**Estimating the Magnitude of Peak Flows for Steep Gradient Streams
in New England**

Dr. Jennifer Jacobs, PI

**Prepared for
The New England Transportation Consortium
November 17, 2010**

NETCR81   **Project No. NETC 04-3**

ACKNOWLEDGEMENTS

1. Report No. NETCR81	2. Government Accession No. N/A	3. Recipient's Catalog No. N/A
4. Title and Subtitle Estimating the Magnitude of Peak Flows for Steep Gradient Streams in New England		5. Report Date November 17, 2010
		6. Performing Organization Code N/A
7. Author(s) Jennifer Jacobs, PI Patrick Jardin, Student Assistant		8. Performing Organization Report No. NETCR81
9. Performing Organization Name and Address Department of Civil Engineering University of New Hampshire Durham NH 03824		10 Work Unit No. (TRAIS) N/A
		11. Contract or Grant No. N/A
12. Sponsoring Agency Name and Address New England Transportation Consortium C/O Advanced Technology & Manufacturing Center University of Massachusetts Dartmouth 151 Martine Street Fall River, MA 02723		13. Type of Report and Period Covered Final Report
		14. Sponsoring Agency Code NETC 04-03 A study conducted in cooperation with the U.S. DOT
15 Supplementary Notes N/A		

16. Abstract

Estimates of these flood events are used by the Federal, State, regional, and local officials to safely and economically design hydraulic structures as well as for effective floodplain management. The regression relationships developed to predict flows at ungauged sites do not always hold true for steep slope watersheds in New England. This study developed the regression relationships to predict peak flows for ungaged, unregulated steep streams in New England with recurrence intervals of 2, 5, 10, 25, 50, 100, and 500 years. For watersheds having a main channel slope that exceeds 50 ft per mile, peak flows are well estimated by the watershed drainage area and the mean annual precipitation. For these steep watersheds, the series of regression equations was found to perform as well or better than the individual state regression equations.

17. Key Words Flood Flows, Steep Watersheds	18. Distribution Statement No restrictions. This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161.		
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 49	22. Price N/A

Form DOT F 1700.7 (8-72)   Reproduction of completed page authorized

SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
LENGTH				
in	inches	25.4	millimetres	mm
ft	feet	0.305	metres	m
yd	yards	0.914	metres	m
mi	miles	1.61	kilometres	km
AREA				
in^2	square inches	645.2	millimetres squared	mm^2
ft^2	square feet	0.093	metres squared	m^2
yd^2	square yards	0.836	metres squared	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	kilometres squared	km^2
VOLUME				
fl oz	fluid ounces	29.57	millilitres	mL
gal	gallons	3.785	Litres	L
ft^3	cubic feet	0.028	metres cubed	m^3
yd^3	cubic yards	0.765	metres cubed	m^3

NOTE: Volumes greater than 1000 L shall be shown in m^3

Symbol	When You Know	Multiply By	To Find	Symbol
MASS				
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
TEMPERATURE (exact)				
°F	Fahrenheit temperature	5(F-32)/9	Celcius temperature	°C

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
LENGTH				
mm	millimetres	0.039	inches	in
m	metres	3.28	feet	ft
m	metres	1.09	yards	yd
km	kilometres	0.621	miles	mi
AREA				
mm^2	millimetres squared	0.0016	square inches	in^2
m^2	metres squared	10.764	square feet	ft^2
ha	hectares	2.47	acres	ac
km^2	kilometres squared	0.386	square miles	mi^2
VOLUME				
mL	millilitres	0.034	fluid ounces	fl oz
L	litres	0.264	gallons	gal
m^3	metres cubed	35.315	cubic feet	ft^3
m^3	metres cubed	1.308	cubic yards	yd^3
MASS				
g	grams	0.035	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams	1.102	short tons (2000 lb)	T
TEMPERATURE (exact)				
°C	Celcius temperature	1.8C+32	Fahrenheit temperature	°F

°F	-40	0	32	40	80	98.6	120	160	180	200	212
°C	-40	-20	0	20	37	40	60	80	100		

* SI is the symbol for the International System of Measurement

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ABSTRACT

Estimates of these flood events are used by the Federal, State, regional, and local officials to safely and economically design hydraulic structures as well as for effective floodplain management. The regression relationships developed to predict flows at ungauged sites do not always hold true for steep slope watersheds in New England. This study developed the regression relationships to predict peak flows for ungaged, unregulated steep streams in New England with recurrence intervals of 2, 5, 10, 25, 50, 100, and 500 years. For watersheds having a main channel slope that exceeds 50 ft per mile, peak flows are well estimated by the watershed drainage area and the mean annual precipitation. No metric of watershed steepness provided a statistically significantly improvement to prediction capability. For these steep watersheds, the series of regression equations was found to perform as well or better than the individual state regression equations.

1. PURPOSE AND USE OF THIS REPORT

1.1 Introduction

Flood events can have a catastrophic effect on property, life and transportation routes. Estimates of these flood events are used by the Federal, State, regional, and local officials to safely and economically design hydraulic structures as well as for effective floodplain management. Where data are not available, regression relationships are often developed to predict flows at ungauged sites where no observed flood data are available for frequency analysis. Regression relationships have been published for all of the New England states by the United States Geological Survey (USGS) for predicting peak flows. According to Hodgkins (1999), these regression relationships do not always hold true for steep slope watersheds in New England. To address this need, the University of New Hampshire (UNH) and Tufts University in cooperation with the New England Transportation Consortium (NETC), conducted a study to estimate the peak-flow characteristics for steep streams in New England.

This report describes the results of a study to estimate the magnitudes of peak flows for ungaged, unregulated steep streams in New England. Regression relationships are presented which relate basin and climatic characteristics to peak flows for recurrence intervals of 2, 5, 10, 25, 50, 100, and 500 years. In addition, this report describes the methods used to develop the regression relationships. The methods presented here are for streams with natural flow conditions (unregulated) in locations where no streamflow is available and where slopes exceed 50 ft/mi. An evaluation of the equations and limitations for their use also is provided. Estimating peak flow for ungaged sites on regulated streams is not recommended using the results from this project.

1.2 Previous Studies

Previous studies have used regression analyses to provide estimates of high-flow-frequency statistics in New England. The USGS has developed regression equations for each state in New England. Regression equations are used to estimate a response variable (peak flow for a given recurrence interval) for an ungaged drainage basin by measuring explanatory variables (basin characteristics). Table 1 lists the basin characteristics used in current regression equations for each New England state as published in previous studies. Connecticut's USGS regression equations for computing peak flows from ungaged basins were developed using Log-Pearson Type III multiple regression analysis from records of 105 stream gauging stations with 10 to 45 years of continuous records (Ahearn, 2004). Connecticut's regression equation is a three parameter equation. As of 2010, the Connecticut Department of Transportation's Drainage Manual had not been revised to reflect the 2004 equations, although a directive has been issued for their use (personal communication, M. Hogan November 2010). The Maine Department of Transportation practices uses the 1999 USGS regression equations (Hodgkins, 1999) for watersheds with an area greater than 1 mi^2 and the rational method for watersheds with an area less than 0.5 mi^2. For watersheds between 0.5 mi^2 and 1.0 mi^2, regression equations or the rational method could be used. Based upon the USGS study conducted in Maine watersheds (Hodgkins, 1999), this study examines 14 other explanatory variables including drainage area, main-channel length, main-channel slope, mean basin elevation, percent forest cover, mean basin snowfall, percent area lakes and ponds, mean annual precipitation, and 24-hour, 2-year rain.

Table 1 Explanatory basin characteristics used to determine peak streamflow values by state and study.

State	Explanatory Variables
Connecticut (Ahearn, 2004)	Drainage Area, Mean Basin Elevation, 24-hour Precipitation by Return Period
Maine (Hodgkins, 1999)	Drainage Area, Basin Wetlands
Massachusetts (Wandle, 1983)	Drainage Area, Basin Storage, Main-Channel Slope, Mean Basin Elevation
New Hampshire (Olson, 2009)	Drainage Area, Main-Channel Slope, 2-year, 24-hour Precipitation
Rhode Island (Wandle, 1983)	Drainage Area, Mean Basin Elevation, Forest Cover
Vermont (Olson, 2002)	Drainage Area, Basin Storage, 2-year, 24-hour Precipitation, Seasonal Snow, Mean Annual Precipitation, Altitude

2. ESTIMATING THE MAGNITUDE OF PEAK FLOWS

2.1 Streamflow Data Used in This Study

To complete the main objective of this research, to develop a set of regional regression relationships to predict flood flows for steep slope watersheds, a set of watersheds and their basin characteristics was developed. All watersheds within New England having USGS historical peak flow data were considered for this analysis. From those sites, a subgroup of steep watersheds was identified based on the main channel slope. This group was further refined based on standard USGS selection criteria for gauging stations' streamflow data.

Upstream from each stream junction point (gauging station), the main channel is the stream that drains the most area and is usually considered the highest order stream. The slope is determined from the elevation at the points of 85 and 10 percent of the total length of the main channel above the point of interest. The main channel slope is computed as the difference in elevation, in feet, divided by the length, in miles, between the two points (Wandle, 1983). The main channel slope for each basin was determined using a Geographic Information System (GIS). While there is no clear definition of steep with respect to watersheds, Figure 1 shows the distribution of streams having slopes that exceed 50 ft/mi. Two threshold slopes were examined. A threshold of main channel slopes greater than 50 ft/mi included nearly 200 watersheds. A main channel slope steeper than 100 ft/mi included only 100 watersheds. The analysis was performed using the 50 ft/mi and the 100 ft/mi threshold.

The identified steep sloped watersheds were required to meet the Bulletin 17B guidelines (Interagency Advisory Committee, 1982). Bulletin 17B guidelines require that each stream gauging station have a sufficient record of at least 10 years of data. These stations cannot have flood flows that are altered by reservoir regulation or unusual events like dam failures. A station is considered significantly regulated if its drainage basin has storage that exceeds 4.5 million ft^3 per mi^2 (Benson, 1962). The peak-flow dataset used for statistical analysis at a gauging station must be a reliable and representative sample of random, homogeneous events.

Prior to calculating a flood flow, each site was reviewed to determine if the annual maximum stream flow observations follow the log Pearson type III distribution. While there are many measures and forms of outlier analysis for typical data, outliers were identified using L-moment diagrams and a discordancy statistic. L-moment analysis follows the approach introduced by Hosking (1990). Hosking and Wallis (1997) recommend using L-moments statistics to calculate a "discordancy" value as follows

For i=1:n
$$u_i = \begin{bmatrix} L-CV_i \\ L-skew_i \\ L-kurtosis_i \end{bmatrix}$$

where the vector for each n sites is the L-CV, L-skew, and L-kurtosis values for site i.
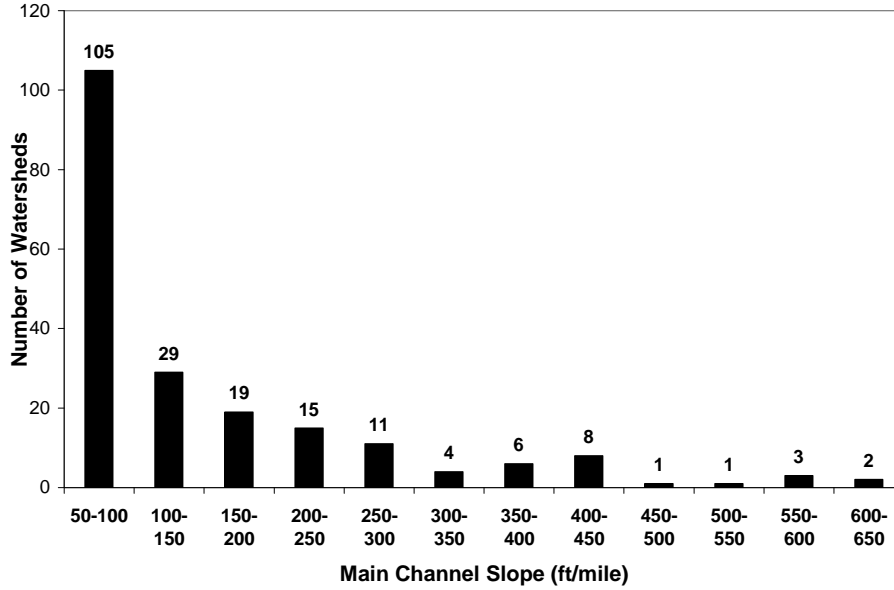
Figure 1. Distribution of main channel slopes for New England watersheds that exceed 50 ft/mi.

The averages of *L-CV_i*, *L-skew_i*, and *L-kurtosis_i* are denoted as ubar where

$$ubar = \frac{1}{n}\sum_{i=1}^{n}u_i$$

and is a vector of the same dimensions as u_i where the row entries are in that order. The

A matrix is determined as

$$A = \sum_{i=1}^{n}\left[(u_i - ubar)*(u_i - ubar)^T\right]$$

where T indicates the transpose vector (1 x 3) which multiplies the original vector (3 x 1) for each site i. The resulting matrix A is a 3 x 3 matrix. Discordancy values are calculated for each site as

$$D_i = \frac{1}{3}*n*(u_i - ubar)^T * A^{-1}(u_i - ubar)$$

Hosking and Wallis recommend that sites with $D_i > 3$ be removed (Hosking and Wallis 1997). Ten sites exceeded that threshold. These sites were also identified as outliers in an L-moment diagram. Notably three Rhode Island watersheds all had high discordancy values and were removed from the analysis.

