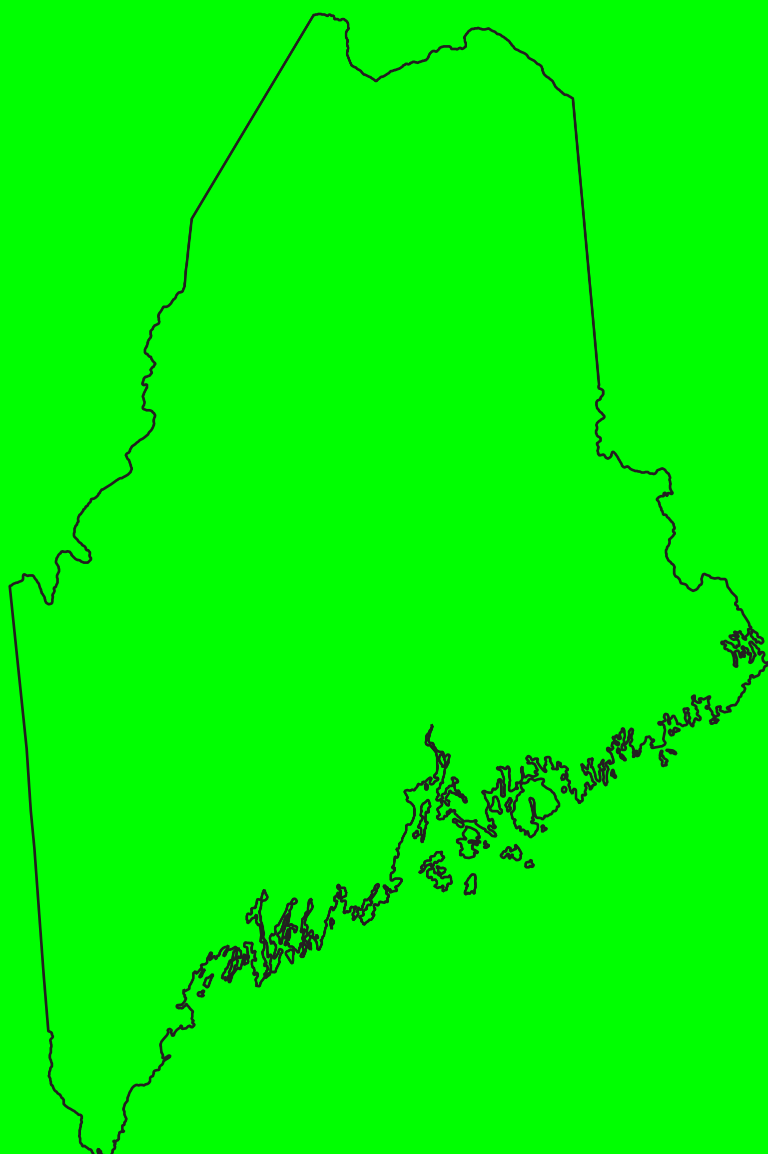
Estimating Flood Magnitude and Frequency on Gaged and Ungaged Streams in Maine



Scientific Investigations Report 2020–5092

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

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By Pamela J. Lombard and Glenn A. Hodgkins

Prepared in cooperation with the Maine Department of Transportation

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Contents

Figures

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Conversion Factors

U.S. customary units to International System of Units

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 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)
cubic foot per second per square mile ([ft^3/s]/mi^2)	0.01093	cubic meter per second per square kilometer ([m^3/s]/km^2)

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

$$°C = (°F – 32) / 1.8.$$

Datum

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.

Abbreviations

$<$	less than
AEP	annual exceedance probability
AVP	average variance of prediction
B–GLS	Bayesian generalized least-squares regression
B–WLS	Bayesian weighted least-squares regression
CSG	crest stage gage
EMA	expected moments algorithm
EVR	error variance ratio
GIS	geographic information system
GLS	generalized least squares
LTP	long-term persistence
MBV	misrepresentation of the beta variance
MGBT	multiple Grubbs-Beck test
MSE	mean square error
OLS	ordinary least squares
p	probability
P_{RL}	pseudorecord length
PILF	potentially influential low flood
R^2	coefficient of determination
RMSE	root mean square error
SE_{pred}	standard error of prediction
STP	short-term persistence
USGS	U.S. Geological Survey
VIF	variance inflation factor
WLS	weighted least squares

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Abstract

Accurate estimates of flood frequency and magnitude on rivers and streams in Maine are a key component of effective flood risk management, flood mitigation, and flood recovery programs for the State. Flood-frequency estimates are published here for 148 streamgages in and adjacent to Maine. Equations are provided for users to compute flood-frequency estimates at any location on a stream that does not have a streamgage. Estimates and equations are presented for peak flows with annual exceedance probabilities (AEPs) of 50, 20, 10, 4, 2, 1, 0.5, and 0.2 percent. AEPs correspond to flood recurrence intervals of 2, 5, 10, 25, 50, 100, 200, and 500 years, respectively. New estimates use a regional skew coefficient of 0.02 with a standard error of prediction of 0.30 developed specifically for Maine as a part of this work.

Equations are designed for use at ungaged sites without substantial flow regulation or urbanization in Maine, with drainage areas between 0.26 and 5,680 square miles. The equations were developed from streamflows and basin characteristics at 124 unregulated streamgages using generalized least-squares regression techniques. Explanatory variables used in the equations for computing peak flows are drainage area, percentage of area in the basin that contains wetlands, and basin mean 24-hour rainfall intensities. The average standard error of prediction (ASEP) for these equations ranges from −31.5 to 45.9 percent for the 50-percent AEP and from −34.2 to 52.0 percent for the 0.2-percent AEP. Equations that use only drainage area are provided for use in cases where lower accuracy is acceptable. The ASEP for estimating peak flows with these simpler equations ranges from −40 to 66 percent for the 50-percent AEP and from −44 to 79 percent for the 0.2-percent AEP.

Final peak flows at unregulated streamgages are computed as weighted averages between the at-station peak flows and peak flows computed at those same sites using the regression equations. Peak flow estimates and equations presented here are accessible in the U.S. Geological Survey StreamStats application. StreamStats is a web application that computes selected basin characteristics and estimates of peak flows and other available streamflow statistics for user-selected streams in Maine.

Introduction

Flood-frequency analysis is a statistical technique used to predict the magnitude and frequency of peak flows in a stream. The objective of frequency analysis is to relate the magnitude of peak flows to their frequency of occurrence through a probability distribution. The probabilities computed correspond to the annual exceedance probability (AEP), or the probability in any year that a peak flow is exceeded. The flood-frequency analyses in this report, prepared in cooperation with Maine Department of Transportation, follow the methodology described in the current version of the national guidelines for flood-frequency analyses, hereafter referred to as “Bulletin 17C” (England and others, 2018).

A peak-flow frequency analysis is based on a statistical evaluation of annual maximum instantaneous flows collected at streamgages. Previous peak-flow studies in Maine and elsewhere have commonly described peak-flow frequency relative to recurrence intervals, which are the inverse of AEPs. Describing peak-flow frequency in terms of recurrence intervals has caused some confusion; for example, use of the term “100-year flood,” where 100 years is the recurrence interval, can give the false impression that a flow will occur only once every 100 years. In fact, the flow has a 1-percent chance of occurring in any given year. As a result, the U.S. Geological Survey (USGS) and other agencies have encouraged the use of AEP instead of recurrence interval (Holmes and Dinicola, 2010). Streamflows at AEPs of 50, 20, 10, 4, 2, 1, 0.5, and 0.2 percent correspond to recurrence intervals of 2, 5, 10, 25, 50, 100, 200, and 500 years, respectively. Rainfall intensities are typically given in terms of recurrence intervals and thus will be referenced by recurrence interval in this report.

The Bulletin 17C methodology (England and others, 2018) prescribes the use of the log-Pearson type III distribution of the peak-flow data as the basic distribution for defining the annual peak flow series, consistent with the previous guidelines (Interagency Advisory Committee on Water Data, 1982). The log-Pearson type III distribution requires estimates of three moments; the mean, the standard deviation, and the skew coefficient of the population of logarithms of annual instantaneous peak flows at each streamgage.

The mean, the standard deviation, and the skew coefficient can be estimated from the available sample data (annual peak flows); however, a skew coefficient calculated from a small sample tends to be an unreliable estimator of the population skew coefficient. Accordingly, the guidelines in Bulletin 17C indicate that the skew coefficient calculated from at-station sample data (station skew) needs to be weighted with a regional skew determined from an analysis of selected long-term streamgages in the study region. A new regional skew was computed for Maine as a part of this study.

The guidelines for flood-frequency analyses have undergone several updates since they were first published in 1967. Recent updates (England and others, 2018) include the adoption of a generalized representation of flood data that allows for interval and censored data types; a new method, called the expected moments algorithm (EMA), which extends the method of moments so that it can accommodate interval data; a generalized approach to the identification of low outliers in flood data using the multiple Grubbs-Beck test (MGBT; Grubbs and Beck, 1972; Cohn and others, 2013); and an improved method for deriving regional skew coefficients and computing confidence intervals.

Purpose and Scope

This report provides estimates of peak flows at AEPs of 50, 20, 10, 4, 2, 1, 0.5, and 0.2 percent (recurrence intervals of 2, 5, 10, 25, 50, 100, 200, and 500 years, respectively) for streamgages in and adjacent to Maine and describes methods, including the use of equations developed from regression analyses, for estimating peak flows at selected AEPs on ungaged Maine streams without substantial regulation or urbanization. In addition, this report presents a method for estimating the standard error of prediction for each estimate made with the regression equations and describes methods for transferring a flood-streamflow estimate for a selected AEP at a streamgage to a site upstream or downstream based on the change in drainage area.

Description of Study Area

The State of Maine (fig. 1), in the northeastern United States, has a land area of 30,843 square miles (mi^2); with a population of 1.34 million people (U.S. Census Bureau, 2018). Maine is largely rural and forested with rolling topography of moderate to low relief throughout the State except for the high relief of the Appalachian Mountain Range in west-central Maine. Land elevation ranges from sea level at the Atlantic coast (Gulf of Maine) to 5,267 feet (ft; 1,606 meters [m]) at the peak of Mount Katahdin (U.S. Geological Survey, 2001). The physiographic characteristics of west-central Maine extend into northernmost New Hampshire. The study basins are mostly forested, with deciduous or evergreen growth. Open water covers as much as 19 percent of the basin areas and wetlands of all types compose from 0 to 29 percent of the study basin areas.

Maine has a temperate climate with mild summers and cold winters. Climatological averages computed for the 30-year period from 1981 to 2010 indicate a mean annual air temperature for Maine of 42.5 degrees Fahrenheit (°F; 5.8 degrees Celsius [°C]). Mean annual air temperature ranged from 37.3 °F (2.9 °C) at Allagash to 47.8 °F (8.8 °C) at Sanford (National Climatic Data Center, 2015). Maine has a mean annual precipitation of 45.4 inches (in.) for the 30-year period from 1981 to 2010 (National Climatic Data Center, 2015).

Annual peak flows in Maine typically occur during spring and fall. Frontal systems, thunderstorms, tropical storms, coastal storms, nor’easters (most frequent and strongest from September through April), snowmelt, and wet antecedent soil moisture conditions can all contribute to annual floods in the Northeast. In spring, snowmelt, rain on snow, or saturated or frozen soils are a primary cause of flooding in Maine. Although fall floods in Maine can be caused by hurricane or tropical-storm related precipitation, hurricane related flooding is more prevalent in the southern New England States (National Oceanic and Atmospheric Administration, 2013). Severe flooding over a small area may occur at any time as the result of an intense rainfall event (for example, a thunderstorm) or an obstruction in the flow of a stream or river such as woody debris or sediment blocking a culvert.

Major floods on Maine rivers occurred in April 1923, March 1936, and May 1953 (all resulting from extreme precipitation on top of heavy snowpacks; Maloney and Bartlett, 1991); April 1987 (snowmelt, combined with rain from two slow moving low pressure systems; Fontaine and Nielsen, 1994); October 1996 (rain from a coastal low pressure system combined with moisture from Hurricane Lili; Hodgkins and Stewart, 1997); May 2006 (15 in. of rain from a stalled low pressure system in southern Maine; Stewart and Kempf, 2008); April 2007 (rain on snow in southern Maine; Lombard, 2009); and spring 2008 (rain on snow in northern Maine; Lombard, 2010). A summary of historical flooding in major drainage basins in Maine from 1970 to 2007 was documented by ENSR Corporation (2007).

Previous Studies

Peak-flow equations were developed for Maine in 1975 (Morrill, 1975) and updated in 1999 (Hodgkins, 1999) using regional regression techniques. The 1975 equations were based on drainage area, main-channel slope, and the area of lakes and ponds in the basin to estimate the 2- to 100-year peak-flow recurrence intervals. Data for the equations were based on peak-flow records at 60 streamgages throughout Maine. Estimates of the error of the equations were not reported (Morrill, 1975). The updated 1999 equations were based on drainage area and the percentage of wetlands to

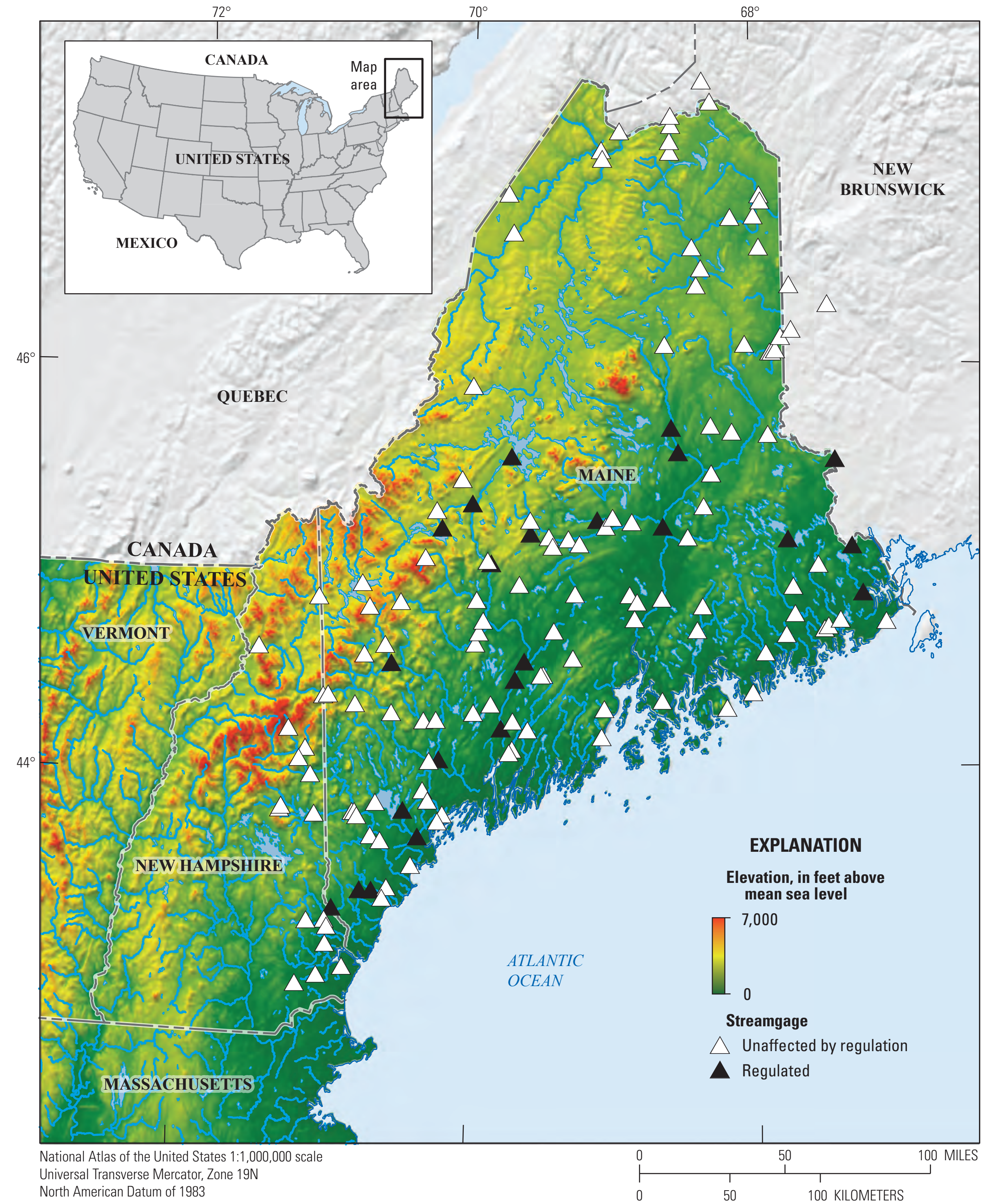

Figure 1. Locations of U.S. Geological Survey and Environment and Climate Change Canada streamgages and basins in Maine, New Hampshire, and Canada used in this study.

predict 2- to 500-year peak-flow recurrence intervals. Data for these equations were from 98 streamgages and estimates of error were provided (Hodgkins, 1999). Equations for estimating peak flows at small basins (0.3 to 12 mi^2) in Maine were published in 2015 (Lombard and Hodgkins, 2015). A regional skew of 0.029 with a mean square error (MSE) of prediction of 0.088 was calculated for Maine in 1999 (Hodgkins, 1999) using a weighted mean at each of the 44 streamgages analyzed, with the weight being the number of years of record at the streamgage. Peak flow estimates, equations, and regional skew values calculated for Maine in previous studies are superseded by this report.

Data Compilation

Annual peak-flow data were compiled to compute the magnitude and frequency of peak flows for 148 streamgages in Maine (127), and within 20 miles of the Maine border in New Hampshire (16) and New Brunswick, Canada (5; 4 of which are operated by Environment and Climate Change Canada, and 1 of which is operated by USGS; fig. 1). Streamgages used in the analyses are currently operating (2019) or were discontinued but have a minimum of 10 years of record.

Basin characteristics listed in appendix table 1.1 were compiled at 124 of the 148 streamgages because they drain rural, unregulated basins (basins without substantial storage from dams), and thus were used to derive regional regression equations for estimating peak-flow statistics at ungaged sites (fig. 1). Streamgages used to compute the regression equations include 103 streamgages in Maine, 16 in New Hampshire, and 5 in New Brunswick, Canada.

The remaining 24 Maine streamgages drain regulated basins. If a streamgage basin had more than 4.5 million cubic feet of usable storage per square mile of drainage area, it was considered regulated (Benson, 1962). Data from these regulated streamgages were used to estimate the magnitude and frequency of flood flows for these AEPs. These AEPs can be used to estimate peak flows at nearby ungaged sites on the same river as the regulated streamgage, but they were not used in the development of the regional regression equations for estimating AEPs at natural ungaged sites.

Peak-Flow Data

Annual instantaneous peak-flow data were downloaded from the USGS National Water Information System database (fig. 1; U.S. Geological Survey, 2019a) and from the Environment and Climate Change Canada database (Environment and Climate Change Canada, 2018). Data include peak flows from current and discontinued, continuous-record streamgages and from current and discontinued crest-stage gages (streamgages that record only the peak-flow information). Data through water year 2018 were used at all streamgages where available. Analyses included data through water year 2019 at a small number of streamgages (Kiah and others, 2019). The water year is designated by the calendar year in which it ends. It begins October 1 of the previous calendar year and ends September 30. Peaks were not used if they were known to be affected by dam breaks or were daily mean peaks rather than instantaneous peaks.

Physical and Climatic Basin Characteristics

For the streamgages included in this investigation, more than 80 basin characteristics were selected and tested as potential explanatory variables in the regression analyses based on their potential relations to peak flows and the ability to measure the basin characteristics using digital datasets and a geographic information system (GIS; appendix table 1.1) Data generated during this study are available as a USGS data release (Lombard, 2020). The ability to measure the basin characteristics using GIS is important to facilitate automation of the process for measuring the basin characteristics and solving the regression equations in StreamStats (U.S. Geological Survey, 2020). The name, units of measure, method of measurement, and source data for each basin characteristic are listed in appendix table 1.1. These variables can be broadly grouped into topography, climate, hydrology, geology, soils, and land-use type categories. The study basins used in the development of the regression equations range in size from 0.26 to 5,680 mi^2 (table 1), with mean basin elevations ranging from 73 ft (22 m) at the coast in southern Maine to 3,350 ft (1,020 m) in mountainous northern New Hampshire. The range of values for the explanatory variables used in the final regression equations can be found in table 1.

Trend Analyses of Peak Flows

Current methods for completing flood-frequency analyses in Bulletin 17C (England and others, 2018) assume stationarity (the assumption that the statistical distribution of data from past observations will continue unchanged in the future). This assumption allows researchers to estimate the flood magnitude and frequency from past records and apply them to the future without adjustments. Because of the effects of climate change and changing land use on peak flows, the assumption of peak-flow stationarity has recently been questioned (Milly and others, 2008; Hirsch, 2011). Bulletin 17C, however, specifically states that the flood-frequency methods presented as a part of that work do not apply to watersheds where flood flows are appreciably altered by reservoir regulation, basin changes, hydrologic nonstationarities, climate variability, or climate change (England and others, 2018).

Trends in peak flows in New England documented in the literature are complex. Hodgkins and Dudley (2005) documented increases in annual peak flows at 22 out of 27 sites in New England that had an average of 71 years of record through 2002, with 8 of those increases being statistically

Table 1. Range of explanatory variables used in the development of the regression equations for estimating peak flows at selected annual exceedance probabilities for ungaged, unregulated streams in Maine.

[All streamgages are shown in figure 1. RI, recurrence interval]

Explanatory variable	Minimum	Maximum	Mean
Drainage area, in square miles	0.26	5,680	249
Percentage of basin covered by wetlands	0	29.4	10.6
24-hour rainfall with 2-year RI (inches)	1.92	4.17	2.89
24-hour rainfall with 5-year RI (inches)	2.48	5.38	3.62
24-hour rainfall with 10-year RI (inches)	2.84	6.38	4.22
24-hour rainfall with 25-year RI (inches)	3.30	7.75	5.04
24-hour rainfall with 50-year RI (inches)	3.65	8.79	5.66
24-hour rainfall with 100-year RI (inches)	3.99	9.88	6.31
24-hour rainfall with 200-year RI (inches)	5.26	11.1	7.09
24-hour rainfall with 500-year RI (inches)	5.95	13.1	8.21

significant (probability less than $p<0.1$). Collins (2009) determined that 25 out of 28 streamgages in New England with an average of 75 years of record through 2006 had increasing peak flows, 10 of which were statistically significant ($p<0.1$). Collins also determined a step-change increase around 1970.

Hodgkins (2010) determined that annual peak flows have increased at 22 out of 28 streamgages in Maine during the last century. The median change in annual peak flows for the 20 unregulated streamgages in the study was an increase of 18.4 percent based on a linear change and an increase of 15.0 percent based on a step change in 1970. Hodgkins also compared 30-year subperiods with the full period of record (50 years or more) at 28 long-term streamgages in Maine and determined that increases in the 5- and 100-year flows based on recent years of record are modest when compared to peak flows based on complete periods of record and are well within the variability of the estimates. Furthermore, increases during the 1967–96 subperiod were greater than the most recent subperiod of 1977–2006. Hodgkins (2010) concluded that flood-frequency analyses are sensitive to very high peak flows that may occur once every century or less, and thus, it can be problematic to use only more recent periods of record such as the last 30 years of data, especially when that period does not include the peak of record. The peak of record occurred more than 30 years ago in more than one-half of the sites in Maine. Analyzing only the most recent period of record at these sites to account for any observed trends that may be due to climate change would mean that the peak of record is not included in the analyses of these sites, biasing the long-term estimates low. In a more recent study, peak flows at minimally altered basins in Maine increased by an average of 29 percent from 1941 to 2015 and 19 percent from 1966 to 2015 (Dudley and others, 2018; Hodgkins and others, 2019).

In another study, potential future peak flows with 50- and 1-percent AEPs were modeled using the Precipitation-Runoff Modeling System (Hodgkins and Dudley, 2013). For likely changes projected for the northeastern United States for the middle of the 21st century (temperature increase of 3.6 °F and precipitation increases of 0 to 15 percent), peak-flow changes at the four coastal Maine basins in this study are modeled to be evenly distributed between increases and decreases of less than 25 percent. Decreases in winter snowpack modeled to occur with increasing air temperatures offset increased flows because of increased precipitation (Hodgkins and Dudley, 2013). Demaria and others (2016) project decreased 3-day 1-percent AEP peak flows in Maine by the middle of the current century.

