--
01399570	Non-coastal	PR	1989–2008	16.93	4.69	--	4.54	--
01400300	Non-coastal	PR	1989–2008	4.20	2.73	--	3.94	--
01400350	Non-coastal	PR	1989–2008	0.77	2.63	--	3.91	--
01400589	Coastal Plain	PR	1989–2008	6.91	--	3.91	--	21.25
01400750	Coastal Plain	PR	1989–2008	3.41	--	3.91	--	33.81
01400900	Non-coastal	PR	1989–2008	16.94	1.18	--	3.96	--
01400970	Non-coastal	PR	1989–2008	3.84	1.79	--	3.85	--
01401000	Non-coastal	CR	1989–2008	44.44	1.57	--	3.89	--
01401650	Non-coastal	CR	1989–2008	5.29	2.01	--	3.79	--
01403075	Non-coastal	PR	1989–2008	1.24	1.04	--	3.95	--
01403540	Non-coastal	CR	1989–2008	5.49	1.02	--	4.00	--
01407065	Coastal Plain	PR	1989–2008	3.34	--	3.97	--	14.22
01407250	Coastal Plain	PR	1989–2008	6.87	--	3.89	--	20.26
01407290	Coastal Plain	PR	1989–2008	6.41	--	3.87	--	20.56
01407320	Coastal Plain	PR	1989–2008	9.70	--	3.88	--	20.66
01407400	Coastal Plain	PR	1989–2008	9.72	--	3.88	--	15.80
01407450	Coastal Plain	PR	1989–2008	5.46	--	3.91	--	36.06
01407618	Coastal Plain	PR	1989–2008	6.18	--	4.10	--	19.61
01407628	Coastal Plain	PR	1989–2008	2.52	--	4.11	--	20.75
01407636	Coastal Plain	PR	1989–2008	1.07	--	4.10	--	12.38
01407700	Coastal Plain	PR	1989–2008	9.47	--	4.02	--	38.12
01407755	Coastal Plain	PR	1989–2008	5.66	--	4.07	--	15.14
01407830	Coastal Plain	PR	1989–2008	10.69	--	3.91	--	22.75
01407900	Coastal Plain	PR	1989–2008	33.60	--	3.92	--	25.12
01408000	Coastal Plain	CR	1989–2008	44.04	--	3.93	--	30.64
01408009	Coastal Plain	PR	1989–2008	3.63	--	3.97	--	45.37
01408015	Coastal Plain	PR	1989–2008	6.18	--	3.98	--	46.28
0140802850	Coastal Plain	PR	1989–2008	63.15	--	3.95	--	37.66
01408100	Coastal Plain	PR	1989–2008	19.31	--	3.95	--	34.70
01408150	Coastal Plain	PR	1989–2008	27.40	--	3.96	--	28.27
01408500	Coastal Plain	CR	1989–2008	123.74	--	3.95	--	24.56
01408800	Coastal Plain	PR	1989–2008	2.91	--	3.90	--	7.43
01408830	Coastal Plain	PR	1989–2008	20.10	--	3.94	--	14.49

Table 5. Values of basin characteristics for contiuous-record streamflow-gaging stations and partial-record stations in New Jersey used in the regression analysis for the current (1989–2008) land- and water-use conditions.—Continued

[PR, partial-record station; CR, continuous-record streamflow-gaging station; mi², square miles; in/hr, inches per hour; in, inches; --, not applicable]

U.S. Geological Survey station number	Low-flow regression region	Station type	Current period of record	Basin characteristics				
				Drainage area (mi²)	Soil permeability (in/hr)	Average April precipitation (in)	Average June precipitation (in)	Percent storage
01409150	Coastal Plain	PR	1989–2008	10.36	--	3.97	--	9.22
0140940310	Coastal Plain	PR	1989–2008	2.34	--	3.86	--	10.36
01409405	Coastal Plain	PR	1989–2008	7.08	--	3.88	--	19.43
01409575	Coastal Plain	PR	1989–2008	4.83	--	3.81	--	34.96
01409780	Coastal Plain	PR	1989–2008	21.90	--	3.84	--	38.52
01410150	Coastal Plain	CR	1989–2008	8.15	--	3.93	--	15.12
01410200	Coastal Plain	PR	1989–2008	5.63	--	3.91	--	15.41
01411000	Coastal Plain	CR	1989–2008	56.95	--	3.84	--	25.63
01411035	Coastal Plain	PR	1989–2008	4.52	--	3.81	--	11.11
01411040	Coastal Plain	PR	1989–2008	8.37	--	3.81	--	15.35
01411042	Coastal Plain	PR	1989–2008	2.25	--	3.80	--	7.52
01411053	Coastal Plain	PR	1989–2008	20.12	--	3.81	--	16.54
01411140	Coastal Plain	PR	1989–2008	19.96	--	3.87	--	33.52
01411250	Coastal Plain	PR	1989–2008	3.77	--	3.70	--	5.83
01411300	Coastal Plain	CR	1989–2008	30.77	--	3.73	--	22.95
01411302	Coastal Plain	PR	1989–2008	4.10	--	3.65	--	24.37
01411305	Coastal Plain	PR	1989–2008	7.50	--	3.62	--	10.88
01411388	Coastal Plain	PR	1989–2008	1.36	--	3.37	--	25.63
01411410	Coastal Plain	PR	1989–2008	0.41	--	3.50	--	23.24
01411418	Coastal Plain	PR	1989–2008	0.35	--	3.57	--	55.90
01411428	Coastal Plain	PR	1989–2008	4.03	--	3.62	--	22.60
01411442	Coastal Plain	PR	1989–2008	8.31	--	3.63	--	31.67
01411445	Coastal Plain	PR	1989–2008	11.88	--	3.63	--	24.62
01411466	Coastal Plain	PR	1989–2008	6.37	--	3.79	--	28.88
01411500	Coastal Plain	CR	1989–2008	112.25	--	3.78	--	19.38
01411955	Coastal Plain	PR	1989–2008	3.36	--	3.61	--	14.16
01412100	Coastal Plain	PR	1989–2008	32.26	--	3.75	--	16.26
01439800	Non-coastal	PR	1989–2008	23.75	1.62	--	4.43	--
01439830	Non-coastal	PR	1989–2008	29.31	1.72	--	4.42	--
01439920	Non-coastal	PR	1989–2008	14.70	3.95	--	4.37	--
01440000	Non-coastal	CR	1989–2008	65.02	2.81	--	4.41	--
01440100	Non-coastal	PR	1989–2008	7.66	0.65	--	4.54	--
01442760	Non-coastal	PR	1989–2008	3.55	0.97	--	4.50	--
01443305	Non-coastal	PR	1989–2008	0.35	6.73	--	4.44	--
01443500	Non-coastal	CR	1989–2008	126.03	2.53	--	4.48	--
01443510	Non-coastal	PR	1989–2008	13.08	0.88	--	4.55	--
01445100	Non-coastal	PR	1989–2008	48.39	3.92	--	4.53	--
01445160	Non-coastal	PR	1989–2008	6.10	2.55	--	4.52	--

Table 5. Values of basin characteristics for contiuous-record streamflow-gaging stations and partial-record stations in New Jersey used in the regression analysis for the current (1989–2008) land- and water-use conditions.—Continued

[PR, partial-record station; CR, continuous-record streamflow-gaging station; mi², square miles; in/hr, inches per hour; in, inches; --, not applicable]

