Prepared in cooperation with the Montana Department of Transportation, Montana Department of Environmental Quality, and Montana Department of Natural Resources and Conservation

Montana StreamStats—A Method for Retrieving Basin and Streamflow Characteristics in Montana

Chapter A of
Montana StreamStats

Scientific Investigations Report 2015–5019–A

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

Cover photograph: Swiftcurrent Creek above Swiftcurrent Lake at Many Glacier, Montana. Photograph by Don Bischoff, U.S. Geological Survey, June 4, 2005.

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SALLY JEWELL, Secretary

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Conversion Factors

U.S. customary units to International System of Units

Multiply	By	To obtain
	Length	
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
square mile (mi^2)	259.0	hectare (ha)
square mile (mi^2)	2.590	square kilometer (km^2)
	Volume	
acre-foot (acre-ft)	1,233	cubic meter (m^3)
	Flow Rate	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)

International System of Units to U.S. customary units

Multiply	By	To obtain
	Length	
meter (m)	3.281	foot (ft)

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

°F = (1.8 × °C) + 32.

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

°C = (°F – 32) / 1.8.

Datum

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

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

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

Supplemental Information

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as °C = (°F – 32) / 1.8.

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 2011 is the period from October 1, 2010, through September 30, 2011.

Abbreviations

AEP	annual exceedance probability
AL7Q10	streamflow for which a consecutive 7-day annual low-flow can be expected to be lower, on average, once every 10 years (also known as the non-exceedance probability of 10 percent) based on annual low-flow data
CONTDA	contributing drainage area
CSG	crest-stage gage
DEM	digital elevation model
FAC	flow accumulation
FDR	flow direction
GIS	geographic information system
GLS	generalized least squares
HUC	hydrologic unit code
MDT	Montana Department of Transportation
MOVE.1	maintenance of variance type 1
MT DEQ	Montana Department of Environmental Quality
MT DNRC	Montana Department of Natural Resources and Conservation
NED	National Elevation Dataset
NGP	National Geospatial Program
NHD	National Hydrography Dataset
NHDPlusV2	NHDPlus Version 2
NID	National Inventory of Dams
NLCD	National Land Cover Dataset
NWIS	National Water Information System
OLS	ordinary least squares
PRISM	Parameter-elevation Regression on Independent Slopes Model
USGS	U.S. Geological Survey
WBD	Watershed Boundary Dataset
WIE	Weighted Independent Estimates

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Montana StreamStats—A Method for Retrieving Basin and Streamflow Characteristics in Montana

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Abstract

The U.S. Geological Survey (USGS) provides streamflow characteristics and other related information needed by water-resource managers to protect people and property from floods, plan and manage water-resource activities, and protect water quality. Streamflow characteristics provided by the USGS, such as peak-flow and low-flow frequencies for streamflow-gaging stations, are frequently used by engineers, flood forecasters, land managers, biologists, and others to guide their everyday decisions. In addition to providing streamflow characteristics at streamflow-gaging stations, the USGS also develops regional regression equations and drainage area-adjustment methods for estimating streamflow characteristics at locations on ungaged streams. Regional regression equations can be complex and often require users to determine several basin characteristics, which are physical and climatic characteristics of the stream and its drainage basin. Obtaining these basin characteristics for streamflow-gaging stations and ungaged sites traditionally has been time consuming and subjective, and led to inconsistent results.

StreamStats is a Web-based geographic information system application that was created by the USGS to provide users with access to an assortment of analytical tools that are useful for water-resource planning and management. StreamStats allows users to easily obtain streamflow and basin characteristics for USGS streamflow-gaging stations and user-selected locations on ungaged streams. The USGS, in cooperation with Montana Department of Transportation, Montana Department of Environmental Quality, and Montana Department of Natural Resources and Conservation, completed a study to develop a StreamStats application for Montana, compute streamflow characteristics at streamflow-gaging stations, and develop regional regression equations to estimate streamflow characteristics at ungaged sites. Chapter A of this Scientific Investigations Report describes the Montana StreamStats application and the datasets, streamflow-gaging stations, streamflow characteristics, and regression equations (as described fully in Chapters B through G of this report) that are used for development of the StreamStats application for Montana.

Introduction

The U.S. Geological Survey (USGS) periodically updates and provides streamflow characteristics at streamflow-gaging stations (hereinafter referred to as gaging stations). Streamflow characteristics, such as the 1-percent flood (the streamflow that has a 1-percent chance of being exceeded in any given year, sometimes referred to as the 100-year flood) and the consecutive 7-day annual low-flow that can be expected to be lower, on average, once every 10 years (AL7Q10), are frequently used by engineers, flood forecasters, land managers, biologists, and others to protect people and property from floods, plan and manage water-resource activities, and protect water quality. In addition to streamflow characteristics, the physical and climatic characteristics of a drainage basin (basin characteristics) are often needed to understand the mechanisms controlling water availability, water quality, and aquatic habitats at various locations.

Streamflow characteristics commonly are needed at locations that are not at or near a gaging station with reported streamflow characteristics. To address this need, the USGS periodically performs regional analyses of streamflow characteristics at gaging stations to develop regression equations and other predictive methods that can then be used to estimate streamflow characteristics for ungaged streams. Use of these regional regression equations for estimating streamflow characteristics can be complex and often requires the user to determine several basin characteristics that may need interpretation. Basin characteristics used in regional regression equations most commonly include the contributing drainage area and mean annual precipitation; however, other physical and climatic characteristics such as mean basin elevation and slope, evapotranspiration, and land cover also are used in the regression equations. Obtaining these basin characteristics for gaging stations and ungaged sites traditionally has been time consuming, subjective, and can lead to inconsistent results.

