Prepared in cooperation with the Minnesota Department of Transportation and the Minnesota Pollution Control Agency

Techniques for Estimating the Magnitude and Frequency of Peak Flows on Small Streams in Minnesota Based on Data through Water Year 2005

Scientific Investigations Report 2009–5250

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

Cover photograph: U.S. Geological Survey streamflow gage 05104500 Roseau River below South Fork near Malung, Minnesota, Flood of June 2002. See U.S. Geological Survey Open File Report *http://nd.water.usgs.gov/pubs/ofr/ofr02278/pdf/ofr02278.pdf* (Photo by U.S. Geological Survey).

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Contents

Abstract 1
Introduction 1
Purpose and Scope 2
Acknowledgments 2
Techniques for Estimating Peak-Flow Frequency 2
Frequency Analysis of Annual Peak-Flow Data at Selected Gaging Stations 2
Regional Peak-Flow Frequency Methods 4
Estimating Basin Characteristics 4
Methods Used to Define Peak-Flow Hydrologic Regions 7
Generalized Least Squares Method 9
Techniques for Estimating the Magnitude and Frequency of Peak Flows on Small Ungaged Streams 10
Regional Regression Equation Technique 10
Region of Influence Regression Technique 11
Comparison Between Regional Regression Equation and Region of Influence Regression Techniques 11
Accuracy and Limitations of the Peak-Flow Estimation Techniques 13
Summary 15
References Cited 16

Figures

1–3. Maps showing:
1. Steamflow-gaging stations for which peak-flow frequency estimates were determined and peak-flow hydrologic regions for Minnesota 3
2. Generalized mean annual runoff in Minnesota for peak-flow estimation 6
3. Reclustered hydrologic landscape units for Minnesota 8

4–5. Graphs showing:
4. The relation between station cross correlation and geographic distance by relative common area distance for streamflow-gaging stations at *A* large, *B* intermediate or mixed, and *C* small basins 10
5. Relation between the lapse function and standardized distance for selected values of the decrease rate (*r*) 11

Tables

1. Peak-flow frequency estimates for selected streamflow-gaging stations 20
2. Basin characteristics of streamflow-gaging stations used in this report 40
3. Streamflow-gaging stations used to estimate generalized mean annual runoff 48
4. Characteristics of the seven reclustered hydrologic landscape units for Minnesota 7
5. Regional regression equations, standard errors of the estimate, and the equivalent number of years of record 12
6. Mean prediction error sum of squares (PRESS/n) statistics for selected regions and recurrence intervals 13
7. Maximum and minimum values and geometric mean of the basin characteristics used in the regional regression analysis for each region 14

Conversion Factors and Datum

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
inch (in.)	25.4	millimeter (mm)
mile (mi)	1.609	kilometer (km)
	Area	
square mile (mi^2)	259.0	hectare (ha)
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)
	Slope	
feet per mile (ft/mi)	0.1894	meter per kilometer (m/km)

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

Water year is the 12-month period, October 1 through September 30, and is designated by the calendar year in which it ends. Thus, the water year ending September 30, 2005 is called "water year 2005."

Acronyms

DEM	digital elevation model
EMA	expected moments algorithm
EY	equivalent years of record
GIS	geographic information system
GLS	generalized least squares
HU	hydrologic unit
MNDNR	Minnesota Department of Natural Resources
NED	National Elevation Dataset
NSS	National Streamflow Statistics program
NWI	National Wetlands Inventory
ROI	region of influence regression
RRE	regional regression equation
PRESS/n	mean predication error sum of squares
SEE	standard errors of the estimate
SEP	standard error of prediction
STATSGO	State Soil Geographic
USGS	U.S. Geological Survey
UTM	Universal Transverse Mercator
VIF	variance inflation factor

Techniques for Estimating the Magnitude and Frequency of Peak Flows on Small Streams in Minnesota Based on Data through Water Year 2005

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Abstract

Knowledge of the peak flow of floods of a given recurrence interval is essential for regulation and planning of water resources and for design of bridges, culverts, and dams along Minnesota's rivers and streams. Statistical techniques are needed to estimate peak flow at ungaged sites because long-term streamflow records are available at relatively few places. Because of the need to have up-to-date peak-flow frequency information in order to estimate peak flows at ungaged sites, the U.S. Geological Survey (USGS) conducted a peak-flow frequency study in cooperation with the Minnesota Department of Transportation and the Minnesota Pollution Control Agency.

Estimates of peak-flow magnitudes for 1.5-, 2-, 5-, 10-, 25-, 50-, 100-, and 500-year recurrence intervals are presented for 330 streamflow-gaging stations in Minnesota and adjacent areas in Iowa and South Dakota based on data through water year 2005. The peak-flow frequency information was subsequently used in regression analyses to develop equations relating peak flows for selected recurrence intervals to various basin and climatic characteristics. Two statistically derived techniques—regional regression equation and region of influence regression—can be used to estimate peak flow on ungaged streams smaller than 3,000 square miles in Minnesota. Regional regression equations were developed for selected recurrence intervals in each of six regions in Minnesota: A (northwestern), B (north central and east central), C (northeastern), D (west central and south central), E (southwestern), and F (southeastern). The regression equations can be used to estimate peak flows at ungaged sites. The region of influence regression technique dynamically selects streamflow-gaging stations with characteristics similar to a site of interest. Thus, the region of influence regression technique allows use of a potentially unique set of gaging stations for estimating peak flow at each site of interest. Two methods of selecting streamflow-gaging stations, similarity and proximity, can be used for the region of influence regression technique.

The regional regression equation technique is the preferred technique as an estimate of peak flow in all six regions for ungaged sites. The region of influence regression technique is not appropriate for regions C, E, and F because the interrelations of some characteristics of those regions do not agree with the interrelations throughout the rest of the State. Both the similarity and proximity methods for the region of influence technique can be used in the other regions (A, B, and D) to provide additional estimates of peak flow. The peak-flow-frequency estimates and basin characteristics for selected streamflow-gaging stations and regional peak-flow regression equations are included in this report.

Introduction

Knowledge of the peak flow of floods of a given recurrence interval is essential for regulation and planning of water resources and for design of bridges, culverts, and dams along Minnesota's rivers and streams. Statistical techniques are needed to estimate peak flow at ungaged sites because long-term streamflow records are available at relatively few locations.

For the purpose of estimating peak-flow frequencies, continuous daily streamflow records for streamflow-gaging stations (hereinafter referred to as gaging station) in Minnesota span a relatively short period. The longest record is for the Mississippi River at St. Paul, which is continuous from 1867 to 2005, except for 1871. Gaging of several streams to obtain daily streamflow records was started in about 1909. The number of gaging stations decreased between 1912 and 1920. During the late 1920s and early 1930s, the number of gaging stations increased and many of those stations have been in operation through 2005. Over the years, gaging stations were added where flow information was needed, and other stations were discontinued where additional data were not as critical. Gaging stations operated to obtain daily records generally are located on streams that drain areas greater than 300 square miles (mi^2) and flow continuously, although in 2008 about 18 percent of daily-record gaging stations in Minnesota had drainage areas of less than 300 mi^2.

In the 1950s, planners for the Interstate Highway System learned that little peak-flow information was available for streams smaller than about 60 mi^2. This information was needed to determine the bridge and culvert sizes to use at road crossings. As a result, small-stream flood investigation studies were initiated nationwide. The program in Minnesota began in 1958 and during the next 6 years about 150 gaging stations were established to determine annual peak flow and stage on streams draining about 60 mi^2 or less. These peak-flow gaging stations differ from daily-record gaging stations in that streamflow record generally is not continuous—only peak streamflows are recorded. Most of those stations were operated through the 1970s. In the 1980s, gaging for annual peak flow and stage for most of the drainage basins of less than 10 mi^2 was discontinued. In the past few years, new peak-flow gaging stations were established throughout the State on streams draining areas from 10 mi^2 to several hundred square miles.

Several previous studies (Prior, 1949; Prior and Hess, 1961; Wiitala, 1965; Patterson and Gamble, 1968; Guetzkow, 1977; Jacques and Lorenz, 1987; Lorenz and others, 1997) have provided peak-flow frequency information at selected gaging stations and presented methods for calculating peak-flow frequency data at ungaged sites in Minnesota. Analysis of annual peak-flow records for the first of these reports that used the Log Pearson Type III method of analysis (Guetzkow, 1977) may not have included information about historical floods that occurred before the systematic collection of data and the period of record for many streams was very short from the standpoint of flood history. Gueztzkow (1977) included most of the long-term record stations with low annual peaks from the 1930s drought and high annual peaks during the 1950s and 1960s. Historical flood information was incorporated in the analysis done in subsequent reports. Jacques and Lorenz (1987) also used fewer regions than Guetzkow (1977), which resulted in larger standard errors of estimate for the regional equations. Because of the need to have up-to-date peak-flow frequency information in order to estimate peak flows at ungaged sites, the U.S. Geological Survey (USGS) conducted a peak-flow frequency study in cooperation with the Minnesota Department of Transportation and the Minnesota Pollution Control Agency.

Purpose and Scope

The purpose of this report is to (1) describe the methods and results of the analysis of peak-flow frequency at selected gaging stations in Minnesota and to present the results in adjacent areas in Iowa and South Dakota, and (2) document two statistically derived techniques for estimating peak-flow data at ungaged sites on small unregulated streams in Minnesota. The peak-flow frequency estimates were developed for 330 gaging stations using data through water year 2005. Two techniques—regional regression equation and region of influence regression— for estimating peak-flow data at ungaged sites are described. Because no streams used in this analysis were substantially affected by development, care is needed when applying the results in urban areas.

Gaging stations that have drainage areas greater than 3,000 mi^2 were not included in this analysis because regulation is prevalent on rivers of that size. River basins affected by regulation include the Red Lake, Minnesota, Mississippi, Rainy, St. Louis, and Red River of the North (Red River). Other gaging stations that were not included in this analysis had peak flows that were affected by controlled storage or regulated releases.

Acknowledgments

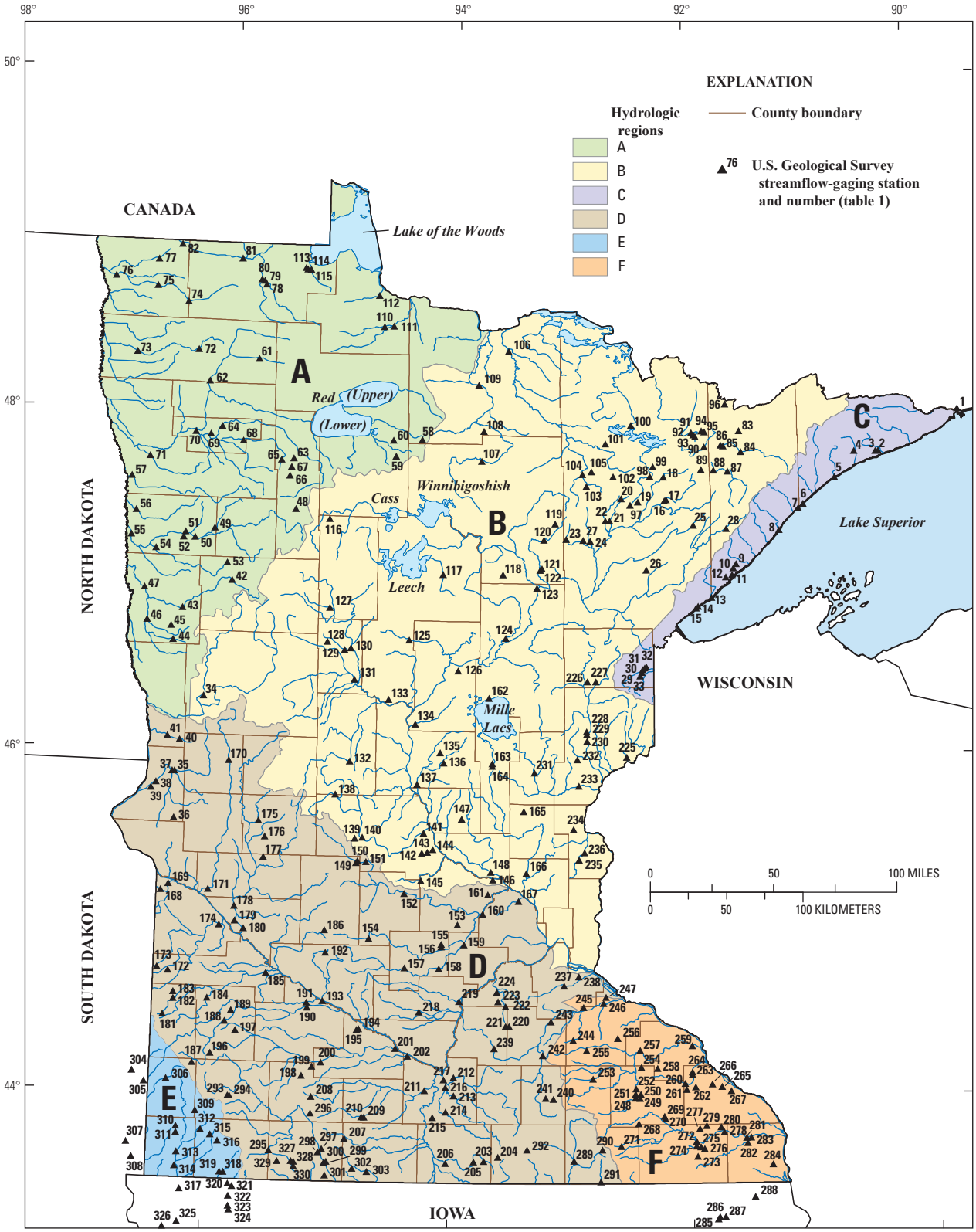
The authors thank David Eash and Joyce Williamson (USGS) for providing basin characteristics and peak-flow analyses of gaging stations in Iowa and South Dakota.

Techniques for Estimating Peak-Flow Frequency

This section describes the techniques and computations of the analysis of peak-flow frequency at selected gaging stations in Minnesota and adjacent areas in Iowa and South Dakota and the methods and analyses that were required to develop the techniques for estimating peak-flow data on small ungaged streams. This section also presents preliminary computations of basin characteristics required for regression analysis.

Frequency Analysis of Annual Peak-Flow Data at Selected Gaging Stations

The frequency analysis of annual peak-flow data for selected recurrence intervals (table 1, at the back of this report) was computed for 330 gaging stations (fig. 1) using data through water year 2005. Peak-flow records for gaging stations in Minnesota are available online at *http://nwis.waterdata.usgs.gov/mn/nwis/peak.* All gaging stations for which peak-flow data were determined had at least 10 years of peak-flow record that could be analyzed. Peak-flow frequency estimates for most gaging stations were determined by fitting a log-Pearson Type III probability distribution to the recorded annual peak flows according to the procedures outlined in Bulletin 17B (Interagency Advisory Committee on Water Data, 1982). The computer program PEAKFQ (Flynn and others, 2006) was used to compute the frequency estimates for those gaging stations. The procedures in Bulletin 17B include tests for unusually high and low peaks, called outliers, that can affect the analysis. Peaks flagged as high outliers require user judgment about putting the outlier into some historical period of record. Peaks flagged as low outliers generally are excluded from the analysis and the conditional probability adjustment described in appendix 5 of Bulletin 17B (Interagency Advisory



Base from Minnesota Department of Natural Resources, 1993, 1:24,000 and 1:100,000
Universal Transverse Mercator projection, Zone 15
Horizontal coordinate information is referenced to the North American Datum 1983 (NAD 83)

Figure 1. Steamflow-gaging stations for which peak-flow frequency estimates were determined and peak-flow hydrologic regions for Minnesota.

Committee on Water Data, 1982) is applied to the analysis. Bulletin 17B recommends the use of a skew coefficient that is based on the skew of the log-series of the period of record (commonly termed the "station skew") weighted with a generalized, or regional, skew coefficient. The weighting is based on the length of the period of record and the estimated standard error for the method used to determine the generalized skew coefficient. The generalized skew coefficients for Minnesota gaging stations used in the peak-flow frequency analysis for this report were based on Lorenz (1997).

The approach used in the Log-Pearson Type III analyses for Minnesota gaging stations follows.

1. Where the period of record is continuous or has multiple continuous periods and there is no indication of a historical flood, the record has been treated as though it was a homogeneous systematic record. All gaging stations not listed elsewhere in this section are included in this category. These gaging stations include any where low outliers were flagged and automatically excluded from the analysis.

2. Some historical flood peaks that were estimated from records such as newspaper reports were not included in the Log-Pearson Type III analysis because of uncertainty in magnitude, uncertainty in the correct historical period, and because the estimated magnitudes of the peaks are not unusual based on the systematic peaks. These gaging stations were 05061000, 05078230, 05134200, 05217000, 05313500, 05355200, 05374000, and 05476010 (table 1).

3. Other historical peaks for short-record sites or well-documented peaks within a known period were included in the Log-Pearson Type III analysis. These gaging stations were 05128500, 05278930, 05319500, 05338500, 05345000, and 05379000 (table 1).

4. The relatively short records at gaging stations 05372800, 05372930, 05372950, and 05383850 (table 1) had systematic peaks that were substantially large outliers. Based on correlation with the nearby long-record gaging station 05372995, those peaks could be placed into an historical context that matched the 55-year record of that gaging station. The peak-flow analyses for the short-record gaging stations were modified to place the large outliers into the 55-year period that matched the longer-record station.

5. Exceptions to the Bulletin 17B procedure were gaging stations 04015250, 04021690, 05131750, 05221020, 05229450, 05244200, 05272300, 05272950, 05278120, 05305200, 05318195, 05318897, 05384500, 05387030, and 06482933, which had left-censored peak-flow data (peak flows below the minimum flow that could be quantified) and for which an alternate method was used (Cohn and others, 1997). The alternate method, the expected moments algorithm (EMA), was used to reduce bias that results from the methods described in Bulletin 17B. Both methods assume that the peaks have a log-Pearson Type III distribution, which is characterized by the mean, standard deviation, and skewness of the log-transformed peak-flow values. EMA code for the R statistical package was used (T.A. Cohn, U.S. Geological Survey, written commun., 2006) for these Minnesota gaging stations that had left-censored peak data.

The peak-flow frequency estimates for gaging stations in Iowa and South Dakota were obtained from USGS offices in those states. The peak-flow frequency estimates for stations outside of Minnesota also are included in table 1. The analyses for gaging stations outside of Minnesota were based on the procedures applicable for the respective state (David Eash, U.S. Geological Survey, written commun., 2006, for Iowa; and Joyce Williamson, U.S. Geological Survey, written commun., 2007, for South Dakota). The peak-flow frequency estimates for gaging stations outside of Minnesota were thought to be very similar to the reported values if uniform procedures, using consistent generalized skew coefficient and using EMA for left-censored peaks, had been applied because those modifications result in relatively small adjustments to the frequency analysis of the station record.

Regional Peak-Flow Frequency Methods

Regional equations expressing peak-flow frequency as a function of various explanatory variables were developed using regression methods. The generalized least squares (GLS) method was used to develop the regression equations within each of six peak-flow hydrologic regions (fig. 1).

Estimating Basin Characteristics

Seven basin characteristics were used as possible explanatory variables in the regression equations. The selections of basin characteristics for this study were based on the results from previous studies and the availability of soil data since the previous study (Lorenz and others, 1997). Drainage area, main-channel slope, lake area, storage area, and generalized mean annual runoff were all used as explanatory variables in previous studies. The selection of soil hydrologic groups A (high infiltration rate and low runoff potential) and D (very slow infiltration rate and high runoff potential) as basin characteristics was based on recent studies that indicated soil could be an important characteristic in estimating flood peaks (Perry and others, 2004; Soong and others, 2004; Walker and Krug, 2003). All of those studies used soil permeability, but soil hydrologic group was used in this study to avoid interpreting large ranges of soil permeability in the State Soil Geographic (STATSGO) database (U.S. Department of Agriculture, 1991).

Basin characteristics for the 330 gaging stations for which peak-flow data were determined were estimated by compiling applicable datasets, converting to common formats, correcting anomalies, delineating boundaries, and computing values of selected characteristics. Basins for USGS gaging stations were delineated using a geographic information system

(GIS) to analyze 10-meter digital elevation models (DEMs) derived from 30-meters DEMs (Minnesota Department of Natural Resources (MNDNR), 2009, Data Deli), which had elevations lowered by stream traces to force mapped drainage patterns. Level 6 (12-digit) hydrologic unit (HU) boundaries (Natural Resources Conservation Service and others, 2004) and lakeshed boundaries created by the Minnesota Lake Watershed Delineation Project (Solstad and Vaughn, 2007) were used to aid basin delineation. These boundaries were used to force correct basin boundaries by adding elevation to the DEMs along the boundaries. Several other data sources were used to delineate basins that included areas outside Minnesota. Canadian DEMs were obtained from the online application Geobase (Canadian Council on Geomatics, 2008). These Canadian DEMs had a resolution of 0.75 arc seconds, or approximately 22.5 meters. The USGS National Elevation Dataset (NED) was used for delineating basins in neighboring states. The stream trace data used to force mapped drainage patterns was the "DNR 24K Streams" from the MNDNR (2009) Data Deli. The MNDNR streams layer was modified to ensure correct directionality and checked to ensure that there were no streams crossing Level 6 HUs or MNDNR lakeshed boundaries. Arc Hydro, a geospatial hydrologic data structure and suite of GIS tools for managing water-resources data (Center for Research in Water Resources, 2003), was used to delineate basins and to compute basin characteristics (table 2, at the back of this report).

Basin polygons for the gaging stations were overlaid with each of the characteristics layers, and a value (that is, mean or percent) was computed. Due to Arc Hydro requirements, all characteristics layers were in grid format; characteristics layers that were not in grid format when retrieved from the data source were converted to grid format.

