Prepared in cooperation with the Montana Department of Natural Resources and Conservation, North Dakota Department of Water Resources, South Dakota Department of Transportation, and Wyoming Water Development Office

Methods for Peak-Flow Frequency Analysis for Streamgages in or near Montana, North Dakota, South Dakota, and Wyoming

Scientific Investigations Report 2025–5019

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

Cover. Photographs showing (clockwise from top left) flooding at U.S. Geological Survey (USGS) streamgage 06207500 on Clarks Fork Yellowstone River near Belfry, Montana, taken by Dennis Elliott (USGS) on June 13, 2022; flooding at USGS streamgage 05116000 on Souris River near Foxholm, North Dakota, taken by Brent Hanson (USGS) on June 30, 2011; flooding at USGS streamgage 09258980 on Muddy Creek below Young Draw near Baggs, Wyoming, taken by Eric Blajszczak (USGS) on April 13, 2023; and flooding at USGS streamgage 06479010 on Vermillion River near Vermillion, South Dakota, taken by Tyler Meyer (USGS) and Jesse Rigge (USGS) on June 24, 2024.

Methods for Peak-Flow Frequency Analysis for Streamgages in or near Montana, North Dakota, South Dakota, and Wyoming

By Seth A. Siefken, Tara Williams-Sether, Nancy A. Barth, Katherine J. Chase, and Mark A. Cedar Face

Prepared in cooperation with the Montana Department of Natural Resources and Conservation, North Dakota Department of Water Resources, South Dakota Department of Transportation, and Wyoming Water Development Office

Scientific Investigations Report 2025–5019

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

U.S. Geological Survey, Reston, Virginia: 2025

For more information on the USGS—the Federal source for science about the Earth, its natural and living resources, natural hazards, and the environment—visit https://www.usgs.gov or call 1–888–392–8545.

For an overview of USGS information products, including maps, imagery, and publications, visit https://store.usgs.gov/ or contact the store at 1–888–275–8747.

Suggested citation:
Siefken, S.A., Williams-Sether, T., Barth, N.A., Chase, K.J., and Cedar Face, M.A., 2025, Methods for peak-flow frequency analysis for streamgages in or near Montana, North Dakota, South Dakota, and Wyoming: U.S. Geological Survey Scientific Investigations Report 2025–5019, 19 p., https://doi.org/10.3133/sir20255019.

Associated data for this publication:
Siefken, S.A., Williams-Sether, T., Barth, N.A., Taylor, N.J., Hamilton, W.B., and Cedar Face, M.A., 2025, Peak-flow frequency analyses for selected streamgages in Montana, North Dakota, South Dakota, and Wyoming: U.S. Geological Survey data release, https://doi.org/10.5066/P1WHRK8H.

U.S. Geological Survey, 2024, USGS water data for the Nation: U.S. Geological Survey National Water Information System database, https://doi.org/10.5066/F7P55KJN.

ISSN 2328-0328 (online)

Acknowledgments

The authors would like to thank the staff at our local partner agencies who supported this work, especially Doug Brugger and Steve Story from the Montana Department of Natural Resources and Conservation, Steve Johnson and Kevin Marton from the South Dakota Department of Transportation, Mike Hall and Aaron Carranza from the North Dakota Department of Water Resources, and Barry Lawrence, Mabel Jones, and Chace Tavelli from the Wyoming Water Development Office.

The authors would like to thank Dan Armstrong (U.S. Geological Survey [USGS]) and Olivia Drukker (USGS) for their assistance in preparing the map for this report. The authors also acknowledge the contribution of Steve Sando (USGS) and Peter McCarthy (USGS) for their Montana peak-flow frequency methods report upon which this report was modeled.

Lastly, we would like to acknowledge our colleague and friend Chuck Parrett (1945–2024), USGS hydrologist in Montana and California who developed and refined methods for understanding floods throughout the United States. Chuck mentored countless scientists within and outside the USGS. He will be missed.

Contents

Figures

Conversion Factors

U.S. customary units to International System of Units

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
acre	4,047	square meter (m^2)
acre	0.4047	hectare (ha)
acre	0.4047	square hectometer (hm^2)
acre	0.004047	square kilometer (km^2)
square mile (mi^2)	259.0	hectare (ha)
square mile (mi^2)	2.590	square kilometer (km^2)
	Volume	
acre-foot (acre-ft)	1,233	cubic meter (m^3)
acre-foot (acre-ft)	0.001233	cubic hectometer (hm^3)
	Flow rate	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)

Datums

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

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

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

Supplemental Information

A water year is the 12-month period from October 1 through September 30 of the following calendar year. The water year is designated by the calendar year in which it ends. For example, water year 2025 is the period from October 1, 2024, through September 30, 2025.

Abbreviations

AEP	annual exceedance probability
BWLS/BGLS	Bayesian weighted least squares/Bayesian generalized least squares
CSG	crest-stage gage
EMA	expected moments algorithm
MGBT	multiple Grubbs-Beck test
MOVE.3	Maintenance of Variance Extension type III
NWIS	National Water Information System
PILF	potentially influential low flood
RRE	regional regression equation
USGS	U.S. Geological Survey

Methods for Peak-Flow Frequency Analysis for Streamgages in or near Montana, North Dakota, South Dakota, and Wyoming

By Seth A. Siefken, Tara Williams-Sether, Nancy A. Barth, Katherine J. Chase, and Mark A. Cedar Face

Abstract

The U.S. Geological Survey, in cooperation with the Montana Department of Natural Resources and Conservation, North Dakota Department of Water Resources, South Dakota Department of Transportation, and the Wyoming Water Development Office, has developed standard methods of peak-flow frequency analysis for studies in Montana, North Dakota, South Dakota, and Wyoming. These methods describe the implementation of national flood frequency guidelines described in Bulletin 17C (https://doi.org/10.3133/tm4B5) for the four States and deviations from Bulletin 17C standard procedures to accommodate unusual hydrologic conditions. A U.S. Geological Survey data release accompanying this report (https://doi.org/10.5066/P1WHRK8H) provides example peak-flow frequency analyses for selected streamgages in the study area. The methods described in this report can be used to publish similar data releases for other streamgages in the study area.

Introduction

The U.S. Geological Survey, in cooperation with the Montana Department of Natural Resources and Conservation, North Dakota Department of Water Resources, South Dakota Department of Transportation, and the Wyoming Water Development Office, has developed standard methods of peak-flow frequency analysis for studies in Montana, North Dakota, South Dakota, and Wyoming. The U.S. Geological Survey (USGS) Techniques and Methods report by England and others (2018), hereafter referenced as Bulletin 17C, describes procedures for computing peak-flow frequency from annual peak-flow data recorded at streamgages. This report describes the application of Bulletin 17C guidelines for studies published by the USGS for Montana, North Dakota, South Dakota, and Wyoming. These procedures cover standard Bulletin 17C analysis, deviations from Bulletin 17C to accommodate sites with unusual hydrologic conditions such as artificial streamflow alteration or mixed-population floods, and methods to improve analyses using Maintenance of Variance Extension type III (MOVE.3) record extension (Vogel and Stedinger, 1985) and weighting with regional regression equations (RREs) following the method of Sando and McCarthy (2018). Substantial reference throughout this report is made to the national guidelines for flood frequency analysis published in Bulletin 17C and previous guidelines published for Montana (Sando and McCarthy, 2018). Specific citations to these references are provided; however, some phrases and terminology from these documents are used without citation to facilitate the presentation of information.

Purpose and Scope

The purpose of this report is to document the methods used for peak-flow frequency analysis for streamgages in Montana, North Dakota, South Dakota, Wyoming, and nearby, hydrologically similar locations used to inform regional studies in these States. A USGS data release accompanying this report (Siefken and others, 2025) presents peak-flow frequency analyses for example streamgages in various hydrologic settings within the study area. The data release includes tables and plots that document the interpretive decisions involved in the analysis and present the results of the analysis, as well as data and specification files for the analysis. The methods documented in this report update methods published for Montana (Sando and McCarthy, 2018), North Dakota (Williams-Sether, 2015), South Dakota (Sando, 1998), and Wyoming (Miller, 2003).

The USGS is just one of many government agencies that use peak-flow frequency statistics. When possible, coordination between the USGS and other government agencies on future peak-flow frequency analyses that follow the methods in this report can aid in ensuring consistency between USGS analyses and those from other agencies.

Terminology

This report describes methods of peak-flow frequency analysis in the context of quantifying flood risk. Within this report, the terms “peak flow” and “flood” are defined as in Sando and McCarthy (2018, p. 2), “A flood is any high streamflow that overtops the natural or artificial banks of a stream and is defined on the basis of stage. An annual peak flow is the annual maximum instantaneous discharge recorded for each water year (October 1 through September 30 and designated by the calendar year in which it ends) that an individual streamgage is operated and is defined on the basis of discharge. The stage associated with a given annual peak flow might not overtop the river banks and thus the peak flow might not qualify as a flood. Conversely, multiple floods that overtop the stream banks might happen in a single year. In various frequency-analysis literature the terms ‘peak flow’ and ‘flood’ are sometimes used synonymously.” In this report, ‘peak flow’ is the preferred term in referring to discharge-based data; however, in some cases ‘flood’ is used in describing large streamflow events that exceed river banks and also in discussion of information taken from references in which the terms ‘peak flow’ and ‘flood’ are used synonymously. In this report, some uses of the term “peak-flow frequency” are shortened to “frequency.”

Description of Study Area

The study area covers the four States of Montana, South Dakota, North Dakota, and Wyoming, as well as nearby areas with similar hydrologic characteristics where streamgages may provide regional information for one or more of the four States. The four States cover a combined area of 393,000 square miles with considerable variation in climate, topography, and hydrology. Peak flows in the western part of the study area are driven primarily by snowmelt, while in the Dakotas and the central and eastern parts of Montana and Wyoming, peak flows are driven by more complex mechanisms that can include both rainfall and snowmelt. The following sections provide an overview of the hydroclimatic factors that drive annual peak flows in each State in the study region.

Montana

Montana is the largest State in the study and spans three major drainage basins—the Missouri River Basin, the Columbia River Basin, and the Hudson Bay Basin, as shown in figure 1. Elevations across the State range from about 1,800 to 12,800 feet (ft) above the North American Vertical Datum of 1988 (NAVD 88), leading to large variations in temperature and precipitation (Frankson and others, 2022a). The topography of western Montana is mountainous, whereas the eastern part of the State consists of rolling plains. In the central part of the State are several isolated mountain ranges surrounded by wide valleys and open plains. At the transition between mountains and plains, orographic effects can produce intense rainfall resulting in large floods (Hansen and others, 1988; Sando and McCarthy, 2018).

High elevation regions in the western part of the State accumulate large snowpacks from late fall through early spring. Melting snowpack contributes much of the annual runoff in western Montana (Sando and McCarthy, 2018). Snowpack is more variable in the lower elevation eastern part of Montana. In some years, large snowpacks accumulate on the plains, the rapid melting of which can result in substantial flooding, such as the widespread flooding on the Milk River in 1952 (Wells, 1955). In other years, runoff from prairie snowpack may be minimal, and rainfall may be the primary source of runoff on prairie streams. Pederson and others (2011) provide further information on the contributions of rainfall and snowmelt on annual peak flow.