The USGS, in cooperation with Montana Department of Transportation (MDT), Montana Department of Environmental Quality (MT DEQ), and Montana Department of Natural Resources and Conservation (MT DNRC), completed a study to develop a StreamStats application for Montana, compute streamflow characteristics at gaging stations, and develop regional regression equations to estimate streamflow characteristics at ungaged sites. StreamStats is a Web-based geographic information system (GIS) application created by the USGS to provide users with access to an assortment of data and analytical tools. StreamStats provides streamflow and basin characteristics for USGS gaging stations and provides tools to delineate drainage basins, compute basin characteristics, and solve regression equations to estimate streamflow characteristics at ungaged sites.

Purpose and Scope

Chapter A of this Scientific Investigations Report describes the Montana StreamStats application and the datasets, gaging stations, streamflow characteristics, and regression equations that are used in the Montana StreamStats application. The Montana StreamStats application, the geospatial datasets, and basin characteristics used to develop the StreamStats application are the primary focus of this report chapter. Additionally, this report chapter provides an overview of the data, methods, and results used for computing streamflow characteristics and regional regression equations (as described fully in Chapters B through G of this Scientific Investigations Report) that are accessible in Montana StreamStats.

Montana StreamStats

StreamStats is a Web-based GIS application that was created by the USGS to provide users with access to an assortment of analytical tools that are useful for water-resource planning and management (U.S. Geological Survey, 2015a). StreamStats allows users to easily obtain streamflow and basin characteristics for gaging stations and user-selected locations on ungaged streams. The StreamStats application was created by the USGS to be used at a national level; however, local USGS water science centers are responsible for developing and processing the necessary geospatial data, computing streamflow characteristics, and developing regional regression equations to be deployed within StreamStats.

StreamStats is accessed through a map-based user interface and can perform analyses on selected sites much faster than historically used manual techniques. StreamStats, as well as a brief description of the application and links to user instructions, definitions, fact sheets, and other information, can be accessed at http://water.usgs.gov/osw/streamstats/. It is recommended that, in addition to the application description and user instructions, users read the limitations for the StreamStats application before attempting to use StreamStats. Users who plan to use StreamStats to estimate streamflow characteristics for ungaged sites in Montana also should review the reports listed on the State introductory pages (http://water.usgs.gov/osw/streamstats/montana.html) to understand how the regression equations were developed and how they should be applied, and to view any special instructions for estimating streamflow characteristics for ungaged sites in the State.

StreamStats functionality is primarily based on the ArcHydro Data Model and Tools (Esri, Inc., 2013) and is implemented using ArcGIS Server technology (ESRI, Inc., 2015). StreamStats incorporates a map-based user interface for site selection; a Microsoft® Access database that contains information for data-collection stations; a GIS program that delineates drainage basins and measures basin characteristics; and a GIS database that contains digital representations of the land surface (digital elevation model [DEM] and derivative products), historical climate data, and other data needed for locating sites of interest in the user interface, delineating drainage basins, and measuring drainage-basin characteristics (U.S. Geological Survey, 2015a). StreamStats version 2, which was retired July 15, 2015, included stream-network navigation tools for searching upstream and downstream along streams from selected sites to identify activities that may affect streamflow or water quality at sites. These tools are not available in the current StreamStats version 3, but they are being redeveloped for eventual release in StreamStats version 4.

Geospatial Datasets Used in Montana StreamStats

StreamStats requires three primary geospatial datasets to perform network navigation and delineate basin drainages: a stream network; a DEM representation of the land surface; and a set of previously delineated, quality-assured drainage boundaries. The Montana StreamStats application uses the NHD Plus Version 2 (NHDPlusV2) (Horizon Systems Corporation, 2013) as the source for these required datasets. The NHDPlusV2 is an integrated suite of application-ready geospatial datasets that incorporate the National Hydrography Dataset (NHD) stream network (1:100,000-scale), a 30-meter DEM from the National Elevation Dataset (NED), and derived hydrologic units (12-digit) from the Watershed Boundary Dataset (WBD). The NHDPlusV2 also includes various other value-added attributes to enhance stream-network navigation, analysis, and display. Elevations in the DEM in NHDPlusV2 were modified whereby grid cells that coincide with WBD boundaries were artificially raised and grid cells that coincide with stream networks were artificially lowered resulting in a hydrologic-enforced DEM. The hydrologic-enforced DEM was then used to generate flow accumulation (FAC) and flow direction (FDR) derivative rasters to ensure proper watershed delineation. The NHD, WBD, and NED are maintained through stewardship programs led by the USGS National Geospatial Program (NGP) and involving State and Federal agencies (Horizon Systems Corporation, 2013).

National Hydrography Dataset

The NHD is a 1:100,000-scale digital vector dataset that is used to represent the stream network in Montana with features such as rivers, streams, canals, lakes, ponds, dams, and gaging stations (U.S. Geological Survey, 2015b). Each segment of the stream network is represented by an NHD Flowline (hereinafter referred to as flowline), which contains attributes such as flow direction, length, and name. Potential errors in flowlines can be identified by comparing the contributing drainage areas (CONTDAs) computed for gaging stations for this study with those from the USGS National Water Information System (NWIS; U.S. Geological Survey, 2015c) using the station identification number in table 1–1 in appendix 1 at the back of this report chapter (available at http://dx.doi.org/10.3133/sir20155019A). Differences greater than 2 percent were flagged and the flowlines in the drainage basin were reviewed for errors. Errors identified in the flowlines included improper flow direction, improper flow path, and flowlines that were not connected to the stream network. Included in the NHDPlusV2 is a feature class, called Sinks, which represents terminal ends of flowlines that do not connect to the stream network. Sinks are used to insert an artificially low data point in the DEM, which forces all flow from the basin into the sink. In some cases, where a closed basin is present, the sink and associated terminal of the flowline are properly identified and located; however, in many cases the Sinks feature class included sinks that were not located in a closed basin, and edits to the DEM-derived FAC and FDR rasters were required to ensure proper watershed delineations.

