Prepared in cooperation with the Minnesota Pollution Control Agency

Methods to Estimate Historical Daily Streamflow for Ungaged Stream Locations in Minnesota

Scientific Investigations Report 2015–5181

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

Cover photograph: Redwood River near Redwood Falls, Minnesota.
Photograph by the U.S. Geological Survey.

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Conversion Factors

Inch/Pound to International System of Units

Multiply	By	To obtain
	Length	
foot (ft)	0.3048	meter (m)
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)

Supplemental Information

Water year is the 12-month period of October 1 through September 30 and is designated by the calendar year in which it ends.

Datum

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

Abbreviations

BaSE	Baseline Streamflow Estimator
FDC	flow-duration curve
GIS	geographic information system
LFF	low-flow frequency
MA SYE	Massachusetts Sustainable-Yield Estimator
MOVE	maintenance of variance extension
MPCA	Minnesota Pollution Control Agency
NSE	Nash-Sutcliffe efficiency
NYSET	New York Streamflow Estimation Tool
USGS	U.S. Geological Survey

Methods to Estimate Historical Daily Streamflow for Ungaged Stream Locations in Minnesota

By David L. Lorenz and Jeffrey R. Ziegeweid

Abstract

Effective and responsible management of water resources relies on a thorough understanding of the quantity and quality of available water; however, streamgages cannot be installed at every location where streamflow information is needed. Therefore, methods for estimating streamflow at ungaged stream locations need to be developed. This report presents a statewide study to develop methods to estimate the structure of historical daily streamflow at ungaged stream locations in Minnesota. Historical daily mean streamflow at ungaged locations in Minnesota can be estimated by transferring streamflow data at streamgages to the ungaged location using the QPPQ method. The QPPQ method uses flow-duration curves at an index streamgage, relying on the assumption that exceedance probabilities are equivalent between the index streamgage and the ungaged location, and estimates the flow at the ungaged location using the estimated flow-duration curve. Flow-duration curves at ungaged locations can be estimated using recently developed regression equations that have been incorporated into StreamStats (http://streamstats.usgs.gov/), which is a U.S. Geological Survey Web-based interactive mapping tool that can be used to obtain streamflow statistics, drainage-basin characteristics, and other information for user-selected locations on streams.

Introduction

Effective and responsible management of water resources relies on a thorough understanding of the quantity and quality of available water. Streamgages provide valuable water-quantity information that facilitates responsible management of water resources, including reservoir management, recreational activities, maintenance of aquatic habitat, and contaminant monitoring; however, streamgages cannot be installed at every location where streamflow information is needed. Therefore, methods for estimating daily mean streamflow at ungaged locations need to be developed. Approaches for estimating daily streamflow have been developed into estimation tools by the U.S. Geological Survey (USGS) in Massachusetts (Massachusetts Sustainable-Yield Estimator [MA SYE]; Archfield and others, 2010), Pennsylvania (Baseline Streamflow Estimator [BaSE]; Stuckey and others, 2012), and New York (New York Streamflow Estimation Tool [NYSET]; Gazoorian, 2015). The MA SYE, BaSE, and NYSET tools apply the QPPQ method introduced by Fennessey (1994) and used by Hughes and Smakhtin (1996), Smakhtin (1999), Smakhtin and Masse (2000), Mahamoud (2008), Shu and Ouarda (2012), and Linhart and others (2013). The QPPQ method uses flow-duration curves (FDCs) at an index streamgage, relying on the assumption that exceedance probabilities are equivalent between the index streamgage and the ungaged location, and estimates the flow at the ungaged location using the estimated FDC. The MA SYE and BaSE tools have been effective at estimating the natural, unaltered daily streamflow hydrograph at ungaged locations in their respective study areas and provide user-friendly ways of computing streamflow statistics commonly used for water-resource management and habitat protection. Recently, regression equations were developed to estimate flow-duration exceedance probabilities and low-flow frequency (LFF) statistics for ungaged locations on streams in Minnesota (Ziegeweid and others, 2015). These regression equations can be used to develop methods for estimating daily mean streamflow.

The QPPQ method can be used to assist water-resource managers and researchers to describe and quantify hydrologic variability and describe the hydrologic response of a river basin, and within a wide range of uncertainty, estimate the streamflow at ungaged sites. The measures of variability and streamflow can be used for irrigation planning, waste-load allocation, water-quality management, categorizing fish assemblages and other characteristics of aquatic organisms, and other tasks that require knowledge of the variability of streamflow in small basins.

In 2012, the USGS initiated a statewide study in cooperation with the Minnesota Pollution Control Agency (MPCA) to develop methods for estimating historical daily streamflow at ungaged stream locations in Minnesota. For this study, methods were developed that use FDCs based on regression equations (Ziegeweid and others, 2015) to estimate historical daily streamflow data for ungaged locations on small streams (that is, those with drainage areas less than 3,000 square miles [mi^2]) in Minnesota.

This study for ungaged stream locations in Minnesota builds upon the work presented in Ziegeweid and others (2015) who developed regression equations for estimating 13 FDC statistics. Those FDC statistics are needed for estimating historical daily streamflow using the QPPQ method at ungaged stream locations in Minnesota.

Purpose and Scope

This report describes how regression equations developed by Ziegeweid and others (2015) can be used to estimate historical daily streamflow in small streams at ungaged locations in Minnesota. The steps described include (1) constructing FDCs at ungaged locations, (2) selecting index streamgages, and (3) transferring hydrographs from the index streamgage to the ungaged location. Methods presented in this report apply only to streams in Minnesota with drainage areas less than 3,000 mi^2 and flows that are not substantially affected by regulation, diversion, or urbanization, which are limitations set by the analysis done by Ziegeweid and others (2015).

The purpose of estimating historical daily streamflow is to describe the hydrograph structure—variability of flow and approximate timing of flows—rather than the actual daily streamflow at the ungaged location. As such, the estimated streamflow is more suitable for management of recreational activities and maintenance of aquatic habitat than for studies of contaminant transport and load estimation, where more accurate streamflow is required. The estimated FDCs could be modified by other mass-balance methods to estimate streamflow that more nearly match the expected daily streamflow for use in water budgets and possibly contaminant transport. Those methods are beyond the scope of this report.

Description of the Study Area

The study area (fig. 1) includes the State of Minnesota and a 50-mile (mi) buffer around Minnesota in the neighboring States of Iowa, North Dakota, South Dakota, and Wisconsin. Canadian portions of the basins were not included because basin characteristics were not available in StreamStats (U.S. Geological Survey, 2015). The study area is divided into five hydrologic regions (fig. 1) developed using a combination of statistical analyses from previous studies (Jacques and Lorenz, 1988; Lorenz and others, 1997; Lorenz and others, 2010) and the concept of hydrologic landscape units (Winter, 2001; Wolock and others, 2004). Ziegeweid and others (2015) state “Region BC represents the combined regions B and C from Lorenz and others (2010) because not enough streamgages with low-flow data were available in region C to develop regional regression equations. Residual analyses confirmed that regions B and C could be combined without affecting the ability of the regional regression equations to accurately estimate FDC and LFF statistics.”