To ensure that time series of peak flow streamflow values did not have trends; the Mann-Kendall trend test (Helsel and Hirsch, 1992) was performed. Trends were not tested on stream-gaging stations with less than 15 years of record because a trend over a short period cannot be distinguished from serial correlation. The standard group significance level of 0.05 was applied using the Bonferroni correction for the 203 individual correlations with a significance level of 0.000246. Two stations were found to have trends and removed from this study; Middle B Westfield River at Goss Heights, MA (1180500) and Hubbard River nr. West Hartland, CT. (1187300).

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Using the criteria described above, a database of 184 watersheds were selected for this study. The main channel slope for these 184 watersheds ranges from 50 – 625 ft/mile. The watersheds are distributed across each of the New England states except Rhode Island, as shown in Figure 2.

2.2 Flow-Frequency Characteristics at Stream-Gaging Stations

To determine the peak flows for the 2-, 10-, 25-, 50-, 100-, and 500-year recurrence intervals, the Bulletin 17B approach was used. For each gauging station, the USGS historical annual peak streamflow data were downloaded. The peak flows for the different recurrence intervals were determined at each specified gauging station based on the Bulletin 17B guidelines. The Bulletin 17B guidelines account for zero flows, low outliers, historic peaks, regional information, confidence intervals, and expected quantile probabilities. A log Pearson type III distribution was fit to the peak discharges for each basin. The mean, standard deviation, and coefficient of skewness are calculated using the common base 10 logarithms of the peak discharges. Bulletin 17B uses a weighted skewness coefficient that is determined by combining the basin skewness value with a generalized skew coefficient. The generalized skew coefficient was developed for the steep watershed in this study according to the Bulletin 17B guidelines and adjusted for bias (Tasker and Stedinger, 1986). The PeakFQ software, developed by the USGS, was used for the computations. The peak flows for the 2-, 10-, 25-, 50-, 100-, and 500-year recurrence intervals at USGS streamflow-gaging stations are listed in Appendix A.

2.3 Evaluation of Basin Characteristics

Regression equations are used to estimate a response variable (peak flow for a given recurrence interval) for an ungaged drainage basin by measuring explanatory variables (basin characteristics). Explanatory variables should make hydrologic sense, explain a significant amount of the variability of the response variable, and be reasonably easy to measure. From the regression equations developed and published in previous studies, the following basin characteristics were determined for each station:

- Drainage Area (mi^2),
- Basin Length (mi),
- Basin Perimeter (mi),
- Basin Slope (ft/mi),
- Relief (ft), Width (mi),
- Channel Length (mi),
- Main Channel Slope (ft/mi),
- Mean Annual Precipitation (in),
- Percent Basin Area of Lakes or Ponds,
- Soil Index,
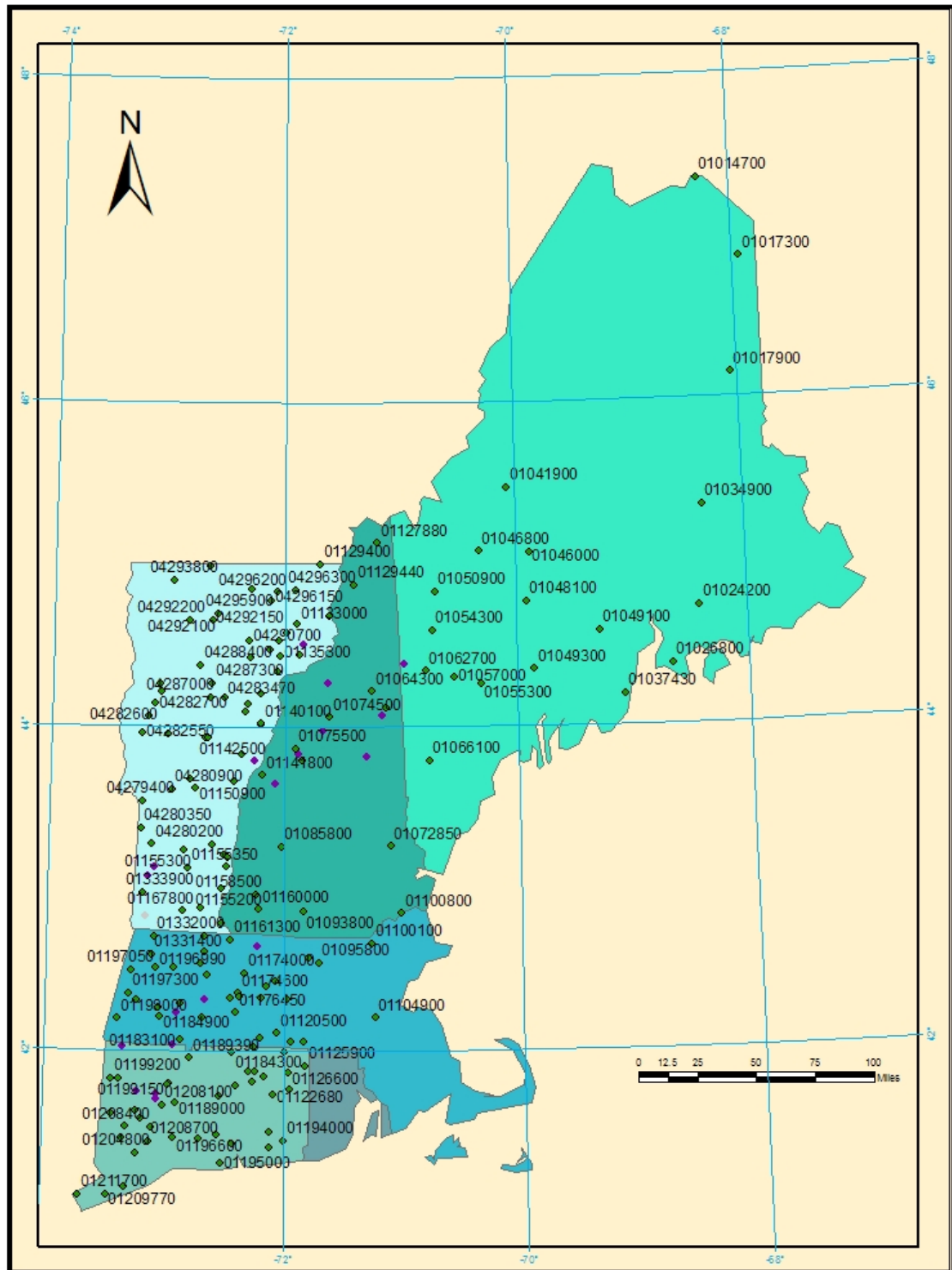
Figure 2. Locations and station numbers for those watersheds in New England used in the steep watershed regression analysis.

- Storage,
- Percent Forest,
- Mean Basin Snowfall, and
- 24-hr 2-year Rainfall Intensity.

Basin characteristics were derived based on two methods. The first method was by using recent basin characteristics developed by the USGS to develop state specific regression equations to determine flows for ungaged stations. This period of time, assures that the data are up to date and representative of the current basin characteristics. The second method of deriving the basin characteristics was to use Geographic Information System (GIS) coverages.

2.4 Regression Analysis

The next step in the development of regression equations was to identify basin characteristics that best describe the peak flows. The weighted least squares (WLS) technique was used (Helsel and Hirsch, 2002) to aid in the identification of the best variables. Peak flood discharge (response variable) was estimated from the basin characteristics (explanatory variables). Each gauging station in this study has a different peak flow record length (n). When developing the regression equations using WLS, the record length (n) was the weighting factor. In order to preserve linearity, a frequently used data transformation was made. Benson (1960) indicates that a logarithmic transformation is appropriate for hydrologic data. For this data, the base-10 logarithms (log) of the peak flood discharges and basin characteristics were used to develop the regression equations. The regression equations were formed in the statistical program JMP. A linear relationship is valid for the logarithms of physical characteristics and peak flow values. The regression relationship was performed on logarithmic transformations.

The preliminary step was to conduct a stepwise regression. This is a preliminary step because it tends to pick variables that confound several independent effects and build models that are hard to interpret in the real world. However, its major advantage is that it builds a model with a small number of predictor variables that produce a high R^2 value. Thus, the preliminary stepwise regression was used to choose the set of basin characteristics that describe the peak flow of interest. Once these variables were determined, then a weighted least square regression analysis was used to determine the model.

Several statistical tests were used to determine which parameters were left in the model and which ones were deleted. To test for multicollinearity of the explanatory variables, the variance inflation factor (VIF) was calculated to eliminate redundant variables. A VIF greater that 10, suggests that a parameter is highly correlated to another in the regression equation. Usually the parameter that is easiest to determine, is selected to remain in the regression equation analysis. Using the VIF, explanatory variables, basin perimeter, relief, width, and channel length, were found to be highly correlated with other variables and were removed from the analysis.

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With the remaining explanatory variables, a stepwise WLS regression was performed to identify the best combination of transformed explanatory variable for the steep watersheds. The PRESS (prediction error sum of squares) statistic was used to identify the best combination of independent variables. Parameters were eliminated from the regression equation if they had a p-value greater than 0.05 (the standard threshold). In regression, the p-value indicates whether or not the addition of that variable is significant in predicting the response. It compares the model without that variable to a model including that variable and determines what the chance is that the observed difference would be seen by random chance. The lower the p-value, the greater influence the parameter has on predicting the peak flows. Those variables which were not significant were removed from the model. The remaining variables were Drainage Area, Basin Length, Mean Annual Precipitation, and Storage. Notably, the basin slope was not found to be a significant explanatory variable.

Once a preliminary regression equation was developed with a reduced number of parameters, Cook's D statistic and the DFFITS values (Helsel and Hirsh, 1993) were used to show the influence of individual stations on the regression equation. DFFITS is the scale difference between the predicted responses from the model constructed from all of the data and the predicted responses from the model constructed by settling the i-th observation aside. An individual station is said to show high influence when the following condition holds true, $\left|DFFITS_i\right| \geq 2\sqrt{p/n}$, where p is the number of parameters used in the regression and n is sample size of the dataset.

Using this method, there were several observations that had high influence for the 100 year return period regression which was used as the benchmark, but no spatial pattern was evident (Figure 3). There was some organization to the influential stations, with a cluster in northern NH and a few sites in the Berkshires. These sites exert a stronger influence on the position of the regression line than other observations. These sites exert a stronger influence on the position of the regression line than other observations. Some of these exert such a strong influence that they can cause errors in the regression equation because the line that is fit includes these outliers. This can also change the significance values of certain variables. The high influence sites were removed from the analysis (Helsel and Hirsch, 1993).

Having removed the high influence stations, a second stepwise regression was run to determine which parameters best described the peak flows because if the stations that were deleted were truly of high influence on the peak flows, then the parameters used to predict the peak flows in the new regression could be different. Thus, the stepwise WLS regression was repeated after removing the outlier sites. The variables Drainage Area and Mean Annual Precipitation were selected as the best possible combination of the explanatory variables.

Regression diagnostic tools were used to review the credibility of the WLS regression model. Residual plots, normality plots of the residuals, and the predicted versus observed flood values were reviewed. Regression residuals for the 100-yr model were plotted to identify regional patterns (Figure 4). No pattern was evident. The DFFITS, VIF and PRESS statistics were analyzed. All regression diagnostics indicated that the explanatory variables provide an excellent model.

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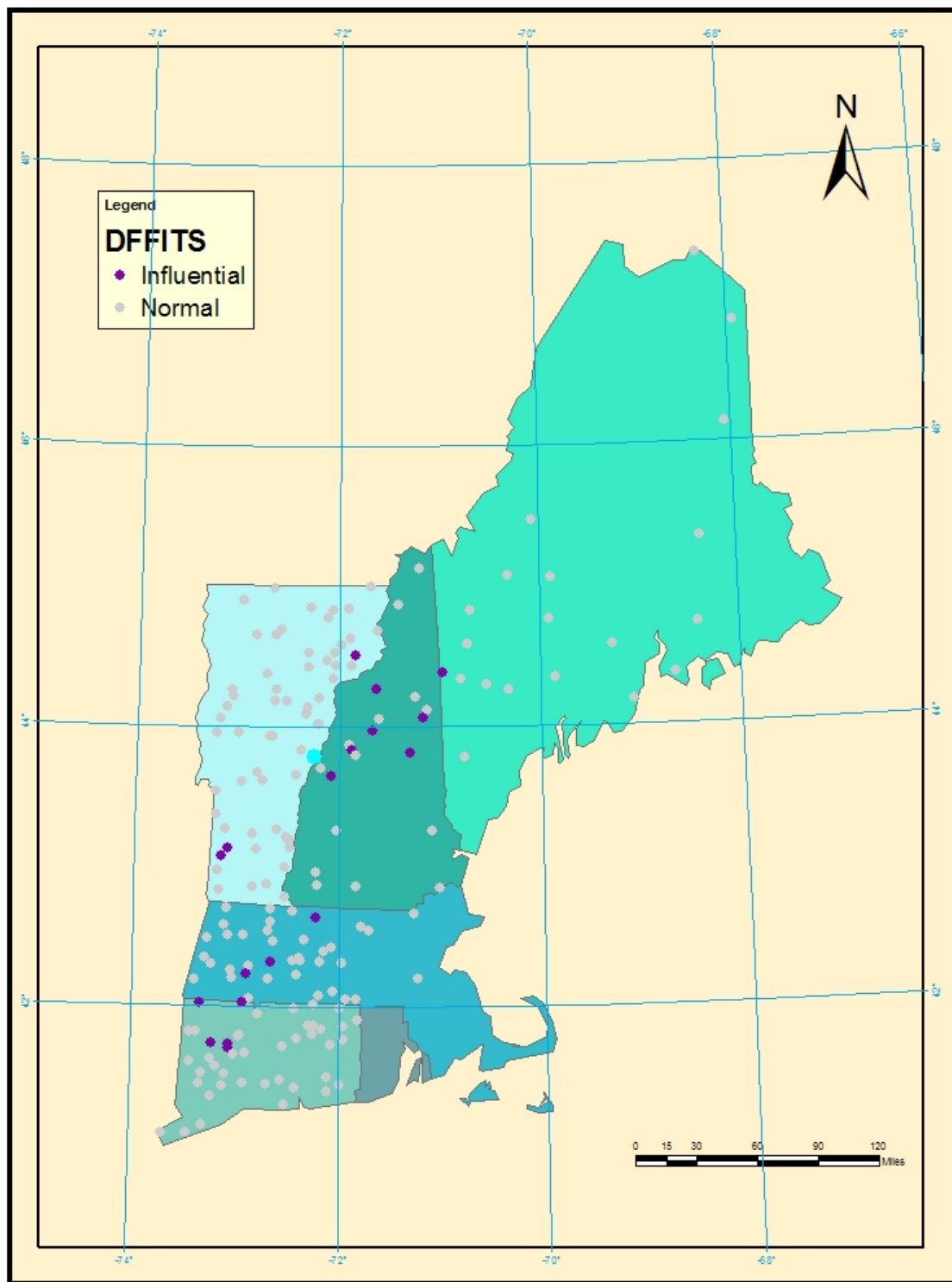
Figure 3. Influential stations based on DFFITS analysis for those watersheds in New England used in the steep watershed regression analysis.