Watershed Boundary Dataset

The WBD is a drainage boundary framework that defines the areal extent of surface-water drainage to a point, accounting for all land and surface areas. The framework is a nationally consistent and seamless dataset that complements the NHD and ensures that basin delineations for a selected point on a stream do not cross basin boundaries. The WBD was developed under the leadership of the Subcommittee on Spatial Water Data (Advisory Committee on Water Information, 2015) and is used to define hydrologic units, which represent regions that are divided and subdivided, generally at confluences, into successively smaller hydrologic units and identified by a unique hydrologic unit code (HUC). The WBD has undergone a certification process in accordance with the Federal Standard (U.S. Geological Survey and U.S. Department of Agriculture, Natural Resources Conservation Service, 2013) and has been mandated by several Federal agencies as the official hydrologic unit dataset for Federal environmental compliance and reporting (Lins, 2012a).

Historically, drainage areas for gaging stations were derived by manual delineation of polygonal basin areas on paper topographic maps and reported in USGS Annual Water Data Reports (U.S. Geological Survey, 2015d) and in NWIS. In 2012, the USGS officially accepted the WBD as the authoritative dataset for hydrologic unit boundaries for the Nation (Lins, 2012a) and provided guidance for digitally deriving drainage areas (Dupree and Crowfoot, 2012; Lins, 2012b) using the NHD, WBD, and NED. New drainage areas were computed for the Montana gaging stations using geospatial datasets and following guidance from Dupree and Crowfoot (2012) and Lins (2012b), and the drainage areas were updated in NWIS in 2015.

National Elevation Dataset

The NED is the primary elevation data product produced and distributed by the USGS (U.S. Geological Survey, 2015b) and is available nationally at a grid spacing of 1 arc-second (approximately 30 meters, thus referred to as the 30-meter NED). The NED is a raster product designed to provide national elevation data in a seamless form with a consistent datum, units, and coordinate reference system; and is updated regularly as newer data become available. A snapshot of the NED was used to create the FAC and FDR rasters in the NHDPlusV2 dataset, which StreamStats uses for basin delineations. StreamStats uses the original, unmodified NED to compute elevation and slope-derived basin characteristics, such as mean basin elevation and mean basin slope. The NED data are documented in compliance with the Federal Geographic Data Committee's Content Standard for Digital Geospatial Metadata (Gesch and others, 2009).

National Hydrography Dataset of Dams

The NHD includes a point layer for dams. The dams in NHD were derived from the National Inventory of Dams (NID) database, which includes dams that are more than 25 feet high, hold more than 50 acre-feet of water, or are considered a significant hazard if they fail (U.S. Army Corps of Engineers, 2014). The NHD database of dams included 2,924 dams in Montana, which were reviewed to ensure the dams were properly located on an identifiable dam or body of water and were located on the appropriate flowlines. Additionally, the MT DNRC provided a database of dams (Chadrick Hill, Montana Department of Natural Resources and Conservation, written commun., 2011), which was used to check and edit the NHD dams and obtain reservoir storage information and dam construction dates. Of the 2,924 dams in the NHD, 107 could not be located on an identifiable reservoir or dam within the original plotted vicinity and thus were removed from the database. The CONTDAs for the remaining 2,817 dams were computed using methods described by Dupree and Crowfoot (2012) and Lins (2012b) and are listed in table 1–2 in appendix 1 at the back of this report chapter (available at http://dx.doi.org/10.3133/sir20155019A).

The 2,817 dams listed in table 1–2 are only a small subset of the total number of dams in Montana. Currently (2015), a comprehensive database that includes all of the dams in Montana is not available. A pilot study was initiated by MT DNRC to identify all of the dams in the Pumpkin Creek watershed in eastern Montana (Jim Robinson, Montana Department of Natural Resources and Conservation, written commun., 2011). During the pilot study, 488 dams associated with water rights in Montana were identified in the Pumpkin Creek watershed. Only 23 of these dams are listed in the NHD and NID. The requirements set by the U.S. Army Corps of Engineers for inclusion of dams in the NID ensures that the largest dams in Montana, which have the greatest amount of storage and greatest potential to affect streamflow characteristics, are included in the NHD; however, small dams, specifically those associated with water rights, have the ability to affect streamflow, particularly low flows. Additionally, the NHD does not include most of the low-head diversion dams, which are widely used in Montana to divert water for irrigation and municipal supply. In some cases, these low-head diversion dams have the ability to divert most of the streamflow for a given stream or river. For example, the Deadman's Basin diversion canal withdraws water from the Musselshell River in central Montana and has a capacity of 600 cubic feet per second (ft^3/s) (Montana Department of Natural Resources and Conservation, 2015); however, the mean annual streamflow for Musselshell River at Harlowton, Montana (USGS gaging station 06120500; map number 212 in figure 1) is 156 ft^3/s (water years 1907–2002; water year is the 12-month period from October 1 through September 30 and is designated by the year in which it ends), and the mean monthly streamflows only exceed 500 ft^3/s in the month of June, which has a mean monthly streamflow of 507 ft^3/s (McCarthy, 2005). Any future activities to refine NHD and geospatial datasets in Montana should incorporate low-head diversion dams and dams associated with MT DNRC water rights.