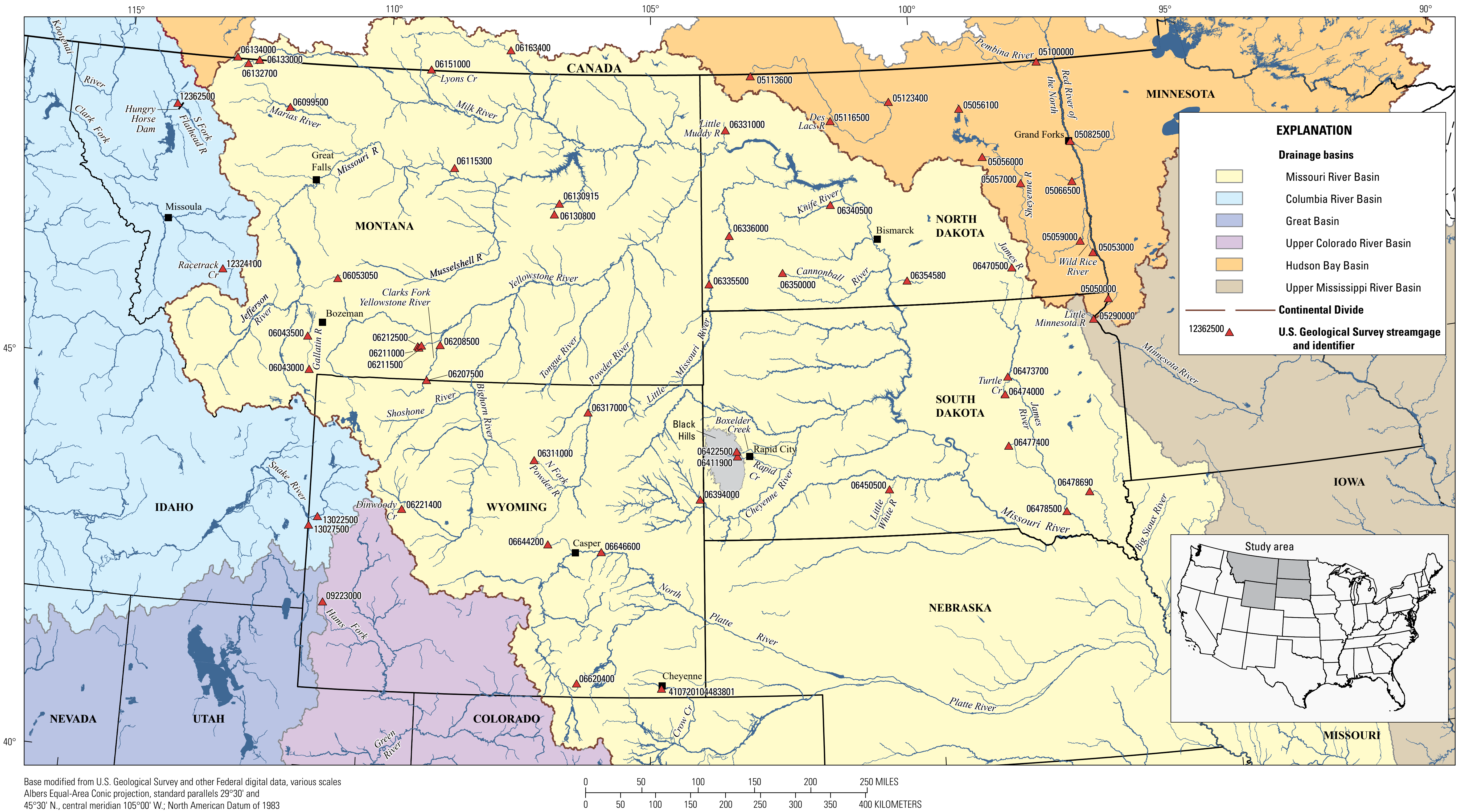
Many of the largest floods in Montana have resulted from spring rainfall coinciding with snowmelt runoff. Such large floods have occurred in 1908 (National Weather Service, 2024b), 1953 (Wells, 1957), 1964 (Boner and Stermitz, 1967), 1975 (Johnson and Omang, 1976), and 2022 (Chase and others, 2024). Other floods, such as those in southeastern Montana in 1978 (Parrett and others, 1984) and central Montana in 2011 (National Weather Service, 2024b) resulted almost entirely from rainfall.

North Dakota

North Dakota is separated into two major drainage basins by a Continental Divide running from the northwest to the southeastern part of the State, as shown in figure 1. The part of the State northeast of this Continental Divide falls within the Hudson Bay Basin, and the southwestern part falls within the Missouri River Basin. Elevations across the State range from about 750 to 3,500 ft above NAVD 88 (Williams-Sether, 1992). The topography of North Dakota is predominated by rolling plains with occasional buttes and bluffs but no mountains.

The climate of North Dakota is best described as semiarid; precipitation is highly variable, and humidity is low (Enz, 2003). Cycles of persistent dry or wet conditions within North Dakota may greatly affect floods. Floods in the Hudson Bay Basin in North Dakota are mainly associated with rapid spring snowmelt, which may be accompanied by rain. In general, the later spring snowmelt begins, the more likely it will be accelerated by high temperatures, rainfall, or both, making flooding more likely (Enz, 2003). Floods in the Missouri River Basin in North Dakota are mainly associated with spring snowmelt or heavy summer rainfall. Local floods occur occasionally on all the tributaries within both basins.

Notable floods in North Dakota have usually followed years where the snowpack is large and spring snowmelt is rapid. The Red River of the North and its tributaries in eastern North Dakota have a rich history of flood records that date back to the 1700s (Ryberg and others, 2007). Some floods that have affected the entire State were in 1950, 1997, 2009, and 2011 (Macek-Rowland and Gross, 2011; National Weather Service, 2024c).



Base modified from U.S. Geological Survey and other Federal digital data, various scales
Albers Equal-Area Conic projection, standard parallels 29°30′ and
45°30′ N., central meridian 105°00′ W.; North American Datum of 1983

Figure 1. Map showing locations of basins and selected streamgages from Siefken and others (2025) in Montana, Wyoming, North Dakota, and South Dakota used as examples accompanying this report.

South Dakota

South Dakota is primarily within the Missouri River Basin, although small parts of eastern South Dakota drain into the Hudson Bay Basin through the Red River of the North or the Upper Mississippi River Basin through the Minnesota River (fig. 1). Elevations in the State range from about 1,000 ft above NAVD 88 in the northeast to more than 7,000 ft above NAVD 88 in the Black Hills area (fig. 1). Most of western South Dakota is well drained, and contributing drainage areas are equal to the total drainage areas for most streamgages (Sando and others, 2008). In contrast, many parts of eastern South Dakota are relatively flat and poorly drained with large volumes of depression storage. Additionally, the low channel gradients in some parts of eastern South Dakota frequently result in backwater conditions during flood stages (Thompson, 2006). These hydrogeologic features may have substantial effects on the behaviors of annual peak flows in eastern South Dakota because of long-term persistence of antecedent moisture over weeks, months, or even years (Sando and others, 2008).

Flood-generating mechanisms in South Dakota include snowmelt, intense rainfall events, and rain-on-snow events. Smaller spring floods occur when the river ice breakup is earlier in the spring and the rate of snowmelt is slow, thus reducing the magnitude of the peak. In contrast, the largest river ice breakup floods are caused by high antecedent moisture, heavy snow cover, frozen ground surface, and precipitation coinciding with a late seasonal river ice breakup (McCabe and Crosby, 1959).

Some of the largest floods on record, such as in the Black Hills, are generated by localized summertime convective storms that produce heavy precipitation over a short period of time, including the June 9, 1972, flood, during which 15 inches of rain fell in about 6 hours near Nemo, South Dakota (Schwarz and others, 1975). The 1984, 1995, and 1997 regional floods, primarily in eastern South Dakota, were generated by multiple causal mechanisms: higher than average antecedent moisture conditions, high winter snowfall, springtime snowmelt, and heavy precipitation in April and May (Engel and Benson, 1987; Teller and others, 1995; Teller and Burr, 1998; Holmes and others, 2013).

Wyoming

Wyoming is separated into four major drainage basins—the Missouri River Basin, the Columbia River Basin, the Upper Colorado River Basin, and the Great Basin, as shown in figure 1. All the flow from Wyoming into the Columbia River Basin is through the Snake River, and all the flow into the upper Colorado River is through the Green River. Elevations range from about 3,100 to 13,800 ft above NAVD 88, causing wide variations in temperature throughout the State (Frankson and others, 2022b). Northwestern Wyoming is dominated by high mountain ranges, whereas southern and eastern Wyoming are marked by high mountain ranges interspersed by wide expanses of arid plains. All four of Wyoming's river systems drain high, mountainous regions, but only the Missouri and Upper Colorado River Basins include substantial areas of plains or desert in Wyoming.

Mountain streamflows are typically dominated by snowmelt, and peak flows usually occur in late spring or early summer. Streams originating on the plains are frequently ephemeral, flowing for only short periods of time after local rainstorms or snowmelt, and generally have greater annual variability in peak flows than mountain streams (Miller, 2003). Timing of peak flows on these streams also tends to be more variable, and annual peak flows are commonly observed from later winter through late summer (Zelt and others, 1999).

Floods in Wyoming have resulted from rainfall (Rostvedt, 1965), and rain falling on snow (Rostvedt and others, 1970). Damaging floods resulting exclusively from snowmelt are unusual in Wyoming, although the third greatest discharge in the USGS peak-flow database (U.S. Geological Survey, 2024a) for a streamgage in Wyoming was at Snake River above Reservoir, near Alpine, Wyoming (USGS streamgage 13022500; U.S. Geological Survey, 2024t). That flood resulted primarily from melting of heavy snowpack in 1997 (National Weather Service, 2024a). The largest discharge in the streamgage record of Wyoming was at Powder River at Arvada, Wyo. (USGS streamgage 06317000; U.S. Geological Survey, 2024p), in the fall of 1923 because of heavy rainfall in late September (Follansbee and Hodges, 1925).

Methods for At-Site Peak-Flow Frequency Analysis

At-site peak-flow frequency analysis refers to analysis of peak-flow data collected at a streamgage that does not incorporate regional information from regression equations or MOVE.3 record extension. The frequency-analysis methods in this report follow the Bulletin 17C guidelines with allowance for informed-user adjustments to address special considerations for unusual peak-flow data.

The USGS peakfq software package (Siefken and others, 2024) is the primary tool for computing at-site peak-flow frequency estimates, although the methods could be applied with other software. The workflow for at-site frequency analysis consists of the following steps:

1. Collecting applicable data and applying any needed data preprocessing, such as data correction or data combination;

2. Analyzing the effect of nonstationarity, including upstream alteration or urbanization, and modifying the data accordingly;

3. Incorporating historical information with perception thresholds for ungaged periods of the analysis; and

4. Selecting appropriate analysis options for regional skew and low outlier thresholds.

Data Sources, Data Correction, and Data Combination

Data sources for use in peak-flow frequency analyses include systematic records and historical flood information (Bulletin 17C). The minimum record length of peak-flow data for a frequency analysis is 10 years (Bulletin 17C). For locations at which 10 years of peak-flow data are not available, the methods in this report should not be used for peak-flow frequency analysis. Even 10 years of data may not be sufficient to provide a reliable frequency analysis, particularly for sites with highly variable or highly skewed peak flows. If additional data from historical information or data combination are available for a streamgage, these data can be used to supplement streamgage data for at-site peak-flow frequency analysis.