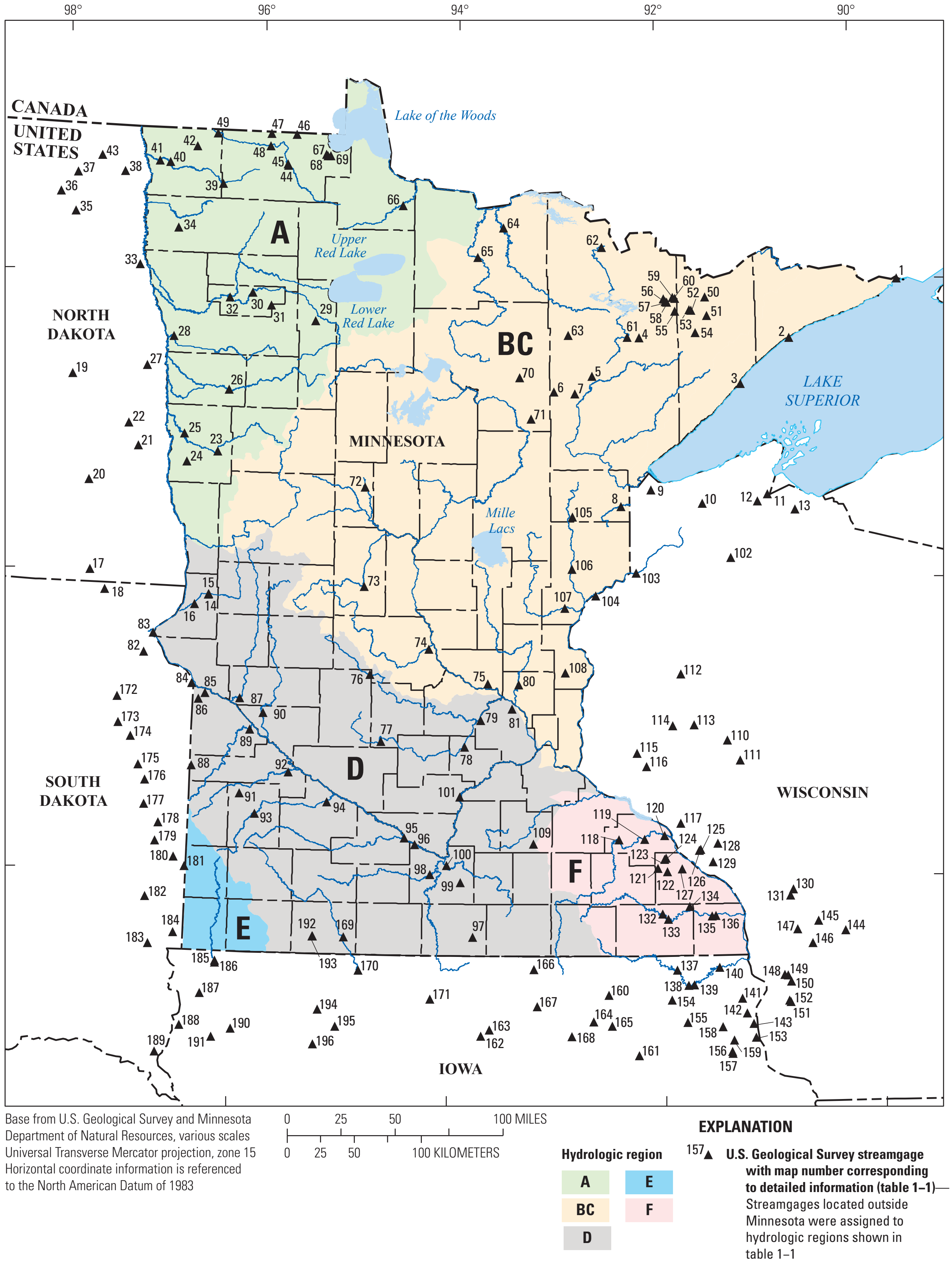
Differences among the five hydrologic regions are described using the hydrologic landscape unit information presented in Lorenz and others (2010). Region A is the most heterogeneous region, with generally low slopes that become increasingly moderate near the drainage boundary. Most of region BC is dominated by sandy soils and low to moderate slopes, but the northeastern portion of region BC along the north shore of Lake Superior and the northeastern Canadian border generally is high in slope. Low slopes near the center of region D change to moderate slopes and less sandy soils around the drainage boundaries. Region E is similar to the drainage boundaries of region D, with moderate slopes and low sand content in the soils; however, there are distinct differences in the drainage patterns between regions D and E. Finally, high slope areas in region F change to moderately sloped areas along the western drainage boundary.

The study area (fig. 1) includes selected index streamgages in the State of Minnesota, but some selected index streamgages are in the surrounding States of Iowa, North Dakota, South Dakota, and Wisconsin. For the neighboring States, only those streamgages that were used in Ziegeweid and others (2015) are used as index streamgages. For Minnesota, inactive streamgages that have at least 10 years of record and all active (as of 2015) streamgages that are unaffected by regulation, diversion, or urbanization are used as index streamgages. Table 1 (at the back of this report) provides additional information for the index streamgages shown on figure 1.

Methods to Estimate Historical Daily Streamflow

Daily mean streamflow can be estimated for ungaged locations in Minnesota by transferring streamflow data at index streamgages to the ungaged location using the QPPQ method (Fennessey, 1994). The QPPQ method uses FDCs at ungaged locations and index streamgages and relies on the assumption that exceedance probabilities are equivalent between an ungaged location and an index streamgage. Details of applying the method are presented in the following sections.

If the ungaged location was previously gaged for a period long enough to establish an FDC (10 years), then the FDC for the location can be based on measured streamflow rather than estimated streamflow. If the gaging period was not long enough to establish an FDC, then the estimated FDC can be used and possibly adjusted by the mean flow to closer approximate streamflow at the ungaged location. In addition, other record-extension methods can be used for previously gaged locations. One common record-extension method is the maintenance of variance extension (MOVE), which adjusts for changes in flow conditions between the concurrent and non-concurrent records (Hirsch, 1982; Vogel and Stedinger, 1985).



Base from U.S. Geological Survey and Minnesota Department of Natural Resources, various scales
Universal Transverse Mercator projection, zone 15
Horizontal coordinate information is referenced to the North American Datum of 1983

Figure 1. Minnesota and parts of neighboring States showing selected index streamgages.

Estimation of the Ungaged Flow-Duration Curve

An FDC is a cumulative frequency curve that shows the fraction of time that specified streamflow is equaled or exceeded (Searcy, 1959). Typically, FDCs are constructed using the complete records for the index streamgage, but FDCs can be constructed from any reference time period. An FDC is built by sorting streamflow observed during a given period of time by magnitude and calculating the probability that a specified streamflow value will be equaled or exceeded. For this report, the fraction of time that the streamflow is equaled or exceeded is termed exceedance probability.

At an ungaged location, the FDC is constructed from point estimates of streamflow for 13 exceedance probabilities (0.0001, 0.001, 0.02, 0.05, 0.1, 0.25, 0.5, 0.75, 0.9, 0.95, 0.99, 0.999, and 0.9999) that cover the range of streamflow. Regression equations, developed using physical and climatic basin characteristics and streamflow data from a subset of index streamgages, are applied to estimate each of the 13 exceedance probabilities (Ziegeweid and others, 2015). To construct a continuous daily FDC, streamflow at all other exceedance probabilities is determined by log-q-normal interpolation, which interpolates values based on the log of streamflow and the quantile of the normal distribution based on the probability, completing the FDC between the 13 exceedance-probability estimates for the ungaged location.

Selection of Index Streamgages in Minnesota and Neighboring States

Selection of an index streamgage is an important step in obtaining the best estimates of daily streamflow in an unaltered stream at an ungaged location. Index streamgages can be identified using several methods. Archfield and others (2010) used kriging to maximize the correlation in streamflow between streamgages and potential ungaged locations to identify index streamgages, an approach that works well when examining fixed periods of time. In contrast, Farmer and others (2014) selected index streamgages using the nearest-neighbor method. Once index streamgages were selected, both studies (Archfield and others, 2010; Farmer and others, 2014) used the QPPQ method, which is described in the "Estimation of Unaltered Daily Mean Streamflow" section, to estimate daily streamflow at ungaged stream locations. For this Minnesota study, the nearest-neighbor method was used to determine the Spearman rank correlation coefficients (Spearman's rho; Helsel and Hirsch, 2002) between streamgages separated by various distances, and Spearman's rho was used to evaluate whether compared streamgages were suitable index streamgages.