Datasets Available in Canada

Development of basin characteristics in Montana was limited to the availability of regional physical and climatic data that were consistent and continuous throughout entire drainage basins, whether they were encompassed by local, regional, State, or international boundaries. Montana shares an international boundary with three Canada provinces: British Columbia, Alberta, and Saskatchewan (fig. 1). Streams originate in Montana and each of the three Canada provinces and cross the international boundary flowing to Canada and to the United States, depending on the location. Thus, selection of data for basin characteristics required similarly developed datasets available for areas in Canada as well as for Montana, Idaho, North Dakota, South Dakota, and Wyoming. In addition to selecting physical and climatic data that were consistent and continuous, the stream hydrography also was needed for areas in Canada.

The NHDPlusV2 includes data for each of the 8-digit HUCs that cross the international boundary. The NHDPlusV2 data for these 8-digit HUCs were developed cooperatively by the United States and Canada as part of the Canada-U.S. Transboundary Hydrographic Harmonization (Laitta, 2010). For most transboundary drainage basins, the 8-digit HUCs in NHDPlusV2 incorporated the entire basin needed for this study; however, data from the upper and central Kootenay River in British Columbia were not included in NHDPlusV2. Digital elevation data for the upper and central Kootenay River Basin were obtained from Government of Canada (Natural Resources Canada, 2007) and used to develop necessary rasters for computing basin drainage areas and other basin characteristics. A continuous land-use dataset was created by merging the Northern Land Cover of Canada Circa 2000 (Natural Resources Canada, 2009) with the 2001 National Land Cover Dataset (NLCD; Homer and others, 2007). Continuous grids for monthly precipitation, annual precipitation, and temperature were developed by merging datasets for 1971–2000 for the Parameter-elevation Regression on Independent Slopes Model (PRISM; PRISM Climate Group, 2004) and the Long Term mean Climate Grids for Canada (Natural Resources Canada, 2015).

Streamflow-Gaging Stations and Classification of Regulation

StreamStats includes a map layer for gaging stations, which includes all of the gaging stations in Montana for which streamflow data have been collected. Streamflow data for the gaging stations shown in StreamStats can be accessed through NWIS (U.S. Geological Survey, 2015c), and computed streamflow characteristics can be accessed through the StreamStats Data-Collection Station Report that is provided within StreamStats. The StreamStats Data-Collection Report includes a link to NWIS, descriptive information, physical characteristics, and computed streamflow characteristics for each gaging station. As part of this study, basin and streamflow characteristics were computed for 755 gaging stations operated by the USGS that are located in or near Montana and have 10 or more years of record (fig. 1, table 1–1). The basin and streamflow characteristics computed for these 755 gaging stations are available in the StreamStats Data-Collection Station Report, which also provides citations for the computed basin and streamflow characteristics. Basin and streamflow characteristics may be available from multiple citations for an individual gaging station. The user should carefully review the characteristics and understand that characteristics may be reported for multiple periods of record and may not be consistent from one citation to the next.

Reservoir storage and operations have the potential to substantially affect streamflow characteristics; therefore, it is necessary to use gaging stations that are considered unregulated or minimally regulated for development of regional regression equations. For this study, gaging stations for which streamflow characteristics were computed were evaluated and classified as regulated or unregulated. A gaging station is considered to be unregulated if the cumulative drainage area upstream from all dams is less than 20 percent of the drainage area of the gaging station and no large diversion canals are upstream from the gaging station. A gaging station is considered to be regulated if the cumulative drainage area of all upstream dams exceeds 20 percent of the drainage area of the given gaging station. If the drainage area of a single upstream