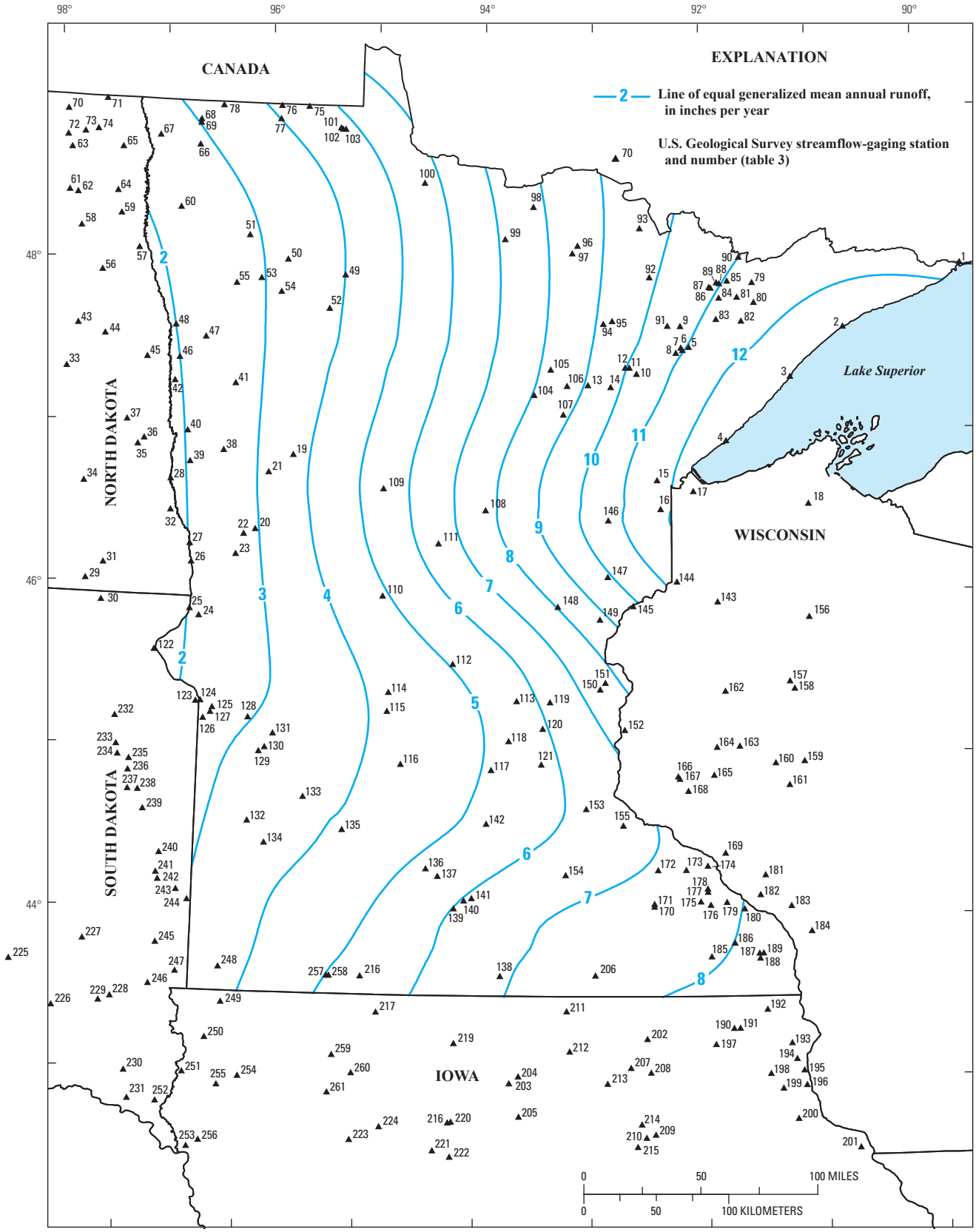
The drainage area, variable name *DAREA* (table 2), is the area in square miles within the basin for each gaging station. It represents the entire area within the basin and includes any areas that might be considered noncontributing.

The main-channel slope, variable name *SLOPE*, is defined as the slope of the main channel in feet per mile between the 10th and 85th percentile of the distance between the gaging station and the basin boundary. The Arc Hydro tool identified the main channel based on the 10-m resolution Level 2 DEMs, identified the 10- and 85-percentile points, and extracted the elevation of the two percentile points. The difference in elevation between the points was divided by the main channel stream length between the points to compute the slope in feet per mile.

Lake area, variable name *LAKE*, and storage area, variable name *STOR*, were computed from National Wetlands Inventory (NWI) data (U.S. Fish and Wildlife Service, 2008). NWI data were extracted for the basin for each gaging station to estimate the percentage of lake and storage area in each basin. Lake area included all NWI polygons classified as 'Lacustrine,' and storage area included all polygons classified as 'Lacustrine' or 'Palustrine.' The percentage for each variable was computed as the total area of all extracted polygons divided by the drainage area, and multiplied by 100. The variables in the regression equations have a constant of 1 added to them, so a computed value for percent lake area of 0 would be 1 when used in the regression equation.

The soil hydrologic group A, variable name *SOILA*, and the soil hydrologic group D, variable name *SOILD*, were computed from STATSGO (U.S. Department of Agriculture, 1991). Soils of hydrologic group A have a high infiltration rate even when thoroughly wetted, and primarily consist of deep, well-drained to excessively drained sands or gravels. Soils of hydrologic group D have an extremely slow infiltration rate when thoroughly wetted and primarily consist of clay soils that have high swelling potentials, soils that have permanent high water tables, soils that have claypan or clay layers at or near the surface, or shallow soils over nearly impervious material. The total area of soils classified as hydrologic group A or D was computed for each STATSGO mapping unit from the component soil information. The percent area for each variable was computed as the total area of all extracted mapping units divided by the drainage area and multiplied by 100. The variables in the regression equations have a constant of 1 added to them, so a computed value for percent soil hydrologic group A of 0 would be 1 when used in the regression equation.

Generalized mean annual runoff, variable name ROFF, is an estimate of the mean regional streamflow in inches. A map of mean annual runoff was prepared to provide updated, generalized mean annual runoff values for this study by using 261 daily-record gaging stations from Minnesota and the surrounding states of Iowa, North and South Dakota, and Wisconsin (fig. 2, table 3, at the back of this report). These gaging stations include 117 of the 330 peak-gaging stations (table 1) that had at least 10 years of continuous streamflow data between 1940 and 2005. Some additional gaging stations within Minnesota were included in these gaging stations that could not be used for the peak-flow analysis because of some condition, such as regulation, that affects peak flow, but not the mean annual flow. All complete water years from 1940 through 2005 were used in the analysis. This range of dates was selected because most peak-flow records correspond to that period. The loess() function in S-PLUS (Insightful, 2005) was used to create the generalized mean annual runoff grid. The explanatory variables were the easting and northing of the basin centroid in meters of Universal Transverse Mercator (UTM) zone 15. The following were control arguments of the final model for the loess() function: span = 0.3, degree = 2, normalize = FALSE, and family = "gaussian;" the documentation for the loess() function (Insightful, 2005) provides details about the control arguments. The predicted values for the centroids of each basin are reported in the fitted annual runoff column in table 3. The range of the residuals was from -4.13 to 4.23 in., and the residual standard error was 1.29 in. The final generalized mean annual runoff contour map for this study is shown in figure 2. The generalized mean annual runoff values reported in table 2 were computed for the basin polygons, based on the mean of grid cells within the basin (Center for Research in Water Resources, 2003), for each gaging station using the Arc Hydro



Base from Minnesota Department of Natural Resources, 1993, 1:24,000 and 1:100,000
Universal Transverse Mercator projection, Zone 15
Horizontal coordinate information is referenced to the North American Datum 1983

Figure 2. Generalized mean annual runoff in Minnesota for peak-flow estimation.

GIS extension and are not expected to agree exactly with those reported in table 3.

Methods Used to Define Peak-Flow Hydrologic Regions

Previous reports, including Jacques and Lorenz (1987) and Lorenz and others (1997) , used an analysis of the pattern of residuals of state-wide regressions to delineate initial peak-flow hydrologic regions. Those regression equations included drainage area, main-channel slope, lake area, storage area, and mean annual runoff as explanatory variables. The initial peak-flow hydrologic regions for those reports were refined by residual analysis of the regional regression equations.

To better understand the most important explanatory variables in each region, the concept of hydrologic landscape units (Winter, 2001; Wolock and others, 2004) was used to define initial peak-flow hydrologic regions for this analysis. Those initial peak-flow hydrologic regions were validated and updated based on regional regressions.

Wolock and others (2004) developed a map of the entire United States that showed 20 different hydrologic landscape units. To develop the initial hydrologic regions, data for Minnesota reported in Wolock and others (2004) were extracted and reclustered into seven groups using the k-means algorithm of Hartigan and Wong (1979). That k-means algorithm is an iterative procedure that assigns observations to one of the specified groups to minimize the squared Euclidean distance from the center of the group. Only the variables percent sand, mean slope, percent flatland in upland areas, percent flatland in lowland areas, and precipitation minus potential evapotranspiration were used in the reclustering (Wolock, U.S. Geological Survey, written commun., 2005). Bedrock permeability class was not used in the reclustering because it is not likely to affect surface runoff. The square root of the mean slope was used and the precipitation minus potential evapotranspiration was down-weighted by a factor of 2 for the k-means clustering. The results of the reclustering of the Minnesota data are shown in figure 3. The characteristics of each of the seven reclustered units are described in table 4.

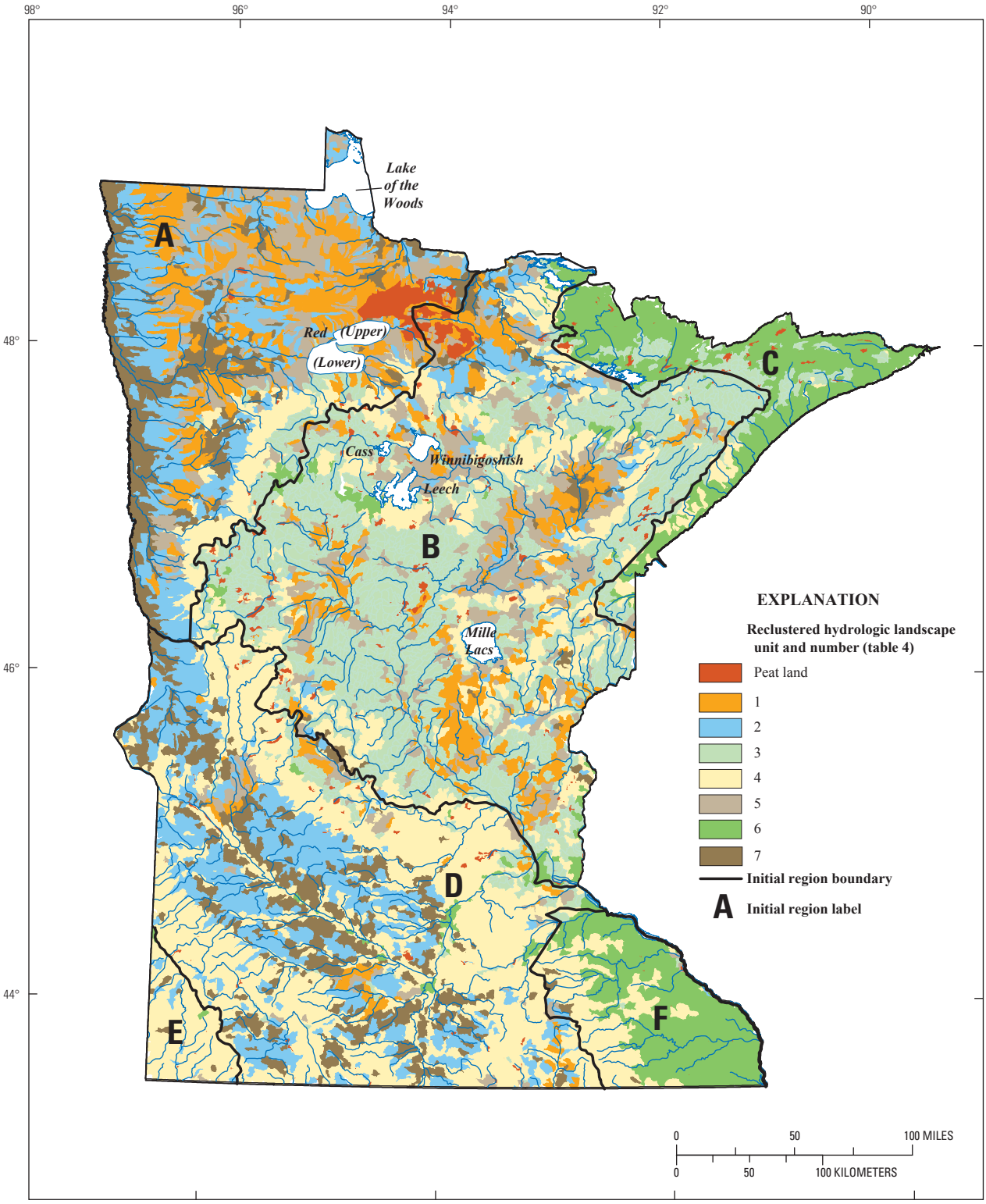
The initial peak-flow hydrologic regions also are shown on figure 3. The initial regions were based on a subjective assessment of the association of the seven reclustered groups of hydrologic landscape units and by dividing the regions generally along drainage boundaries. Region A represents one of the most heterogonous regions with low-slope groups 2 and 7 near the Red River, moderately sloped groups 3 and 4 near the drainage boundary, and sandy groups 1 and 5 between those areas. Region B is dominated by sandy groups 1, 3, and 5 with varying slope and flat areas. Regions C and F are composed primarily of moderately sloped groups 3 and 4. Region D is composed of low-slope groups 2 and 7 adjacent to the upper parts of the Minnesota River and moderately sloped group 4 with relatively low sand content in upland areas and the lower part of the Minnesota River. Region E, in southwestern Minnesota, was separated from Region D although the associations in regions D and E appear similar, because the drainage patterns are distinctly different (map 2 in Minnesota Department of Natural Resources, 1997). Region F also shows a drainage pattern different from region D (map 2 in Minnesota Department of Natural Resources, 1997), and likewise was separated from region D.

Regional regression equations were developed for these initial regions, and the residuals were analyzed for consistency—the residuals were required to be approximately normally distributed, homoscedastic (having constant variance throughout the range of fitted values), and show no regional pattern. The only change between the initial (fig. 3) and the final (fig. 1) regions is the change of the relatively high-slope areas in northern Minnesota from initial region C to final region B. The residuals for the gaging stations in that changed area showed a consistent low bias when included in hydrologic region C, but showed no bias when included in hydrologic region B. No other areas with a distinct bias were noted. The change from the initial regions can be partially explained because the slope characteristics of the entire streams in the final region C are different from slope characteristics of the entire streams in the high-slope areas in northern Minnesota in final region B and cluster analysis only considers the characteristics of individual small units.

The region for each gaging station used in developing the regional regression equations is listed in table 1. The regional

Table 4. Characteristics of the seven reclustered hydrologic landscape units for Minnesota.

Reclustered group number (fig.1)	Description	Sand (percent)	Slope (feet per mile)	Upland flat (percent)	Lowland flat (percent)	Precipitation minus evapotranspiration (inches)
1	Sandy/flat upland	59	0.40	54	29	1.80
2	Low slope/flat lowland	25	.37	23	60	-.40
3	Sandy/moderate slope	64	1.23	8	26	4.50
4	Moderate slope	31	1.17	14	19	3.00
5	Sandy/flat lowland	54	.46	11	70	2.60
6	High slope	34	2.39	2	6	7.30
7	Low slope/flat upland	21	.50	66	12	-1.00



Base from Minnesota Department of Natural Resources, 1993, 1:24,000 and 1:100,000
Universal Transverse Mercator projection, Zone 15
Horizontal coordinate information is referenced to the North American Datum 1983 (NAD 83)

Figure 3 Reclustered hydrologic landscape units for Minnesota.

boundaries generally follow small drainage divides so that the drainage basin of a small stream will not overlap two regions, making interpretation easier for all small streams.

Generalized Least Squares Method

Tasker and others (1986) described the use of GLS to estimate the 100-year peak flow for an area in Arizona. They showed that the GLS method provided better estimates than the ordinary least squares method. The GLS method accounts for variance in peak flow frequency estimates at each gaging station because of the difference in record length—the variance decreases with increased record length. The GLS method also accounts for cross-correlated peak-flow data between stations having concurrent record. Cross correlation is the correlation between peak flows at any two gaging stations as a result of similar weather patterns affecting both gaging stations. In ordinary least squares regression, cross-correlated peak-flow data decrease the effective amount of information in an analysis and can contribute to errors in predictive precision (model error) and errors in determination of the coefficients of the explanatory variables (Stedinger and Tasker, 1985).

The GLS method requires a reasonable estimate of the cross correlation between flows at every pair of stations (Tasker and Stedinger, 1989). An estimate based on the measured flows is not reliable because of the short concurrent records usually encountered in peak-flow data. Therefore, sample cross correlations are estimated by relating the distance between each pair of stations to the correlation between peak flows. For this analysis, the "distance" between stations has two components: one is the geographic distance between stations, measured as the distance between stations in miles; the second is related to the relative common area of the two stations. In Minnesota, large basins are more likely to be affected in similar ways by large storms or spring thaws, and small basins are more likely to be affected by local storms that occur within a small area. To express the relative common area as a distance between two stations, a relative distance function is needed. The common area is defined as the square root of the product of the areas of the basins in square miles. The relative common area is expressed as a relative distance by dividing an arbitrary large value by the common area (Equation 1); for this study, the drainage area of the largest basin was chosen as the arbitrary large value.

$$RCA = \frac{\sqrt{A_i * A_j}}{A_m} \qquad (1)$$

Where

RCA	=	the relative common area;
A_i and A_j	=	the basin areas; and
A_m	=	the arbitrary large area.

The logarithm of that relative distance was used for this study because it linearized the relation between observed cross correlation and the relative common area distance.

The relation between cross correlation and geographic distance conditioned by the relative common area distance is shown in figure 4. The magnitude of relation between cross correlation and geographic distance, represented by the smooth line in each plot, decreases as the similarity in area decreases—the left plot represents the basins most similar in size (large basins) and the right plot represents those basins least similar (small basins).

A flexible function is needed to describe the decrease in cross correlation as a function of distance. A function was created to calculate the decrease in cross correlation as a function of distance that requires two arguments, the standardized distance, and the rate of decrease.

$$\rho = 1 - \frac{\exp((1 + D/r)^r - 1) - 1/(\exp((1 + D/r)^r - 1)}{\exp((1 + D/r)^r - 1) + 1/(\exp((1 + D/r)^r - 1)} = lapse\,(D,r) \qquad (2)$$

where

ρ	=	the estimated cross correlation;
D	=	the standardized distance;
r	=	the function decrease rate;
exp()	=	the exponentiation function; and
lapse()	=	the name used for the function.

The lapse function decreases for several selected values of the decrease rate (fig. 5).

Stations with at least 30 years of record were selected for the analysis of cross correlation and distance. From stations with at least 30 years of concurrent record, 4,195 pairs of correlations were available. These 4,195 data pairs were used in a nonlinear regression model that related the observed cross correlation to the distance between stations in miles, the relative distance between stations in area, and a rate of decrease. The final function was

$$Cor_{est} = 0.968\ lapse(Dist / 269 + RCA / 8.44,\ 0.805) \qquad (3)$$

where

Cor_{est}	=	the estimated cross correlation;
0.968	=	the intercept term;
lapse	=	the function defined in (2);
Dist	=	the geographic distance between gaging stations, in miles;
269	=	the coefficient to standardize the geographic distance;
RCA	=	the relative distance between stations defined previously in this section;
8.44	=	the coefficient to standardize Area; and
0.805	=	the decrease rate.

The lines on figure 5 are estimated values that describe the general relation between cross correlation and geographic distance.

The GLS method was used to develop preliminary equations relating the annual peak flow with a recurrence interval within each of the six hydrologic regions in Minnesota. A

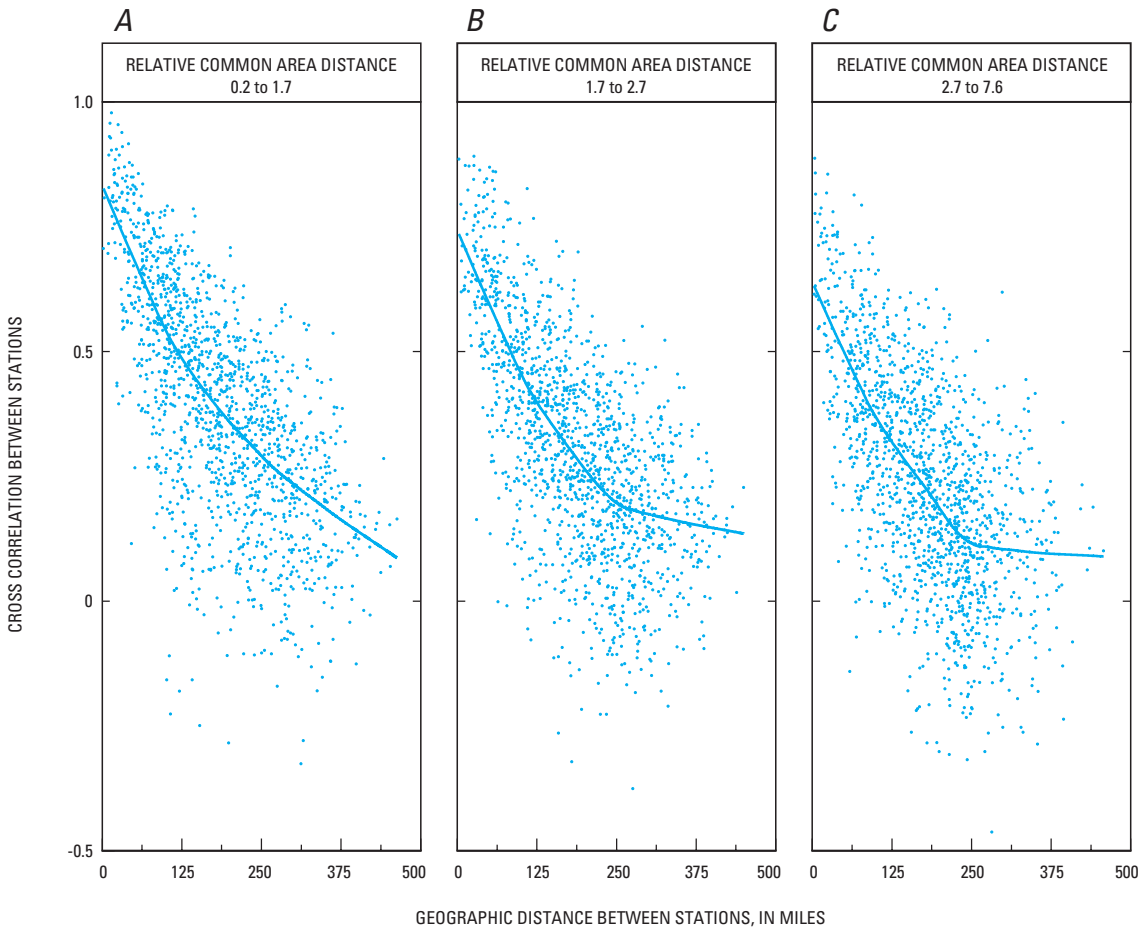


Figure 4. The relation between station cross correlation and geographic distance by relative common area distance for streamflow-gaging stations at *A* large, *B* intermediate or mixed, and *C* small basins.

manual selection of possible combinations of explanatory variables were used in the regression analysis for selected (2-, 25-, and 100-year) recurrence intervals, and the combination producing the minimum mean model error variance and acceptable diagnostic residual plots for linearity, uniformity of variance, and normality was considered the best. To make consistent estimations at the selected recurrence intervals, a consistent set of explanatory variables was used in all of the regression equations. A set of consistent explanatory variables that had logically consistent coefficients and were statistically significant at the 5-percent level was selected for the regression equations for all recurrence intervals within that region.