The index streamgage must be unaltered by regulation and similar to the ungaged locations of interest. For the purposes of this report, an index streamgage is defined as the outlet of a basin that has upstream land cover, geology, and hydrologic characteristics similar to the ungaged basin and is based on a similar term in Stuckey and others (2012). A set of index streamgages from the streamgage network in Minnesota and surrounding States was identified to estimate correlations with ungaged locations (table 1). Other streamgages maintained by the USGS, the Minnesota Department of Natural Resources, or other agencies could be used once they have established records of at least 10 years length. It is important that the index streamgage basin characteristics should be relatively similar to the ungaged basin characteristics, particularly the location of lakes or wetlands that affect the timing of streamflow. Possible effects, including peak-flow attenuation and slower response to rainfall, from large lakes and wetlands just upstream from the ungaged or potential index streamgage should be considered when selecting the index streamgage.

Estimation of Unaltered Daily Mean Streamflow

Daily mean streamflow in unaltered small streams at ungaged locations in Minnesota can be estimated using the QPPQ method (Fennessey, 1994). The three-step process of the QPPQ method is shown in figure 2: (1) for each day, the observed daily mean streamflow at the index station (the "gaged hydrograph") is determined; (2) the probability of exceeding that observed streamflow is determined from the "gaged flow-duration curve" and transferred to the "estimated flow-duration curve"; and (3) the estimated flow for the ungaged location for that day is determined and the "estimated ungaged hydrograph" is constructed.

Evaluation of Index Streamgages

For streamgages in this study, the nearest-neighbor method produced consistently better Spearman's rho, computed from the estimated and observed streamflows, when drainage-area ratios for the compared streamgages were between 0.25 and 4 than when drainage-area ratios were outside of this range; however, within this range of drainage-area ratios, the Spearman's rho decreased as the distance between streamgages increased. For streamgages about 10 mi apart, Spearman's rho for daily streamflow between streamgages was 0.87. When the distances between streamgages were increased to about 50 mi, Spearman's rho decreased to 0.78. In the study area, the only potential ungaged locations without a suitable index streamgage within 50 mi are some tributaries to Lake Superior.

Evaluation of Estimated Daily Streamflow

Observed and estimated streamflows were compared for nine pairs of streamgages (table 2) to assess the performance of the QPPQ method for streams within the study area. The

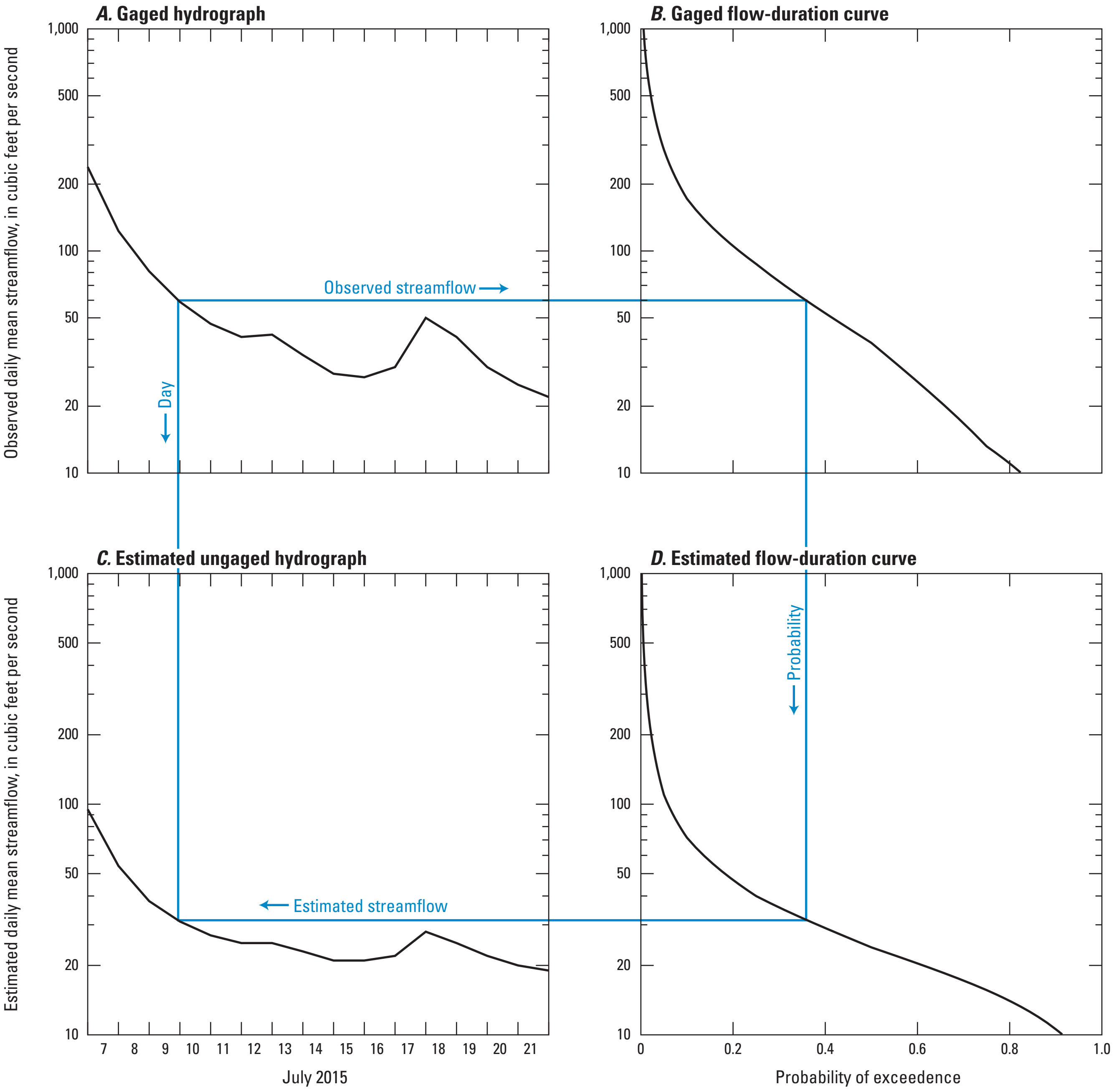


Figure 2. Example of the QPPQ method (Fennessey, 1994) used to estimate daily mean streamflow at ungaged locations for part of the annual hydrograph showing *A*, the gaged hydrograph; *B*, the gaged flow-duration curve; *C*, the estimated flow-duration curve; and *D*, the estimated ungaged hydrograph.

nine pairs of streamgages were randomly selected from the streamgages used in Ziegeweid and others (2015) based on a distance of less than 50 mi, drainage-area ratios ranging from 0.25 to 4, and concurrent record. The selected pairs of streamgages represent a range in distance from 5 to 43 miles and drainage-area ratios from 0.3 to 2.72 (table 2). Only data from the most recent complete water year available from the USGS National Water Information System (U.S. Geological Survey, 2013) common to the pair of streamgages were used in the comparison; a water year is the 12-month period of October 1 through September 30 and is designated by the calendar year in which it ends. For each pair, the index streamgage had the smaller streamgage station number and the target streamgage had the larger streamgage station number. The QPPQ method was applied for the pair after the FDC was estimated at the target streamgage using the regional regression equations. The Spearman's rho values for the selected water year ranged from 0.62 to 0.92, and the mean Spearman's

Table 2. Selected pairs of streamgages for assessment of performance of the QPPQ method (Fennessey, 1994) for estimating ungaged streamflow in Minnesota.

Index station number	Target station number	Drainage area ratio (index/target)	Distance (miles)	Water year	Spearman's rho	Nash-Sutcliffe efficiency
04014500	05124480	0.55	43	1993	0.77	-0.72
04018900	04019300	2.72	19	1978	0.86	0.44
05087500	05093000	0.92	29	1956	0.81	-0.20
05093000	05107500	0.27	28	1956	0.84	-1.45
05270500	05275000	1.87	32	2012	0.92	0.74
05275000	05279000	0.48	31	1979	0.62	0.60
05372000	05374500	0.30	18	1951	0.77	0.27
05376000	05376500	1.29	5	1971	0.91	0.62
05420680	05457700	0.32	26	2012	0.78	0.42

rho of 0.79 closely approximates the mean Spearman's rho for streamgages in the study area within 50 mi of each other (0.78).