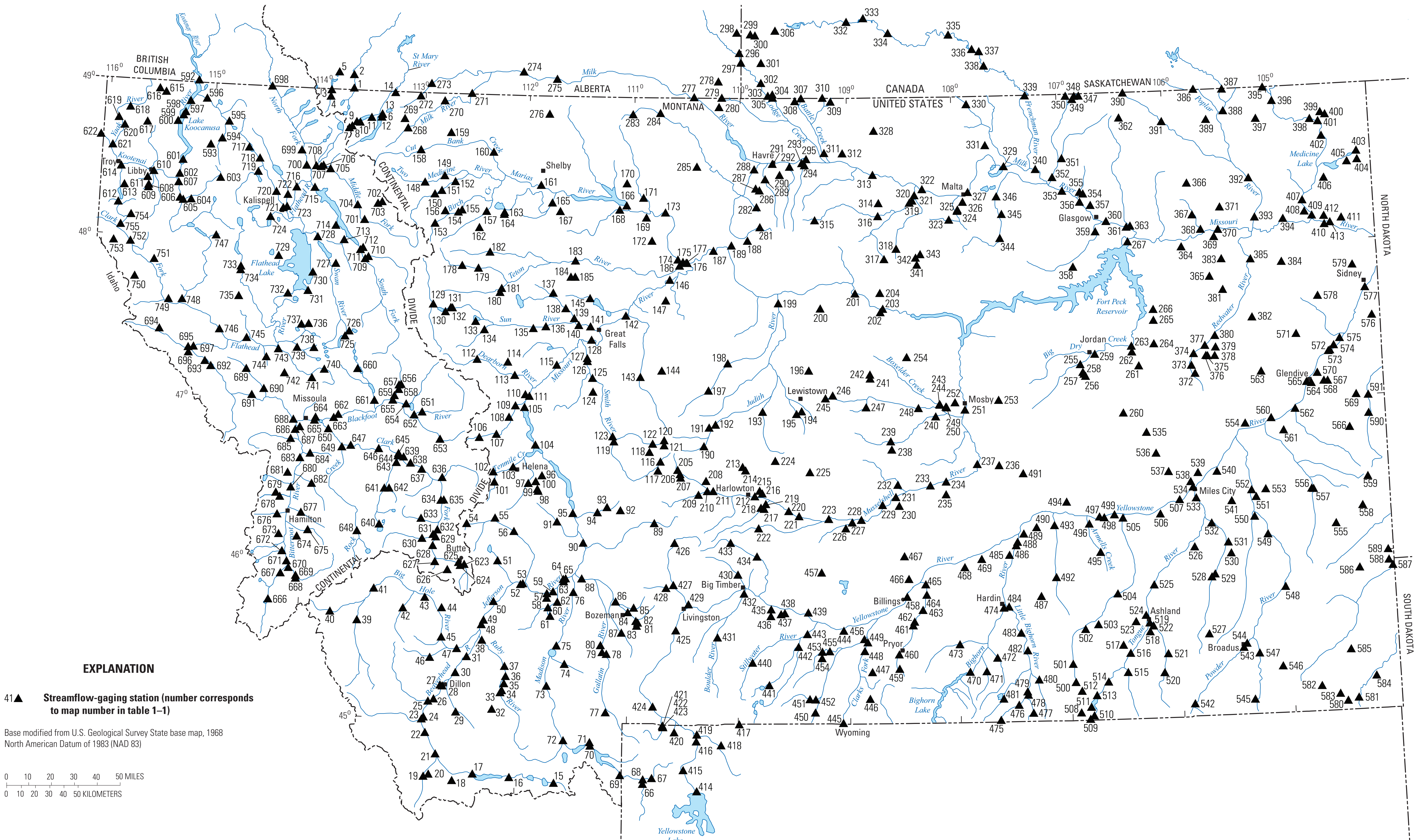

Figure 1. Streamflow-gaging stations in and near Montana.

dam exceeds 20 percent of the drainage area of a given gaging station, the regulation is classified as major. If no single upstream dam has a drainage area that exceeds 20 percent of the drainage area of a given gaging station, the regulation is classified as minor. In cases where a large diversion canal was known to be located on the channel upstream from a gaging station, the gaging station was classified as major regulation. The selection of large diversion canals was primarily based on the regulation status of gaging stations from previous studies (Parrett and Johnson, 2004; McCarthy, 2005) and gaging-station information provided by USGS Annual Water Data Reports (U.S. Geological Survey, 2015d), and could not be evaluated on a statewide basis due to lack of information on diversion dams and associated canals. Four diversion dams, which were not included in the NHD dams dataset, were identified as causing substantial regulation to streamflow. These four dams are the St. Mary River Canal diversion dam, Barretts diversion dam, Sun River diversion dam, and Deadman's Basin diversion canal and can easily be identified in table 1–3 in appendix 1 at the back of this report chapter (available at http://dx.doi.org/10.3133/sir20155019A) as dams that do not have a dam identification number. The regulation status and year in which regulation began for each gaging station is presented in table 1–1; the 2,817 NHD dams that were used to determine regulation are listed in table 1–2; and information on the regulation structures, including selected large diversion dams, affecting most of the gaging stations classified as major regulation is presented in table 1–3.

For gaging stations classified as having minor dam regulation, the cumulative drainage area upstream from the dams exceeds 20 percent; however, no single upstream dam exceeds 20 percent of the gaging station's drainage area. Peak-flow frequency analyses were performed on the total period of record for gaging stations classified as having minor dam regulation; however, all other computations of streamflow characteristics treated dams with minor regulation the same as dams with major regulation. Gaging stations classified as having major regulation were evaluated for periods prior to regulation and post-regulation. If 10 or more years of streamflow records were available for the post-regulation period, streamflow characteristics were computed and classified as regulated. Similarly, streamflow characteristics were computed for unregulated periods of record if 10 or more years of streamflow records were available prior to dam construction. Streamflow characteristics for unregulated periods on gaging stations classified as regulated were computed to assist development of regional regression equations for unregulated streamflow characteristics.

Classification of the regulation status of a gaging station was completed for this study in 2014 and is based on the NHD point layer for dams present in the gaging-station drainage basins and the storage start dates of the dams. In a few cases, a gaging station was classified as regulated in 2014, but the 20-percent regulation criteria was not met until after streamflow measurements at the gaging station were discontinued (referred to as a discontinued gaging station). Thus, a gaging station might have been classified as regulated in 2014 but have no streamflow data for a regulated period. Classifying the regulation status of a discontinued gaging station is intended to provide accurate classification should the gaging station be reactivated.

The criteria used for defining regulation status of gaging stations in Montana were primarily based on affected drainage area and do not account for storage capacity of the dams, total diversions of streamflow, or any other metrics that may be used to determine regulation. Any future activities to define regulation effects on streamflow characteristics should incorporate storage capacity information considered in relation to streamflow characteristics. Furthermore, statewide datasets for irrigation diversions currently (2015) are not readily available at sufficient scale and coverage for systematically assessing effects on the application of streamflow characteristics within a statewide gaging-station network. Compilation of a statewide dataset of locations and capacities of irrigation canals would allow for better definition of regulation effects from stream diversions on streamflow characteristics.

Basin Characteristics Calculated in Montana StreamStats

StreamStats functionality and NHDPlusV2 were used to determine drainage-basin boundaries and the contributing areas within those boundaries (CONTDAs) for the gaging stations used to develop the new regional regression equations. The drainage-basin boundaries for the gaging stations were then overlaid in a GIS on other georeferenced datasets, such as the NLCD (Homer and others, 2007) and PRISM (PRISM Climate Group, 2004) datasets, to determine additional basin characteristics (physical and climatic) for use as potential explanatory variables in the regional regression analyses.