Hodgkins and others (2017) analyzed the occurrence of major floods (25- to 100-year recurrence interval floods) at 645 stations across North America. This analysis required that streamgage data be grouped within large regions. There were no significant long-term trends in major-flood occurrence across North America from 1951 to 2010 but there were some significant relations between major floods and the Atlantic Multidecadal Oscillation.

Stationarity is still a primary assumption in Bulletin 17C (England and others, 2018). The guidelines recommend incorporating the effect of climate variability or change in flood risk if sufficient scientific evidence supports the attribution and quantification of any increased flood risk (Hirsch, 2011; England and others, 2018).

Methods for Trend Analyses

Unregulated streamgages in Maine with at least 30 years of record, which are typically considered long-term streamgages, were examined for the existence of trends. Four periods were analyzed for trends in peak flows at streamgages: 30, 50, 70, and 90 years, using data through 2016. All 10-year blocks for each period were required to be at least 80-percent complete so that no part of the time series of annual instantaneous peak flows would have substantial missing data. These length and completeness criteria resulted in 23 streamgages for the 30-year period, 20 for the 50-year period, 16 for the 70-year period, and 5 for the 90-year period.

The magnitudes of trends for annual instantaneous peak flows were computed with the Sen's slope (also known as the Kendall-Theil robust line), which is the median of all possible pairwise slopes in each time series (Helsel and Hirsch, 2002). The significance of trends over time is very sensitive to assumptions of whether underlying hydroclimatic data are independent, have short-term persistence (STP) or have long-term persistence (LTP) (Cohn and Lins, 2005; Koutsoyiannis and Montanari, 2007; Hamed, 2008; Khaliq and others, 2009; Kumar and others, 2009; Hodgkins and Dudley, 2011). Persistence refers to serial correlation or year-to-year dependence in time-series data. In STP, the correlation over time decays exponentially or faster as more years are included. For LTP, however, the decay is slower (Koutsoyiannis and Montanari, 2007). The existence of persistence results in a violation of the assumption of independent data and an overestimation of the significance of trends (Cohn and Lins, 2005). Although the presence of LTP in hydroclimatic data series is difficult to prove without very long records (generally greater than 100 years) (Vogel and others, 1998; Khaliq and others, 2009) the significance of trends was computed using methods that consider the possibility of STP and LTP.

Because the long-term time-series structure of peak-flow data is not well understood, we report temporal trend significance with three null hypotheses of the serial structure of the data: independence, STP, and LTP (Hamed and Rao, 1998; Hamed, 2008). Trends were considered statistically significant at the *p*-value of less than or equal to 0.05.

Trend Results

Peak-flow trend results depend on the period of record considered and assumptions about the serial correlation structure of the annual peak flows. For the 30-year period (1987–2016), 19.0 percent of streamgages (15/79) have significant positive trends if independence of annual peak flows is assumed. If STP is assumed, 10.1 percent of streamgages (8/79) have significant positive trends, and if LTP is assumed, no streamgages have significant trends. There are no significant negative trends for any assumption of the serial correlation structure.

For the 50-year period (1967–2016), there are many fewer significant trends than for 30-year trends; 6.2 percent of streamgages (4/64) have significant positive trends if independence of annual peak flows is assumed. If STP is assumed, 1.6 percent (1/64) of streamgages have significant positive trends, and none have significant trends if LTP is assumed. As with 30-year trends, there were no significant negative trends.

There was a high percentage of significant positive trends for the 70-year period (1947–2016) with the assumption of independence; 47.7 percent of streamgages were significant (21/44). If STP is assumed, this percentage decreased to 36.4 percent (16/44), and if LTP is assumed, this percentage decreased to 9.1 percent (4/44). For the few streamgages with adequate data over 90 years (1927–2016), 33.3 percent (3/9) had significant increases if independence or STP is assumed and 11.1 percent (1/9) had significant increases if LTP is assumed. No streamgages had significant decreases for the 70- or 90-year period.

In summary, these analyses show some evidence of increasing peak flows over time and no evidence for decreasing annual peak flows. The difference in the percentage of significant positive trends based on the period analyzed indicates that multidecadal oscillations may be present and influencing trends in the magnitude of peak flows. For example, many of the streamgages with significant increasing peak-flow trends for the 70-year period (1946–2015) had many low-magnitude peaks before 1965 or 1970; there are many fewer significant trends for the 50-year period (1966–2015).

Stationarity in flood-frequency analyses should be the default assumption, unless one can justify the nonstationarity assumption (Matalas, 2012; Serinaldi and Kilsby, 2015; Salas and others, 2018; Ryberg and others, 2020). This includes understanding the physical processes causing trends. This trend analysis indicates that peak-flow trends can depend on the period analyzed and can vary substantially from site to site, making it difficult to attribute Maine regional trends to a known cause that is expected to continue into the future. Observed significant historical trends may be affected by multidecadal oscillations, making it uncertain if trends will continue. Because of the lack of strong and consistent statistical evidence of significant long-term regional peak-flow trends throughout Maine, the traditional assumption of stationarity is used here with no adjustment for trends.

Flood Magnitude and Frequency at Streamgages

Flood-frequency estimates for streamgages are computed by fitting the series of annual peak flows to a known statistical distribution. Flood-frequency estimates for the current study were computed by fitting base 10 logarithms ($\log_{10}$) of the annual peak flows to a log-Pearson type III frequency distribution (England and others, 2018). Fitting the distribution to a series of annual peak flows requires calculating three statistical moments; the mean, standard deviation, and skew coefficient of the logarithms of the annual peak flows.

The USGS computer program PeakFQ version 7.3 (Flynn and others, 2006) was used to fit the distribution and derive the 50, 20, 10, 4, 2, 1, 0.5, and 0.2-percent AEP flows (recurrence intervals of 2, 5, 10, 25, 50, 100, 200, and 500 years, respectively) for gaged sites. PeakFQ implements Bulletin 17C procedures for flood-frequency analysis of streamflow records including the EMA and MGBT techniques for flood-frequency determinations (Flynn and others, 2006; England and others, 2018). The output from PeakFQ includes estimates of the parameters of the log-Pearson type III distribution, including the logarithmic mean, standard deviation, skew, and MSE of the skew. The output graph includes the fitted frequency curve, systematic peaks, low outliers, censored peaks, interval peaks, historical peaks, thresholds, and confidence intervals.

Peak-flow records of streamgages contain two types of data: (1) systematic, with a peak-flow value recorded for each year, and (2) historical, or isolated measurements made outside the systematic period of record (typically during extreme hydrologic conditions). Systematic and historical peaks are occasionally identified as “censored,” which means that the actual peak flow is uncertain, and the peak is documented as greater than or less than a given value. The EMA can make better use of censored peaks than did previous methods. In addition, the knowledge that a flow would have been noticed and measured if it had occurred (the perception threshold) provides valuable information for the peak-flow frequency analysis. The EMA method allows the use of flow intervals and perception thresholds to describe conditions outside the systematic record. Flow intervals describe the uncertainty associated with a peak flow by defining the peak flow as somewhere within a range of flows rather than as a known value. The definition of the perception thresholds is based on historical documentation and anecdotal information. General perception threshold and flow interval settings for the EMA analysis follow England and others (2018) and are described in table 2. Perception thresholds and periods of record for annual peak-flow records used in this analysis are provided in appendix table 1.2 and in Lombard (2020).

PeakFQ uses the MGBT for fitting frequency curves and identifying potentially influential low floods, also referred to as low outliers. Low outliers can have high leverage or influence in fitting the frequency curve to the record of peak flows, which results in a poor fit of the frequency curve at lower AEPs (larger floods). The peak-flow statistics most frequently used for flood protection and infrastructure design are the streamflows with low AEPs (1, 0.5, and 0.2 percent). Additionally, low outliers often are considered to reflect physical processes that are not necessarily related to the processes associated with large flood events, and their use in the frequency analysis should be limited (Cohn and others, 2013).

Several peak-flow records analyzed contained outliers less than a potentially influential low-flood threshold. Although the low-outlier threshold is typically determined by PeakFQ, it can also be set manually based on visual inspection of the peak-flow distribution. For this study, all fitted frequency curves were visually examined in addition to automated screening; this resulted in some deviation from the automated thresholds as determined by PeakFQ. Specifically, the low-outlier threshold values set by PeakFQ resulted in exclusion of 12 and 45 of the observations as low outliers at USGS sites 01017000 (Arostook River at Washburn, Maine) and 01055000 (Swift River near Roxbury, Maine), respectively. Thus, the low-outlier threshold values were manually lowered to 10,000 and 2,500 cubic feet per second, respectively, for these sites to include additional observations and better reflect the distribution of the peaks. For all other sites, the low-outlier thresholds determined by PeakFQ and MGBT were deemed appropriate.

Regional Skew

The skew coefficient is one of the three moments of the log-Pearson type III distribution and measures the asymmetry of the distribution of annual peak flows. The skew coefficient is zero when the mean of the annual series equals the median (the 50th percentile value in a sample) and the mode (the most common value in a sample); the skew coefficient is positive when the mode and median are less than the mean and negative when the median and mode exceed the mean. The skew coefficient is strongly affected by the presence of outliers. Large positive skews typically are the result of high outliers, and large negative skews typically are the result of low outliers.

The station skew coefficient, calculated using the annual peak-flow record for a streamgage, is sensitive to extreme events that may occur infrequently; therefore, Bulletin 17C

Table 2. General perception threshold and flow interval settings applied to various scenarios in the expected moments algorithm analysis to estimate peak-flow statistics at streamgages in and near Maine.

Annual scenario or peak-flow type	Perception thresholds		Flow intervals	
	Minimum	Maximum	Minimum	Maximum
Systematic record peak, known with confidence	0	Infinity	Peak	Peak
Systematic record peak, peak greater than stated value	0	Peak	Peak	Infinity
Historical peak[1]	Historical peak	Infinity	Historical peak	Historical peak
Crest-stage gage peak within measurable range	Lowest flow measurable by gage	Infinity	Peak	Peak
Crest-stage gage peak less than measurable range, peak less than stated value	Lowest flow measurable by gage	Infinity	0	Crest-stage gage base
Gaps in systematic record, no other available information	Infinity	Infinity	0	Infinity
Gaps in systematic record, additional information available from historical peak(s)[2]	Historical peak	Infinity	0	Historical peak

[1]For streamgages with multiple historical peaks, the lowest historical peak generally was used to define the perception thresholds.

[2]The selection and application of perception thresholds and flow intervals for gaps in systematic record were subjective and site dependent. See appendix table 1.2 for site-specific information.

(England and others, 2018) recommends weighting the station skew with a regional skew coefficient to better represent long-term conditions at each station. The regional skew coefficient is calculated using station skew coefficients for stations with longer annual peak-flow record within the region (stations with at least 30 years of record). The weighted skew coefficient for a given station is then computed as the weighted average of the regional skew coefficient and the station skew coefficient; weights are assigned according to the MSE of the regional skew coefficient and the MSE of each station skew value. Flood-frequency estimates for all stations with unregulated flow records were computed using this weighted skew method.

The national method for computing regional skew was updated in 2018 (Bulletin 17C, England and others, 2018). The Bulletin 17C guidelines recommend using a Bayesian weighted least-squares/Bayesian generalized least-squares (B–WLS/B–GLS) regression to compute a regional skew (Veilleux, 2011; Veilleux and others, 2011; England and others, 2018). The B–WLS/B–GLS method accounts for the precision of the skewness estimator for each station depending on record length, accounts for the spatial cross correlation among stations, and provides a reasonable description of the model-error variance (the error resulting from an imperfect model) when it is small compared to the sampling-error variance (the error that results from only using a sample of the entire population). This technique is particularly appropriate for flood-flow frequency studies computed using EMA (England and others, 2018).

The B–WLS/B–GLS methods recommended by Bulletin 17C (England and others, 2018) are used here for calculating effective (pseudo) record length (P_{RL}), unbiasing at-station skew and MSE estimates, and developing cross-correlation models. First, an ordinary least-squares (OLS) regression is used to develop an initial regional skewness model that is used to generate an initial stable regional skewness coefficient estimate for each site. That stable regional estimate is the basis for computing the variance of each at-station skewness coefficient estimator used in the Weighted Least-Squares (WLS) regression. Next, a B–WLS regression is used to generate estimators of the regional skewness coefficient model parameters. Finally, B–GLS is used to estimate the precision of those B–WLS parameter estimators, to estimate the model-error variance and the precision of that variance estimator, and to compute various diagnostic statistics (England and others, 2018). Multiple regional skew studies documenting this methodology have been published for areas throughout the United States; for example, in the southeastern United States (Feaster and others, 2009; Gotvald and others, 2009; Weaver and others, 2009), California (Parrett and others, 2011; Gotvald and others, 2012), Iowa (Eash and others, 2013), Arizona (Paretti and others, 2014), Missouri (Southard and Veilleux, 2014), Vermont (Olson, 2014), and New England (Veilleux and others, 2019). These studies can be accessed at U.S. Geological Survey (2019b).

Bulletin 17C advises the use of large multistate regional skew studies to determine regional skew values to be weighted with at-station skew values (England and others, 2018). Initial investigation of at-station skews throughout New England, however, determined that peak-flow distributions, and thus unbiased station skew values in Maine, deviate from the pattern of at-station skew values for the wider New England region (Veilleux and others, 2019). This is likely due to differing hydrologic drivers; storms in Maine are less likely to be caused by hurricanes than they are elsewhere in New England. Further, the greater snowpack in Maine, especially in northern and mountainous areas of the State, likely contributes to the distribution of peaks in Maine differing from the rest of New England. To accurately capture these hydrologic patterns specific to Maine, a regional skew was calculated for Maine that includes streamgages in or within 20 miles of Maine.

Calculation of Maine Regional Skew Coefficient

Site Selection

A total of 51 unregulated USGS streamgages in Maine or adjacent States were selected for the calculation of the Maine regional skew after removing sites with insufficient record length or redundancy. Sites were removed if they did not have at least 20 years of record through water year 2017. Of the sites, 20 percent have record lengths between 20 and 30 years, with the remainder having record lengths greater than 30 years. If sites were nested (the drainage area of one streamgage is contained within the drainage area of another streamgage), and the ratio of the drainage area of the larger basin divided by the drainage area of the smaller basin was less than or equal to 5, the sites were considered potentially redundant, and the site with the shorter period of record was removed (Eash and others, 2013). The 51 sites used in this analysis includes 38 sites in Maine, 8 sites in New Hampshire, and 5 sites in Canada (appendix table 1.3; Lombard, 2020).

Calculation of Pseudorecord Lengths and At-Station Skews

Historical periods (periods during which data about occurrence or nonoccurrence of large floods were collected before establishing systematic protocols) at many of the sites provide valuable information about peak-flow distributions that can be incorporated using the EMA; however, it is less information than would be provided by an equivalent number of systematic peaks. P_{RL} values were calculated for each site in this study to take systematic record and historical periods into account and weight them appropriately (appendix table 1.3; Lombard, 2020). The P_{RL} is used for unbiasing the station skew and is used in the cross-correlation model. If a site does not have any historical period, the P_{RL} is equivalent to the systematic record. Calculations used to compute the P_{RL} are described in Eash and others (2013).

At-station skews and their MSEs were initially determined for each site in the skew analysis by use of PeakFQ (appendix table 1.3; Veilleux and others, 2014; Lombard, 2020), the USGS program for implementing flood-frequency analyses as outlined in Bulletin 17C. In contrast to peak-flow estimation methods wherein the upper end of the distribution is of primary importance, the flow distribution is important for skew estimation; low-outlier thresholds that result in frequency curves that best fit the flow distributions are desirable.

Bias was removed from the initial skewness values using P_{RL} values and correction factors developed by Tasker and Stedinger (1986) and used in Reis and others (2005). Unbiased at-station skew values and their MSEs are presented in appendix table 1.3 (Lombard, 2020) for each streamgage in this analysis.

Cross-Correlation Model

A cross-correlation model for the annual peaks in Maine was developed using annual peak flows from 13 sites with at least 80 years of concurrent peaks, resulting in 72 streamgage pairs of concurrent peaks. A logit model, termed the Fisher Z transformation (Z), provided a convenient transformation of the sample correlations, $r_{ij,}$ from the (–1, +1) range to the (–∞, +∞) range:

$$Z = \log\left(\frac{1+r}{1-r}\right). \tag{1}$$

Various models relating the cross correlation for streamgages i and j, p_{ij}, to various basin characteristics were considered. The model that was adopted uses only one explanatory variable for estimating p_{ij} and is based on the distance between the basin centroids, D_{ij}, as the only explanatory variable (Veilleux and others, 2019):

$$\rho_{ij} = \frac{\exp(2Z_{ij})-1}{\exp(2Z_{ij})+1}, \tag{2}$$

where

Z_{ij} is equal to exp (0.2021−0.0067*D_{ij}).

The cross-correlation model was used to estimate streamgage-to-streamgage cross correlations for concurrent annual peak flows at all streamgage pairs used in this study.

Maine Regional Skew Results

Many basin characteristics including drainage area, basin perimeter, mean basin elevation, mean basin slope, channel length, stream density, mean annual precipitation, and percentage of basin wetlands were tested as potential explanatory variables in the regional skew equation. None of these basin characteristics were significant in explaining site-to-site variability in skewness, and thus, a constant model that does not vary with site characteristics was selected to predict regional skew for Maine.

A constant regional skew coefficient of 0.020 was calculated for Maine and replaces the previous skew value of 0.029 published in Hodgkins (1999). This new regional skew coefficient has a model-error variance of 0.08, an average variance of prediction at a new site (AVP_{new}) of 0.09. The AVP_{new} is equivalent to the MSE used in Bulletin 17B (Interagency Advisory Committee on Water Data, 1982) to describe the precision of the regional skewness. The standard error of prediction (square root of the AVP_{new}) for the new regional skew is 0.30. The estimated fraction of the variability in the true skewness from site to site explained by the model is typically described by the *Pseudo* $R(2/\delta)$, in percent, (Gruber and others, 2007; Parrett and others, 2011). A constant model does not explain any variability, so the *Pseudo* $R(2/\delta)$ equals 0.

Bayesian Regression Diagnostics for the Maine Regional Skew

The error variance ratio (EVR) is a modeling diagnostic used to evaluate whether a simple OLS regression is sufficient or a more sophisticated Weighted Least-Squares (WLS) or Generalized Least-Squares (GLS) regression is appropriate. EVR is the ratio of the average sampling-error variance to the model-error variance. Generally, an EVR greater than 0.20 indicates that the sampling-error variance is not negligible when compared to the model-error variance, indicating the need for a WLS or GLS regression analysis. The EVR had a value of 2.3 for the constant model, indicating that the sampling error was large compared to the model error. An OLS model that neglects sampling error in the streamgage skewness estimators may not provide a statistically reliable analysis of the data. Given the variation of record lengths from site to site, it was important to use a WLS or GLS analysis to evaluate the final precision of the model rather than using a simpler OLS analysis.

The misrepresentation of the beta variance (MBV^*) statistic was used to determine whether a WLS regression was sufficient or if a GLS regression would be more appropriate to determine the precision of the estimated regression parameters (Griffis, 2006; Veilleux, 2011). For the Maine regional skew study, the MBV^* was equal to 4.3 for the constant model. This is a large value, indicating the cross correlation among the skewness estimators influenced the precision with which the regional average skew coefficient could be estimated, and thus, a WLS analysis would misrepresent the variance of the constant in the model. Moreover, a WLS model would result in underestimation of the variance of prediction, given that the sampling error in the constant term in both models was sufficiently large to make an appreciable contribution to the average variance of prediction. These metrics confirm that the more robust B–WLS/B–GLS regression approach as outlined in Bulletin 17C is the best method to use for this study.

Leverage and Influence

Leverage indicates observations that have a large effect on the fit of the regression. Influence indicates observations with large residuals. Influential observations that also have high leverage have the greatest impact on the resultant model. High influence is defined as Cook's D values that are greater than the threshold of 0.078 computed as $4p/n$, where p is 1 for the constant model, and n is the sample size of 51. High leverage is defined as leverage values that are greater than the threshold of 0.039 computed as $2p/n$. No sites in the regression analysis had high leverage; the range of leverage values reflect the variation in record length among sites. The most influential streamgage was USGS site 01055000 (Swift River near Roxbury, Maine), with a Cook's D of 1.63, but it did not have high leverage or a high residual (at-station residual rank of 50). Environment and Climate Change Canada site 01AF009, Iroquois River at Moulin Morneault, Canada, had the largest skew, the largest MSE, and the largest residual (at-station residual rank of 1) and was 1 of the 16 sites with high influence, but it did not have high leverage. Indicators such as leverage and influence are useful for flagging outlier sites such as 01055000 that behave differently than other sites. A site being an outlier, however, is not sufficient justification for removing it from analyses or model development if there is not a physical reason (such as regulation) to remove it. The inclusion of outlier sites in the model results in a more realistic estimate of error for sites not used in the development of the model.

Estimates of Flood Magnitude and Frequency at Streamgages

The magnitude of peak flows for selected AEPs for streamgages used in this study are listed in appendix table 1.4 (Lombard, 2020). At-station EMA estimates are given in appendix table 1.4 for regulated and unregulated streamgages; however, regression and weighted estimates are only provided for the unregulated stations. The streamflows reported in appendix table 1.4 supersede streamflows reported in Hodgkins (1999) because of 20 additional years of data and updated techniques.

Unregulated Streamgages

Three estimates of peak flows are given at unregulated streamgages (appendix table 1.4). They include the at-station estimate (EMA), the regression-equation estimate (regression), and a weighted average of the other two estimates (weighted). The weighted average is the most accurate estimate, where available, because the average of the two independent estimates is expected to be more accurate than either of the independent estimates. It weights the regression equations more heavily at streamgages that have shorter records and less heavily at streamgages that have longer records.

Regulated Streamgages

Reservoir storage and operations have the potential to substantially affect streamflow characteristics. The sample of annual peak flows for a streamgage is assumed to be representative of future peak flows; therefore, use of all peak flows from a streamgage is not always appropriate. There are several regulated streamgages in Maine where substantial regulation was added (sometimes in addition to substantial regulation already in place) during the period for which annual peak flows are available. The older, less regulated annual peak flows were not used in the flow-frequency analyses if the drainage-basin regulation at the time of the older peaks differed from the regulation at the time of the newer peaks. In addition, older peaks were not used if the annual peak-flow data at a streamgage indicated that the regulation of peak flows had changed substantially over time.

At-station estimates at regulated stations are computed using at-station skew values only. Regional skew values do not necessarily apply to regulated stations and are not incorporated into the flow-frequency analyses at these streamgages. Regression equations are not applicable to regulated streamgages, and no regression or weighted estimates are given in appendix table 1.4.

Maximum Recorded Floods

The maximum recorded annual peak flows (appendix table 1.5) plotted in relation to drainage area for each streamgage in this study are shown in figure 2. Annual peak flows affected by dam failure, ice jam breach, or a similar event are not included. A New England regional envelope curve developed by Crippen and Bue (1977) is also shown in figure 2 along with a line developed using a regional least-squares regression analysis indicating the relation between drainage area and the peak flow with a 1-percent AEP. As shown in figure 2, the maximum recorded annual peak flows at streamgages used in this investigation are all below the regional envelope curve. This figure can be used to evaluate the reasonableness of flood estimates made by using techniques described in this report.