Peak-flow data may be from either continuously operated streamgages or crest-stage gages (CSGs). CSGs only capture the peak streamflow at the site between site visits but provide a cost-effective method of collecting peak-flow data on small, remote streams. All data used in peak-flow frequency analysis should be carefully examined. Any unusually large or small peaks should be investigated to verify the data are not in error. Rarely, published peak-flow values may be corrected for use in peak-flow frequency analysis.

Systematic Records

The primary source of data for peak-flow frequency analyses is the USGS National Water Information System (NWIS) peak-flow database (U.S. Geological Survey, 2024a); however, peak-flow data are sometimes available from other data sources. For streamgages currently or previously operated jointly with Canada through the International Joint Commission, additional data may be available from Environment and Climate Change Canada. Data from other government or private sources may also provide valuable information for frequency analysis; however, any data from a source other than NWIS must be evaluated before use to verify data collection procedures meet appropriate quality standards for peak-flow frequency analysis. The data should be of a similar quality level to USGS peak-flow data as described in Rantz and others (1982).

Data Correction

Data correction refers to manually adjusting NWIS peak-flow data. These adjustments are applied in cases of unique hydrologic conditions that are not adequately captured in the NWIS database. Data corrections are documented in the peak-flow frequency-analysis data releases.

Peak flows affected by dam breaks are commonly addressed by data correction. A flow interval representing known upper and lower bounds of the peak flow without the effect of the dam break may be used or, if a detailed investigation of the dam break is available, a point value excluding the effect of the dam break may be substituted. For example, the 1964 peak flow of 241,000 cubic feet per second (ft^3/s) recorded for Marias River near Shelby, Montana (USGS streamgage 06099500; U.S. Geological Survey 2024d), was increased by an upstream dam break. In the example in the associated data release (Siefken and others, 2025), a value of 150,000 ft^3/s is substituted for the 1964 peak flow based on investigation of what the peak discharge would have been without the dam break (Sando and McCarthy, 2018).

Peak-flow values determined to be opportunistic may also require data correction. An opportunistic peak is a peak-flow value collected during an ungaged period (outside of the systematic period of record) that is not large enough to determine nonexceedance during all or part of the ungaged period. An effort to document opportunistic peaks with the appropriate qualifier in the NWIS database has been made, but some qualifiers have not been applied in the database because future analysis of data (using data sources not readily available currently) may determine the peak to not be opportunistic. In such cases, the peak-flow value in question may be excluded from a particular analysis but not have an opportunistic qualifier applied in the NWIS database.

Other data corrections may also be applied to account for unique hydrologic conditions. One example of this from Siefken and others (2025) is Red Lodge Creek below Cooney Reservoir near Boyd, Mont. (USGS streamgage 06212500; U.S. Geological Survey, 2024m). Peak flows at this site are highly affected by the operation of Cooney Reservoir (not shown on figure 1). However, Cooney Reservoir does not have any dedicated flood storage (Montana Department of Natural Resources and Conservation, 2021) and so cannot be relied upon to provide substantial protection against large floods. Therefore, naturalized annual peak flows were calculated at the site from two upstream streamgages, Red Lodge Creek above Cooney Reservoir near Boyd, Mont. (USGS streamgage 06211000; U.S. Geological Survey, 2024k), and Willow Creek near Boyd, Mont. (USGS streamgage 06211500; U.S. Geological Survey, 2024l). The naturalized annual peak flows were then used for the peak-flow frequency analysis. The example in the associated data release (Siefken and others, 2025) includes the naturalized flow analysis and analysis on the regulated flows for comparison.

Data Combination

Data combination refers to combining the nonconcurrent peak-flow records of two or more closely located streamgages on the same channel. Records are combined to produce an analysis that represents a larger sample of peak-flow data on the channel when the drainage areas of the streamgages differ by less than about 5 percent (Sando and McCarthy, 2018). Data combination assumes that peak discharge at two such streamgages is essentially equivalent, which should be true for most such sites in the study area provided no substantial tributary contributes flow between the two streamgages.

When data combination is used, the analysis is reported using the site number for the site with the most recent peak-flow data. The years for which peak-flow data were combined from different streamgages are documented in the associated data release. An example of this from Siefken and others (2025) is Clarks Fork Yellowstone River at Edgar, Mont. (USGS streamgage 06208500; U.S. Geological Survey, 2024i), where peak-flow data are combined with data from the nearby streamgages Clarks Fork Yellowstone River at Fromberg, Mont. (USGS streamgage 06208000; U.S. Geological Survey, 2024h; not shown in fig. 1), and Clarks Fork Yellowstone River near Silesia, Mont. (USGS streamgage 06208800; U.S. Geological Survey, 2024j; not shown in fig. 1).

Nonstationarity Considerations

A basic assumption for the analysis procedures within Bulletin 17C is that the statistical properties of the distribution of peak flows are stationary; that is, the mean, variance, and skew are constant. From the onset of the USGS streamgage program through most of the 20th century, the stationarity assumption for streamgages unaffected by upstream regulation or diversions was widely accepted. However, in recent decades, a better understanding of multi-year climatic persistence (extended periods of relatively wet or relatively dry conditions) and studies documenting changes in climate and land use have caused a reexamination of the stationarity assumption (Milly and others, 2008; Lins and Cohn, 2011; Stedinger and Griffis, 2011; Koutsoyiannis and Montanari, 2015; Serinaldi and Kilsby, 2015).

Nonstationarity is a property of a peak-flow series such that the statistical distribution properties change either gradually or abruptly through time. Individual nonstationarities may be attributed to one source (for example, reservoir regulation, land-use change, or climate) but often are the result of a mixture of sources (Vogel and others, 2011), which makes detection and attribution of nonstationarities challenging (Barth and others, 2022). Neglecting trends and abrupt changes in peak-flow frequency analysis may result in a poor representation of the true flood risk. However, Bulletin 17C does not offer guidance on how to incorporate nonstationarities when estimating flood magnitudes for associated recurrence intervals and further identifies a future need for additional studies that incorporate changing climate or drainage basin characteristics into the analysis (Bulletin 17C). Thus, peak-flow frequency-analysis results using the methods of this report generally do not address potential nonstationarities in the peak-flow time series.

Streamgages with obvious and substantial nonstationarity should not be analyzed using the methods of this report. An example of this has been observed at Dinwoody Creek above Lakes, Near Burris, Wyo. (USGS streamgage 06221400; U.S. Geological Survey, 2024n). Mud Lake (not shown on figure 1), about 1 mile upstream from the streamgage, has a subterranean outlet. The hydraulic function of the outlet seems to have been substantially altered before or during 2017 spring runoff, which is the largest peak flow ever observed at the site. A marked increase in annual peak flow after 2016 is shown in figure 2. As a result, peak-flow data before 2017 are not considered representative of the current hydrology of the site. Because less than 10 years of data have been collected since 2017, a peak-flow frequency analysis cannot be completed for the site at the present time.

Analysis of Sites with Upstream Alteration

Discharge at many streamgages in the study area is affected to some extent by upstream alterations such as storage reservoirs or irrigation diversions. The effects of these alterations on peak flow range from negligible to completely controlling. Small diversions tend to have minor effects on peak flow, but large flood control reservoirs may store a large proportion of runoff and considerably decrease the peak flow downstream. Some alterations to peak streamflows may be such that annual peak flows do not follow a log-Pearson type III distribution. As Bulletin 17C notes, frequency analysis for altered streams is an area that could benefit from additional research to develop improved methods (Bulletin 17C); however, Bulletin 17C procedures with informed adjustments can usually produce acceptable peak-flow frequency estimates on altered streams.

If the streamgage period of record spans construction, modification, or removal of flow-modifying structures (including dams and diversions), the streamflow record can be split into altered and unaltered periods (or into separate periods that reflect different degrees of alteration) for peak-flow frequency analyses. Separate peak-flow frequency analyses can then be computed on data from the separate periods so that all data used in an individual analysis are affected by the same degree of alteration. An example of splitting a record because of a change in alteration status in Siefken and others (2025) is the analysis of South Fork Flathead River near Columbia Falls, Mont. (USGS streamgage 12362500; U.S. Geological Survey, 2024s), where the construction of Hungry Horse Dam greatly altered peak streamflows starting in 1952 (Stene, 1995).

The NWIS peak-flow database includes peak discharge qualification codes (5 and 6) designed to indicate whether a given peak-flow value was affected by upstream alteration or not (U.S. Geological Survey, 2024a). However, these codes have not been applied consistently across the study region and so cannot be used as the sole determination of alteration status.

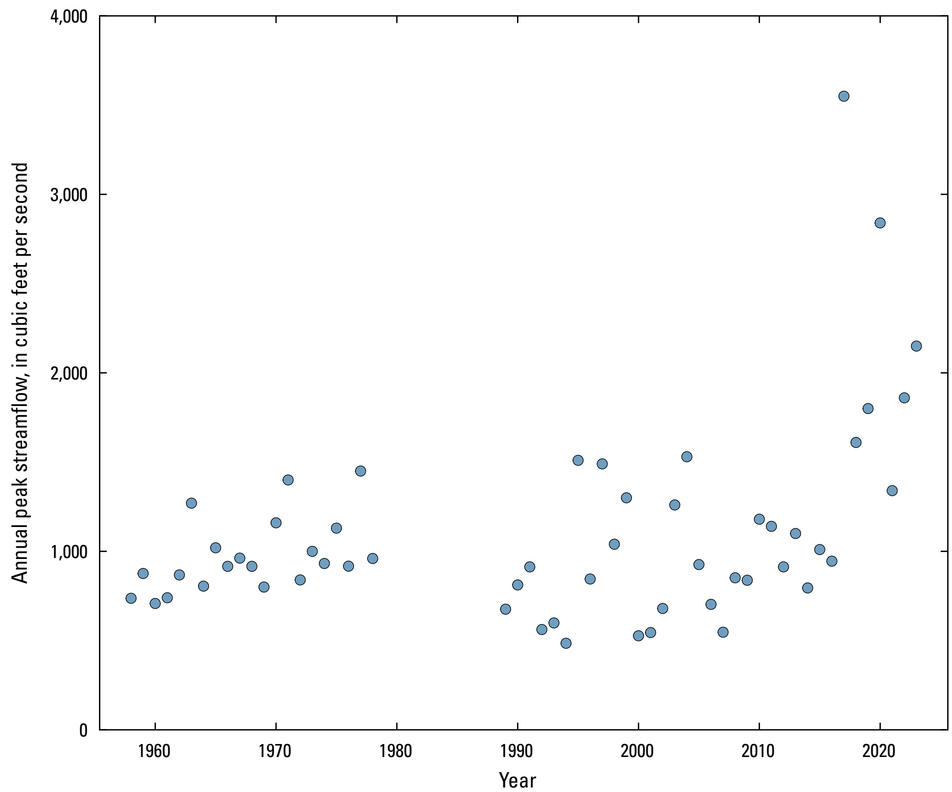


Figure 2. Graph showing annual peak streamflow from 1958 to 2023 for Dinwoody Creek above Lakes, near Burris, Wyoming (U.S. Geological Survey streamgage 06221400; U.S. Geological Survey, 2024n).

McCarthy and others (2016) determined alteration ("regulation") status of streamgages by computing the cumulative drainage area upstream from all dams in relation to the streamgage drainage area. Wieczorek and others (2021) included the cumulative drainage area upstream from dams, the streamgage drainage area, the storage behind the dams and the amount of precipitation in the drainage basin in a dam disturbance index:

$$DI_{dams,x} = \frac{\sum_i^d (S_i A_i)}{P_x A_x^2}, \quad (1)$$

where

$DI_{dams,x}$ is the unitless disturbance index for alteration owing to dams at location x;

S_i is the storage volume behind dam i, in acre-feet;

A_i is the drainage area upstream from dam i, in acres;

P_x is the mean annual precipitation at location x, in feet; and

A_x is the drainage area at location x, in acres.