Basin characteristics investigated as potential explanatory variables in the regional regression analyses were selected based on previous studies performed in Montana, theoretical relations with streamflow characteristics, and the ability to generate the characteristics using GIS analyses and digital datasets. In previous regional regression studies from Montana, basin characteristics were manually measured or estimated using topographic maps, planimeters, and overlaying transparent gridded cells on the maps. The number of candidate basin characteristics used in these studies ranged from 2 (Berwick, 1958) to 12 (Parrett and Omang, 1981). Although as many as 40 basin characteristics were explored for potential use as explanatory variables in the new regional regression equations, only a limited number of basin characteristics could be made available in StreamStats because of limitations in real-time processing capabilities. Only basin characteristics used as explanatory variables in the new regional regression equations or that provide basic information about selected drainage basins are available in StreamStats. The basin characteristics explored as explanatory variables for the new regional regression equations are listed in table 1. Basin characteristics used as explanatory variables in the new regional regression equations and provided in StreamStats also are presented in table 1. Basin characteristics that were used as explanatory variables are reported for the selected 755 gaging stations (fig. 1, table 1–1) in StreamStats. Although StreamStats also can be used to compute basin characteristics for a user-selected location, the computed basin characteristics will be restricted to available datasets provided in StreamStats.

Streamflow Characteristics for Streamflow-Gaging Stations Included in Montana StreamStats

Information about streamflow characteristics is essential for development and management of surface-water resources. Many individuals and agencies, including the MDT, MT DEQ, MT DNRC, and the Montana Department of Fish, Wildlife, and Parks, have continuing needs for streamflow characteristics indicating the seasonal variability in streamflow for use in designing infrastructure, developing wastewater permits, evaluating flows available for withdrawal, and assessing the health of aquatic habitat. The USGS's NWIS is a comprehensive and distributed application that supports the acquisition, processing, and long-term storage of water data, including surface-water data collected at gaging stations. Data collected at gaging stations are processed and stored in NWIS for public consumption and analysis of various streamflow characteristics.

Peak-flow data are collected at gaging stations and represent the largest instantaneous streamflow during the water year. Peak-flow data are used to compute flood magnitudes and exceedance probabilities, which are used for the design of highway infrastructure, flood-plain mapping, and many other purposes. In addition to collecting peak-flow data at continuously operated gaging stations, the USGS, in cooperation with MDT, has been collecting peak-flow data at partial-record crest-stage gages (CSGs) since 1955. The CSGs provide peak-flow data for numerous locations throughout Montana where continuous-record gaging stations were not operated, and typically are located on streams with CONTDAs less than about 40 square miles (mi^2). The peak-flow data from 725 gaging stations in or near Montana that have 10 or more years of data were used to update statewide peak-flow frequency analyses (Sando, McCarthy, and Dutton, 2016).

Daily data, also referred to as the daily mean streamflow, represent the mean of the instantaneous streamflows recorded at a gaging station for each day. As described in Chapter E (McCarthy, 2016), daily mean streamflows were used to compute mean monthly and mean annual streamflows; low-flow characteristics, such as the AL7Q10; high-flow characteristics; and flow-duration curves. Annual low-flow, annual high-flow, and seasonal flow characteristics are particularly useful for characterizing flow variability and duration. Low-flow frequency data for annual and seasonal periods indicate how frequently low flows might occur and are used to assess the wastewater assimilation capacity of streams, develop wastewater permits, determine total maximum daily loads of streams, and assess health of aquatic habitat. Annual high-flow frequency data, in conjunction with peak-flow frequency analyses, indicate how frequently large flows might occur and are used for flood planning and the design of highway bridges, culverts, dams, and levees on or near streams. The daily mean streamflow data from 408 gaging stations in or near Montana that have 10 or more years, or 10 or more seasons, of daily streamflow data were used to update statewide streamflow characteristics (McCarthy, 2016).

The analyses of peak-flow data included data through water year 2011, whereas the analyses of daily-flow data included data through water year 2009. Originally, analyses of the peak-flow data for this study were going to include data through water year 2009; however, very large floods occurred in 2011 in some areas of Montana, which greatly affected flood-frequency analyses. Thus, the scope for the peak-flow analyses was changed to include data through 2011. Results from the peak-flow and daily-flow data analyses for gaging stations in or near Montana are available in StreamStats by selecting a gaging station of interest in the Montana StreamStats application. The following subsections of this report chapter summarize the methods and results for these analyses of gaging-station data as found in Chapter B (Sando, McCarthy, and others, 2016), Chapter C (Sando, McCarthy, and Dutton, 2016), Chapter D (Sando, S.K., Sando, Roy, and others, 2016), and Chapter E (McCarthy, 2016) of this Scientific Investigations Report.

Temporal Trends and Stationarity in Annual Peak Flow and Peak-Flow Timing

A complementary study of general patterns in peak-flow temporal trends and stationarity for 24 long-term gaging stations in Montana was completed in cooperation with the MDT and MT DNRC (Sando, McCarthy, and others, 2016). The 24 gaging stations were the only ones in Montana that met the criteria of having (1) at least 75 years of record; (2) at least 5 years of record during the 1930s, which were unusually dry years; and (3) generally small effects from urbanization or large reservoir storage. The primary focus of the investigation was to identify general patterns in peak-flow temporal trends and stationarity relevant to application of peak-flow frequency analyses within the statewide gaging-station network. Temporal trends were analyzed for two hydrologic variables: annual peak-flow magnitude and peak-flow timing. The annual peak-flow magnitude is the maximum instantaneous discharge in cubic feet per second, recorded each year a gaging station was operated. Peak-flow timing is the day of the annual peak flow, recorded each year a gaging station was operated. Study results provided evidence that annual peak flow for most of the long-term gaging stations were not trending in magnitude or timing and thus can be considered stationary for application of peak-flow frequency analyses within a statewide

Table 1. Basin characteristics evaluated as potential explanatory variables in the regional regression equations.