U.S. Geological Survey station number	Low-flow regression region	Station type	Current period of record	Basin characteristics				
				Drainage area (mi²)	Soil permeability (in/hr)	Average April precipitation (in)	Average June precipitation (in)	Percent storage
01445200	Non-coastal	PR	1989–2008	12.86	2.87	--	4.53	--
01445400	Non-coastal	PR	1989–2008	90.34	3.73	--	4.55	--
01445430	Non-coastal	PR	1989–2008	92.44	3.69	--	4.55	--
01445490	Non-coastal	PR	1989–2008	4.28	2.13	--	4.55	--
01445500	Non-coastal	CR	1989–2008	106.02	3.48	--	4.55	--
01446400	Non-coastal	PR	1989–2008	156.58	3.23	--	4.54	--
01455100	Non-coastal	PR	1989–2008	14.19	2.59	--	4.26	--
01455135	Non-coastal	PR	1989–2008	9.16	4.02	--	4.59	--
01455370	Non-coastal	PR	1989–2008	8.11	1.80	--	4.74	--
01455780	Non-coastal	PR	1989–2008	16.27	1.98	--	4.64	--
01458570	Non-coastal	PR	1989–2008	10.09	3.15	--	4.34	--
01460880	Non-coastal	PR	1989–2008	22.91	1.73	--	4.21	--
01461300	Non-coastal	PR	1989–2008	26.54	1.20	--	4.17	--
01461900	Non-coastal	PR	1989–2008	14.88	1.78	--	4.03	--
01464460	Coastal Plain	PR	1989–2008	21.45	--	3.87	--	23.68
01464480	Coastal Plain	PR	1989–2008	3.14	--	3.87	--	15.37
01464500	Coastal Plain	CR	1989–2008	81.53	--	3.83	--	28.87
01465865	Coastal Plain	PR	1989–2008	12.80	--	3.86	--	40.09
01465893	Coastal Plain	PR	1989–2008	6.39	--	3.79	--	47.78
01465965	Coastal Plain	PR	1989–2008	1.95	--	3.72	--	9.00
01466500	Coastal Plain	CR	1989–2008	2.34	--	3.81	--	11.59
0146700260	Coastal Plain	PR	1989–2008	5.93	--	3.69	--	26.75
01467027	Coastal Plain	PR	1989–2008	5.51	--	3.92	--	14.03
01467150	Coastal Plain	CR	1989–2008	17.08	--	3.87	--	11.07
01467160	Coastal Plain	PR	1989–2008	5.32	--	3.87	--	16.49
01467180	Coastal Plain	PR	1989–2008	10.61	--	3.88	--	14.12
01475033	Coastal Plain	PR	1989–2008	0.73	--	3.81	--	5.51
0147503330	Coastal Plain	PR	1989–2008	0.95	--	3.81	--	5.20
01475100	Coastal Plain	PR	1989–2008	6.40	--	3.77	--	7.93
01477100	Coastal Plain	PR	1989–2008	10.11	--	3.79	--	13.60
01477120	Coastal Plain	CR	1989–2008	25.94	--	3.77	--	12.62
01477510	Coastal Plain	PR	1989–2008	20.99	--	3.75	--	14.79
01482510	Coastal Plain	PR	1989–2008	3.75	--	3.72	--	17.90
01482950	Coastal Plain	PR	1989–2008	3.77	--	3.69	--	17.96
01483010	Coastal Plain	PR	1989–2008	5.29	--	3.66	--	14.32

[1]Current period of record is given in water years, the 12-month period from October 1 through September 30 with the water year designated by the calendar year in which it ends.

Table 7. Left-censored parametric survival regression equations for the baseline land- and water-use conditions in the non-Coastal low-flow regression region in New Jersey.

[Q#, percentile flow duration; M1D, minimum 1-day daily flow; M7D10Y, minimum 7-day 10-year low flow; DRNAREA, drainage area in square miles; PERMSSUR, soil permeability from Soil Survey Geographic Database (SSURGO); JUNAVPRE, average June precipitation in inches]

Low-flow statistic	Low-flow regression equation	Standard error of the estimate	p-value[1]
January M1D-Q_{99} (M1D01D99)[2]	0.1287*DRNAREA1.03	144	**0.057**
February M1D-Q_{99} (M1D02D99)	0.162*DRNAREA1.10	111	0.029
March M1D-Q_{99} (M1D03D99)	0.1287*DRNAREA1.06*(PERMSSUR+1)0.602	66.2	0.028
April M1D-Q_{99} (M1D04D99)	0.0008*DRNAREA^1.04*JUNAVPRE^3.62*(PERMSSUR+1)^0.645	62	0.051
May M1D-Q_{99} (M1D05D99)	0.0556*DRNAREA^1.05*(PERMSSUR+1)^1.08	87.8	0.052
June M1D-Q_{99} (M1D06D99)	0.1119*DRNAREA^1.05	174	**0.070**
July M1D-Q99 (M1D07D99)	0.0545*DRNAREA^1.05	291	**0.130**
August M1D-Q_{99} (M1D08D99)	0.045*DRNAREA^1.02	322	**0.150**
September M1D-Q_{99} (M1D09D99)	0.0416*DRNAREA^1.06	317	**0.140**
October M1D-Q_{99} (M1D10D99)	0.0498*DRNAREA^1.06	340	**0.150**
November M1D-Q_{99} (M1D11D99)	0.0781*DRNAREA^1.04	239	**0.110**
December M1D-Q_{99} (M1D12D99)	0.1466*DRNAREA^1.01	140	**0.056**
January M1D-Q_{90} (M1D01D90)	0.0057*DRNAREA^0.953*JUNAVPRE^2.47*(PERMSSUR+1)^0.478	48.1	0.039
February M1D-Q_{90} (M1D02D90)	0.0043*DRNAREA^0.966*JUNAVPRE^2.77*(PERMSSUR+1)^0.465	44.8	0.029
March M1D-Q_{90} (M1D03D90)	0.007*DRNAREA^0.964*JUNAVPRE^2.82*(PERMSSUR+1)^0.374	28.9	0.008
April M1D-Q_{90} (M1D04D90)	0.0047*DRNAREA^0.988*JUNAVPRE^3.05*(PERMSSUR+1)^0.418	30.3	0.009
May M1D-Q_{90} (M1D05D90)	0.0017*DRNAREA^0.973*JUNAVPRE^3.26*(PERMSSUR+1)^0.600	52.7	0.041
June M1D-Q_{90} (M1D06D90)	0.0854*DRNAREA^0.985*(PERMSSUR+1)^0.859	74.7	0.044
July M1D-Q_{90} (M1D07D90)	0.1541*DRNAREA^0.970	125	0.052
August M1D-Q_{90} (M1D08D90)	0.1212*DRNAREA^0.963	135	**0.060**
September M1D-Q_{90} (M1D09D90)	0.1054*DRNAREA^0.995	129	0.051
October M1D-Q_{90} (M1D10D90)	0.1423*DRNAREA^0.960	122	0.051
November M1D-Q90 (M111D90)	0.0707*DRNAREA^0.959*(PERMSSUR+1)^0.861	76.0	0.049
December M1D-Q_{90} (M1D12D90)	0.12*DRNAREA^0.967*(PERMSSUR+1)^0.674	63.9	0.033
January M1D-Q_{85} (M1D01D85)	0.0108*DRNAREA^0.946*JUNAVPRE^2.22*(PERMSSUR+1)^0.432	41.1	0.025
February M1D-Q_{85} (M1D02D85)	0.0097*DRNAREA^0.957*JUNAVPRE^2.40*(PERMSSUR+1)^0.403	37.6	0.019
March M1D-Q_{85} (M1D03D85)	0.0076*DRNAREA^0.967*JUNAVPRE^2.86*(PERMSSUR+1)^0.344	25.6	0.006
April M1D-Q_{85} (M1D04D85)	0.0056*DRNAREA^0.983*JUNAVPRE^3.05*(PERMSSUR+1)^0.375	27.5	0.006
May M1D-Q_{85} (M1D05D85)	0.0017*DRNAREA^0.970*JUNAVPRE^3.40*(PERMSSUR+1)^0.518	47.8	0.032
June M1D-Q_{85} (M1D06D85)	0.1075*DRNAREA^0.976*(PERMSSUR+1)^0.788	67.0	0.035
July M1D-Q_{85} (M1D07D85)	0.1827*DRNAREA^0.965	109	0.040
August M1D-Q_{85} (M1D08D85)	0.1466*DRNAREA^0.958	115	0.045
September M1D-Q_{85} (M1D09D85)	0.1287*DRNAREA^0.983	113	0.041
October M1D-Q_{85} (M1D10D85)	0.1738*DRNAREA^0.946	108	0.042
November M1D-Q_{85} (M111D85)	0.0916*DRNAREA^0.956*(PERMSSUR+1)^0.783	68.1	0.039
December M1D-Q_{85} (M1D12D85)	0.0021*DRNAREA^0.936*JUNAVPRE^3.52	58.6	0.027

Table 7. Left-censored parametric survival regression equations for the baseline land- and water-use conditions in the non-Coastal low-flow regression region in New Jersey.—Continued

[Q#, percentile flow duration; M1D, minimum 1-day daily flow; M7D10Y, minimum 7-day 10-year low flow; DRNAREA, drainage area in square miles; PERMSSUR, soil permeability from Soil Survey Geographic Database (SSURGO); JUNAVPRE, average June precipitation in inches]