The final regression model coefficients were determined using the weighted least square (WLS) regression technique. WLS is often used to maximize the efficiency of parameter estimation and allows one to use data sets with data points of varying quality. WLS is similar to Generalized Least-squares (GLS) regression in that both assume that the independent variables have different variances. GLS is used when independent variables have different variances and correlated errors. The Durbin-Watson statistic was used to evaluate the dependence of residuals. Because it did not show any positive or negative serial correlation, the WLS regression method was used to develop the final coefficients. When developing the regression equations using WLS, the record length in years (n) was the weighting factor. Therefore, those stations with a longer record length were given more influence on the predicted peak flow values.   With the basin characteristic parameters that were generated in the stepwise regression process, a WLS regression was performed. The final peak-flow regression equations are presented in Table 2.

Table 2. Regression equations and their accuracy for estimating peak flows for steep, ungaged, unregulated drainage basins in New England. Steep is defined as a main channel slope that exceeds 50 ft per mile. [Q is peak flow, in cubic feet per second; A is drainage area, in square miles; P is mean annual precipitation in inches]

Peak-flow regression equation by recurrence interval	Standard Error of the Estimate (percent)		$(PRESS/n)^{1/2}$ (percent)		Average Prediction Error (percent)		Average Equivalent Yrs of Record
$Q_2=0.01601A^{0.889}P^{2.12}$	47.1%	-32.0%	46.9%	-31.9%	48.1%	-32.5%	2.09
$Q_5=0.01965A^{0.889}P^{2.19}$	45.1%	-31.1%	44.8%	-30.9%	46.1%	-31.6%	3.03
$Q_{10}=0.02430A^{0.891}P^{2.21}$	46.5%	-31.7%	46.4%	-31.7%	47.5%	-32.2%	3.89
$Q_{25}=0.03387A^{0.893}P^{2.20}$	50.4%	-33.5%	50.7%	-33.7%	51.5%	-34.0%	4.73
$Q_{50}=0.04372A^{0.895}P^{2.18}$	54.5%	-35.3%	55.2%	-30.9%	55.8%	-35.8%	5.10
$Q_{100}=0.05765A^{0.897}P^{2.15}$	59.4%	-37.3%	60.5%	-37.7%	60.8%	-37.8%	5.29
$Q_{500}=0.111A^{0.903}P^{2.08}$	73.4%	-42.3%	75.3%	-43.0%	75.1%	-42.9%	
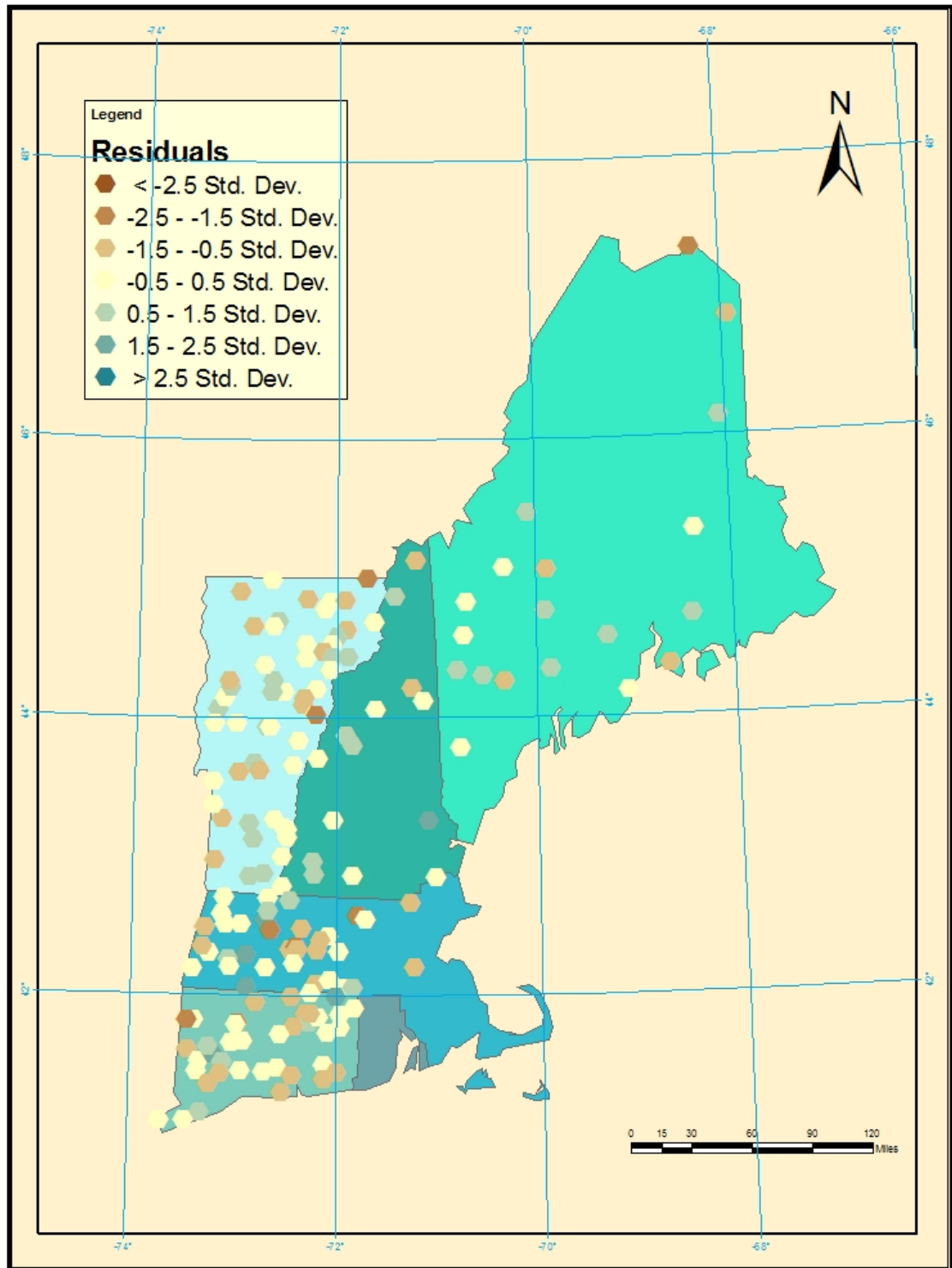
Figure 4. Residuals by stations for those watersheds in New England used in the steep watershed regression 100-yr model.

2.5 Application and Technique

Peak-flow regression equations for recurrence intervals of 2, 5, 10, 25, 50, 100, and 500 years are presented in Table 2. The variables used in the equations are described in the table caption and below. Accuracy and limitations are discussed in the following section. All of the regression equations in this report are statistical models. They are not based directly on rainfall-runoff processes. For this reason, when applying these equations, the explanatory variables should be computed by the same methods that were used in the development of the equations. Using "more accurate" methods of computing the explanatory variables (for example, updating the annual precipitation or using local precipitation data) will result in peak-flow estimates of unknown accuracy.

The regression equations are applicable only to sites on steep, ungaged, unregulated streams in the New England watersheds. The explanatory variables are drainage area and annual average precipitation. Use of the equations should be limited to sites within the range of the explanatory variables as listed in Appendix A. Annual average precipitation ranged from 35.3 to 73.5 inches. Drainage area ranged from 0.21 to 130 square miles. Outside this range, the accuracy will likely be reduced, but its magnitude is unknown.

A - Drainage area - The contributing area, in square miles, of a drainage basin. The term "contributing" means that flow from an area could contribute flow to a study site on a stream. All units of drainage area, except square miles, will result in incorrect estimates of peak flows. The drainage area can be computed from a number of sources. A series of reports that lists drainage areas at selected points on many streams in New England have been published by the USGS. The drainage areas for most gaged watersheds are listed on the USGS National Water Information System website. Drainage areas can be computed from geographic information system (GIS) coverages or computed using the USGS StreamStats software (http://water.usgs.gov/osw/streamstats/, access November 2010).

P - Mean Annual Precipitation – The average annual precipitation, in inches, for the watershed. The mean annual precipitation should be obtained from the PRISM 1961 to 1990 maps because these maps were used in the development of the regression equations. These annual precipitation estimates were using the PRISM model (Daly et al. 1994, Daly et al. 1997). The PRISM estimates are part of a national effort by the USDA Natural Resources Conservation Service and Oregon State University to develop state-of-the-art precipitation maps for each state in the US, including Alaska and Hawaii. Data input to their model consisted of 1961-90 mean monthly precipitation from over 8000 NOAA Cooperative sites, SNOTEL sites, and selected state network stations. Data-sparse areas were supplemented by a total of about 500 shorter-term stations. A station was included in this data set if it had at least 20 years of valid data, regardless of its period of record. The annual maps were created by summing the 12 monthly maps. The annual maps underwent extensive peer-review by many state climatologists and other experts. Figure 5 shows the PRISM values for the New England states. The ArcInfo data product is available from http://www.prism.oregonstate.edu/products/ (accessed November 2010).
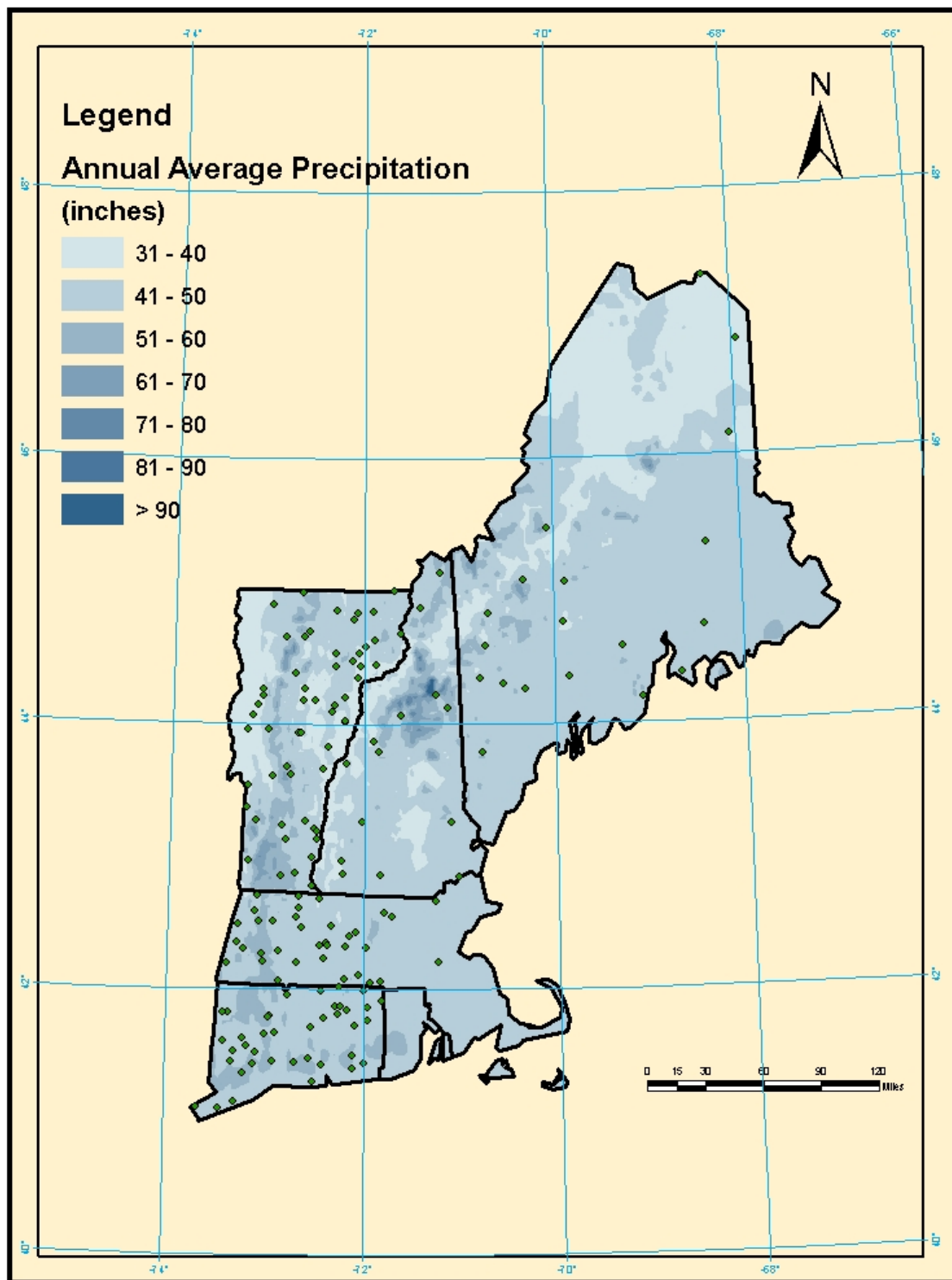
Figure 5. PRISM rainfall values and stations for those watersheds in New England used in the steep watershed regression.