For at-site statistical analyses in the State of Wyoming, Armstrong and others (2025) calculated a disturbance index for alteration owing to diversions ($DI_{diversions,x}$) as follows:

$$DI_{diversions,\,x} = \frac{Q_{div}}{Q_{meanNHD}}, \quad (2)$$

where

$DI_{diversions,x}$ is the disturbance index for alteration owing to diversions at location x;

Q_{div} is the diversion flow amount, in cubic feet per second; and

$Q_{meanNHD}$ is the mean annual flow from NHDPlus (U.S. Geological Survey and U.S. Environmental Protection Agency, 2012), in cubic feet per second.

Disturbance indexes have been applied in different ways in Montana, Wyoming, North Dakota, and South Dakota. Armstrong and others (2025) developed thresholds for classifying streamgages as "altered" or "unaltered" because of dams and diversions and used a multitiered approach to generate final classifications of streamflow alteration for each streamgage. In a separate study, Marti and Ryberg (2023) used the dam disturbance index published by Wieczorek and others (2021) to identify altered (or regulated) USGS streamgages in Montana, North Dakota, South Dakota, and other States in the Central United States. Although disturbance index values computed using equations 1 and 2 can be highly informative for determining the extent to which peak flows at a streamgage are affected by upstream alteration, calculating accurate disturbance index values is challenging if accurate datasets for dam locations, storage volumes, diversion flow amounts, and upstream drainage areas are not available.

Alteration status for frequency analyses published using the methods in this report is described using three broad categories:

- Major alteration—Flow at the streamgage is affected by a dam or other hydraulic structure, which has an obvious and substantial effect on peak flow. Major alteration is most commonly the result of onstream storage reservoirs, although it can result from diversions or canal transfers from other basins. Reservoirs considered to cause major alteration are generally impounded by dams listed in the National Inventory of Dams and typically have storage capacities of 100 acre-feet or more.
- Minor alteration—The streamgage is downstream from a large diversion, a canal transferring water from another basin, or one or more dams. The upstream alteration affects peak flows at the site, but the primary purpose of the alteration is generally not for flood control.
- Unaltered—Any alteration of peak flow from upstream hydraulic structures is negligible for the purposes of peak-flow frequency analysis.

In some cases, even though a known change in upstream alteration occurred during the streamgage record, the effect of the alteration change may be minor enough that it is preferable to analyze all the data together in one frequency analysis rather than split the data before and after the change occurred. Such analyses using the total period of data are given the alteration classification of “total.”

Analysis of Sites Affected by Urbanization

Urbanization of a drainage basin can also affect peak flows (Konrad, 2003). Although few streamgages in the study area are affected by urbanization to an extent to be a concern for peak-flow frequency analysis, it is an important consideration for some sites, such as Crow Creek at 5th Street, Cheyenne, Wyo. (USGS streamgage 410720104483801; U.S. Geological Survey, 2024u). Peak-flow values affected by urbanization are denoted with a “C” qualifier in the NWIS database (U.S. Geological Survey, 2024a). Peak-flow values affected by urbanization are analyzed separately from any nonurbanized values at the same site, and the alteration status of the site is denoted as urbanization in the analysis.

Standard Procedures for Implementing Bulletin 17C Guidelines

The procedure for fitting the log-Pearson type III distribution using the expected moments algorithm (EMA) described in Bulletin 17C incorporates several additional inputs besides the observed peak-flow data. These inputs include perception thresholds, the potentially influential low flood (PILF) threshold, and regional skew information (Bulletin 17C). The standard procedure for implementing Bulletin 17C guidelines in the study area is to use the multiple Grubbs-Beck test (MGBT) (Cohn and others, 2013) to determine the PILF threshold and to use a weighted skew coefficient incorporating regional skew information.

Applying Perception Thresholds

Lower and upper perception thresholds need to be specified for every year of the record in a peak-flow frequency analysis (Bulletin 17C). For periods of systematic streamgage operation, the lower perception threshold is usually set to zero and the upper perception threshold is set to infinity, indicating it would be possible to observe any discharge value at the streamgage. CSGs may not be able to observe any discharge value; setting perception thresholds for this case is described in the following section. For periods where a streamgage has been discontinued or ceased operation (ungaged period), and no historical peak-flow information is available, the lower and upper perception thresholds are both set to infinity, indicating no information about that particular period is available.

Procedures for Crest-Stage Gages

The peak flow for a given year might be too small to be measured by the lowest point on a CSG because the gages are usually installed such that flow can occur but not leave a mark on the gage. In this case, the lower perception threshold for each water year should be set to a value corresponding to the minimum measurable discharge at the CSG for that water year (Bulletin 17C). However, the PILF threshold is usually greater than the lowest measurable flood for a CSG, making it unnecessary to explicitly incorporate the minimum measurable discharge from the bottom of the CSG into the frequency analysis. If a PILF threshold is not greater than the minimum discharge that the CSG could measure for every year in the analysis, perception thresholds based on the discharge recordable by the gage should be included in the analysis.

Procedures for Incorporating Historical Information

Historical information is incorporated into peak-flow frequency analyses using flow intervals and perception thresholds, as described in Bulletin 17C. Some historical information is available in NWIS from “largest since” years associated with peak-flow values, indicating a certain peak-flow value was the largest since at least the given year. For example, at Beaver Creek near Newcastle, Wyo. (USGS streamgage 06394000; U.S. Geological Survey, 2024q), the 1962 peak flow of 11,900 ft^3/s is noted to be the largest since 1927. Therefore, the lower perception threshold for the ungaged years from water year 1928 to water year 1944 can be set to the 1962 flood discharge of 11,900 ft^3/s. The lower perception threshold for 1943 is set to zero because the streamgage was operated that year (Siefken and others, 2025). Other historical flood information is available in USGS water supply papers, streamgage site descriptions, and outside sources including newspapers and accounts of local residents.

Historical information can also be incorporated from data collected at other streamgages in the area. For example, if a large flood event occurred while a streamgage of interest was not operating but the event was recorded at an upstream or downstream streamgage, it may be possible to set a perception threshold for the streamgage of interest based on the recorded value at the other streamgage. In such cases, it is still preferable to have additional information specific to the streamgage of interest to corroborate the perception threshold set based on data from the other streamgage.

The value of a perception threshold for historical flood information at a streamgage is usually set as the discharge of a flood of known magnitude at the streamgage. For example, the 1964 flood discharge at the Marias River near Shelby, Mont. (USGS streamgage 06099500; U.S. Geological Survey, 2024d), was greater than any flood since at least 1881. As discussed in the “Data Correction” section, the 1964 discharge in NWIS was modified by Siefken and others (2025) to reflect what the discharge would have been without the dam break, so the lower perception threshold for the ungaged period before water year 1964 is set to the corrected 1964 flood discharge of 150,000 ft^3/s. Any flood after 1881 with greater discharge would have been noted as being greater than the 1964 discharge. Perception thresholds do not have to be set based on recorded floods at a streamgage, but recorded floods are usually the best information available for setting perception thresholds. All perception thresholds and flow intervals used to incorporate historical flood information are documented in the data release.

Procedures for Incorporating Paleoflood Information

Paleoflood data derived from geologic or botanical records can provide valuable information on rare, large-magnitude floods outside of the historical flood record. Harden and others (2021) provide guidance on appropriate methods for paleoflood studies. Any paleoflood data incorporated into analyses published following the methods in this report should be from studies consistent with the methods described in Harden and others (2021). Paleoflood studies considered unreliable should not be used in peak-flow frequency analysis.

Because paleoflood data may have large uncertainty, special procedures are required to appropriately represent the data in a peak-flow frequency analysis. Perception thresholds are used to represent time periods for which the paleoflood study indicated floods did not exceed a certain value. Individual paleofloods identified by a study are represented as either intervals or censored values because of the large uncertainty of paleoflood estimates. Harden and others (2021) provide additional guidance on representing paleoflood data in peak-flow frequency studies. Paleoflood data from Harden and others (2011) are included in the analysis for Boxelder Creek near Nemo, S. Dak. (USGS streamgage 06422500; U.S. Geological Survey, 2024r), in the accompanying data release by Siefken and others (2025).

Standard Procedures for Handling Low Outliers

In peak-flow frequency analysis, low discharge values can exert a large distorting effect on the fitted frequency curve (Bulletin 17C). The MGBT (Cohn and others, 2013) provides an effective test for identifying low outliers. Discharge values less than the identified PILF threshold are represented as intervals from zero to the PILF threshold to prevent them from distorting the fitted frequency curve (Bulletin 17C). Using the MGBT is the standard procedure for handling low outlier detection.

Standard Procedures for Weighted Skew Coefficients

The standard procedure for determining the skew coefficients is to weight the at-site skew coefficient computed from observed data at a streamgage with a regional skew coefficient. The at-site skew coefficient can have large uncertainty in even modest-length systematic records (Griffis and Stedinger, 2009) that can often be improved by weighting with regional skew information. Bulletin 17C indicates that regional skew estimates should be developed using the Bayesian weighted least squares/Bayesian generalized least squares (BWLS/BGLS) method (Veilleux and others, 2011).

At the time of this writing, a BWLS/BGLS regional skew study has not been completed for any part of the study area. Until such a study is published, the best available regional skew information for the study area is the national skew map published in U.S. Interagency Advisory Committee on Water Data (1982), referred to hereafter as the “Bulletin 17B national skew map.” As BWLS/BGLS regional skew studies become available for the study area, the values from those studies should be used instead of those from the Bulletin 17B national skew map.

Parrett and Johnson (2004) analyzed skew coefficients in Montana and concluded that the differences between the generalized skew coefficients from the Bulletin 17B national skew map and the regional skew coefficients from their analysis were "small and probably not significant" Parrett and Johnson, 2004, p. 8). Thus, Parrett and Johnson (2004) determined that the generalized skew coefficients from the Bulletin 17B national skew map were appropriate for frequency analysis. Parrett and Johnson (2004) also calculated a standard error of the Bulletin 17B national skew map specific to Montana streamgages and obtained a value of 0.64 compared to the published value of 0.55 (U.S. Interagency Advisory Committee on Water Data, 1982). The analysis included 201 streamgages on unregulated streams having 25 or more years of record. Those 201 streamgages included many sites with mixed-population floods for which regional skew has been considered nonapplicable in past peak-flow frequency studies (Parrett and Johnson, 2004; Sando and others, 2016; Sando and McCarthy, 2018). Annual peak flows that are caused by different hydrometeorological events associated with distinct flood-generating mechanisms such as snowmelt and rainfall only or a combination of these are considered mixed populations (Bulletin 17C). These mixed populations can have abnormally large skew coefficients and (or) abnormal slope changes in the plotting positions (Bulletin 17C). As a result, the value of 0.64 likely overestimates the standard error of the Bulletin 17B national skew map for the sites at which regional skew is applicable. Therefore, this study recommends using the Bulletin 17B national standard error value of 0.55 for Montana streamgages at which regional skew is applicable.