Low-flow statistic	Low-flow regression equation	Standard error of the estimate	p-value[1]
January M1D-Q_{75} (M1D01D75)	0.0102*DRNAREA^0.948*JUNAVPRE^2.45*(PERMSSUR+1)^0.369	34.7	0.015
February M1D-Q_{75} (M1D02D75)	0.0124*DRNAREA^0.953*JUNAVPRE^2.41*(PERMSSUR+1)^0.331	32.6	0.013
March M1D-Q_{75} (M1D03D75)	0.0109*DRNAREA^0.981*JUNAVPRE^2.73*(PERMSSUR+1)^0.320	22.3	0.003
April M1D-Q_{75} (M1D04D75)	0.0065*DRNAREA^0.975*JUNAVPRE^3.12*(PERMSSUR+1)^0.314	23.7	0.004
May M1D-Q_{75} (M1D05D75)	0.0025*DRNAREA^0.968*JUNAVPRE^3.32*(PERMSSUR+1)^0.460	40.0	0.020
June M1D-Q_{75} (M1D06D75)	0.0003*DRNAREA^0.933*JUNAVPRE^4.80	60.9	0.028
July M1D-Q_{75} (M1D07D75)	0.2276*DRNAREA^0.975	88.3	0.024
August M1D-Q_{75} (M1D08D75)	0.1882*DRNAREA^0.965	93.2	0.028
September M1D-Q_{75} (M1D09D75)	0.172*DRNAREA^0.976	96.0	0.029
October M1D-Q_{75} (M1D10D75)	0.2254*DRNAREA^0.945	88.7	0.027
November M1D-Q_{75} (M111D75)	0.1367*DRNAREA^0.949*(PERMSSUR+1)^0.668	57.4	0.026
December M1D-Q_{75} (M1D12D75)	0.011*DRNAREA^0.924*JUNAVPRE^2.28*(PERMSSUR+1)^0.405	42.0	0.028
January M1D-Q_{50} (M1D01D50)	0.0132*DRNAREA^0.954*JUNAVPRE^2.55*(PERMSSUR+1)^0.311	24.2	0.005
February M1D-Q_{50} (M1D02D50)	0.0164*DRNAREA^0.949*JUNAVPRE^2.56*(PERMSSUR+1)^0.243	22.9	0.004
March M1D-Q_{50} (M1D03D50)	0.0105*DRNAREA^0.997*JUNAVPRE^3.00*(PERMSSUR+1)^0.249	17.8	0.002
April M1D-Q_{50} (M1D04D50)	0.0074*DRNAREA^0.980*JUNAVPRE^3.23*(PERMSSUR+1)^0.257	20.6	0.003
May M1D-Q_{50} (M1D05D50)	0.0031*DRNAREA^0.974*JUNAVPRE^3.47*(PERMSSUR+1)^0.352	30.8	0.009
June M1D-Q_{50} (M1D06D50)	0.0026*DRNAREA^0.942*JUNAVPRE^3.21*(PERMSSUR+1)^0.454	45.1	0.031
July M1D-Q_{50} (M1D07D50)	0.1466*DRNAREA^0.942*(PERMSSUR+1)^0.681	63.0	0.034
August M1D-Q_{50} (M1D08D50)	0.13*DRNAREA^0.935*(PERMSSUR+1)^0.663	66.5	0.040
September M1D-Q_{50} (M1D09D50)	0.12*DRNAREA^0.948*(PERMSSUR+1)^0.679	69.3	0.043
October M1D-Q_{50} (M1D10D50)	0.162*DRNAREA^0.943*(PERMSSUR+1)^0.573	59.4	0.030
November M1D-Q_{50} (M111D50)	0.0113*DRNAREA^0.943*JUNAVPRE^2.34*(PERMSSUR+1)^0.373	38.7	0.021
December M1D-Q_{50} (M1D12D50)	0.0101*DRNAREA^0.941*JUNAVPRE^2.75*(PERMSSUR+1)^0.272	27.8	0.008
January M1D-Q_{25} (M1D01D25)	0.0124*DRNAREA^0.970*JUNAVPRE^2.86*(PERMSSUR+1)^0.233	19.0	0.002
February M1D-Q_{25} (M1D02D25)	0.0215*DRNAREA^0.972*JUNAVPRE^2.62*(PERMSSUR+1)^0.161	17.4	0.002
March M1D-Q_{25} (M1D03D25)	0.0075*DRNAREA^0.996*JUNAVPRE^3.45*(PERMSSUR+1)^0.174	16.0	0.001
April M1D-Q_{25} (M1D04D25)	0.0072*DRNAREA^0.990*JUNAVPRE^3.51*(PERMSSUR+1)^0.170	18.6	0.002
May M1D-Q_{25} (M1D05D25)	0.0049*DRNAREA^0.985*JUNAVPRE^3.41*(PERMSSUR+1)^0.260	25.6	0.005
June M1D-Q_{25} (M1D06D25)	0.0036*DRNAREA^0.945*JUNAVPRE^3.30*(PERMSSUR+1)^0.345	36.4	0.017
July M1D-Q_{25} (M1D07D25)	0.0032*DRNAREA^0.922*JUNAVPRE^3.13*(PERMSSUR+1)^0.418	47.1	0.037
August M1D-Q_{25} (M1D08D25)	0.0072*DRNAREA^0.930*JUNAVPRE^2.41*(PERMSSUR+1)^0.482	49.6	0.043
September M1D-Q_{25} (M1D09D25)	0.0063*DRNAREA^0.949*JUNAVPRE^2.51*(PERMSSUR+1)^0.445	50.1	0.041
October M1D-Q_{25} (M1D10D25)	0.0052*DRNAREA^0.934*JUNAVPRE^2.92*(PERMSSUR+1)^0.340	40.4	0.024
November M1D-Q_{25} (M111D25)	0.011*DRNAREA^0.972*JUNAVPRE^2.74*(PERMSSUR+1)^0.228	27.5	0.007
December M1D-Q_{25} (M1D12D25)	0.0099*DRNAREA^0.965*JUNAVPRE^2.99*(PERMSSUR+1)^0.230	21.6	0.003

Table 7. Left-censored parametric survival regression equations for the baseline land- and water-use conditions in the non-Coastal low-flow regression region in New Jersey.—Continued

[Q#, percentile flow duration; M1D, minimum 1-day daily flow; M7D10Y, minimum 7-day 10-year low flow; DRNAREA, drainage area in square miles; PERMSSUR, soil permeability from Soil Survey Geographic Database (SSURGO); JUNAVPRE, average June precipitation in inches]

Low-flow statistic	Low-flow regression equation	Standard error of the estimate	p-value[1]
January M7D10Y (M7D10Y01)	0.0068*DRNAREA^0.970*JUNAVPRE^2.42*(PERMSSUR+1)^0.513	45.4	0.030
February M7D10Y (M7D10Y02)	0.0102*DRNAREA^0.952*JUNAVPRE^2.44*(PERMSSUR+1)^0.382	35.2	0.016
March M7D10Y (M7D10Y03)	0.0147*DRNAREA^0.991*JUNAVPRE^2.55*(PERMSSUR+1)^0.276	23.2	0.004
April M7D10Y (M7D10Y04)	0.006*DRNAREA^0.975*JUNAVPRE^3.08*(PERMSSUR+1)^0.326	26.2	0.006
May M7D10Y (M7D10Y05)	0.0033*DRNAREA^0.959*JUNAVPRE^3.11*(PERMSSUR+1)^0.439	42.0	0.024
June M7D10Y (M7D10Y06)	0.1075*DRNAREA^1.01*(PERMSSUR+1)^0.748	68.9	0.035
July M7D10Y (M7D10Y07)	0.1572*DRNAREA^1.03	116	0.037
August M7D10Y (M7D10Y08)	0.113*DRNAREA^1.04	130	0.045
September M7D10Y (M7D10Y09)	0.1054*DRNAREA^1.05	131	0.045
October M7D10Y (M7D10Y10)	0.1353*DRNAREA^1.05	109	0.031
November M7D10Y (M7D10Y11)	0.1065*DRNAREA^0.973*(PERMSSUR+1)^0.700	69.7	0.040
December M7D10Y (M7D10Y12)	0.0089*DRNAREA^0.948*JUNAVPRE^2.18*(PERMSSUR+1)^0.478	52.0	0.046
August and September M1D-Q_{75} (M1D0809D75)	0.3867*DRNAREA^0.955	63.6	0.011
August and September M1D-Q_{90} (M1D0809D90)	0.2516*DRNAREA^0.977	80.7	0.019
August and September M1D-Q_{99} (M1D0809D99)	0.113*DRNAREA^1.04	135	0.049

[1] P-value indicated in **bold red** text are for low-flow statistics in which a significant regression equation was unable to be determined from the dataset.

[2] Abbreviation in parentheses is used in the New Jersey StreamStats statistics output.

Table 8. Left-censored parametric survival regression equations for the baseline land and water use conditions in the Coastal Plain low-flow regression region in New Jersey.