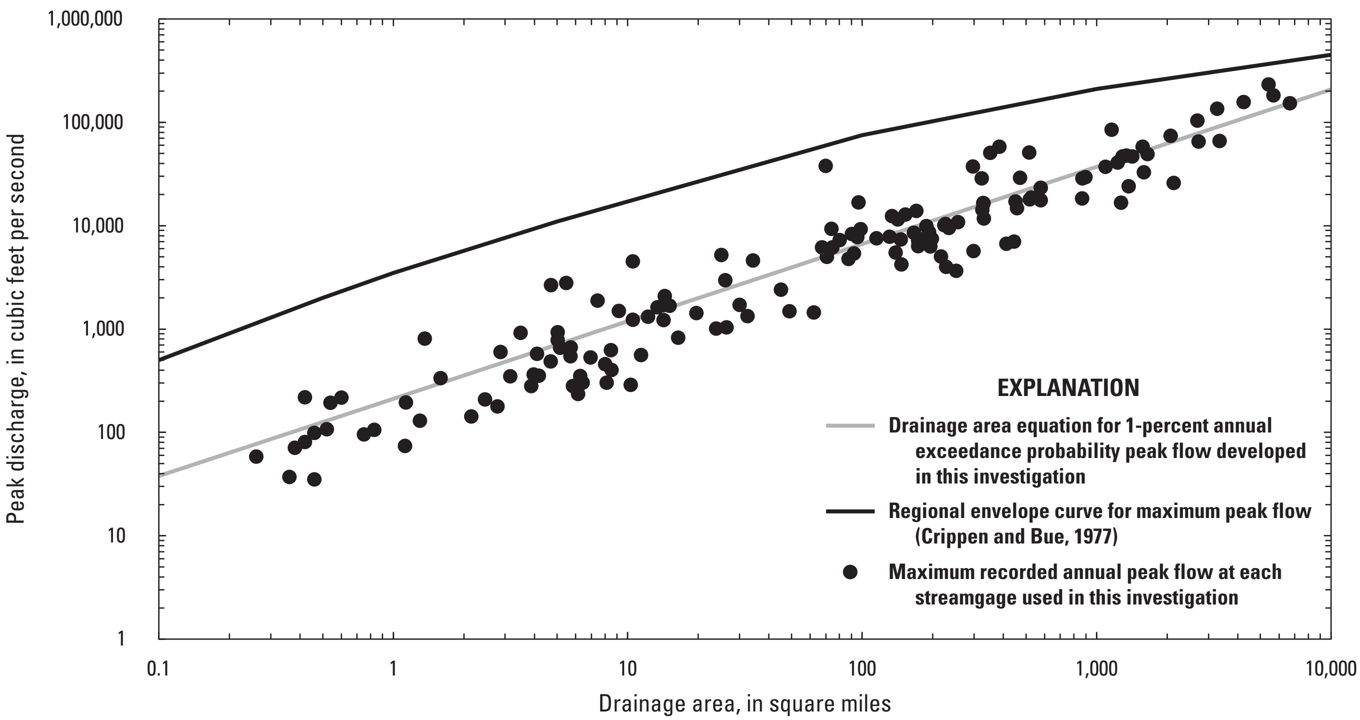

Figure 2. Maximum recorded annual peak flows at streamgages in and near Maine in relation to drainage area, and a regional envelope line and a regression line relating the 100-year peak flow to drainage area.

Flood Magnitude and Frequency at Ungaged Sites

Regression equations are developed here to estimate peak flow at ungaged locations (the response variable) using measured basin characteristics (explanatory variables) calculated by a GIS at these same stations. This regionalization of the peak-flow statistics using multiple linear regression follows standard USGS methods outlined in Farmer and others (2019). Explanatory variables should make hydrologic sense, explain a substantial amount of the variability of the response variable, have a linear relation with the response variable, and be easy for the user to calculate.

The general form of the regression equations developed from multiple-linear regression analysis is provided in the following equation:

$$Y_P = b_0 + b_1X_1 + b_2X_2 + \ldots + b_nX_n + e_i, \tag{3}$$

where

Y_p is the magnitude of the peak flow having an AEP of P percent,

b_0 to b_n are the coefficients developed from the regression analysis,

X_1 to X_n are the n explanatory variables (basin characteristics), and

e_i is the residual error (difference between the observed and predicted values of the response variable) for site i.

When logarithmic transformations are needed to obtain a linear relation between the explanatory and response variable, equation 3 takes the form

$$Y_P = 10^{b0} X_1^{b1}\, X_2^{b2} \ldots X_j^{bj} + e_i. \tag{4}$$

A subset of streamgages (124 of the 148) was used to derive regional regression equations for estimating peak-flow statistics at ungaged sites because they drain unregulated rural basins (fig. 1). Streamgages used to compute the regression equations include 103 streamgages in Maine, 16 in New Hampshire, and 5 in New Brunswick, Canada.

Exploratory Data Analysis

OLS regression analyses were used for exploratory data analyses. All-subsets regression in the smwrStats package (Helsel and Hirsch, 2002) of statistical software R (R Core Team, 2015) was used to determine the best combinations of basin characteristics to use as explanatory variables in the multiple-linear regression equations for estimating AEP streamflows. The best OLS fit for models with one, two, and three explanatory variables was evaluated. Linearity, homoscedasticity (constant variance in the response variable over the range of the explanatory variables), and normality in the relation between explanatory variables and response variables are important assumptions for OLS and were examined with component-plus-residual plots (Cook and Weisberg, 1982). Matrices of scatter plots between estimated peak flows and basin and climatic characteristics were created to evaluate which characteristics had the best visual linear relation for each statistic and if transformations of variables would be appropriate to develop relations that were more linear. Various transformations were evaluated, including $\log_{10}$, natural logarithm, addition of a constant, square root, and reciprocal square root. The $\log_{10}$ transformation resulted in the best linear relations and most constant variance about the regression line for all statistical streamflows used as the response variable, and for many of the explanatory variables including drainage area.

The final basin characteristics were selected using OLS and its associated statistical metrics. Explanatory variables in the OLS models were selected to minimize the standard model error and to maximize the adjusted coefficient of determination (adj-R^2). Individual points with high leverage or high influence as identified with Cook's D statistic were examined for accuracy and appropriateness (Cook, 1977; Helsel and Hirsch, 2002). Multicollinearity (where two or more variables are linearly dependent and thus correlated) was tested for using variance inflation factors (VIFs). VIFs greater than 3 can indicate possible multicollinearity, and VIFs greater than 10 indicate serious problems (Helsel and Hirsch, 2002). VIFs were less than 2 for all explanatory variables selected for the final models, and thus, multicollinearity was unlikely. Serial correlation was evaluated using the Durbin-Watson test statistic. The nonsignificance of the Durbin-Watson test statistic for all models indicated that model residuals were independent.

Regional Regression Equations

GLS regression techniques (Stedinger and Tasker, 1985; Tasker and Stedinger, 1989; Griffis and Stedinger, 2007) were used to compute the final coefficients and measures of accuracy for the regression equations. GLS regression provides improved estimates of statistical streamflows and improved estimates of the predictive accuracy of the regression equations when streamgages have different lengths of record and when concurrent flows at different streamgages are correlated (Stedinger and Tasker, 1985). Streamflows are often correlated across multiple streamgages as a result of regional or statewide storms. GLS regression gives less weight to streamgages that have shorter periods of record or whose concurrent peak flows are correlated with other streamgages. WREG version 2.02, the USGS weighted-multiple-linear regression program written in the R programming language (https://github.com/USGS-R/WREG), was used to compute the GLS equations.

The final set of regression equations for estimating peak flows at ungaged locations in Maine is listed in table 3. The basin characteristics used as explanatory variables that produced the best fit and lowest errors in the equations include the following: A, drainage area, in square miles; W, the percentage of wetlands in the basin based on the U.S. Fish and Wildlife Service National Wetland Inventory GIS wetlands coverage; and $I24HxY$, the basinwide mean of the 24-hour rainfall intensity that occurs on average once every x years, in inches (table 3 and appendix table 1.6). The AEP or recurrence interval of the rainfall intensity variable ($I24HxY$) will be different for each equation and should correspond to the inverse of the AEP of the statistic being calculated. For example, to calculate the Q50 (the peak flow with a 50-percent chance of occurring in any given year), the $I24H2Y$ rainfall intensity variable should be used (the 24-hour duration rainfall intensity that occurs on average once every 2 years). For the Q1, the $I24H100Y$ should be used.

All explanatory variables included in the final regression equations were statistically significant at the 95-percent confidence level (p-value < 0.05) and were not correlated with

Table 3. Regional flood-frequency equations and performance metrics for estimating statistical peak flows for ungaged streams in Maine.

[R^2, coefficient of determination; log, logarithmic; Q, statistical discharge; A, drainage area, in square miles; W, percentage of wetlands in the basin; $I24HxY$, 24-hour rainfall intensity with 2- to 500-year recurrence intervals, basinwide mean in inches]

Annual exceedance probability (percent)	Recurrence interval (years)	Regional regression equation	Pseudo R^2	Root mean square error		Average standard error of prediction	
				Log unit	Percent	Log unit	Percent
50	2	$Q50=24.946\ A^{0.860}\ 10^{-0.0223*W}\ 10^{0.174*I24H2Y}$	0.966	0.172	−32.7 to 48.6	0.164	−31.5 to 45.9
20	5	$Q20=42.560\ A^{0.835}\ 10^{-0.0236*W}\ 10^{0.137*I24H5Y}$	0.966	0.171	−32.6 to 48.4	0.160	−30.8 to 44.4
10	10	$Q10=56.494\ A^{0.823}\ 10^{-0.0242*W}\ 10^{0.116*I24H10Y}$	0.964	0.175	−33.1 to 49.5	0.163	−31.4 to 45.7
4	25	$Q4=75.336\ A^{0.809}\ 10^{-0.0248*W}\ 10^{0.0968*I24H25Y}$	0.961	0.181	−34.1 to 51.6	0.167	−31.9 to 46.8
2	50	$Q2=89.125\ A^{0.801}\ 10^{-0.0252*W}\ 10^{0.0873*I24H50Y}$	0.961	0.186	−34.9 to 53.6	0.166	−31.7 to 46.4
1	100	$Q1=105.196\ A^{0.793}\ 10^{-0.0255*W}\ 10^{0.0782*I24H100Y}$	0.959	0.192	−35.7 to 55.6	0.170	−32.3 to 47.8
0.5	200	$Q0.5=126.765\ A^{0.782}\ 10^{-0.0252*W}\ 10^{0.0673*I24H200Y}$	0.953	0.200	−36.9 to 58.6	0.178	−33.7 to 50.8
0.2	500	$Q0.2=167.880\ A^{0.772}\ 10^{-0.0255*W}\ 10^{0.0530*I24H500Y}$	0.951	0.210	−38.4 to 62.3	0.182	−34.2 to 51.9

other explanatory variables used in the same equation. The same explanatory variables were used to develop all seven streamflow equations to minimize the possibility of predictive inconsistencies between estimates of different probabilities and to ensure that estimates increase with decreasing probabilities. Ranges of the basin characteristics used to develop the equations (and thus, the ranges for which they should be used) are presented in table 1.

The most significant explanatory variable (strongest predictor of flow), *A*, is related positively to peak flows; sites with larger drainage areas will produce larger estimates of peak flows for a given AEP. The second most significant explanatory variable, *W*, is related negatively to peak flows; drainage basins with higher percentages of wetlands will produce smaller estimates of peak flow because of the ability of the basin to store larger amounts of water. *I*24*HxY* is related positively to AEP peak flows; the basins with higher 24-hour rainfall intensities for a given recurrence interval result in higher peak flows.

Residual diagnostic plots were inspected to ensure the appropriateness of the models. The plots indicated that the residuals are equally distributed around zero for each of the models; furthermore, the residuals indicate no spatial pattern, indicating no geographical biases in the single state-wide models or need for additional explanatory variables to account for geographic biases. As discussed in the skew analysis, leverage and influence statistics for the GLS analysis are regression diagnostics for an individual streamgage. If streamgages have high leverage and high influence, they are evaluated for potential erroneous data reporting or conditions that would make the streamgage inappropriate for regression. If no errors could be determined, high leverage or influence metrics alone were insufficient justification for removing the streamgages from the regression analysis, and these streamgages were kept in the analysis. The threshold for substantial leverage computed by GLS regression was 0.645 for all AEPs, and the threshold for substantial influence was computed as 0.0323. Three USGS streamgages were flagged as having high leverage and high influence; 01017550 (Williams Brook at Phair, Maine), 01049550 (Togus Stream at Togus, Maine), and 01073785 (Winnicut River at Greenland, near Portsmouth, New Hampshire) at all AEPs. All three were examined for anomalies in the data. Although all three have relatively small drainage areas and relatively high percentages of the basin with wetlands, justification for removing them was not found and they were left in the analysis.

Accuracy and Limitations

Several overall measures of the accuracy of the regression equations are presented in tables 3 and 4, such as the pseudocoefficient of determination (pseudo R^2), the root mean square error (RMSE), and the average standard error of prediction (ASEP). The pseudo R^2 indicates the variability observed in the response variable that is accounted for by the regression model after removing the effect of the sampling error. The closer the pseudo R^2 is to 1, the better the regression explains the variation in the response variables. The RMSE is a measure of how much the regression results deviate from the observed data. The ASEP is a measure of the expected accuracy of a regression model when it is applied at an ungaged location (fig. 3, table 1). The glossary gives additional explanation of these metrics, and equations for calculating these metrics are available in Eng and others (2009) and Gotvald and others (2012).

If the regression equations presented in table 3 are applied only to unregulated rural streams in Maine with variables inside the two-dimensional ranges of explanatory variables shown in figure 3, the probability that the true value of the peak flow at a given frequency will be between the positive and negative percentage of standard errors of prediction is about 68 percent. If the equations are applied outside the range of explanatory variables, on a stream that was regulated, or outside of Maine, the accuracy of the estimated flows would

Table 4. Drainage-area-only equations and measures of their accuracy for select recurrence intervals.

[R^2, coefficient of determination; log, logarithmic; *Q*, statistical discharge; *A*, drainage area, in square miles]

Annual exceedance probability (percent)	Recurrence interval (years)	Equation	Pseudo R^2	Root mean square error		Average standard error of prediction	
				Log unit	Percent	Log unit	Percent
50	2	$Q50=54.075\ A^{0.818}$	0.938	0.228	−40.8 to 69.0	0.221	−39.9 to 66.3
20	5	$Q20=88.716\ A^{0.791}$	0.930	0.234	−41.7 to 71.4	0.227	−40.7 to 68.5
10	10	$Q10=114.815\ A^{0.777}$	0.925	0.240	−42.5 to 73.8	0.231	−41.3 to 70.3
4	25	$Q4=151.008\ A^{0.763}$	0.920	0.248	−43.5 to 77.1	0.235	−41.8 to 71.9
2	50	$Q2=180.717\ A^{0.753}$	0.917	0.255	−44.4 to 79.8	0.237	−42.0 to 72.5
1	100	$Q1=212.324\ A^{0.745}$	0.912	0.261	−45.2 to 82.5	0.242	−42.7 to 74.6
0.5	200	$Q0.5=246.037\ A^{0.737}$	0.909	0.268	−46.0 to 85.3	0.244	−42.9 to 75.3
0.2	500	$Q0.2=295.121\ A^{0.727}$	0.904	0.277	−47.1 to 89.1	0.248	−43.6 to 77.2

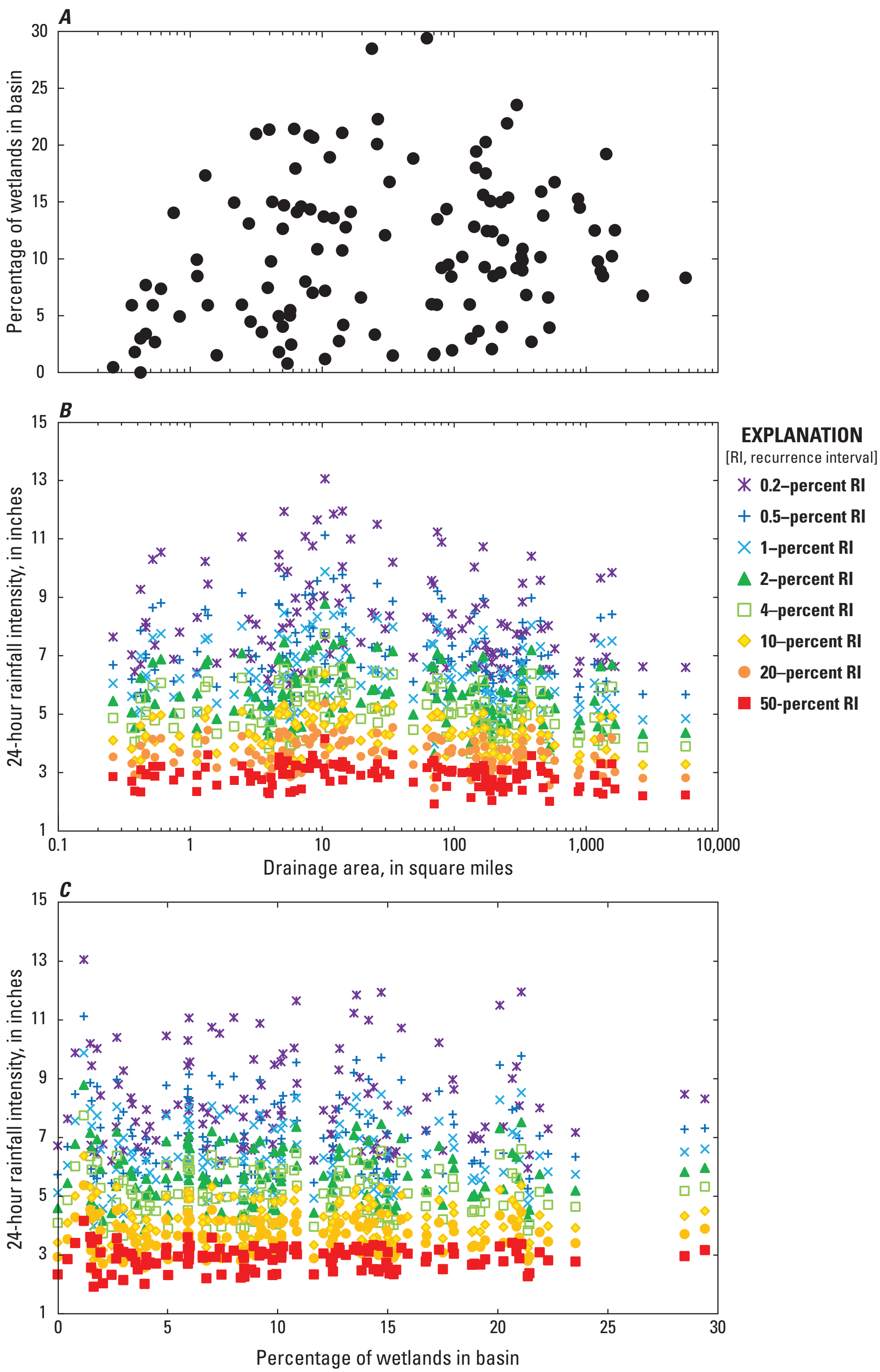

Figure 3. Two-dimensional ranges of explanatory variables used to develop the regression equations for estimating peak flows at selected recurrence intervals for streams in and near Maine. *A*, for drainage area and percentage of wetlands; *B*, for drainage area and 24-hour rainfall intensities with from 2- to 500-year recurrence intervals (RIs); *C*, for percentage of wetlands in the basin and 24-hour rainfall intensities with from 2- to 500-year RIs.

be unknown. Furthermore, determining the basin characteristics for use in the regression equations with data sources other than those listed in appendix table 1.1 or using different computational methods than those outlined in this report will produce estimates with unknown accuracy.

Accuracy of Individual Estimates Computed Using the Regression Equations

The pseudo R^2, the root mean square error, and the average standard error of prediction (table 3) are average estimates of the overall accuracy of the regression equations. For example, the ASEP is the square root of the average variance of prediction at a group of sites that have the same basin characteristics as the streamgages used in development of the regression equations. The ASEP has a model error component (the error resulting from an imperfect model), and a sampling error component (the error that results from only using a sample of the entire population). Although the actual standard error of prediction varies from site to site depending on the values of the explanatory variables, the error associated with the different values of the explanatory variables is a small part of the total standard error of prediction. For this reason, the ASEP can reasonably be used as an approximate standard error of prediction for individual sites. If a standard error of prediction for an individual site is desired, it can be calculated as explained below.

The variance of prediction of a peak-flow estimate at a particular site is computed according to Hodge and Tasker (1995) as follows:

$$V_{pred} = \gamma^2 + x_i (X^{tr} \Delta^{-1} X)^{-1} x_i^{tr}, \tag{5}$$

where

- V_{pred} is the standard error of prediction;
- γ^2 is the model-error variance (see appendix table 1.7);
- x_i is a row vector containing 1, $\log_{10}A$, W, and $I24HxY$;
- tr is the matrix algebra symbol for transposing a matrix;
- $(X^{tr}\Delta^{-1}X)^{-1}$ is the $(p{\times}p)$ matrix with
- X being a $(n{\times}p)$ matrix that has rows of logarithmically transformed basin characteristics augmented by a 1 and
- Δ being the $(n{\times}n)$ covariance matrix used for weighting sample data in the GLS regression;
- n is the number of streamgages used in the regression analysis; and
- p is the number of basin characteristics plus 1 (appendix table 1.7).

The standard error of prediction of an estimate can be converted to positive and negative percentages of errors with the following formulas:

$$SE_{pred} = (V_{pred})^{0.5}, \tag{6}$$

where

- SE_{pred} is the standard error of prediction in logarithmic units, and
- V_{pred} is the variance of prediction in logarithmic units; and

$$S_{pos} = 100(10^{SEpred} - 1) \text{ and} \tag{7}$$

$$S_{neg} = 100(10^{-SEpred} - 1), \tag{8}$$

where

- S_{pos} is the positive percentage of error of prediction,
- S_{neg} is the negative percentage of error of prediction.

The probability that the true value of the peak flow at a given frequency is between the positive and negative percentage of standard errors of prediction is about 68 percent. For example, if S_{neg} is −27.1 percent and S_{pos} is 37.1 percent, there is a 68-percent chance that the true streamflow at a site ranges from −27.1 to 37.1 percent of the estimated streamflow.

Prediction Intervals

Prediction intervals define the range that likely contains the value of the estimated statistic for a new site. They indicate the uncertainty in the equations and are analogous to confidence intervals but apply to individual estimates for ungaged sites that were not used in the development of the equations and thus are typically larger than confidence intervals, which are computed for a sample parameter such as the mean. For example, one can be 90-percent certain that the true value of a peak-flow estimate lies within the 90-percent prediction interval. Prediction intervals for the selected percentages can be computed as follows:

$$PI = Q_{pred} 10^{(t_{\frac{\alpha}{2},n-p} SE_{pred})} \text{ and} \tag{9}$$

$$PI_{lower} = \frac{Q_{pred}}{10^{(t_{\frac{\alpha}{2},n-p} SE_{pred})}}, \tag{10}$$

where

- PI_{upper} is the upper prediction interval, in cubic feet per second;
- PI_{lower} is the lower prediction interval, in cubic feet per second;

Q_{pred} is the computed peak flow at a selected frequency from the regression equation, in cubic feet per second;

$t_{\frac{\alpha}{2},n-p}$ is the critical value from a Student's t-distribution at alpha level α (α=0.10 for a 90-percent prediction interval; α=0.05 for a 95-percent prediction interval) with $n-p$ degrees of freedom; n=124, the number of streamgages used in the regression analysis; and p=3, the number of basin characteristics in the regression equation, plus 1; and

SE_{pred} is the standard error of prediction of a peak flow frequency estimate.

Drainage-Area-Only Regression Equations

Regression equations with only one explanatory variable—drainage area—can provide quick estimates of peak flows that are easier to calculate, although less accurate, than those computed by the regression equations with multiple explanatory variables. These simplified equations can also be used if the percentage of wetlands in the basin is outside the range of percentage of wetlands for which the full equation was designed. It is unknown whether the drainage-area-only equations or the full equations would be more accurate in this case; however, the drainage-area-only equations would have a known accuracy. The simplified peak-flow regression equations for AEPs of 50, 20, 10, 4, 2, 1, 0.5, and 0.2 percent (recurrence intervals of 2, 5, 10, 25, 50, 100, 200, and 500 years, respectively) are presented in table 4 as are their root mean square error, and average standard error of prediction. The same 124 streamgages used to develop the full equation were used to develop the simplified drainage-area-only equations, and thus, the equations are still applicable to any ungaged site in Maine with a drainage area between 0.22 and 5,680 mi^2.

Application and Methods

Weighted Estimates at Streamgages

An estimate of peak flow for a selected AEP for a rural, unregulated streamgage can be improved by combining the regression-equation estimate with the at-station estimate computed from the streamgage record. The procedure recommended by Cohn and others (2013) is to weight these two estimates by the inverse of their variances. The variance of the at-station estimate is related to the years of record at a site.