2.6 Accuracy and Limitations

The first performance metric that was calculated was the Standard Error of the Estimate (Ser). Flynn (2003) summarizes SER as "The standard error of the estimate (*Ser*, in percent), is a measure of the average precision with which the regression equations estimate streamflow statistics for stream-gaging stations used to develop regression equations (Ries and Friesz, 2000). The standard error of estimate is a measure of the deviation of the observed data from the corresponding predictive data values and is similar to standard deviation for a normal distribution. Approximately 68 percent of the observed data will be contained within ± one standard error of the regression line."

The second statistic was the Average Prediction Error (APE). Flynn (2003) summarizes APE as "The Average Prediction Error (APE), which is an overall measure of how accurately the regression model can predict streamflow statistics for ungaged sites where the average is taken from prediction sites with *X* variables identical to the observed data. Average Prediction Error represents an estimate of the average squared-model error for the *n* sites plus an estimate of the average squared error as a result of estimating the true model parameters from a sample of data." Here *"X"* refers to the number of estimated parameters.

The Ser and APE calculations are often times used to calculate confidence intervals for the means of the different return periods. These are used as a standard deviation, which makes sense as they are an error of measure, and either or both can be used to generate the confidence intervals. Only one standard deviation is used to surround the mean, so it is a 67% confidence interval. These confidence intervals are reported as percentages of the means.

The PRESS statistic is an excellent overall measure of the regression equations. The PRESS statistic is a validation-type statistic. In summary, one station is removed from the data set and the remaining stations are used to recalculate the regression equation. This new equation is used to predict the value for the missing station and to determine the residual difference between that predicted and the observed value. The process is repeated for each station. The PRESS statistic is presented as confidence intervals based on percentages of the means.

The final statistic that was calculated is the Average Equivalent Years of Record (AEYR), following (Hardison, 1971). Hardison describes AEYR as "As the standard error of prediction of a streamflow characteristic depends largely on the variability of the annual event, it tends to be much larger in some sections of the country than in others. One way to remove this regional variability is to express the accuracy of prediction in terms of the equivalent years of record that would be required to give results of equal accuracy." Essentially AEYR indicates how many years of peak flow data will be needed to get similar results to the regression.

A summary of the statistics is presented in Table 2. These statistics were also calculated for only those watersheds having basins slopes greater than 100 ft per mile for the 100-yr model (Table 2) and a two parameter regression model using only those watersheds having main channel slopes greater than 100 ft per mile. While model performance was nearly identical among the three approaches, the model presented in

Table 2 provides predictions for a greater range of channel slopes without compromising performance for the steep channels.

2.7 Steep Water Predictions Compared to USGS State Predictions

As noted in Section I of this report, each New England state has a set of regression equations to predict flood flows for watersheds in that state. In this section, the performance of the steep watershed regression equations is compared to that for the individual states. Of the steep watersheds used in this analysis, 131 watersheds were also used in the State regression studies. Flood flow predictions using the steep watershed regression equations (Table 2) and the appropriate State regression equation were compared to the USGS Bulletin 17B estimates of peak flows.

Figure 6 shows the Bulletin 17B flood flow estimates versus those predicted using the steep watershed regression estimates and the State regression equations by return period. The observed, Bulletin 17B flood flows, and the predicted values, using State USGS regression equations or Steep watershed regression equations, were compared using metrics described in Willmott (1982). Table 3 provides a quantitative analysis of the results. For the 2-, 5-, and 10-yr return periods, the steep watershed predictions are typically marginally better than the State estimates. The steep watershed formulations result in more significant improvements for the larger flood events. Thus for watersheds having main channel slopes that exceed 50 ft per mile, the single, steep watershed regression equations appear to be as good or better than the individual State regression equations. For the lower return periods, it appears that the floods are not large enough to be distinguished from typical New England conditions. This suggests that the watershed area dominates the peak flow predictions. Watershed area comes through consistently for all the state and steep watershed regressions. For the higher return periods, the new regression equations are consistently better than the existing state predictions.

The original motivation for this work was the finding by Hodgkins (1999) that the regression relationships developed for Maine did not always hold true for steep slope watersheds. In particular, Hodgkins (1999) identified three steep, NH watersheds as outliers: Ellis River near Jackson, N.H. (station number 01064300); Lucy Brook near North Conway, N.H. (01064400); and Cold Brook at South Tamworth, N.H. (01064800). For the current study, the latter two sites were removed from the analysis because their DFFITS values were extremely high. Ellis River near Jackson, N.H. (station number 01064300) was included in the analysis.

The current study's regression equations performed better than the USGS NH equations (Olson, 2009) for this site as compared to those flood flows estimated using Bulletin 17B. For the 2-yr return period, floods were 1444, 1211, and 1250 cfs for the USGS NH, this steep water study, and Bulletin 17B, respectively. For the 5-yr return period, floods were 2647, 2008, and 2030 cfs for the USGS NH, this steep water study, and Bulletin 17B, respectively. For the 10-yr return period, floods were 3666, 2719, and 2590 cfs for the USGS NH, this steep water study, and Bulletin 17B, respectively. For the 25-yr return period, floods were 4982, 3648, and 3330 cfs for the USGS NH, this steep water study, and Bulletin 17B, respectively. For the 50-yr return period, floods were 6053, 4342, and 3900 cfs for the USGS NH, this steep water study, and Bulletin 17B,

respectively. For the 100-yr return period, floods were 7337, 5057, and 4480 cfs for the USGS NH, this steep water study, and Bulletin 17B, respectively. For the 500-yr return period, floods were 10223, 7311, and 5910 cfs for the USGS NH, this steep water study, and Bulletin 17B, respectively.

Regarding the two watersheds removed from both this study and the earlier study, Cold Brook at South Tamworth, N.H. and Lucy Brook near North Conway, N.H. (01064400), both these watersheds were relatively small and had measured 100-yr and 500-yr flood flows that were typically twice as large as the regression equation predictions for both this study and the NH USGS study. Cold Brook (01064800) only had 10 years of peak flows (WY 1964 to 1973) with only four of those flows in the April and early May time period when one would expect a typical snowmelt flood. Thus, the Cold Brook record may not be representative of the typical record for the other sites.

In contrast, Lucy Brook (01064400) had a longer period of record (WY 1965 to 1992) with a traditional flood regime. It is possible that there are gaging problems at this station. However, it appears more likely that the actual precipitation for Lucy Brook watershed differs from that estimated by PRISM. That watershed is relatively small and located in the Echo Lake, Cathedral Ledges area of the White Mountains just west of North Conway, NH. The PRISM precipitation does vary in this region in a manner that appears to account for topographic effects, but it clearly has Lucy Brook area receiving less precipitation than the Jackson, NH area directly north. If precipitation in Lucy Brook were similar to that for Ellis River (73.5 rather than 55 inches annually and 6.23 versus 4.45 inches in April) both the NH USGS and the steep watersheds regression approach would perform considerably better.

In summary, it appears precipitation variations matter in steep watersheds for extreme flood flows. For our region, those variations appear to be largely a function of topography (see Figure 5). Thus models which include precipitation or topography may perform better for regions in which there are variations in topography. Notably, all regression models except that for Maine include either precipitation or topography or both. However, the best means to determine the best estimate of precipitation is for these watersheds and its relationship to topography is still an open question. Because most regression relationships rely on the PRISM dataset for precipitation data, any errors caused by that dataset's ability to relate topography and precipitation will directly impact estimate of precipitation.

2.8 Conclusions and Recommendations

Estimates of these flood events are used by the Federal, State, regional, and local officials to safely and economically design hydraulic structures as well as for effective floodplain management. The regression relationships developed to predict flows at ungauged sites do not always hold true for steep slope watersheds in New England. This study developed the regression relationships to predict peak flows for ungaged, unregulated steep streams in New England with recurrence intervals of 2, 5, 10, 25, 50, 100, and 500 years. For watersheds having a main channel slope that exceeds 50 ft per mile, peak flows are well estimated by the watershed drainage area and the mean annual precipitation. No metric of watershed steepness provided a statistically significantly

improvement to prediction capability. For these steep watersheds, the series of regression equations was found to perform as well or better than the individual state regression equations.

For most of the study region, precipitation variations appear to be largely a function of topography. The present and all New England State regression models except that for Maine include either precipitation or topography or both. Thus models which include precipitation or topography may perform better for regions in which there are variations in topography. Because most regression relationships rely on the PRISM dataset for precipitation data, any errors caused by that dataset's ability to relate topography and precipitation will directly impact estimate of precipitation. Analyses that use regional precipitation data for future predictions may benefit from improved understanding of the PRISM dataset errors and enhanced characterization of regional precipitation data.