[Q#, flow duration percentile; M1D, minimum 1-day daily flow; M7D10Y, minimum 7-day 10-year low flow; DRNAREA, drainage area in square miles; PERMSSUR, soil permeability; APRAVPRE, average April precipitation in inches; STORAGE, percent storage landuse]

Low-flow statistic	Low-flow regression equation	Standard error of estimate	p-value[1]
January M1D-Q_{99} (M1D01D99)[2]	0.134*DRNAREA^1.35	81.3	0.024
February M1D-Q_{99} (M1D02D99)	0.162*DRNAREA^1.30	103	0.041
March M1D-Q_{99} (M1D03D99)	0.2645*DRNAREA^1.18	117	0.065
April M1D-Q_{99} (M1D04D99)	0.3606*DRNAREA^1.10	127	0.087
May M1D-Q_{99} (M1D05D99)	0.3362*DRNAREA^1.05	106	0.073
June M1D-Q_{99} (M1D06D99)	0.1466*DRNAREA^1.21	83.0	0.033
July M1D-Q_{99} (M1D07D99)	0.0376*DRNAREA^1.46	179	0.074
August M1D-Q_{99} (M1D08D99)	0.0317*DRNAREA^1.46	177	0.073
September M1D-Q_{99} (M1D09D99)	0.0354*DRNAREA^1.45	217	0.096
October M1D-Q_{99} (M1D10D99)	0.0469*DRNAREA^1.46	185	0.079
November M1D-Q_{99} (M111D99)	0.0596*DRNAREA^1.48	166	0.064
December M1D-Q_{99} (M1D12D99)	0.1086*DRNAREA^1.32	117	0.050
January M1D-Q_{90} (M1D01D90)	0.0743*DRNAREA^1.12*(PERMSSUR +1)^0.824	46.6	0.038
February M1D-Q_{90} (M1D02D90)	0.0926*DRNAREA^1.12*(PERMSSUR +1)^0.764	45.0	0.035
March M1D-Q_{90} (M1D03D90)	0.5326*DRNAREA^1.12	71.7	0.030
April M1D-Q_{90} (M1D04D90)	0.5326*DRNAREA^1.10	73.2	0.032
May M1D-Q_{90} (M1D05D90)	0.045*DRNAREA^1.10*(PERMSSUR +1)^1.05	49.7	0.047
June M1D-Q_{90} (M1D06D90)	0.357*DRNAREA^1.07	69.4	0.031
July M1D-Q_{90} (M1D07D90)	0.1979*DRNAREA^1.16	86.7	0.041
August M1D-Q_{90} (M1D08D90)	0.1845*DRNAREA^1.14	86.9	0.042
September M1D-Q_{90} (M1D09D90)	0.1827*DRNAREA^1.16	94.0	0.048
October M1D-Q_{90} (M1D10D90)	0.2101*DRNAREA^1.16	87.2	0.041
November M1D-Q_{90} (M111D90)	0.00000007*DRNAREA^1.17*APRAVPRE^11.3	54.0	0.045
December M1D-Q_{90} (M1D12D90)	0.0578*DRNAREA^1.12*(PERMSSUR +1)^0.901	49.6	0.045
January M1D-Q_{85} (M1D01D85)	0.000006*DRNAREA^1.10*APRAVPRE^8.52	44.3	0.034
February M1D-Q_{85} (M1D02D85)	0.000008*DRNAREA^1.09*APRAVPRE^8.26	41.8	0.030
March M1D-Q_{85} (M1D03D85)	0.5945*DRNAREA^1.11	65.3	0.025
April M1D-Q_{85} (M1D04D85)	0.6065*DRNAREA^1.09	66.4	0.027
May M1D-Q_{85} (M1D05D85)	0.000002*DRNAREA^1.07*APRAVPRE^9.40	49.4	0.046
June M1D-Q_{85} (M1D06D85)	0.3829*DRNAREA^1.07	67.1	0.029
July M1D-Q_{85} (M1D07D85)	0.2671*DRNAREA^1.10	79.2	0.038
August M1D-Q_{85} (M1D08D85)	0.2516*DRNAREA^1.10	81.1	0.041
September M1D-Q_{85} (M1D09D85)	0.2441*DRNAREA^1.11	86.1	0.045
October M1D-Q_{85} (M1D10D85)	0.278*DRNAREA^1.11	80.1	0.039
November M1D-Q_{85} (M111D85)	0.0000004*DRNAREA^1.13*APRAVPRE^10.1	50.0	0.042
December M1D-Q_{85} (M1D12D85)	0.000002*DRNAREA^1.10*APRAVPRE^9.06	46.9	0.039

Table 8. Left-censored parametric survival regression equations for the baseline land and water use conditions in the Coastal Plain low-flow regression region in New Jersey.—Continued

[Q#, flow duration percentile; M1D, minimum 1-day daily flow; M7D10Y, minimum 7-day 10-year low flow; DRNAREA, drainage area in square miles; PERMSSUR, soil permeability; APRAVPRE, average April precipitation in inches; STORAGE, percent storage landuse]

Low-flow statistic	Low-flow regression equation	Standard error of estimate	p-value[1]
January M1D-Q_{75} (M1D01D75)	0.00001*DRNAREA^1.10*APRAVPRE^7.92	41.3	0.029
February M1D-Q_{75} (M1D02D75)	0.00002*DRNAREA^1.13*APRAVPRE^8.62*(STORAGE+1)^-0.367	36.2	0.054
March M1D-Q_{75} (M1D03D75)	0.00004*DRNAREA^1.12*APRAVPRE^7.87*(STORAGE+1)^-0.270	34.1	0.048
April M1D-Q_{75} (M1D04D75)	0.00003*DRNAREA^1.07*APRAVPRE^7.49	38.0	0.026
May M1D-Q_{75} (M1D05D75)	0.000004*DRNAREA^1.06*APRAVPRE^8.89	46.9	0.042
June M1D-Q_{75} (M1D06D75)	0.4274*DRNAREA^1.07	63.8	0.026
July M1D-Q_{75} (M1D07D75)	0.357*DRNAREA^1.06	71.3	0.034
August M1D-Q_{75} (M1D08D75)	0.3465*DRNAREA^1.06	72.2	0.035
September M1D-Q_{75} (M1D09D75)	0.343*DRNAREA^1.06	76.3	0.040
October M1D-Q_{75} (M1D10D75)	0.3753*DRNAREA^1.08	64.7	0.026
November M1D-Q_{75} (M111D75)	0.000002*DRNAREA^1.09*APRAVPRE^9.35	46.2	0.038
December M1D-Q_{75} (M1D12D75)	0.00001*DRNAREA^1.10*APRAVPRE^8.54	43.7	0.033
January M1D-Q_{50} (M1D01D50)	0.00004*DRNAREA^1.12*APRAVPRE^8.06*(STORAGE+1)^-0.328	34.9	0.051
February M1D-Q_{50} (M1D02D50)	0.0001*DRNAREA^1.10*APRAVPRE^7.06*(STORAGE+1)^-0.281	33.1	0.046
March M1D-Q_{50} (M1D03D50)	0.0001*DRNAREA^1.10*APRAVPRE^7.00*(STORAGE+1)^-0.215	31.5	0.041
April M1D-Q_{50} (M1D04D50)	0.0001*DRNAREA^1.09*APRAVPRE^7.38*(STORAGE+1)^-0.265	33.6	0.049
May M1D-Q_{50} (M1D05D50)	0.00002*DRNAREA^1.05*APRAVPRE^7.78	41.1	0.032
June M1D-Q_{50} (M1D06D50)	0.000001*DRNAREA^1.05*APRAVPRE^9.92	51.6	0.053
July M1D-Q_{50} (M1D07D50)	0.4538*DRNAREA^1.06	62.7	0.025
August M1D-Q_{50} (M1D08D50)	0.4538*DRNAREA^1.06	60.8	0.024
September M1D-Q_{50} (M1D09D50)	0.4449*DRNAREA^1.06	62.1	0.025
October M1D-Q_{50} (M1D10D50)	0.4724*DRNAREA^1.08	57.8	0.020
November M1D-Q_{50} (M111D50)	0.000005*DRNAREA^1.09*APRAVPRE^8.58	42.3	0.032
December M1D-Q_{50} (M1D12D50)	0.00001*DRNAREA^1.14*APRAVPRE^8.82*(STORAGE+1)^-0.357	36.6	0.054
January M1D-Q_{25} (M1D01D25)	0.0002*DRNAREA^1.10*APRAVPRE^6.73*(STORAGE+1)^-0.228	32.9	0.047
February M1D-Q_{25} (M1D02D25)	0.0004*DRNAREA^1.09*APRAVPRE^6.25*(STORAGE+1)^-0.210	31.0	0.041
March M1D-Q_{25} (M1D03D25)	0.0003*DRNAREA^1.09*APRAVPRE^6.54*(STORAGE+1)^-0.171	29.7	0.038
April M1D-Q_{25} (M1D04D25)	0.0005*DRNAREA^1.07*APRAVPRE^6.16*(STORAGE+1)^-0.173	30.4	0.040
May M1D-Q_{25} (M1D05D25)	0.0001*DRNAREA^1.05*APRAVPRE^6.77	36.9	0.025
June M1D-Q_{25} (M1D06D25)	0.00002*DRNAREA^1.03*APRAVPRE^7.79	42.8	0.037
July M1D-Q_{25} (M1D07D25)	0.000004*DRNAREA^1.03*APRAVPRE^8.85	48.1	0.048
August M1D-Q_{25} (M1D08D25)	0.000003*DRNAREA^1.04*APRAVPRE^9.05	47.5	0.046
September M1D-Q_{25} (M1D09D25)	0.000002*DRNAREA^1.04*APRAVPRE^9.52	48.5	0.047
October M1D-Q_{25} (M1D10D25)	0.000003*DRNAREA^1.06*APRAVPRE^9.05	44.5	0.037
November M1D-Q_{25} (M111D25)	0.00002*DRNAREA^1.07*APRAVPRE^7.80	38.1	0.026
December M1D-Q_{25} (M1D12D25)	0.0001*DRNAREA^1.11*APRAVPRE^7.35*(STORAGE+1)^-0.303	32.9	0.046