The procedure recommended by Cohn and others (2013) was applied to rural, unregulated streamgages used in this study, and the weighted peak-flow results are provided in appendix table 1.4. If regression-equation estimates or weighted estimates are not given in table 1.4, it is an indication that the streamgage is regulated and only the at-station estimates computed using the EMA should be used. The weighted peak flows were computed with the following equation:

$$\log_{10} Q_w = \frac{(\log_{10} Q_s)(V_{pred}) + (\log_{10} Q_{r(g)})(V_s)}{(V_{pred} + V_s)} \qquad (11)$$

where

Q_w is the weighted peak flow, in cubic feet per second;

Q_s is the at-station (EMA) estimate of peak flow for the selected AEP, in cubic feet per second (appendix table 1.4);

V_{pred} is the variance of prediction of the regression-equation result ($Q_{r(g)}$), in logarithmic units (appendix table 1.8, model-error variance);

$Q_{r(g)}$ is the peak flow for the selected AEP from the regression equation applied at the streamgage, in cubic feet per second (appendix table 1.4); and

V_s is the variance of estimate of the AEP at-station peak flow in logarithmic units (Q_s; appendix table 1.7).

Confidence intervals for the weighted peak flow, Q_w, can be computed with equations 9 and 10; however, the standard error of prediction for the weighted peak flow, SE_w, is substituted for the standard error of prediction for the regression estimate, SE_{pred}. The standard error of prediction for the weighted peak flow can be computed with the following formula:

$$SE_w = \left(\frac{V_s V_{pred}}{V_s + V_{pred}}\right)^{0.5}. \qquad (12)$$

Estimates at Ungaged Sites Near Gaged Locations

Estimates of the magnitude of peak flows at selected AEPs for ungaged sites that are relatively near a streamgage (see specifics below) and are on the same unregulated stream can be improved by combining the estimate from the regression equations with the estimate from the nearby streamgage. A method for adjusting the weighted discharge at a streamgage, Q_w, to a site of interest upstream or downstream from the streamgage is provided based on an equation provided in Sauer (1974) and applied in Feaster and others (2009). The method provided in equation 13 below calculates the weighted average peak flow at the ungaged site $Q_{w(u)}$ by increasing the weight of the regression-equation peak-flow estimate over the weight of the at-station peak-flow estimate the farther upstream or downstream the site of interest is from the streamgage:

$$Q_{w(u)} = \left[\left(\frac{2\Delta A}{A_g} \right) + \left(1 - \frac{2\Delta A}{A_g} \right) \left(\frac{Q_{w(g)}}{Q_{r(g)}} \right) \right] Q_{r(u)} \qquad (13)$$

where

$Q_{w(u)}$ is the weighted average peak flow at the ungaged site;

ΔA is the absolute value of the difference between the drainage areas of the gaged station and the ungaged station, in square miles;

A_g is the drainage-basin area of the streamgage (appendix table 1.6);

$Q_{w(g)}$ is the weighted average peak flow at the streamgage (appendix table 1.4);

$Q_{r(g)}$ is the peak flow at the streamgage computed using the regression equation (appendix table 1.4); and

$Q_{r(u)}$ is the peak flow for the ungaged site on a gaged unregulated stream computed using the regression equation.

Using equation 13, full weight is given to the regression estimates when the drainage area for the ungaged site is equal to 0.5 or 1.5 times the drainage area for the gaged station and increasing weight to the gaged station estimates as the drainage-area ratio approaches 1. The weighting procedure should not be applied when the drainage-area ratio for the ungaged site and gaged station is less than 0.5 or greater than 1.5 or for regulated streams. Techniques for estimating peak flows for regulated streams are beyond the scope of this report. Equation 13 and simple drainage area ratio methods have been shown to be unreliable for some regulated streams in Maine (Hodgkins, 1999).

Maine StreamStats

The basin and climatic characteristics (appendix table 1.6), and regional peak-flow regression equations (table 3), are integrated in the USGS StreamStats program (https://streamstats.usgs.gov) to allow estimation of peak-flow statistics at ungaged locations on Maine streams. StreamStats is a web-based GIS application that provides users an assortment of analytical tools useful for water resources planning and engineering design. StreamStats makes the process of calculating flow statistics for ungaged sites faster and more consistent than using manual calculation methods. StreamStats users choose locations of interest from an interactive map and easily obtain flow statistics, basin characteristics, and descriptive information. If a user selects the location of a USGS streamgage, they can obtain available, published flow statistics for the streamgage. If a user selects an ungaged location, StreamStats will delineate the drainage-basin boundary, measure basin characteristics, and estimate flow statistics for the site based on available, published regional regression equations. If the ungaged location has basin and climatic characteristics within the range of characteristics used to develop the regional regression equations, StreamStats also will output prediction intervals and the standard error of prediction (described in the “Uncertainty and Limitations” section). Ries and others (2008) provide a detailed description of the StreamStats application.

Summary

This report, prepared by the U.S. Geological Survey in cooperation with the Maine Department of Transportation, documents the development of regression equations for estimating peak-flow magnitudes for rural, unregulated streams in Maine at annual exceedance probabilities (AEPs) of 50, 20, 10, 4, 2, 1, 0.5, and 0.2 percent (recurrence intervals of 2, 5, 10, 25, 50, 100, 200, and 500 years, respectively). Regression techniques were used to determine relations between the peak-flow magnitudes for selected AEPs and selected basin characteristics at 124 unregulated streamgages in and near Maine.

The peak-flow magnitudes at selected AEPs for 148 streamgages in Maine, and within 20 miles of the Maine border in New Hampshire and New Brunswick, Canada, were determined by following guidelines in Bulletin 17C. Peak flows at selected AEPs were computed using the expected moments algorithm and using a new regional skew coefficient of 0.020 with a standard error of prediction of 0.30 that was developed specifically for Maine as a part of this work.

Although some streamgages demonstrated positive trends in peak flows over 30-, 50-, 70, and 90-year periods, trends were inconsistent across streamgages and periods; they may be influenced by multidecadal oscillations. Furthermore, analyzing only the most recent periods of record (such as the most recent 30 years) means that the peak of record would not be included in analyses for at least one-half of the streamgages analyzed, and thus, estimates of peak flows could end up lower than they would be using the entire period of record. Stationarity was assumed for these analyses.

More than 80 basin characteristics at each streamgage were calculated using a geographic information system and were tested for use in the regression equations. An ordinary least-squares linear regression testing all possible subsets of the explanatory variables was used to narrow down the basin characteristics to the three variables that best explained the variability among the magnitude of peak flows at gaged sites. These variables are drainage area, the percentage of the basin covered by wetlands, and the 24-hour intensity of the precipitation. The final regression equations and estimates of error were developed using Generalized Least-Squares regression techniques. The average standard error of prediction for estimating peak flows with these equations ranged from −31.5 to 45.9 percent for the 50-percent AEP and from −34.2 to 52.0 percent for the 0.2-percent AEP.

The developed regression equations can be used as a method for estimating peak flows at selected AEPs for ungaged, unregulated, rural streams in Maine. For unregulated gaged locations, weighted estimates for peak flows are presented; they were computed by weighting flood-frequency estimates at gaged locations with results from the regression equations to produce more accurate estimates. In addition, a technique is presented for estimating peak flows at selected AEPs for ungaged sites upstream or downstream from a streamgage using a drainage-area adjustment and within 50 to 150 percent of the drainage area at a gage.

Streamflow estimates presented here improve upon previous peak-flow regression equations developed for Maine because they incorporate 20 additional years of peak-flow data and include data from streamgages with drainage areas down to 0.26 square mile. Gaged data from many very small basins were unavailable previously. In addition, estimates and equations developed here benefit from improved statistical techniques including the expected moments algorithm and the multiple Grubbs-Beck test, which allow for improved fit of the flood-frequency distribution and better use of historical data and provide more realistic estimates of error.

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Appendix 1. Supplemental Tables Relating to the Regional Regression Analysis

This appendix contains supplemental tables for the 124 streamgages used to develop the regional regression equations and limited information for the additional 24 streamgages for which flood-frequency estimates are computed but which are not used in the regional regression analyses because of regulation (tables 1.1–1.8). The data are replicated from the U.S. Geological Survey data release published in Lombard (2020).

Table 1.1. Basin characteristics tested for use in the regression equations.

[Shaded basin characteristics were those used in final regression equations. MEGIS, Maine Office of GIS; NHD, National Hydrography Dataset; AEP, annual exceedance probability; NOAA, National Oceanic and Atmospheric Administration; NRCC, Northeast Regional Climate Center; °C, degree Celsius; SIR, U.S. Geological Survey Scientific Investigations Report; NWI, U.S. Fish and Wildlife Service National Wetlands Inventory; NHN, Canadian National Hydrographic Network; NALCMS, North American Land Change Monitoring System; %, percent; —, not applicable]

Basin characteristic	Computation method	Unit	Data source
Easting of basin centroid in Maine State plane coordinates	—	Meter	—
Northing of basin centroid in Maine State plane coordinates	—	Meter	—
Mean elevation	Basinwide mean	Meter	[1]The National Map, [2]MEGIS, [3]GeoNB
Maximum elevation in basin	—	Meter	[1]The National Map, [2]MEGIS, [3]GeoNB
Minimum elevation in basin	—	Meter	[1]The National Map, [2]MEGIS, [3]GeoNB
Mean basin slope	Basinwide mean	Percent	[1]The National Map, [2]MEGIS, [3]GeoNB
Relief (maximum elevation minus minimum elevation)	—	Meter	[1]The National Map, [2]MEGIS, [3]GeoNB
Slope of main-channel line using line endpoints	—	Foot per mile	[1]The National Map, [2]MEGIS, [3]GeoNB
Basin Length (main-channel line, from outlet up to basin divide along longest flow path)	—	Mile	[1]The National Map, [2]MEGIS, [3]GeoNB
Outlet elevation	—	Meter	[1]The National Map, [2]MEGIS, [3]GeoNB
Elevation at upstream end of main-channel line	—	Meter	[1]The National Map, [2]MEGIS, [3]GeoNB
Elevation at upstream end of main-channel line minus outlet elevation	—	Meter	[1]The National Map, [2]MEGIS, [3]GeoNB
Drainage area	—	Square mile	[4]NHD
Perimeter of basin	—	Mile	[4]NHD
Sum of stream lengths	—	Mile	[4]NHD
Relative relief (relief divided by perimeter)	—	Foot per mile	—
Basin width (drainage area divided by basin length)	—	Mile	—
Stream density (sum of stream lengths divided by drainage area)	—	Mile per square mile	—
24-hour rainfall with 2-year recurrence interval	Basinwide mean	Inch	[5]NOAA, [6]NRCC
24-hour rainfall with 5-year recurrence interval	Basinwide mean	Inch	[5]NOAA, [6]NRCC
24-hour rainfall with 10-year recurrence interval	Basinwide mean	Inch	[5]NOAA, [6]NRCC
24-hour rainfall with 25-year recurrence interval	Basinwide mean	Inch	[5]NOAA, [6]NRCC
24-hour rainfall with 50-year recurrence interval	Basinwide mean	Inch	[5]NOAA, [6]NRCC
24-hour rainfall with 100-year recurrence interval	Basinwide mean	Inch	[5]NOAA, [6]NRCC
24-hour rainfall with 200-year recurrence interval	Basinwide mean	Inch	[5]NOAA, [6]NRCC
24-hour rainfall with 500-year recurrence interval	Basinwide mean	Inch	[5]NOAA, [6]NRCC
60-minute rainfall with 100-year recurrence interval	Basinwide mean	Inch	[5]NOAA, [6]NRCC
60-minute rainfall with 500-year recurrence interval	Basinwide mean	Inch	[5]NOAA, [6]NRCC
Average annual precipitation, 1981–2010	Basinwide mean	Millimeter	[7]PRISM, [8]Global Climate Data
Average January precipitation, 1981–2010	Basinwide mean	Millimeter	[7]PRISM, [8]Global Climate Data
Average February precipitation, 1981–2010	Basinwide mean	Millimeter	[7]PRISM, [8]Global Climate Data
Average March precipitation, 1981–2010	Basinwide mean	Millimeter	[7]PRISM, [8]Global Climate Data

Table 1.1. Basin characteristics tested for use in the regression equations.—Continued

[Shaded basin characteristics were those used in final regression equations. MEGIS, Maine Office of GIS; NHD, National Hydrography Dataset; AEP, annual exceedance probability; NOAA, National Oceanic and Atmospheric Administration; NRCC, Northeast Regional Climate Center; °C, degree Celsius; SIR, U.S. Geological Survey Scientific Investigations Report; NWI, U.S. Fish and Wildlife Service National Wetlands Inventory; NHN, Canadian National Hydrographic Network; NALCMS, North American Land Change Monitoring System; %, percent; —, not applicable]

Basin characteristic	Computation method	Unit	Data source
Average April precipitation, 1981–2010	Basinwide mean	Millimeter	[7]PRISM, [8]Global Climate Data
Average May precipitation, 1981–2010	Basinwide mean	Millimeter	[7]PRISM, [8]Global Climate Data
Average June precipitation, 1981–2010	Basinwide mean	Millimeter	[7]PRISM, [8]Global Climate Data
Average July precipitation, 1981–2010	Basinwide mean	Millimeter	[7]PRISM, [8]Global Climate Data
Average August precipitation, 1981–2010	Basinwide mean	Millimeter	[7]PRISM, [8]Global Climate Data
Average September precipitation, 1981–2010	Basinwide mean	Millimeter	[7]PRISM, [8]Global Climate Data
Average October precipitation, 1981–2010	Basinwide mean	Millimeter	[7]PRISM, [8]Global Climate Data
Average November precipitation, 1981–2010	Basinwide mean	Millimeter	[7]PRISM, [8]Global Climate Data
Average December precipitation, 1981–2010	Basinwide mean	Millimeter	[7]PRISM, [8]Global Climate Data
Average winter (December–February) precipitation, 1981–2010	Basinwide mean	Millimeter	[7]PRISM, [8]Global Climate Data
Average spring (March–May) precipitation, 1981–2010	Basinwide mean	Millimeter	[7]PRISM, [8]Global Climate Data
Average summer (June–August) precipitation, 1981–2010	Basinwide mean	Millimeter	[7]PRISM, [8]Global Climate Data
Average fall (September–November) precipitation, 1981–2010	Basinwide mean	Millimeter	[7]PRISM, [8]Global Climate Data
Average maximum annual temperature, 1981–2010	Basinwide mean	°C	[7]PRISM, [8]Global Climate Data
Average maximum January temperature, 1981–2010	Basinwide mean	°C	[7]PRISM, [8]Global Climate Data
Average maximum February temperature, 1981–2010	Basinwide mean	°C	[7]PRISM, [8]Global Climate Data
Average maximum March temperature, 1981–2010	Basinwide mean	°C	[7]PRISM, [8]Global Climate Data
Average maximum April temperature, 1981–2010	Basinwide mean	°C	[7]PRISM, [8]Global Climate Data
Average maximum May temperature, 1981–2010	Basinwide mean	°C	[7]PRISM, [8]Global Climate Data
Average maximum June temperature, 1981–2010	Basinwide mean	°C	[7]PRISM, [8]Global Climate Data
Average maximum July temperature, 1981–2010	Basinwide mean	°C	[7]PRISM, [8]Global Climate Data
Average maximum August temperature, 1981–2010	Basinwide mean	°C	[7]PRISM, [8]Global Climate Data
Average maximum September temperature, 1981–2010	Basinwide mean	°C	[7]PRISM, [8]Global Climate Data
Average maximum October temperature, 1981–2010	Basinwide mean	°C	[7]PRISM, [8]Global Climate Data
Average maximum November temperature, 1981–2010	Basinwide mean	°C	[7]PRISM, [8]Global Climate Data
Average maximum December temperature, 1981–2010	Basinwide mean	°C	[7]PRISM, [8]Global Climate Data
Average minimum annual temperature, 1981–2010	Basinwide mean	°C	[7]PRISM, [8]Global Climate Data
Average minimum January temperature, 1981–2010	Basinwide mean	°C	[7]PRISM, [8]Global Climate Data
Average minimum February temperature, 1981–2010	Basinwide mean	°C	[7]PRISM, [8]Global Climate Data
Average minimum March temperature, 1981–2010	Basinwide mean	°C	[7]PRISM, [8]Global Climate Data
Average minimum April temperature, 1981–2010	Basinwide mean	°C	[7]PRISM, [8]Global Climate Data
Average minimum May temperature, 1981–2010	Basinwide mean	°C	[7]PRISM, [8]Global Climate Data

Table 1.1. Basin characteristics tested for use in the regression equations.—Continued

[Shaded basin characteristics were those used in final regression equations. MEGIS, Maine Office of GIS; NHD, National Hydrography Dataset; AEP, annual exceedance probability; NOAA, National Oceanic and Atmospheric Administration; NRCC, Northeast Regional Climate Center; °C, degree Celsius; SIR, U.S. Geological Survey Scientific Investigations Report; NWI, U.S. Fish and Wildlife Service National Wetlands Inventory; NHN, Canadian National Hydrographic Network; NALCMS, North American Land Change Monitoring System; %, percent; —, not applicable]

Basin characteristic	Computation method	Unit	Data source
Average minimum June temperature, 1981–2010	Basinwide mean	°C	[7]PRISM, [8]Global Climate Data
Average minimum July temperature, 1981–2010	Basinwide mean	°C	[7]PRISM, [8]Global Climate Data
Average minimum August temperature, 1981–2010	Basinwide mean	°C	[7]PRISM, [8]Global Climate Data
Average minimum September temperature, 1981–2010	Basinwide mean	°C	[7]PRISM, [8]Global Climate Data
Average minimum October temperature, 1981–2010	Basinwide mean	°C	[7]PRISM, [8]Global Climate Data
Average minimum November temperature, 1981–2010	Basinwide mean	°C	[7]PRISM, [8]Global Climate Data
Average minimum December temperature, 1981–2010	Basinwide mean	°C	[7]PRISM, [8]Global Climate Data
Distance from the coast	Distance	Mile (planar)	[9]SIR 2015–5151
Percentage of basin that is lacustrine	Areal percent	Percent	[10]NWI, [11]NHN Waterbodies
Percentage of basin that is palustrine	Areal percent	Percent	[10]NWI, [11]NHN Waterbodies
Percentage of basin that is riverine	Areal percent	Percent	[10]NWI, [11]NHN Waterbodies
Percentage of basin that is palustrine or lacustrine	Areal percent	Percent	[10]NWI, [11]NHN Waterbodies, [12]NALCMS
Percentage of basin that is wetland (palustrine, riverine, or lacustrine)	Areal percent	Percent	[10]NWI, [11]NHN Waterbodies, [12]NALCMS
Percentage of basin covered by forest	Areal percent	Percent	[12]NALCMS
Percentage of basin covered by barren land	Areal percent	Percent	[12]NALCMS
Percentage of basin covered by developed land	Areal percent	Percent	[12]NALCMS
Percentage of basin covered by fields, grass or agricultural	Areal percent	Percent	[12]NALCMS
Percentage of basin covered by open water	Areal percent	Percent	[12]NALCMS
Percentage of basin covered by shrubland	Areal percent	Percent	[12]NALCMS
Percentage of basin covered by wetland or open water	Areal percent	Percent	[12]NALCMS

[1]U.S. Geological Survey (2005–17).

[2]Maine Geolibrary (2017).

[3]GeoNB (2015–18).

[4]U.S. Geological Survey (2019).

[5]National Oceanic and Atmospheric Administration (2017).

[6]Northeast Regional Climate Center (2016).

[7]PRISM Climate Group (2012a, b, c).

[8]WorldClim (2016).

[9]Dudley (2015).

[10]U.S. Fish and Wildlife Service (2009).

[11]Canadian National Hydrographic Network (2017).

[12]Multi-Resolution Land Characteristics Consortium (2015).

Table 1.2. Summary of data used in the frequency analyses of annual peak-flow data for streamgages in and near Maine.

[NAD 83, North American Datum of 1983; ME, Maine; NH, New Hampshire; —, not applicable]

Streamgage number	Streamgage name	Analysis period, water years[1]	Systematic record, water years[2]	Historical period perception thresholds: Water years	Historical period perception thresholds: Discharge, cubic feet per second	Regulated streamgage that was not used to develop regression equation	Latitude, decimal degrees referenced to NAD 83	Longitude, decimal degrees referenced to NAD 83
01010000	St. John River at Ninemile Bridge, ME	1948–2019	1951–2019	1948–50	36,600	—	46.70055556	−69.7155556
01010070	Big Black River near Depot Mountain, ME	1984–2018	1984–2018	—	—	—	46.89388889	−69.7516667
01010500	St. John River at Dickey, ME	1943–2019	1947–2019	1943–46	89,000	—	47.11305556	−69.0880556
01011000	Allagash River near Allagash, ME	1932–2019	1932–2019	—	—	—	47.0697222	−69.0794444
01011500	St. Francis River near Connors, New Brunswick, Canada[3]	1952–2016	1952–2016	—	—	—	47.20697926	−68.9564281
01012895	Clark Brook near Wallagrass Plantation, ME	2001–17	2001–17	—	—	—	47.10416667	−68.5905556
01012970	Unnamed Brook near Wallagrass Plantation, ME	2001–16	2001–16	—	—	—	47.1572222	−68.5922222
01013500	Fish River near Fort Kent, ME	1904–2019	1904–8; 1930–2019	—	—	—	47.2375	−68.58277778
01014000	St. John River below Fish River, near Fort Kent, ME	1897–2019	1927–2019	1897–1926	121,000	—	47.2833333	−68.58527778
01014700	Factory Brook near Madawaska, ME	1964–74	1964–74	—	—	—	47.3526111	−68.2973333
01015700	Houlton Brook near Oxbow, ME	1964–74	1964–74	—	—	—	46.4383768	−68.4053174
01015800	Aroostook River near Masardis, ME	1958–2019	1958–2019	—	—	—	46.52305556	−68.3716667
01016500	Machias River near Ashland, ME	1952–83	1952–83	—	—	—	46.6283111	−68.4347917
01017000	Aroostook River at Washburn, ME	1931–2019	1931–2019	—	—	—	46.7772222	−68.1572222
01017060	Hardwood Brook below Glidden Brook near Caribou, ME	2009–19	2009–19	—	—	—	46.7836111	−67.9891667
01017290	Little Madawaska River at Caribou, ME	2009–19	2009–19	—	—	—	46.8886111	−67.945
01017300	Nichols Brook near Caribou, ME	1964–74	1964–74	—	—	—	46.8580833	−67.938
01017550	Williams Brook at Phair, ME	2000–19	2000–19	—	—	—	46.62805556	−67.9530556
01017900	Marley Brook near Ludlow, ME	1965–82	1965–82	—	—	—	46.14490556	−68.0613944
01017960	Meduxnekeag River above south branch Meduxnekeag River near Houlton, ME	2004–18	2004–18	—	—	—	46.105	−67.88138889
01018000	Meduxnekeag River near Houlton, ME	1941–2015	1941–82; 2004–15	—	—	—	46.105	−67.8666667
01018009	Pearce Brook at Route 1 at Houlton, ME	2009–18	2009–18	—	—	—	46.11527778	−67.84027778
01018035	Meduxnekeag River at Lowery Road near Houlton, ME	2006–18	2006–18	—	—	—	46.1811111	−67.80388889

Table 1.2. Summary of data used in the frequency analyses of annual peak-flow data for streamgages in and near Maine.—Continued

[NAD 83, North American Datum of 1983; ME, Maine; NH, New Hampshire; —, not applicable]