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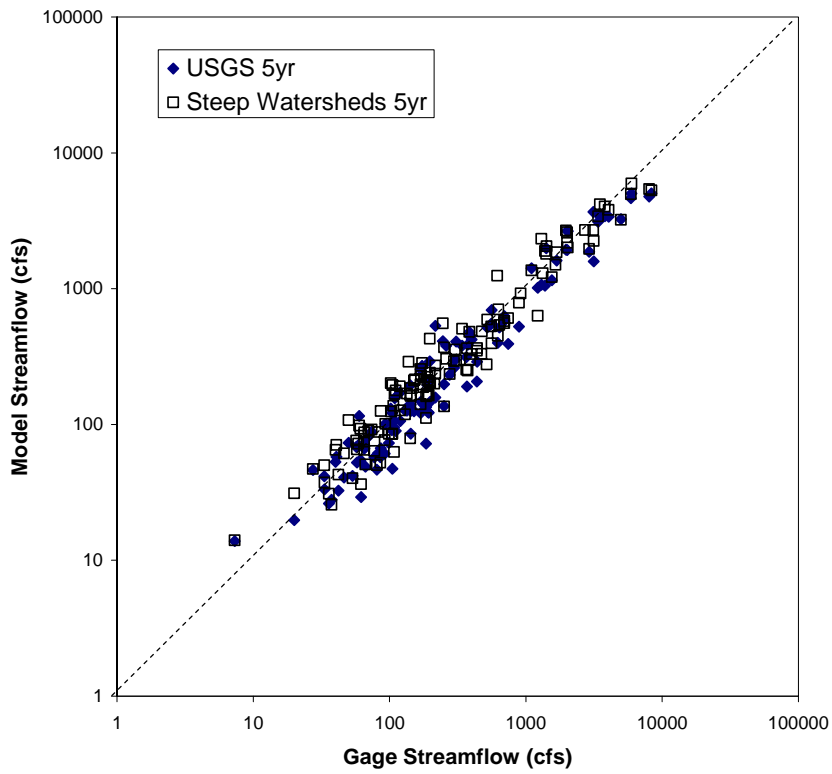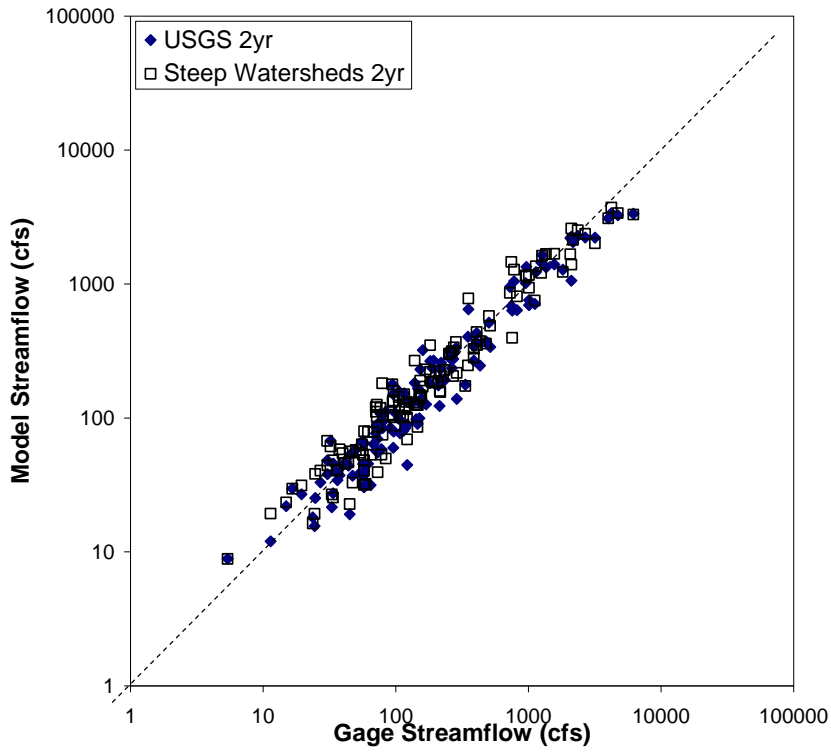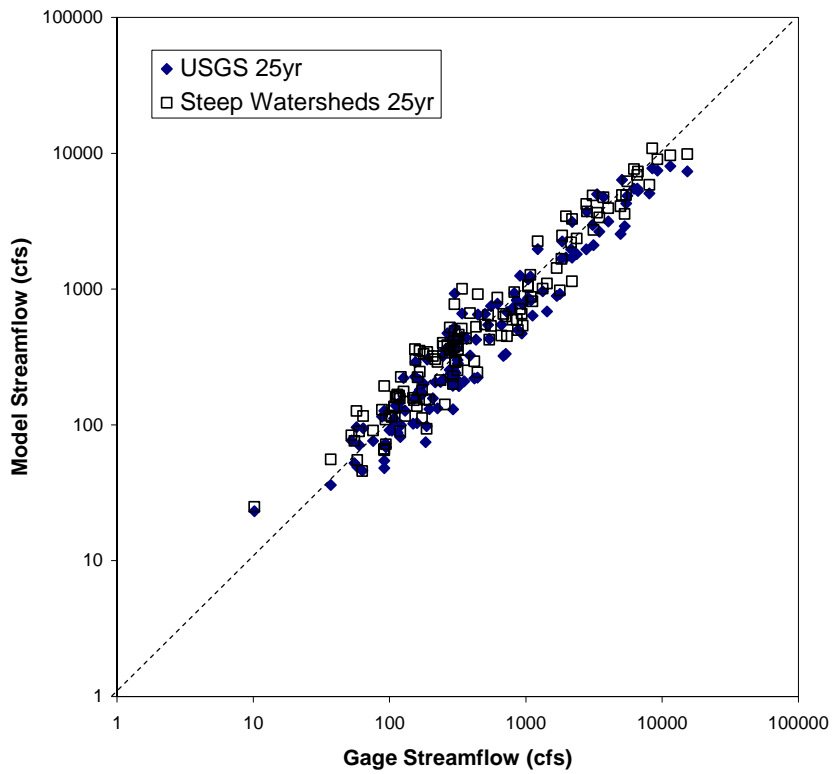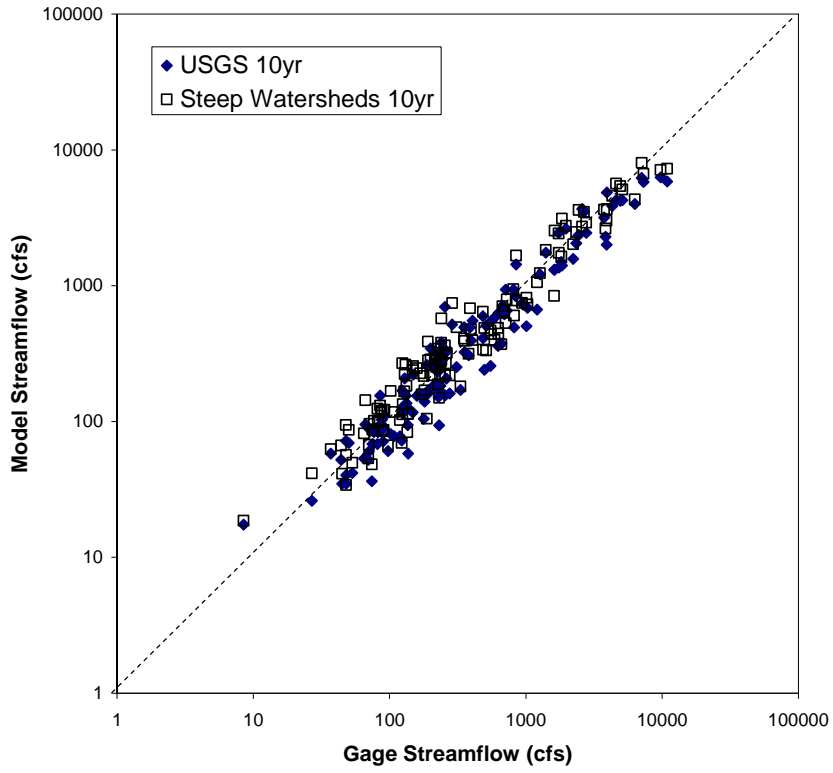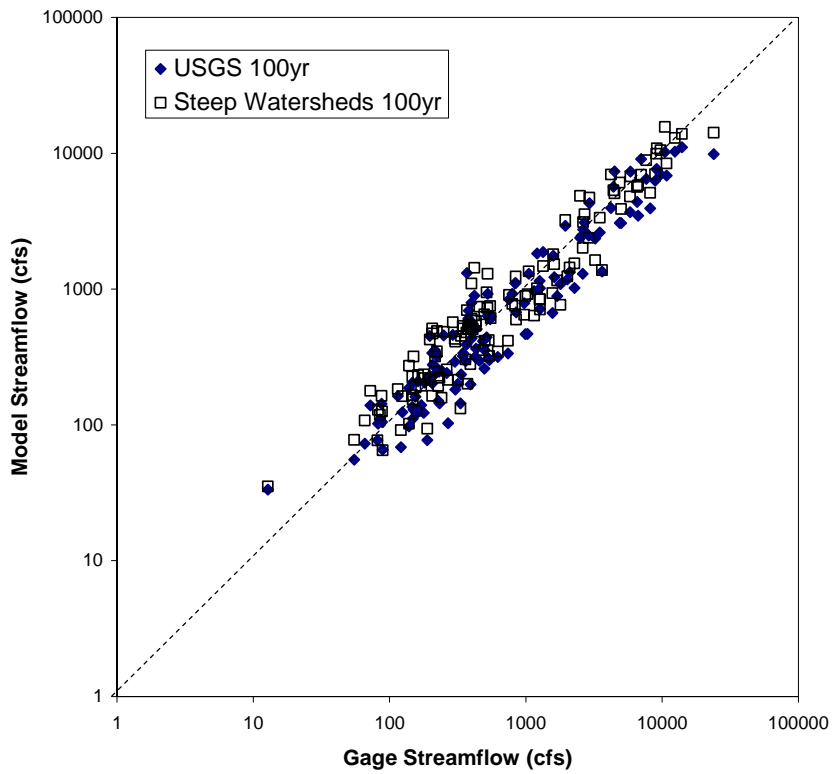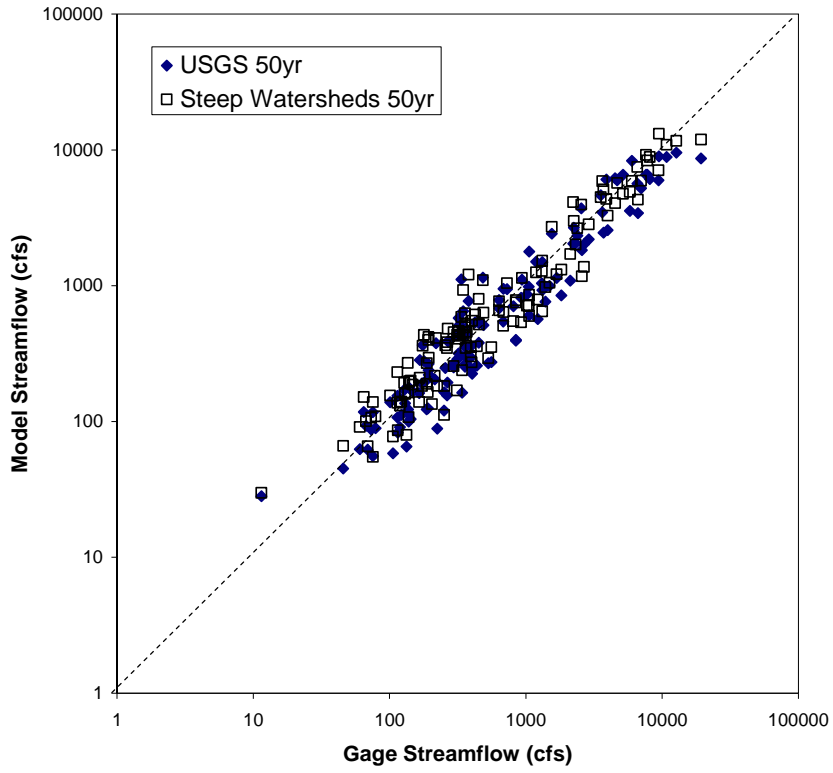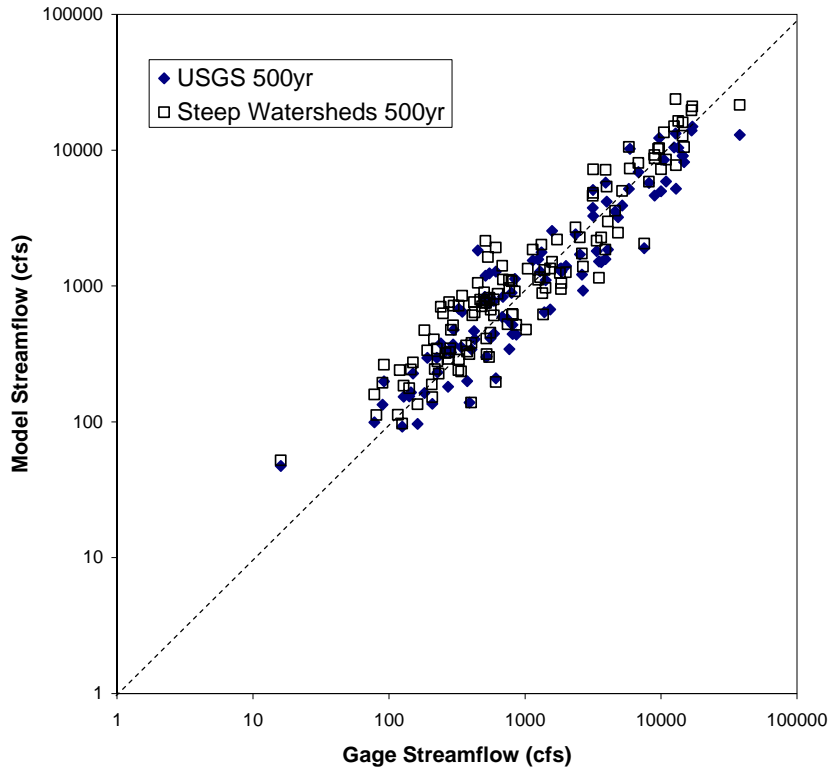
Figure 6. Bulletin 17B flood flow estimates versus those predicted using the steep watershed regression estimates and the State regression equations by return period.

Table 3. Regression equations and their accuracy for estimating peak flows for steep, ungaged, unregulated drainage basins in New England. Steep is defined as a main channel slope that exceeds 50 ft per mile. [N is the number of sites, O is observed; P is predicted, ave is the average flood flows, s.d. is the standard deviation of flood flows, a is the linear regression intercept, b is the linear regression slope, R^2 is the linear regression squared correlation, MAE is the mean absolute error, RMSE is root mean square error]. N, b, and R² are dimensionless. The remaining terms have the units of cfs.

Return Period	Model	N	Ave O	Ave P	s.d. O	s.d. P	a	b	R^2	MAE	RMSE
2-yr	USGS	131	515	443	978	734	72	0.72	0.924	125	346
	Steep	131	515	474	978	766	91	0.74	0.902	130	348
5-yr	USGS	116	806	680	1541	1163	95	0.73	0.925	203	543
	Steep	116	806	749	1541	1275	108	0.79	0.923	186	475
10-yr	USGS	131	1032	880	1852	1406	134	0.73	0.908	273	681
	Steep	131	1032	1020	1852	1652	137	0.86	0.921	234	534
25-yr	USGS	131	1368	1148	2413	1804	185	0.70	0.886	394	962
	Steep	131	1368	1378	2413	2236	167	0.89	0.912	325	718
50-yr	USGS	131	1658	1440	2896	2233	263	0.71	0.847	505	1228
	Steep	131	1658	1660	2896	2699	196	0.88	0.897	416	927
100-yr	USGS	131	1986	1615	3447	2493	302	0.66	0.835	645	1584
	Steep	131	1986	1965	3447	3204	236	0.87	0.878	531	1201
500-yr	USGS	101	3482	2596	5561	3588	645	0.56	0.755	1307	3134
	Steep	101	3482	3474	5561	5281	517	0.85	0.799	1200	2498

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APPENDIX A

Table A.1 Magnitude and frequency discharges at stream-gaging stations used to determine flow characteristics of steep streams

Table A.2. Drainage areas and mean annual precipitation for gaging stations used in regression equations.