Deviations from Standard Procedures

It is sometimes necessary to deviate from standard procedures for implementing Bulletin 17C guidelines because of site-specific hydrology. Common reasons for deviating from standard procedure include upstream alteration, mixed-population floods, and unusual peak-flow distributions not well represented by a log-Pearson type III distribution. Deviations from standard analysis procedures include using at-site skew only instead of a weighted skew value and using a manual PILF value instead of an MGBT PILF value. The objective of all deviations from standard analysis procedures is to best represent the upper part of the flood frequency curve in the analysis.

At-Site Skew

For some streamgages, the regional skew coefficient is not applicable either because of upstream regulation (such as Sheyenne River near Kindred, North Dakota [USGS streamgage 05059000; U.S. Geological Survey, 2024b], and North Milk River near international boundary [USGS streamgage 06134000; U.S. Geological Survey, 2024e]) or because of unique hydrologic conditions that are not well represented by the regional skew coefficient. Unique hydrologic conditions could include mixed-population floods (such as Marias River near Shelby, Mont. [USGS streamgage 06099500; U.S. Geological Survey, 2024d]), or other hydrologic conditions that indicate a regional skew analysis does not represent skewness at the streamgage well (such as Lyons Creek at international boundary [USGS streamgage 06151000; U.S. Geological Survey, 2024f]). For such streamgages, the at-site skew is not weighted with the regional skew coefficient. This approach follows the recommendation in Bulletin 17C that the data and hydrology of the drainage basin for streamgages for which regional and at-site skew coefficients differ by more than 0.5 should be carefully examined and greater weight may be given to the at-site skew (Bulletin 17C). If the streamgage has a long period of record (about 40 years or more), the at-site skew coefficient alone should provide a reasonably good estimate of the true skewness of the distribution. For sites with short periods of record, the at-site skew has high uncertainty, and analyses using only at-site skew will have large uncertainty in flood quantile estimates.

Manual Potentially Influential Low Flood Thresholds

For some streamgages, the low outlier (PILF) threshold determined by the MGBT may not provide the best fit of the peak-flow frequency curve. For such sites, a user-specified (manual) PILF threshold may be used to improve the fitted frequency curve. Use of manual PILF thresholds is common at streamgages with mixed-population floods where specifying a PILF threshold at inflection points below or near the median annual peak discharge may be necessary to obtain the best fit to the upper part of the frequency curve. An example of this in Siefken and others (2025) is North Fork Powder River near Hazelton, Wyo. (USGS streamgage 06311000; U.S. Geological Survey, 2024o).

Mixed-Population Analysis Methods

Annual peak-flow records that have a mixed population of floods commonly have an abnormally shaped frequency curve, which may not be well represented by a log-Pearson type III distribution (Parrett and others, 2011; Gotvald and others, 2012; England and others, 2018). Although no formal procedure is available in Bulletin 17C to address the poor frequency curve fit for mixed populations to the empirical data, they do suggest that, in some situations, separate frequency curves be fit for each type of flood event and combined to produce a total frequency curve. Potential challenges arise with this special treatment, including subsamples based on flood types that may be too small to accurately estimate the three moments of the log-Pearson type III distribution (particularly skewness) or how to identify the different flood types, such as snowmelt, rainfall, or rain on snow, that can occur in the study region. As stated in Bulletin 17C, separating flood types solely based on calendar period is not sufficient unless the events are clearly generated by different flood-generating conditions. Future studies may benefit from considering more indepth approaches to identify flood-generating mechanisms for candidate streamgages with mixed populations and using advanced mixed-population flood frequency methods for the individual streamgage.

For some streamgages in the Black Hills region in western South Dakota, the presence of high outlier floods from mixed-population flood events leads to poor performance of standard flood frequency-analysis procedures. Examining the mechanisms responsible for generating some of these high outlier events reveals common hydrogeologic and meteorologic characteristics. In the eastern Black Hills, flood observations of extreme magnitude are somewhat frequent and may be better analyzed as a smaller subpopulation of events unique to the rest of the overall flood population (Sando and others, 2008). Therefore, a mixed-population method similar to that used by Sando and others (2008) would be more appropriate for many streamgages in the Black Hills region than the methods described in this report. Such a methodology is outside the scope of this report but may be published by the USGS in the future to supplement the methods of this report. For streamgages in the Black Hills with alteration from upstream dams or streamgages with paleoflood data to extend the peak-flow record, the methods described in this report are still applicable.

Methods for Improving Peak-Flow Frequency Analyses

Peak-flow frequency estimates at a streamgage can often be improved by incorporating additional information beyond the peak-flow data available for the site, as discussed in the "Data Sources, Data Correction, and Data Combination" section, and beyond the historical information expressed as perception thresholds, as discussed in the "Procedures for Incorporating Historical Information" section. This improvement can be done using MOVE.3 record extension with nearby sites or weighting with RREs. Whenever MOVE.3 or RRE-weighted analyses are published, the at-site analysis is published as well.

Record Extension with Nearby Sites

For a streamgage with peak discharges highly correlated with one or more nearby, hydrologically similar streamgages, it may be possible to improve peak-flow frequency estimates by extending the peak-flow record using MOVE.3. The streamgage for which the record is being extended is referred to as the "target site," and the one or more streamgages used to extend the peak-flow record are referred to as "index sites."

Modifications to Bulletin 17C Maintenance of Variance Extension Type III Method

In Bulletin 17C, appendix 8 presents a method of record extension recommended for use with the EMA. The method is based on the MOVE.3 method of Vogel and Stedinger (1985). Siefken and McCarthy (2022) presented a variation of the method that takes into consideration the skewness of the extended record. The MOVE.3 method in this report follows the methodology of Siefken and McCarthy (2022) with the following modifications to equation 23 in their paper (reproduced below) that address cases where the value of k is less than zero. The coefficient k relates the variance of the extended record to the variance of the recorded data and the squared difference in the mean of the extended record and recorded data. A negative value of k indicates the variance required for the extended record is too small to accommodate the change in mean and variance from the recorded data.

$$k = (n_1 + n_s - 1)\hat{\sigma}_y^2 - (n_1 - 1)s_{y_1}^2 - n_1\left(\frac{n_1}{n_s} + 1\right)(\hat{\mu}_y - \bar{y}_1)^2, \quad (3)$$

where

k is a coefficient relating variance of the extended record to the variance of the recorded data and the squared difference in the mean of the extended record and recorded data,

n_1 is the number of concurrent peak-flow values at the target and index sites,

n_s is the number of synthesized peak-flow values,

$\bar{y}_1$ is the sample mean of recorded data at the target site,

$\hat{\mu}_y$ is the mean of extended record,

$s_{y_1}^2$ is the sample variance of recorded data at the target site, and

$\hat{\sigma}_y^2$ is the variance of extended record.

For given values of n_1, $\bar{y}_1$, $\hat{\mu}_y$, $s_{y_1}^2$, and $\hat{\sigma}_y^2$, the minimum number of synthesized peak-flow values, n_m, required for k to be nonnegative is described by equations 4 and 5:

$$n_m = \frac{-\delta + \sqrt{\delta^2 + 4 n_1^2 \hat{\sigma}_y^2 \left(\hat{\mu}_y - \bar{y}_1\right)^2}}{2 \sigma_y^2} \quad (4)$$

$$\delta = (n_1 - 1)\left(\hat{\sigma}_y^2 - s_{y_1}^2\right) - n_1 \left(\hat{\mu}_y - \bar{y}_1\right)^2. \quad (5)$$

When the value of n_s is taken as the equivalent years of record (n_e) computed using Bulletin 17C equation 8–19, n_s may be less than n_m for some cases, and record extension with the method of Siefken and McCarthy (2022) is not possible. This limitation can be overcome by computing n_s as the larger value of either n_e or n_m. Using a value of n_s greater than n_e will result in an underestimation of the uncertainty of the computed moments and quantile estimates. However, as long as the difference between n_s and n_e is small compared to the effective length of the extended record, the underestimation of the uncertainty will be minor. Therefore, n_s is computed using equation 6, provided the inequality in equation 7 is satisfied. If the inequality is not satisfied, then MOVE.3 record extension is not possible.

$$n_s = max(n_e, n_m) \quad (6)$$

$$\frac{n_s + n_t}{n_e + n_t} < 1.1, \quad (7)$$

where

max() is a function selecting the maximum input value, and

n_t is the number of peak-flow values at the target site.

The number of synthesized peak-flow values, n_s, will almost always be smaller than the number of additional peak-flow values recorded at the index site because of imperfect correlation between the target and index sites. However, the synthesized values incorporate information from all recorded values at the index site. Water years with recorded peak-flow values at the index site not used to synthesize values at the target site should be treated as missing data when fitting log-Pearson type III distribution using EMA.

Criteria for Use of Maintenance of Variance Extension Type III Record Extension

MOVE.3 record extension can be applied if two streamgages have at least 10 years of concurrent peak-flow records with a Pearson correlation coefficient greater than about 0.80 (Sando and McCarthy, 2018) and the sites are hydrologically similar. As a further criterion, Bulletin 17C recommends MOVE.3 not be used unless the equivalent years of record, n_e, added by the MOVE.3 extension are 4 or 5 years or more. In any case, the modified MOVE.3 method described in this report cannot be used unless at least three additional peak-flow values are synthesized.

Because the MOVE.3 method described in Bulletin 17C uses the log transformation of peak-flow values, MOVE.3 record extension cannot currently be applied to streamgages that have peak-flow values of zero. Development of a record extension method that can accommodate peak-flow values of zero in a statistically rigorous manner would allow MOVE.3 to be used for streamgages that have years without any recorded flow. The data release accompanying this report (Siefken and others, 2025) includes examples of MOVE.3 record extension at several streamgages.

Weighting with Regional Regression Equations

For streamgages on streams where regional regression equations for peak-flow statistics are applicable, the uncertainty of at-site peak-flow statistics computed from streamgage data can be reduced by weighting the at-site estimate with an independent estimate from RREs. In Bulletin 17C, appendix 9 presents the method for weighting at-site and regional regression peak-flow frequency estimates under the assumption that the two estimates are independent and unbiased and that the variances are reliable and consistent. The weighted frequency estimate is computed using the following equation:

$$\hat{X}_{wtd} = \frac{\hat{X}_a * V_b + \hat{X}_b * V_a}{V_b + V_a}, \quad (8)$$

where

$\hat{X}_a$ and $\hat{X}_b$ are the log-transformed frequency estimates from methods *a* and *b*,

V_a and V_b are the variances of the estimates from methods *a* and *b*, and

$\hat{X}_{wtd}$ is the weighted estimate from methods *a* and *b*.

In Bulletin 17C, appendix 9 also provides a method of computing confidence intervals for the weighted estimates. However, the confidence intervals described in appendix 9 of Bulletin 17C do not account for correlation of the weighted estimate with the estimated variance. Cohn and others (2001) describe how highly correlated mean and variance estimators from censored data can result in biased confidence intervals. The method Cohn and others (2001) provide to address this shortcoming computes confidence intervals using a Student's *t*-distribution (rather than a normal distribution) and a correction factor adjusting for the correlation between the quantile estimate and its estimated variance.