Streamgage number	Streamgage name	Analysis period, water years[1]	Systematic record, water years[2]	Historical period perception thresholds		Regulated streamgage that was not used to develop regression equation	Latitude, decimal degrees referenced to NAD 83	Longitude, decimal degrees referenced to NAD 83
				Water years	Discharge, cubic feet per second			
01018500	St. Croix River at Vanceboro, ME	1971–2018	1971–2018[4]	—	—	x	45.5683333	−67.4283333
01019000	Grand Lake Stream at Grand Lake Stream, ME	1929–2018	1929–2018	—	—	x	45.1725	−67.76888889
01021000	St. Croix River at Baring, ME	1881–2018	1923, 1960–2018	1881–1959	24,100	x	45.1369444	−67.3180556
01021200	Dennys River at Dennysville, ME	1956–2018	1956–98, 2002–12	1999–2001, 2013–18	5,390	x	44.90138889	−67.2475
01021300	Wiggins Brook near West Lubec, ME	1965–74	1965–74	—	—	—	44.7573021	−67.08915018
01021470	Libby Brook near Northfield, ME	2001–17	2001–17	—	—	—	44.8008333	−67.725
01021480	Old Stream near Wesley, ME	1999–2018	1999–2018	—	—	—	44.9369444	−67.7361111
01021500	Machias River at Whitneyville, ME	1906–2008	1906–21; 1930–77; 2002–08	—	—	—	44.72305556	−67.5205556
01021600	Middle River near Machias, ME	1965–74	1965–74	—	—	—	44.7372991	−67.4924926
01021890	Unnamed Brook near Crawford, ME	2001–17	2001–17	—	—	—	45.0444444	−67.5569444
01022000	East Machias River near East Machias, ME	1927–58	1927–58	—	—	—	44.768525	−67.40771389
01022260	Pleasant River near Epping, ME	1981–2008	1981–91; 2001–8	—	—	—	44.69777778	−67.7872222
01022500	Narraguagus River at Cherryfield, ME	1948–2018	1948–2018	—	—	—	44.60805556	−67.93527778
01022700	Forbes Pond Brook near Prospect Harbor, ME	1965–74	1965–74	—	—	—	44.40924657	−68.0263932
01022840	Otter Creek near Bar Harbor, ME	2007–18	2007–18	—	—	—	44.33277778	−68.2066667
01023000	West Branch Union River at Amherst, ME	1909–79	1909–10;1912–19; 1930–79	—	—	—	44.84023889	−68.3720167
01024200	Garland Brook near Mariaville, ME	1965–82	1965–82	—	—	—	44.7214361	−68.41096389
01026800	Frost Pond Brook near Sedgwick, ME	1965–74	1965–74	—	—	—	44.37007767	−68.6575259
01027200	North Branch Penobscot River near Pittston Farm, ME	2002–19	2002–19	—	—	—	45.93527778	−69.9936111
01028000	West Branch Penobscot River near Medway, ME	1917–39	1917–39	—	—	x	45.6068194	−68.53962778
01029200	Seboeis River near Shin Pond, ME	1998–2019	1998–2019	—	—	—	46.14305556	−68.6336111
01029500	East Branch Penobscot River at Grindstone, ME	1903–2018	1903–82; 2000–18	—	—	x	45.73027778	−68.5894444
01030000	Penobscot River near Mattawamkeag, ME	1941–95	1941–91	1992–95	40,000	x	45.5663333	−68.40366389

Table 1.2. Summary of data used in the frequency analyses of annual peak-flow data for streamgages in and near Maine.—Continued

[NAD 83, North American Datum of 1983; ME, Maine; NH, New Hampshire; —, not applicable]

Streamgage number	Streamgage name	Analysis period, water years[1]	Systematic record, water years[2]	Historical period perception thresholds		Regulated streamgage that was not used to develop regression equation	Latitude, decimal degrees referenced to NAD 83	Longitude, decimal degrees referenced to NAD 83
				Water years	Discharge, cubic feet per second			
01030300	Trout Brook near Danforth, ME	1964–73	1964–73	—	—	—	45.695339	−67.9014019
01030350	Wytopitlock Stream near Wytopitlock, ME	2009–18	2009–18	—	—	—	45.7086111	−68.1580556
01030400	Gulliver Brook near Monarda, ME	1964–74	1964–74	—	—	—	45.73977798	−68.3078011
01030500	Mattawamkeag River near Mattawamkeag, ME	1903–2019	1903–2019	—	—	—	45.5011111	−68.3058333
01031300	Piscataquis River at Blanchard, ME	1997–2018	1997–2018	—	—	—	45.2672222	−69.58388889
01031450	Kingsbury Stream at Abbot Village, ME	1998–2018	1998–2018	—	—	—	45.1844444	−69.4522222
01031470	Brewster Brook near Parkman, ME	2000–16	2000–16	—	—	—	45.1375	−69.425
01031500	Piscataquis River near Dover-Foxcroft, ME	1857–2018	1903–2018	1857–1902	37,300	—	45.175	−69.3147222
01031510	Black Stream near Dover-Foxcroft, ME	2009–18	2009–18	—	—	—	45.15027778	−69.23638889
01031600	Morrison Brook near Sebec Corners, ME	1965–77	1965–77	—	—	—	45.23796389	−69.0512611
01033000	Sebec River at Sebec, ME	1925–93	1925–35; 1937–82; 1985–93		—	x	45.27	−69.1122222
01033500	Pleasant River near Milo, ME	1921–2018	1921–79	1980–2018	27,900	—	45.28257778	−69.00343889
01034000	Piscataquis River at Medford, ME	1847–2018	1925–2018	1847–1924, 1983–89	85,000	—	45.26055556	−68.8686111
01034500	Penobscot River at West Enfield, ME	1854–2018	1902–2018	1854–1901	125,000	x	45.2361111	−68.65138889
01034900	Coffin Brook near Lee, ME	1964–74	1964–74	—	—	—	45.33839309	−68.36113147
01035000	Passadumkeag River at Lowell, ME	1916–79	1916–79	—	—	—	45.1839361	−68.474425
01036380	Unnamed Brook near Bradley, ME	2000–16	2000–16	—	—	—	44.87916667	−68.6583333
01036500	Kenduskeag Stream near Kenduskeag, ME	1909–79	1909–19; 1942–79	—	—	—	44.8971444	−68.8836833
01037000	Kenduskeag Stream near Bangor, ME	1909–2018	1909–19; 2011–18	—	—	—	44.8611111	−68.8316667
01037200	Shaw Brook near Northern Maine Junction, ME	1964–74	1964–74	—	—	—	44.7775709	−68.84920449
01037380	Ducktrap River near Lincolnville, ME	1999–2018	1999–2018	—	—	—	44.32916667	−69.0608333
01037430	Goose River at Rockport, ME	1964–74	1964–74	—	—	—	44.18924579	−69.07976019
01038000	Sheepscot River at North Whitefield, ME	1939–2018	1939–2018	—	—	—	44.22277778	−69.59388889
01041000	Kennebec River at Moosehead, ME	1920–82	1929–82	1920–28	13,400	x	45.58485	−69.71696389
01041900	Mountain Brook near Lake Parlin, ME	1964–74	1964–74	—	—	—	45.4700487	−70.0645083
01042500	Kennebec River at The Forks, ME	1902–2018	1929–2018	1902–28	23,700	x	45.3397222	−69.9619444

Table 1.2. Summary of data used in the frequency analyses of annual peak-flow data for streamgages in and near Maine.—Continued

[NAD 83, North American Datum of 1983; ME, Maine; NH, New Hampshire; —, not applicable]

Streamgage number	Streamgage name	Analysis period, water years[1]	Systematic record, water years[2]	Historical period perception thresholds: Water years	Historical period perception thresholds: Discharge, cubic feet per second	Regulated streamgage that was not used to develop regression equation	Latitude, decimal degrees referenced to NAD 83	Longitude, decimal degrees referenced to NAD 83
01043500	Dead River near Dead River, ME	1950–2009; 2013–18	1950–82, 2015–18[5]	1983–2009, 2013–14	17,300	x	45.22905	−70.20112778
01044550	Spencer Stream near Grand Falls, ME	2000–19	2000–19	—	—	—	45.3136111	−70.2416667
01045000	Dead River at the Forks, ME	1951–79	1951–79[6]	—	—	x	45.34905556	−69.99018889
01046000	Austin Stream at Bingham, ME	1932–2018	1932–69; 2009–18	—	—	—	45.0644444	−69.8805556
01046500	Kennebec River at Bingham, ME	1908–09; 1931–2018	1951–2018[7]	1908–09, 1931–50	58,800	x	45.0519444	−69.8855556
01046800	South Branch Carrabassett River at Bigelow, ME	1964–74	1964–74			—	45.0792218	−70.3170119
01047000	Carrabassett River near North Anson, ME	1926–2018	1926–2018			—	44.86916667	−69.955
01047200	Sandy River near Madrid, ME	2009–18	2009–18			—	44.85777778	−70.48527778
01047860	Unnamed Brook near New Sharon, ME	2000–16	2000–16			—	44.6522222	−69.9611111
01048000	Sandy River near Mercer, ME	1776–2018	1929–2018	1776–1928, 1980–86	51,100	—	44.70805556	−69.9375
01048100	Pelton Brook near Anson, ME	1965–74	1965–74			—	44.7661711	−69.9083913
01048220	East Branch Wesserunsett Stream near Athens, ME	2009–18	2009–18			—	44.9475	−69.6569444
01048500	Kennebec River at Waterville, ME	1903–86	1929–55[8]	1903–28, 1956–86	134,000	x	44.563775	−69.6199417
01048840	Unnamed Brook near Newport, ME	2000–16	2000–16			—	44.9008333	−69.2661111
01049000	Sebasticook River near Pittsfield, ME	1929–2013	1929–2013			—	44.71666667	−69.41388889
01049100	Hall Brook at Thorndike, ME	1964–74	1964–74			—	44.58118075	−69.28004419
01049130	Johnson Brook at South Albion, ME	1981–91	1981–91			—	44.49818889	−69.4861306
01049180	Unnamed Brook near Albion, ME	2000–16	2000–11; 2014–16			—	44.4958333	−69.50277778
01049265	Kennebec River at North Sidney, ME	1761–2018	1979–93, 2001–18	1761–1978, 1994–2000	232,000	x	44.4722222	−69.68388889
01049300	North Branch Tanning Brook near Manchester, ME	1964–83	1964–83	—	—	—	44.34981667	−69.8514083
01049373	Mill Stream at Winthrop, ME	1978–92	1978–92	—	—	—	44.30671944	−69.97105278

Table 1.2. Summary of data used in the frequency analyses of annual peak-flow data for streamgages in and near Maine.—Continued

[NAD 83, North American Datum of 1983; ME, Maine; NH, New Hampshire; —, not applicable]

Streamgage number	Streamgage name	Analysis period, water years[1]	Systematic record, water years[2]	Historical period perception thresholds		Regulated streamgage that was not used to develop regression equation	Latitude, decimal degrees referenced to NAD 83	Longitude, decimal degrees referenced to NAD 83
				Water years	Discharge, cubic feet per second			
01049500	Cobbosseecontee Stream at Gardiner, ME	1891–2018	1891–1964; 1977–2018	—	—	x	44.22916667	−69.7780556
01049550	Togus Stream at Togus, ME	1982–95	1982–1995	—	—	—	44.26613056	−69.6979361
01049690	Unnamed Brook near Dresden, ME	2000–16	2000–16	—	—	—	44.12555556	−69.7005556
01049700	Gardiner Pond Brook at Dresden Mills, ME	1965–74	1965–74	—	—	—	44.1081293	−69.7219892
01050490	Unnamed Brook near Rangeley, ME	2001–17	2001–17	—	—	—	44.95027778	−70.75638889
01050900	Four Ponds Brook near Houghton, ME	1964–74	1964–74	—	—	—	44.8320013	−70.70173588
01052500	Diamond River near Wentworth Location, NH	1942–2019	1942–2019	—	—	—	44.8775	−71.0575
01054135	Unnamed Brook near Gilead, ME	2000–16	2000–16	—	—	—	44.385	−71.0136111
01054200	Wild River at Gilead, ME	1960–2018	1960–2018	—	—	—	44.39055556	−70.9797222
01054300	Ellis River at South Andover, ME	1964–2019	1964–82; 2001–19	—	—	—	44.5933333	−70.7330556
01054500	Androscoggin River at Rumford, ME	1870–2018	1893–2018	1870–92	55,200	x	44.5519444	−70.5441667
01055000	Swift River near Roxbury, ME	1930–2019	1930–2019	—	—	—	44.64277778	−70.58888889
01055300	Bog Brook near Buckfield, ME	1964–74	1964–74	—	—	—	44.2659029	−70.3156125
01055500	Nezinscot River at Turner Center, ME	1914–2018	1942–2018	1914–41, 1997–2001	13,900	—	44.26944444	−70.2297222
01057000	Little Androscoggin River near South Paris, ME	1897–2018	1914–2018	1897–1913, 1924–31	7,810	—	44.30388889	−70.5397222
01058500	Little Androscoggin River near Auburn, ME	1936–82	1941–82	1936–40	15,800	—	44.0638722	−70.2740694
01059000	Androscoggin River near Auburn, ME	1814–2018	1929–2018	1814–1928	95,800	x	44.0722222	−70.2080556
01059800	Collyer Brook near Gray, ME	1965–2000	1965–82; 1999–2000[9]	—	—	—	43.91789444	−70.3165972
01059845	Unnamed Brook at Gray, ME	2006–16	2006–16	—	—	—	43.86638889	−70.2797222
01060000	Royal River at Yarmouth, ME	1950–18	1950–2004	2005–17	11,500	—	43.79915	−70.1782694
01060070	Chenery Brook near Cumberland, ME	2006–17	2006–17	—	—	—	43.7636111	−70.21138889
01062700	Patte Brook near Bethel, ME	1965–74	1965–74	—	—	—	44.34478856	−70.791735
01063310	Stony Brook at East Sebago, ME	1996–2018	1996–2018	—	—	—	43.85555556	−70.6397222
01064000	Presumpscot River at Outlet of Sebago Lake, ME	1887–2000	1887–88; 1892; 1894–2000	—	—	x	43.81752778	−70.4499361

Table 1.2. Summary of data used in the frequency analyses of annual peak-flow data for streamgages in and near Maine.—Continued

[NAD 83, North American Datum of 1983; ME, Maine; NH, New Hampshire; —, not applicable]

Streamgage number	Streamgage name	Analysis period, water years[1]	Systematic record, water years[2]	Historical period perception thresholds		Regulated streamgage that was not used to develop regression equation	Latitude, decimal degrees referenced to NAD 83	Longitude, decimal degrees referenced to NAD 83
				Water years	Discharge, cubic feet per second			
01064118	Presumpscot River at Westbrook, ME	1976–2018	1976–95, 1997, 2017–18	1996–2016	23,300	x	43.68694444	−70.3472222
01064200	Mill Brook near Old Orchard Beach, ME	1965–74	1965–74	—	—	—	43.5445281	−70.3914389
01064300	Ellis River near Jackson, NH	1964–2004	1964–2004	—	—	—	44.2189557	−71.2492401
01064380	East branch Saco River at Town Hall Road, near Lower Bartlett, NH	1967–76	1967–76	—	—	—	44.1217349	−71.13007159
01064400	Lucy Brook near North Conway, NH	1965–92	1965–92	—	—	—	44.070347	−71.17284918
01064500	Saco River near Conway, NH	1904–2019	1904–09; 1930–2019	—	—	—	43.9908333	−71.0905556
01064800	Cold Brook at South Tamworth, NH	1964–73	1964–73	—	—	—	43.8159075	−71.29673778
01064801	Bearcamp River at South Tamworth, NH	1993–2018	1993–2018	—	—	—	43.83007396	−71.2878488
01065000	Ossipee River at Effingham Falls, NH	1937–96	1943–90	1937–1942, 1991–1996	5,960	—	43.79507526	−71.059234
01065500	Ossipee River at Cornish, ME	1917–96	1917–96	—	—	—	43.8077083	−70.79757778
01066000	Saco River at Cornish, ME	1786–2019	1917–2019	1786–1916	42,400	—	43.80805556	−70.7816667
01066100	Pease Brook near Cornish, ME	1965–97	1965–97	—	—	—	43.78757778	−70.765525
01066500	Little Ossipee River near south Limington, ME	1937–2018	1941–82	1936–1940, 1983–2018	8,530, 8,220	—	43.6894361	−70.6705556
01067000	Saco River at West Buxton, ME	1786–2018	1908–48	1786–1907, 1917–1919, 1949–2018	58,200	—	43.66591667	−70.6027444
01067950	Kennebunk River near Kennebunk, ME	2008–18	2008–18	—	—	—	43.4322222	−70.5533333
01068910	Mousam River at Route 4 near Sanford, ME	2007–18	2007, 2009–18	2007–2008	2,400	x	43.4183333	−70.7380556
01069500	Mousam River near West Kennebunk, ME	1940–2018	1940–84, 2009–18	1985–2008	6,100	x	43.4183333	−70.6583333
01069700	Branch Brook near Kennebunk, ME	1965–2018	1965–2018	1975–1991, 1992–2008	1,330, 1,020	—	43.37916667	−70.5833333
01072500	Salmon Falls River near South Lebanon, ME	1930–76	1930–69	1970–1976	5,490	x	43.3281083	−70.92713889
01072800	Cocheco River near Rochester, NH	1996–2018	1996–2018	—	—	—	43.26841527	−70.9736739
01072850	Mohawk Brook near center Strafford, NH	1965–2006	1965–2006	—	—	—	43.2631369	−71.09673079

Table 1.2. Summary of data used in the frequency analyses of annual peak-flow data for streamgages in and near Maine.—Continued

[NAD 83, North American Datum of 1983; ME, Maine; NH, New Hampshire; —, not applicable]

Streamgage number	Streamgage name	Analysis period, water years[1]	Systematic record, water years[2]	Historical period perception thresholds: Water years	Historical period perception thresholds: Discharge, cubic feet per second	Regulated streamgage that was not used to develop regression equation	Latitude, decimal degrees referenced to NAD 83	Longitude, decimal degrees referenced to NAD 83
01072870	Isinglass River at Rochester Neck Road, near Dover, NH	2003–18	2003–18	—	—	—	43.23480487	−70.9564507
01073000	Oyster River near Durham, NH	1935–2018	1935–2018	—	—	—	43.1486955	−70.9650603
01073600	Dudley Brook near Exeter, NH	1963–2018	1963–85	1986–2017	660	—	42.99314276	−71.02172508
01073785	Winnicut River at Greenland, near Portsmouth, NH	2003–18	2003–18	—	—	—	43.0358333	−70.8475
01130000	Upper Ammonoosuc River near Groveton, NH	1936–2018	1936–68; 1970–80; 1983–2004; 2010–18	—	—	—	44.62505316	−71.4689721
010735562	Exeter River at Odell Road, near Sandown, NH	2009–18	2009–18	—	—	—	42.94897557	−71.16478279
01AF009	Iroquois River at Moulin Morneault, New Brunswick, Canada	1991–2017	1991–93; 1995–2017	—	—	—	—	1994
01AJ003	Meduxnekeag River near Belleville, New Brunswick, Canada	1967–2016	1967–68; 1970–85; 1987–95; 1997; 1999–2016	—	—	—	—	1969, 1986, 1996, 1998
01AJ004	Big Presque Isle Stream at Tracey Mills, New Brunswick, Canada	1967–2017	1967–2017	—	—	—	—	—
01AJ010	Becaguimec Stream at Coldstream, New Brunswick, Canada	1973–2017	1973–77; 1979–2000; 2002–17	—	—	—	—	1978, 2001

[1]Analysis period includes relevant historical information (information outside of the period of systematic data collection at or near a streamgage).

[2]Note that systematic record includes only systematic record that was used in analyses. In some cases, regulation regime changed and earlier systematic data not used.

[3]This streamgage, 01011500. St. Francis River near Connors, New Brunswick is in Canada but operated by the U.S. Geological Survey.

[4]Systematic peaks from 1929 to 1970 had different regulation and were not used in the analyses.

[5]Systematic peaks from 1983 to 2009 and from 2013 to 2014 had different regulation and were included only as a historical period. No information was available for 2010–12.

[6]Systematic peaks from 1904 to 1950 had different regulation and were not used.

[7]Systematic peaks from 1908 to 1909 and from 1931 to 1950 had different regulation and were included only as a historical period. No information was available for 1910–30.

[8]Systematic peaks from 1893 to 1902 had different regulation and were not used.

[9]The 1997 historical peak is treated as missing because it does not give any additional information about other peaks.

Table 1.3. Streamgages evaluated for development of the regional skew used for estimating peak-flow frequency in Maine.

[mi^2, square mile; ME, Maine; NH, New Hampshire]

Streamgage number	Streamgage name	Drainage area, mi^2	[1]Pseudorecord length, in years	[2]Unbiased skew	Mean square error of skew
01010000	St. John River at Ninemile Bridge, ME	1,340	70	−0.638	0.1182
01010070	Big Black River near Depot Mountain, ME	193	34	−0.527	0.193
01011000	Allagash River near Allagash, ME	1,230	86	−0.085	0.0659
01011500	St. Francis River near Connors, New Brunswick, Canada[3]	527	65	0.22	0.0933
01013500	Fish River near Fort Kent, ME	867	93	−0.033	0.059
01014000	St. John River below Fish River, near Fort Kent, ME	5,680	120	−0.112	0.065
01016500	Machias River near Ashland, ME	328	32	0.079	0.1628
01017000	Aroostook River at Washburn, ME	1,650	87	−0.397	0.0824
01018000	Meduxnekeag River near Houlton, ME	173	54	−0.142	0.1047
01021500	Machias River at Whitneyville, ME	457	71	0.328	0.093
01022000	East Machias River near East Machias, ME	252	32	−0.056	0.161
01022500	Narraguagus River at Cherryfield, ME	227	70	0.006	0.0754
01023000	West Branch Union River at Amherst, ME	147	60	0.175	0.0973
01029200	Seboeis River near Shin Pond, ME	173	20	1.015	0.3812
01030500	Mattawamkeag River near Mattawamkeag, ME	1,420	115	0.09	0.0507
01031300	Piscataquis River at Blanchard, ME	115	21	−0.375	0.2682
01031450	Kingsbury Stream at Abbot Village, ME	95.2	20	−0.093	0.2522
01031500	Piscataquis River near Dover-Foxcroft, ME	297	123	−0.038	0.0489
01033500	Pleasant River near Milo, ME	323	65	0.345	0.1058
01035000	Passadumkeag River at Lowell, ME	298	64	0.323	0.1014
01036500	Kenduskeag Stream near Kenduskeag, ME	177	49	−0.509	0.1514
01038000	Sheepscot River at North Whitefield, ME	146	79	0.666	0.1084
01046000	Austin Stream at Bingham, ME	90.4	47	0.225	0.1246
01047000	Carrabassett River near North Anson, ME	352	92	−0.149	0.0651
01048000	Sandy River near Mercer, ME	516	110	−0.252	0.081
01049000	Sebasticook River near Pittsfield, ME	578	85	−0.102	0.0675
01049300	North Branch Tanning Brook near Manchester, ME	1.13	20	0.529	0.2957
01052500	Diamond River near Wentworth Location, NH	153	76	−0.153	0.0775
01054200	Wild River at Gilead, ME	69.9	53	−0.421	0.1265
01054300	Ellis River at South Andover, ME	131	36	−0.489	0.1807
01055000	Swift River near Roxbury, ME	96.4	88	−0.842	0.1138

Table 1.3. Streamgages evaluated for development of the regional skew used for estimating peak-flow frequency in Maine.—Continued

[mi^2, square mile; ME, Maine; NH, New Hampshire]

Streamgage number	Streamgage name	Drainage area, mi^2	[1]Pseudorecord length, in years	[2]Unbiased skew	Mean square error of skew
01055500	Nezinscot River at Turner Center, ME	170	99	0.302	0.0882
01057000	Little Androscoggin River near South Paris, ME	73.9	120	−0.131	0.0626
01058500	Little Androscoggin River near Auburn, ME	329	47	0.672	0.2106
01059800	Collyer Brook near Gray, ME	14.2	20	−0.728	0.3177
01060000	Royal River at Yarmouth, ME	142	59	0.061	0.0964
01063310	Stony Brook at East Sebago, ME	1.3	22	0.629	0.2847
01064300	Ellis River near Jackson, NH	10.5	41	−0.467	0.1606
01064400	Lucy Brook near North Conway, NH	4.71	28	−0.139	0.1892
01064801	Bearcamp River at South Tamworth, NH	67.5	25	−0.107	0.2068
01066000	Saco River at Cornish, ME	1,290	126	0.043	0.0534
01066500	Little Ossipee River near south Limington, ME	166	52	0.344	0.1467
01069700	Branch Brook near Kennebunk, ME	9.17	24	0.605	0.3035
01072800	Cocheco River near Rochester, NH	80.2	22	0.742	0.2976
01073000	Oyster River near Durham, NH	12.2	83	0.305	0.08
01073600	Dudley Brook near Exeter, NH	5.14	25	−0.124	0.2395
01130000	Upper Ammonoosuc River near Groveton, NH	230	70	−0.194	0.0869
01AF009	Iroquois River at Moulin Morneault, New Brunswick, Canada	70.8	24	1.635	0.5771
01AJ003	Meduxnekeag River near Belleville, New Brunswick, Canada	472	45	0.095	0.1202
01AJ004	Big Presque Isle Stream at Tracey Mills, New Brunswick, Canada	188	49	0.407	0.1339
01AJ010	Becaguimec Stream at Coldstream, New Brunswick, Canada	134	41	0.288	0.1455

[1]The pseudorecord length takes the systematic record and the historical period into account and weights them appropriately.