[Shaded StreamStats abbreviations indicate that basin characteristic can be computed by the Montana StreamStats application. --, basin characteristic was not an explanatory variable in the regional regression equations]

StreamStats abbreviation	Abbreviation for basin characteristics used in regression equations	Description
APRAVTMP	--	Mean April temperature, in degrees Fahrenheit[1]
AUGAVTMP	--	Mean August temperature, in degrees Fahrenheit[1]
BASINPERIM	--	Perimeter of the contributing drainage area, in miles[2]
BSLDEM30M	--	Mean basin slope for the contributing drainage area[2]
COMPRAT	--	Compactness ratio for the contributing drainage area, computed using the CONTDA and BASINPERIM basin characteristics[2]
CONTDA	A	Contributing drainage area, in square miles[2]
DECAVTMP	--	Mean December temperature, in degrees Fahrenheit[1]
EL5000	E5000	Percentage of contributing drainage basin above 5,000 feet elevation[2]
EL5500	--	Percentage of contributing drainage basin above 5,500 feet elevation[2]
EL6000	E6000	Percentage of contributing drainage basin above 6,000 feet elevation[2]
EL6500	--	Percentage of contributing drainage basin above 6,500 feet elevation[2]
EL7000	--	Percentage of contributing drainage basin above 7,000 feet elevation[2]
ELEV	E	Mean basin elevation, in feet[2]
ELEVMAX	--	Maximum basin elevation, in feet[2]
ET0306MOD	ETSPR	Spring (March–June) mean monthly evapotranspiration (2000–12), in inches per month[3]
ET0710MOD	--	Summer (July–October) mean monthly evapotranspiration (2000–12), in inches per month[3]
FEBAVTMP	--	Mean February temperature, in degrees Fahrenheit[1]
IRRIGAT_MT	--	Percentage of contributing drainage basin under some irrigation regime[4]
JANAVTMP	--	Mean January temperature, in degrees Fahrenheit[1]
JULYAVTMP	--	Mean July temperature, in degrees Fahrenheit[1]
JUNEAVTMP	--	Mean June temperature, in degrees Fahrenheit[1]
LAKESNHDH	--	Percentage of contributing drainage basin in lakes, ponds, and reservoirs[5]
LC01CRPHAY	--	Percentage of contributing drainage basin covered by agriculture[6]
LC01DEV	--	Percentage of contributing drainage basin covered by urban land[6]
LC01FOREST	F	Percentage of contributing drainage basin covered by forest[6]
LC01WETLND	--	Percentage of contributing drainage basin covered by wetlands[6]
MARAVTMP	--	Mean March temperature, in degrees Fahrenheit[1]
MAXTEMP	--	Mean annual maximum temperature, in degrees Fahrenheit[1]
MAYAVTMP	--	Mean May temperature, in degrees Fahrenheit[1]
MINBELEV	--	Minimum basin elevation, in feet[2]
MINTEMP	--	Mean annual minimum temperature, in degrees Fahrenheit[1]
NFSL30_30M	--	Percentage of contributing drainage basin with north-facing slopes greater than or equal to 30 percent[2]
NOVAVTMP	--	Mean November temperature, in degrees Fahrenheit[1]
OCTAVTMP	--	Mean October temperature, in degrees Fahrenheit[1]
PRECIP	P	Mean annual precipitation, in inches[1]
RELIEF	--	Difference between the maximum and minimum elevations of the basin, in feet[2]

Table 1. Basin characteristics evaluated as potential explanatory variables in the regional regression equations.—Continued

[Shaded StreamStats abbreviations indicate that basin characteristic can be computed by the Montana StreamStats application. --, basin characteristic was not an explanatory variable in the regional regression equations]

StreamStats abbreviation	Abbreviation for basin characteristics used in regression equations	Description
SEPAVTMP	--	Mean September temperature, in degrees Fahrenheit[1]
SLOP30_30M	SLP30	Percentage of contributing drainage basin with slopes greater than or equal to 30 percent[2]
SLOP50_30M	SLP50	Percentage of contributing drainage basin with slopes greater than or equal to 50 percent[2]
TEMP	--	Mean annual temperature, in degrees Fahrenheit[1]

[1]Parameter-elevation Regressions on Independent Slopes Model (PRISM Climate Group, 2004) and Long Term Mean Climate Grids for Canada (Natural Resources Canada, 2015) for 1971–2000.

[2]30-meter National Elevation Dataset (NED; Gesch and others, 2002). Elevation refers to distance above North American Vertical Datum of 1988.

[3]Moderate Resolution Imaging Spectroradiometer (MODIS) global evapotranspiration product (MOD16) data (Mu and others, 2007).

[4]Final Land Unit (FLU) classification (Montana Department of Revenue, 2014).

[5]National Hydrography Dataset (NHD) high-resolution waterbodies (Horizon Systems Corporation, 2013).

[6]2001 National Land Cover Dataset (NLCD; Homer and others, 2007), Northern Land Cover of Canada Circa 2000 (LCC2000; Natural Resources Canada, 2009).

gaging-station network. Additional information about this study is provided in Chapter B (Sando, McCarthy, and others, 2016).