Techniques for Estimating the Magnitude and Frequency of Peak Flows on Small Ungaged Streams

This section presents two statistically derived techniques—regional regression equation (RRE) and region of influence regression (ROI)—for estimating peak flows on small, ungaged streams in Minnesota. Both of the techniques relate physical and climatic characteristics to peak flows for 1.5-, 2-, 5-, 10-, 25-, 50-, 100-, and 500-year recurrence intervals. This section also describes the comparison between the two techniques and describes the accuracy and limitations of the techniques.

Regional Regression Equation Technique

As previously described, the GLS method was used to develop regression equations for each recurrence interval and for each region shown on figure 1. Regression equations, the standard errors of the estimate (SEE), and the equivalent years of record (EY) are described in a following section “Accuracy and Limitations of the Estimating Techniques” and are listed in table 5. The SEE values are included for comparison to previous RRE. The basin characteristics storage area (*STOR*) and soil hydrologic group D (*SOILD*) were not significant explanatory variables in the regression equations for any of the six regions.

The National Streamflow Statistics (NSS) Program, available online at *http://water.usgs.gov/software/nss.html*, provides

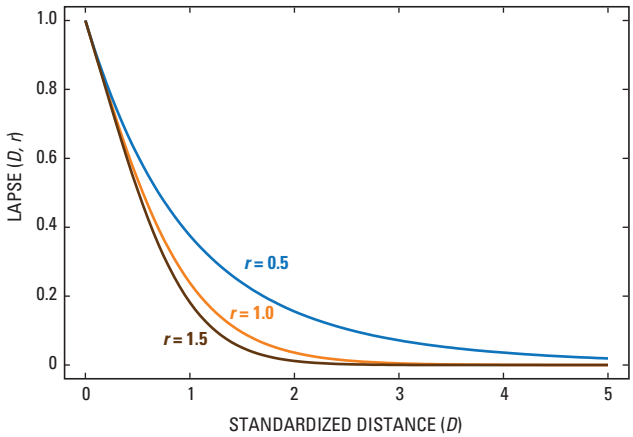


Figure 5. Relation between the lapse function and standardized distance for selected values of the decrease rate (r).

a tool for estimating the magnitude and frequency of flood characteristics for ungaged sites in Minnesota, the other states, the Commonwealth of Puerto Rico, and American Samoa. Using NSS reduces the possibility of computational errors associated with manual computation. The basin characteristics described in this report and used in NSS can be obtained from topographic maps, or digital map data derived from various sources. The USGS has developed a Web application named StreamStats (*http://streamstats.usgs.gov/*) that automates the process of computing streamflow statistics for ungaged sites and provides previously computed streamflow statistics for USGS gaging stations. StreamStats provides a map-based user interface that appears in a Web-browser window. Users can obtain estimates of streamflow statistics for ungaged sites by clicking on site locations in the interface. A GIS program determines boundaries of the drainage basins for the ungaged sites, measures the physical characteristics of the drainage basins, and inserts the characteristics into the NSS program to solve the regression equations in table 5 that estimate the streamflow statistics for the sites. This process for measuring the basin characteristics is faster, more accurate, and more consistent than previous manual methods. Users also can obtain previously published streamflow statistics and other information for USGS gaging stations by clicking on station locations in the user interface.

Region of Influence Regression Technique

The fundamental premise of the ROI technique is that there is no need for distinct boundaries between regions (Burn, 1990). The ROI technique defines a new set of regression equations for each ungaged site by selecting gaging stations with characteristics that are similar to that ungaged site. Thus, the ROI technique allows use of a potentially unique set of gaging stations for each site of interest. Two methods are available for this technique. The similarity method selects gaging stations that have similar characteristics (variables). The proximity method selects gaging stations that are nearby. Predictions obtained by use of the ROI technique generally are closer to the center of the data used to develop the equation than predictions obtained by use of more traditional regression methods. Thus, extrapolation and other errors resulting from assumption of linearity are reduced (Ensminger, 1998). Because ROI computations are mathematically complex, computer programs are necessary to solve the equations. NSS contains the algorithms needed to perform the ROI procedure for states where the ROI method was developed.

Comparison Between Regional Regression Equation and Region of Influence Regression Techniques

One method for comparing the RRE technique to the ROI technique is to use the PRESS/n statistic, which is the mean prediction error sum of squares. The PRESS/n statistic is determined by removing each station (of n sites) from the analysis, re-developing the regression equations, and comparing the re-estimated peak-flow value to the previously determined value for that station in a region. The differences between the re-estimated and previously determined values are squared and the mean for all stations is computed. That way, n analyses are made without the estimated station being included. It is a reasonably unbiased comparison if the stations are not highly cross correlated.

A listing of the PRESS/n statistics for regions A, B, and D for the 2-, 25-, and 100-year recurrence intervals are in table 6. Regions C, E, and F were excluded from the analysis because the interrelations among some characteristics of these regions are different from those for the rest of the state. For example, regions C and F have larger slope-to-drainage-area ratios than other regions in the state. The 2-, 25-, and 100-year recurrence intervals were selected as representative of the range of all eight recurrence intervals. The minimum PRESS/n statistics indicate the preferred technique for each region.

The regional regression equation technique appears preferable for all regions. Only the PRESS/n statistic for the ROI proximity method for the 2-year recurrence interval in region D is less than the corresponding PRESS/n statistic for the RRE technique. However, the PRESS/n statistics for the 25- and 100-year recurrence intervals in region D are much larger for the proximity ROI technique than for the RRE technique. Therefore, the preferred technique for all regions is RRE. The ROI techniques may be useful for reviewing the value obtained by using the RRE technique, or to provide a second or third estimate of peak flow. The smaller values for the PRESS/n statistics for the regional RRE technique than for either method in the ROI technique indicate that the regions are relatively homogenous and that using hydrologic landscape units and possibly other drainage characteristics is a useful technique to define regions.

Table 5. Regional regression equations, standard errors of the estimate, and the equivalent number of years of record.

[PK, peak flow for recurrence interval; *DAREA*, drainage area; *SLOPE*, main-channel slope; *LAKE*, lake area; *SOILA*, soil hydrologic group A; *ROFF*, generalized mean annual runoff; log, common logarithm; regions are shown in figure 1]

Regression equation	Standard errors estimate (percent)	Equivalent years of record
Region A (number of gaging stations used in regression = 47)		
$PK1.5 = 7.15\ DAREA^{0.740}\ SLOPE^{0.222}\ (LAKE+1)^{-0.194}$	33	7.9
$PK2 = 8.85\ DAREA^{0.751}\ SLOPE^{0.326}\ (LAKE+1)^{-0.259}$	31	8.2
$PK5 = 12.9\ DAREA^{0.767}\ SLOPE^{0.528}\ (LAKE+1)^{-0.367}$	31	10.8
$PK10 = 15.3\ DAREA^{0.773} SLOPE^{0.632}\ (LAKE+1)^{-0.414}$	33	12.8
$PK25 = 17.9\ DAREA^{0.779}\ SLOPE^{0.743}\ (LAKE+1)^{-0.457}$	37	14.9
$PK50 = 19.6\ DAREA^{0.782}\ SLOPE^{0.815}\ (LAKE+1)^{-0.483}$	40	15.9
$PK100 = 21.2\ DAREA^{0.785}\ SLOPE^{0.879}\ (LAKE+1)^{-0.503}$	43	16.5
$PK500 = 24.1\ DAREA^{0.79}\ SLOPE^{1.009}\ (LAKE+1)^{-0.54}$	50	17.1
Region B (number of gaging stations used in regression = 91)		
$PK1.5 = 3.44\ DAREA^{0.067(9.031 + \log(DAREA))}\ (LAKE+1)^{-0.368}\ (SOILA+1)^{-0.104}\ ROFF^{0.916}$	33	3.7
$PK2 = 5.79\ DAREA^{0.075(7.719 + \log(DAREA))}\ (LAKE+1)^{-0.401}\ (SOILA+1)^{-0.123}\ ROFF^{0.855}$	33	3.2
$PK5 = 15.9\ DAREA^{0.088(5.879 + \log(DAREA))}\ (LAKE+1)^{-0.464}\ (SOILA+1)^{-0.155}\ ROFF^{0.735}$	37	3.7
$PK10 = 26.5\ DAREA^{0.095(5.182 + \log(DAREA))}\ (LAKE+1)^{-0.495}\ (SOILA+1)^{-0.169}\ ROFF^{0.674}$	39	4.4
$PK25 = 45.6\ DAREA^{0.101(4.576 + \log(DAREA))}\ (LAKE+1)^{-0.526}\ (SOILA+1)^{-0.183}\ ROFF^{0.608}$	42	5.3
$PK50 = 64.4\ DAREA^{0.104(4.233 + \log(DAREA))}\ (LAKE+1)^{-0.545}\ (SOILA+1)^{-0.191}\ ROFF^{0.566}$	44	5.9
$PK100 = 87.7\ DAREA^{0.107(3.959 + \log(DAREA))}\ (LAKE+1)^{-0.561}\ (SOILA+1)^{-0.198}\ ROFF^{0.529}$	47	6.4
$PK500 = 163\ DAREA^{0.112(3.472 + \log(DAREA))}\ (LAKE+1)^{-0.593}\ (SOILA+1)^{-0.21}\ ROFF^{0.45}$	53	7.2
Region C (number of gaging stations used in regression = 20)		
$PK1.5 = 42.2\ DAREA^{0.863}\ (LAKE+1)^{-0.54}$	40	2.8
$PK2 = 57.9\ DAREA^{0.844}\ (LAKE+1)^{-0.556}$	42	2.4
$PK5 = 114\ DAREA^{0.801}\ (LAKE+1)^{-0.59}$	45	2.8
$PK10 = 167\ DAREA^{0.778}\ (LAKE+1)^{-0.612}$	47	3.5
$PK25 = 256\ DAREA^{0.751}\ (LAKE+1)^{-0.639}$	49	4.5
$PK50 = 343\ DAREA^{0.734}\ (LAKE+1)^{-0.659}$	51	5.1
$PK100 = 449\ DAREA^{0.718}\ (LAKE+1)^{-0.679}$	53	5.7
$PK500 = 793\ DAREA^{0.684}\ (LAKE+1)^{-0.724}$	59	6.5
Region D (number of gaging stations used in regression = 107)		
$PK1.5 = 0.892\ DAREA^{0.778}\ SLOPE^{0.422}\ (LAKE+1)^{-0.29}\ ROFF^{1.144}$	56	3.1
$PK2 = 1.58\ DAREA^{0.785}\ SLOPE^{0.436}\ (LAKE+1)^{-0.328}\ ROFF^{1.011}$	50	3.5
$PK5 = 4.62\ DAREA^{0.795}\ SLOPE^{0.453}\ (LAKE+1)^{-0.392}\ ROFF^{0.78}$	43	6.3
$PK10 = 7.98\ DAREA^{0.799}\ SLOPE^{0.456}\ (LAKE+1)^{-0.419}\ ROFF^{0.671}$	42	8.8
$PK25 = 14\ DAREA^{0.802}\ SLOPE^{0.456}\ (LAKE+1)^{-0.444}\ ROFF^{0.567}$	43	11.4
$PK50 = 19.9\ DAREA^{0.803}\ SLOPE^{0.455}\ (LAKE+1)^{-0.458}\ ROFF^{0.507}$	46	12.8
$PK100 = 27.1\ DAREA^{0.804}\ SLOPE^{0.454}\ (LAKE+1)^{-0.469}\ ROFF^{0.459}$	48	13.8
$PK500 = 48.9\ DAREA^{0.803}\ SLOPE^{0.449}\ (LAKE+1)^{-0.488}\ ROFF^{0.376}$	56	14.8
Region E (number of gaging stations used in regression = 23)		
$PK1.5 = 1.26\ DAREA^{0.907}\ SLOPE^{0.939}$	23	25.9
$PK2 = 0.49\ DAREA^{1.03}\ SLOPE^{1.353}$	22	25.4
$PK5 = 4.53\ DAREA^{0.898}\ SLOPE^{1.000}$	23	30.7
$PK10 = 8.42\ DAREA^{0.878}\ SLOPE^{0.965}$	26	32.6
$PK25 = 9.29\ DAREA^{0.888}\ SLOPE^{1.104}$	30	35.3

Table 5. Regional regression equations, standard errors of the estimate, and the equivalent number of years of record.—Continued

[PK, peak flow for recurrence interval; *DAREA*, drainage area; *SLOPE*, main-channel slope; *LAKE*, lake area; *SOILA*, soil hydrologic group A; *ROFF*, generalized mean annual runoff; log, common logarithm; regions are shown in figure 1]

Regression equation	Standard errors estimate (percent)	Equivalent years of record
Region E (number of gaging stations used in regression = 23)—Continued		
$PK50 = 30.8\ DAREA^{0.822}\ SLOPE^{0.840}$	36	31.3
$PK100 = 36.8\ DAREA^{0.801}\ SLOPE^{0.898}$	42	27.7
$PK500 = 163\ DAREA^{0.734}\ SLOPE^{0.617}$	54	24.1
Region F (number of gaging stations used in regression = 44)		
$PK1.5 = 90.4\ DAREA^{0.615}\ SLOPE^{-0.047}$	46	4.0
$PK2 = 104\ DAREA^{0.624}\ SLOPE^{0.024}$	39	5.0
$PK5 = 140\ DAREA^{0.636}\ SLOPE^{0.146}$	28	12.5
$PK10 = 165\ DAREA^{0.64}\ SLOPE^{0.205}$	25	21.2
$PK25 = 197\ DAREA^{0.643}\ SLOPE^{0.266}$	24	31.1
$PK50 = 220\ DAREA^{0.643}\ SLOPE^{0.306}$	25	34.6
$PK100 = 243\ DAREA^{0.644}\ SLOPE^{0.341}$	28	35.0
$PK500 = 298\ DAREA^{0.644}\ SLOPE^{0.409}$	35	31.1

Accuracy and Limitations of the Peak-Flow Estimation Techniques

The accuracy of a statistically derived equation is measured by the closeness of the estimated value to the true value. Regression analyses give an unbiased estimate of the true value and statistics to assess the accuracy of the estimate.

The SEE, also called residual standard error, is a measure of the fit of the observed data about the regression surface (Riggs, 1968). The SEE is expressed as a percentage of the estimated value. It has traditionally been used for comparing the relative accuracy of the equations, although it is less useful for GLS regressions.

The standard error of prediction (SEP) is an estimate of the accuracy of the result of applying a regression equation to a set of explanatory variables. It accounts for the regression error and the uncertainty of the coefficients of the explanatory variables (Riggs, 1968). It varies from site to site because it is a function of the basin characteristics at a site.

Hardison (1971) presented an equation that defines the EY represented by the regression equation. The EY is the ratio of the mean variance of the logarithms of the annual peak flow to the mean square error of prediction, multiplied by a factor dependent on the recurrence interval. It is an estimate of the number of years of record that would be needed at a site to compute a peak flow at that recurrence interval with the same confidence interval.

Table 6. Mean prediction error sum of squares (PRESS/n) statistics for selected regions and recurrence intervals.

Recurrence interval (years)	Regional regression equations	Similarity region of influence	Proximity region of influence
Region A			
2	0.02734	0.03048	0.03512
25	.03954	.04793	.05593
100	.05341	.06596	.07090
Region B			
2	.02533	.03152	.03307
25	.04261	.05516	.06111
100	.05429	.07088	.07828
Region D			
2	.05173	.06435	.05015
25	.05021	.05740	.05588
100	.06612	.07522	.07674

Table 7. Maximum and minimum values and geometric mean of the basin characteristics used in the regional regression analysis for each region.

[mi², square miles; ft/mi, feet per mile; in/yr, inches per year]

Statistic	Drainage area (*DAREA*) (mi²)	Main-channel slope (*SLOPE*) (ft/mi)	Lake area (*LAKE*) (percent)	Storage area (*STOR*) (percent)	Soil hydrologic group A (*SOILA*) (percent)	Soil hydrlogic group D (*SOILD*) (percent)	Generalized mean annual runoff (*ROFF*) (in/yr)
Region A							
Minimum	2.81	1.74	0	4.79	0	0	2.34
Geometric mean	99.6	5.63	.67	20.5	4.82	1.46	3.49
Maximum	1,570	37.4	13.0	95.0	32.8	25.3	6.03
Region B							
Minimum	.23	0.67	0	1.84	0	0	3.03
Geometric mean	41.5	7.76	2.14	25.4	6.95	2.76	7.96
Maximum	1,700	238	23.7	63.9	54.5	39.0	12.24
Region C							
Minimum	.21	11.2	0	1.68	.15	8.56	11.42
Geometric mean	9.27	52.6	.59	15.1	3.00	24.8	12.23
Maximum	607	235	11.8	30.2	36.4	86.0	12.70
Region D							
Minimum	.15	1.49	0	0	0	0	2.15
Geometric mean	33.8	8.12	.71	3.74	.77	.78	4.52
Maximum	2,640	77.2	14.0	24.9	17.7	47.5	7.74
Region E							
Minimum	.09	4.04	0	0	0	0	2.90
Geometric mean	20.4	12.0	.01	1.53	.18	.17	3.81
Maximum	1,580	117	.11	4.88	1.21	1.17	4.59
Region F							
Minimum	.06	4.64	0	0	0	0	6.67
Geometric mean	32.3	19.6	.03	1.30	.71	1.44	7.66
Maximum	1,540	229	.25	4.44	4.06	19.1	8.46

The 90-percent prediction interval is another measure of the uncertainty of the estimated value. It is the estimated value multiplied or divided by a factor that is dependent on the mean SEP and the critical value of the t-distribution for a particular model. The information necessary to compute prediction intervals are included in the equations for Minnesota in the NSS (U.S. Geological Survey, 2009).

The accuracy of the estimating equation is limited by the uncertainty of the input data. Uncertainty has two components: variance, a measure of the random variation about the true value, and bias, the consistent deviation of the value from the true value. How well the peak-flow estimates from the log-Pearson Type III analysis of the recorded annual peak flows predicts the actual population of peak flows depends on the sample size, the accuracy of each recorded peak value, and how well the log-Pearson Type III distribution fits the actual distribution (Interagency Advisory Committee on Water Data, 1982).

The accuracy of the regression estimate is affected by errors in the explanatory variables. Errors in quantifying the drainage-basin characteristics result from an inability to completely describe the effect of those characteristics. For example, the effects of wetlands and lakes depend on their size and location in the basin and in the stream channels, but the explanatory variable storage is simply expressed as a percentage of total drainage area without regard to size or location.

Bias of an estimate can result from systematic errors in the computation of the response variable. Bias in the computation of the response variable probably is the result of collecting peak-flow data over a period that does not reflect the long-term population of peak flows. Most short-term records at gaging stations used in this analysis were from water years 1960 through 1985 and recent (through water year 2005)

periods. The derived peak-flow statistics reflect those periods, which may not be representative of the long-term conditions.

The accuracy of an estimate made using the techniques presented in this report also can be affected by the user. Each user will make certain decisions based on their best judgment about the actual outline of the drainage basin, the path of the main channel, interpolation of generalized runoff, and the source of lake and wetland data. These individual sources of error can be reduced by use of shared computer datasets that are updated as improved information becomes available and the use of a GIS that provides consistent results.

The accuracy of peak-flow estimates made at sites immediately downstream from a lake or ponded area where the storage capacity could substantially alter peak-flow characteristics can be improved by a routing adjustment. In such places, the frequency relations could be used as an aid in developing a hydrograph of the inflow and then a simulation of that flow can be routed through the lake to determine the peak of the outflow.

The values of the explanatory variables used in this analysis were all computed from consistent datasets using a GIS or spatial interpolation software. Careful analysis using 7½-minute USGS topographic maps should provide accurate estimates of drainage area, main-channel slope, percent storage, and percent lake. Interpolation of generalized runoff from figure 2 can be improved by using Fitted Annual Runoff data from table 3 in conjunction with data from nearby gaging stations.

Multi-collinearity among the explanatory variables can have adverse effects on the accuracy of coefficients of those variables in the regression equation (Helsel and Hirsch, 1992). Freund and Minton (1979) indicated that estimations from regressions where the explanatory variables exhibit multi-collinearity are reliable when the correlation structure of the estimated site is similar to that of the data used to construct the regression equation. This condition likely is true for any site in Minnesota using any of the techniques for estimating peak flow described herein.

Collinearity can be intrinsic in the data, such as the relation between main-channel slope and drainage area, or introduced in the computation of variables, such as percent lake area and percent storage area. The correlation (a measure of collinearity) between slope and drainage area is about -0.77 in Minnesota. The correlation between percent storage and percent lake is less than 0.54 for regions in Minnesota. A measure of multi-collinearity is the variance inflation factor (VIF). Helsel and Hirsch (1992) stated that VIFs of less than 10 were not a concern in multiple linear regression analyses. The VIF for each explanatory variable in each RRE in this study was less than 10.

Peak-flow frequency regression equations presented in this report can be used to estimate the peak flows of several recurrence intervals on most small ungaged streams in Minnesota. The applicability and accuracy of these relations depend partly on whether the basin characteristics of the site are within the range of the characteristics used to define the peak-flow regression equations. The range in sampled basin characteristics is large enough to allow the application of the equations at most sites where streamflow is not affected by regulation, diversion, or urbanization. The minimum, geometric mean (corrected for offsets, if necessary), and maximum values for each basin characteristic for each region are listed in table 7.

The geometric mean is included in table 7 because it represents the central value of the data better than the arithmetic mean. Where runoff is included as an explanatory variable, the range of those data is sufficient to ensure that any value in that region is within the range. The NSS program (U.S. Geological Survey, 2009) will issue a warning message if the estimated peak flow is an extrapolation beyond the data on which the estimation is based.