Table A.1. Magnitude and frequency discharges at stream-gaging stations used to determine flow characteristics of steep streams

[All streamgages are located on figure 2; USGS, U.S. Geological Survey; cfs, cubic feet per second; No., number; mi^2, square miles]

USGS stream-gaging station No.	Gaging Station Name	2-year	5-year	10-year	25-year	50-year	100-year	500-year	Period of Record	Flood of Record (cfs)	Drainage Area (mi^2)
01014700	Factory Brook Near Madawaska, Me	160	217	255	301	336	370	449	1964-1974	281	5.83
01017300	Nichols Brook Near Caribou, Me	106	169	216	278	327	379	507	1964-1973	281	3.94
01017900	Marley Brook Near Ludlow, Me	84	142	188	255	312	374	545	1964-1981	100	1.47
01024200	Garland Brook Near Mariaville, Me	411	694	939	1330	1680	2100	3370	1965-1982	619	9.79
01026800	Frost Pond Brook Near Sedgwick, Me	169	251	310	389	451	516	680	1964-1974	350	5.68
01034900	Coffin Brook Near Lee, Me	68	103	128	161	188	216	286	1964-1973	143	2.21
01037430	Goose River At Rockport, Me	387	558	674	823	936	1050	1320	1964-1973	624	8.32
01041900	Mountain Brook Near Lake Parlin, Me	217	375	512	728	922	1150	1840	1063-1974	918	3.91
01046000	Austin Stream At Bingham, Me	2360	3790	4940	6640	8110	9760	14400	1932-1969	4860	90
01046800	South Branch Carrabassett River At Bigelow, Me	1120	1550	1820	2150	2390	2630	3150	1963-1973	1620	14.2
01048100	Pelton Brook Near Anson, Me	755	1220	1610	2180	2670	3230	4830	1964-1973	2080	14.1
01049100	Hall Brook At Thorndike, Me	193	390	589	949	1320	1800	3500	1963-1973	933	5.23
01049300	North Branch Tanning Brook Near Manchester, Maine	73.2	108	135	173	205	241	339	1963-1973	74	0.93
01050900	Four Ponds Brook Near Houghton, Me	96.6	169	229	322	404	497	768	1963-1973	349	3.41

USGS stream-gaging station No.	Gaging Station Name	2-year	5-year	10-year	25-year	50-year	100-year	500-year	Period of Record	Flood of Record (cfs)	Drainage Area (mi^2)
01054200	Wild River At Gilead, Maine	8830	14000	17400	21700	24700	27700	34300	1959-2003	7510	69.6
01054300	Ellis River At South Andover, Maine	4220	5960	7080	8480	9490	10500	12800	1963-2003	5420	130
01055000	Swift River Near Roxbury, Maine	6180	9870	12500	16000	18700	21500	28200	1930-2003	9120	96.9
01055300	Bog Brook Near Buckfield, Me	182	246	288	341	380	419	511	1963-1973	166	10.5
01057000	Little Androscoggin River Near South Paris, Maine	2170	3390	4300	5560	6570	7660	10500	1914-2003	9340	73.5
01062700	Patte Brook Near Bethel, Me	219	401	557	800	1020	1270	2000	1964-1973	664	5.35
01064300	Ellis River Near Jackson, Nh	1250	2030	2590	3330	3900	4480	5910	1964-2003	99	10.9
01064380	E Br Saco R @ Town Hall Rd, Nr Lower Bartlett, Nh	2070	3130	3930	5070	6000	7000	9680	1966-1976	4610	32
01064400	Lucy Brook Near North Conway, Nh	571	1050	1430	1960	2390	2850	4030	1964-1991	571	4.68
01064500	Saco River Near Conway, NH	17000	26200	32700	41200	47700	54400	70700	1904-2003	33900	385
01064800	Cold Brook At South Tamworth, Nh	416	1030	1720	3100	4610	6670	14600	1963-1973	507	5.41
01066100	Pease Brook Near Cornish, Me	153	260	353	502	637	797	1290	1965-1996	486	4.62
01072850	Mohawk Brook Near Center Strafford, Nh	274	638	1030	1780	2580	3630	7530	1965-1977	351	7.34
01074500	East Branch Pemigewasset River Near Lincoln, Nh	6050	9120	11600	15100	18200	21500	31000	1929-1972	11800	104
01075000	Pemigewasset River At Woodstock, Nh	11800	19100	24700	32600	39100	46000	64400	1940-2003	16900	193
01075500	Baker River At Wentworth, Nh	2890	4780	6460	9170	11700	14700	24100	1940-1951	3740	58.8

USGS stream-gaging station No.	Gaging Station Name	2-year	5-year	10-year	25-year	50-year	100-year	500-year	Period of Record	Flood of Record (cfs)	Drainage Area (mi^2)
01075800	Stevens Brook Near Wentworth, Nh	203	393	573	878	1170	1540	2740	1964-1998	270	2.94
01076000	Baker River Near Rumney, Nh	5170	8730	11800	16500	20900	25900	41000	1927-2003	12600	143
01085800	West Branch Warner River Near Bradford, Nh	351	562	711	907	1060	1210	1580	1963-2003	351	5.75
01093800	Stony Brook Tributary Near Temple, Nh	188	308	407	556	686	833	1250	1963-2004	343	3.6
01094400	North Nashua River At Fitchburg, Ma	1690	2360	2800	3370	3790	4220	5240	1973-2004	2830	64.2
01095800	Easter Brook Near North Leominster, Ma	36.3	57.7	74.9	100	122	147	217	1964-1973	85	0.92
01100100	Richardson Brook Near Lowell, Ma	105	170	221	296	360	431	629	1962-1983	424	4.22
01100800	Cobbler Brook Near Merrimac, Ma	57.6	80.8	97.5	120	138	158	207	1962-1983	117	0.77
01104900	Mill Brook At Westwood, Ma	30.5	50.1	66.6	91.7	114	139	214	1964-1974	96	1.52
01105550	Plantingfield Brook At Norwood, Ma	132	166	188	215	235	256	304	1963-1974	185	1.52
01109100	Taunton River Tributary Near Fall River, Ma	45.2	65.1	79.2	98	113	128	166	1964-1983	108	0.23
01119255	Delphi Bk Nr Staffordville, Ct.	86.3	176	263	411	555	732	1310	1964-1976	310	2.59
01119360	Conat Bk At W Willington, Ct.	57.9	97.3	130	179	221	270	408	1964-1983	150	2.4
01119450	Eagleville Bk At Storrs, Ct.	83.8	108	124	143	157	171	203	1953-1969	123	0.36
01119600	Ash Bk Nr N Coventry, Ct.	150	194	225	266	297	329	410	1960-1970	260	2.79
01120500	Safford Bk Nr Woodstock Valley, Ct.	334	516	662	877	1060	1270	1850	1951-1981	445	4.15

USGS stream-gaging station No.	Gaging Station Name	2-year	5-year	10-year	25-year	50-year	100-year	500-year	Period of Record	Flood of Record (cfs)	Drainage Area (mi^2)
01121000	Mount Hope River Near Warrenville, Ct.	1010	1650	2230	3140	3990	5000	8150	1938-2003	2640	28.6
01121300	Fenton R At East Willington, Ct.	343	560	727	963	1160	1370	1920	1964-1976	750	11.4
01122680	Merrick Bk Nr Scotland, Ct.	267	462	632	900	1140	1430	2300	1960-1984	1020	5.21
01123160	Wales Brook Tributary Near Wales, Ma	27	40.2	50.2	64	75.4	87.6	120	1964-1983	63	0.73
01124050	Tufts Branch At Dudley, Ma	57.8	92.3	119	159	191	228	327	1963-1983	128	1.1
01124750	Browns Brook Near Webster, Ma	14.9	33.3	53.3	91.7	133	189	401	1963-1977	53	0.49
01125300	English Neighborhood Bk At N Woodstock, Ct.	188	406	620	988	1350	1790	3230	1962-1984	1200	4.66
01125650	Wappoquia Bk Nr Pomfret,Ct.	239	400	543	771	983	1230	2020	1964-1984	850	4.21
01125900	Cady Bk At East Putnam, Ct.	304	538	729	1010	1250	1520	2260	1964-1984	950	8.29
01126600	Blackwell Bk Nr Brooklyn, Ct.	504	916	1270	1830	2320	2900	4600	1962-1976	840	17
01127700	Trading Cove Bk Nr Thamesville, Ct.	356	580	764	1040	1280	1550	2330	1961-1974	940	8.46
01127760	Hunts Bk At Old Norwich Rd At Quaker Hill, Ct	240	390	516	709	881	1080	1670	1964-1976	650	11.5
01127880	Big Brook Near Pittsburg, Nh	265	341	389	445	485	524	610	1964-1984	300	6.36
01129400	Black Brook At Averill, Vt	30.6	40.7	47.8	57.3	64.7	72.4	91.7	1964-1978	54	0.882
01129440	Mohawk River Near Colebrook Nh	2110	3150	3910	4950	5790	6670	8960	1987-2003	2450	36.7

USGS stream-gaging station No.	Gaging Station Name	2-year	5-year	10-year	25-year	50-year	100-year	500-year	Period of Record	Flood of Record (cfs)	Drainage Area (mi^2)
01129700	Paul Stream Tributary Near Brunswick Springs, Vt	50	73.8	92	118	139	162	225	1966-2003	126	1.481
01133000	East Branch Passumpsic River Near East Haven, Vt	1360	1970	2440	3090	3640	4220	5810	1927-2003	2310	51.329
01133200	Quimby Brook Near Lyndonville, Vt	79.7	130	172	237	295	361	557	1964-2003	290	2.151
01133300	Cold Hill Brook Near Lyndon, Vt	55.6	93.2	125	173	215	263	405	1964-1977	195	1.639
01134500	Moose River At Victory, Vt	2090	2770	3240	3860	4340	4840	6080	1947-2003	4100	75.166
01134800	Kirby Brook At Concord, Vt	387	623	819	1120	1390	1700	2620	1964-2004	400	8.126
01135150	Pope Brook (Site W-3) Near North Danville, Vt	152	190	215	246	268	291	345	1991-2003	90	3.269
01135300	Sleepers River (Site W-5) Near St. Johnsbury, Vt	1820	2920	3850	5320	6640	8180	12900	1990-2003	1380	42.504
01135700	Joes Brook Tributary Near East Barnet, Vt	33.7	53.6	69.9	94.2	115	139	208	1964-2003	103	0.7
01137500	Ammonoosuc River At Bethlehem Junction, Nh	4380	6330	7740	9670	11200	12800	17000	1940-2003	6300	87.6
01138800	Keenan Brook At Groton, Vt	94.3	173	239	339	426	523	797	1964-1973	275	4.723
01139700	Waits River Tributary Near West Topsham, Vt	45.2	70.1	87.7	111	128	147	191	1964-2003	94	1.211
01139800	East Orange Branch At East Orange, Vt	252	386	484	620	728	842	1140	1959-2003	260	8.79
01140000	South Branch Waits River Near Bradford, Vt	965	1410	1740	2190	2550	2930	3920	1940-1951	1350	43.817

USGS stream-gaging station No.	Gaging Station Name	2-year	5-year	10-year	25-year	50-year	100-year	500-year	Period of Record	Flood of Record (cfs)	Drainage Area (mi^2)
01140100	South Branch Waits R Tr Near Bradford Center, Vt	5.4	7.3	8.5	10.2	11.5	12.8	16	1964-1974	9	0.211
01140800	West Br Ompompanoosuc R Tr At South Strafford, Vt	78	104	124	151	173	197	261	1964-1977	168	1.349
01141500	Ompompanoosuc River At Union Village, Vt	2550	3540	4210	5090	5760	6450	8130	1927-2003	3320	130.729
01141800	Mink Brook Near Etna, Nh	215	366	486	662	810	973	1420	1963-1998	261	4.6
01142400	Third Branch White River Tributary At Randolph, Vt	47.2	85.6	123	187	251	332	611	1964-2004	130	0.827
01142500	Ayers Brook At Randolph, Vt	725	1100	1400	1850	2250	2700	3990	1927-2003	1550	30.466
01145000	Mascoma River At West Canaan, Nh	1600	2230	2640	3140	3500	3860	4670	1938-2004	3190	80.5
01150800	Kent Brook Near Killington, Vt	214	370	497	685	846	1030	1530	1964-2004	300	3.261
01150900	Ottauquechee River Near West Bridgewater, Vt	1010	1380	1630	1970	2230	2500	3170	1985-2004	1460	23.25
01151200	Ottauquechee River Tributary Near Quechee, Vt	16.6	27.4	37	52.6	67.3	85	141	1964-2004	93	0.77
01153300	Middle Branch Williams River Tr At Chester, Vt	137	195	238	297	344	394	524	1964-2003	367	3.182
01153500	Williams River At Brockways Mills, Vt	4010	5900	7300	9230	10800	12400	16800	1938-1984	5340	102.292
01153550	Williams River Near Rockingham Vt	6200	8340	9730	11500	12700	14000	17000	1987-2003	6670	111.913
01154000	Saxtons River At Saxtons River, Vt	2680	4060	5110	6590	7790	9090	12500	1936-2003	3350	72.085

USGS stream-gaging station No.	Gaging Station Name	2-year	5-year	10-year	25-year	50-year	100-year	500-year	Period of Record	Flood of Record (cfs)	Drainage Area (mi^2)
01155200	Sackets Brook Near Putney, Vt	284	522	725	1040	1310	1620	2530	1964-1973	268	10.147
01155300	Flood Brook Near Londonderry, Vt	516	890	1210	1690	2120	2620	4070	1964-1973	596	9.285
01155350	Trib To West River Trib @ Rt 30, Nr Jamaica, Vt	56.6	98.8	136	196	252	317	522	1964-2003	320	0.926
01156300	Whetstone Brook Tributary Near Marlboro, Vt	122	185	231	292	341	392	519	1963-2004	253	1.076
01156450	Connecticut River Tributary Near Vernon, Vt	53.4	82.5	108	149	187	233	376	1964-2003	128	1.103
01158500	Otter Brook Near Keene, Nh	1140	2010	2780	4020	5170	6550	10900	1924-1957	4040	42.3
01160000	S Br Ashuelot River At Webb, Nr Marlborough, Nh	954	1680	2350	3460	4520	5820	10000	1920-1978	3070	36
01161300	Millers Brook At Northfield, Ma	108	194	276	419	560	740	1360	1964-1983	680	2.3
01165000	East Branch Tully River Near Athol, Ma	743	1300	1840	2780	3710	4880	8940	1917-1990	3650	50.5
01167800	Beaver Brook At Wilmington, Vt	432	742	1010	1430	1820	2270	3640	1963-1977	593	6.361
01169000	North River At Shattuckville, Ma	4750	7710	10100	13600	16700	20100	29600	1940-2004	8740	89
01169900	South River Near Conway, Ma	1820	2950	3920	5460	6850	8490	13500	1966-2004	1570	24.1
01170100	Green River Near Colrain, Ma	2490	3450	4120	5020	5730	6470	8330	1968-2004	2420	41.4
01170200	Allen Brook Near Shelburne Falls, Ma	24.7	46.3	64.9	93.5	119	148	232	1964-1973	89	0.72
01170900	Mill River Near South Deerfield, Ma	139	197	240	299	347	399	534	1963-1974	300	6.42