[2]Skew values were unbiased using the pseudorecord length.

[3]This streamgage, 01011500, St. Francis River near Connors, New Brunswick, is in Canada but operated by the U.S. Geological Survey.

Table 1.4. Peak flows for selected annual exceedance probabilities for selected streamgages in and near Maine.

[The table is available for download at https://doi.org/10.3133/sir20205092.]

Table 1.5. Maximum recorded annual peak flow at streamgages in and near Maine used to develop the regression equations.

[All streamgages are shown in figure 1. mi^2, square mile; ft^3/s, cubic foot per second; ME, Maine; NH, New Hampshire; —, not applicable]

Streamgage number	Streamgage name	[1]Drainage area (mi^2)	Maximum recorded peak		[2]Analysis period, water years
			Date	Discharge (ft^3/s)	
01010000	St. John River at Ninemile Bridge, ME	1,340	2019	47,700	1948–2019
01010070	Big Black River near Depot Mountain, ME	193	4/1/1987	8,680	1984–2018
01010500	St. John River at Dickey, ME	2,690	4/30/2008	104,000	1943–2019
01011000	Allagash River near Allagash, ME	1,230	4/30/2008	40,900	1932–2019
01011500	St. Francis River near Connors, New Brunswick, Canada[3]	527	5/1/2018	18,700	1952–2016
01012895	Clark Brook near Wallagrass Plantation, ME	1.12	4/29/2008	74	2001–17
01012970	Unnamed Brook near Wallagrass Plantation, ME	0.38	2003	71	2001–16
01013500	Fish River near Fort Kent, ME	867	4/30/2008	18,300	1904–2019
01014000	St. John River below Fish River, near Fort Kent, ME	5,680	4/30/2008	183,000	1897–2019
01014700	Factory Brook near Madawaska, ME	5.83	5/2/1974	281	1964–74
01015700	Houlton Brook near Oxbow, ME	6.14	4/29/1973	236	1964–74
01015800	Aroostook River near Masardis, ME	895	5/1/2008	29,500	1958–2019
01016500	Machias River near Ashland, ME	328	6/29/1954	16,600	1952–83
01017000	Aroostook River at Washburn, ME	1,650	5/1/2008	49,500	1931–2019
01017060	Hardwood Brook below Glidden Brook near Caribou, ME	5.7	4/20/2019	544.0	2009–19
01017290	Little Madawaska River at Caribou, ME	234	4/27/2018	9,520	2009–19
01017300	Nichols Brook near Caribou, ME	3.87	10/3/1970	281	1964–74
01017550	Williams Brook at Phair, ME	3.97	4/15/2014	364	2000–19
01017900	Marley Brook near Ludlow, ME	1.59	7/5/1973	335	1965–82
01017960	Meduxnekeag River above south branch Meduxnekeag River near Houlton, ME	87.4	12/14/2010	4,760	2004–18
01018000	Meduxnekeag River near Houlton, ME	173	12/14/2010	7,160	1941–2015
01018009	Pearce Brook at Route 1 at Houlton, ME	6.93	12/14/2010	532	2009–18
01018035	Meduxnekeag River at Lowery Road near Houlton, ME	256	12/14/2010	10,800	2006–18
01018500	St. Croix River at Vanceboro, ME	412	6/3/1984	6,730	1971–2018
01019000	Grand Lake Stream at Grand Lake Stream, ME	228	12/2/2005	3,990	1929–2018
01021000	St. Croix River at Baring, ME	1,370	5/1/1923	24,100	1923–2018
01021200	Dennys River at Dennysville, ME	92.3	12/13/2010	5,390	1956–2012
01021300	Wiggins Brook near West Lubec, ME	5.02	12/12/1967	779	1965–74
01021470	Libby Brook near Northfield, ME	6.42	3/29/2005	302	2001–17
01021480	Old Stream near Wesley, ME	30	12/14/2010	1,710	1999–2018
01021500	Machias River at Whitneyville, ME	457	5/29/1961	14,800	1906–2008

Table 1.5. Maximum recorded annual peak flow at streamgages in and near Maine used to develop the regression equations.—Continued

[All streamgages are shown in figure 1. mi^2, square mile; ft^3/s, cubic foot per second; ME, Maine; NH, New Hampshire; —, not applicable]

Streamgage number	Streamgage name	[1]Drainage area (mi^2)	Maximum recorded peak		[2]Analysis period, water years
			Date	Discharge (ft^3/s)	
01021600	Middle River near Machias, ME	8.12	4/2/1970	302	1965–74
01021890	Unnamed Brook near Crawford, ME	0.83	7/26/2013	106	2001–17
01022000	East Machias River near East Machias, ME	252	12/15/1950	3,660	1927–58
01022260	Pleasant River near Epping, ME	62.1	4/18/2007	1,450	1981–2008
01022500	Narraguagus River at Cherryfield, ME	227	5/28/1961	10,400	1948–2018
01022700	Forbes Pond Brook near Prospect Harbor, ME	8.54	4/2/1970	402	1965–74
01022840	Otter Creek near Bar Harbor, ME	1.36	9/7/2008	806	2007–18
01023000	West Branch Union River at Amherst, ME	147	5/25/1979	4,220	1909–79
01024200	Garland Brook near Mariaville, ME	10.5	12/27/1969	1,230.0	1965–82
01026800	Frost Pond Brook near Sedgwick, ME	6.26	2/4/1970	350	1965–74
01027200	North Branch Penobscot River near Pittston Farm, ME	224	4/30/2018	10,300	2002–19
01028000	West Branch Penobscot River near Medway, ME	2,130	6/16/1917	25,900	1917–39
01029200	Seboeis River near Shin Pond, ME	173	4/30/2008	6,350	1998–2019
01029500	East Branch Penobscot River at Grindstone, ME	1,090	4/30/1923	37,000	1903–2018
01030000	Penobscot River near Mattawamkeag, ME	3,350	4/29/1973	66,000	1941–91
01030300	Trout Brook near Danforth, ME	4.18	4/25/1970	354	1964–73
01030350	Wytopitlock Stream near Wytopitlock, ME	49	4/16/2014	1,490	2009–18
01030400	Gulliver Brook near Monarda, ME	11.4	7/5/1973	562	1964–74
01030500	Mattawamkeag River near Mattawamkeag, ME	1,420	5/1/1923	46,600	1903–2019
01031300	Piscataquis River at Blanchard, ME	115	4/9/2000	7,550	1997–2018
01031450	Kingsbury Stream at Abbot Village, ME	95.2	12/13/2010	7,750	1998–2018
01031470	Brewster Brook near Parkman, ME	0.54	8/21/2015	194	2000–16
01031500	Piscataquis River near Dover-Foxcroft, ME	297	4/1/1987	37,300	1903–2018
01031510	Black Stream near Dover-Foxcroft, ME	26.4	4/16/2014	1,040	2009–18
01031600	Morrison Brook near Sebec Corners, ME	4.1	11/3/1966	575	1965–77
01033000	Sebec River at Sebec, ME	325	3/20/1936	14,300	1925–93
01033500	Pleasant River near Milo, ME	323	11/4/1966	28,600	1921–2018
01034000	Piscataquis River at Medford, ME	1,160	4/1/1987	85,000	1925–2018
01034500	Penobscot River at West Enfield, ME	6,670	5/1/1923	153,000	1902–2018
01034900	Coffin Brook near Lee, ME	2.15	12/27/1969	143	1964–74
01035000	Passadumkeag River at Lowell, ME	298	5/2/1923	5,680	1916–79

Table 1.5. Maximum recorded annual peak flow at streamgages in and near Maine used to develop the regression equations.—Continued

[All streamgages are shown in figure 1. mi^2, square mile; ft^3/s, cubic foot per second; ME, Maine; NH, New Hampshire; —, not applicable]

Streamgage number	Streamgage name	[1]Drainage area (mi^2)	Maximum recorded peak		[2]Analysis period, water years
			Date	Discharge (ft^3/s)	
01036380	Unnamed Brook near Bradley, ME	0.75	9/30/2015	96	2000–16
01036500	Kenduskeag Stream near Kenduskeag, ME	177	4/1/1987	7,400	1909–87
01037000	Kenduskeag Stream near Bangor, ME	195	4/15/1909	6,300	1909–2018
01037200	Shaw Brook near Northern Maine Junction, ME	2.87	12/27/1969	598	1964–74
01037380	Ducktrap River near Lincolnville, ME	15.1	4/7/2009	1,680	1999–2018
01037430	Goose River at Rockport, ME	8.47	3/23/1972	624	1964–74
01038000	Sheepscot River at North Whitefield, ME	146	4/1/1987	7,350	1939–2018
01041000	Kennebec River at Moosehead, ME	1,270	5/3/74, 9/25/81	16,700	1920–82
01041900	Mountain Brook near Lake Parlin, ME	3.49	7/5/1973	918	1964–74
01042500	Kennebec River at The Forks, ME	1,590	4/18/1983	32,900	1902–2018
01043500	Dead River near Dead River, ME	519	9/12/1954	18,000.0	1940–2018
01044550	Spencer Stream near Grand Falls, ME	198	4/30/2008	7,470	2000–19
01045000	Dead River at the Forks, ME	869	3/20/1936, 5/14/1912	28,700	1951–79
01046000	Austin Stream at Bingham, ME	90.4	11/3/1966	8,280	1932–2018
01046500	Kennebec River at Bingham, ME	2,720	6/1/1984	65,200	1908–2018
01046800	South Branch Carrabassett River at Bigelow, ME	13.4	11/6/1969	1,620	1964–74
01047000	Carrabassett River near North Anson, ME	352	4/1/1987	50,700	1926–2018
01047200	Sandy River near Madrid, ME	25.1	8/28/2011	5,210	2009–18
01047860	Unnamed Brook near New Sharon, ME	0.46	2000	99	2000–16
01048000	Sandy River near Mercer, ME	516	4/1/1987	51,100	1929–2019
01048100	Pelton Brook near Anson, ME	14.4	12/21/1973	2,080	1965–74
01048220	East Branch Wesserunsett Stream near Athens, ME	19.6	12/13/2010	1,430	2009–18
01048500	Kennebec River at Waterville, ME	4,230	12/16/1901	157,000	1893–1955
01048840	Unnamed Brook near Newport, ME	0.36	9/30/2015	37.1	2000–16
01049000	Sebasticook River near Pittsfield, ME	578	4/3/1987	17,600	1929–2013
01049100	Hall Brook at Thorndike, ME	5.02	12/27/1969	933	1964–74
01049130	Johnson Brook at South Albion, ME	2.78	4/1/1987	178	1981–91
01049180	Unnamed Brook near Albion, ME	0.46	2006	35	2000–16
01049265	Kennebec River at North Sidney, ME	5,410	4/2/1987	232,000	1979–2018
01049300	North Branch Tanning Brook near Manchester, ME	1.13	12/17/1973	195.0	1964–83
01049373	Mill Stream at Winthrop, ME	32.4	4/2/1987	1,330	1978–92

Table 1.5. Maximum recorded annual peak flow at streamgages in and near Maine used to develop the regression equations.—Continued

[All streamgages are shown in figure 1. mi², square mile; ft³/s, cubic foot per second; ME, Maine; NH, New Hampshire; —, not applicable]

Streamgage number	Streamgage name	[1]Drainage area (mi²)	Maximum recorded peak		[2]Analysis period, water years
			Date	Discharge (ft³/s)	
01049500	Cobbosseecontee Stream at Gardiner, ME	217	3/21/1936	5,020	1891–2018
01049550	Togus Stream at Togus, ME	23.8	4/1/1987	1,010	1982–95
01049690	Unnamed Brook near Dresden, ME	0.42	2001	218	2000–16
01049700	Gardiner Pond Brook at Dresden Mills, ME	8.02	12/17/1973	456	1965–74
01050490	Unnamed Brook near Rangeley, ME	0.42	5/27/2011	81	2001–17
01050900	Four Ponds Brook near Houghton, ME	3.15	7/30/1969	349	1964–74
01052500	Diamond River near Wentworth Location, NH	153	3/31/1998	12,800	1942–2019
01054135	Unnamed Brook near Gilead, ME	0.26	7/11/2007	58	2000–16
01054200	Wild River at Gilead, ME	69.9	8/28/2011	37,800	1965–2018
01054300	Ellis River at South Andover, ME	131	12/18/2003	7,830	1964–2019
01054500	Androscoggin River at Rumford, ME	2,070	3/20/1936	74,000	1893–2018
01055000	Swift River near Roxbury, ME	96.4	10/24/1959	16,800	1930–2019
01055300	Bog Brook near Buckfield, ME	10.3	2/11/1970	289	1964–74
01055500	Nezinscot River at Turner Center, ME	170	3/27/1953	13,900	1942–2018
01057000	Little Androscoggin River near South Paris, ME	73.9	4/1/1987	9,340	1914–2018
01058500	Little Androscoggin River near Auburn, ME	329	3/28/1953	16,500	1936–82
01059000	Androscoggin River near Auburn, ME	3,270	3/20/1936	135,000	1929–2018
01059800	Collyer Brook near Gray, ME	14.2	12/27/1969	1,220	1965–2000
01059845	Unnamed Brook at Gray, ME	0.52	2007	107	2006–16
01060000	Royal River at Yarmouth, ME	142	3/13/1977	11,500	1950–2018
01060070	Chenery Brook near Cumberland, ME	0.6	8/13/2014	217	2006–17
01062700	Patte Brook near Bethel, ME	5.71	7/1/1973	664	1965–74
01063310	Stony Brook at East Sebago, ME	1.3	9/17/1999	130	1996–2018
01064000	Presumpscot River at Outlet of Sebago Lake, ME	444	4/7/1902	7,000	1887–2000
01064118	Presumpscot River at Westbrook, ME	577	10/22/1996	23,300	1976–2018
01064200	Mill Brook near Old Orchard Beach, ME	2.46	4/2/1973	208	1965–74
01064300	Ellis River near Jackson, NH	10.5	11/3/1966	4,500	1964–2004
01064380	East branch Saco River at Town Hall Road, near Lower Bartlett, NH	34.2	4/25/1968	4,610	1967–76
01064400	Lucy Brook near North Conway, NH	4.71	8/11/1990	2,660	1965–92
01064500	Saco River near Conway, NH	385	8/29/2011	58,200	1904–2019
01064800	Cold Brook at South Tamworth, NH	5.46	7/4/1973	2,800	1964–73

Table 1.5. Maximum recorded annual peak flow at streamgages in and near Maine used to develop the regression equations.—Continued

[All streamgages are shown in figure 1. mi^2, square mile; ft^3/s, cubic foot per second; ME, Maine; NH, New Hampshire; —, not applicable]

Streamgage number	Streamgage name	[1]Drainage area (mi^2)	Maximum recorded peak		[2]Analysis period, water years
			Date	Discharge (ft^3/s)	
01064801	Bearcamp River at South Tamworth, NH	67.5	6/14/1998	6,150	1993–2018
01065000	Ossipee River at Effingham Falls, NH	330	3/28/1953	11,700	1943–90
01065500	Ossipee River at Cornish, ME	451	3/21/1936	17,200	1917–96
01066000	Saco River at Cornish, ME	1,290	3/21/1936	46,600	1917–2019
01066100	Pease Brook near Cornish, ME	4.69	4/23/1969	486	1965–97
01066500	Little Ossipee River near south Limington, ME	166	3/19/1936	8,530	1937–2018
01067000	Saco River at West Buxton, ME	1,570	3/22/1936	58,200	1908–48
01067950	Kennebunk River near Kennebunk, ME	26.1	2/26/2010	2,960	2008–18
01068910	Mousam River at Route 4 near Sanford, ME	45	4/1/2007	2,400	2007–18
01069500	Mousam River near West Kennebunk, ME	98.5	4/1/2007	9,230	1940–2018
01069700	Branch Brook near Kennebunk, ME	9.17	5/1/2006	1,500	1965–2018
01072500	Salmon Falls River near South Lebanon, ME	139	3/19/1936	5,490	1930–69
01072800	Cocheco River near Rochester, NH	80.2	4/16/2007	7,240	1996–2018
01072850	Mohawk Brook near center Strafford, NH	7.44	5/14/2006	2,370	1965–2006
01072870	Isinglass River at Rochester Neck Road, near Dover, NH	74.6	4/17/2007	6,160.0	2003–18
01073000	Oyster River near Durham, NH	12.2	4/16/2007	1,320	1935–2018
01073600	Dudley Brook near Exeter, NH	5.14	5/14/2006	660	1963–2018
01073785	Winnicut River at Greenland, near Portsmouth, NH	14.2	2/26/2010	1,700	2003–18
01130000	Upper Ammonoosuc River near Groveton, NH	230	5/20/1969	24,100	1936–2018
010735562	Exeter River at Odell Road, near Sandown, NH	16.4	2/26/2010	822	2009–18
01AF009	Iroquois River at Moulin Morneault, New Brunswick, Canada	71	2008	5,014.7	1991–2017
01AJ003	Meduxnekeag River near Belleville, New Brunswick, Canada	472	2010	29,099	1967–2016
01AJ004	Big Presque Isle Stream at Tracey Mills, New Brunswick, Canada	188	1973	9,923	1967–2017
01AJ010	Becaguimec Stream at Coldstream, New Brunswick, Canada	134	2010	12,420	1973–2017

[1]Drainage area determined from a geographical information system and digital datasets and may not match previously published drainage area.

[2]Analysis period includes relevant historical information (information outside of the period of systematic data collection at or near a streamgage).

[3]This streamgage, 01011500, St. Francis River near Connors, New Brunswick, is in Canada but operated by the U.S. Geological Survey.

Table 1.6. Basin characteristics used to develop the final regression equations.

[mi^2, square mile; RI, recurrence interval; ME, Maine; NH, New Hampshire]

Streamgage number	Streamgage name	Drainage area (mi^2)	[1]Area of wetlands (percent)	[2]24-hour rainfall (basinwide mean in inches)							
				2-year RI	5-year RI	10-year RI	25-year RI	50-year RI	100-year RI	200-year RI	500-year RI
01010000	St. John River at Ninemile Bridge, ME	1,340	8.49	2.26	2.87	3.33	3.94	4.40	4.87	5.75	6.66
01010070	Big Black River near Depot Mountain, ME	193	2.06	2.04	2.71	3.16	3.74	4.16	4.59	5.78	6.77
01010500	St. John River at Dickey, ME	2,690	6.76	2.21	2.81	3.26	3.87	4.33	4.80	5.68	6.62
01011000	Allagash River near Allagash, ME	1,230	9.77	2.32	2.91	3.40	4.08	4.59	5.13	5.76	6.77
01011500	St. Francis River near Connors, New Brunswick, Canada[3]	527	3.95	2.02	2.57	2.97	3.48	3.87	4.26	5.63	6.53
01012895	Clark Brook near Wallagrass Plantation, ME	1.12	9.94	2.35	2.92	3.39	4.04	4.53	5.04	5.60	6.44
01012970	Unnamed Brook near Wallagrass Plantation, ME	0.38	1.79	2.36	2.93	3.40	4.05	4.54	5.05	5.61	6.45
01013500	Fish River near Fort Kent, ME	867	15.3	2.35	2.91	3.38	4.03	4.51	5.02	5.58	6.42
01014000	St. John River below Fish River, near Fort Kent, ME	5,680	8.33	2.23	2.82	3.28	3.90	4.37	4.85	5.67	6.60
01014700	Factory Brook near Madawaska, ME	5.83	2.45	2.33	2.88	3.33	3.95	4.43	4.92	5.44	6.20
01015700	Houlton Brook near Oxbow, ME	6.14	21.4	2.38	2.94	3.41	4.05	4.54	5.04	5.60	6.41
01015800	Aroostook River near Masardis, ME	895	14.5	2.51	3.10	3.60	4.28	4.80	5.33	5.93	6.81
01016500	Machias River near Ashland, ME	328	8.97	2.40	2.98	3.46	4.13	4.63	5.16	5.74	6.62
01017000	Aroostook River at Washburn, ME	1,650	12.5	2.44	3.02	3.50	4.17	4.67	5.19	5.78	6.63
01017060	Hardwood Brook below Glidden Brook near Caribou, ME	5.7	5.02	2.32	2.85	3.29	3.90	4.36	4.84	5.34	6.04
01017290	Little Madawaska River at Caribou, ME	234	11.6	2.34	2.89	3.34	3.97	4.44	4.93	5.46	6.22
01017300	Nichols Brook near Caribou, ME	3.87	7.45	2.33	2.89	3.34	3.97	4.45	4.94	5.46	6.21
01017550	Williams Brook at Phair, ME	3.97	21.4	2.28	2.80	3.24	3.84	4.29	4.76	5.26	5.95
01017900	Marley Brook near Ludlow, ME	1.59	1.52	2.57	3.17	3.66	4.33	4.84	5.37	5.93	6.74
01017960	Meduxnekeag River above south branch Meduxnekeag River near Houlton, ME	87.4	14.4	2.52	3.09	3.57	4.23	4.73	5.24	5.79	6.59
01018000	Meduxnekeag River near Houlton, ME	173	17.5	2.52	3.09	3.56	4.21	4.71	5.22	5.77	6.56
01018009	Pearce Brook at Route 1 at Houlton, ME	6.93	14.6	2.44	3.00	3.46	4.09	4.58	5.07	5.61	6.38
01018035	Meduxnekeag River at Lowery Road near Houlton, ME	256	15.4	2.50	3.07	3.54	4.19	4.69	5.19	5.75	6.53
01021300	Wiggins Brook near West Lubec, ME	5.02	12.6	3.07	3.76	4.33	5.12	5.72	6.33	6.99	7.96
01021470	Libby Brook near Northfield, ME	6.42	14.1	3.23	3.97	4.59	5.43	6.08	6.74	7.46	8.50
01021480	Old Stream near Wesley, ME	30.0	12.1	3.05	3.74	4.31	5.10	5.70	6.31	6.98	7.92
01021500	Machias River at Whitneyville, ME	457	15.9	3.05	3.73	4.31	5.10	5.70	6.31	6.98	7.93
01021600	Middle River near Machias, ME	8.12	14.4	3.34	4.09	4.72	5.59	6.25	6.92	7.66	8.72

Table 1.6. Basin characteristics used to develop the final regression equations.—Continued

[mi^2, square mile; RI, recurrence interval; ME, Maine; NH, New Hampshire]