Summary

Knowledge of the peak flow of floods of a given recurrence interval is essential for regulation and planning of water resources and for design of bridges, culverts, and dams along Minnesota's rivers and streams. Statistical techniques are needed to estimate peak flow at ungaged sites because long-term streamflow records are available at relatively few places. Because of the need to have up-to-date peak-flow frequency information in order to estimate peak flows at ungaged sites, the U.S. Geological Survey (USGS) conducted a peak-flow frequency study in cooperation with the Minnesota Department of Transportation and the Minnesota Pollution Control Agency.

Estimates of peak-flow magnitudes for 1.5-, 2-, 5-, 10-, 25-, 50-, 100-, and 500-year recurrence intervals are presented for 330 streamflow-gaging stations in Minnesota and adjacent areas in Iowa and South Dakota based on data through water year 2005. The peak-flow frequency information was subsequently used in regression analyses to develop equations relating peak flows for selected recurrence intervals to various basin and climatic characteristics.

Two statistically derived techniques—regional regression equation and region of influence regression—can be used to estimate peak flow on small, ungaged streams in Minnesota. Regional regression equations were developed for each recurrence interval in each of the six regions in Minnesota: A (northwestern), B (north central and east central), C (northeastern), D (west central and south central), E (southwestern), and F (southeastern). The regression equations can be used to estimate peak flows at ungaged sites. The region of influence regression technique dynamically selects gaging stations with characteristics similar to a site of interest. Two methods of selecting gaging stations, similarity and proximity, can be used in the region of influence regression technique. Thus, the region of influence regression technique allows use of a potentially unique set of gaging stations for estimating peak flow at each site of interest.

The regional regression equation technique is the preferred technique as a first estimate of peak flow in all six regions for ungaged sites. The region of influence regression technique is not appropriate for regions C, E, and F because the interrelations of some characteristics of those regions do not agree with the interrelations throughout the rest of the State. Both the similarity and proximity methods for the region of influence technique can be used in the other regions (A, B, and D) to review the value obtained by the regional regression equation, or to provide a second or third estimate of peak flow. Tables showing the peak-flow-frequency estimates and basin characteristics for selected streamflow-gaging stations, and regional peak-flow regression equations, are presented. Discussions of the accuracy and limitations are also included.

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Tables 1–3

Table 1. Peak-flow frequency estimates for selected streamflow-gaging stations.

[NA, not available]

Station number	Map number (fig. 1)	Station name	Region (fig. 1)	Period of record (water years)	Peak-flow estimates (cubic feet per second) for recurrence intervals (years)							
					1.5	2	5	10	25	50	100	500
04010500	1	Pigeon River at Middle Falls near Grand Portage, Minn.	C	1924–28, 1930–2005	3,630	4,270	5,980	7,200	8,850	10,200	11,500	15,000
04011370	2	Little Devil Track River near Grand Marais, Minn.	C	1961–82	113	146	245	325	444	545	658	974
04011390	3	Little Devil Track River Tributary near Grand Marais, Minn.	C	1966–80, 1982	9.10	12.8	26.8	40.9	66.4	92.3	126	243
04011990	4	Cascade River at Forest Road. 45 near Grand Marais, Minn.	C	1985–2005	622	749	1,100	1,370	1,740	2,040	2,360	3,210
04012500	5	Poplar River at Lutsen, Minn.	C	1913–17, 1930–32, 1934–47, 1953–61, 1976–87	706	865	1,340	1,710	2,260	2,740	3,270	4,750
04013100	6	Lake Superior Tributary near Taconite Harbor, Minn.	C	1964–81	52.4	74.9	167	267	461	672	959	2,060
04013200	7	Caribou River near Little Marais, Minn.	C	1961–85	412	541	1,000	1,450	2,220	2,990	3,960	7,270
04014500	8	Baptism River near Beaver Bay, Minn.	C	1930–47, 1949–93	1,910	2,380	3,850	5,080	6,980	8,670	10,600	16,400
04015150	9	Crow Creek near Silver Creek, Minn.	C	1960–75	30.4	40.1	75.0	109	169	228	304	565
04015200	10	Encampment River Tributary at Silver Creek, Minn.	C	1960–90	40.9	51.8	88.2	121	174	224	284	476
04015250	11	Silver Creek Tributary near Two Harbors, Minn.	C	1965–2005	226	310	614	910	1,420	1,930	2,560	4,680
04015300	12	Little Stewart River near Two Harbors, Minn.	C	1960–2000	140	171	262	332	433	517	610	865
04015330	13	Knife River near Two Harbors, Minn.	C	1975–2005	2,280	2,740	4,130	5,250	6,940	8,400	10,100	14,800
04015360	14	Lake Superior Tributary #2 at French River, Minn.	C	1964–81	98.8	143	315	497	833	1,190	1,650	3,320

Table 1. Peak-flow frequency estimates for selected streamflow-gaging stations. —Continued

[NA, not available]

Station number	Map number (fig. 1)	Station name	Region (fig. 1)	Period of record (water years)	Peak-flow estimates (cubic feet per second) for recurrence intervals (years)							
					1.5	2	5	10	25	50	100	500
04015370	15	Talmadge River at Duluth, Minn.	C	1964–2000	195	261	489	702	1,060	1,400	1,820	3,190
04015500	16	Second Creek near Aurora, Minn.	B	1955–80	106	122	165	196	237	270	305	393
04016000	17	Partridge River near Aurora, Minn.	B	1943–82	708	939	1,610	2,110	2,810	3,370	3,960	5,460
04017000	18	Embarrass River at Embarrass, Minn.	B	1943–64	430	570	994	1,330	1,820	2,220	2,660	3,850
04017700	19	Mckinley Lake Tributary at Mckinley, Minn.	B	1960–81	8.70	12.5	24.4	34.1	48.2	59.9	72.5	105
04018800	20	East Two River Tributary at Virginia, Minn.	B	1959–72	46.1	53.8	73.0	85.7	102	114	126	154
04018900	21	East Two River near Iron Junction, Minn.	B	1967–79	269	334	502	617	763	873	984	1,250
04019000	22	West Two River near Iron Junction, Minn.	B	1954–62, 1966–79	441	543	799	966	1,170	1,320	1,470	1,800
04019300	23	West Swan River near Silica, Minn.	B	1964–79	195	250	400	505	641	745	849	1,100
04019500	24	East Swan River near Toivola, Minn.	B	1954–62, 1965–71	1,030	1,180	1,530	1,750	2,010	2,200	2,380	2,790
04020480	25	North Branch Whiteface River near Fairbanks, Minn.	B	1979–2005	116	152	260	345	467	569	680	978
04020700	26	Bug Creek at Shaw, Minn.	B	1979–2005	219	285	491	665	929	1,160	1,430	2,200
04021205	27	Floodwood River above Floodwood, Minn.	B	1972–87	879	1,100	1,680	2,070	2,580	2,970	3,360	4,270
04021690	28	Cloquet River near Toimi, Minn.	B	1986–2005	379	466	712	898	1,160	1,380	1,610	2,230
04024095	29	Nemadji River near Holyoke, Minn.	C	1972–2005	1,450	1,730	2,480	3,010	3,710	4,250	4,810	6,210
04024098	30	Deer Creek near Holyoke, Minn.	C	1977–2001	249	352	716	1,060	1,620	2,160	2,800	4,830
04024100	31	Rock Creek near Blackhoof, Minn.	C	1961–65, 1967–8	324	446	829	1,140	1,600	1,990	2,420	3,590

Table 1. Peak-flow frequency estimates for selected streamflow-gaging stations. —Continued

[NA, not available]

Station number	Map number (fig. 1)	Station name	Region (fig. 1)	Period of record (water years)	Peak-flow estimates (cubic feet per second) for recurrence intervals (years)							
					1.5	2	5	10	25	50	100	500
04024110	32	Rock Creek Tributary near Blackhoof, Minn.	C	1961–86	13.2	18.4	35.9	51.0	74.4	95.1	119	186
04024200	33	South Fork Nemadji River near Holyoke, Minn.	C	1961–85	560	740	1,260	1,650	2,200	2,630	3,090	4,260
05040500	34	Pelican River near Fergus Falls, Minn.	B	1910–12, 1943–47, 1949–80	237	299	475	607	789	936	1,090	1,500
05047500	35	Mustinka River above Twelvemile Creek near Charlesville, Minn.	D	1944–55	206	290	558	785	1,130	1,420	1,750	2,670
05047970	36	West Branch Twelvemile Creek Tributary near Graceville, Minn.	D	1964–67, 1969–73, 1975–89	20.1	31.5	75.4	119	192	262	346	607
05048000	37	Mustinka River Below Twelvemile Creek near Charlesville, Minn.	D	1944–55	246	324	542	703	921	1,090	1,270	1,710
05049000	38	Mustinka River above Wheaton, Minn.	D	1920–24, 1931–58, 1985–2005	557	984	2,760	4,540	7,500	10,200	13,300	22,200
05049200	39	Eighteen Mile Creek near Wheaton, Minn.	D	1965–96	93.2	185	652	1,210	2,260	3,340	4,690	9,020
05050700	40	Rabbit River near Nashua Minn.	D	1979–2005	381	551	1,050	1,410	1,880	2,220	2,570	3,340
05051000	41	Rabbit River at Campbell, Minn.	D	1943–52	1,020	1,400	2,610	3,630	5,150	6,480	7,960	12,100
05060800	42	Buffalo River near Callaway, Minn.	A	1960–76, 1978–2005	185	262	492	665	898	1,080	1,270	1,710
05061000	43	Buffalo River near Hawley, Minn.	A	1945–2005	523	722	1,290	1,710	2,270	2,700	3,130	4,170
05061200	44	Whiskey Creek at Barnesville, Minn.	A	1961–2005	115	157	283	381	520	632	752	1,060
05061400	45	Spring Creek above Downer, Minn.	A	1961–2000	32.4	55.7	166	300	573	876	1,290	2,880
05061500	46	South Branch Buffalo River at Sabin, Minn.	A	1945–2005	780	1,200	2,670	3,960	5,930	7,630	9,520	14,600
05062000	47	Buffalo River near Dilworth, Minn.	A	1931–2005	1,010	1,540	3,430	5,120	7,750	10,100	12,700	20,000

Table 1. Peak-flow frequency estimates for selected streamflow-gaging stations. —Continued

[NA, not available]

Station number	Map number (fig. 1)	Station name	Region (fig. 1)	Period of record (water years)	Peak-flow estimates (cubic feet per second) for recurrence intervals (years)							
					1.5	2	5	10	25	50	100	500
05062280	48	Mosquito Creek near Bagley, Minn.	A	1961–85	22.1	31.8	59.8	80.2	107	127	146	191
05062470	49	Marsh Creek Tributary near Mahnomen, Minn.	A	1961–85	78.9	119	244	342	478	585	694	958
05062500	50	Wild Rice River at Twin Valley, Minn.	A	1909–17, 1931–2005	991	1,510	3,290	4,850	7,250	9,330	11,700	18,000
05062700	51	Wild Rice River Tributary near Twin Valley, Minn.	A	1961–85	62.3	90.6	174	236	316	377	436	573
05062800	52	Coon Creek near Twin Valley, Minn.	A	1962–84	269	472	1,240	1,930	2,960	3,800	4,690	6,890
05063200	53	Spring Creek Tributary near Ogema, Minn.	A	1963–76, 1978–89	43.8	54.7	81.0	97.3	117	130	142	168
05063500	54	South Branch Wild Rice River near Borup, Minn.	A	1944–49, 1972–84	687	965	1,830	2,520	3,510	4,330	5,220	7,520
05064000	55	Wild Rice River at Hendrum, Minn.	A	1944–2005	2,140	2,950	5,350	7,150	9,600	11,500	13,500	18,400
05067500	56	Marsh River near Shelly, Minn.	A	1944–2005	700	1,090	2,310	3,230	4,420	5,300	6,150	8,000
05069000	57	Sand Hill River at Climax, Minn.	A	1943–2005	806	1,200	2,430	3,410	4,780	5,870	7,000	9,780
05073600	58	South Branch Battle River at Northome, Minn.	A	1960–85	42.7	53.3	80.6	99.1	123	140	158	199
05073750	59	Spring Creek near Blackduck, Minn.	A	1960–85	58.0	84.9	181	271	417	554	715	1,210
05073800	60	Perry Creek near Shooks, Minn.	A	1960–85	26.2	35.3	60.9	79.6	105	124	145	193
05075700	61	Mud River near Grygla, Minn.	A	1979–2005	681	887	1,420	1,790	2,240	2,560	2,880	3,600
05076000	62	Thief River near Thief River Falls, Minn.	A	1909–17, 1919–26, 1929–2005	1,060	1,540	2,820	3,650	4,600	5,230	5,790	6,870
05077700	63	Ruffy Brook near Gonvick, Minn.	A	1961–80, 1982–2005	161	206	315	383	463	518	569	677
05078000	64	Clearwater River at Plummer, Minn.	A	1939–2005	1,100	1,430	2,330	2,970	3,810	4,460	5,110	6,670

Table 1. Peak-flow frequency estimates for selected streamflow-gaging stations. —Continued

[NA, not available]

Station number	Map number (fig. 1)	Station name	Region (fig. 1)	Period of record (water years)	Peak-flow estimates (cubic feet per second) for recurrence intervals (years)							
					1.5	2	5	10	25	50	100	500
05078100	65	Lost River at Gonvick, Minn.	A	1960–72	114	151	243	302	373	422	468	566
05078180	66	Silver Creek near Clearbrook, Minn.	A	1960–85	39.1	55.2	98.4	127	162	186	209	256
05078200	67	Silver Creek Tributary at Clearbrook, Minn.	A	1960–81	40.3	54.5	93.6	121	158	185	212	276
05078230	68	Lost River at Oklee, Minn.	A	1950, 1961–2005	895	1,210	2,040	2,600	3,310	3,820	4,320	5,410
05078400	69	Clearwater River Tributary near Plummer, Minn.	A	1961–90	36.4	51.6	100	141	200	250	305	453
05078500	70	Clearwater River at Red Lake Falls, Minn.	A	1910–17, 1935–2005	2,440	3,330	5,840	7,630	9,970	11,700	13,500	17,600
05079901	71	Burnham Creek near Crookston, Minn.	A	1986–2005	547	916	2,200	3,260	4,740	5,900	7,060	9,750
05086900	72	Middle River near Newfolden Minn.	A	1979–2005	231	382	952	1,480	2,300	3,010	3,800	5,920
05087500	73	Middle River at Argyle, Minn.	A	1945, 1950–2005	586	938	2,070	2,950	4,110	4,980	5,840	7,720
05093000	74	South Branch Two Rivers at Pelan, Minn.	A	1929–38, 1954–56	252	421	1,050	1,610	2,470	3,200	4,000	6,070
05094000	75	South Branch Two Rivers at Lake Bronson, Minn.	A	1929–37, 1941–47, 1954–2001, 2003–05	1,020	1,430	2,610	3,490	4,650	5,530	6,420	8,510
05095500	76	Two Rivers below Hallock, Minn.	A	1945–55	643	942	1,850	2,530	3,450	4,150	4,860	6,510
05096000	77	North Branch Two Rivers near Lancaster, Minn.	A	1930–38, 1941–55	45.5	84.9	253	419	685	919	1,180	1,860
05103000	78	Roseau River near Malung, Minn.	A	1929–38, 1940–46	351	554	1,210	1,720	2,410	2,930	3,460	4,650
05104000	79	South Fork Roseau River near Malung, Minn.	A	1912–14, 1929–38, 1940–46	285	453	997	1,420	1,980	2,410	2,830	3,760
05104500	80	Roseau River below South Fork near Malung, Minn.	A	1929–38, 1940–2005	1,130	1,730	3,630	5,130	7,170	8,740	10,300	14,100
05107500	81	Roseau River at Ross, Minn.	A	1919, 1929–91, 1995–2005	1,250	1,720	3,070	4,030	5,280	6,230	7,170	9,340

Table 1. Peak-flow frequency estimates for selected streamflow-gaging stations. —Continued

[NA, not available]

Station number	Map number (fig. 1)	Station name	Region (fig. 1)	Period of record (water years)	Peak-flow estimates (cubic feet per second) for recurrence intervals (years)							
					1.5	2	5	10	25	50	100	500
05112000	82	Roseau River below State Ditch 51 near Caribou, Minn.	A	1917, 1920–2005	1,330	1,670	2,460	2,930	3,440	3,780	4,090	4,690
05124480	83	Kawishiwi River near Ely, Minn.	B	1967–2005	720	887	1,310	1,580	1,920	2,170	2,420	2,980
05124500	84	Isabella River near Isabella, Minn.	B	1953–61, 1976–77	1,490	1,880	2,990	3,820	4,970	5,910	6,900	9,490
05124990	85	Filson Creek near Ely, Minn.	B	1975–85	91.3	117	198	267	372	466	575	894
05125000	86	South Kawishiwi River near Ely, Minn.	B	1952–61, 1976–78, 2003–05	1,590	2,070	3,450	4,520	6,040	7,280	8,620	12,100
05125500	87	Stony River near Isabella, Minn.	B	1953–64	634	807	1,320	1,710	2,280	2,760	3,280	4,700
05125550	88	Stony River near Babbitt, Minn.	B	1976–80, 1986–2005	809	981	1,420	1,730	2,120	2,420	2,720	3,450
05126000	89	Dunka River near Babbitt, Minn.	B	1952–62, 1976–80	261	326	510	650	848	1,010	1,190	1,650
05126500	90	Bear Island River near Ely, Minn.	B	1953–62, 1975–77	197	236	331	394	472	529	586	717
05127205	91	Burntside River near Ely, Minn.	B	1968–78	213	244	322	373	438	486	535	650
05127210	92	Armstrong Creek near Ely, Minn.	B	1968–78	45.0	53.8	78.5	97.0	123	144	167	227
05127215	93	Longstorff Creek near Ely, Minn.	B	1968–78	83.0	98.4	141	172	214	249	286	381
05127220	94	Burgo Creek near Ely, Minn.	B	1968–78	57.0	82.5	181	281	462	645	880	1,690
05127230	95	Shagawa River at Ely, Minn.	B	1968–78	301	340	435	498	579	640	701	848
05127500	96	Basswood River near Winton, Minn.	B	1926–27, 1930–2005	4,090	4,930	7,020	8,380	10,100	11,300	12,500	15,300
05128300	97	Pike River near Gilbert, Minn.	B	1966–81	17.7	22.7	38.0	50.5	69.1	85.1	103	154
05128500	98	Pike River near Embarrass, Minn.	B	1950, 1954–64, 1977–79	574	724	1,180	1,540	2,070	2,520	3,030	4,440

Table 1. PPeak-flow frequency estimates for selected streamflow-gaging stations. —Continued

[NA, not available]

Station number	Map number (fig. 1)	Station name	Region (fig. 1)	Period of record (water years)	Peak-flow estimates (cubic feet per second) for recurrence intervals (years)							
					1.5	2	5	10	25	50	100	500
05128700	99	Pike River Tributary near Wahlsten, Minn.	B	1961–81	37.9	47.2	72.6	90.9	116	135	155	206
05129000	100	Vermilion River below Vermilion Lake near Tower, Minn.	B	1912–17, 1929–81	902	1,080	1,540	1,840	2,230	2,510	2,800	3,460
05129650	101	Little Fork River at Cook, Minn.	B	1968–84	417	527	858	1,130	1,530	1,870	2,260	3,350
05129710	102	Johnson Creek near Britt, Minn.	B	1961–64, 1966–75	23.2	25.8	31.6	35.1	39.1	41.9	44.5	50.4
05130300	103	Boriin Creek near Chisholm, Minn.	B	1959–92	132	173	298	397	539	657	786	1,130
05130500	104	Sturgeon River near Chisholm, Minn.	B	1943–2005	800	1,010	1,590	2,010	2,550	2,970	3,400	4,440
05131000	105	Dark River near Chisholm, Minn.	B	1943–61, 1966–79	241	307	503	661	891	1,090	1,300	1,900
05131500	106	Little Fork River at Littlefork, Minn.	B	1910–17, 1929–2005	7,150	9,030	13,900	17,200	21,400	24,600	27,700	35,000
05131750	107	Big Fork River near Bigfork, Minn.	B	1973–2005	1,020	1,260	1,820	2,170	2,590	2,880	3,150	3,740
05131878	108	Bowerman Brook near Craigville, Minn.	B	1979–2005	169	238	448	612	844	1,030	1,230	1,740
05132000	109	Big Fork River at Big Falls, Minn.	B	1910–12, 1929–94, 1998–2005	4,080	5,300	8,570	10,800	13,800	16,000	18,200	23,400
05134100	110	North Branch Rapid River near Baudette, Minn.	A	1986–89, 1991–2005	454	657	1,350	1,960	2,910	3,760	4,730	7,510
05134200	111	Rapid River near Baudette, Minn.	A	1950, 1957–85	2,190	2,890	4,730	5,950	7,460	8,550	9,600	11,900
05137000	112	Winter Road River near Baudette, Minn.	A	1986–2005	490	779	1,890	2,970	4,760	6,440	8,430	14,400
05139500	113	Warroad River near Warroad, Minn.	A	1946–80	407	601	1,190	1,630	2,210	2,660	3,110	4,150
05140000	114	Bulldog Run near Warroad, Minn.	A	1946–51, 1967–83	85.1	143	335	486	687	836	981	1,300
05140500	115	East Branch Warroad River near Warroad, Minn.	A	1946–54, 1967–83	228	336	662	908	1,240	1,490	1,740	2,320

Table 1. Peak-flow frequency estimates for selected streamflow-gaging stations. —Continued

[NA, not available]