Observed and estimated streamflows for two target streamgages listed in table 2 are compared in figure 3. The observed and estimated streamflows for streamgage Elk River near Big Lake, Minn. (05275000; fig. 3*A*) had the largest Spearman's rho between index and target streamgages (0.92). Although the estimated streamflow generally is overestimated for low flows and underestimated for peak flows, the estimated streamflow closely approximates the timing of changes in the measured hydrograph. The observed and estimated streamflows for streamgage South Fork Crow River near Mayer, Minn. (05279000; fig. 3*B*) had the smallest Spearman's rho between index and target streamgages (0.62). The relation between the estimated and observed low flows (less than 500 cubic feet per second [ft^3/s] at streamgage 05279000 and less than 300 ft^3/s at streamgage 05275000) was less consistent at streamgage 05279000 (fig. 3*B*) than at streamgage 05275000 (fig. 3*A*), and the timing and magnitude of the measured spring peak associated with ice-out was misrepresented by the estimated streamflow at streamgage 05279000. In addition, the estimated streamflow peaks in June and July for streamgage 05279000 were greatly overestimated.

The hydrographs shown in figure 3 illustrate how the magnitudes of observed and estimated streamflows can vary greatly using the methods presented in this report. In figure 3*A*, the observed peak streamflow (in early June) was about 1.8 times larger than the estimated peak streamflow, whereas in figure 3*B*, the estimated peak streamflow in May was about 2.3 times larger than the observed peak streamflow. In addition, for target streamgage Roseau River at Ross, Minn. (05107500), the estimated mean streamflow of 1,400 ft^3/s was about 3.5 times larger than the observed mean streamflow of 406 ft^3/s. Such a large difference between the estimated and observed streamflows is unusual for streamgages in region A (fig. 1), where the standard error of the median flow regression is 79 percent (Ziegeweid and others, 2015).

Several methods can be used to evaluate the accuracy of estimated streamflow. The Nash-Sutcliffe efficiency (NSE; Nash and Sutcliffe, 1970) is useful in evaluating estimated streamflow when the goal of the estimation is to closely approximate the actual measured streamflow (Ziegeweid and Magdalene, 2015). Values of the NSE can range from negative infinity to 1.0, and values close to 1.0 indicate that estimated streamflows closely approximate measured streamflows. The largest NSE value determined for the 9 target streamgages (table 2) was 0.74. Three of the target streamgages had NSE values less than 0, indicating the method was worse than the mean of the data at predicting a given streamflow. However, the goal of using the QPPQ method is to reproduce the structure of the hydrograph, not to predict actual streamflow; thus, the results of the NSE analysis are less important for evaluating the QPPQ method that the results of the Spearman's rho analysis.

StreamStats

StreamStats is a USGS Web-based geographic information system (GIS) tool (http://streamstats.usgs.gov/; Ries and others, 2008) that allows users to obtain streamflow statistics, drainage-basin characteristics, and other information for user-selected locations on streams. Users can select stream locations of interest from an interactive map and can obtain information for these locations. If a user selects the location of a USGS streamgage, the user will get previously published information for the streamgage from a database. If a stream location is selected where no data are available (an ungaged location), a GIS program will estimate information for the location. The GIS program determines the boundary of the drainage basin upstream from the stream location, calculates the basin characteristics of the drainage basin, and solves the appropriate regression equations, based on the physical characteristics of the basin, to estimate streamflow statistics for that location. The results are presented in a table and a

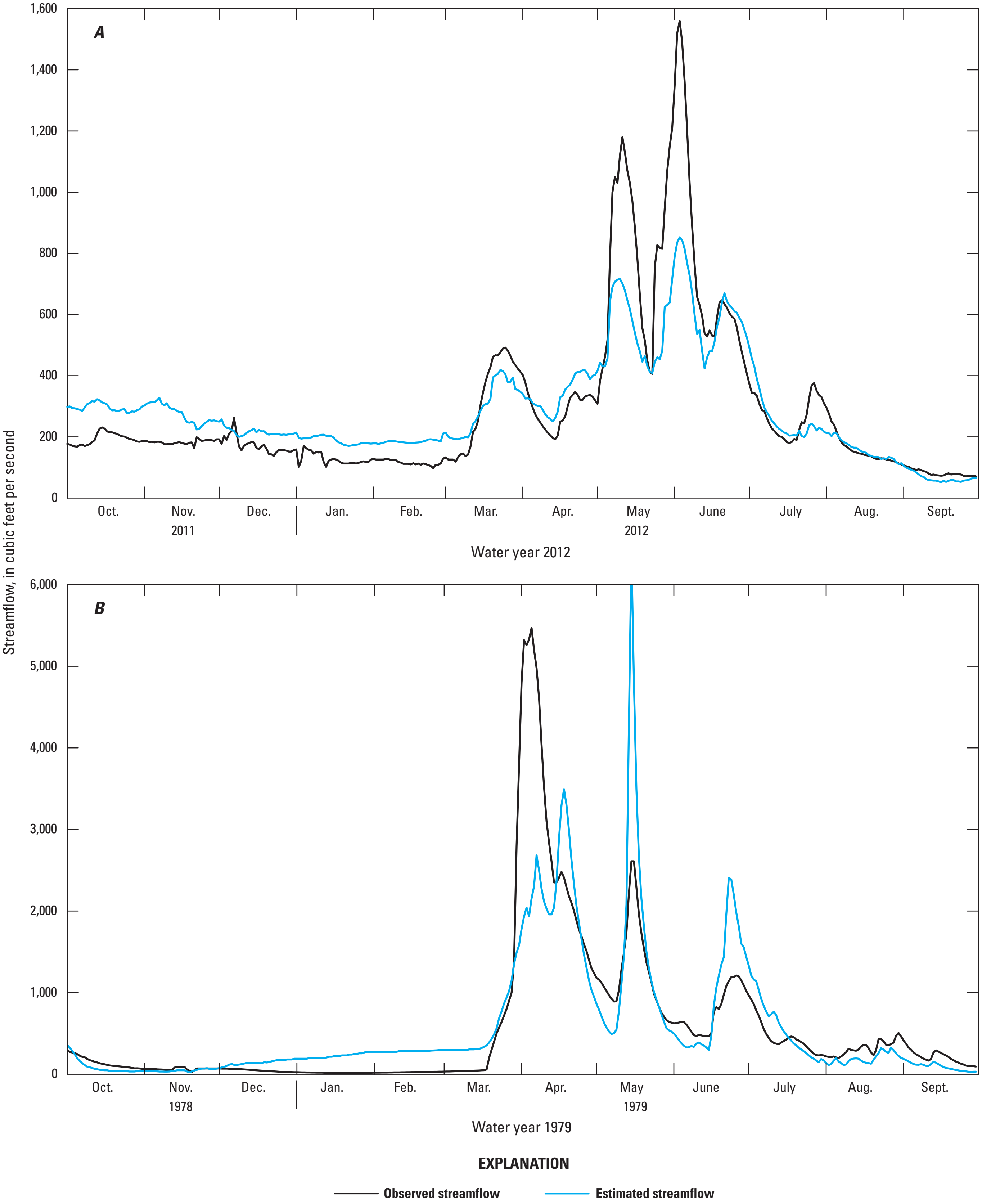


Figure 3. Observed and estimated streamflows for two target streamgages. *A*, streamgage 05275000. *B*, streamgage 05279000.

map showing the basin-boundary outline. These estimates are applicable for stream locations not substantially affected by regulation, diversions, or urbanization. The regression equations developed by Ziegeweid and others (2015) to estimate FDC and LFF statistics in the study area have been incorporated into StreamStats. StreamStats can estimate FDCs at ungaged locations on unaltered streams; the estimated FDCs are then used in the QPPQ method to estimate streamflow.