Theoretically, the same approach could be applied to compute improved confidence intervals for RRE-weighted estimates. However, no method is currently accepted to compute the covariance of the regional regression weighted quantile estimate. As an alternative approach, Sando and McCarthy (2018) used a simple approximation to compute confidence intervals for regional regression weighted estimates using the effective variance of the upper and lower confidence intervals from the at-site quantile estimates as shown in equations 9 through 14:

$$U_{at-site} = \log_{10}(CI_{U,at-site}) \quad (9)$$

$$L_{at-site} = \log10(CI_{L,at-site}) \quad (10)$$

$$V_{eff,U} = \left(\frac{U_{at-site} - \hat{X}_{at-site}}{1.64}\right)^2 \quad (11)$$

$$V_{eff,L} = \left(\frac{L_{at-site} - \hat{X}_{at-site}}{1.64}\right)^2 \quad (12)$$

$$U_{wtd} = \hat{X}_{wtd} + 1.64\sqrt{\frac{V_{eff,U} * V_b}{V_{eff,U} + V_b}} \quad (13)$$

$$L_{wtd} = \hat{X}_{wtd} - 1.64\sqrt{\frac{V_{eff,L} * V_b}{V_{eff,L} + V_b}}, \quad (14)$$

where

$CI_{U,at-site}$ and $CI_{L,at-site}$ are the upper and lower limits of the two-tailed 90-percent confidence interval from the at-site frequency analysis;

$U_{at-site}$ and $L_{at-site}$ are the upper and lower log-transformed confidence limits for the two-tailed 90-percent confidence interval from the at-site frequency analysis;

$\hat{X}_{at-site}$ is the log-transformed estimate from the at-site frequency analysis;

1.64 is the one-tailed Student's *t*-value for the 95-percent (upper) and 5-percent (lower) confidence limits assuming infinite degrees of freedom;

$V_{eff,U}$ and $V_{eff,L}$ are the effective variance for the upper and lower confidence limits;

V_b is the variance of the second method, such as RREs; and

U_{wtd} and L_{wtd} are the upper and lower log-transformed confidence limits for the two-tailed 90-percent confidence interval.

In the example data release accompanying this report (Siefken and other, 2025), 10 streamgages use weighting with RREs to improve at-site frequency estimates. Although weighted estimates generally improve the reliability and accuracy of at-site frequency estimates, the RREs may provide a poor representation of hydrologic conditions at a streamgage (Sando and McCarthy, 2018). Where variation between the at-site and weighted estimate is substantial, careful evaluation should be made as to which result is more reliable.

Methods for Peak-Flow Frequency Reporting

Peak-flow frequency analyses completed using the methods described in this report are published as USGS data releases, such as Siefken and others (2025). The data releases include the peak-flow data used in the analysis, a specifications file containing analysis options used in the peakfq software, and results of each analysis in the data release.

When multiple analyses are published for the same alteration status for a streamgage (for example an at-site and RRE-weighted or MOVE.3 analysis), a summary file is included in the data release containing a column indicating which analysis is considered the "preferred" analysis for use in hydraulic design and floodplain mapping. The preferred analysis is considered to be the most representative analysis of peak-flow frequency after review by two or more USGS analysts. If a MOVE.3 analysis is published for a site, that analysis is always considered the preferred analysis. If an at-site and an RRE-weighted analysis are published, the RRE-weighted analysis is generally considered preferred if fewer than 20 years of data are used in the at-site analysis (Bulletin 17C, appendix 9). However, if examination of the analysis indicates the RREs likely provide a poor representation of peak-flow frequency at the site, then the at-site analysis is considered preferred. When 20 or more years of data are used in an at-site analysis, an RRE-weighted analysis may still be considered preferred if the RRE-weighted analysis has considerably lower variance for one or more annual exceedance probability (AEP) estimates and the RREs seem to appropriately represent the peak-flow hydrology of the streamgage.

For most streamgages, estimates are published for selected AEPs from 66.7 percent to 0.2 percent. The methods described in this report may also be used to compute estimates for the 0.1-percent AEP, provided at least 100 years of combined systematic, historical, and paleoflood information is available for the streamgage, of which at least 50 years is systematic record. Even if a streamgage has sufficient data to compute the 0.1-percent AEP estimate, an analyst may elect not to publish the estimates for the 0.1-percent AEP, depending on the needs of the data release and the discretion of the analyst. In the accompanying example data release (Siefken and others, 2025), 0.1-percent AEP estimates are published for Gallatin River near Gallatin Gateway, Mont. (USGS streamgage 06043500; U.S. Geological Survey, 2024c); Clarks Fork Yellowstone River near Belfry, Mont. (USGS streamgage 06207500; U.S. Geological Survey, 2024g); and Clarks Fork Yellowstone River at Edgar, Mont. (USGS streamgage 06208500; U.S. Geological Survey, 2024i).

Summary

The U.S. Geological Survey, in cooperation with the Montana Department of Natural Resources and Conservation, North Dakota Department of Water Resources, South Dakota Department of Transportation, and the Wyoming Water Development Office, has developed standard methods of peak-flow frequency analysis for studies in Montana, North Dakota, South Dakota, and Wyoming. This report documents the methods for peak-flow frequency analysis for studies published by the U.S. Geological Survey for Montana, North Dakota, South Dakota, and Wyoming. At-site peak-flow frequency follows the guidelines of Bulletin 17C (https://doi.org/10.3133/tm4B5), and the expected moments algorithm is used for fitting the log-Pearson type III distribution. The standard procedure is to use the multiple Grubbs-Beck test (https://doi.org/10.1002/wrcr.20392) for identifying low outliers and weight the at-site skew coefficient with a regional skew coefficient. For some sites, the peak-flow records are not well represented by the standard procedures, and user-informed adjustments of using a manual low outlier value or using the at-site skew coefficient without weighting with regional skew are made.

Many at-site frequency estimates may be improved by incorporating information from other streamgages in the region. Frequency estimates for unregulated streamgages generally can be improved by weighting the at-site frequency estimates with frequency estimates from regional regression equations (https://doi.org/10.3133/sir20185046). Maintenance of Variance Extension type III record extension (https://doi.org/10.1029/WR021i005p00715) may be used to improve frequency estimates for a streamgage with peak discharges highly correlated with one or more nearby, hydrologically similar streamgages. The methods for improving at-site frequency estimates by weighting with regional regression equations and by record extension are described in the report.

A U.S. Geological Survey data release accompanying this report (https://doi.org/10.5066/P1WHRK8H) presents peak-flow frequency analyses for example streamgages in various hydrologic settings within the study area. The data release includes tables and graphical plots that document the interpretive decisions involved in the analysis and present the results of the analysis. The methodology in this report may be used to publish similar data for other streamgages in the study region.

References Cited

Armstrong, D.W., Lange, D.A., and Chase, K.J., 2025, Methods to determine streamflow statistics based on data through water year 2021 for selected streamgages in or near Wyoming: U.S. Geological Survey Scientific Investigations Report 2024–5104, 10 p., accessed January 28, 2025, at https://doi.org/10.3133/sir20245104.

Barth, N.A., Ryberg, K.R., Gregory, A., and Blum, A.G., 2022, Introduction to attribution of monotonic trends and change points in peak streamflow across the conterminous United States using a multiple working hypotheses framework, 1941–2015 and 1966–2015, chap. A *of* Ryberg, K.R., ed., Attribution of monotonic trends and change points in peak streamflow across the conterminous United States using a multiple working hypotheses framework, 1941–2015 and 1966–2015: U.S. Geological Survey Professional Paper 1869, p. A1–A29, accessed March 14, 2024, at https://doi.org/10.3133/pp1869.

Boner, F.C., and Stermitz, F., 1967, Floods of June 1964 in northwestern Montana: U.S. Geological Survey Water-Supply Paper 1840–B, 242 p., accessed December 10, 2024, at https://doi.org/10.3133/wsp1840B.

Chase, K.J., Dutton, D., Hamilton, W.B., Siefken, S.A., Vander Voort, C., and Whiteman, A., 2024, June 2022 floods in the Upper Yellowstone River Basin: U.S. Geological Survey Fact Sheet 2024–3035, 6 p., accessed September 6, 2024, at https://doi.org/10.3133/fs20243035.

Cohn, T.A., England, J.F., Berenbrock, C.E., Mason, R.R., Stedinger, J.R., and Lamontagne, J.R., 2013, A generalized Grubbs-Beck test statistic for detecting multiple potentially influential low outliers in flood series: Water Resources Research, v. 49, no. 8, p. 5047–5058, accessed January 2, 2024, at https://doi.org/10.1002/wrcr.20392.

Cohn, T.A., Lane, W.L., and Stedinger, J.R., 2001, Confidence intervals for expected moments algorithm flood quantile estimates: Water Resources Research, v. 37, no. 6, p. 1695–1706, accessed January 2, 2024, at https://doi.org/10.1029/2001WR900016.

Engel, G.B., and Benson, R.D., 1987, Floods in eastern Nebraska and southeastern South Dakota, June 1984: U.S. Geological Survey Open-File Report 87–215, 31 p., accessed July 3, 2024, at https://doi.org/10.3133/ofr87215.

England, J.F., Jr., Cohn, T.A., Faber, B.A., Stedinger, J.R., Thomas, W.O., Jr., Veilleux, A.G., Kiang, J.E., and Mason, R.R., Jr., 2018, Guidelines for determining flood flow frequency—Bulletin 17C (ver. 1.1, May 2019): U.S. Geological Survey Techniques and Methods, book 4, chap. B5, 148 p., accessed December 9, 2024, at https://doi.org/10.3133/tm4B5.

Enz, J.W., 2003, North Dakota topographic, climatic, and agricultural overview: North Dakota State University, 3 p., accessed January 3, 2024, at https://www.ndsu.edu/fileadmin/ndsco/documents/ndclimate.pdf.

Follansbee, R., and Hodges, P.V., 1925, Some floods in the Rocky Mountain Region, *in* Grover, N.C., Contributions to the hydrology of the United States, 1923–1924: U.S. Geological Survey Water-Supply Paper 520, p. 105–125, accessed January 2, 2024, at https://doi.org/10.3133/wsp520.

Frankson, R., Kunkel, K.E., Champion, S.M., Easterling, D.R., and Jencso, K., 2022a, Montana state climate summary 2022: Silver Spring, Md., National Oceanic and Atmospheric Administration Technical Report NESDIS 150–MT, 5 p., accessed July 3, 2024, at https://statesummaries.ncics.org/chapter/mt/.

Frankson, R., Kunkel, K.E., Stevens, L.E., Easterling, D.R., Stewart, B.C., Umphlett, N.A., and Stiles, C.J., 2022b, Wyoming state climate summary 2022: Silver Spring, Md., National Oceanic and Atmospheric Administration Technical Report NESDIS 150–WY, 5 p., accessed July 3, 2024, at https://statesummaries.ncics.org/chapter/wy/.

Gotvald, A.J., Barth, N.A., Veilleux, A.G., and Parrett, C., 2012, Methods for determining magnitude and frequency of floods in California, based on data through water year 2006: Scientific Investigations Report 2012–5113, accessed January 28, 2025, at https://doi.org/10.3133/sir20125113.

Griffis, V.W., and Stedinger, J.R., 2009, Log-Pearson type 3 distribution and its application in flood frequency analysis. III—Sample skew and weighted skew estimators: Journal of Hydrologic Engineering, v. 14, no. 2, p. 121–130, accessed January 4, 2024, at https://doi.org/10.1061/(ASCE)1084-0699(2009)14:2(121).

Hansen, E.M., Fenn, D.D., Schreiner, L.C., Stodt, R.W., and Miller, J.F., 1988, Probable maximum precipitation estimates—United States between the Continental Divide and the 103rd meridian: National Oceanic and Atmospheric Administration Hydrometeorological Report no. 55A, 242 p., 6 pls., accessed December 9, 2024, at https://hdsc.nws.noaa.gov/pub/hdsc/data/papers/HMR55A.pdf.