Station number	Map number (fig. 1)	Station name	Region (fig. 1)	Period of record (water years)	Peak-flow estimates (cubic feet per second) for recurrence intervals (years)							
					1.5	2	5	10	25	50	100	500
05200200	116	Hennepin Creek near Becida, Minn.	B	1979–2000	69.2	89.3	148	192	255	306	360	504
05205200	117	Boy River near Remer, Minn.	B	1986–2005	278	340	501	613	760	871	986	1,260
05210200	118	Smith Creek near Hill City, Minn.	B	1961–2000	52.7	76.9	159	232	345	444	556	875
05216700	119	O'Brien Creek near Nashwauk, Minn.	B	1959–72	67.7	76.8	97.1	109	123	133	142	161
05216860	120	Swan River near Calumet, Minn.	B	1964–90	253	322	513	651	839	987	1,140	1,530
05216980	121	Swan River Tributary at Warba, Minn.	B	1964–90	30.1	37.4	55.7	67.5	81.9	92.2	102	124
05217000	122	Swan River near Warba, Minn.	B	1950, 1954–69	616	714	948	1,100	1,280	1,410	1,540	1,830
05217700	123	Bluff Creek near Jacobson, Minn.	B	1961–67, 1969–81	24.7	34.3	63.9	87.6	122	150	180	260
05221020	124	Willow River Below Palisade, Minn.	B	1972–2005	1,280	1,620	2,500	3,100	3,850	4,410	4,960	6,230
05229450	125	Pine River near Pine River, Minn.	B	1986–2005	514	647	1,010	1,260	1,610	1,870	2,150	2,830
05241500	126	Rabbit River near Crosby, Minn.	B	1946–63	16.2	22.1	39.7	53.4	72.8	88.6	106	149
05243725	127	Straight River near Park Rapids, Minn.	B	1987–2005	85.1	92.2	109	119	130	139	147	166
05244000	128	Crow Wing River at Nimrod, Minn.	B	1910–14, 1931–74, 1976–87, 1992–2005	1,020	1,260	1,900	2,350	2,940	3,400	3,860	5,010
05244100	129	Kitten Creek near Sebeka, Minn.	B	1961–78	72.8	104	204	287	411	517	633	948
05244200	130	Cat River near Nimrod, Minn.	B	1961–2001, 2003–05	126	169	296	394	534	648	770	1,090
05244440	131	Leaf River near Aldrich, Minn.	B	1972–2005	1,320	1,770	3,070	4,070	5,470	6,600	7,790	10,900
05245100	132	Long Prairie River at Long Prairie, Minn.	B	1972–2005	632	819	1,380	1,830	2,490	3,050	3,660	5,350

Table 1. Peak-flow frequency estimates for selected streamflow-gaging stations. —Continued

[NA, not available]

Station number	Map number (fig. 1)	Station name	Region (fig. 1)	Period of record (water years)	Peak-flow estimates (cubic feet per second) for recurrence intervals (years)							
					1.5	2	5	10	25	50	100	500
05245800	133	Sevenmile Creek near Pillager, Minn.	B	1979–93	70.4	95.5	172	233	321	394	474	685
05261520	134	Nokasippi River near Fort Ripley, Minn.	B	1986–2005	368	487	822	1,070	1,390	1,640	1,900	2,540
05267800	135	Big Mink Creek Tributary near Lastrup, Minn.	B	1962–80	7.50	11.8	27.7	42.6	66.6	88.3	113	185
05267900	136	Hillman Creek near Pierz, Minn.	B	1964–2002	294	460	1,020	1,490	2,180	2,740	3,340	4,850
05268000	137	Platte River at Royalton, Minn.	B	1930–36, 1972–73, 1975–2005	979	1,390	2,590	3,470	4,650	5,540	6,440	8,530
05270150	138	Ashley Creek near Sauk Centre, Minn.	B	1986–2005	308	386	580	707	864	978	1,090	1,340
05270300	139	Sauk River Tributary at Spring Hill, Minn.	B	1960–2000	113	161	337	509	809	1,110	1,470	2,710
05270310	140	Sauk River Tributary #2 near St. Martin, Minn.	B	1960, 1962–85	15.5	25.0	68.0	118	219	330	483	1,070
05270500	141	Sauk River near St. Cloud, Minn.	B	1910–12, 1930–81, 1991–2005	1,110	1,500	2,680	3,640	5,020	6,170	7,420	10,800
05271800	142	Johnson Creek Tributary at Luxemburg, Minn.	B	1964–67, 1969–89	24.2	33.2	62.5	87.6	126	161	200	313
05272000	143	Johnson Creek Tributary #2 near St. Augusta, Minn.	B	1964–83	63.5	84.1	144	188	250	299	351	481
05272300	144	Johnson Creek near St. Augusta, Minn.	B	1964–69, 1971–2005	202	286	559	789	1,140	1,430	1,760	2,680
05272950	145	Clearwater River near South Haven, Minn.	B	1985–2005	190	288	610	872	1,250	1,550	1,860	2,650
05273700	146	Otsego Creek near Otsego, Minn.	B	1964–67, 1969–89	66.6	91.3	164	219	295	355	418	574
05274200	147	Stony Brook Tributary near Foley, Minn.	B	1960–89	29.3	44.5	96.6	142	210	269	334	508
05275000	148	Elk River near Big Lake, Minn.	B	1911–17, 1932–87, 1991–2005	1,120	1,600	3,020	4,060	5,430	6,480	7,520	9,940
05276000	149	North Fork Crow River near Regal, Minn.	D	1944–54	653	816	1,250	1,560	1,970	2,290	2,610	3,410

Table 1. Peak-flow frequency estimates for selected streamflow-gaging stations. —Continued

[NA, not available]

Station number	Map number (fig. 1)	Station name	Region (fig. 1)	Period of record (water years)	Peak-flow estimates (cubic feet per second) for recurrence intervals (years)							
					1.5	2	5	10	25	50	100	500
05276100	150	North Fork Crow River Tributary near Paynesville, Minn.	D	1960–85	13.9	19.1	35.4	48.5	67.6	83.4	101	147
05276200	151	North Fork Crow River at Paynesville, Minn.	D	1973, 1975–2000	569	771	1,380	1,860	2,540	3,110	3,710	5,310
05278120	152	North Fork Crow River near Kingston, Minn.	D	1985–2005	1,220	1,770	3,440	4,730	6,500	7,890	9,320	12,800
05278350	153	Fountain Creek near Montrose, Minn.	D	1962–85, 1991	41.3	51.6	81.1	104	137	164	193	273
05278500	154	South Fork Crow River at Cosmos, Minn.	D	1945–64	239	339	680	980	1,450	1,880	2,360	3,780
05278700	155	Otter Creek near Lester Prairie, Minn.	D	1961–89	79.4	113	222	313	451	569	700	1,060
05278750	156	Otter Creek Tributary near Lester Prairie, Minn.	D	1962–89, 1991	22.1	28.7	46.3	58.5	74.3	86.0	97.8	125
05278850	157	Buffalo Creek Tributary near Brownton, Minn.	D	1962–63, 1965–69, 1971–72, 1974–76, 1978–87, 1991	24.9	34.9	65.7	90.4	126	156	187	271
05278930	158	Buffalo Creek near Glencoe, Minn.	D	1972–80, 1991–94, 1998–2005	928	1,280	2,310	3,090	4,170	5,030	5,920	8,130
05279000	159	South Fork Crow River near Mayer, Minn.	D	1934–84, 1986–91	1,480	2,210	4,690	6,830	10,100	12,900	16,000	24,400
05280000	160	Crow River at Rockford, Minn.	D	1910–17, 1930–2005	2,620	3,830	7,520	10,400	14,300	17,400	20,500	28,100
05280300	161	School Lake Creek Tributary near St. Michael, Minn.	D	1964–90	20.6	30.8	70.0	110	179	248	333	617
05284100	162	Mille Lacs Lake Tributary near Wealthwood, Minn.	B	1961–72	9.20	13.8	29.6	43.1	63.5	81.0	100	152
05284600	163	Robinson Brook near Onamia, Minn.	B	1960–79, 1981–85	60.1	88.8	176	241	327	393	458	609
05284620	164	Rum River Tributary near Onamia, Minn.	B	1960–85	40.0	56.2	111	160	237	306	387	625
05284920	165	Stanchfield Creek Tributary near Day, Minn.	B	1961–85	25.5	36.1	68.5	93.9	130	158	189	264

Table 1. Peak-flow frequency estimates for selected streamflow-gaging stations. —Continued

[NA, not available]

Station number	Map number (fig. 1)	Station name	Region (fig. 1)	Period of record (water years)	Peak-flow estimates (cubic feet per second) for recurrence intervals (years)							
					1.5	2	5	10	25	50	100	500
05286000	166	Rum River near St. Francis, Minn.	B	1930–2005	2,870	3,840	6,390	8,090	10,200	11,700	13,100	16,100
05287890	167	Elm Creek near Champlin, Minn.	D	1979–2005	241	332	578	748	961	1,120	1,270	1,600
05292704	168	North Fork Yellow Bank River near Odessa, Minn.	D	1991–2005	590	1,140	3,560	6,010	9,980	13,500	17,400	27,600
05293000	169	Yellow Bank River near Odessa, Minn.	D	1940–2005	746	1,250	3,070	4,660	6,990	8,900	10,900	15,900
05293371	170	Pomme de Terre (Site 210) near Elbow Lake, Minn.	D	1986–2005	165	210	336	430	560	664	775	1,060
05294000	171	Pomme de Terre River at Appleton, Minn.	D	1931–2001, 2004–05	497	739	1,590	2,370	3,620	4,750	6,050	9,880
05299100	172	Lazarus Creek Tributary near Canby, Minn.	D	1960–67, 1969–73, 1975–90	62.2	111	301	478	748	975	1,220	1,840
05299750	173	Florida Creek near Burr, Minn.	D	1983–84, 1991–2005	165	283	787	1,320	2,260	3,170	4,270	7,740
05300000	174	Lac Qui Parle River near Lac Qui Parle, Minn.	D	1911–14, 1931–33, 1935–2005	1,000	1,580	3,810	5,970	9,560	12,900	16,800	28,600
05302500	175	Little Chippewa River near Starbuck, Minn.	D	1979–2005	103	142	276	395	586	761	966	1,580
05302970	176	Outlet Creek Tributary near Starbuck, Minn.	D	1962, 1964–67, 1969–85	6.70	10.0	20.7	29.8	43.1	54.3	66.3	98.1
05303450	177	Hassel Creek near Clontarf, Minn.	D	1962–80	40.7	53.5	93.8	128	179	224	275	423
05304500	178	Chippewa River near Milan, Minn.	D	1937–2005	1,390	2,060	4,360	6,370	9,470	12,200	15,200	23,700
05305000	179	Chippewa River near Watson, Minn.	D	1911–17, 1931–36	238	512	2,200	4,630	10,100	16,500	25,600	61,100
05305200	180	Spring Creek near Montevideo, Minn.	D	1959–2000	62.0	102	255	401	638	850	1,090	1,780
05311200	181	North Branch Yellow Medicine River near Ivanhoe, Minn.	D	1960–85	48.6	89.2	266	451	765	1,060	1,400	2,380

Table 1. Peak-flow frequency estimates for selected streamflow-gaging stations. —Continued

[NA, not available]

Station number	Map number (fig. 1)	Station name	Region (fig. 1)	Period of record (water years)	Peak-flow estimates (cubic feet per second) for recurrence intervals (years)							
					1.5	2	5	10	25	50	100	500
05311250	182	North Branch Yellow Medicine River Tributary near Wilno, Minn.	D	1960–73, 1975–85	11.6	16.9	32.8	44.9	61.3	74.0	86.9	118
05311300	183	North Branch Yellow Medicine Tributary #2 near Porter, Minn.	D	1960–75	76.8	93.1	136	167	208	240	273	356
05311400	184	South Branch Yellow Medicine River at Minneota, Minn.	D	1960–87, 1998–2005	364	559	1,250	1,870	2,850	3,710	4,680	7,410
05313500	185	Yellow Medicine River near Granite Falls, Minn.	D	1919, 1931–38, 1940–2005	834	1,410	3,540	5,460	8,380	10,800	13,500	20,300
05313800	186	Kandiyohi County Ditch #16 near Blomkest, Minn.	D	1960–72	22.4	32.2	61.6	83.9	114	138	162	220
05314900	187	Redwood River at Ruthton, Minn.	D	1959–81	71.8	117	278	418	627	800	986	1,460
05315000	188	Redwood River near Marshall, Minn.	D	1940–2005	462	732	1,730	2,640	4,100	5,400	6,880	11,000
05315200	189	Prairie Ravine near Marshall, Minn.	D	1959–85	26.4	38.6	77.7	110	155	193	233	335
05316500	190	Redwood River near Redwood Falls, Minn.	D	1910–14, 1931–2005	721	1,260	3,460	5,630	9,170	12,400	16,000	26,100
05316538	191	Ramsey Creek near Redwood Falls, Minn.	D	1991–93, 1995–2005	320	432	751	985	1,300	1,540	1,790	2,390
05316550	192	West Fork Beaver Creek near Olivia, Minn.	D	1959–81	50.7	73.7	149	211	303	380	464	685
05316570	193	Beaver Creek near Beaver Falls, Minn.	D	1972, 1974–80, 1982–2005	551	724	1,230	1,620	2,180	2,630	3,120	4,400
05316690	194	Spring Creek Tributary near Sleepy Eye, Minn.	D	1966–90	26.7	39.1	78.1	109	153	189	226	321
05316700	195	Spring Creek near Sleepy Eye, Minn.	D	1959–2000	141	207	425	609	886	1,120	1,380	2,080
05316800	196	Cottonwood River Tributary near Balaton, Minn.	D	1959–85	19.5	36.8	117	204	359	508	687	1,230
05316850	197	Meadow Creek Tributary near Marshall, Minn.	D	1961–72	9.20	17.2	54.1	95.1	169	241	329	600
05316900	198	Dry Creek near Jeffers, Minn.	D	1961–85	86.8	133	298	448	683	892	1,130	1,800

Table 1. Peak-flow frequency estimates for selected streamflow-gaging stations. —Continued

[NA, not available]

Station number	Map number (fig. 1)	Station name	Region (fig. 1)	Period of record (water years)	Peak-flow estimates (cubic feet per second) for recurrence intervals (years)							
					1.5	2	5	10	25	50	100	500
05316920	199	Cottonwood River Tributary near Sanborn, Minn.	D	1966–72, 1975–90, 1993–94	17.8	28.1	65.4	99.6	153	201	255	406
05316950	200	Cottonwood River near Springfield, Minn.	D	1969, 1973–2005	2,060	2,970	6,090	8,850	13,100	17,000	21,300	33,800
05317000	201	Cottonwood River near New Ulm, Minn.	D	1910–13, 1931–2005	2,350	3,450	7,330	10,900	16,600	21,900	28,000	46,200
05317200	202	Little Cottonwood River near Courtland, Minn.	D	1974–94, 1996–2005	415	582	1,120	1,570	2,260	2,840	3,490	5,290
05317845	203	East Branch Blue Earth River near Walters, Minn.	D	1979–2005	325	382	509	584	669	726	779	890
05317850	204	Foster Creek near Alden, Minn.	D	1959–84	63.7	90.3	166	219	288	338	388	499
05318000	205	East Branch Blue Earth River near Bricelyn, Minn.	D	1951–70, 1973–87	251	373	761	1,070	1,510	1,860	2,220	3,130
05318100	206	East Branch Blue Earth River Tributary near Blue Earth, Minn.	D	1960–85	108	152	287	396	552	681	819	1,180
05318195	207	Elm Creek at County Road 103 near Trimont, Minn.	D	1991–2005	523	835	1,950	2,950	4,470	5,770	7,190	11,000
05318300	208	Watonwan River near Delft, Minn.	D	1960–2003	60.4	106	324	587	1,120	1,690	2,480	5,380
05318890	209	South Fork Watonwan River near Odin, Minn.	D	1979–82, 1984–97	294	458	1,030	1,520	2,260	2,890	3,580	5,400
05318897	210	South Fork Watonwan River near Ormsby, Minn.	D	1979–82, 1984–96, 1998–2005	273	433	1,020	1,570	2,440	3,210	4,090	6,580
05319500	211	Watonwan River near Garden City, Minn.	D	1940–45, 1953, 1965, 1969, 1977–2005	2,040	2,800	5,230	7,290	10,400	13,100	16,200	24,800
05320200	212	Le Sueur River Tributary near Mankato, Minn.	D	1959–63, 1965–85	12.7	19.4	47.2	77.3	134	194	272	555
05320300	213	Cobb River Tributary near Mapleton, Minn.	D	1959–85	103	133	222	291	390	471	560	796
05320400	214	Maple River Tributary near Mapleton, Minn.	D	1959–85	89.1	140	348	567	963	1,360	1,870	3,580

Table 1. Peak-flow frequency estimates for selected streamflow-gaging stations. —Continued

[NA, not available]

Station number	Map number (fig. 1)	Station name	Region (fig. 1)	Period of record (water years)	Peak-flow estimates (cubic feet per second) for recurrence intervals (years)							
					1.5	2	5	10	25	50	100	500
05320440	215	Judicial Ditch #49 near Amboy, Minn.	D	1959–72	145	203	394	561	820	1,050	1,310	2,070
05320480	216	Maple River near Rapidan, Minn.	D	1973–2005	1,720	2,180	3,370	4,160	5,120	5,820	6,510	8,030
05320500	217	Le Sueur River near Rapidan, Minn.	D	1940–45, 1949–2005	3,300	4,590	8,530	11,600	16,100	19,700	23,500	33,500
05326100	218	Middle Branch Rush River near Gaylord, Minn.	D	1979–2000	404	553	1,010	1,370	1,890	2,320	2,780	3,980
05327000	219	High Island Creek near Henderson, Minn.	D	1974–2005	760	1,050	1,880	2,460	3,210	3,770	4,320	5,570
05330150	220	Sand Creek Tributary near Montogomery, Minn.	D	1961–81	16.5	20.6	32.2	41.1	53.4	63.4	74.2	103
05330200	221	Rice Lake Tributary near Montgomery, Minn.	D	1960–85	36.8	50.5	91.9	124	170	207	247	348
05330300	222	Sand Creek near New Prague, Minn.	D	1960–67, 1969–2005	203	273	481	643	872	1,060	1,260	1,780
05330550	223	East Branch Raven Stream near New Prague, Minn.	D	1960–85	129	167	284	379	522	646	785	1,180
05330600	224	Sand Creek Tributary #2 near Jordan, Minn.	D	1960–63, 1965–85	33.2	48.3	104	157	246	332	437	771
05335170	225	Crooked Creek near Hinckley, Minn.	B	1986–2005	594	781	1,290	1,640	2,110	2,460	2,810	3,630
05336200	226	Glaisby Brook near Kettle River, Minn.	B	1960–2005	293	383	644	843	1,120	1,350	1,590	2,210
05336300	227	Moose River Tributary at Moose Lake, Minn.	B	1960–81	50.7	72.5	146	210	310	398	498	783
05336550	228	Wolf Creek Tributary near Sandstone, Minn.	B	1960–89	33.8	53.7	124	185	276	354	438	657
05336600	229	Kettle River Tributary at Sandstone, Minn.	B	1960–81	10.9	16.4	34.4	49.2	70.6	88.1	107	154
05336700	230	Kettle River below Sandstone, Minn.	B	1965, 1968–2005	4,980	6,300	9,830	12,300	15,500	17,900	20,300	26,100
05337400	231	Knife River near Mora, Minn.	B	1975–2001	563	813	1,560	2,130	2,910	3,500	4,110	5,560

Table 1. PPeak-flow frequency estimates for selected streamflow-gaging stations. —Continued

[NA, not available]

Station number	Map number (fig. 1)	Station name	Region (fig. 1)	Period of record (water years)	Peak-flow estimates (cubic feet per second) for recurrence intervals (years)							
					1.5	2	5	10	25	50	100	500
05338200	232	Mission Creek near Hinckley, Minn.	B	1960–85	55.7	73.0	121	155	200	236	271	358
05338500	233	Snake River near Pine City, Minn.	B	1914–17, 1950, 1952–87, 1992–2005	3,800	4,910	7,780	9,690	12,100	13,800	15,400	19,200
05339747	234	Goose Creek at Harris, Minn.	B	1986–2001, 2003–05	123	171	302	391	503	583	661	829
05340000	235	Sunrise River near Stacy, Minn.	B	1949–65	247	308	465	572	711	816	922	1,170
05340050	236	Sunrise River near Lindstrom, Minn.	B	1966–85	335	391	522	605	706	778	849	1,010
05345000	237	Vermillion River near Empire, Minn.	D	1942–45, 1965, 1974–2005	488	703	1,450	2,140	3,260	4,280	5,490	9,130
05345900	238	Vermillion River Tributary near Hastings, Minn.	D	1960–67, 1969–72	12.0	25.7	112	240	535	893	1,410	3,550
05348550	239	Cannon River below Sabre Lake near Kilkenny, Minn.	D	1985–2005	212	267	408	503	624	714	803	1,010
05352700	240	Turtle Creek Tributary #2 near Pratt, Minn.	D	1960–85	37.7	56.8	120	174	251	316	385	563
05352800	241	Turtle Creek Tributary near Steele Center, Minn.	D	1960–76, 1978–85	68.9	97.3	185	256	356	438	525	750
05353800	242	Straight River near Faribault, Minn.	D	1966–2005	2,420	3,030	4,530	5,490	6,650	7,460	8,250	9,970
05355024	243	Cannon River at Northfield, Minn.	D	1980–2005	3,640	4,550	6,710	8,040	9,590	10,700	11,700	13,700
05355100	244	Little Cannon River Tributary near Kenyon, Minn.	F	1960–76, 1978–86	116	176	386	572	861	1,110	1,400	2,200
05355150	245	Pine Creek near Cannon Falls, Minn.	F	1960–80	99.2	155	347	515	767	981	1,210	1,830
05355200	246	Cannon River at Welch, Minn.	F	1888, 1911–13, 1931–87, 1992–2005	4,660	6,160	10,600	14,000	18,700	22,600	26,700	37,400
05355230	247	Cannon River Tributary near Welch, Minn.	F	1960–81	13.4	20.3	43.2	62.3	90.2	113	138	202
05372800	248	South Fork Zumbro River on Belt Line at Rochester, Minn.	F	1970–83	1,550	2,130	3,970	5,520	7,880	9,930	12,200	18,800

Table 1. Peak-flow frequency estimates for selected streamflow-gaging stations. —Continued

[NA, not available]