USGS stream-gaging station No.	Gaging Station Name	2-year	5-year	10-year	25-year	50-year	100-year	500-year	Period of Record	Flood of Record (cfs)	Drainage Area (mi^2)
01171200	Scarboro Brook At Dwight, Ma	72	102	124	154	179	206	277	1963-1973	148	2.9
01171500	Mill River At Northampton, Ma	2220	3290	4030	4980	5700	6430	8170	1938-2004	3870	52.6
01171910	Broad Brook Near Holyoke, Ma	70.9	111	148	208	266	335	561	1964-1983	393	2.27
01173040	Pleasant Brook Near Barre, Ma	37.6	61.2	81.6	114	143	178	283	1965-1973	123	1.22
01173260	Moose Brook Near Barre, Ma	79.2	138	191	277	358	456	765	1963-1973	128	4.63
01173330	Fish Brook Near Gilbertville, Ma	39.7	65.1	86.4	119	148	181	278	1964-1973	104	1.2
01173900	Middle Branch Swift River At North New Salem, Ma	95.1	152	202	281	353	438	700	1964-1973	320	4.77
01174000	Hop Brook Near New Salem, Ma	151	217	261	317	359	401	501	1948-1982	175	3.39
01174600	Cadwell Creek Near Pelham, Ma	33.1	45.8	54.6	66.3	75.2	84.5	107	1962-1994	37	0.6
01174900	Cadwell Creek Near Belchertown, Ma	118	177	220	276	321	367	484	1962-1996	181	2.55
01175600	Caruth Brook Near Paxton, Ma	95.6	143	178	225	264	304	410	1965-1983	203	2.27
01176450	Roaring Brook Near Belchertown, Ma	94.6	151	192	249	295	344	468	1963-1974	185	2.74
01178230	Mill Brook At Plainfield, Ma	181	303	397	529	637	752	1050	1964-1983	470	4.45
01180000	Sykes Brook At Knightville, Ma	57.9	120	181	291	400	540	1020	1946-1973	159	1.73
01180500	Middle B Westfield River At Goss Heights, Ma	2800	4950	7020	10600	14100	18600	34000	1911-1989	6240	52.7
01180800	Walker Brook Near Becket Center, Ma	156	276	380	540	684	849	1340	1962-1977	165	2.94

USGS stream-gaging station No.	Gaging Station Name	2-year	5-year	10-year	25-year	50-year	100-year	500-year	Period of Record	Flood of Record (cfs)	Drainage Area (mi^2)
01181000	West Branch Westfield River At Huntington, Ma	5100	8830	12000	16900	21200	26200	40800	1936-2004	10500	94
01183100	Dickinson Brook Tributary At Granville, Ma	53.2	119	182	291	396	523	930	1964-1983	208	0.7
01184300	Gillette Bk At Somers, Ct.	116	197	263	364	453	553	842	1960-1984	375	3.64
01184900	Haley Pond Outlet Near Otis, Ma	11.4	20	26.9	37.1	45.7	55.1	81	1964-1973	30	0.26
01187300	Hubbard River Nr. West Hartland, Ct.	960	1820	2590	3820	4930	6240	10200	1938-2003	10500	19.9
01187400	Valley Bk Nr West Hartland, Ct.	271	610	1010	1840	2810	4220	10300	1941-1972	5400	7.03
01187850	Clear Bk Nr Collinsville, Ct.	13.5	25	35.2	51.6	66.7	84.4	138	1927-1973	34	0.59
01188000	Burlington Brook Near Burlington, Ct.	271	472	631	860	1050	1260	1810	1932-2003	673	4.1
01189000	Pequabuck R At Forestville, Ct.	1570	2720	3760	5440	7000	8890	14800	1938-2003	6500	45.8
01189390	E.Br.Salmon Bk At Granby,Ct.	779	1420	1970	2810	3550	4390	6820	1964-1976	1100	39.5
01189500	Salmon Bk Near Granby, Ct.	2090	5090	8890	17300	27700	43600	118000	1947-1963	18400	67.4
01192600	South Branch Salmon Bk At Buckingham, Ct.	22.5	44.3	65.9	104	142	191	358	1936-1981	30	0.94
01192800	Parmalee Bk Nr Durham, Ct.	215	329	413	528	620	716	963	1960-1983	517	2.79
01193120	Ponset Bk Nr Higganum, Ct	239	424	588	854	1100	1390	2310	1962-1982	1700	5.72
01193800	Hemlock Valley Bk At Hadlyme, Ct.	120	189	240	311	369	430	589	1960-1976	87	2.62
01194000	Eightmile R At North Plain, Ct.	821	1330	1750	2360	2900	3490	5180	1938-1984	1480	20.1

USGS stream-gaging station No.	Gaging Station Name	2-year	5-year	10-year	25-year	50-year	100-year	500-year	Period of Record	Flood of Record (cfs)	Drainage Area (mi^2)
01195000	Menunketesuck R Nr Clinton, Ct.	408	631	812	1080	1320	1590	2350	1938-1982	573	11.2
01196600	Willow Bk Nr Cheshire, Ct.	267	476	673	1010	1340	1750	3130	1960-1983	3000	9.34
01196990	Windsor Brook Tributary At Windsor, Ma	24.4	35.9	45	58.1	69.2	81.5	116	1963-1973	52	0.3
01197050	Churchill Brook At Pittsfield, Ma	32.2	59.9	85.3	127	167	215	369	1964-1973	139	1.16
01197155	Housatonic River Tributary No. 2 At Lee, Ma	35.9	65.4	90.7	130	165	206	324	1965-1973	88	0.73
01197300	Marsh Brook At Lenox, Ma	80.3	109	129	155	175	197	250	1963-1973	70	2.12
01198000	Green River Near Great Barrington, Ma	1270	2010	2670	3720	4690	5860	9540	1952-1996	2700	51
01198500	Blackberry R At Canaan, Ct.	1970	4190	6550	11000	15700	22100	45900	1948-1981	6220	45.9
01199150	Furnace Bk At Cornwall Bridge,Ct.	305	576	831	1260	1670	2170	3810	1945-1976	4060	13.3
01199200	Guinea Bk At West Woods Rd At Ellsworth, Ct	95.8	154	200	266	321	382	547	1960-1981	143	3.5
01201190	West Aspetuck R At Sand Rd Nr New Milford, Ct	353	617	848	1220	1550	1950	3160	1963-1972	845	23.8
01201890	Pond Bk Nr Hawleyville, Ct.	418	778	1110	1650	2170	2790	4760	1963-1976	1400	11.9
01202700	Butternut Bk Nr Litchfield, Ct.	229	406	554	781	980	1210	1860	1960-1984	860	2.42
01203100	Jacks Bk Nr Roxbury Falls, Ct	537	928	1240	1690	2070	2480	3600	1961-1984	1600	7.9
01203600	Nonewaug River At Minortown, Ct.	1330	2520	3560	5190	6670	8380	13500	1955-2003	1210	17.7

USGS stream-gaging station No.	Gaging Station Name	2-year	5-year	10-year	25-year	50-year	100-year	500-year	Period of Record	Flood of Record (cfs)	Drainage Area (mi^2)
01203700	Wood Ck Nr Bethlehem, Ct.	185	305	411	580	735	919	1490	1962-1984	700	3.39
01204800	Copper Mill Bk Nr Monroe, Ct.	147	213	259	318	363	408	517	1959-1976	121	2.45
01206400	Leadmine Bk Nr Harwington,Ct.	1080	1950	2780	4190	5550	7240	12900	1931-1984	657	19.6
01206500	Leadmine Bk Nr Thomaston, Ct.	1600	3170	4780	7700	10700	14700	28900	1931-1959	3660	24.3
01208100	Hancock Bk Nr Terryville, Ct.	116	175	218	276	322	370	489	1960-1981	300	1.18
01208400	Hop Bk Nr Middlebury,Ct.	414	723	994	1430	1820	2290	3710	1955-2003	1700	9.43
01208700	Little R At Oxford, Ct.	233	367	467	607	721	843	1160	1960-1984	1350	4.54
01208950	Sasco Brook Near Southport, Ct.	256	475	694	1090	1490	2020	3900	1960-2003	785	7.38
01209770	Fivemile R Nr Norwalk,Ct.	565	870	1100	1420	1690	1970	2730	1955-1984	2750	8.96
01211700	E Br Byram R At Round Hill, Ct.	98.9	169	227	316	395	484	745	1960-1975	245	1.69
01328900	Tanner Brook Near Sunderland, Vt	30.8	44.6	55.6	72	86	102	147	1964-2003	84	2.336
01329000	Batten Kill At Arlington, Vt	3220	4520	5490	6860	7980	9190	12400	1929-1984	7280	149.793
01331400	Dry Brook Near Adams, Ma	479	695	844	1040	1190	1340	1720	1962-1973	290	7.67
01332000	North Branch Hoosic River At North Adams, Ma	2370	3780	4930	6670	8190	9910	14900	1927-1990	4200	40.9
01333800	South Stream Near Bennington, Vt	76.4	102	121	148	170	194	259	1963-1973	166	7.714
01333900	Paran Creek Near South Shaftsbury, Vt	76.5	119	149	189	219	250	325	1964-2004	193	2.375
01334000	Walloomsac River Near North Bennington, Vt	3380	4940	6040	7510	8650	9830	12800	1932-2004	6350	115.542

USGS stream-gaging station No.	Gaging Station Name	2-year	5-year	10-year	25-year	50-year	100-year	500-year	Period of Record	Flood of Record (cfs)	Drainage Area (mi^2)
04279400	Poultney River Tributary At East Poultney, Vt	57.7	77.4	89.5	104	114	124	145	1964-2004	98	1.144
04280200	Mettawee River Tributary No. 2 At East Ruppert, Vt	70.8	105	131	166	193	223	299	1963-1974	130	1.661
04280300	Mettawee River Tributary Near Pawlet, Vt	72	143	205	305	395	499	807	1963-1973	70	2.09
04280350	Mettawee River Near Pawlet, Vt	2110	3500	4600	6230	7610	9150	13400	1985-2003	2860	70.483
04280900	Moon Brook At Rutland, Vt	72.7	107	133	167	194	223	296	1964-1977	153	1.841
04282000	Otter Creek At Center Rutland, Vt	5390	7420	8740	10400	11600	12800	15500	1929-2003	10100	308.026
04282200	Neshobe River At Brandon, Vt	668	765	820	881	922	959	1040	1968-1977	800	17.857
04282300	Brandy Brook At Bread Loaf, Vt	114	191	256	353	438	534	810	1963-2004	546	1.879
04282525	New Haven River @ Brooksville, Nr Middlebury, Vt	4720	8030	10900	15300	19300	23900	37900	1990-2003	6880	116.086
04282550	Beaver Brook At Cornwall, Vt	59.4	66.5	70.7	75.7	79.1	82.4	89.7	1964-1973	73	1.059
04282600	Little Otter Creek Tributary Near Bristol, Vt	33.8	57	76.9	108	137	171	272	1964-1978 1999-2004	168	1.521
04282700	Lewis Creek Tributary At Starksboro, Vt	234	439	626	934	1220	1570	2670	1963-2003	310	5.344
04282750	Lewis Creek Tributary No. 2 Near Rockville, Vt	41.3	58.9	71.4	88.1	101	115	150	1964-1977	95	1.226
04282850	Winooski River Tributary No 2 Near Cabot, Vt	19.5	33.2	44.1	59.9	73.3	88	128	1964-1973	52	0.577

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USGS stream-gaging station No.	Gaging Station Name	2-year	5-year	10-year	25-year	50-year	100-year	500-year	Period of Record	Flood of Record (cfs)	Drainage Area (mi^2)
04283470	Stevens Branch Tributary At South Barre, Vt	23.7	37.5	48	63.1	75.5	89	125	1964-1974	62	0.494
04287000	Dog River At Northfield Falls, Vt	3180	4990	6300	8050	9420	10800	14400	1935-2003	4390	76.619
04287300	Sunny Brook Near Montpelier, Vt	146	251	331	442	531	624	864	1964-2003	128	2.383
04288400	Bryant Brook At Waterbury Center, Vt	143	199	236	281	314	347	422	1964-2003	302	2.632
04290700	Bailey Brook At East Hardwick, Vt	91.6	134	168	216	257	302	427	1964-2003	285	2.549
04292100	Stony Brook Near Eden, Vt	288	437	551	713	847	993	1390	1964-2003	320	4.238
04292150	Gihon River Tributary Near Johnson, Vt	45	61.7	74.2	91.6	106	121	162	1964-1974	112	0.465
04292200	Lamoille River Tributary At Jeffersonville, Vt	33	42.1	48	55.3	60.6	65.8	78	1964-1974	48	0.581
04293400	Whittaker Brook At Richford, Vt	64.6	105	137	184	224	269	391	1963-2004	216	0.878
04293800	Missisquoi River Tributary At Sheldon Junction, Vt	61.7	86.1	102	121	136	150	182	1963-2002	122	1.727
04295900	Ware Brook Near Coventry, Vt	118	143	159	178	193	207	240	1963-1974	171	2.839
04296150	Lord Brook Near Evansville, Vt	209	297	356	432	489	548	687	1964-2003	425	4.608
04296200	Brownington Branch Near Evansville, Vt	122	186	235	305	362	424	592	1964-2003	97	2.213
04296300	Pherrins River Tributary Near Island Pond, Vt	44	65.1	82.1	108	130	155	227	1964-2004	140	1.02

Table A.2. Drainage areas and mean annual precipitation for gaging stations used in regression equations.