Limitations of the Methods

The methods presented in this study have several limitations. The regional regression equations developed by Ziegeweid and others (2015) apply only to stream locations in Minnesota where streamflow is not substantially affected by regulation, diversions, or urbanization. Furthermore, the applicability and accuracy of the regional equations depend on whether the basin characteristics calculated for an ungaged stream location are within the range of the characteristic values used to develop the regression equations. In addition, selection of an index streamgage is based primarily on proximity of the streamgage to the ungaged location. Although the closest streamgage should provide good estimates of streamflow statistics, other factors need to be considered in order to select the index streamgage that provides the most accurate estimates of streamflow statistics. For example, if the streamflow upstream from the nearest streamgage is affected substantially by an upstream lake or wetland, and the ungaged location is not affected substantially by a lake or wetland, then the user might consider selecting a different index streamgage that is unaffected by lakes or wetlands upstream from the streamgage.

Summary

Effective and responsible management of water resources relies on a thorough understanding of the quantity and quality of available water; however, streamgages cannot be installed at every location where streamflow information is needed. Therefore, methods for estimating streamflow at ungaged locations need to be developed. This report presents the results of a statewide study to develop methods to estimate the structure of historical daily streamflow at ungaged stream locations in Minnesota. Historical daily mean streamflow at ungaged locations in Minnesota can be estimated by transferring streamflow data at streamgages to the ungaged location using the QPPQ method. The QPPQ method uses flow-duration curves at index streamgages and ungaged locations and relies on the assumption that exceedance probabilities are equivalent between an index streamgage and an ungaged location. Flow-duration curves at ungaged locations can be estimated using recently developed regression equations that have been incorporated into StreamStats (http://streamstats.usgs.gov/), which is a USGS Web-based interactive mapping tool that can be used to obtain streamflow statistics, drainage-basin characteristics, and other information for user-selected locations on streams.

Nine pairs of streamgages and Spearman's rho were used to evaluate the ability of the QPPQ method to predict measured (observed) hydrographs. Spearman's rho for the nine target streamgages ranged from 0.62 to 0.92, with a mean (0.79) that closely approximates the mean Spearman's rho for streamgages in the study area within 50 miles of each other (0.78).

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References Cited

Archfield, S.A., Vogel, R.M., Steeves, P.A., Brandt, S.L., Weiskel, P.K., and Garabedian, S.P., 2010, The Massachusetts Sustainable-Yield Estimator—A decision-support tool to assess water availability at ungaged stream locations in Massachusetts: U.S. Geological Survey Scientific Investigations Report 2009–5227, 41 p. [Also available at http://pubs.er.usgs.gov/publication/sir20095227.]

Farmer, W.H., Archfield, S.A., Over, T.M., Hay, L.E., LaFontaine, J.H., and Kiang, J.E., 2014, A comparison of methods to predict historical daily streamflow time series in the southeastern United States: U.S. Geological Survey Scientific Investigations Report 2014–5231, 34 p. [Also available at http://dx.doi.org/10.3133/sir20145231.]

Fennessey, N.M., 1994, A hydro-climatological model of daily streamflow for the northeast United States: Medford, Massachusetts, Tufts University, Ph.D. dissertation, [variously paged].

Gazoorian, C.L., 2015, Estimation of unaltered daily means streamflow at ungaged streams of New York, excluding Long Island, water years 1961–2010: U.S. Geological Survey Scientific Investigations Report 2014–5220, 29 p. [Also available at http://dx.doi.org/10.3133/sir20145220.]

Helsel, D.R., and Hirsch, R.M., 2002, Statistical methods in water resources: U.S. Geological Survey Techniques of Water-Resources Investigations, book 4, chap. A3, 524 p. [Also available at http://pubs.usgs.gov/twri/twri4a3/.]

Hirsch, R.M., 1982, A comparison of four streamflow record extension techniques: Water Resources Research, v. 18, no. 4, p. 1081–1088. [Also available at http://dx.doi.org/10.1029/WR018i004p01081.]

Hughes, D.A., and Smakhtin, V.U., 1996, Daily flow time series patching or extension—A spatial interpolation approach based on flow duration curves: Hydrological Sciences Journal, v. 41, no. 6, p. 851–871. [Also available at http://dx.doi.org/10.1080/02626669609491555.]

Jacques, J.E., and Lorenz, D.L., 1988, Techniques for estimating the magnitude and frequency of floods in Minnesota: U.S. Geological Survey Water-Resources Investigations Report 87–4170, 48 p. [Also available at http://pubs.er.usgs.gov/publication/wri874170]

Linhart, S.M., Nania, J.F., Christiansen, D.E., Hutchinson, K.J., Sanders, C.L., Jr., and Archfield, S.A., 2013, Comparison between two statistically based methods, and two physically based models developed to compute daily mean streamflow at ungaged locations in the Cedar River Basin, Iowa: U.S. Geological Survey Scientific Investigations Report 2013–5111, 7 p. [Also available at http://pubs.usgs.gov/sir/2013/5111/.]

Lorenz, D.L., Carlson, G.H., and Sanocki, C.A., 1997, Techniques for estimating peak flow on small streams in Minnesota: U.S. Geological Survey Water-Resources Investigations Report 97–4249, 42 p. [Also available at http://pubs.er.usgs.gov/publication/wri974249.]

Lorenz, D.L., Sanocki, C.A., and Kocian, M.J., 2010, Techniques for estimating the magnitude and frequency of peak flows on small streams in Minnesota based on data through water year 2005: U.S. Geological Survey Scientific Investigations Report 2009–5250, 54 p. [Also available at http://pubs.usgs.gov/sir/2009/5250/.]

Mahamoud, Y.M., 2008, Prediction of daily flow duration curves and streamflow for ungauged catchments using regional flow duration curves: Hydrological Sciences Journal, v. 53, no. 4, p. 706–724. [Also available at http://dx.doi.org/10.1623/hysj.53.4.706.]

Nash, J.E., and Sutcliffe, J.V., 1970, River flow forecasting through conceptual models part I—A discussion of principles: Journal of Hydrology, v. 10, no. 3, p. 282–290. [Also available at http://dx.doi.org/10.1016/0022-1694(70)90255-6.]

Ries, K.G., III, Guthrie, J.D., Rhea, A.H., Steeves, P.A., and Stewart, D.W., 2008, StreamStats—A water resources Web application: U.S. Geological Survey Fact Sheet 2008–3067, 6 p. [Also available at http://pubs.usgs.gov/fs/2008/3067/.]

Searcy, J.K., 1959, Flow-duration curves: U.S. Geological Survey Water-Supply Paper 1542–A, 33 p. [Also available at http://pubs.er.usgs.gov/publication/wsp1542A/.]

Shu, C., and Ouarda, T.B.M.J., 2012, Improved methods for daily streamflow estimates at ungauged sites: Water Resources Research, v. 48, no. 2, W02523. [Also available at http://dx.doi.org/10.1029/2011WR011501.]

Smakhtin, V.U., 1999, Generation of natural daily flow time series in regulated rivers using a non-linear spatial interpolation technique: Regulated Rivers—Research and Management, v. 15, no. 4, p. 311–323. [Also available at http://dx.doi.org/10.1002/(SICI)1099-1646(199907/08)15:4<311::AID-RRR544>3.0.CO;2-W.]

Smakhtin, V.U., and Masse, B., 2000, Continuous daily hydrograph simulation using duration curves of a precipitation index: Hydrological Processes, v. 14, no. 6, p. 1083–1100. [Also available at http://dx.doi.org/10.1002/(SICI)1099-1085(20000430)14:6<1083::AID-HYP998>3.0.CO;2-2.]