Harden, T.M., O'Connor, J.E., Driscoll, D.G., and Stamm, J.F., 2011, Flood-frequency analyses from paleoflood investigations for Spring, Rapid, Boxelder, and Elk Creeks, Black Hills, western South Dakota: U.S. Geological Survey Scientific Investigations Report 2011–5131, 136 p., accessed December 9, 2024, at https://doi.org/10.3133/sir20115131.

Harden, T.M., Ryberg, K.R., O'Connor, J.E., Friedman, J.M., and Kiang, J.E., 2021, Historical and paleoflood analyses for probabilistic flood-hazard assessments—Approaches and review guidelines: U.S. Geological Survey Techniques and Methods, book 4, chap. B6, 91 p., accessed December 9, 2024, at https://doi.org/10.3133/tm4B6.

Holmes, R.R., Jr., Wiche, G.J., Koenig, T.A., and Sando, S.K., 2013, Peak streamflows and runoff volumes for the Central United States, February through September, 2011: U.S. Geological Survey Professional Paper 1798–C, 60 p., accessed October 21, 2021, at https://doi.org/10.3133/pp1798C.

Johnson, M.V., and Omang, R.J., 1976, Floods of May–July 1975 along the Continental Divide in Montana: U.S. Geological Survey Open-File Report 76–424, 11 p., accessed December 9, 2024, at https://doi.org/10.3133/ofr76424.

Konrad, C.P., 2003, Effects of urban development on floods: U.S. Geological Survey Fact Sheet 076–03, 4 p., accessed October 18, 2023, at https://doi.org/10.3133/fs07603.

Koutsoyiannis, D., and Montanari, A., 2015, Negligent killing of scientific concepts—The stationarity case: Hydrological Sciences Journal, v. 60, no. 7–8, p. 1174–1183, accessed December 9, 2024, at https://doi.org/10.1080/02626667.2014.959959.

Lins, H.F., and Cohn, T.A., 2011, Stationarity—Wanted dead or alive?: Journal of the American Water Resources Association, v. 47, no. 3, p. 475–480, accessed December 9, 2024, at https://doi.org/10.1111/j.1752-1688.2011.00542.x.

Macek-Rowland, K.M., and Gross, T.A., 2011, 2009 Spring floods in North Dakota, western Minnesota, and northeastern South Dakota: U.S. Geological Survey Scientific Investigations Report 2010–5225, 41 p., accessed December 9, 2024, at https://doi.org/10.3133/sir20105225.

Marti, M.K., and Ryberg, K.R., 2023, Method for identification of reservoir regulation within U.S. Geological Survey streamgage basins in the Central United States using a decadal dam impact metric: U.S. Geological Survey Open-File Report 2023–1034, 15 p., accessed March 14, 2023, at https://doi.org/10.3133/ofr20231034.

McCabe, J.A., and Crosby, O.A., 1959, Floods in North and South Dakota—Frequency and magnitude: U.S. Geological Survey Open-File Report 59–80, 132 p., accessed June 15, 2021, at https://doi.org/10.3133/ofr5980.

McCarthy, P.M., Dutton, D.M., Sando, S.K., and Sando, R., 2016, Montana StreamStats—A method for retrieving basin and streamflow characteristics in Montana: U.S. Geological Survey Scientific Investigations Report 2015–5019–A, 16 p., accessed December 9, 2024, at https://doi.org/10.3133/sir20155019A.

Miller, K.A., 2003, Peak-flow characteristics of Wyoming streams: U.S. Geological Survey Water-Resources Investigations Report 2003–4107, 79 p., 2 pls., accessed December 9, 2024, at https://doi.org/10.3133/wri034107.

Milly, P.C.D., Betancourt, J., Falkenmark, M., Hirsch, R.M., Kundzewicz, Z.W., Lettenmaier, D.P., and Stouffer, R.J., 2008, Stationarity is dead—Whither water management?: Science, v. 319, no. 5863, p. 573–574, accessed December 9, 2024, at https://doi.org/10.1126/science.1151915.

Montana Department of Natural Resources and Conservation, 2021, Cooney Dam: Montana Department of Natural Resources and Conservation Fact Sheet, 2 p., accessed January 12, 2024, at https://dnrc.mt.gov/_docs/water/State_Water_Projects/Rehab/Project_Fact_Sheets/Cooney-Fact-Sheet-210913.pdf.

National Weather Service, 2024a, Flooding in Idaho: National Weather Service digital data, accessed January 3, 2024, at https://www.weather.gov/safety/flood-states-id.

National Weather Service, 2024b, Flooding in Montana: National Weather Service digital data, accessed January 3, 2024, at https://www.weather.gov/safety/flood-states-mt.

National Weather Service, 2024c, Flooding in North Dakota: National Weather Service digital data, accessed February 8, 2024, at https://www.weather.gov/safety/flood-states-nd.

Parrett, C., Carlson, D.D., Gordon, C.S., Jr., and Chin, E.H., 1984, Floods of May 1978 in southeastern Montana and northeastern Wyoming: U.S. Geological Survey Professional Paper 1244, 74 p., accessed December 9, 2024, at https://doi.org/10.3133/pp1244.

Parrett, C., and Johnson, D.R., 2004, Methods for estimating flood frequency in Montana based on data through water year 1998: U.S. Geological Survey Water-Resources Investigations Report 2003–4308, 101 p., 1 pl., accessed December 9, 2024, at https://doi.org/10.3133/wri034308.

Parrett, C., Veilleux, A., Stedinger, J.R., Barth, N.A., Knifong, D.L., and Ferris, J.C., 2011, Regional skew for California, and flood frequency for selected sites in the Sacramento-San Joaquin River Basin, based on data through water year 2006: U.S. Geological Survey Scientific Investigations Report 2010–5260, 94 p., accessed January 28, 2025, at https://doi.org/10.3133/sir20105260.

Pederson, G.T., Gray, S.T., Ault, T., Marsh, W., Fagre, D.B., Bunn, A.G., Woodhouse, C.A., and Graumlich, L.J., 2011, Climatic controls on the snowmelt hydrology of the northern Rocky Mountains: Journal of Climate, v. 24, no. 6, p. 1666–1687, accessed December 9, 2024, at https://doi.org/10.1175/2010JCLI3729.1.

Rantz, S.E., and others, 1982, Measurement and computation of streamflow (v. 1 and 2): U.S. Geological Survey Water-Supply Paper 2175, 631 p., accessed December 9, 2024, at https://doi.org/10.3133/wsp2175.

Rostvedt, J.O., 1965, Summary of floods in the United States during 1960: U.S. Geological Water Supply Paper 1790–B, 147 p., accessed December 9, 2024, at https://doi.org/10.3133/wsp1790B.

Rostvedt, J.O., and others 1970, Summary of floods in the United States during 1965: U.S. Geological Water Supply Paper 1850–E, 110 p., accessed December 9, 2024, at https://doi.org/10.3133/wsp1850E.

Ryberg, K.R., Macek-Rowland, K.M., Banse, T.A., and Wiche, G.J., 2007, A history of flooding in the Red River Basin: U.S. Geological Survey General Information Product 55, accessed January 3, 2024, at https://doi.org/10.3133/gip55.

Sando, S.K., 1998, Techniques for estimating peak-flow magnitude and frequency relations for South Dakota streams: U.S. Geological Survey Water-Resources Investigations Report 98–4055, 48 p., accessed December 9, 2024, at https://doi.org/10.3133/wri984055.

Sando, S.K., Driscoll, D.G., and Parrett, C., 2008, Peak-flow frequency estimates based on data through water year 2001 for selected streamflow-gaging stations in South Dakota: U.S. Geological Survey Scientific Investigations Report 2008–5104, 367 p., accessed December 9, 2024, at https://doi.org/10.3133/sir20085104.

Sando, S.K., and McCarthy, P.M., 2018, Methods for peak-flow frequency analysis and reporting for streamgages in or near Montana based on data through water year 2015: U.S. Geological Survey Scientific Investigations Report 2018–5046, 39 p., accessed January 3, 2024, at https://doi.org/10.3133/sir20185046.

Sando, S.K., McCarthy, P.M., and Dutton, D.M., 2016, Peak-flow frequency analyses and results based on data through water year 2011 for selected streamflow-gaging stations in or near Montana: U.S. Geological Survey Scientific Investigations Report 2015–5019–C, 27 p., accessed December 9, 2024, at https://doi.org/10.3133/sir20155019C.

Schwarz, F.K., Hughes, L.A., Hansen, E.M., Petersen, M.S., and Kelly, D.B., 1975, The Black Hills-Rapid City Flood of June 9–10, 1972—A description of the storm and flood: U.S. Geological Survey Professional Paper 877, 47 p., accessed June 20, 2023, at https://doi.org/10.3133/pp877.

Serinaldi, F., and Kilsby, C.G., 2015, Stationarity is undead—Uncertainty dominates the distribution of extremes: Advances in Water Resources, v. 77, p. 17–36, accessed December 9, 2024, at https://doi.org/10.1016/j.advwatres.2014.12.013.

Siefken, S.A., Crouch, S., Rucker, S., Wavra, H.N., Faunce, K.E., and Boles, C., 2024, peakfq—Peak Flow Frequency: U.S. Geological Survey software release, accessed December 9, 2024, at https://doi.org/10.5066/P14NQH6T.

Siefken, S.A., and McCarthy, P.M., 2022, Controlling skewness in MOVE3 peak-flow record extensions: Journal of Hydrologic Engineering, v. 27, no. 9, article 04022015, 10 p., accessed January 3, 2024, at https://doi.org/10.1061/(ASCE)HE.1943-5584.0002192.

Siefken, S.A., Williams-Sether, T., Barth, N.A., Taylor, N.J., Hamilton, W.B., and Cedar Face, M.A., 2025, Peak-flow frequency analyses for selected streamgages in Montana, North Dakota, South Dakota, and Wyoming: U.S. Geological Survey data release, https://doi.org/10.5066/P1WHRK8H.

Stedinger, J.R., and Griffis, V.W., 2011, Getting from here to where? Flood frequency analysis and climate: Journal of the American Water Resources Association, v. 47, no. 3, p. 506–513, accessed December 9, 2024, at https://doi.org/10.1111/j.1752-1688.2011.00545.x.

Stene, E.A., 1995, Hungry Horse Project: Bureau of Reclamation, 18 p., accessed January 4, 2024, at https://www.usbr.gov/history/ProjectHistories/HUNGRY%20HORSE%20PROJECT.pdf.

Teller, R.W., and Burr, M.J., 1998, Floods in north-central and eastern South Dakota, spring 1997: U.S. Geological Survey Fact Sheet 021–98, accessed March 14, 2024, at https://doi.org/10.3133/fs02198.

Teller, R.W., Burr, M.J., and Rahder, D.L., 1995, Floods in South Dakota, spring 1995: Fact Sheet 164–95, 4 p., accessed March 14, 2024, at https://doi.org/10.3133/fs16495.

Thompson, R.F., 2006, Peak stages from backwater conditions at streamflow-gaging stations in and near South Dakota through water year 2001: U.S. Geological Survey Open-File Report 2006–1395, 55 p., accessed June 20, 2023, at https://doi.org/10.3133/ofr20061395.

U.S. Geological Survey, 2024a, Peak streamflow for the Nation, *in* USGS water data for the Nation: U.S. Geological Survey National Water Information System database, accessed December 9, 2024, at https://doi.org/10.5066/F7P55KJN. [Information directly accessible at https://nwis.waterdata.usgs.gov/usa/nwis/peak.]