Streamgage number	Streamgage name	Drainage area (mi^2)	[1]Area of wetlands (percent)	[2]24-hour rainfall (basinwide mean in inches)							
				2-year RI	5-year RI	10-year RI	25-year RI	50-year RI	100-year RI	200-year RI	500-year RI
01021890	Unnamed Brook near Crawford, ME	0.83	4.92	3.01	3.69	4.25	5.02	5.61	6.21	6.86	7.81
01022000	East Machias River near East Machias, ME	252	21.9	3.09	3.78	4.36	5.15	5.75	6.37	7.05	8.01
01022260	Pleasant River near Epping, ME	62.1	29.4	3.17	3.89	4.50	5.33	5.96	6.61	7.32	8.32
01022500	Narraguagus River at Cherryfield, ME	227	15.0	3.10	3.81	4.39	5.21	5.82	6.46	7.14	8.10
01022700	Forbes Pond Brook near Prospect Harbor, ME	8.54	20.7	3.42	4.21	4.87	5.78	6.48	7.19	7.95	9.01
01022840	Otter Creek near Bar Harbor, ME	1.36	5.91	3.60	4.45	5.15	6.12	6.86	7.60	8.38	9.45
01023000	West Branch Union River at Amherst, ME	147	19.4	2.86	3.50	4.03	4.77	5.33	5.90	6.51	7.36
01024200	Garland Brook near Mariaville, ME	10.5	7.18	2.93	3.59	4.15	4.91	5.49	6.08	6.72	7.60
01026800	Frost Pond Brook near Sedgwick, ME	6.26	18.0	3.26	4.04	4.69	5.59	6.27	6.98	7.79	8.97
01027200	North Branch Penobscot River near Pittston Farm, ME	224	8.80	2.50	3.07	3.54	4.18	4.67	5.18	5.74	6.56
01029200	Seboeis River near Shin Pond, ME	173	20.3	2.78	3.42	3.95	4.68	5.24	5.82	6.46	7.37
01030300	Trout Brook near Danforth, ME	4.18	15.0	2.57	3.14	3.60	4.24	4.73	5.23	5.77	6.56
01030350	Wytopitlock Stream near Wytopitlock, ME	49	18.8	2.67	3.27	3.78	4.47	4.99	5.53	6.11	6.94
01030400	Gulliver Brook near Monarda, ME	11.4	18.9	2.70	3.32	3.83	4.54	5.07	5.62	6.21	7.06
01030500	Mattawamkeag River near Mattawamkeag, ME	1,420	19.2	2.68	3.28	3.78	4.47	5.00	5.54	6.12	6.96
01031300	Piscataquis River at Blanchard, ME	115	10.2	3.00	3.69	4.27	5.06	5.66	6.28	6.96	7.93
01031450	Kingsbury Stream at Abbot Village, ME	95.2	8.43	3.01	3.68	4.24	5.01	5.59	6.19	6.81	7.70
01031470	Brewster Brook near Parkman, ME	0.54	2.67	2.88	3.52	4.06	4.79	5.35	5.92	6.52	7.36
01031500	Piscataquis River near Dover-Foxcroft, ME	297	9.18	2.99	3.66	4.22	5.00	5.58	6.19	6.83	7.74
01031510	Black Stream near Dover-Foxcroft, ME	26.4	22.3	2.82	3.45	3.98	4.71	5.27	5.84	6.44	7.29
01031600	Morrison Brook near Sebec Corners, ME	4.1	9.77	2.83	3.48	4.01	4.74	5.30	5.87	6.47	7.32
01033500	Pleasant River near Milo, ME	323	10.2	2.91	3.59	4.15	4.93	5.52	6.12	6.78	7.75
01034000	Piscataquis River at Medford, ME	1,160	12.5	2.90	3.57	4.12	4.89	5.46	6.06	6.70	7.62
01034900	Coffin Brook near Lee, ME	2.15	14.9	2.74	3.36	3.87	4.58	5.13	5.68	6.27	7.10
01035000	Passadumkeag River at Lowell, ME	298	23.5	2.78	3.40	3.92	4.64	5.19	5.75	6.34	7.17
01036380	Unnamed Brook near Bradley, ME	0.75	14.1	2.74	3.34	3.84	4.53	5.05	5.58	6.13	6.88
01036500	Kenduskeag Stream near Kenduskeag, ME	177	12.4	2.77	3.39	3.91	4.62	5.16	5.72	6.30	7.12
01037000	Kenduskeag Stream near Bangor, ME	195	12.4	2.77	3.39	3.91	4.62	5.16	5.71	6.29	7.11
01037200	Shaw Brook near Northern Maine Junction, ME	2.87	4.48	2.71	3.31	3.81	4.50	5.02	5.56	6.12	6.90
01037380	Ducktrap River near Lincolnville, ME	15.1	12.8	3.25	4.06	4.74	5.67	6.37	7.11	7.98	9.30

Table 1.6. Basin characteristics used to develop the final regression equations.—Continued

[mi^2, square mile; RI, recurrence interval; ME, Maine; NH, New Hampshire]

Streamgage number	Streamgage name	Drainage area (mi^2)	[1]Area of wetlands (percent)	[2]24-hour rainfall (basinwide mean in inches)							
				2-year RI	5-year RI	10-year RI	25-year RI	50-year RI	100-year RI	200-year RI	500-year RI
01037430	Goose River at Rockport, ME	8.47	7.01	3.59	4.54	5.32	6.41	7.21	8.07	9.11	10.76
01038000	Sheepscot River at North Whitefield, ME	146	18.0	3.04	3.81	4.44	5.31	5.97	6.65	7.44	8.64
01041900	Mountain Brook near Lake Parlin, ME	3.49	3.54	2.76	3.42	3.97	4.72	5.29	5.89	6.56	7.53
01044550	Spencer Stream near Grand Falls, ME	198	8.48	2.54	3.16	3.66	4.36	4.89	5.44	6.06	7.04
01046000	Austin Stream at Bingham, ME	90.4	9.50	3.04	3.71	4.28	5.05	5.65	6.25	6.90	7.81
01046800	South Branch Carrabassett River at Bigelow, ME	13.4	2.76	3.22	3.94	4.58	5.45	6.11	6.80	7.65	8.80
01047000	Carrabassett River near North Anson, ME	352	6.82	2.93	3.62	4.18	4.97	5.56	6.18	6.85	7.84
01047200	Sandy River near Madrid, ME	25.1	3.33	3.05	3.77	4.38	5.22	5.85	6.51	7.27	8.36
01047860	Unnamed Brook near New Sharon, ME	0.46	7.69	2.92	3.60	4.18	4.98	5.58	6.21	6.92	7.97
01048000	Sandy River near Mercer, ME	516	6.60	2.98	3.69	4.27	5.08	5.69	6.33	7.02	8.03
01048100	Pelton Brook near Anson, ME	14.4	4.19	2.75	3.39	3.93	4.67	5.23	5.81	6.46	7.39
01048220	East Branch Wesserunsett Stream near Athens, ME	19.6	6.59	2.91	3.56	4.10	4.84	5.40	5.98	6.60	7.46
01048840	Unnamed Brook near Newport, ME	0.36	5.92	2.70	3.31	3.82	4.53	5.06	5.61	6.20	7.03
01049000	Sebasticook River near Pittsfield, ME	578	16.7	2.78	3.41	3.94	4.66	5.21	5.77	6.38	7.24
01049100	Hall Brook at Thorndike, ME	5.02	4.04	2.93	3.62	4.20	5.00	5.60	6.22	6.93	7.95
01049130	Johnson Brook at South Albion, ME	2.78	13.1	3.00	3.73	4.33	5.16	5.79	6.44	7.18	8.25
01049180	Unnamed Brook near Albion, ME	0.46	3.40	2.96	3.67	4.26	5.07	5.69	6.33	7.05	8.14
01049300	North Branch Tanning Brook near Manchester, ME	1.13	8.47	2.90	3.64	4.25	5.09	5.72	6.38	7.14	8.31
01049373	Mill Stream at Winthrop, ME	32.4	16.8	2.94	3.68	4.29	5.14	5.78	6.45	7.21	8.37
01049550	Togus Stream at Togus, ME	23.8	28.5	2.96	3.71	4.33	5.19	5.83	6.51	7.28	8.48
01049690	Unnamed Brook near Dresden, ME	0.42	2.99	3.10	3.92	4.60	5.54	6.25	6.99	7.87	9.27
01049700	Gardiner Pond Brook at Dresden Mills, ME	8.02	20.8	3.14	3.97	4.67	5.63	6.34	7.11	8.00	9.42
01050490	Unnamed Brook near Rangeley, ME	0.42	0.00	2.34	2.93	3.42	4.09	4.59	5.13	5.74	6.72
01050900	Four Ponds Brook near Houghton, ME	3.15	21.0	2.89	3.60	4.18	4.99	5.60	6.24	6.97	8.08
01052500	Diamond River near Wentworth Location, NH	153	3.64	2.51	3.09	3.57	4.22	4.72	5.24	5.81	6.67
01054135	Unnamed Brook near Gilead, ME	0.26	0.455	2.86	3.54	4.10	4.87	5.45	6.05	6.69	7.64
01054200	Wild River at Gilead, ME	69.9	1.55	3.42	4.25	4.95	5.91	6.64	7.39	8.25	9.44
01054300	Ellis River at South Andover, ME	131	5.98	3.02	3.74	4.34	5.17	5.79	6.44	7.15	8.22
01055000	Swift River near Roxbury, ME	96.4	1.96	3.09	3.83	4.44	5.29	5.93	6.59	7.34	8.43
01055300	Bog Brook near Buckfield, ME	10.3	13.7	3.15	3.96	4.63	5.55	6.24	6.97	7.79	9.05

Table 1.6. Basin characteristics used to develop the final regression equations.—Continued

[mi², square mile; RI, recurrence interval; ME, Maine; NH, New Hampshire]

Streamgage number	Streamgage name	Drainage area (mi²)	[1]Area of wetlands (percent)	[2]24-hour rainfall (basinwide mean in inches) 2-year RI	5-year RI	10-year RI	25-year RI	50-year RI	100-year RI	200-year RI	500-year RI
01055500	Nezinscot River at Turner Center, ME	170	9.26	3.11	3.88	4.53	5.42	6.09	6.80	7.59	8.78
01057000	Little Androscoggin River near South Paris, ME	73.9	5.97	2.85	3.55	4.14	4.94	5.55	6.18	6.88	7.91
01058500	Little Androscoggin River near Auburn, ME	329	10.9	3.02	3.81	4.46	5.36	6.04	6.75	7.57	8.84
01059800	Collyer Brook near Gray, ME	14.2	10.7	3.19	4.09	4.85	5.88	6.65	7.48	8.46	10.05
01059845	Unnamed Brook at Gray, ME	0.52	5.92	3.21	4.14	4.92	5.98	6.77	7.62	8.65	10.30
01060000	Royal River at Yarmouth, ME	142	12.8	3.18	4.08	4.84	5.87	6.64	7.46	8.45	10.03
01060070	Chenery Brook near Cumberland, ME	0.6	7.36	3.21	4.17	4.97	6.07	6.88	7.76	8.81	10.54
01062700	Patte Brook near Bethel, ME	5.71	5.47	2.95	3.66	4.25	5.07	5.69	6.33	7.07	8.11
01063310	Stony Brook at East Sebago, ME	1.3	17.3	3.18	4.11	4.87	5.93	6.71	7.56	8.57	10.23
01064200	Mill Brook near Old Orchard Beach, ME	2.46	5.97	3.23	4.25	5.08	6.24	7.09	8.02	9.15	11.07
01064300	Ellis River near Jackson, NH	10.5	1.19	4.17	5.38	6.38	7.75	8.79	9.88	11.12	13.06
01064380	East branch Saco River at Town Hall Road, near Lower Bartlett, NH	34.2	1.48	3.62	4.55	5.31	6.36	7.16	7.99	8.86	10.20
01064400	Lucy Brook near North Conway, NH	4.71	1.79	3.54	4.39	5.14	6.16	6.94	7.74	8.73	10.03
01064500	Saco River near Conway, NH	385	2.69	3.57	4.52	5.31	6.38	7.20	8.05	8.98	10.41
01064800	Cold Brook at South Tamworth, NH	5.46	0.797	3.41	4.29	5.02	6.02	6.78	7.57	8.47	9.89
01064801	Bearcamp River at South Tamworth, NH	67.5	6.01	3.32	4.20	4.92	5.90	6.64	7.41	8.25	9.58
01065000	Ossipee River at Effingham Falls, NH	330	9.85	3.23	4.10	4.80	5.78	6.51	7.28	8.13	9.48
01065500	Ossipee River at Cornish, ME	451	10.2	3.22	4.09	4.81	5.79	6.53	7.31	8.19	9.58
01066000	Saco River at Cornish, ME	1,290	8.91	3.30	4.18	4.90	5.89	6.64	7.43	8.30	9.66
01066100	Pease Brook near Cornish, ME	4.69	4.94	3.24	4.19	4.98	6.06	6.87	7.74	8.78	10.46
01066500	Little Ossipee River near south Limington, ME	166	15.6	3.24	4.22	5.03	6.15	6.98	7.87	8.96	10.73
01067000	Saco River at West Buxton, ME	1,570	10.2	3.29	4.19	4.92	5.94	6.70	7.51	8.42	9.85
01067950	Kennebunk River near Kennebunk, ME	26.1	20.1	3.30	4.35	5.22	6.43	7.31	8.28	9.47	11.50
01069700	Branch Brook near Kennebunk, ME	9.17	10.8	3.29	4.36	5.25	6.46	7.36	8.34	9.56	11.65
01072800	Cocheco River near Rochester, NH	80.2	9.19	3.11	4.10	4.92	6.06	6.89	7.80	8.96	10.89
01072850	Mohawk Brook near center Strafford, NH	7.44	8.00	3.15	4.16	5.00	6.15	7.00	7.93	9.08	11.08
01072870	Isinglass River at Rochester Neck Road, near Dover, NH	74.6	13.5	3.18	4.20	5.05	6.22	7.08	8.03	9.21	11.23
01073000	Oyster River near Durham, NH	12.2	13.6	3.29	4.36	5.26	6.49	7.39	8.39	9.64	11.85
01073600	Dudley Brook near Exeter, NH	5.14	14.7	3.31	4.40	5.31	6.55	7.46	8.47	9.72	11.94

Table 1.6. Basin characteristics used to develop the final regression equations.—Continued

[mi^2, square mile; RI, recurrence interval; ME, Maine; NH, New Hampshire]

Streamgage number	Streamgage name	Drainage area (mi^2)	[1]Area of wetlands (percent)	[2]24-hour rainfall (basinwide mean in inches)							
				2-year RI	5-year RI	10-year RI	25-year RI	50-year RI	100-year RI	200-year RI	500-year RI
01073785	Winnicut River at Greenland, near Portsmouth, NH	14.2	21.1	3.37	4.46	5.37	6.61	7.52	8.53	9.78	11.95
01130000	Upper Ammonoosuc River near Groveton, NH	230	4.01	2.67	3.28	3.80	4.50	5.04	5.59	6.21	7.09
010735562	Exeter River at Odell Road, near Sandown, NH	16.4	14.1	3.12	4.11	4.94	6.07	6.91	7.82	8.98	11.00
01AF009	Iroquois River at Moulin Morneault, New Brunswick, Canada	70.8	1.64	1.92	2.48	2.84	3.30	3.65	3.99	5.69	6.52
01AJ003	Meduxnekeag River near Belleville, New Brunswick, Canada	472	13.8	2.48	3.05	3.52	4.17	4.66	5.17	5.75	6.53
01AJ004	Big Presque Isle Stream at Tracey Mills, New Brunswick, Canada	188	15.1	2.37	2.93	3.39	4.02	4.50	4.99	5.56	6.29
01AJ010	Becaguimec Stream at Coldstream, New Brunswick, Canada	134	2.98	2.15	2.75	3.15	3.66	4.03	4.40	5.78	6.56

[1]Percentage of basin that is palustrine, lacustrine, or riverine as defined by the U.S. Fish and Wildlife Service National Wetlands Inventory and by the Canadian National Hydrographic Network. See table 1.1.

[2]National Oceanic and Atmospheric Administration Atlas 14 precipitation frequency estimates and Northeast Regional Climate Center extreme rainfall trends. See table 1.1.

[3]This streamgage, 01011500, St. Francis River near Connors, New Brunswick, is in Canada but operated by the U.S. Geological Survey.

Table 1.7. Variances of estimates at selected annual exceedance probabilities for streamgages in and near Maine.

[%, percent; ME, Maine; NH, New Hampshire]

Streamgage number	Streamgage name	Variance of estimate for given annual exceedance probability, in logarithmic units							
		50%	20%	10%	4%	2%	1%	0.50%	0.20%
01010000	St. John River at Ninemile Bridge, ME	0.0003	0.0003	0.0004	0.0007	0.0009	0.0011	0.0015	0.002
01010070	Big Black River near Depot Mountain, ME	0.0007	0.0008	0.001	0.0015	0.002	0.0025	0.0032	0.0042
01010500	St. John River at Dickey, ME	0.0003	0.0004	0.0005	0.0007	0.0009	0.0012	0.0016	0.0021
01011000	Allagash River near Allagash, ME	0.0003	0.0004	0.0006	0.0009	0.0013	0.0017	0.0023	0.0032
01011500	St. Francis River near Connors, New Brunswick, Canada[1]	0.0004	0.0006	0.0008	0.0012	0.0017	0.0023	0.003	0.0041
01012895	Clark Brook near Wallagrass Plantation, ME	0.0029	0.004	0.0055	0.008	0.0104	0.013	0.0161	0.0207
01012970	Unnamed Brook near Wallagrass Plantation, ME	0.0068	0.0069	0.0101	0.0161	0.0216	0.0279	0.0347	0.0447
01013500	Fish River near Fort Kent, ME	0.0002	0.0003	0.0003	0.0006	0.0008	0.0011	0.0014	0.002
01014000	St. John River below Fish River, near Fort Kent, ME	0.0002	0.0002	0.0003	0.0004	0.0005	0.0007	0.001	0.0014
01014700	Factory Brook near Madawaska, ME	0.0024	0.0032	0.0042	0.006	0.0076	0.0094	0.0114	0.0144
01015700	Houlton Brook near Oxbow, ME	0.0029	0.0037	0.005	0.0073	0.0094	0.0116	0.0141	0.0178
01015800	Aroostook River near Masardis, ME	0.0004	0.0005	0.0006	0.0009	0.0012	0.0016	0.002	0.0027
01016500	Machias River near Ashland, ME	0.0011	0.0015	0.0021	0.0031	0.004	0.0052	0.0066	0.0087
01017000	Aroostook River at Washburn, ME	0.0003	0.0003	0.0004	0.0006	0.0008	0.0011	0.0014	0.002
01017060	Hardwood Brook below Glidden Brook near Caribou, ME	0.0056	0.0075	0.0099	0.0141	0.0178	0.022	0.0267	0.0335
01017290	Little Madawaska River at Caribou, ME	0.002	0.0027	0.0036	0.0051	0.0065	0.008	0.0097	0.0122
01017300	Nichols Brook near Caribou, ME	0.0077	0.0102	0.0135	0.0192	0.0243	0.03	0.0364	0.0458
01017550	Williams Brook at Phair, ME	0.0021	0.0028	0.0038	0.0056	0.0073	0.0092	0.0115	0.0148
01017900	Marley Brook near Ludlow, ME	0.0041	0.0054	0.0073	0.0106	0.0136	0.0171	0.0211	0.0272
01017960	Meduxnekeag River above south branch Meduxnekeag River near Houlton, ME	0.0014	0.002	0.0027	0.0039	0.005	0.0063	0.0077	0.0099
01018000	Meduxnekeag River near Houlton, ME	0.0006	0.0008	0.0011	0.0017	0.0023	0.0031	0.004	0.0054
01018009	Pearce Brook at Route 1 at Houlton, ME	0.0046	0.0061	0.0081	0.0114	0.0144	0.0178	0.0215	0.0269
01018035	Meduxnekeag River at Lowery Road near Houlton, ME	0.0013	0.0018	0.0024	0.0034	0.0043	0.0054	0.0066	0.0084
01021300	Wiggins Brook near West Lubec, ME	0.0047	0.0063	0.0084	0.0119	0.0151	0.0186	0.0225	0.0282
01021470	Libby Brook near Northfield, ME	0.0022	0.0027	0.0035	0.005	0.0064	0.0079	0.0097	0.0124
01021480	Old Stream near Wesley, ME	0.0017	0.0023	0.0032	0.0047	0.0062	0.0078	0.0097	0.0126
01021500	Machias River at Whitneyville, ME	0.0003	0.0004	0.0006	0.001	0.0013	0.0018	0.0024	0.0033
01021600	Middle River near Machias, ME	0.0017	0.0023	0.0031	0.0043	0.0055	0.0067	0.0081	0.0102
01021890	Unnamed Brook near Crawford, ME	0.0031	0.0042	0.0056	0.0081	0.0104	0.0131	0.0161	0.0207
01022000	East Machias River near East Machias, ME	0.0005	0.0006	0.0009	0.0013	0.0017	0.0022	0.0028	0.0037
01022260	Pleasant River near Epping, ME	0.0011	0.0015	0.002	0.0029	0.0037	0.0047	0.0058	0.0075
01022500	Narraguagus River at Cherryfield, ME	0.0004	0.0005	0.0007	0.0012	0.0016	0.0022	0.0028	0.0039

Table 1.7. Variances of estimates at selected annual exceedance probabilities for streamgages in and near Maine.—Continued

[%, percent; ME, Maine; NH, New Hampshire]

Streamgage number	Streamgage name	Variance of estimate for given annual exceedance probability, in logarithmic units							
		50%	20%	10%	4%	2%	1%	0.50%	0.20%
01022700	Forbes Pond Brook near Prospect Harbor, ME	0.0049	0.0065	0.0086	0.0121	0.0153	0.0188	0.0228	0.0285
01022840	Otter Creek near Bar Harbor, ME	0.0023	0.0032	0.0044	0.0063	0.0081	0.0101	0.0123	0.0156
01023000	West Branch Union River at Amherst, ME	0.0004	0.0006	0.0008	0.0013	0.0017	0.0023	0.003	0.0041
01024200	Garland Brook near Mariaville, ME	0.0037	0.0052	0.0071	0.0105	0.0136	0.0172	0.0213	0.0275
01026800	Frost Pond Brook near Sedgwick, ME	0.0042	0.0052	0.0067	0.0093	0.0116	0.0142	0.0171	0.0213
01027200	North Branch Penobscot River near Pittston Farm, ME	0.0009	0.0011	0.0014	0.002	0.0025	0.0032	0.0039	0.005
01029200	Seboeis River near Shin Pond, ME	0.0009	0.0012	0.0017	0.0025	0.0033	0.0042	0.0052	0.0068
01030300	Trout Brook near Danforth, ME	0.0067	0.0089	0.0118	0.0167	0.0211	0.0259	0.0314	0.0393
01030350	Wytopitlock Stream near Wytopitlock, ME	0.0009	0.0012	0.0015	0.0022	0.0027	0.0034	0.0041	0.0051
01030400	Gulliver Brook near Monarda, ME	0.0033	0.0044	0.0059	0.0084	0.0107	0.0132	0.016	0.0202
01030500	Mattawamkeag River near Mattawamkeag, ME	0.0002	0.0002	0.0003	0.0005	0.0006	0.0009	0.0012	0.0017
01031300	Piscataquis River at Blanchard, ME	0.0011	0.0015	0.0021	0.003	0.0039	0.005	0.0062	0.008
01031450	Kingsbury Stream at Abbot Village, ME	0.001	0.0013	0.0018	0.0026	0.0034	0.0043	0.0053	0.0068
01031470	Brewster Brook near Parkman, ME	0.0075	0.0095	0.0133	0.02	0.0261	0.0331	0.041	0.0526
01031500	Piscataquis River near Dover-Foxcroft, ME	0.0004	0.0005	0.0007	0.0011	0.0015	0.0021	0.0027	0.0038
01031510	Black Stream near Dover-Foxcroft, ME	0.0029	0.0038	0.005	0.0071	0.0089	0.011	0.0133	0.0167
01031600	Morrison Brook near Sebec Corners, ME	0.0074	0.0104	0.0142	0.0206	0.0264	0.033	0.0404	0.0515
01033500	Pleasant River near Milo, ME	0.001	0.0012	0.0015	0.0023	0.0031	0.0041	0.0054	0.0074
01034000	Piscataquis River at Medford, ME	0.0005	0.0006	0.0008	0.0012	0.0016	0.0021	0.0028	0.0038
01034900	Coffin Brook near Lee, ME	0.0042	0.0055	0.0074	0.0105	0.0132	0.0164	0.0198	0.025
01035000	Passadumkeag River at Lowell, ME	0.0004	0.0005	0.0007	0.0011	0.0016	0.0021	0.0027	0.0038
01036380	Unnamed Brook near Bradley, ME	0.0044	0.0038	0.0057	0.0094	0.0129	0.0169	0.0212	0.0276
01036500	Kenduskeag Stream near Kenduskeag, ME	0.0006	0.0007	0.0009	0.0014	0.0019	0.0024	0.0031	0.0042
01037000	Kenduskeag Stream near Bangor, ME	0.001	0.0013	0.0017	0.0026	0.0034	0.0044	0.0057	0.0076
01037200	Shaw Brook near Northern Maine Junction, ME	0.0066	0.0089	0.0119	0.0169	0.0214	0.0264	0.0321	0.0404
01037380	Ducktrap River near Lincolnville, ME	0.0026	0.0035	0.0047	0.0069	0.0089	0.0113	0.014	0.0181
01037430	Goose River at Rockport, ME	0.0033	0.004	0.0052	0.0071	0.0089	0.011	0.0132	0.0165
01038000	Sheepscot River at North Whitefield, ME	0.0005	0.0007	0.0011	0.0018	0.0025	0.0034	0.0045	0.0063
01041900	Mountain Brook near Lake Parlin, ME	0.0068	0.0093	0.0125	0.0179	0.0228	0.0283	0.0344	0.0434
01044550	Spencer Stream near Grand Falls, ME	0.0007	0.0009	0.0012	0.0019	0.0025	0.0032	0.0039	0.005
01046000	Austin Stream at Bingham, ME	0.0011	0.0014	0.0019	0.0029	0.004	0.0052	0.0067	0.0091
01046800	South Branch Carrabassett River at Bigelow, ME	0.0027	0.0032	0.0041	0.0057	0.0071	0.0088	0.0106	0.0132