Stuckey, M.H., Koerkle, E.H., and Ulrich, J.E., 2012, Estimation of baseline daily mean streamflows for ungaged locations on Pennsylvania streams, water years 1960–2008: U.S. Geological Survey Scientific Investigations Report 2012–5142, 61 p. [Also available at http://pubs.usgs.gov/sir/2012/5142.]

U.S. Geological Survey, 2013, National Water Information System (NWISWeb): U.S. Geological Survey database, accessed 05/03/2013, at http://waterdata.usgs.gov/nwis/sw.

U.S. Geological Survey, 2015, StreamStats: accessed November 10, 2015, at http://streamstats.usgs.gov/.

Vogel, R.M., and Stedinger, J.R., 1985, Minimum variance streamflow record augmentation procedures: Water Resources Research, v. 21, no. 5, p. 715–723. [Also available at http://dx.doi.org/10.1029/WR021i005p00715.]

Winter, T.C., 2001, The concept of hydrologic landscapes: Journal of the American Water Resources Association, v. 37, no. 2, p. 335–349. [Also available at http://dx.doi.org/10.1111/j.1752-1688.2001.tb00973.x.]

Wolock, D.M., Winter, T.C., and McMahon, G., 2004, Delineation and evaluation of hydrologic-landscape regions in the United States using geographic information system tools and multivariate statistical analyses: Environmental Management, v. 34, supplement 1, p. S71–S88. [Also available at http://dx.doi.org/10.1007/s00267-003-5077-9.]

Ziegeweid, J.R., Lorenz, D.L., Sanocki, C.A., and Czuba, C.R., 2015, Methods for estimating flow-duration curve and low-flow frequency statistics for ungaged locations on small streams in Minnesota: U.S. Geological Survey Scientific Investigations Report 2015–5170, 29 p. [Also available at http://dx.doi.org/10.3133/sir20155170.]

Ziegeweid, J.R., and Magdalene, Suzanne, 2015, Development of regression equations to revise estimates of historical streamflows for the St. Croix River at Stillwater, Minnesota (water years 1910–2011), and Prescott, Wisconsin (water years 1910–2007): U.S. Geological Survey Scientific Investigations Report 2014–5239, 23 p. [Also available at http://dx.doi.org/10.3133/sir20145239.]

Table 1

Table 1. Index streamgages in Minnesota and neighboring States.

[Water year is the 12-month period of October 1 through September 30 and is designated by the calendar year in which it ends. Minn., Minnesota; Wis., Wisconsin; N. Dak., North Dakota; S. Dak., South Dakota]

Map number (fig. 1)	Station number	Station name	Region	Drainage area (square miles)	Water years with streamflow record
1	04010500	Pigeon River at Middle Falls near Grand Portage, Minn.	BC	607	1921–22, 1924–2012
2	04012500	Poplar River at Lutsen, Minn.	BC	113	1913–17, 1930–32, 1934–47, 1953–61, 2008–11
3	04014500	Baptism River near Beaver Bay, Minn.	BC	138	1930–47, 1949–93, 2009–10
4	04017000	Embarrass River at Embarrass, Minn.	BC	94.5	1943–64
5	04018900	East Two River near Iron Junction, Minn.	BC	41.7	1967–79
6	04019300	West Swan River near Silica, Minn.	BC	15.3	1963–78
7	04019500	East Swan River near Toivola, Minn.	BC	136	1954–62, 1965–71
8	04024098	Deer Creek near Holyoke, Minn.	BC	7.56	1977–2001
9	04024430	Nemadji River near South Superior, Wis.	BC	421	1974–2012
10	04025500	Bois Brule River at Brule, Wis.	BC	151	1943–81, 1984–2012
11	040263205	Whittlesey Creek near Ashland, Wis.	BC	11.4	1999–2012
12	040263491	North Fish Creek near Moquah, Wis.	BC	84.9	1990–91, 1995–97, 2001–10
13	04027000	Bad River near Odanah, Wis.	BC	596	1915–22, 1948–2012
14	05047500	Mustinka River above Twelvemile Creek near Charlesville, Minn.	D	200	1943–55
15	05048000	Mustinka River below Twelvemile Creek near Charlesville , Minn.	D	722	1943–55
16	05049000	Mustinka River above Wheaton, Minn.	D	787	1916–17, 1919–24, 1931–58
17	05051600	Wild Rice River near Rutland, N. Dak.	D	414	1960–2012
18	05051650	La Belle Creek near Veblen, S. Dak.	D	9.49	1988–99
19	05059600	Maple River near Hope, N. Dak.	A	20.6	1965–2012
20	05059700	Maple River near Enderlin, N. Dak.	A	824	1956–2012
21	05060000	Maple River near Mapleton, N. Dak.	A	1,440	1959–75, 2001–12
22	05060500	Rush River at Amenia, N. Dak.	A	91.6	1947–2012
23	05061000	Buffalo River near Hawley, Minn.	A	336	1945–80, 1983–2012
24	05061500	South Branch Buffalo River at Sabin, Minn.	A	461	1945–80, 1984–2012
25	05062000	Buffalo River near Dilworth, Minn.	A	986	1931–2012
26	05062500	Wild Rice River at Twin Valley, Minn.	A	934	1910–17, 1931–83, 1990–2001, 2003–12
27	05066500	Goose River at Hillsboro, N. Dak.	A	1,190	1931–32, 1934–2012
28	05069000	Sand Hill River at Climax, Minn.	A	459	1943–2012
29	05077700	Ruffy Brook near Gonvick, Minn.	A	46.7	1960–78, 1986
30	05078000	Clearwater River at Plummer, Minn.	A	553	1939–79, 1982–2012

Table 1. Index streamgages in Minnesota and neighboring States.—Continued

[Water year is the 12-month period of October 1 through September 30 and is designated by the calendar year in which it ends. Minn., Minnesota; Wis., Wisconsin; N. Dak., North Dakota; S. Dak., South Dakota]

Map number (fig. 1)	Station number	Station name	Region	Drainage area (square miles)	Water years with streamflow record
31	05078230	Lost River at Oklee, Minn.	A	249	1960–2012
32	05078500	Clearwater River at Red Lake Falls, Minn.	A	1,360	1910–17, 1935–2012
33	05083000	Turtle River at Manvel, N. Dak.	A	518	1946–70
34	05087500	Middle River at Argyle, Minn.	A	251	1945, 1951–2012
35	05088000	South Branch Park River near Park River, N. Dak.	A	185	1940–50
36	05089100	Middle Branch Park River near Union, N. Dak.	A	13	1966–86
37	05089500	Cart Creek at Mountain, N. Dak.	A	13.2	1955–84
38	05092200	Pembina County Drain 20 near Glasston, N. Dak.	A	81.3	1972–86
39	05093000	South Branch Two Rivers at Pelan, Minn.	A	272	1929–38, 1954–56
40	05095000	Two Rivers at Hallock, Minn.	A	670	1911–14, 1929–30, 1941–43, 2008–11
41	05095500	Two Rivers below Hallock, Minn.	A	691	1945–55
42	05096000	North Branch Two Rivers near Lancaster, Minn.	A	31.6	1929–38, 1941–55
43	05101500	Tongue River at Cavalier, N. Dak.	A	158	1939–51
44	05104000	South Fork Roseau River near Malung, Minn.	A	214	1911–14, 1929–38, 1940–46
45	05104500	Roseau River below South Fork near Malung, Minn.	A	428	1947–2012
46	05106000	Sprague Creek near Sprague, Manitoba, Canada	A	164	1929–81, 2000–12
47	05107000	Pine Creek near Pine Creek, Minn.	A	31.1	1929–53
48	05107500	Roseau River at Ross, Minn.	A	1,010	1929–91, 1995–2012
49	05112000	Roseau River below State Ditch 51 near Caribou, Minn.	A	1,410	1917, 1920–19, 1970–2012
50	05124480	Kawishiwi River near Ely, Minn.	BC	251	1966–2012
51	05124500	Isabella River near Isabella, Minn.	BC	340	1953–61, 1976–77
52	05124990	Filson Creek In Sesw Sec. 24 near Winton, Minn.	BC	9.52	1975–85
53	05125000	South Kawishiwi River near Ely, Minn.	BC	442	1952–61, 1976–78, 2003–12
54	05125500	Stony River near Isabella, Minn.	BC	175	1953–64
55	05126500	Bear Island River near Ely, Minn.	BC	65.8	1953–62, 1975–77
56	05127205	Burntside River near Ely, Minn.	BC	68.8	1967–78
57	05127210	Armstrong Creek near Ely, Minn.	BC	5.83	1967–78
58	05127215	Longstorff Creek near Ely, Minn.	BC	8.09	1967–78
59	05127220	Burgo Creek near Ely, Minn.	BC	2.98	1967–78
60	05127230	Shagawa River at Ely, Minn.	BC	99.6	1967–78