Table 8. Left-censored parametric survival regression equations for the baseline land and water use conditions in the Coastal Plain low-flow regression region in New Jersey.—Continued

[Q#, flow duration percentile; M1D, minimum 1-day daily flow; M7D10Y, minimum 7-day 10-year low flow; DRNAREA, drainage area in square miles; PERMSSUR, soil permeability; APRAVPRE, average April precipitation in inches; STORAGE, percent storage landuse]

Low-flow statistic	Low-flow regression equation	Standard error of estimate	p-value[1]
January M7D10Y (M7D10Y01)	0.000006*DRNAREA^1.10*APRAVPRE^8.52	42.3	0.031
February M7D10Y (M7D10Y02)	0.00001*DRNAREA^1.10*APRAVPRE^8.04	39.6	0.026
March M7D10Y (M7D10Y03)	0.000006*DRNAREA^1.15*APRAVPRE^9.21*(STORAGE+1)^-0.281	35.8	0.050
April M7D10Y (M7D10Y04)	0.000002*DRNAREA^1.09*APRAVPRE^9.31	42.9	0.032
May M7D10Y (M7D10Y05)	0.000002*DRNAREA^1.08*APRAVPRE^9.42	47.4	0.041
June M7D10Y (M7D10Y06)	0.3906*DRNAREA^1.08	65.7	0.027
July M7D10Y (M7D10Y07)	0.3073*DRNAREA^1.07	79.5	0.042
August M7D10Y (M7D10Y08)	0.2808*DRNAREA^1.06	80.4	0.044
September M7D10Y (M7D10Y09)	0.2645*DRNAREA^1.06	135	0.110
October M7D10Y (M7D10Y10)	0.2982*DRNAREA^1.08	131	0.098
November M7D10Y (M7D10Y11)	0.000001*DRNAREA^1.10*APRAVPRE^10.0	49.0	0.042
December M7D10Y (M7D10Y12)	0.000003*DRNAREA^1.10*APRAVPRE^8.97	46.0	0.037
August and September M1D-Q_{75} (M1D0809D75)	0.0000003*DRNAREA^1.08*APRAVPRE^10.5	46.9	0.040
August and September M1D-Q_{90} (M1D0809D90)	0.0000002*DRNAREA^1.06*APRAVPRE^10.8	61.7	0.024
August and September M1D-Q_{99} (M1D0809D99)	0.1086*DRNAREA^1.33	84.6	0.027

[1] P-value indicated in **bold red** text are for low-flow statistics in which a significant regression equation was unable to be determined from the dataset.

[2] Abbreviation in parentheses is used in the New Jersey StreamStats statistics output.

Table 9. Left-censored parametric survival regression equations for the current land- and water-use conditions in the non-Coastal low-flow regression region in New Jersey.

[Q#, flow duration percentile; M1D, minumim 1-day daily flow; M7D10Y, minimum 7-day 10-year flow; DRNAREA, drainage area in square miles; PERMSSUR, soil permeability, JUNAVPRE, average June precipitation in inches]

Low-flow statistic	Low-flow regression equation	Standard error of estimate	p-value[1]
January M1D-Q_{99} (M1D01D99)[2]	0.0659*DRNAREA^1.21	127	**0.069**
February M1D-Q_{99} (M1D02D99)	0.1686*DRNAREA^1.10	70.9	0.030
March M1D-Q_{99} (M1D03D99)	0.1809*DRNAREA^1.08	70.3	0.031
April M1D-Q_{99} (M1D04D99)	0.4107*DRNAREA^1.01	72.4	0.039
May M1D-Q_{99} (M1D05D99)	0.2369*DRNAREA^1.13	72.6	0.030
June M1D-Q_{99} (M1D06D99)	0.0821*DRNAREA^1.20	142	**0.083**
July M1D-Q_{99} (M1D07D99)	0.0226*DRNAREA^1.28	259	**0.150**
August M1D-Q_{99} (M1D08D99)	0.0171*DRNAREA^1.27	306	**0.170**
September M1D-Q_{99} (M1D09D99)	0.0161*DRNAREA^1.29	277	**0.160**
October M1D-Q_{99} (M1D10D99)	0.0219*DRNAREA^1.35	217	**0.110**
November M1D-Q_{99} (M111D99)	0.0365*DRNAREA^1.30	156	**0.080**
December M1D-Q_{99} (M1D12D99)	0.0743*DRNAREA^1.20	113	**0.059**
January M1D-Q_{90} (M1D01D90)	0.2254*DRNAREA^1.06	75.3	0.037
February M1D-Q_{90} (M1D02D90)	0.0009*DRNAREA^1.05*JUNAVPRE^4.06	41.7	0.029
March M1D-Q_{90} (M1D03D90)	0.002*DRNAREA^1.03*JUNAVPRE^3.52*(PERMSSUR+1)^0.384	30.9	0.035
April M1D-Q_{90} (M1D04D90)	0.0015*DRNAREA^1.03*JUNAVPRE^3.70*(PERMSSUR+1)^0.364	33.4	0.042
May M1D-Q_{90} (M1D05D90)	0.0002*DRNAREA^1.04*JUNAVPRE^5.26	46.6	0.036
June M1D-Q_{90} (M1D06D90)	0.1466*DRNAREA^1.17	89.8	0.041
July M1D-Q_{90} (M1D07D90)	0.0596*DRNAREA^1.24	126	**0.065**
August M1D-Q_{90} (M1D08D90)	0.0376*DRNAREA^1.25	137	**0.073**
September M1D-Q_{90} (M1D09D90)	0.0396*DRNAREA^1.23	142	**0.081**
October M1D-Q_{90} (M1D10D90)	0.0539*DRNAREA^1.24	109	0.052
November M1D-Q_{90} (M111D90)	0.1033*DRNAREA^1.16	86.1	0.039
December M1D-Q_{90} (M1D12D90)	0.172*DRNAREA^1.12	66.7	0.025
January M1D-Q_{85} (M1D01D85)	0.0017*DRNAREA^1.00*JUNAVPRE^3.50*(PERMSSUR+1)^0.375	35.3	0.051
February M1D-Q_{85} (M1D02D85)	0.0019*DRNAREA^1.02*JUNAVPRE^3.32*(PERMSSUR+1)^0.449	35.2	0.048
March M1D-Q_{85} (M1D03D85)	0.0036*DRNAREA^1.01*JUNAVPRE^3.28*(PERMSSUR+1)^0.369	26.6	0.026
April M1D-Q_{85} (M1D04D85)	0.0019*DRNAREA^1.03*JUNAVPRE^3.67*(PERMSSUR+1)^0.325	30.4	0.034
May M1D-Q_{85} (M1D05D85)	0.0003*DRNAREA^1.04*JUNAVPRE^5.00	44.3	0.032
June M1D-Q_{85} (M1D06D85)	0.167*DRNAREA^1.16	81.8	0.035
July M1D-Q_{85} (M1D07D85)	0.0699*DRNAREA^1.24	110	0.052
August M1D-Q_{85} (M1D08D85)	0.0478*DRNAREA^1.23	121	**0.063**
September M1D-Q_{85} (M1D09D85)	0.0437*DRNAREA^1.25	122	**0.062**
October M1D-Q_{85} (M1D10D85)	0.0679*DRNAREA^1.20	98.1	0.046
November M1D-Q_{85} (M111D85)	0.1353*DRNAREA^1.17	69.7	0.025
December M1D-Q_{85} (M1D12D85)	0.1409*DRNAREA^1.06*(PERMSSUR+1)^0.601	41.8	0.029

Table 9. Left-censored parametric survival regression equations for the current land- and water-use conditions in the non-Coastal low-flow regression region in New Jersey.—Continued

[Q#, flow duration percentile; M1D, minumim 1-day daily flow; M7D10Y, minimum 7-day 10-year flow; DRNAREA, drainage area in square miles; PERMSSUR, soil permeability, JUNAVPRE, average June precipitation in inches]