Table 1.7. Variances of estimates at selected annual exceedance probabilities for streamgages in and near Maine.—Continued

[%, percent; ME, Maine; NH, New Hampshire]

Streamgage number	Streamgage name	Variance of estimate for given annual exceedance probability, in logarithmic units							
		50%	20%	10%	4%	2%	1%	0.50%	0.20%
01047000	Carrabassett River near North Anson, ME	0.0006	0.0007	0.0009	0.0014	0.0019	0.0026	0.0034	0.0047
01047200	Sandy River near Madrid, ME	0.0039	0.0052	0.007	0.0099	0.0125	0.0154	0.0186	0.0234
01047860	Unnamed Brook near New Sharon, ME	0.0052	0.0067	0.0093	0.0137	0.0177	0.0224	0.0276	0.0354
01048000	Sandy River near Mercer, ME	0.0005	0.0006	0.0007	0.001	0.0012	0.0016	0.0021	0.0028
01048100	Pelton Brook near Anson, ME	0.0068	0.0086	0.0118	0.0172	0.0219	0.0272	0.0331	0.0415
01048220	East Branch Wesserunsett Stream near Athens, ME	0.0031	0.0041	0.0054	0.0076	0.0096	0.0118	0.0143	0.0179
01048840	Unnamed Brook near Newport, ME	0.0057	0.0066	0.0089	0.0129	0.0165	0.0206	0.0252	0.032
01049000	Sebasticook River near Pittsfield, ME	0.0003	0.0004	0.0005	0.0008	0.0011	0.0015	0.002	0.0028
01049100	Hall Brook at Thorndike, ME	0.0107	0.015	0.0202	0.029	0.0369	0.0458	0.0557	0.0704
01049130	Johnson Brook at South Albion, ME	0.0053	0.0071	0.0094	0.0134	0.017	0.021	0.0255	0.0321
01049180	Unnamed Brook near Albion, ME	0.002	0.0024	0.0032	0.0046	0.0059	0.0074	0.0091	0.0115
01049300	North Branch Tanning Brook near Manchester, ME	0.0018	0.0026	0.0035	0.0052	0.0067	0.0085	0.0106	0.0138
01049373	Mill Stream at Winthrop, ME	0.0054	0.0076	0.0103	0.0151	0.0194	0.0243	0.0299	0.0383
01049550	Togus Stream at Togus, ME	0.0031	0.0042	0.0056	0.0081	0.0104	0.013	0.0159	0.0202
01049690	Unnamed Brook near Dresden, ME	0.0037	0.0042	0.0054	0.0076	0.0097	0.0121	0.0147	0.0185
01049700	Gardiner Pond Brook at Dresden Mills, ME	0.0046	0.0065	0.0088	0.0126	0.0161	0.0199	0.0242	0.0305
01050490	Unnamed Brook near Rangeley, ME	0.0031	0.0042	0.0056	0.0081	0.0104	0.0131	0.0161	0.0207
01050900	Four Ponds Brook near Houghton, ME	0.0072	0.0096	0.0128	0.0182	0.023	0.0284	0.0345	0.0434
01052500	Diamond River near Wentworth Location, NH	0.0003	0.0004	0.0005	0.0007	0.001	0.0013	0.0017	0.0024
01054135	Unnamed Brook near Gilead, ME	0.0021	0.0029	0.0039	0.0058	0.0074	0.0093	0.0115	0.0147
01054200	Wild River at Gilead, ME	0.0014	0.0017	0.0023	0.0034	0.0045	0.006	0.0077	0.0104
01054300	Ellis River at South Andover, ME	0.0008	0.0009	0.0012	0.0018	0.0023	0.003	0.0038	0.005
01055000	Swift River near Roxbury, ME	0.0008	0.0008	0.001	0.0015	0.0021	0.0028	0.0037	0.0051
01055300	Bog Brook near Buckfield, ME	0.0023	0.0028	0.0036	0.005	0.0062	0.0076	0.0092	0.0115
01055500	Nezinscot River at Turner Center, ME	0.0007	0.0009	0.0012	0.0019	0.0026	0.0036	0.0047	0.0065
01057000	Little Androscoggin River near South Paris, ME	0.0006	0.0007	0.0009	0.0013	0.0018	0.0024	0.0031	0.0043
01058500	Little Androscoggin River near Auburn, ME	0.0011	0.0016	0.0022	0.0034	0.0047	0.0062	0.008	0.0108
01059800	Collyer Brook near Gray, ME	0.0024	0.0029	0.0039	0.0055	0.007	0.0087	0.0107	0.0137
01059845	Unnamed Brook at Gray, ME	0.0029	0.0035	0.0049	0.0072	0.0093	0.0116	0.0142	0.0179
01060000	Royal River at Yarmouth, ME	0.0008	0.001	0.0013	0.002	0.0027	0.0036	0.0047	0.0063
01060070	Chenery Brook near Cumberland, ME	0.0025	0.0033	0.0044	0.0062	0.0079	0.0098	0.0119	0.015
01062700	Patte Brook near Bethel, ME	0.0094	0.0124	0.0165	0.0233	0.0294	0.0362	0.0438	0.0549

Table 1.7. Variances of estimates at selected annual exceedance probabilities for streamgages in and near Maine.—Continued

[%, percent; ME, Maine; NH, New Hampshire]

Streamgage number	Streamgage name	Variance of estimate for given annual exceedance probability, in logarithmic units							
		50%	20%	10%	4%	2%	1%	0.50%	0.20%
01063310	Stony Brook at East Sebago, ME	0.0037	0.0052	0.0072	0.0108	0.0141	0.0181	0.0227	0.0297
01064200	Mill Brook near Old Orchard Beach, ME	0.0054	0.0071	0.0095	0.0133	0.0168	0.0207	0.025	0.0314
01064300	Ellis River near Jackson, NH	0.0017	0.002	0.0026	0.0037	0.0049	0.0064	0.0081	0.0108
01064380	East branch Saco River at Town Hall Road, near Lower Bartlett, NH	0.0044	0.0058	0.0077	0.0109	0.0137	0.0169	0.0204	0.0256
01064400	Lucy Brook near North Conway, NH	0.0033	0.0044	0.0061	0.009	0.0118	0.0152	0.019	0.0249
01064500	Saco River near Conway, NH	0.0006	0.0008	0.001	0.0017	0.0023	0.0032	0.0042	0.0058
01064800	Cold Brook at South Tamworth, NH	0.0202	0.0271	0.036	0.051	0.0644	0.0794	0.0961	0.1206
01064801	Bearcamp River at South Tamworth, NH	0.0007	0.001	0.0013	0.002	0.0026	0.0033	0.0041	0.0054
01065000	Ossipee River at Effingham Falls, NH	0.0004	0.0006	0.0008	0.0013	0.0018	0.0024	0.0032	0.0044
01065500	Ossipee River at Cornish, ME	0.0004	0.0006	0.0008	0.0013	0.0018	0.0024	0.0032	0.0044
01066000	Saco River at Cornish, ME	0.0003	0.0004	0.0005	0.0007	0.001	0.0013	0.0017	0.0023
01066100	Pease Brook near Cornish, ME	0.0068	0.0092	0.0124	0.0175	0.0222	0.0274	0.0332	0.0417
01066500	Little Ossipee River near south Limington, ME	0.0014	0.0017	0.0022	0.0032	0.0042	0.0054	0.007	0.0094
01067000	Saco River at West Buxton, ME	0.0008	0.001	0.0012	0.0018	0.0023	0.003	0.0038	0.005
01067950	Kennebunk River near Kennebunk, ME	0.0038	0.0053	0.0072	0.0103	0.0131	0.0163	0.0199	0.0251
01069700	Branch Brook near Kennebunk, ME	0.0039	0.0041	0.005	0.0069	0.0088	0.0112	0.014	0.0185
01072800	Cocheco River near Rochester, NH	0.0027	0.0039	0.0054	0.0081	0.0107	0.0137	0.0171	0.0224
01072850	Mohawk Brook near center Strafford, NH	0.0137	0.0182	0.0244	0.0348	0.0443	0.0551	0.0672	0.0852
01072870	Isinglass River at Rochester Neck Road, near Dover, NH	0.0045	0.0065	0.0089	0.0131	0.017	0.0214	0.0264	0.034
01073000	Oyster River near Durham, NH	0.0007	0.0009	0.0013	0.0022	0.003	0.0041	0.0055	0.0076
01073600	Dudley Brook near Exeter, NH	0.0022	0.0026	0.0033	0.0046	0.0059	0.0075	0.0092	0.012
01073785	Winnicut River at Greenland, near Portsmouth, NH	0.0049	0.0067	0.009	0.0131	0.0169	0.0212	0.0261	0.0334
01130000	Upper Ammonoosuc River near Groveton, NH	0.0004	0.0005	0.0006	0.0009	0.0013	0.0017	0.0022	0.003
010735562	Exeter River at Odell Road, near Sandown, NH	0.0052	0.007	0.0094	0.0133	0.0168	0.0208	0.0252	0.0316
01AF009	Iroquois River at Moulin Morneault, New Brunswick, Canada	0.0011	0.0016	0.0022	0.0034	0.0045	0.0057	0.0072	0.0095
01AJ003	Meduxnekeag River near Belleville, New Brunswick, Canada	0.0009	0.0012	0.0017	0.0026	0.0035	0.0046	0.0059	0.0079
01AJ004	Big Presque Isle Stream at Tracey Mills, New Brunswick, Canada	0.0007	0.001	0.0014	0.0022	0.003	0.004	0.0052	0.007
01AJ010	Becaguimec Stream at Coldstream, New Brunswick, Canada	0.001	0.0014	0.0019	0.0029	0.0039	0.0051	0.0065	0.0088

[1]This streamgage, 01011500, St. Francis River near Connors, New Brunswick, is in Canada but operated by the U.S. Geological Survey.

Table 1.8. Covariance matrices for generalized least-squares regression equations.

[Covariance matrices are $(X^T\Lambda^{-1}X)^{-1}$. Numbers in matrices are in scientific notation. AEP, annual exceedance probability; %, percent]

Peak-flow AEP model	Model-error variance (γ^2)	Explanatory variable	$(Xtr\ L^{-1}\ X)^{-1}$ matrix			
			Intercept	Drainage area	Area of wetlands (percent)	24-hour rainfall intensity
50-percent AEP	0.0256	Intercept	1.6717E-02	−8.0997E-04	−3.0913E-05	−5.0493E-03
		Drainage area	−8.0997E-04	2.7523E-04	−6.3820E-06	1.2586E-04
		Percentage of wetland	−3.0913E-05	−6.3820E-06	5.8250E-06	−8.3046E-06
		24-hour rainfall with 50% AEP	−5.0493E-03	1.2586E-04	−8.3046E-06	1.7239E-03
20-percent AEP	0.0242	Intercept	1.5418E-02	−8.0583E-04	−3.4479E-05	−3.6546E-03
		Drainage area	−8.0583E-04	2.7683E-04	−6.0262E-06	9.2708E-05
		Percentage of wetland	−3.4479E-05	−6.0262E-06	5.7319E-06	−5.5161E-06
		24-hour rainfall with 20% AEP	−3.6546E-03	9.2708E-05	−5.5161E-06	9.9722E-04
10-percent AEP	0.0252	Intercept	1.5640E-02	−8.8191E-04	−3.7409E-05	−3.1331E-03
		Drainage area	−8.8191E-04	3.0272E-04	−6.3872E-06	8.3890E-05
		Percentage of wetland	−3.7409E-05	−6.3872E-06	6.2046E-06	−5.1625E-06
		24-hour rainfall with 10% AEP	−3.1331E-03	8.3890E-05	−5.1625E-06	7.3420E-04
4-percent AEP	0.0261	Intercept	1.6103E-02	−9.8702E-04	−4.0224E-05	−2.6519E-03
		Drainage area	−9.8702E-04	3.3608E-04	−6.7735E-06	7.5318E-05
		Percentage of wetland	−4.0224E-05	−6.7735E-06	6.7791E-06	−4.9447E-06
		24-hour rainfall with 4% AEP	−2.6519E-03	7.5318E-05	−4.9447E-06	5.2106E-04
2-percent AEP	0.0273	Intercept	1.6955E-02	−1.0840E-03	−4.3406E-05	−2.4619E-03
		Drainage area	−1.0840E-03	3.6619E-04	−7.1718E-06	7.2218E-05
		Percentage of wetland	−4.3406E-05	−7.1718E-06	7.3162E-06	−4.8057E-06
		24-hour rainfall with 1% AEP	−2.4619E-03	7.2218E-05	−4.8057E-06	4.3106E-04
1-percent AEP	0.0268	Intercept	1.7025E-02	−1.1472E-03	−4.4331E-05	−2.1890E-03
		Drainage area	−1.1472E-03	3.8292E-04	−7.1737E-06	6.6723E-05
		Percentage of wetland	−4.4331E-05	−7.1737E-06	7.5205E-06	−4.5633E-06
		24-hour rainfall with 2% AEP	−2.1890E-03	6.6723E-05	−4.5633E-06	3.4438E-04
0.5-percent AEP	0.0296	Intercept	1.9785E-02	−1.2356E-03	−6.8631E-05	−2.2667E-03
		Drainage area	−1.2356E-03	4.2461E-04	−7.4276E-06	5.9116E-05
		Percentage of wetland	−6.8631E-05	−7.4276E-06	8.3615E-06	−1.8434E-06
		24-hour rainfall with 0.5% AEP	−2.2667E-03	5.9116E-05	−1.8434E-06	3.1522E-04
0.2-percent AEP	0.0306	Intercept	1.8946E-02	−1.3252E-03	−7.4913E-05	−1.8120E-03
		Drainage area	−1.3252E-03	4.6126E-04	−7.7923E-06	5.1231E-05
		Percentage of wetland	−7.4913E-05	−7.7923E-06	8.9722E-06	−1.5996E-06
		24-hour rainfall with 0.2% AEP	−1.8120E-03	5.1231E-05	−1.5996E-06	2.1757E-04

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Glossary

adjusted *R*-squared (*or* adjusted coefficient of determination) The adjusted coefficient of determination, a measure of the percentage of the variation explained by the explanatory variables of the equation adjusted for the number of parameters in the equation.

annual exceedance probability (AEP) The probability that a given flood will be exceeded during a given year. The reciprocal of the exceedance probability is referred to as the recurrence interval or return period and is expressed in years.

annual peak flow The maximum instantaneous discharge in each **water year**. This is the highest value observed in the record of 15-minute or 60-minute values, depending on the recording interval of the device.

average standard error of prediction (ASEP) A measure of how well the equation estimates peak flows for sites not used to develop the equations. The square root of the **average variance of prediction** that can be expressed in log units or in percent.

average variance of prediction (AVP) The average spread or dispersion of the predicted value from the observed value at a new site not used in the development of the equations. A measure of how well the equation estimates peak flows for new ungaged sites not used to develop the equations.

Bayesian model A statistical model that uses probability to represent all uncertainty within the model, both the uncertainty regarding the output and the input. The Bayesian approach provides a more reasonable description of model errors than **generalized least squares** when the errors are small compared to the sampling errors.

Bayesian weighted least-squares/Bayesian generalized least-squares (B–WLS/B–GLS) regression A method to compute a regional skew for flood frequency analyses that accounts for the precision of the skewness estimator for each station depending on record length. It also accounts for the spatial cross correlation among stations and provides a reasonable description of the model error when it is small compared to the sampling error.

censored data Unknown values within a dataset above or below specified thresholds.

confidence interval A range of values calculated from a sample of the data that likely contains a population parameter (for example a 95-percent confidence interval means we are 95-percent confident that a population parameter such as the mean falls within this range).

Cook's D A statistic for estimating the influence of a data point when performing a least-squares regression analysis.

covariance A measure of how much two random variables change together. Positive values indicate variables tend to show similar behavior, whereas negative values indicate the greater value of one variable correspond to the smaller value of the other variable.

crest-stage gage (CSG) A simple, economical, reliable, and easily installed device for obtaining the elevation of the flood peak of a stream between visits to the gage. These gages are nonrecording and thus multiple peaks and their dates and times are not determined.

cross correlation A measure of the similarity between two time series of observations in space.

Durbin-Watson test statistic A statistic that tests model residuals for serial correlation.

error variance ratio (EVR) The ratio of the average sampling error to the model-error used to evaluate whether a simple ordinary least-squares regression is sufficient or a more sophisticated weighted least-squares or generalized least-squares regression is appropriate.

expected moments algorithm (EMA) Method for fitting a probability distribution to annual peak-flow data using a generalized method of moments, similar to the standard **log-Pearson type III (LP–III)** method. The **EMA**, however, can also account for multiple **potentially influential low floods**; and use interval data, whereas the **LP–III** is restricted to point data. Interval data provide additional information, such as the potential range of annual peak flows outside of the systematic and historic record and the uncertainties around recorded peak flows used in the analysis.

flow interval Floods whose magnitude are not known exactly but are known to fall within a range or interval.

gaging record Streamflow data collected at streamgaging stations. A gaging record can consist of systematic data and historical flood data.

generalized least-squares (GLS) regression A regression model that explains the spatial variability of a flood statistics for selected recurrence intervals, by relating it to basin variables as does **ordinary least-squares regression**. However, it accounts for differences in record lengths at gages used in the regression, and for correlation among estimators of the flood statistics at different gages and thus can provide more appropriate estimates of errors.

historical peaks A flood measured, or estimated, outside the systematic period of record. Typically, these are floods whose peak is determined by indirect measurement methods.

historical period The period of record prior to systematic data collection in which all floods above a selected flood stage are expected to be recorded. The record generally consists of diaries, news accounts, and documented flood marks on buildings.

influence An indication of whether an observation in a regression model is likely to be an outlier and thus have a large effect on the fit of a regression model. Influential observations that also have high **leverage** have the greatest impact on a model.

level of significance A standard way of expressing the strength of evidence of a hypothesis. It is the probability of rejecting a hypothesis when it is in fact true. At a 10-percent level of significance, the probability is 1/10, and the *p*-value is 0.1.

leverage A measure of how far away an observation of an explanatory variable is from other observations of that variable. An observation with high leverage has the potential to have a large effect on the fit of a regression model if it also has high **influence**.

log-Pearson type III (LP–III) A distribution for defining annual flood series determined from estimates of three moments; the mean, the standard deviation, and the skew coefficient of the population of logarithms of annual instantaneous peak flows at each streamgage.

long-term persistence (LTP) Persistence refers to year-to-year dependence in time-series data. In LTP, the decay in the correlation over time is slow as compared to **short-term persistence (STP)**, however without **STP**, there is not **LTP**. If there is **STP** or **LTP**, the assumption of time-series independence in a time series is violated.

Mallow's C_p A statistic for estimating the overall quality of a regression model. It is designed to achieve a good compromise between including all relevant variables to explain as much variance in flood statistics as possible to minimize model bias, and reducing the number of model variables to minimize the variance of the resulting estimates.

mean square error (MSE) The average of the squares of the differences between the estimated values and the measured values. This metric represents how closely, on average, an estimated value matches a measured value.

method of moments A standard statistical method of estimating the parameters of a distribution from the moments of the sample data. The log-Pearson type III distribution requires estimates of three moments; the mean, the standard deviation, and the skew using the logarithms of annual instantaneous peak flows at each streamgage.

misrepresentation of the beta variance (MBV) A statistic used to determine whether a **weighted least-squares regression** is sufficient or if a **generalized least-squares regression** would be more appropriate to determine the precision of estimated regression parameters.

model error The portion of error that can be attributed to having an imperfect model.

multiple Grubbs-Beck test A statistical test used to identify multiple **potentially influential low flood** observations in an annual maximum flood time series.

multicollinearity A statistical phenomenon in which two or more explanatory variables in a multiple regression model are highly correlated. If this occurs, the regression coefficients may change erratically in response to small changes in the model or the predictor variable. Multicollinearity violates the regression assumption that explanatory variables be independent.

ordinary least-squares (OLS) regression A linear regression method that minimizes the sum of square differences between the observed and predicted values. It explains spatial variability of the response variable by relating it to one or more explanatory variables. For the current study, OLS regression is used to explain the variability flood statistics by use of basin variables such as drainage area.

outlier Outliers are observations that are exceedingly low or high compared to the vast majority of the data.

PeakFQ A USGS application that implements **expected moments algorithm (EMA)** procedures for flood frequency analyses of annual peak streamflows. It includes estimates of the parameters of the log-Pearson type III distribution, the fitted frequency curve, systematic peaks, low outliers, censored peaks, interval peaks, historical peaks, thresholds, and confidence intervals.

perception threshold The stage or flow above which it is estimated an information source would provide information on the flood peak in any given year. Perception thresholds reflect the range of flows that would have been measured or recorded had they occurred. Perception thresholds are used for historical data, when the information provided is based on observation during periods with no systematic streamflow data collection. They are also used at **crest stage gages (CSGs)** to indicate the elevation above which a measurement would be recorded. Peak flows for a given year may be too small to be measured by the lowest point on a crest stage gage.

potentially influential low flood (PILF) A small-magnitude flood in an annual maximum flood series, that does not represent the physical processes that cause the largest flood observations. PILFs can exert high leverage and influence on the flood frequency distribution.

prediction interval The range that likely contains the value of the response variable for a new observation not used in the development of the equations. Typically larger than the **confidence interval** because it predicts in what range a future individual observation of a response variable will fall, while a confidence interval shows the likely range of values associated with some statistical parameter of the data, such as the population mean.

pseudocoefficient of determination (pseudo R^2) The estimated fraction of the variability from site to site explained by a regression model, after removing the effect of the sampling error. The closer the pseudo R^2 is to 1, the better the regression explains the variation in the response variables.

pseudorecord length (P_{RL}) The number of years of record at a streamgage, taking systematic and historical record into account and weighting them appropriately.

recurrence interval The long-term average time between events such as floods, also known as a return period. The reciprocal of the recurrence interval is the annual exceedance probability.

regional skew coefficient A skew coefficient derived by a procedure that integrates values obtained at many locations. The station skew computed at an individual site may be an unreliable estimate of the true skew, especially for sites with short record lengths. Thus station skew should be weighted with a regional, or generalized, skew that is based on data from many long-term streamgages.

root mean square error (RMSE) This metric represents the magnitude of the differences between the estimated and measured values and estimates how well the model predicted peak flows at the streamgages used to develop the regression equations.

sampling error The component of the total error that can be attributed to only using a portion of the total population.

serial correlation The correlation between the values in a time series and the values in that same time series lagged by one or more time steps. The presence of serial correlation indicates that the data in the time series are not independent of each other.

short-term persistence (STP) Persistence refers to year-to-year dependence in time-series data. In **STP**, the correlation over time decays exponentially or faster as more years are included. If there is **STP**, the assumption of time-series independence in a time series is violated.

skew One of the three moments in a flood-frequency distribution which is a numerical measure of the lack of symmetry in the distribution. The skew generally is computed from the logarithms of annual peak flows at the streamgage.

standard deviation A measure of the dispersion or precision of a series of values such as precipitation or streamflow.

standard error of prediction (SE_{pred}) A measure of how well the regression equation will estimate the peak flow when it is applied to an individual site not used in the development of the equation. The SE_{pred} varies from site to site depending on the values of the explanatory variables at that site. **Average standard error of prediction** is often used as an approximation of SE_{pred} because the error associated with different values of the explanatory variable is a relatively small portion of the total standard error of prediction.

StreamStats A USGS online application for computing streamflow statistics at any location on a stream in the United States, based on regional regression equations.

systematic record The period or periods of continuous annual peak-flow record at a streamgage. All flows during the systematic period are measured.

variance A measure of the amount of spread or dispersion of a set of values around their average value.

variance inflation factor (VIF) A statistic for measuring multicollinearity in regression models. A VIF greater than 5 to 10 generally indicates **multicollinearity**, a serious problem in the regression models.

variance of prediction *See* **average variance of prediction**.

water year The 12-month period from October 1 of a given year through September 30 of the following year and designated by the calendar year in which it ends.

weighted least-squares (WLS) regression A regression model that explains the spatial variability of a flood statistics for selected recurrence intervals, by relating it to basin variables. Differs from **ordinary least-squares regression** in that it accounts for differences in record lengths at streamgages used in the regression and differs from **generalized least-squares regression** by not accounting for correlation among estimators of flood statistics at different gages.

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