Table 1. Index streamgages in Minnesota and neighboring States.—Continued

[Water year is the 12-month period of October 1 through September 30 and is designated by the calendar year in which it ends. Minn., Minnesota; Wis., Wisconsin; N. Dak., North Dakota; S. Dak., South Dakota]

Map number (fig. 1)	Station number	Station name	Region	Drainage area (square miles)	Water years with streamflow record
61	05128500	Pike River near Embarrass, Minn.	BC	114	1954–64, 1977–78
62	05129115	Vermilion River near Crane Lake, Minn.	BC	909	1980–2012
63	05130500	Sturgeon River near Chisholm, Minn.	BC	186	1943–2009
64	05131500	Little Fork River at Littlefork, Minn.	BC	1,700	1910–16, 1929–2012
65	05132000	Big Fork River at Big Falls, Minn.	BC	1,500	1910, 1929–79, 1983–93, 1998–2012
66	05134200	Rapid River near Baudette, Minn.	A	581	1957–85, 2008–11
67	05139500	Warroad River near Warroad, Minn.	A	168	1946–80
68	05140000	Bulldog Run near Warroad, Minn.	A	11.2	1946–51, 1966–77
69	05140500	East Branch Warroad River near Warroad, Minn.	A	51.2	1946–54, 1966–77
70	05212700	Prairie River near Taconite, Minn.	BC	364	1967–83, 2001–12
71	05217000	Swan River near Warba, Minn.	BC	245	1954–69
72	05244000	Crow Wing River at Nimrod, Minn.	BC	917	1910–14, 1931–81, 1992–2012
73	05245100	Long Prairie River at Long Prairie, Minn.	BC	448	1972–2012
74	05270500	Sauk River near St. Cloud, Minn.	BC	1,040	1910–13, 1929–81, 1991–2012
75	05275000	Elk River near Big Lake, Minn.	BC	555	1911–17, 1931–87, 1991–2012
76	05276000	North Fork Crow River near Regal, Minn.	D	210	1944–54
77	05278500	South Fork Crow River at Cosmos, Minn.	D	234	1945–64
78	05279000	South Fork Crow River near Mayer, Minn.	D	1,150	1934–79
79	05280000	Crow River at Rockford, Minn.	D	2,640	1909–17, 1929–2012
80	05286000	Rum River near St. Francis, Minn.	BC	1,390	1929–2012
81	05287890	Elm Creek near Champlin, Minn.	BC	86.9	1979–2012
82	05289985	Big Coulee Creek near Peever, S. Dak.	D	12.1	1988–2003
83	05290000	Little Minnesota River near Peever, S. Dak.	D	449	1940–81, 1990–2002, 2009–12
84	05291000	Whetstone River near Big Stone City, S. Dak.	D	406	1910–12, 1931–2012
85	05292704	North Fork Yellow Bank River near Odessa, Minn.	D	209	1992–2003
86	05293000	Yellow Bank River near Odessa, Minn.	D	459	1940–99, 2001–12
87	05294000	Pomme De Terre River at Appleton, Minn.	D	865	1931–99, 2004–12
88	05299700	Cobb Creek near Gary, S. Dak.	D	70.4	1993–2002
89	05300000	Lac Qui Parle River near Lac Qui Parle, Minn.	D	959	1910–14, 1931–32, 1934–99, 2001–12
90	05304500	Chippewa River near Milan, Minn.	D	1,870	1938–2012

Table 1. Index streamgages in Minnesota and neighboring States.—Continued

[Water year is the 12-month period of October 1 through September 30 and is designated by the calendar year in which it ends. Minn., Minnesota; Wis., Wisconsin; N. Dak., North Dakota; S. Dak., South Dakota]

Map number (fig. 1)	Station number	Station name	Region	Drainage area (square miles)	Water years with streamflow record
91	05311400	South Branch Yellow Medicine River at Minneota, Minn.	D	115	1960–81, 1983–87
92	05313500	Yellow Medicine River near Granite Falls, Minn.	D	667	1931–38, 1940–2012
93	05315000	Redwood River near Marshall, Minn.	D	259	1940–2012
94	05316500	Redwood River near Redwood Falls, Minn.	D	624	1910–14, 1931–2012
95	05317000	Cottonwood River near New Ulm, Minn.	D	1,310	1910–13, 1931–37, 1939–2012
96	05317200	Little Cottonwood River near Courtland, Minn.	D	169	1974–2009
97	05318000	East Branch Blue Earth River near Bricelyn, Minn.	D	120	1951–70
98	05319500	Watonwan River near Garden City, Minn.	D	847	1940–45, 1977–2012
99	05320270	Little Cobb River near Beauford, Minn.	D	128	1996–99, 2002–12
100	05320500	Le Sueur River near Rapidan, Minn.	D	1,110	1940–45, 1950–2012
101	05327000	High Island Creek near Henderson, Minn.	D	240	1974–2012
102	05331833	Namekagon River at Leonards, Wis.	BC	126	1996–2001, 2005–12
103	05333500	St. Croix River near Danbury, Wis.	BC	1,540	1914–81, 1985–2012
104	05336000	St. Croix River near Grantsburg, Wis.	BC	2,960	1923–70, 2008–10
105	05336200	Glaisby Brook near Kettle River, Minn.	BC	26.4	1960–70
106	05336700	Kettle River below Sandstone, Minn.	BC	871	1968–2012
107	05338500	Snake River near Pine City, Minn.	BC	969	1914–17, 1952–81, 1992–2012
108	05340000	Sunrise River near Stacy, Minn.	BC	168	1949–64
109	05353800	Straight River near Faribault, Minn.	D	436	1966–2012
110	05365000	Duncan Creek at Chippewa Falls, Wis.	BC	118	1943–55
111	05366500	Eau Claire River near Fall Creek, Wis.	BC	759	1943–55
112	053674464	Yellow River at Barron, Wis.	BC	140	1992–2005
113	05367500	Red Cedar River near Colfax, Wis.	BC	1,090	1914–61, 1990
114	05368000	Hay River at Wheeler, Wis.	BC	432	1951–2012
115	05369945	Eau Galle River at Low-wtr Bridge at Spring Valley, Wis.	F	48	1982–83, 1986–95
116	05370500	Eau Galle River at Elmwood, Wis.	F	91.6	1943–53
117	05372000	Buffalo River near Tell, Wis.	F	403	1933–51
118	05374000	Zumbro River at Zumbro Falls, Minn.	F	1,150	1910–17, 1929–80
119	05374500	Zumbro River at Theilman, Minn.	F	1,340	1938–56
120	05374900	Zumbro River at Kellogg, Minn.	F	1,420	1976–90, 2010–12

Table 1. Index streamgages in Minnesota and neighboring States.—Continued

[Water year is the 12-month period of October 1 through September 30 and is designated by the calendar year in which it ends. Minn., Minnesota; Wis., Wisconsin; N. Dak., North Dakota; S. Dak., South Dakota]