U.S. Geological Survey, 2024b, USGS 05059000 Sheyenne River near Kindred, ND, *in* USGS water data for the Nation: U.S. Geological Survey National Water Information System database, accessed December 9, 2024, at https://doi.org/10.5066/F7P55KJN. [Site information directly accessible at https://nwis.waterdata.usgs.gov/nwis/peak/?site_no=05059000.]

U.S. Geological Survey, 2024c, USGS 06043500 Gallatin River near Gallatin Gateway, MT, *in* USGS water data for the Nation: U.S. Geological Survey National Water Information System database, accessed December 9, 2024, at https://doi.org/10.5066/F7P55KJN. [Site information directly accessible at https://nwis.waterdata.usgs.gov/nwis/peak/?site_no=06043500.]

U.S. Geological Survey, 2024d, USGS 06099500 Marias River near Shelby MT, *in* USGS water data for the Nation: U.S. Geological Survey National Water Information System database, accessed December 9, 2024, at https://doi.org/10.5066/F7P55KJN. [Site information directly accessible at https://nwis.waterdata.usgs.gov/nwis/peak/?site_no=06099500.]

U.S. Geological Survey, 2024e, USGS 06134000 North Milk River near international boundary, *in* USGS water data for the Nation: U.S. Geological Survey National Water Information System database, accessed December 9, 2024, at https://doi.org/10.5066/F7P55KJN. [Site information directly accessible at https://nwis.waterdata.usgs.gov/nwis/peak/?site_no=06134000.]

U.S. Geological Survey, 2024f, USGS 06151000 Lyons Creek at international boundary, *in* USGS water data for the Nation: U.S. Geological Survey National Water Information System database, accessed December 9, 2024, at https://doi.org/10.5066/F7P55KJN. [Site information directly accessible at https://nwis.waterdata.usgs.gov/nwis/peak/?site_no=06151000.]

U.S. Geological Survey, 2024g, USGS 06207500 Clarks Fork Yellowstone River nr Belfry MT, *in* USGS water data for the Nation: U.S. Geological Survey National Water Information System database, accessed December 9, 2024, at https://doi.org/10.5066/F7P55KJN. [Site information directly accessible at https://nwis.waterdata.usgs.gov/nwis/peak/?site_no=06207500.]

U.S. Geological Survey, 2024h, USGS 06208000 Clarks Fork Yellowstone River at Fromberg MT, *in* USGS water data for the Nation: U.S. Geological Survey National Water Information System database, accessed December 9, 2024, at https://doi.org/10.5066/F7P55KJN. [Site information directly accessible at https://nwis.waterdata.usgs.gov/nwis/peak/?site_no=06208000.]

U.S. Geological Survey, 2024i, USGS 06208500 Clarks Fork Yellowstone River at Edgar MT, *in* USGS water data for the Nation: U.S. Geological Survey National Water Information System database, accessed December 9, 2024, at https://doi.org/10.5066/F7P55KJN. [Site information directly accessible at https://nwis.waterdata.usgs.gov/nwis/peak/?site_no=06208500.]

U.S. Geological Survey, 2024j, USGS 06208800 Clarks Fork Yellowstone River nr Silesia MT, *in* USGS water data for the Nation: U.S. Geological Survey National Water Information System database, accessed December 9, 2024, at https://doi.org/10.5066/F7P55KJN. [Site information directly accessible at https://nwis.waterdata.usgs.gov/nwis/peak/?site_no=06208800.]

U.S. Geological Survey, 2024k, USGS 06211000 Red Lodge Cr ab Cooney Re nr Boyd MT, *in* USGS water data for the Nation: U.S. Geological Survey National Water Information System database, accessed December 9, 2024, at https://doi.org/10.5066/F7P55KJN. [Site information directly accessible at https://nwis.waterdata.usgs.gov/nwis/peak/?site_no=06211000.]

U.S. Geological Survey, 2024l, USGS 06211500 Willow Creek near Boyd MT, *in* USGS water data for the Nation: U.S. Geological Survey National Water Information System database, accessed December 9, 2024, at https://doi.org/10.5066/F7P55KJN. [Site information directly accessible at https://nwis.waterdata.usgs.gov/nwis/peak/?site_no=06211500.]

U.S. Geological Survey, 2024m, USGS 06212500 Red Lodge Cr bl Cooney Reservoir nr Boyd MT, *in* USGS water data for the Nation: U.S. Geological Survey National Water Information System database, accessed December 9, 2024, at https://doi.org/10.5066/F7P55KJN. [Site information directly accessible at https://nwis.waterdata.usgs.gov/nwis/peak/?site_no=06212500.]

U.S. Geological Survey, 2024n, USGS 06221400 Dinwoody Creek above Lakes near Burris, WY, *in* USGS water data for the Nation: U.S. Geological Survey National Water Information System database, accessed December 9, 2024, at https://doi.org/10.5066/F7P55KJN. [Site information directly accessible at https://nwis.waterdata.usgs.gov/nwis/peak/?site_no=06221400.]

U.S. Geological Survey, 2024o, USGS 06311000 North Fork Powder River near Hazelton, WY, *in* USGS water data for the Nation: U.S. Geological Survey National Water Information System database, accessed December 9, 2024, at https://doi.org/10.5066/F7P55KJN. [Site information directly accessible at https://nwis.waterdata.usgs.gov/nwis/peak/?site_no=06311000.]

U.S. Geological Survey, 2024p, USGS 06317000 Powder River at Arvada, WY, *in* USGS water data for the Nation: U.S. Geological Survey National Water Information System database, accessed December 9, 2024, at https://doi.org/10.5066/F7P55KJN. [Site information directly accessible at https://nwis.waterdata.usgs.gov/nwis/peak/?site_no=06317000.]

U.S. Geological Survey, 2024q, USGS 06394000 Beaver Creek near Newcastle, WY, *in* USGS water data for the Nation: U.S. Geological Survey National Water Information System database, accessed December 9, 2024, at https://doi.org/10.5066/F7P55KJN. [Site information directly accessible at https://nwis.waterdata.usgs.gov/nwis/peak/?site_no=06394000.]

U.S. Geological Survey, 2024r, USGS 06422500 Boxelder Creek near Nemo, SD, *in* USGS water data for the Nation: U.S. Geological Survey National Water Information System database, accessed December 9, 2024, at https://doi.org/10.5066/F7P55KJN. [Site information directly accessible at https://nwis.waterdata.usgs.gov/nwis/peak/?site_no=06422500.]

U.S. Geological Survey, 2024s, USGS 12362500 S F Flathead River nr Columbia Falls MT, *in* USGS water data for the Nation: U.S. Geological Survey National Water Information System database, accessed December 9, 2024, at https://doi.org/10.5066/F7P55KJN. [Site information directly accessible at https://nwis.waterdata.usgs.gov/nwis/peak/?site_no=12362500.]

U.S. Geological Survey, 2024t, USGS 13022500 Snake River above Reservoir, near Alpine, WY, *in* USGS water data for the Nation: U.S. Geological Survey National Water Information System database, accessed December 9, 2024, at https://doi.org/10.5066/F7P55KJN. [Site information directly accessible at https://nwis.waterdata.usgs.gov/nwis/peak/?site_no=13022500.]

U.S. Geological Survey, 2024u, USGS 410720104483801 Crow Creek at 5th Street, Cheyenne, WY, *in* USGS water data for the Nation: U.S. Geological Survey National Water Information System database, accessed December 9, 2024, at https://doi.org/10.5066/F7P55KJN. [Site information directly accessible at https://nwis.waterdata.usgs.gov/nwis/peak/?site_no=410720104483801.]

U.S. Geological Survey and U.S. Environmental Protection Agency, 2012, NHDPlus (National Hydrography Dataset Plus), ver. 2: U.S. Geological Survey and U.S. Environmental Protection Agency digital data, accessed April 2021 at https://www.epa.gov/waterdata/nhdplus-national-hydrography-dataset-plus.

U.S. Interagency Advisory Committee on Water Data, 1982, Guidelines for determining flood flow frequency: Hydrology Subcommittee, Bulletin 17B, 28 p., accessed December 9, 2024, at https://water.usgs.gov/osw/bulletin17b/dl_flow.pdf.

Veilleux, A.G., Stedinger, J.R., and Lamontagne, J.R., 2011, Bayesian WLS/GLS regression for regional skewness analysis for regions with large cross-correlations among flood flows, *in* World Environmental and Water Resources Congress 2011—Bearing knowledge for sustainability: American Society of Civil Engineers Environmental and Water Resources Institute, p. 3103–3112, accessed December 9, 2024, at https://doi.org/10.1061/9780784411735.

Vogel, R.M., and Stedinger, J.R., 1985, Minimum variance streamflow record augmentation procedures: Water Resources Research, v. 21, no. 5, p. 715–723, accessed January 27, 2025, at https://doi.org/10.1029/WR021i005p00715.

Vogel, R.M., Yaindl, C., and Walter, M., 2011, Nonstationarity—Flood magnification and recurrence reduction factors in the United States: Journal of the American Water Resources Association, v. 47, no. 3, p. 464–474, accessed December 9, 2024, at https://doi.org/10.1111/j.1752-1688.2011.00541.x.

Wells, J.V.B., 1955, Floods of April 1952 in the Missouri River basin: U.S. Geological Survey Water-Supply Paper 1260–B, 264 p., 3 pls., accessed December 9, 2024, at https://doi.org/10.3133/wsp1260B.

Wells, J.V.B., 1957, Floods of May–June 1953 in the Missouri River basin in Montana: U.S. Geological Survey Water-Supply Paper 1320–B, 93 p., 2 pls., accessed December 9, 2024, at https://doi.org/10.3133/wsp1320B.

Wieczorek, M.E., Wolock, D.M., and McCarthy, P.M., 2021, Dam impact/disturbance metrics for the conterminous United States, 1800 to 2018: U.S. Geological Survey data release, accessed March 14, 2024, at https://doi.org/10.5066/P92S9ZX6.

Williams-Sether, T., 1992, Techniques for estimating peak-flow frequency relations for North Dakota streams: U.S. Geological Survey Water-Resources Investigations Report 92–4020, 57 p., accessed December 9, 2024, at https://pubs.usgs.gov/wri/1992/4020/report.pdf.

Williams-Sether, T., 2015, Regional regression equations to estimate peak-flow frequency at sites in North Dakota using data through 2009: U.S. Geological Survey Scientific Investigations Report 2015–5096, 12 p., accessed December 9, 2024, at https://doi.org/10.3133/sir20155096.

Zelt, R.B., Boughton, G., Miller, K.A., Mason, J.P., and Gianakos, L.M., 1999, Environmental setting of the Yellowstone River Basin, Montana, North Dakota, and Wyoming: U.S. Geological Survey Water-Resources Investigations Report 98–4269, 112 p., accessed December 9, 2024, at https://doi.org/10.3133/wri984269.

For more information about this publication, contact:
Director, USGS Wyoming-Montana Water Science Center
3162 Bozeman Avenue
Helena, MT 59601
406–457–5900

For additional information, visit: https://www.usgs.gov/centers/wy-mt-water/

Publishing support provided by the
Rolla Publishing Service Center

Siefken and others—**Methods for Peak-Flow Frequency Analysis in or near Montana, North Dakota, South Dakota, and Wyoming**—SIR 2025–5019

ISSN 2328-0328 (online)
https://doi.org/10.3133/sir20255019