State	Station	Name	Drainage Area (mi2)	Mean Annual Precip (in)
VT	1129400	Black Brook At Averill, Vt	0.88	44.3
VT	1129700	Paul Stream Tributary Near Brunswick Springs, Vt	1.48	40.4
VT	1133000	East Branch Passumpsic River Near East Haven, Vt	51.3	44.7
VT	1133200	Quimby Brook Near Lyndonville, Vt	2.15	39.1
VT	1133300	Cold Hill Brook Near Lyndon, Vt	1.64	40.5
VT	1134800	Kirby Brook At Concord, Vt	8.13	41.8
VT	1135150	Pope Brook (Site W-3) Near North Danville, Vt	3.27	44.0
VT	1135300	Sleepers River (Site W-5) Near St. Johnsbury, Vt	42.5	41.9
VT	1135700	Joes Brook Tributary Near East Barnet, Vt	0.70	37.6
VT	1138800	Keenan Brook At Groton, Vt	4.72	42.2
VT	1139700	Waits River Tributary Near West Topsham, Vt	1.21	43.4
VT	1139800	East Orange Branch At East Orange, Vt	8.79	41.7
VT	1140000	South Branch Waits River Near Bradford, Vt	43.8	39.8
VT	1140100	South Branch Waits R Tr Near Bradford Center, Vt	0.21	37.8
VT	1140800	West Br Ompompanoosuc R Tr At South Strafford, Vt	1.35	40.5
VT	1142400	Third Branch White River Tributary At Randolph, Vt	0.83	39.6
VT	1142500	Ayers Brook At Randolph, Vt	30.5	40.6
VT	1150800	Kent Brook Near Killington, Vt	3.26	55.0
VT	1150900	Ottauquechee River Near West Bridgewater, Vt	23.3	52.6
VT	1151200	Ottauquechee River Tributary Near Quechee, Vt	0.77	38.8
VT	1153300	Middle Branch Williams River Tr At Chester, Vt	3.18	43.0
VT	1153500	Williams River At Brockways Mills, Vt	102	44.7
VT	1153550	Williams River Near Rockingham Vt	112	44.4
VT	1154000	Saxtons River At Saxtons River, Vt	72.1	45.7
VT	1155200	Sackets Brook Near Putney, Vt	10.2	43.3
VT	1155300	Flood Brook Near Londonderry, Vt	9.29	51.2
VT	1155350	Trib To West River Trib @ Rt 30, Nr Jamaica, Vt	0.93	47.3
VT	1156300	Whetstone Brook Tributary Near Marlboro, Vt	1.08	50.3
VT	1156450	Connecticut River Tributary Near Vernon, Vt	1.10	44.7
VT	1167800	Beaver Brook At Wilmington, Vt	6.36	53.0
VT	1333900	Paran Creek Near South Shaftsbury, Vt	2.38	46.6
VT	4279400	Poultney River Tributary At East Poultney, Vt	1.14	38.0
VT	4280200	Mettawee River Tributary No. 2 At East Ruppert, Vt	1.66	54.4
VT	4280300	Mettawee River Tributary Near Pawlet, Vt	2.09	45.8
VT	4280350	Mettawee River Near Pawlet, Vt	70.5	48.2
VT	4280900	Moon Brook At Rutland, Vt	1.84	44.4
VT	4282300	Brandy Brook At Bread Loaf, Vt	1.88	48.2
VT	4282525	New Haven River @ Brooksville, Nr Middlebury, Vt	116	44.2
VT	4282550	Beaver Brook At Cornwall, Vt	1.06	35.3
VT	4282600	Little Otter Creek Tributary Near Bristol, Vt	1.52	36.7
VT	4282700	Lewis Creek Tributary At Starksboro, Vt	5.34	45.1
VT	4282750	Lewis Creek Tributary No. 2 Near Rockville, Vt	1.23	39.1
VT	4282850	Winooski River Tributary No 2 Near Cabot, Vt	0.58	44.9

State	Station	Name	Drainage Area (mi2)	Mean Annual Precip (in)
VT	4283470	Stevens Branch Tributary At South Barre, Vt	0.49	35.3
VT	4287000	Dog River At Northfield Falls, Vt	76.6	41.3
VT	4287300	Sunny Brook Near Montpelier, Vt	2.38	39.8
VT	4288400	Bryant Brook At Waterbury Center, Vt	2.63	45.9
VT	4290700	Bailey Brook At East Hardwick, Vt	2.55	42.8
VT	4292100	Stony Brook Near Eden, Vt	4.24	48.5
VT	4292150	Gihon River Tributary Near Johnson, Vt	0.47	42.4
VT	4292200	Lamoille River Tributary At Jeffersonville, Vt	0.58	41.6
VT	4293400	Whittaker Brook At Richford, Vt	0.88	48.4
VT	4293800	Missisquoi River Tributary At Sheldon Junction, Vt	1.73	43.8
VT	4295900	Ware Brook Near Coventry, Vt	2.84	42.7
VT	4296150	Lord Brook Near Evansville, Vt	4.61	43.3
VT	4296200	Brownington Branch Near Evansville, Vt	2.21	44.4
VT	4296300	Pherrins River Tributary Near Island Pond, Vt	1.02	42.7
NH	1064300	Ellis River Near Jackson, Nh	10.9	73.5
NH	1064380	E Br Saco R @ Town Hall Rd, Nr Lower Bartlett, Nh	32.0	54.4
NH	1072850	Mohawk Brook Near Center Strafford, Nh	7.34	47.4
NH	1074500	East Branch Pemigewasset River Near Lincoln, Nh	104	61.8
NH	1075500	Baker River At Wentworth, Nh	58.8	45.4
NH	1085800	West Branch Warner River Near Bradford, Nh	5.75	45.4
NH	1093800	Stony Brook Tributary Near Temple, Nh	3.60	48.1
NH	1127880	Big Brook Near Pittsburg, Nh	6.36	48.8
NH	1129440	Mohawk River Near Colebrook Nh	36.7	47.2
NH	1141800	Mink Brook Near Etna, Nh	4.60	40.5
NH	1158500	Otter Brook Near Keene, Nh	42.3	43.9
NH	1160000	S Br Ashuelot River At Webb, Nr Marlborough, Nh	36.0	43.6
ME	1014700	Factory Brook Near Madawaska, Me	5.83	38.0
ME	1017300	Nichols Brook Near Caribou, Me	3.94	38.5
ME	1017900	Marley Brook Near Ludlow, Me	1.47	37.8
ME	1024200	Garland Brook Near Mariaville, Me	9.79	42.8
ME	1026800	Frost Pond Brook Near Sedgwick, Me	5.68	44.2
ME	1034900	Coffin Brook Near Lee, Me	2.21	39.5
ME	1037430	Goose River At Rockport, Me	8.32	44.5
ME	1041900	Mountain Brook Near Lake Parlin, Me	3.91	43.0
ME	1046000	Austin Stream At Bingham, Me	90.0	42.8
ME	1046800	South Branch Carrabassett River At Bigelow, Me	14.2	52.5
ME	1048100	Pelton Brook Near Anson, Me	14.1	39.0
ME	1049100	Hall Brook At Thorndike, Me	5.23	41.5
ME	1049300	North Branch Tanning Brook Near Manchester, Maine	0.93	41.0
ME	1050900	Four Ponds Brook Near Houghton, Me	3.41	46.0
ME	1054300	Ellis River At South Andover, Maine	130	44.2
ME	1055300	Bog Brook Near Buckfield, Me	10.5	41.5
ME	1057000	Little Androscoggin River Near South Paris, Maine	73.5	43.1
ME	1062700	Patte Brook Near Bethel, Me	5.35	43.0
ME	1066100	Pease Brook Near Cornish, Me	4.62	44.0

State	Station	Name	Drainage Area (mi2)	Mean Annual Precip (in)
MA	1094400	North Nashua River At Fitchburg, Ma	64.2	43.0
MA	1095800	Easter Brook Near North Leominster, Ma	0.92	42.0
MA	1100100	Richardson Brook Near Lowell, Ma	4.22	40.0
MA	1100800	Cobbler Brook Near Merrimac, Ma	0.77	40.0
MA	1104900	Mill Brook At Westwood, Ma	1.52	43.0
MA	1123160	Wales Brook Tributary Near Wales, Ma	0.73	46.0
MA	1124050	Tufts Branch At Dudley, Ma	1.10	42.0
MA	1124750	Browns Brook Near Webster, Ma	0.49	42.0
MA	1161300	Millers Brook At Northfield, Ma	2.30	44.0
MA	1165000	East Branch Tully River Near Athol, Ma	50.5	42.2
MA	1169900	South River Near Conway, Ma	24.1	47.0
MA	1170100	Green River Near Colrain, Ma	41.4	46.0
MA	1170200	Allen Brook Near Shelburne Falls, Ma	0.72	45.0
MA	1170900	Mill River Near South Deerfield, Ma	6.42	45.0
MA	1171200	Scarboro Brook At Dwight, Ma	2.90	44.0
MA	1171910	Broad Brook Near Holyoke, Ma	2.27	46.0
MA	1173040	Pleasant Brook Near Barre, Ma	1.22	44.0
MA	1173260	Moose Brook Near Barre, Ma	4.63	43.0
MA	1173330	Fish Brook Near Gilbertville, Ma	1.20	43.0
MA	1174000	Hop Brook Near New Salem, Ma	3.39	44.5
MA	1174600	Cadwell Creek Near Pelham, Ma	0.60	45.0
MA	1174900	Cadwell Creek Near Belchertown, Ma	2.55	45.0
MA	1175600	Caruth Brook Near Paxton, Ma	2.27	44.0
MA	1176450	Roaring Brook Near Belchertown, Ma	2.74	46.0
MA	1178230	Mill Brook At Plainfield, Ma	4.45	48.0
MA	1180000	Sykes Brook At Knightville, Ma	1.73	44.0
MA	1180800	Walker Brook Near Becket Center, Ma	2.94	47.0
MA	1184900	Haley Pond Outlet Near Otis, Ma	0.26	50.0
MA	1196990	Windsor Brook Tributary At Windsor, Ma	0.30	47.0
MA	1197050	Churchill Brook At Pittsfield, Ma	1.16	46.0
MA	1197155	Housatonic River Tributary No. 2 At Lee, Ma	0.73	46.0
MA	1197300	Marsh Brook At Lenox, Ma	2.12	46.0
MA	1198000	Green River Near Great Barrington, Ma	51.0	44.2
MA	1331400	Dry Brook Near Adams, Ma	7.67	48.0
CT	1119255	Delphi Bk Nr Staffordville, Ct.	2.59	45.0
CT	1119360	Conat Bk At W Willington, Ct.	2.40	43.0
CT	1119450	Eagleville Bk At Storrs, Ct.	0.36	43.0
CT	1119600	Ash Bk Nr N Coventry, Ct.	2.79	43.0
CT	1120500	Safford Bk Nr Woodstock Valley, Ct.	4.15	44.0
CT	1121000	Mount Hope River Near Warrenville, Ct.	28.6	43.5
CT	1121300	Fenton R At East Willington, Ct.	11.4	43.5
CT	1122680	Merrick Bk Nr Scotland, Ct.	5.21	43.0
CT	1125300	English Neighborhood Bk At N Woodstock, Ct.	4.66	45.0
CT	1125650	Wappoquia Bk Nr Pomfret,Ct.	4.21	44.0
CT	1125900	Cady Bk At East Putnam, Ct.	8.29	44.0

State	Station	Name	Drainage Area (mi2)	Mean Annual Precip (in)
CT	1126600	Blackwell Bk Nr Brooklyn, Ct.	17.0	43.0
CT	1127700	Trading Cove Bk Nr Thamesville, Ct.	8.46	45.5
CT	1127760	Hunts Bk At Old Norwich Rd At Quaker Hill, Ct	11.5	47.0
CT	1184300	Gillette Bk At Somers, Ct.	3.64	43.5
CT	1188000	Burlington Brook Near Burlington, Ct.	4.10	48.0
CT	1189000	Pequabuck R At Forestville, Ct.	45.8	47.0
CT	1189390	E.Br.Salmon Bk At Granby,Ct.	39.5	44.0
CT	1192600	South Branch Salmon Bk At Buckingham, Ct.	0.94	43.5
CT	1192800	Parmalee Bk Nr Durham, Ct.	2.79	45.5
CT	1193120	Ponset Bk Nr Higganum, Ct	5.72	47.0
CT	1193800	Hemlock Valley Bk At Hadlyme, Ct.	2.62	47.0
CT	1194000	Eightmile R At North Plain, Ct.	20.1	47.0
CT	1195000	Menunketesuck R Nr Clinton, Ct.	11.2	45.0
CT	1196600	Willow Bk Nr Cheshire, Ct.	9.34	46.0
CT	1199150	Furnace Bk At Cornwall Bridge,Ct.	13.3	42.5
CT	1199200	Guinea Bk At West Woods Rd At Ellsworth, Ct	3.50	42.0
CT	1201190	West Aspetuck R At Sand Rd Nr New Milford, Ct	23.8	43.0
CT	1201890	Pond Bk Nr Hawleyville, Ct.	11.9	45.0
CT	1202700	Butternut Bk Nr Litchfield, Ct.	2.42	44.0
CT	1203100	Jacks Bk Nr Roxbury Falls, Ct	7.90	44.5
CT	1203600	Nonewaug River At Minortown, Ct.	17.7	44.5
CT	1203700	Wood Ck Nr Bethlehem, Ct.	3.39	44.0
CT	1204800	Copper Mill Bk Nr Monroe, Ct.	2.45	47.0
CT	1208100	Hancock Bk Nr Terryville, Ct.	1.18	47.0
CT	1208400	Hop Bk Nr Middlebury,Ct.	9.43	46.0
CT	1208700	Little R At Oxford, Ct.	4.54	47.0
CT	1208950	Sasco Brook Near Southport, Ct.	7.38	45.0
CT	1209770	Fivemile R Nr Norwalk,Ct.	8.96	46.5
CT	1211700	E Br Byram R At Round Hill, Ct.	1.69	46.5