Station number	Map number (fig. 1)	Station name	Region (fig. 1)	Period of record (water years)	Peak-flow estimates (cubic feet per second) for recurrence intervals (years)							
					1.5	2	5	10	25	50	100	500
05372930	249	Bear Creek at Rochester, Minn.	F	1969, 1971–83	777	1,100	2,280	3,460	5,500	7,530	10,100	18,700
05372950	250	Silver Creek at Rochester, Minn.	F	1969–83	358	538	1,280	2,100	3,640	5,290	7,470	15,500
05372990	251	Cascade Creek at Rochester, Minn.	F	1969–83	422	578	1,060	1,440	1,980	2,430	2,920	4,210
05372995	252	South Fork Zumbro River at Rochester, Minn.	F	1951–2005	2,630	3,700	7,340	10,600	15,900	20,800	26,500	43,800
05373080	253	Milliken Creek near Concord, Minn.	F	1979–2005	352	507	1,030	1,490	2,220	2,860	3,590	5,700
05373350	254	Zumbro River Tributary near South Troy, Minn.	F	1962–85	20.2	30.1	64.4	94.6	141	182	229	359
05373700	255	Spring Creek near Wanamingo, Minn.	F	1960–63, 1965–76, 1978–86	284	431	951	1,420	2,140	2,780	3,510	5,530
05373900	256	Trout Brook Tributary near Goodhue, Minn.	F	1960–86	63.9	90.4	184	270	413	547	708	1,210
05374000	257	Zumbro River at Zumbro Falls, Minn.	F	1888, 1910–17, 1930–80, 1985–88, 1990–2005	8,120	10,600	16,900	21,000	26,200	29,900	33,500	41,400
05374400	258	Long Creek near Potsdam, Minn.	F	1966–90	140	196	370	513	724	902	1,100	1,630
05374900	259	Zumbro River at Kellogg, Minn.	F	1976–90	7,400	9,230	13,900	16,900	20,800	23,600	26,300	32,600
05376000	260	North Fork Whitewater River near Elba, Minn.	F	1940–41, 1967–93	997	1,660	4,420	7,310	12,400	17,400	23,500	42,800
05376110	261	Middle Fork Whitewater River at St. Park near St. Charles, Minn.	F	1986, 1988–96	565	925	2,280	3,540	5,530	7,290	9,280	14,800
05376500	262	South Fork Whitewater River near Altura, Minn.	F	1940–87	1,060	1,610	3,320	4,670	6,530	7,990	9,480	13,100
05376800	263	Whitewater River near Beaver, Minn.	F	1938, 1940–56, 1974–85, 1991–92, 1994–99	2,180	3,240	6,790	9,840	14,400	18,300	22,600	34,200
05377500	264	Whitewater River at Beaver, Minn.	F	1938, 1940–56	3,320	4,220	6,640	8,360	10,600	12,400	14,200	18,600
05378235	265	Garvin Brook near Minnesota City, Minn.	F	1982–91	472	838	2,520	4,430	8,040	11,800	16,500	32,500

Table 1. Peak-flow frequency estimates for selected streamflow-gaging stations. —Continued

[NA, not available]

Station number	Map number (fig. 1)	Station name	Region (fig. 1)	Period of record (water years)	Peak-flow estimates (cubic feet per second) for recurrence intervals (years)							
					1.5	2	5	10	25	50	100	500
05378300	266	Straight Valley Creek near Rollingstone, Minn.	F	1959–85	161	268	674	1,050	1,640	2,150	2,710	4,240
05379000	267	Gilmore Creek at Winona, Minn.	F	1940–52, 1954–65, 1991	208	357	1,010	1,710	3,010	4,320	5,970	11,400
05383600	268	North Branch Root River Tributary near Stewartville, Minn.	F	1958–85	44.9	68.3	153	231	356	469	599	978
05383700	269	Mill Creek Tributary near Chatfield, Minn.	F	1959–75	330	405	595	723	885	1,010	1,130	1,410
05383720	270	Mill Creek near Chatfield, Minn.	F	1962–85	1,050	1,510	3,120	4,590	6,990	9,200	11,800	19,700
05383850	271	South Fork Bear Creek near Grand Meadow, Minn.	F	1962–85	476	684	1,380	1,980	2,920	3,750	4,680	7,350
05384000	272	Root River near Lanesboro, Minn.	F	1910–14, 1916–17, 1940–2000	5,760	7,660	12,900	16,700	21,700	25,500	29,400	38,700
05384100	273	Duschee Creek near Lanesboro, Minn.	F	1959–84	127	214	569	925	1,530	2,090	2,750	4,700
05384120	274	South Branch Root River at Lanesboro, Minn.	F	1974–86, 1988	3,230	4,170	6,560	8,110	10,000	11,400	12,700	15,500
05384150	275	Root River Tributary near Whalan, Minn.	F	1959–81	17.3	27.6	67.4	107	173	236	311	539
05384200	276	Gribben Creek near Whalen, Minn.	F	1959–85	371	610	1,610	2,680	4,600	6,530	8,940	16,900
05384300	277	Big Springs Creek near Arendahl, Minn.	F	1959–81	10.9	17.8	45.8	74.3	124	171	229	408
05384350	278	Root River at Rushford, Minn.	F	1985–2005	5,670	7,700	14,000	19,200	26,900	33,500	40,700	60,700
05384400	279	Pine Creek near Arendahl, Minn.	F	1959–63, 1965–85	513	823	1,890	2,780	4,060	5,090	6,160	8,780
05384500	280	Rush Creek near Rushford, Minn.	F	1942–2005	1,110	1,840	4,420	6,610	9,760	12,300	14,900	21,200
05385000	281	Root River near Houston, Minn.	F	1911–17, 1930–83, 1985–2005	7,480	10,100	17,200	22,400	29,300	34,600	40,000	52,800
05385500	282	South Fork Root River near Houston, Minn.	F	1950, 1953–83, 1985–2005	1,580	2,340	5,000	7,380	11,100	14,500	18,300	29,200

Table 1. Peak-flow frequency estimates for selected streamflow-gaging stations. —Continued

[NA, not available]

Station number	Map number (fig. 1)	Station name	Region (fig. 1)	Period of record (water years)	Peak-flow estimates (cubic feet per second) for recurrence intervals (years)							
					1.5	2	5	10	25	50	100	500
05386000	283	Root River below South Fork near Houston, Minn.	F	1938–61	10,300	13,400	22,200	28,800	37,700	44,800	52,200	71,000
05387030	284	Crooked Creek at Freeburg, Minn.	F	1979–2005	229	393	1,020	1,600	2,490	3,250	4,070	6,200
05387490	285	Dry Run Creek near Decorah, Iowa	F	1978, 1984–85, 1987, 1989–91, 1993–94, 1998–2004, 2006	1,570	1,880	2,640	3,130	3,740	4,190	4,630	5,630
05387500	286	Upper Iowa River at Decorah, Iowa	F	1952–83, 1985–2006	4,240	5,690	9,850	12,900	17,100	20,400	23,800	32,300
05388000	287	Upper Iowa River near Decorah, Iowa	F	1914, 1919–27, 1933–52	6,560	8,160	12,400	15,300	19,200	22,100	25,100	32,300
05388250	288	Upper Iowa River near Dorchester, Iowa	F	1941, 1976–95, 1997–2006	5,000	6,420	10,500	13,600	17,900	21,400	25,200	34,900
05457000	289	Cedar River near Austin, Minn.	D	1910–14, 1945–2005	3,020	4,170	7,340	9,560	12,400	14,500	16,500	21,100
05457080	290	Rose Creek Tributary near Dexter, Minn.	D	1962–85	70.8	99.8	196	280	411	527	660	1,040
05457778	291	Little Cedar River near Johnsburg, Minn.	D	1986–2005	947	1,460	3,300	4,980	7,660	10,100	12,800	20,600
05458960	292	Bancroft Creek at Bancroft, Minn.	D	1986–2005	217	300	560	772	1,080	1,350	1,630	2,410
05474750	293	Beaver Creek Tributary #2 near Slayton, Minn.	D	1961–73, 1975–85	60.2	79.0	134	177	237	286	339	477
05474760	294	Beaver Creek Tributary above Slayton, Minn.	D	1961–85	38.5	52.9	94.2	125	166	197	230	307
05474900	295	Elk Creek on County State Aid Highway 1, near Brewster, Minn.	D	1996–2005	600	824	1,540	2,150	3,080	3,890	4,800	7,370
05475400	296	Warren Lake Tributary near Windom, Minn.	D	1960–72, 1976–87	27.6	42.5	103	166	280	396	543	1,050
05475800	297	Des Moines River Tributary near Jackson, Minn.	D	1960–67, 1969–85	16.2	24.1	49.5	70.4	101	126	153	222
05475900	298	Des Moines River Tributary #2 near Lakefield, Minn.	D	1960–67, 1969–85	56.4	73.7	120	153	194	226	258	332
05476000	299	Des Moines River at Jackson, Minn.	D	1909–13, 1931–2005	1,230	1,810	3,770	5,450	8,000	10,200	12,600	19,200

Table 1. Peak-flow frequency estimates for selected streamflow-gaging stations. —Continued

[NA, not available]

Station number	Map number (fig. 1)	Station name	Region (fig. 1)	Period of record (water years)	Peak-flow estimates (cubic feet per second) for recurrence intervals (years)							
					1.5	2	5	10	25	50	100	500
05476010	300	Nelson Creek at Jackson, Minn.	D	1959, 1964–67, 1971–72, 1974–75	224	323	649	931	1,360	1,740	2,160	3,350
05476100	301	Story Brook near Petersburg, Minn.	D	1960–67, 1969–72	431	648	1,380	2,020	2,970	3,780	4,680	7,100
05476900	302	Fourmile Creek near Dunnell, Minn.	D	1960–2000	132	204	480	751	1,210	1,650	2,170	3,810
05476989	303	East Fork Des Moines River above Ceylon, Minn.	D	1986–2005	398	545	971	1,290	1,730	2,070	2,420	3,290
06480400	304	Spring Creek near Flandreau, S. Dak.	E	1983–93	354	598	1,570	2,520	4,080	5,500	7,140	11,800
06480650	305	Flandreau Creek above Flandreau, S. Dak.	E	1982–2006	520	770	1,560	2,200	3,090	3,810	4,550	6,410
06482500	306	North Branch Pipestone Creek near Pipestone, Minn.	E	1991–2005	295	463	1,070	1,630	2,500	3,270	4,140	6,570
06482600	307	West Pipestone Creek Tributary near Garretson, S. Dak.	E	1969–79	67.9	134	433	745	1,260	1,720	2,230	3,610
06482610	308	Split Rock Creek at Corson, S. Dak.	E	1966–97, 2002–05	1,600	2,440	5,620	8,740	14,100	19,100	25,300	44,700
06482933	309	Chanarambie Creek near Edgerton, Minn.	E	1979–2005	190	295	636	905	1,270	1,560	1,850	2,520
06482950	310	Mound Creek near Hardwick, Minn.	E	1959–62, 1964–67, 1969–73, 1975–85	23.0	39.1	109	184	321	458	629	1,190
06482960	311	Mound Creek Tributary at Hardwick, Minn.	E	1959–62, 1964–73, 1975–85, 1996	20.0	37.4	112	188	312	422	547	884
06482970	312	Champepadan Creek at County Road 18 near Leota, Minn.	E	1996–2005	349	456	743	942	1,200	1,390	1,580	2,020
06483000	313	Rock River at Luverne, Minn.	E	1912–14, 1969, 1972, 1974–2001, 2003–05	1,500	2,330	5,690	9,220	15,600	22,000	30,200	57,800
06483050	314	Rock River Tributary near Luverne, Minn.	E	1959–67, 1969–72	19.0	34.4	104	179	312	443	601	1,090
06483200	315	Kanaranzi Creek Tributary near Lismore, Minn.	E	1959–81, 1993	71.4	98.7	183	252	351	433	523	760
06483210	316	Kanaranzi Creek Tributary #2 near Wilmont, Minn.	E	1966–90, 1993	76.1	129	331	516	799	1,040	1,300	1,990

Table 1. Peak-flow frequency estimates for selected streamflow-gaging stations. —Continued

[NA, not available]

Station number	Map number (fig. 1)	Station name	Region (fig. 1)	Period of record (water years)	Peak-flow estimates (cubic feet per second) for recurrence intervals (years)							
					1.5	2	5	10	25	50	100	500
06483270	317	Rock River at Rock Rapids, Iowa	E	1960–74	1,870	3,060	7,590	11,800	18,500	24,500	31,200	49,700
06483350	318	Little Rock River near Rushmore, Minn.	E	1991–2005	222	344	831	1,340	2,240	3,150	4,290	8,110
06483353	319	Little Rock Creek (Site 218) near Rushmore, Minn.	E	1996–2005	137	263	931	1,790	3,570	5,560	8,260	18,300
06483410	320	Otter Creek north of Sibley, Iowa	E	1952–56, 1959–62, 1965–66, 1969–71, 1975–80, 1982–87	NA	137	361	596	1,020	1,440	1,960	3,670
06483420	321	Schutte Creek near Sibley, Iowa	E	1952–57, 1959–62, 1965–67, 1973, 1975–77, 1979–81	43.7	59.8	129	210	378	575	861	2,110
06483430	322	Otter Creek at Sibley, Iowa	E	1952–62, 1965–67, 1969–73, 1975–88	155	263	784	1,420	2,740	4,240	6,320	14,500
06483450	323	Wagner Creek near Ashton, Iowa	E	1952–62, 1964–67, 1969–73, 1975–80	91.8	157	472	863	1,680	2,610	3,920	9,100
06483460	324	Otter Creek near Ashton, Iowa	E	1952–63, 1965–67, 1969–72, 1978–88	500	823	2,310	4,060	7,590	11,500	16,900	37,400
06483495	325	Burr Oak Creek near Perkins, Iowa	E	1966–67, 1969–86, 1989–90, 1992–98, 2004–05	324	551	1,480	2,410	3,970	5,430	7,130	12,200
06483500	326	Rock River near Rock Valley, Iowa	E	1948–2005	3,870	6,000	13,600	20,300	30,600	39,600	49,600	76,900
06603000	327	Little Sioux River near Lakefield, Minn.	D	1949–63	37.4	73.5	276	551	1,150	1,860	2,860	6,820
06603500	328	Jackson County Ditch #11 near Lakefield, Minn.	D	1949–60	19.6	43.7	203	444	1,010	1,710	2,720	6,910
06603520	329	Judicial Ditch #28 Tributary near Spafford, Minn.	D	1959–72	29.6	46.1	110	174	284	391	521	933
06603530	330	Little Sioux River near Spafford, Minn.	D	1962–2005	151	247	665	1,140	2,030	2,990	4,240	8,730

Table 2. Basin characteristics of streamflow-gaging stations used in this report.

[mi², square miles; ft/mi, feet per mile; in/yr, inches per year]

Station number (table 1)	Drainage area (*DAREA*) (mi²)	Main-channel slope (*SLOPE*) (ft/mi)	Lake area (*LAKE*) (percent)	Storage area (*STOR*) (percent)	Soil hydrologic group A (*SOILA*) (percent)	Soil hydrologic group D (*SOILD*) (percent)	Generalized mean annual runoff (*ROFF*) (in/yr)
04010500	607	11.2	11.8	25.4	2.48	34.6	11.73
04011370	7.36	48.6	2.85	22.9	.15	8.85	12.37
04011390	.49	103	0	13.2	.44	8.56	12.37
04011990	88.7	25.0	5.46	27.1	4.53	16.7	12.18
04012500	113	19.9	7.39	27.0	1.32	11.9	12.32
04013100	1.36	235	0	16.7	.86	15.3	12.66
04013200	23.0	50.8	0	15.9	2.24	13.2	12.56
04014500	138	40.7	.67	30.2	1.48	16.9	12.47
04015150	1.18	105	0	26.6	4.13	20.9	12.60
04015200	.94	203	0	1.68	2.52	11.1	12.65
04015250	3.89	142	0	4.76	2.28	57.7	12.70
04015300	4.82	50.7	0	16.8	3.21	50.4	12.56
04015330	86.0	33.1	0	18.7	3.14	41.8	12.49
04015360	1.18	139	0	4.93	2.40	74.8	12.47
04015370	5.87	85.3	0	13.9	1.38	31.8	12.39
04015500	21.8	15.0	1.68	19.2	22.9	8.44	10.81
04016000	153	5.43	2.84	34.1	10.9	5.55	11.15
04017000	94.5	2.89	3.51	38.2	21.2	8.77	10.82
04017700	.23	238	0	4.93	4.52	6.46	10.43
04018800	3.67	50.1	1.14	8.50	19.8	9.23	10.10
04018900	41.7	6.67	3.32	18.2	11.6	7.51	10.12
04019000	66.3	8.28	3.40	19.0	11.0	7.47	9.83
04019300	15.3	9.95	0	15.0	8.97	5.32	9.08
04019500	136	5.64	1.86	30.9	12.1	6.64	9.50
04020480	16.4	6.74	.35	46.4	1.51	3.06	11.76
04020700	24.5	11.5	0	30.8	3.37	1.74	11.49
04021205	204	3.53	.52	63.9	13.8	3.53	9.54
04021690	40.8	15.3	1.12	54.6	7.14	1.12	12.24
04024095	124	14.6	1.00	28.3	32.1	13.1	11.42
04024098	7.55	38.7	0	17.7	9.87	40.1	11.65
04024100	4.82	35.5	0	5.09	1.94	54.9	11.72
04024110	.20	44.3	0	25.6	2.00	86.0	11.85
04024200	20.5	35.5	.27	16.8	36.4	22.7	11.64
05040500	477	2.22	15.3	27.8	3.02	.24	3.03
05047500	200	2.48	3.07	10.1	1.51	.26	2.80
05047970	8.25	10.4	0	2.38	.11	0	2.38
05048000	722	2.28	1.64	7.50	.93	3.91	2.55
05049000	788	2.50	1.52	7.12	.93	3.93	2.52
05049200	50.2	4.81	0	2.34	1.03	22.0	2.15
05050700	113	5.21	1.35	5.12	2.85	1.39	2.58
05051000	252	3.89	.63	3.06	1.75	1.92	2.50

Table 2. Basin characteristics of streamflow-gaging stations used in this report.—Continued

[mi², square miles; ft/mi, feet per mile; in/yr, inches per year]

Station number (table 1)	Drainage area (*DAREA*) (mi²)	Main-channel slope (*SLOPE*) (ft/mi)	Lake area (*LAKE*) (percent)	Storage area (*STOR*) (percent)	Soil hydrologic group A (*SOILA*) (percent)	Soil hydrologic group D (*SOILD*) (percent)	Generalized mean annual runoff (*ROFF*) (in/yr)
05060800	91.9	4.54	13.0	33.0	9.69	0.34	3.48
05061000	336	5.59	5.91	18.5	3.77	.09	3.07
05061200	62.0	16.1	3.67	14.7	3.45	0	2.63
05061400	6.19	14.2	0	6.16	29.6	0	2.39
05061500	461	7.11	1.20	8.74	8.60	2.18	2.38
05062000	987	6.45	2.66	11.6	7.37	1.28	2.59
05062280	4.38	10.9	0	5.23	7.00	0	4.04
05062470	12.9	3.48	0	5.86	1.00	0	2.91
05062500	934	3.90	4.08	18.6	6.84	.62	3.41
05062700	5.01	11.8	0	9.93	32.8	.30	2.55
05062800	45.9	12.7	.23	9.42	21.4	.14	2.58
05063200	5.45	15.3	.54	20.0	1.45	0	3.12
05063500	249	6.53	.68	7.50	6.83	.54	2.67
05064000	1,570	4.20	2.56	13.7	7.94	3.55	3.04
05067500	236	4.90	.10	4.82	9.71	18.2	2.34
05069000	460	4.76	1.92	9.53	4.74	19.4	2.68
05073600	2.81	6.62	2.23	28.6	.13	7.61	6.03
05073750	8.30	15.4	.42	32.0	1.00	4.99	5.55
05073800	3.36	7.22	0	66.6	1.00	2.56	5.51
05075700	183	2.39	0	53.7	1.01	.17	3.77
05076000	967	1.74	1.38	53.6	2.10	2.54	3.52
05077700	46.7	10.1	2.28	18.2	23.0	1.18	3.97
05078000	554	3.33	1.34	22.9	15.2	.71	3.74
05078100	53.3	9.02	5.42	21.1	.05	1.36	3.67
05078180	5.56	37.4	0	20.9	0	3.00	3.79
05078200	5.90	21.8	1.18	16.6	0	.26	3.82
05078230	249	5.02	1.24	17.1	4.76	.61	3.52
05078400	8.00	5.26	0	4.79	3.58	0	2.87
05078500	1,360	3.41	1.78	17.7	10.4	1.12	3.45
05079901	118	10.1	.32	12.6	8.16	25.3	2.44
05086900	85.6	3.54	0	15.3	10.8	0	3.04
05087500	252	4.19	.03	11.7	15.3	.11	2.84
05093000	272	3.39	.13	13.3	6.85	1.34	3.28
05094000	558	3.04	.15	12.3	6.32	1.28	3.28
05095500	691	3.81	.13	11.9	6.05	1.77	3.19
05096000	31.6	3.80	0	13.4	10.9	.66	3.20
05103000	210	3.49	.35	60.4	4.93	2.78	4.16
05104000	214	3.25	.03	36.5	5.93	5.58	3.76
05104500	428	3.63	.19	47.9	5.39	4.25	3.96
05107500	1,010	2.94	.15	43.6	3.89	3.96	4.14
05112000	1,410	2.13	.31	43.7	3.67	3.53	4.05

Table 2. Basin characteristics of streamflow-gaging stations used in this report.—Continued

[mi², square miles; ft/mi, feet per mile; in/yr, inches per year]

Station number (table 1)	Drainage area (*DAREA*) (mi²)	Main-channel slope (*SLOPE*) (ft/mi)	Lake area (*LAKE*) (percent)	Storage area (*STOR*) (percent)	Soil hydrologic group A (*SOILA*) (percent)	Soil hydrologic group D (*SOILD*) (percent)	Generalized mean annual runoff (*ROFF*) (in/yr)
05124480	251	6.38	11.4	27.2	1.45	34.8	11.67
05124500	340	7.28	4.66	29.8	7.16	15.4	11.92
05124990	9.51	13.8	1.94	25.9	0	39.0	11.34
05125000	442	6.44	5.72	30.1	6.28	18.5	11.82
05125500	175	10.3	4.02	47.9	7.40	1.50	11.89
05125550	211	9.85	3.53	46.3	7.85	1.55	11.83
05126000	57.1	12.9	.28	36.3	15.2	9.05	11.36
05126500	65.8	4.53	8.97	38.2	3.40	23.7	10.95
05127205	68.8	5.98	21.4	32.1	3.34	25.1	10.71
05127210	5.83	43.8	0	28.8	4.00	30.0	10.86
05127215	8.09	29.8	9.55	30.1	5.64	25.0	10.90
05127220	2.98	49.3	1.00	17.7	4.00	30.0	10.93
05127230	99.6	1.65	19.3	32.8	3.56	25.1	10.76
05127500	1,410	4.42	9.13	33.4	5.54	20.7	11.52
05128300	1.08	71.1	0	7.95	35.0	12.0	10.29
05128500	114	3.59	.65	34.8	25.5	4.15	10.17
05128700	2.88	8.35	3.26	42.1	9.30	2.35	10.47
05129000	488	1.86	17.1	38.9	10.0	13.7	10.20
05129650	63.4	3.23	1.81	53.6	2.90	13.3	9.89
05129710	8.14	4.19	15.1	44.7	28.4	.57	9.79
05130300	14.6	12.8	.30	26.7	12.0	4.53	9.35
05130500	186	7.09	4.15	32.6	23.3	2.23	9.12
05131000	56.2	13.9	10.5	30.3	52.1	2.94	9.62
05131500	1,700	1.63	2.12	40.3	10.5	17.6	8.76
05131750	605	.67	9.32	44.4	8.19	7.63	6.73
05131878	23.2	10.0	0	41.5	1.61	12.4	7.29
05132000	1,500	.98	5.24	46.5	6.79	12.8	7.10
05134100	174	3.05	0	94.3	5.39	.70	4.82
05134200	581	2.80	0	95.0	2.32	5.69	4.90
05137000	141	4.23	.21	86.5	4.74	.96	5.14
05139500	168	5.44	.13	77.4	5.23	1.10	4.53
05140000	11.2	8.20	0	18.5	.72	.22	4.68
05140500	51.1	5.12	0	64.4	6.07	1.35	4.77
05200200	41.5	5.55	2.19	13.8	2.38	4.79	4.58
05205200	288	1.75	18.2	35.3	7.32	0	6.61
05210200	7.83	31.0	.82	22.4	2.00	0	8.01
05216700	12.2	40.5	5.66	16.2	16.4	5.89	8.78
05216860	113	7.06	9.61	26.0	11.9	4.20	8.82
05216980	4.07	26.4	2.03	29.5	8.94	.10	8.91
05217000	245	2.92	7.74	29.8	10.2	3.43	8.68
05217700	1.45	7.58	0	28.3	54.5	1.00	8.92