Low-flow statistic	Low-flow regression equation	Standard error of estimate	p-value[1]
January M1D-Q_{75} (M1D01D75)	0.0026*DRNAREA^1.02*JUNAVPRE^3.38*(PERMSSUR+1)^0.286	31.9	0.040
February M1D-Q_{75} (M1D02D75)	0.0031*DRNAREA^1.02*JUNAVPRE^3.15*(PERMSSUR+1)^0.375	31.7	0.038
March M1D-Q_{75} (M1D03D75)	0.0055*DRNAREA^1.02*JUNAVPRE^3.21*(PERMSSUR+1)^0.256	23.0	0.019
April M1D-Q_{75} (M1D04D75)	0.0028*DRNAREA^1.02*JUNAVPRE^3.53*(PERMSSUR+1)^0.336	25.4	0.023
May M1D-Q_{75} (M1D05D75)	0.0004*DRNAREA^1.04*JUNAVPRE^4.83	42.0	0.029
June M1D-Q_{75} (M1D06D75)	0.208*DRNAREA^1.14	69.1	0.026
July M1D-Q_{75} (M1D07D75)	0.0963*DRNAREA^1.21	95.5	0.043
August M1D-Q_{75} (M1D08D75)	0.0665*DRNAREA^1.21	104	0.050
September M1D-Q_{75} (M1D09D75)	0.0573*DRNAREA^1.23	106	0.050
October M1D-Q_{75} (M1D10D75)	0.0926*DRNAREA^1.18	85.4	0.037
November M1D-Q_{75} (M111D75)	0.0863*DRNAREA^1.06*(PERMSSUR+1)^0.789	51.0	0.043
December M1D-Q_{75} (M1D12D75)	0.0019*DRNAREA^1.01*JUNAVPRE^3.44*(PERMSSUR+1)^0.341	34.6	0.048
January M1D-Q_{50} (M1D01D50)	0.0057*DRNAREA^1.04*JUNAVPRE^3.06*(PERMSSUR+1)^0.244	23.1	0.018
February M1D-Q_{50} (M1D02D50)	0.0043*DRNAREA^1.03*JUNAVPRE^3.36*(PERMSSUR+1)^0.237	22.9	0.018
March M1D-Q_{50} (M1D03D50)	0.0061*DRNAREA^1.04*JUNAVPRE^3.34*(PERMSSUR+1)^0.166	19.9	0.013
April M1D-Q_{50} (M1D04D50)	0.0044*DRNAREA^1.03*JUNAVPRE^3.42*(PERMSSUR+1)^0.274	22.1	0.016
May M1D-Q_{50} (M1D05D50)	0.0007*DRNAREA^1.02*JUNAVPRE^4.24*(PERMSSUR+1)^0.427	33.8	0.042
June M1D-Q_{50} (M1D06D50)	0.0001*DRNAREA^1.05*JUNAVPRE^5.37	47.8	0.037
July M1D-Q_{50} (M1D07D50)	0.1588*DRNAREA^1.12	78.7	0.032
August M1D-Q_{50} (M1D08D50)	0.1165*DRNAREA^1.19	84.3	0.035
September M1D-Q_{50} (M1D09D50)	0.0983*DRNAREA^1.20	83.7	0.034
October M1D-Q_{50} (M1D10D50)	0.1496*DRNAREA^1.16	70.5	0.025
November M1D-Q_{50} (M111D50)	0.0015*DRNAREA^1.04*JUNAVPRE^3.62*(PERMSSUR+1)^0.304	33.9	0.043
December M1D-Q_{50} (M1D12D50)	0.0029*DRNAREA^1.04*JUNAVPRE^3.51*(PERMSSUR+1)^0.192	26.2	0.025
January M1D-Q_{25} (M1D01D25)	0.0028*DRNAREA^1.04*JUNAVPRE^3.89*(PERMSSUR+1)^0.146	22.4	0.017
February M1D-Q_{25} (M1D02D25)	0.0077*DRNAREA^1.05*JUNAVPRE^3.16*(PERMSSUR+1)^0.181	19.1	0.011
March M1D-Q_{25} (M1D03D25)	0.0048*DRNAREA^1.05*JUNAVPRE^3.68*(PERMSSUR+1)^0.108	20.0	0.013
April M1D-Q_{25} (M1D04D25)	0.0043*DRNAREA^1.04*JUNAVPRE^3.62*(PERMSSUR+1)^0.236	21.5	0.015
May M1D-Q_{25} (M1D05D25)	0.0014*DRNAREA^1.03*JUNAVPRE^4.02*(PERMSSUR+1)^0.354	28.1	0.028
June M1D-Q_{25} (M1D06D25)	0.0004*DRNAREA^1.02*JUNAVPRE^4.55*(PERMSSUR+1)^0.436	34.7	0.044
July M1D-Q_{25} (M1D07D25)	0.0001*DRNAREA^1.04*JUNAVPRE^5.72	50.2	0.041
August M1D-Q_{25} (M1D08D25)	0.0003*DRNAREA^1.07*JUNAVPRE^4.66	55.4	0.050
September M1D-Q_{25} (M1D09D25)	0.0002*DRNAREA^1.04*JUNAVPRE^5.04	53.8	0.049
October M1D-Q_{25} (M1D10D25)	0.0008*DRNAREA^1.04*JUNAVPRE^3.99*(PERMSSUR+1)^0.339	36.8	0.050
November M1D-Q_{25} (M111D25)	0.0013*DRNAREA^1.04*JUNAVPRE^4.14*(PERMSSUR+1)^0.194	25.9	0.023
December M1D-Q_{25} (M1D12D25)	0.0027*DRNAREA^1.04*JUNAVPRE^3.87*(PERMSSUR+1)^0.098	23.9	0.020

Table 9. Left-censored parametric survival regression equations for the current land- and water-use conditions in the non-Coastal low-flow regression region in New Jersey.—Continued

[Q#, flow duration percentile; M1D, minumim 1-day daily flow; M7D10Y, minimum 7-day 10-year flow; DRNAREA, drainage area in square miles; PERMSSUR, soil permeability, JUNAVPRE, average June precipitation in inches]

Low-flow statistic	Low-flow regression equation	Standard error of estimate	p-value[1]
January M7D10Y (M7D10Y01)	0.005*DRNAREA^1.01*JUNAVPRE^2.62*(PERMSSUR+1)^0.474	35.3	0.050
February M7D10Y (M7D10Y02)	0.004*DRNAREA^1.02*JUNAVPRE^2.85*(PERMSSUR+1)^0.425	33.6	0.045
March M7D10Y (M7D10Y03)	0.0111*DRNAREA^1.03*JUNAVPRE^2.55*(PERMSSUR+1)^0.270	26.1	0.026
April M7D10Y (M7D10Y04)	0.003*DRNAREA^1.01*JUNAVPRE^3.45*(PERMSSUR+1)^0.283	28.8	0.032
May M7D10Y (M7D10Y05)	0.0003*DRNAREA^1.04*JUNAVPRE^4.91	42.9	0.030
June M7D10Y (M7D10Y06)	0.1809*DRNAREA^1.15	73.1	0.028
July M7D10Y (M7D10Y07)	0.0765*DRNAREA^1.21	105	0.051
August M7D10Y (M7D10Y08)	0.04*DRNAREA^1.25	163	**0.096**
September M7D10Y (M7D10Y09)	0.0437*DRNAREA^1.24	133	**0.071**
October M7D10Y (M7D10Y10)	0.0665*DRNAREA^1.21	107	0.053
November M7D10Y (M7D10Y11)	0.1451*DRNAREA^1.15	66.9	0.023
December M7D10Y (M7D10Y12)	0.1177*DRNAREA^1.06*(PERMSSUR+1)^0.652	46.9	0.038
August and September M1D-Q_{75} (M1D0809D75)	0.1959*DRNAREA^1.12	65.1	0.023
August and September M1D-Q_{90} (M1D0809D90)	0.1237*DRNAREA^1.14	74.7	0.030
August and September M1D-Q_{99} (M1D0809D99)	0.062*DRNAREA^1.22	101	0.047

[1] P-value indicated in **bold red** text are for low-flow statistics in which a significant regression equation was unable to be determined from the dataset.

[2] Abbreviation in parentheses is used in the New Jersey StreamStats statistics output.

Table 10. Left-censored parametric survival regression equations for the current land- and water-use conditions in the Coastal Plain low-flow regression region in New Jersey.