Map number (fig. 1)	Station number	Station name	Region	Drainage area (square miles)	Water years with streamflow record
121	05376000	North Fork Whitewater River near Elba, Minn.	F	100	1940–41, 1968–93
122	05376500	South Fork Whitewater River near Altura, Minn.	F	78	1940–71
123	05376800	Whitewater River near Beaver, Minn.	F	271	1975–85, 1991, 1994–99, 2008–12
124	05377500	Whitewater River at Beaver, Minn.	F	288	1940–56
125	05378183	Joos Valley Creek near Fountain City, Wis.	F	6.02	1991–95, 2003–07
126	05378185	Eagle Creek at Ct Highway G near Fountain City, Wis.	F	14.4	1991–95, 2003–07
127	05378300	Straight Valley Creek near Rollingstone, Minn.	F	5.12	1971–85
128	05379400	Trempealeau River at Arcadia, Wis.	F	554	1961–77, 2002–04
129	05379500	Trempealeau River at Dodge, Wis.	F	626	1914–19, 1934–2012
130	05382325	La Crosse River at Sparta, Wis.	F	168	1993–2005, 2009–12
131	05382500	Little La Crosse River near Leon, Wis.	F	77.4	1934–61, 1979–81
132	05383950	Root River near Pilot Mound, Minn.	F	566	2003–12
133	05384000	Root River near Lanesboro, Minn.	F	616	1910–14, 1916–17, 1941–85, 1987–90
134	05384500	Rush Creek near Rushford, Minn.	F	132	1943–79
135	05385000	Root River near Houston, Minn.	F	1,250	1910–17, 1929–83, 1991–2000, 2004–08
136	05386000	Root River below South Fork near Houston, Minn.	F	1,540	1938–61
137	05387440	Upper Iowa River at Bluffton, Iowa	F	367	2003–12
138	05387500	Upper Iowa River at Decorah, Iowa	F	511	1952–83, 2003–12
139	05388000	Upper Iowa River near Decorah, Iowa	F	569	1914, 1919–27, 1934–51
140	05388250	Upper Iowa River near Dorchester, Iowa	F	768	1939, 1976–2012
141	05388500	Paint Creek at Waterville, Iowa	F	41.7	1953–73
142	05389000	Yellow River near Ion, Iowa	F	219	1935–51, 2005–12
143	05389400	Bloody Run Creek near Marquette, Iowa	F	34.3	1992–2012
144	05404116	West Branch Baraboo River at Hillsboro, Wis.	F	39	1989–2012
145	05407470	Kickapoo River at State Highway 33 at Ontario, Wis.	F	117	2002–12
146	05408000	Kickapoo River at La Farge, Wis.	F	266	1939–2012
147	05408500	Knapp Creek near Bloomingdale, Wis.	F	8.48	1955–69
148	05409830	North Fork Nederlo Creek near Gays Mills, Wis.	F	2.28	1968–79
149	05409890	Nederlo Creek near Gays Mills, Wis.	F	10.1	1968–80
150	05410000	Kickapoo River at Gays Mills, Wis.	F	616	1914–34, 1964–77

Table 1. Index streamgages in Minnesota and neighboring States.—Continued

[Water year is the 12-month period of October 1 through September 30 and is designated by the calendar year in which it ends. Minn., Minnesota; Wis., Wisconsin; N. Dak., North Dakota; S. Dak., South Dakota]

Map number (fig. 1)	Station number	Station name	Region	Drainage area (square miles)	Water years with streamflow record
151	05410490	Kickapoo River at Steuben, Wis.	F	687	1983–2012
152	05410500	Kickapoo River-old Site-at Steuben, Wis.	F	689	1933–82
153	05411400	Sny Magill Creek near Clayton, Iowa	F	27.6	1992–2001
154	05411600	Turkey River at Spillville, Iowa	F	177	1957–73, 1978–91, 2010–12
155	05411850	Turkey River near Eldorado, Iowa	F	641	2001–12
156	05412000	Turkey River at Elkader, Iowa	F	894	1933–42
157	05412020	Turkey River above French Hollow Cr at Elkader, Iowa	F	906	2002–12
158	05412060	Silver Creek near Luana, Iowa	F	4.11	1986–98
159	05412100	Roberts Creek above Saint Olaf, Iowa	F[1]	70.6	1986–2001
160	05420560	Wapsipinicon River near Elma, Iowa	D	96.5	1959–92
161	05420680	Wapsipinicon River near Tripoli, Iowa	D	346	1996–98, 2001–04, 2007–12
162	05448500	West Branch Iowa River near Klemme, Iowa	D	115	1948–58
163	05449000	East Branch Iowa River near Klemme, Iowa	D	134	1948–76, 1978–95
164	05457700	Cedar River at Charles City, Iowa	D	1,070	1965–95, 1997, 2001–12
165	05458000	Little Cedar River near Ionia, Iowa	D	297	1955–2012
166	05459000	Shell Rock River near Northwood, Iowa	D	302	1946–86
167	05459500	Winnebago River at Mason City, Iowa	D	488	1933–2012
168	05460500	Shell Rock River at Marble Rock, Iowa	D	1,300	1943–53
169	05476000	Des Moines River at Jackson, Minn.	D	1,240	1931–2012
170	05476500	Des Moines River at Estherville, Iowa	D	1,400	1952–94
171	05478000	East Fork Des Moines River near Burt, Iowa	D	421	1952–74
172	06479215	Big Sioux River near Florence, S. Dak.	E	68.2	1985–12
173	06479438	Big Sioux River near Watertown, S. Dak.	E	525	1973–2012
174	06479515	Willow Creek near Watertown, S. Dak.	E	109	1972–86
175	06479529	Stray Horse Creek near Castlewood, S. Dak.	E	74.1	1969–85
176	06479640	Hidewood Creek near Estelline, S. Dak.	E	163	1969–85
177	06479770	Big Sioux River near Bruce, S. Dak.	E	2,400	2001–12
178	06479910	Sixmile Creek near Brookings, S. Dak.	E	60.1	1971–80
179	06479980	Medary Creek near Brookings, S. Dak.	E	197	1981–90
180	06480400	Spring Creek near Flandreau, S. Dak.	E	61.3	1983–93

Table 1. Index streamgages in Minnesota and neighboring States.—Continued

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Map number (fig. 1)	Station number	Station name	Region	Drainage area (square miles)	Water years with streamflow record
181	06480650	Flandreau Creek above Flandreau, S. Dak.	E	101	1982–91
182	06481480	Skunk Creek near Chester, S. Dak.	E	262	1985–87, 2002–12
183	06481500	Skunk Creek at Sioux Falls, S. Dak.	E	620	1948–2001, 2004–12
184	06482610	Split Rock Creek at Corson, S. Dak.	E	482	1966–89, 2002–12
185	06483270	Rock River at Rock Rapids, Iowa	E	788	1960–74
186	06483290	Rock River below Tom Creek at Rock Rapids, Iowa	E	844	2001–12
187	06483500	Rock River near Rock Valley, Iowa	E	1,580	1949–2012
188	06484000	Dry Creek at Hawarden, Iowa	E	49	1949–69
189	06485696	Brule Creek near Elk Point, S. Dak.	E	205	1983–94
190	06600100	Floyd River at Alton, Iowa	E	266	1956–2012
191	06600300	West Branch Floyd River near Struble, Iowa	E	178	1956–94
192	06603000	Little Sioux River near Lakefield, Minn.	D	15.6	1949–62
193	06603500	Jackson County Ditch #11 near Lakefield, Minn.	D	7.65	1949–60
194	06605000	Ocheyedan River near Spencer, Iowa	D	438	1978–2012
195	06605600	Little Sioux River at Gillett Grove, Iowa	D	1,350	1959–73
196	06605850	Little Sioux River at Linn Grove, Iowa	D	1,560	1973–2012

[1] Not used in analysis.

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