Table 2. Basin characteristics of streamflow-gaging stations used in this report.—Continued

[mi², square miles; ft/mi, feet per mile; in/yr, inches per year]

Station number (table 1)	Drainage area (*DAREA*) (mi²)	Main-channel slope (*SLOPE*) (ft/mi)	Lake area (*LAKE*) (percent)	Storage area (*STOR*) (percent)	Soil hydrologic group A (*SOILA*) (percent)	Soil hydrologic group D (*SOILD*) (percent)	Generalized mean annual runoff (*ROFF*) (in/yr)
05221020	513	1.91	2.60	43.9	11.3	2.36	8.13
05229450	266	3.06	7.37	27.0	22.3	0	6.34
05241500	8.92	11.6	23.7	34.8	1.12	7.88	7.83
05243725	59.0	5.81	1.65	9.31	43.5	.16	4.52
05244000	917	2.78	5.10	27.9	35.2	.22	4.95
05244100	18.5	9.25	.56	19.7	7.08	0	4.87
05244200	47.9	5.54	.21	31.6	10.6	0	5.02
05244440	858	3.95	1.13	22.8	15.4	.03	4.62
05245100	448	1.50	10.7	25.3	5.45	0	4.15
05245800	19.4	13.1	.07	14.2	37.5	0	6.12
05261520	188	3.64	4.75	28.6	18.4	.04	7.17
05267800	1.27	19.6	0	19.2	3.11	0	6.57
05267900	45.5	8.23	0	29.8	1.57	0	6.79
05268000	431	3.71	1.97	26.7	18.8	.29	6.57
05270150	123	4.46	2.06	14.3	14.8	.06	4.10
05270300	7.16	10.3	0	4.53	0	0	4.25
05270310	.32	70.3	0	1.84	3.41	.05	4.42
05270500	1,040	2.36	4.11	16.8	11.4	.54	4.44
05271800	6.96	5.21	2.43	21.8	9.08	0	4.77
05272000	15.3	10.6	1.37	21.5	15.7	.08	4.82
05272300	45.1	10.7	.58	21.4	29.2	.23	4.88
05272950	79.9	11.4	2.60	16.9	3.88	.77	4.59
05273700	3.22	21.2	0	9.47	0	1.72	5.52
05274200	2.40	9.43	0	22.2	0	0	5.67
05275000	554	2.86	1.31	20.2	30.3	.18	5.65
05276000	210	3.83	.88	16.8	11.6	.72	4.03
05276100	.67	34.6	0	8.97	.11	0	4.24
05276200	237	4.07	.80	17.0	12.7	.78	4.04
05278120	775	3.17	4.69	20.1	11.5	1.26	4.16
05278350	6.52	2.72	1.74	24.9	0	4.28	4.95
05278500	234	2.77	6.34	14.3	.07	.49	4.13
05278700	31.2	2.69	1.70	13.9	0	1.73	4.75
05278750	1.20	13.8	0	2.48	0	3.00	4.89
05278850	9.20	7.21	8.84	16.3	0	0	4.66
05278930	373	2.00	1.45	7.51	0	.15	4.50
05279000	1,150	1.87	3.14	11.6	.04	.80	4.51
05280000	2,640	2.61	5.80	21.6	8.11	1.57	4.44
05280300	4.26	7.48	13.4	24.1	0	1.11	5.36
05284100	.56	33.5	0	20.7	49.8	0	8.27
05284620	2.79	10.9	0	32.5	0	.12	7.18
05284920	1.23	44.6	0	15.7	1.00	5.00	7.01

Table 2. Basin characteristics of streamflow-gaging stations used in this report.—Continued

[mi², square miles; ft/mi, feet per mile; in/yr, inches per year]

Station number (table 1)	Drainage area (*DAREA*) (mi²)	Main-channel slope (*SLOPE*) (ft/mi)	Lake area (*LAKE*) (percent)	Storage area (*STOR*) (percent)	Soil hydrologic group A (*SOILA*) (percent)	Soil hydrologic group D (*SOILD*) (percent)	Generalized mean annual runoff (*ROFF*) (in/yr)
05286000	1,390	2.92	16.1	38.8	13.1	0.86	7.21
05287890	86.9	5.89	1.84	22.0	.03	1.44	5.65
05292704	209	18.1	.66	5.12	1.00	7.64	2.44
05293000	460	11.9	.74	6.29	.78	6.76	2.57
05293371	317	4.05	14.0	24.5	3.86	0	3.23
05294000	865	2.26	6.77	14.6	4.90	.01	2.99
05299100	3.03	55.2	0	4.87	0	2.86	2.96
05299750	73.4	7.53	.16	6.50	.36	.81	2.61
05300000	960	7.27	.86	6.17	.30	4.27	2.85
05302500	95.4	6.18	10.6	21.9	1.12	0	3.52
05302970	.15	63.6	0	5.39	1.00	0	3.33
05303450	7.36	35.3	0	14.9	2.02	0	3.33
05304500	1,870	2.84	5.04	13.9	5.28	.48	3.43
05305000	2,040	2.75	4.62	12.9	4.98	.44	3.42
05305200	16.7	4.61	0	.86	0	.05	3.38
05311200	14.8	8.50	0	4.97	.02	0	3.00
05311250	.27	77.2	0	0	0	0	3.13
05311300	3.82	38.1	0	2.18	0	.34	3.11
05311400	115	12.2	.90	5.82	.02	1.59	3.36
05313500	668	6.86	.73	4.57	.19	1.99	3.37
05313800	.86	11.7	0	.12	0	0	3.96
05314900	5.79	27.0	0	2.60	.60	0	3.54
05315000	259	8.38	2.39	7.89	.21	.11	3.50
05315200	5.52	8.12	0	3.84	0	2.58	3.67
05316500	624	6.68	1.27	5.01	.56	.97	3.66
05316538	63.8	2.02	0	.40	1.02	0	3.96
05316550	8.60	2.88	0	2.36	0	0	4.03
05316570	198	4.00	0	2.32	0	.02	4.07
05316690	3.47	7.87	0	.16	0	1.00	4.74
05316700	32.8	2.10	0	2.61	0	.50	4.64
05316800	1.58	26.1	0	2.59	0	0	3.74
05316850	.49	51.1	0	0	0	3.00	3.81
05316900	3.18	47.7	0	1.82	0	0	4.58
05316920	.35	46.2	0	1.86	6.89	.29	4.54
05316950	777	5.85	.52	3.37	1.84	.49	4.20
05317000	1,310	4.60	.43	3.30	1.88	.37	4.34
05317200	169	6.77	.25	3.09	8.47	.92	5.01
05317845	30.3	9.02	0	.51	0	0	7.06
05317850	2.17	24.8	0	.08	2.91	0	7.10
05318000	120	5.86	1.69	4.66	.16	0	6.99
05318100	9.39	6.84	0	.27	0	0	6.67

Table 2. Basin characteristics of streamflow-gaging stations used in this report.—Continued

[mi², square miles; ft/mi, feet per mile; in/yr, inches per year]

Station number (table 1)	Drainage area (*DAREA*) (mi²)	Main-channel slope (*SLOPE*) (ft/mi)	Lake area (*LAKE*) (percent)	Storage area (*STOR*) (percent)	Soil hydrologic group A (*SOILA*) (percent)	Soil hydrologic group D (*SOILD*) (percent)	Generalized mean annual runoff (*ROFF*) (in/yr)
05318195	76.5	9.02	0.32	1.70	0.35	0	5.22
05318300	13.0	14.7	.54	3.37	3.67	0	4.71
05318890	107	6.37	1.74	3.07	.67	0	5.16
05318897	107	6.30	1.73	3.05	.66	0	5.17
05319500	847	4.96	1.09	3.51	4.01	.05	5.40
05320200	1.31	17.8	0	11.6	0	11.7	6.12
05320300	8.04	8.14	0	1.40	0	12.3	6.40
05320400	5.77	10.4	0	.34	0	47.5	6.42
05320440	19.4	6.96	0	.81	0	.31	6.29
05320480	339	2.46	1.53	3.53	0	12.3	6.54
05320500	1,110	3.88	1.50	4.91	.10	7.01	6.65
05326100	67.5	3.53	0	1.27	0	0	4.78
05327000	240	3.27	1.93	10.1	.62	.80	4.83
05330150	.22	64.2	0	0	0	.61	5.97
05330200	3.06	11.6	0	12.4	0	1.96	5.96
05330300	62.9	2.33	4.21	17.3	0	3.16	5.88
05330550	22.2	9.86	.76	16.0	0	0	5.70
05330600	2.67	13.8	0	12.7	0	0	5.55
05335170	93.1	12.0	.82	31.5	4.26	1.77	10.68
05336200	26.4	9.39	0	43.4	5.44	4.41	10.74
05336300	1.42	37.9	0	18.4	1.00	8.00	10.80
05336550	6.16	6.61	0	18.2	2.90	6.83	9.97
05336600	.45	20.8	0	18.7	1.00	8.00	9.97
05336700	870	5.26	1.63	35.6	12.5	4.40	10.50
05337400	104	8.93	2.00	28.8	2.33	.46	8.23
05338200	3.28	19.0	0	24.0	0	0	9.25
05338500	969	4.33	1.24	30.4	3.10	1.51	8.41
05339747	43.9	3.61	5.49	34.0	7.27	4.38	7.63
05340000	168	2.95	7.97	39.7	30.7	.21	7.07
05340050	240	2.41	10.3	38.5	23.4	.40	7.22
05345000	129	8.37	.88	10.8	8.95	.63	6.04
05345900	38.4	5.90	.09	2.51	17.7	0	6.26
05348550	87.8	1.49	6.42	20.5	0	2.89	6.10
05352700	1.03	29.0	0	1.76	0	1.31	7.15
05352800	5.04	15.5	0	.19	0	0	7.12
05353800	436	3.59	.59	3.93	0	.90	6.97
05355024	928	1.87	3.43	9.64	.86	1.27	6.61
05355100	2.22	51.5	0	2.58	0	0	6.58
05355150	20.6	11.8	0	.81	12.9	4.72	6.37
05355200	1,340	3.24	2.55	8.11	2.24	1.19	6.54
05355230	.06	79.9	0	0	0	0	6.67

Table 2. Basin characteristics of streamflow-gaging stations used in this report.—Continued

[mi², square miles; ft/mi, feet per mile; in/yr, inches per year]

Station number (table 1)	Drainage area (*DAREA*) (mi²)	Main-channel slope (*SLOPE*) (ft/mi)	Lake area (*LAKE*) (percent)	Storage area (*STOR*) (percent)	Soil hydrologic group A (*SOILA*) (percent)	Soil hydrologic group D (*SOILD*) (percent)	Generalized mean annual runoff (*ROFF*) (in/yr)
05372800	155	7.51	0.13	4.44	0	3.23	7.39
05372930	78.4	19.6	0	3.68	2.97	19.1	7.53
05372950	17.7	27.2	0	3.28	.39	3.78	7.50
05372990	38.2	14.7	.09	1.91	0	.01	7.36
05372995	301	7.55	.11	3.77	1.32	7.02	7.43
05373080	21.8	5.46	0	.60	0	0	7.06
05373350	.12	143	0	0	0	0	7.23
05373700	10.0	18.2	0	2.13	0	0	6.81
05373900	.14	125	0	0	0	0	6.88
05374000	1,150	5.71	.25	2.70	1.13	2.63	7.15
05374400	4.45	48.2	0	.50	0	0	7.41
05374900	1,420	5.02	.20	2.77	1.20	2.13	7.18
05376000	100	11.1	0	1.68	.37	5.23	7.53
05376110	39.1	19.2	0	1.83	.37	2.77	7.66
05376500	78.0	15.1	0	1.54	1.87	5.00	7.75
05376800	271	11.8	.02	2.14	2.17	3.96	7.65
05377500	288	11.6	.02	2.20	2.29	3.76	7.65
05378235	45.0	25.0	.06	.60	.08	.39	7.96
05378300	5.12	93.2	0	.74	.03	.16	7.83
05379000	9.08	88.5	0	.41	.16	.79	8.02
05383600	.74	43.8	0	2.46	0	1.24	7.58
05383700	2.41	58.0	0	2.15	0	14.6	7.65
05383720	22.4	41.9	0	2.12	0	12.0	7.65
05383850	14.1	13.8	0	2.80	0	0	7.62
05384000	615	5.93	.03	2.05	.89	.94	7.67
05384100	3.85	63.8	0	1.18	3.78	1.42	8.02
05384120	284	9.02	.05	1.64	4.06	.22	7.92
05384150	.08	229	0	0	0	0	7.98
05384200	7.88	73.4	0	.39	3.14	.39	8.01
05384300	.13	58.3	0	0	0	0	7.89
05384350	992	5.48	.03	1.88	2.81	.65	7.77
05384400	28.3	15.6	0	.60	1.00	2.02	7.87
05384500	132	18.4	0	.57	3.80	.95	7.92
05385000	1,250	5.26	.03	1.73	3.38	.69	7.82
05385500	275	10.9	0	.78	.83	.55	8.13
05386000	1,540	5.20	.02	1.57	3.02	.65	7.88
05387030	44.5	38.2	.13	.75	.31	.85	8.28
05387490	20.8	24.8	0	1.26	.23	2.09	8.46
05387500	511	4.83	.03	1.41	.54	2.38	8.12
05388000	568	4.64	.03	1.34	.52	2.71	8.16
05388250	768	4.92	.02	1.20	.49	3.65	8.22

Table 2. Basin characteristics of streamflow-gaging stations used in this report.—Continued

[mi², square miles; ft/mi, feet per mile; in/yr, inches per year]

Station number (table 1)	Drainage area (*DAREA*) (mi²)	Main-channel slope (*SLOPE*) (ft/mi)	Lake area (*LAKE*) (percent)	Storage area (*STOR*) (percent)	Soil hydrologic group A (*SOILA*) (percent)	Soil hydrologic group D (*SOILD*) (percent)	Generalized mean annual runoff (*ROFF*) (in/yr)
05457000	398	3.01	0.73	2.22	0	3.53	7.36
05457080	.97	33.7	0	2.64	0	0	7.57
05457778	46.5	8.44	0	2.22	1.18	.02	7.74
05458960	29.2	5.61	0	.51	.08	.79	7.19
05474750	5.00	22.8	2.30	4.72	0	0	3.98
05474760	2.10	33.7	0	.46	0	0	4.01
05474900	61.2	7.43	0	.91	0	0	4.49
05475400	3.34	26.8	0	.29	.20	0	4.85
05475800	1.43	17.7	0	5.25	3.89	0	5.24
05475900	5.14	20.2	0	.31	5.00	0	5.17
05476000	1,240	2.55	2.26	5.56	.93	.09	4.41
05476010	6.25	43.8	0	1.26	5.00	0	5.30
05476100	26.1	21.2	0	.75	3.36	0	5.35
05476900	15.5	13.8	0	.19	0	0	5.53
05476989	126	6.29	.78	1.75	.01	0	5.55
06480400	61.3	10.1	0	.96	1.21	.90	2.97
06480650	101	7.83	0	3.30	.34	.57	3.19
06482500	31.0	11.9	0	2.14	.16	.83	3.40
06482600	2.12	41.3	0	.84	0	0	2.90
06482610	482	4.08	.03	1.91	.03	.42	3.10
06482933	57.8	6.33	0	4.25	.14	1.17	3.85
06482950	2.47	19.4	0	4.88	0	0	3.45
06482960	.09	117	0	.74	0	0	3.48
06482970	48.2	7.81	0	2.73	.49	0	3.90
06483000	419	4.11	.01	3.49	.66	.45	3.66
06483050	.21	75.3	0	0	0	0	3.61
06483200	2.52	26.7	0	3.39	0	0	3.95
06483210	2.15	29.2	0	3.45	0	0	4.09
06483270	789	4.09	.03	2.87	.98	.24	3.78
06483350	39.5	7.18	0	1.68	.35	0	4.40
06483353	32.0	11.0	0	.71	.11	0	4.23
06483410	13.9	4.80	0	2.31	0	0	4.52
06483420	1.54	25.4	0	0	0	0	4.45
06483430	33.2	6.68	0	1.02	0	0	4.50
06483450	7.03	16.7	0	.21	0	0	4.53
06483460	88.7	6.15	.11	.67	0	0	4.59
06483495	30.1	14.4	0	.15	0	0	4.05
06483500	1,580	4.04	.02	1.82	.59	.12	3.95
06603000	15.6	6.74	0	2.62	0	0	4.91
06603500	7.65	4.47	0	.08	.53	0	5.03
06603520	3.24	12.3	0	.26	0	0	4.87
06603530	41.1	6.73	0	1.26	.10	0	4.93

Table 3. Streamflow-gaging stations used to estimate generalized mean annual runoff.

Station number	Map number (fig. 2)	Station name	Period of record (water years)	Mean annual runoff for period of record (inches)	Fitted annual runoff (inches)
04010500	1	Pigeon River at Middle Falls near Grand Portage, Minn.	1940–2005	11.15	11.47
04012500	2	Poplar River at Lutsen, Minn.	1940–47, 1953–61	12.37	12.39
04014500	3	Baptism River near Beaver Bay, Minn.	1940–47, 1950–93	16.71	12.75
04015330	4	Knife River near Two Harbors, Minn.	1975–2005	14.76	12.94
04015475	5	Partridge River above Colby Lake at Hoyt Lakes, Minn.	1979–88	11.22	11.40
04015500	6	Second Creek near Aurora, Minn.	1956–80	10.50	10.86
04016000	7	Partridge River near Aurora, Minn.	1943–82	9.42	11.27
04016500	8	St. Louis River near Aurora, Minn.	1943–87	11.00	11.49
04017000	9	Embarrass River at Embarrass, Minn.	1943–64	9.89	10.85
04018750	10	St. Louis River at Forbes, Minn.	1965–89	10.64	11.12
04018900	11	East Two River near Iron Junction, Minn.	1967–79	10.72	10.16
04019000	12	West Two River near Iron Junction, Minn.	1954–62, 1966–79	9.35	9.86
04019300	13	West Swan River near Silica, Minn.	1964–78	8.57	9.11
04019500	14	East Swan River near Toivola, Minn.	1954–62, 1965–71	11.36	9.54
04024000	15	St. Louis River at Scanlon, Minn.	1940–2005	10.32	10.80
04024098	16	Deer Creek near Holyoke, Minn.	1977–2001	12.86	12.13
04024430	17	Nemadji River near South Superior, Wisc.	1975–2005	12.63	12.43
040263491	18	North Fish Creek near Moquah, Wisc.	1990–91, 1995–97, 2001–05	15.85	14.37
05030000	19	Otter Tail River near Detroit Lakes, Minn.	1940–71	2.82	4.66
05030500	20	Otter Tail River near Elizabeth, Minn.	1993–2005	4.65	4.58
05040000	21	Pelican River near Detroit Lakes, Minn.	1943–53	4.30	3.95
05040500	22	Pelican River near Fergus Falls, Minn.	1943–80	2.29	3.48
05046000	23	Otter Tail River below Orwell Dam near Fergus Falls, Minn.	1940–2005	3.23	4.16
05049000	24	Mustinka River above Wheaton, Minn.	1940–58, 2005	1.12	2.47
05050000	25	Bois De Sioux River near White Rock, S. Dak.	1942–2005	1.33	2.23
05051300	26	Bois De Sioux River near Doran, Minn.	1944–98, 2000–03	2.38	2.18
05051500	27	Red River of the North at Wahpeton, N. Dak.	1944–98, 2000–03	2.12	2.86
05051522	28	Red River of the North at Hickson, N. Dak.	1976–2005	2.59	2.09
05051600	29	Wild Rice River near Rutland, N. Dak.	1960–82, 1984	.21	.29
05051650	30	La Belle Creek near Veblen, S. Dak.	1988–99	3.41	1.45
05051700	31	Wild Rice River near Cayuga, N. Dak.	1957–79	.27	.41
05053000	32	Wild Rice River near Abercrombie, N. Dak.	1940–2005	.74	.93
05059600	33	Maple River near Hope, N. Dak.	1965–82	1.90	.84
05059700	34	Maple River near Enderlin, N. Dak.	1957–2005	.92	.74
05060000	35	Maple River near Mapleton, N. Dak.	1959–75	.90	.91
05060100	36	Maple River below Mapleton, N. Dak.	1945–58, 1996–2005	1.02	.91
05060500	37	Rush River at Amenia, N. Dak.	1947–2005	1.48	1.16
05061000	38	Buffalo River near Hawley, Minn.	1946–80, 1986–2005	3.57	3.47

Table 3. Streamflow-gaging stations used to estimate generalized mean annual runoff.—Continued