[Q#, flow duration percentile; M1D, minimum 1-day daily flow; M7D10Y, monthly 7-day 10-year flow; DRNAREA, drainage area in square miles; APRAVPRE, average April precipitation in inches; STORAGE, percent storage landuse]

Low-flow statistic	Low-flow regression equation	Standard error of estimate	p-value[1]
January M1D-Q_{99} (M1D01D99)[2]	0.1827*DRNAREA^1.25	95.0	0.022
February M1D-Q_{99} (M1D02D99)	0.000001*DRNAREA^1.20*APRAVPRE^9.30	76.3	0.048
March M1D-Q_{99} (M1D03D99)	0.0000005*DRNAREA^1.17*APRAVPRE^9.82	59.4	0.030
April M1D-Q_{99} (M1D04D99)	0.00001*DRNAREA^1.09*APRAVPRE^8.68*(STORAGE+1)^-0.425	38.3	0.037
May M1D-Q_{99} (M1D05D99)	0.00001*DRNAREA^1.11*APRAVPRE^8.83*(STORAGE+1)^-0.507	39.3	0.039
June M1D-Q_{99} (M1D06D99)	0.0000003*DRNAREA^1.20*APRAVPRE^9.83	76.7	0.049
July M1D-Q_{99} (M1D07D99)	0.0872*DRNAREA^1.28	120	0.035
August M1D-Q_{99} (M1D08D99)	0.0573*DRNAREA^1.27	126	0.039
September M1D-Q_{99} (M1D09D99)	0.0735*DRNAREA^1.28	117	0.034
October M1D-Q_{99} (M1D10D99)	0.0973*DRNAREA^1.28	113	0.032
November M1D-Q_{99} (M111D99)	0.1177*DRNAREA^1.29	115	0.032
December M1D-Q_{99} (M1D12D99)	0.1496*DRNAREA^1.24	98.7	0.025
January M1D-Q_{90} (M1D01D90)	0.00001*DRNAREA^1.14*APRAVPRE^8.72*(STORAGE+1)^-0.379	41.4	0.039
February M1D-Q_{90} (M1D02D90)	0.0001*DRNAREA^1.12*APRAVPRE^6.99*(STORAGE+1)^-0.386	33.2	0.025
March M1D-Q_{90} (M1D03D90)	0.0001*DRNAREA^1.11*APRAVPRE^6.90*(STORAGE+1)^-0.310	32.5	0.023
April M1D-Q_{90} (M1D04D90)	0.0001*DRNAREA^1.10*APRAVPRE^7.53*(STORAGE+1)^-0.401	32.2	0.024
May M1D-Q_{90} (M1D05D90)	0.00004*DRNAREA^1.12*APRAVPRE^7.96*(STORAGE+1)^-0.493	36.9	0.033
June M1D-Q_{90} (M1D06D90)	0.00001*DRNAREA^1.12*APRAVPRE^9.38*(STORAGE+1)^-0.610	40.9	0.043
July M1D-Q_{90} (M1D07D90)	0.0000002*DRNAREA^1.10*APRAVPRE^10.4	67.3	0.045
August M1D-Q_{90} (M1D08D90)	0.1604*DRNAREA^1.12	86.3	0.025
September M1D-Q_{90} (M1D09D90)	0.0000001*DRNAREA^1.08*APRAVPRE^10.7	65.7	0.045
October M1D-Q_{90} (M1D10D90)	0.0000003*DRNAREA^1.10*APRAVPRE^10.1	58.7	0.034
November M1D-Q_{90} (M111D90)	0.000002*DRNAREA^1.12*APRAVPRE^8.74	54.0	0.026
December M1D-Q_{90} (M1D12D90)	0.000006*DRNAREA^1.16*APRAVPRE^9.14*(STORAGE+1)^-0.478	41.9	0.040
January M1D-Q_{85} (M1D01D85)	0.0001*DRNAREA^1.11*APRAVPRE^7.34*(STORAGE +1)^-0.367	35.3	0.029
February M1D-Q_{85} (M1D02D85)	0.0002*DRNAREA^1.11*APRAVPRE^6.73*(STORAGE +1)^-0.362	31.2	0.021
March M1D-Q_{85} (M1D03D85)	0.0002*DRNAREA^1.11*APRAVPRE^6.70*(STORAGE +1)^-0.293	30.7	0.020
April M1D-Q_{85} (M1D04D85)	0.0002*DRNAREA^1.10*APRAVPRE^6.65*(STORAGE +1)^-0.371	29.9	0.020
May M1D-Q_{85} (M1D05D85)	0.0001*DRNAREA^1.11*APRAVPRE^7.80*(STORAGE +1)^-0.467	35.6	0.030
June M1D-Q_{85} (M1D06D85)	0.00001*DRNAREA^1.12*APRAVPRE^9.37*(STORAGE +1)^-0.60	39.9	0.041
July M1D-Q_{85} (M1D07D85)	0.000001*DRNAREA^1.06*APRAVPRE^9.64	58.9	0.037
August M1D-Q_{85} (M1D08D85)	0.0000001*DRNAREA^1.06*APRAVPRE^11.0	67.3	0.049
September M1D-Q_{85} (M1D09D85)	0.0000003*DRNAREA^1.04*APRAVPRE^10.3	61.2	0.042
October M1D-Q_{85} (M1D10D85)	0.0000003*DRNAREA^1.19*APRAVPRE^11.5*(STORAGE +1)^-0.665	48.0	0.053
November M1D-Q_{85} (M111D85)	0.000004*DRNAREA^1.18*APRAVPRE^9.44*(STORAGE +1)^-0.462	44.7	0.044
December M1D-Q_{85} (M1D12D85)	0.00002*DRNAREA^1.12*APRAVPRE^8.64*(STORAGE +1)^-0.474	36.5	0.031

Table 10. Left-censored parametric survival regression equations for the current land- and water-use conditions in the Coastal Plain low-flow regression region in New Jersey.—Continued

[Q#, flow duration percentile; M1D, minimum 1-day daily flow; M7D10Y, monthly 7-day 10-year flow; DRNAREA, drainage area in square miles; APRAVPRE, average April precipitation in inches; STORAGE, percent storage landuse]

Low-flow statistic	Low-flow regression equation	Standard error of estimate	p-value[1]
January M1D-Q_{75} (M1D01D75)	0.0001*DRNAREA^1.11*APRAVPRE^6.98*(STORAGE +1)^-0.354	32.4	0.023
February M1D-Q_{75} (M1D02D75)	0.0002*DRNAREA^1.09*APRAVPRE^6.60*(STORAGE +1)^-0.321	29.3	0.019
March M1D-Q_{75} (M1D03D75)	0.0004*DRNAREA^1.10*APRAVPRE^6.12*(STORAGE +1)^-0.259	28.2	0.016
April M1D-Q_{75} (M1D04D75)	0.0007*DRNAREA^1.09*APRAVPRE^5.90*(STORAGE +1)^-0.306	28.0	0.017
May M1D-Q_{75} (M1D05D75)	0.0001*DRNAREA^1.10*APRAVPRE^7.42*(STORAGE +1)^-0.438	33.8	0.027
June M1D-Q_{75} (M1D06D75)	0.00001*DRNAREA^1.12*APRAVPRE^9.04*(STORAGE +1)^-0.581	38.9	0.038
July M1D-Q_{75} (M1D07D75)	0.000002*DRNAREA^1.15*APRAVPRE^10.4*(STORAGE +1)^-0.674	45.3	0.052
August M1D-Q_{75} (M1D08D75)	0.000001*DRNAREA^1.03*APRAVPRE^9.42	57.6	0.038
September M1D-Q_{75} (M1D09D75)	0.0000008*DRNAREA^0.992*APRAVPRE^9.67	53.2	0.035
October M1D-Q_{75} (M1D10D75)	0.000001*DRNAREA^1.14*APRAVPRE^10.8*(STORAGE +1)^-0.645	43.1	0.046
November M1D-Q_{75} (M111D75)	0.00001*DRNAREA^1.14*APRAVPRE^8.75*(STORAGE +1)^-0.451	38.9	0.035
December M1D-Q_{75} (M1D12D75)	0.00004*DRNAREA^1.12*APRAVPRE^7.87*(STORAGE +1)^-0.409	34.2	0.026
January M1D-Q_{50} (M1D01D50)	0.0006*DRNAREA^1.08*APRAVPRE^5.97*(STORAGE +1)^-0.263	28.3	0.017
February M1D-Q_{50} (M1D02D50)	0.0022*DRNAREA^1.06*APRAVPRE^4.99*(STORAGE +1)^-0.205	25.8	0.014
March M1D-Q_{50} (M1D03D50)	0.0025*DRNAREA^1.06*APRAVPRE^4.87*(STORAGE +1)^-0.183	24.7	0.012
April M1D-Q_{50} (M1D04D50)	0.0033*DRNAREA^1.06*APRAVPRE^4.75*(STORAGE +1)^-0.213	25.1	0.013
May M1D-Q_{50} (M1D05D50)	0.0006*DRNAREA^1.07*APRAVPRE^6.13*(STORAGE +1)^-0.357	29.9	0.021
June M1D-Q_{50} (M1D06D50)	0.00004*DRNAREA^1.10*APRAVPRE^8.07*(STORAGE +1)^-0.525	36.3	0.033
July M1D-Q_{50} (M1D07D50)	0.00001*DRNAREA^1.11*APRAVPRE^9.15*(STORAGE +1)^-0.598	39.6	0.040
August M1D-Q_{50} (M1D08D50)	0.000003*DRNAREA^1.11*APRAVPRE^10.0*(STORAGE +1)^-0.596	40.0	0.041
September M1D-Q_{50} (M1D09D50)	0.000004*DRNAREA^1.11*APRAVPRE^9.81*(STORAGE +1)^-0.571	39.7	0.041
October M1D-Q_{50} (M1D10D50)	0.00001*DRNAREA^1.11*APRAVPRE^9.22*(STORAGE +1)^-0.493	37.4	0.034
November M1D-Q_{50} (M111D50)	0.00004*DRNAREA^1.11*APRAVPRE^7.99*(STORAGE +1)^-0.392	33.6	0.025
December M1D-Q_{50} (M1D12D50)	0.0001*DRNAREA^1.11*APRAVPRE^6.99*(STORAGE +1)^-0.328	31.0	0.021
January M1D-Q_{25} (M1D01D25)	0.0024*DRNAREA^1.07*APRAVPRE^4.91*(STORAGE +1)^-0.172	26.2	0.014
February M1D-Q_{25} (M1D02D25)	0.0056*DRNAREA^1.05*APRAVPRE^4.30*(STORAGE +1)^-0.148	24.7	0.012
March M1D-Q_{25} (M1D03D25)	0.0151*DRNAREA^1.04*APRAVPRE^3.58*(STORAGE +1)^-0.117	23.4	0.011
April M1D-Q_{25} (M1D04D25)	0.0117*DRNAREA^1.04*APRAVPRE^3.81*(STORAGE +1)^-0.125	22.9	0.010
May M1D-Q_{25} (M1D05D25)	0.0035*DRNAREA^1.06*APRAVPRE^4.75*(STORAGE +1)^-0.259	27.2	0.016
June M1D-Q25 (M1D06D25)	0.0002*DRNAREA^1.08*APRAVPRE^7.12*(STORAGE +1)^-0.433	32.0	0.025
July M1D-Q_{25} (M1D07D25)	0.00005*DRNAREA^1.10*APRAVPRE^7.95*(STORAGE +1)^-0.50	36.4	0.033
August M1D-Q_{25} (M1D08D25)	0.0001*DRNAREA^1.08*APRAVPRE^7.74*(STORAGE +1)^-0.468	35.1	0.031
September M1D-Q_{25} (M1D09D25)	0.00003*DRNAREA^1.09*APRAVPRE^8.25*(STORAGE +1)^-0.458	36.5	0.033
October M1D-Q_{25} (M1D10D25)	0.00004*DRNAREA^1.11*APRAVPRE^7.98*(STORAGE +1)^-0.423	33.9	0.026
November M1D-Q_{25} (M111D25)	0.0002*DRNAREA^1.09*APRAVPRE^6.77*(STORAGE +1)^-0.283	29.3	0.018
December M1D-Q_{25} (M1D12D25)	0.0007*DRNAREA^1.09*APRAVPRE^5.89*(STORAGE +1)^-0.254	25.8	0.013