Station number	Map number (fig. 2)	Station name	Period of record (water years)	Mean annual runoff for period of record (inches)	Fitted annual runoff (inches)
05061500	39	South Branch Buffalo River at Sabin, Minn.	1946–80, 1986–2005	2.00	2.57
05062000	40	Buffalo River near Dilworth, Minn.	1940–2005	2.43	2.82
05062500	41	Wild Rice River at Twin Valley, Minn.	1940–83, 1990–2005	3.41	3.96
05064000	42	Wild Rice River at Hendrum, Minn.	1945–84, 1986–2005	2.96	3.39
05064900	43	Beaver Creek near Finley, N. Dak.	1965–2003	.96	.95
05065500	44	Goose River near Portland, N. Dak.	1940–75, 1981–82	.78	1.02
05066500	45	Goose River at Hillsboro, N. Dak.	1940–2005	1.21	1.08
05067500	46	Marsh River near Shelly, Minn.	1945–83, 1986–89	3.90	2.41
05068000	47	Sand Hill River at Beltrami, Minn.	1945–58	.21	3.18
05069000	48	Sand Hill River at Climax, Minn.	1947–84, 1986–2005	2.80	2.81
05074500	49	Red Lake River near Red Lake, Minn.	1940–94, 2000–05	3.65	5.20
05075000	50	Red Lake River at High Landing near Goodridge, Minn.	1940–2000, 2002–05	3.88	5.01
05076000	51	Thief River near Thief River Falls, Minn.	1940–81, 1983–2005	3.20	3.46
05077700	52	Ruffy Brook near Gonvick, Minn.	1961–78	4.06	4.50
05078000	53	Clearwater River at Plummer, Minn.	1940–79, 1983–2005	4.37	4.11
05078230	54	Lost River at Oklee, Minn.	1961–81, 1983–2005	4.00	3.88
05078500	55	Clearwater River at Red Lake Falls, Minn.	1940–81, 1983–2005	3.60	3.75
05082625	56	Turtle River at Turtle River State Park near Arvilla, N. Dak.	1993–2005	2.12	1.15
05083000	57	Turtle River at Manvel, N. Dak.	1946–70	1.13	1.37
05084000	58	Forest River near Fordville, N. Dak.	1941–2005	1.22	1.15
05085000	59	Forest River at Minto, N. Dak.	1945–2005	.98	1.35
05087500	60	Middle River at Argyle, Minn.	1951–81, 1983–2005	2.79	2.80
05088000	61	South Branch Park River near Park River, N. Dak.	1940–50	1.82	2.47
05089000	62	South Branch Park River below Homme Dam, N. Dak.	1950–94	1.50	1.40
05089500	63	Cart Creek at Mountain, N. Dak.	1955–84	2.24	1.69
05090000	64	Park River at Grafton, N. Dak.	1940–2005	1.36	1.49
05092200	65	Pembina County Drain 20 near Glasston, N. Dak.	1972–82	.39	2.11
05094000	66	South Branch Two Rivers at Lake Bronson, Minn.	1942–43, 1946–47, 1954–81, 1986–2005	3.86	3.18
05095500	67	Two Rivers below Hallock, Minn.	1946–55	2.16	3.16
05096000	68	North Branch Two Rivers near Lancaster, Minn.	1942–55	5.50	3.23
05096500	69	State Ditch #85 near Lancaster, Minn.	1943–55	3.65	3.83
05099600	70	Pembina River at Walhalla, N. Dak.	1940–90, 1994–95, 2001–05	1.02	1.34
05100000	71	Pembina River at Neche, N. Dak.	1940–2005	1.13	1.36
05100500	72	Herzog Creek near Concrete, N. Dak.	1955–77	2.23	1.75
05101000	73	Tongue River at Akra, N. Dak.	1952–82	1.81	1.68
05101500	74	Tongue River at Cavalier, N. Dak.	1940–51	1.86	1.68
05106000	75	Sprague Creek near Sprague, Manitoba, Canada	1941–81, 2000–05	4.97	4.87
05107000	76	Pine Creek near Pine Creek, Minn.	1940–53	5.61	4.47
05107500	77	Roseau River at Ross, Minn.	1940–91, 1996–2005	4.01	4.18

Table 3. Streamflow-gaging stations used to estimate generalized mean annual runoff.—Continued

Station number	Map number (fig. 2)	Station name	Period of record (water years)	Mean annual runoff for period of record (inches)	Fitted annual runoff (inches)
05112000	78	Roseau River below State Ditch 51 near Caribou, Minn.	1941–43, 1973–2005	3.71	4.10
05124480	79	Kawishiwi River near Ely, Minn.	1967–2005	10.52	11.71
05124500	80	Isabella River near Isabella, Minn.	1953–61, 1977	10.81	12.02
05124990	81	Filson Creek near Ely, Minn.	1975–85	10.64	11.38
05125500	82	Stony River near Isabella, Minn.	1953–64	9.56	11.98
05126000	83	Dunka River near Babbitt, Minn.	1952–62, 1976–80	9.69	11.47
05126500	84	Bear Island River near Ely, Minn.	1953–62, 1976–77	8.16	10.97
05127000	85	Kawishiwi River near Winton, Minn.	1940–2005	11.86	11.72
05127210	86	Armstrong Creek near Ely, Minn.	1968–78	11.94	10.85
05127215	87	Longstorff Creek near Ely, Minn.	1968–78	12.13	10.91
05127220	88	Burgo Creek near Ely, Minn.	1968–78	14.85	10.93
05127230	89	Shagawa River at Ely, Minn.	1968–78	12.36	10.75
05127500	90	Basswood River near Winton, Minn.	1940–2005	11.02	11.60
05128500	91	Pike River near Embarrass, Minn.	1954–64, 1978	9.40	10.15
05129000	92	Vermilion River below Vermilion Lake near Tower, Minn.	1940–81	9.42	10.14
05129115	93	Vermilion River near Crane Lake, Minn.	1980–2005	9.48	9.75
05130500	94	Sturgeon River near Chisholm, Minn.	1943–2005	9.41	9.07
05131000	95	Dark River near Chisholm, Minn.	1943–61, 1966–79	9.80	9.56
05131448	96	Wood Duck Creek near Nett Lake, Minn.	1996–2005	9.07	8.60
05131455	97	Nett Lake River near Nett Lake, Minn.	1996–2005	9.64	8.70
05131500	98	Little Fork River at Littlefork, Minn.	1940–2005	9.05	8.66
05132000	99	Big Fork River at Big Falls, Minn.	1940–79, 1983–93, 1998–2005	7.43	7.18
05134200	100	Rapid River near Baudette, Minn.	1957–85	8.16	4.81
05139500	101	Warroad River near Warroad, Minn.	1947–80	3.62	4.40
05140000	102	Bulldog Run near Warroad, Minn.	1947–51, 1967–77	3.06	4.60
05140500	103	East Branch Warroad River near Warroad, Minn.	1947–54, 1967–77	3.03	4.67
05211000	104	Mississippi River at Grand Rapids, Minn.	1940–2005	5.51	6.65
05212700	105	Prairie River near Taconite, Minn.	1968–83, 2002–05	7.99	8.41
05216860	106	Swan River near Calumet, Minn.	1965–90	7.71	8.86
05217000	107	Swan River near Warba, Minn.	1954–69	6.94	8.76
05241500	108	Rabbit River near Crosby, Minn.	1946–62	9.36	8.55
05244000	109	Crow Wing River at Nimrod, Minn.	1940–81, 1992–2005	6.34	6.02
05245100	110	Long Prairie River at Long Prairie, Minn.	1972–2005	5.18	4.56
05247500	111	Crow Wing River near Pillager, Minn.	1969–86, 1988–2005	5.31	6.14
05270500	112	Sauk River near St. Cloud, Minn.	1940–81, 1991–2005	4.49	4.49
05275000	113	Elk River near Big Lake, Minn.	1940–87, 1991–2005	6.91	5.59
05276000	114	North Fork Crow River near Regal, Minn.	1944–54	3.90	4.00
05278000	115	Middle Fork Crow River near Spicer, Minn.	1950–87	5.05	4.01
05278500	116	South Fork Crow River at Cosmos, Minn.	1946–64	2.67	4.25
05279000	117	South Fork Crow River near Mayer, Minn.	1940–79	3.24	4.57
05280000	118	Crow River at Rockford, Minn.	1940–2005	4.65	4.53

Table 3. Streamflow-gaging stations used to estimate generalized mean annual runoff.—Continued

Station number	Map number (fig. 2)	Station name	Period of record (water years)	Mean annual runoff for period of record (inches)	Fitted annual runoff (inches)
05286000	119	Rum River near St. Francis, Minn.	1940–2005	6.77	7.14
05287890	120	Elm Creek near Champlin, Minn.	1979–2005	6.17	5.64
05289500	121	Minnehaha Creek at Minnetonka Mills, Minn.	1954–64	1.33	5.46
05290000	122	Little Minnesota River near Peever, S. Dak.	1940–81, 1990–2002	1.62	1.18
05291000	123	Whetstone River near Big Stone City, S. Dak.	1940–2005	2.18	1.67
05292000	124	Minnesota River at Ortonville, Minn.	1940–2005	1.54	1.51
05292500	125	Minnesota River near Odessa, Minn.	1945–62	1.30	1.60
05292704	126	North Fork Yellow Bank River near Odessa, Minn.	1992–99, 2001–02	5.41	2.08
05293000	127	Yellow Bank River near Odessa, Minn.	1940–99, 2002–2005	2.05	2.24
05294000	128	Pomme de Terre River at Appleton, Minn.	1940–99, 2004–2005	2.07	2.94
05300000	129	Lac Qui Parle River near Lac Qui Parle, Minn.	1940–99, 2002–2005	2.43	2.87
05301000	130	Minnesota River near Lac Qui Parle, Minn.	1943–94, 1999–2005	2.80	2.34
05304500	131	Chippewa River near Milan, Minn.	1940–2005	2.82	3.32
05311400	132	South Branch Yellow Medicine River at Minneota, Minn.	1961–81, 1983–87	3.36	3.37
05313500	133	Yellow Medicine River near Granite Falls, Minn.	1940–2005	2.98	3.46
05315000	134	Redwood River near Marshall, Minn.	1941–2005	3.64	3.53
05316500	135	Redwood River near Redwood Falls, Minn.	1940–2005	3.49	3.82
05317000	136	Cottonwood River near New Ulm, Minn.	1940–2005	4.18	4.57
05317200	137	Little Cottonwood River near Courtland, Minn.	1974–2005	5.78	5.20
05318000	138	East Branch Blue Earth River near Bricelyn, Minn.	1952–70	4.23	6.99
05319500	139	Watonwan River near Garden City, Minn.	1941–45, 1977–2005	6.23	5.50
05320000	140	Blue Earth River near Rapidan, Minn.	1940–45, 1950–2005	6.01	6.02
05320500	141	Le Sueur River near Rapidan, Minn.	1940–45, 1950–2005	6.72	6.70
05327000	142	High Island Creek near Henderson, Minn.	1974–2005	5.87	4.82
05332500	143	Namekagon River near Trego, Wisc.	1940–70, 1988–2005	13.80	12.99
05333500	144	St. Croix River near Danbury, Wisc.	1940–81, 1985–2005	11.90	13.11
05336000	145	St. Croix River near Grantsburg, Wisc.	1940–70	12.05	9.96
05336200	146	Glaisby Brook near Kettle River, Minn.	1960–70	10.07	11.18
05336700	147	Kettle River below Sandstone, Minn.	1968–2005	11.06	11.08
05337400	148	Knife River near Mora, Minn.	1975–2001	8.18	8.51
05338500	149	Snake River near Pine City, Minn.	1952–81, 1992–2005	8.58	8.68
05340000	150	Sunrise River near Stacy, Minn.	1950–64	5.17	7.13
05340050	151	Sunrise River near Lindstrom, Minn.	1966–85	5.96	7.18
05341500	152	Apple River near Somerset, Wisc.	1940–70, 1987–2005	8.36	8.66
05345000	153	Vermillion River near Empire, Minn.	1943, 1974–2005	7.39	6.02
05353800	154	Straight River near Faribault, Minn.	1966–2005	8.98	7.00
05355200	155	Cannon River at Welch, Minn.	1940–71, 1992–2005	7.02	6.62
05356000	156	Chippewa River at Bishops Bridge near Winter, Wisc.	1940–2005	12.78	13.61
05356500	157	Chippewa River near Bruce, Wisc.	1940–2005	12.72	12.80
05360500	158	Flambeau River near Bruce, Wisc.	1952–2005	13.13	13.22
05364000	159	Yellow River at Cadott, Wisc.	1943–61	10.18	11.05
05365000	160	Duncan Creek at Chippewa Falls, Wisc.	1943–55	10.07	9.60
05366500	161	Eau Claire River near Fall Creek, Wisc.	1943–55	9.67	9.78

Table 3. Streamflow-gaging stations used to estimate generalized mean annual runoff.—Continued

Station number	Map number (fig. 2)	Station name	Period of record (water years)	Mean annual runoff for period of record (inches)	Fitted annual runoff (inches)
053674464	162	Yellow River at Barron, Wisc.	1992–2005	10.59	10.12
05367500	163	Red Cedar River near Colfax, Wisc.	1940–61, 1990	9.67	10.44
05368000	164	Hay River at Wheeler, Wisc.	1951–2005	10.53	8.93
05369000	165	Red Cedar River at Menomonie, Wisc.	1940–2005	10.59	9.82
05369945	166	Eau Galle River at Low-Water Bridge at Spring Valley, Wisc.	1983, 1987–95	8.18	7.77
05370000	167	Eau Galle River at Spring Valley, Wisc.	1969–2005	7.47	7.74
05370500	168	Eau Galle River at Elmwood, Wisc.	1943–53	6.40	7.68
05372000	169	Buffalo River near Tell, Wisc.	1940–51	8.37	8.31
05372995	170	South Fork Zumbro River at Rochester, Minn.	1982–2005	8.47	7.43
05373000	171	South Fork Zumbro River near Rochester, Minn.	1953–81	6.84	7.43
05374000	172	Zumbro River at Zumbro Falls, Minn.	1940–80, 2003, 2005	6.58	7.17
05374500	173	Zumbro River at Theilman, Minn.	1940–56	6.36	7.17
05374900	174	Zumbro River at Kellogg, Minn.	1976–90	8.53	7.17
05376000	175	North Fork Whitewater River near Elba, Minn.	1940–41, 1968–93	6.61	7.53
05376500	176	South Fork Whitewater River near Altura, Minn.	1940–71	4.87	7.77
05376800	177	Whitewater River near Beaver, Minn.	1976–85, 1994–99	8.64	7.66
05377500	178	Whitewater River at Beaver, Minn.	1940–56	6.26	7.66
05378300	179	Straight Valley Creek near Rollingstone, Minn.	1971–85	6.20	7.89
05379000	180	Gilmore Creek at Winona, Minn.	1940–62	5.57	8.02
05379400	181	Trempealeau River at Arcadia, Wisc.	1961–77, 2002–04	9.71	8.27
05379500	182	Trempealeau River at Dodge, Wisc.	1940–2005	9.74	8.47
05382000	183	Black River near Galesville, Wisc.	1940–2005	11.62	9.76
05383000	184	La Crosse River near West Salem, Wisc.	1940–70	9.46	8.79
05384000	185	Root River near Lanesboro, Minn.	1941–85, 1987–90	7.82	7.66
05384500	186	Rush Creek near Rushford, Minn.	1943–79	5.66	7.94
05385000	187	Root River near Houston, Minn.	1940–83, 1991–2000, 2005	8.46	7.80
05385500	188	South Fork Root River near Houston, Minn.	1954–83	7.02	8.13
05386000	189	Root River below South Fork near Houston, Minn.	1940–61	7.02	7.90
05387500	190	Upper Iowa River at Decorah, Iowa	1952–83, 2003–05	8.74	8.13
05388000	191	Upper Iowa River near Decorah, Iowa	1940–51	9.25	8.17
05388250	192	Upper Iowa River near Dorchester, Iowa	1976–2005	10.79	8.23
05388500	193	Paint Creek at Waterville, Iowa	1953–73	5.03	8.54
05389000	194	Yellow River at Ion, Iowa	1940–51, 2005	9.28	8.61
05389400	195	Bloody Run Creek near Marquette, Iowa	1992–2005	8.91	8.71
05411400	196	Sny Magill Creek near Clayton, Iowa	1992–2001	10.32	8.76
05411600	197	Turkey River at Spillville, Iowa	1957–73, 1978–91	9.40	8.33
05412060	198	Silver Creek near Luana, Iowa	1987–98	9.84	8.72
05412100	199	Roberts Creek above St. Olaf, Iowa	1987–2001	5.31	8.74
05412500	200	Turkey River at Garber, Iowa	1940–2005	9.32	8.78
05414500	201	Little Maquoketa River near Durango, Iowa	1940–81	8.99	9.05
05420560	202	Wapsipinicon River near Elma, Iowa	1959–92	9.44	8.04
05448500	203	West Branch Iowa River near Klemme, Iowa	1949–58	4.62	7.48
05449000	204	East Branch Iowa River near Klemme, Iowa	1949–76, 1978–95	7.40	7.70

Table 3. Streamflow-gaging stations used to estimate generalized mean annual runoff.—Continued

Station number	Map number (fig. 2)	Station name	Period of record (water years)	Mean annual runoff for period of record (inches)	Fitted annual runoff (inches)
05449500	205	Iowa River near Rowan, Iowa	1941–76, 1978–2005	7.91	7.80
05457000	206	Cedar River near Austin, Minn.	1945–2005	8.57	7.35
05457700	207	Cedar River at Charles City, Iowa	1965–95, 1997, 2001–05	9.82	7.65
05458000	208	Little Cedar River near Ionia, Iowa	1955–2005	8.35	8.06
05458500	209	Cedar River at Janesville, Iowa	1940–42, 1946–2005	8.60	7.92
05458900	210	West Fork Cedar River at Finchford, Iowa	1946–2005	9.00	8.59
05459000	211	Shell Rock River near Northwood, Iowa	1946–86	7.31	7.33
05459500	212	Winnebago River at Mason City, Iowa	1940–2005	7.88	7.43
05460500	213	Shell Rock River at Marble Rock, Iowa	1943–53	7.24	7.58
05462000	214	Shell Rock River at Shell Rock, Iowa	1954–2005	8.49	7.86
05463000	215	Beaver Creek at New Hartford, Iowa	1946–2005	8.75	9.18
05476000	216	Des Moines River at Jackson, Minn.	1940–2005	4.88	4.44
05476500	217	Des Moines River at Estherville, Iowa	1952–94	4.38	4.52
05476750	218	Des Moines River at Humboldt, Iowa	1965–2005	6.43	5.37
05478000	219	East Fork Des Moines River near Burt, Iowa	1952–74	4.22	6.04
05479000	220	East Fork Des Moines River at Dakota City, Iowa	1941–2005	6.86	6.68
05480000	221	Lizard Creek near Clare, Iowa	1941–81	5.09	7.36
05480500	222	Des Moines River at Fort Dodge, Iowa	1947–2005	6.07	5.94
05482135	223	North Raccoon River near Newell, Iowa	1983–95	10.83	6.72
05482170	224	Big Cedar Creek near Varina, Iowa	1960–91	7.30	6.94
06478052	225	Enemy Creek near Mitchell, S. Dak.	1976–80, 1982–87	1.66	.61
06478390	226	Wolf Creek near Clayton, S. Dak.	1976–88	1.38	1.26
06478540	227	Little Vermillion R near Salem, S. Dak.	1967–2005	1.31	1.57
06478600	228	East Fork Vermillion River near Parker, S. Dak.	1996–2005	1.58	2.10
06478690	229	West Fork Vermillion River near Parker, S. Dak.	1962–2005	1.53	1.95
06479000	230	Vermillion River near Wakonda, S. Dak.	1946–83	1.01	2.56
06479010	231	Vermillion River near Vermillion, S. Dak.	1984–2005	2.20	2.75
06479215	232	Big Sioux River near Florence, S. Dak.	1985–2005	.31	1.24
06479438	233	Big Sioux River near Watertown, S. Dak.	1973–2005	.56	1.48
06479500	234	Big Sioux River at Watertown, S. Dak.	1946–72, 2000–05	.39	1.57
06479515	235	Willow Creek near Watertown, S. Dak.	1972–86	2.32	1.74
06479520	236	Big Sioux River below Watertown, S. Dak.	1995–2005	.89	1.79
06479525	237	Big Sioux River near Castlewood, S. Dak.	1977–2005	.66	1.84
06479529	238	Stray Horse Creek near Castlewood, S. Dak.	1969–85	2.21	1.98
06479640	239	Hidewood Creek near Estelline, S. Dak.	1969–85	2.14	2.12
06479910	240	Sixmile Creek near Brookings, S. Dak.	1971–80	1.85	2.49
06479980	241	Medary Creek near Brookings, S. Dak.	1981–90	3.82	2.50
06480000	242	Big Sioux River near Brookings, S. Dak.	1954–2005	1.06	2.53
06480400	243	Spring Creek near Flandreau, S. Dak.	1983–93	4.52	2.81
06480650	244	Flandreau Creek above Flandreau, S. Dak.	1982–91	4.74	2.99
06481000	245	Big Sioux River near Dell Rapids, S. Dak.	1949–2005	1.28	2.60
06481500	246	Skunk Creek at Sioux Falls, S. Dak.	1949–2001, 2004–05	2.02	2.63
06482610	247	Split Rock Creek at Corson, S. Dak.	1966–89, 2002–05	2.90	2.99

Table 3. Streamflow-gaging stations used to estimate generalized mean annual runoff.—Continued

Station number	Map number (fig. 2)	Station name	Period of record (water years)	Mean annual runoff for period of record (inches)	Fitted annual runoff (inches)
06483000	248	Rock River at Luverne, Minn.	1996–97	5.49	3.65
06483270	249	Rock River at Rock Rapids, Iowa	1960–74	2.82	3.76
06483500	250	Rock River near Rock Valley, Iowa	1949–2005	4.30	3.94
06484000	251	Dry Creek at Hawarden, Iowa	1949–69	2.26	3.79
06485696	252	Brule Creek near Elk Point, S. Dak.	1983–94	4.42	3.30
06600000	253	Perry Creek at 38th Street, Sioux City, Iowa	1946–69, 1982–2004	3.94	4.21
06600100	254	Floyd River at Alton, Iowa	1956–2005	4.18	4.72
06600300	255	West Branch Floyd River near Struble, Iowa	1956–94	3.86	4.25
06600500	256	Floyd River at James, Iowa	1940–2005	3.97	4.56
06603000	257	Little Sioux River near Lakefield, Minn.	1949–62	3.08	4.87
06603500	258	Jackson County Ditch #11 near Lakefield, Minn.	1949–60	3.17	5.00
06605000	259	Ocheyedan River near Spencer, Iowa	1978–2005	6.88	5.01
06605600	260	Little Sioux River at Gillett Grove, Iowa	1959–73	3.86	5.29
06605850	261	Little Sioux River at Linn Grove, Iowa	1973–2005	6.40	5.37

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