Table 10. Left-censored parametric survival regression equations for the current land- and water-use conditions in the Coastal Plain low-flow regression region in New Jersey.—Continued

[Q#, flow duration percentile; M1D, minimum 1-day daily flow; M7D10Y, monthly 7-day 10-year flow; DRNAREA, drainage area in square miles; APRAVPRE, average April precipitation in inches; STORAGE, percent storage landuse]

Low-flow statistic	Low-flow regression equation	Standard error of estimate	p-value[1]
January M7D10Y (M7D10Y01)	0.0001*DRNAREA^1.11*APRAVPRE^7.62*(STORAGE +1)^-0.349	32.8	0.023
February M7D10Y (M7D10Y02)	0.0001*DRNAREA^1.11*APRAVPRE^7.34*(STORAGE +1)^-0.362	31.4	0.021
March M7D10Y (M7D10Y03)	0.0002*DRNAREA^1.10*APRAVPRE^6.76*(STORAGE +1)^-0.319	29.7	0.019
April M7D10Y (M7D10Y04)	0.0002*DRNAREA^1.10*APRAVPRE^6.85*(STORAGE +1)^-0.358	30.3	0.020
May M7D10Y (M7D10Y05)	0.00005*DRNAREA^1.11*APRAVPRE^7.83*(STORAGE +1)^-0.437	34.4	0.028
June M7D10Y (M7D10Y06)	0.00001*DRNAREA^1.12*APRAVPRE^9.03*(STORAGE +1)^-0.572	38.5	0.037
July M7D10Y (M7D10Y07)	0.000002*DRNAREA^1.00*APRAVPRE^9.22	55.6	0.038
August M7D10Y (M7D10Y08)	0.0000001*DRNAREA^0.99*APRAVPRE^11.0	63.5	0.052
September M7D10Y (M7D10Y09)	0.0000002*DRNAREA^1.01*APRAVPRE^10.5	59.1	0.042
October M7D10Y (M7D10Y10)	0.0000003*DRNAREA^1.15*APRAVPRE^11.5*(STORAGE +1)^-0.685	45.3	0.051
November M7D10Y (M7D10Y11)	0.000003*DRNAREA^1.13*APRAVPRE^9.83*(STORAGE +1)^-0.544	39.7	0.038
December M7D10Y (M7D10Y12)	0.00002*DRNAREA^1.13*APRAVPRE^8.49*(STORAGE +1)^-0.462	37.1	0.032
August and September M1D-Q_{75} (M1D0809D75)	0.000003*DRNAREA^1.03*APRAVPRE^9.00	43.8	0.020
August and September M1D-Q_{90} (M1D0809D90)	0.0000008*DRNAREA^1.06*APRAVPRE^9.71	50.7	0.026
August and September M1D-Q_{99} (M1D0809D99)	0.139*DRNAREA^1.26	92.8	0.021

[1] P-value indicated in **bold red** text are for low-flow statistics in which a significant regression equation was unable to be determined from the dataset.

[2] Abbreviation in parentheses is used in the New Jersey StreamStats statistics output.

Appendixes 1–6

Excel files accessible from the publication web site

Appendix 1. Flow-duration and low-flow frequency values computed from observed continuous-record streamflow-gaging station and partial-record gaging station data, estimates predicted using regression equations, and percent difference between the two values for the non-coastal region in New Jersey for the baseline land- and water-use conditions. [Observed streamflow values were computed from daily records for continuous-record streamflow-gaging stations, and values were predicted using MOVE.1 for partial-record stations. Streamflow is in cubic feet per second]

Appendix 2. Flow-duration and low-flow frequency values computed from observed continuous-record streamflow-gaging station and partial-record gaging station data, estimates predicted using regression equations, and percent difference between the two values for the Coastal Plain region in New Jersey for the baseline land- and water-use conditions. [Observed streamflow values were computed from daily records for continuous-record streamflow-gaging stations, and values were predicted using MOVE.1 for partial-record stations. Streamflow is in cubic feet per second]

Appendix 3. Flow-duration and low-flow frequency values computed from observed continuous-record streamflow-gaging station and partial-record gaging station data, estimates predicted using regression equations, and percent difference between the two values for the non-coastal region in New Jersey for the current land- and water-use conditions, water years 1989–2008. [Observed streamflow values were computed from daily records for continuous-record streamflow-gaging stations, and values were predicted using MOVE.1 for partial-record stations. Streamflow is in cubic feet per second]

Appendix 4. Flow-duration and low-flow frequency values computed from observed continuous-record streamflow-gaging station and partial-record gaging station data, estimates predicted using regression equations, and percent difference between the two values for the Coastal Plain region in New Jersey for the current land- and water-use conditions, water years 1989–2008. [Observed streamflow values were computed from daily records for continuous-record streamflow-gaging stations, and values were predicted using MOVE.1 for partial-record stations. Streamflow is in cubic feet per second]

Appendix 5. Comparison of flow-duration and low-flow frequency values for continuous-record streamflow-gaging stations and partial-record stations in the non-coastal region in New Jersey between the baseline and current (water years 1989–2008) land- and water-use conditions. [Streamflow values were computed from daily records for continuous-record streamflow-gaging stations, and values were estimated for low-flow partial-record stations. Streamflow is in cubic feet per second]

Appendix 6. Comparison of flow-duration and low-flow frequency values for continuous-record streamflow-gaging stations and partial-record stations in the Coastal Plain region in New Jersey between the baseline and current (water years 1989–2008) land- and water-use conditions. [Streamflow values were computed from daily records for continuous-record streamflow-gaging stations, and values were estimated for low-flow partial-record stations. Streamflow is in cubic feet per second]

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For additional information, write to:

Director
U.S. Geological Survey
New Jersey Water Science Center
3450 Princeton Pike, Suite 110
Lawrenceville, NJ 08648

or visit our Web site at:
http://nj.usgs.gov/

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