Peak-Flow Frequency Analyses

Peak-flow frequency analyses were completed for 725 gaging stations in or near Montana that have 10 or more years of peak-flow records through water year 2011 (Sando, McCarthy, and Dutton, 2016). For 29 of the 725 gaging stations, peak-flow frequency analyses and results are reported for both unregulated and regulated conditions for a total of 754 analyses. Estimates of peak-flow magnitudes for 66.7-, 50-, 42.9-, 20-, 10-, 4-, 2-, 1-, 0.5-, and 0.2-percent annual exceedance probabilities (AEPs) are reported. These AEPs correspond to 1.5-, 2-, 2.33-, 5-, 10-, 25-, 50-, 100-, 200-, and 500-year recurrence intervals. Additional descriptions of the study and results of the peak-flow frequency analyses for the selected gaging stations can be found in Chapter C (Sando, McCarthy, and Dutton, 2016). Peak-flow frequencies for the 725 gaging stations also are available in StreamStats (http://water.usgs.gov/osw/streamstats/; U.S. Geological Survey, 2015a).

Methods for Adjusting Estimates of Peak-Flow Frequencies

The climatic conditions of the specific time period during which peak-flow data were collected can substantially affect how the peak-flow frequency results represent long-term hydrologic conditions at a given gaging station (Sando, S.K., Sando, Roy, and others, 2016). Differences in the timing of the periods of record can result in substantial inconsistencies in frequency results for hydrologically similar gaging stations, and the potential for inconsistencies increases with decreasing peak-flow record length. The representativeness of the frequency estimates for a short-term gaging station can be adjusted by various methods including weighting the at-site results in association with frequency estimates from regional regression equations by using the Weighted Independent Estimates (WIE) program (Cohn and others, 2012). For gaging stations that cannot be adjusted using the WIE program because of regulation or drainage areas too large for application of regression equations, frequency estimates might be improved by record extension procedures, including a mixed-station analysis using the maintenance of variance type 1 (Move.1) procedure (Alley and Burns, 1983).

For 438 selected gaging stations in Montana, the at-site frequency estimates were adjusted by weighting with results from regression equations using the WIE program. The 438 selected gaging stations (1) had periods of record less than or equal to 40 years; (2) represented unregulated or minor regulation conditions; and (3) had drainage areas less than about 2,500 mi^2.

The mixed-station MOVE.1 procedure generally was applied in cases where three or more gaging stations were on the same large river and some of the gaging stations could not be adjusted using the WIE program because of regulation or drainage areas too large for application of regression equations. The mixed-station MOVE.1 procedure was applied to 66 selected gaging stations on 19 large rivers: (1) the

Beaverhead River, (2) the Ruby River, (3) the Bighole River, (4) the Jefferson River, (5) the Madison River, (6) the Missouri River, (7) the Marias River, (8) the Musselshell River, (9) the Yellowstone River, (10) the Little Bighorn River, (11) the Tongue River, (12) the Powder River, (13) the Kootenai River, (14) the Clark Fork, (15) the Bitterroot River, (16) the North Fork Flathead River, (17) the Middle Fork Flathead River, (18) the South Fork Flathead River, and (19) the Flathead River. Additional descriptions of the methods for adjusting peak-flow frequencies and results of this study can be found in Chapter D (Sando, S.K., Sando, Roy, and others, 2016). The flood frequency results for gaging stations that were analyzed using the WIE program or MOVE.1 procedure are available in StreamStats (http://water.usgs.gov/osw/streamstats/; U.S. Geological Survey, 2015a).

Streamflow Characteristics

Streamflow characteristics developed from daily mean streamflows were computed and reported in Chapter E (McCarthy, 2016). Updated streamflow characteristics are presented for 408 gaging stations in Montana and adjacent areas with 10 or more years of daily mean streamflows or 10 or more seasons of daily mean streamflows through water year 2009. Reported streamflow characteristics include the magnitude and probability of annual low and annual high streamflow, the magnitude and probability of low streamflow for three seasons (March–June, July–October, and November–February), streamflow durations for monthly and annual periods, and mean streamflows for monthly and annual periods. Streamflow characteristics are available in StreamStats for the unregulated and regulated periods of record for sites with sufficient data. Additional description of the methods used and study results can be found in Chapter E (McCarthy, 2016), and the streamflow characteristics also are available in StreamStats (http://water.usgs.gov/osw/streamstats/; U.S. Geological Survey, 2015a).

Streamflow Characteristics for Ungaged Sites Calculated in Montana StreamStats

Streamflow characteristics are computed for gaging stations in Montana, are available in StreamStats, and are presented in Chapter B (Sando, McCarthy, and others, 2016), Chapter C (Sando, McCarthy, and Dutton, 2016), Chapter D (Sando, S.K., Sando, Roy, and others, 2016), and Chapter E (McCarthy, 2016) of this Scientific Investigations Report; however, gaging stations and corresponding streamflow characteristics are not available on every stream and river in Montana. Regional regression equations are used to estimate streamflow characteristics when information at gaging stations is not available. Regional regression equations were developed for selected peak-flow frequencies, low-flow frequencies, and other streamflow characteristics in Montana. Streamflow characteristics for gaging stations that are classified as unregulated and streamflow characteristics for unregulated periods at gaging stations that are classified as regulated were used to develop regional regression equations. The regional regression equations were developed using (1) generalized least squares (GLS) for streamflow characteristics that are frequency-based (for example, peak-flow frequencies and AL7Q10), (2) ordinary least squares (OLS) for streamflow characteristics that are not frequency-based (for example, mean annual and mean monthly streamflows), and (3) basin characteristics as explanatory variables. Methods for developing the regional regression equations, as well as descriptions of the regions, basin characteristics, and equations used, are presented in Chapter F (Sando, Roy, and others, 2016) and Chapter G (McCarthy and others, 2016) of this Scientific Investigations Report. Overviews of Chapters F and G are presented in the following subsections of this report chapter.

StreamStats can be used to estimate streamflow characteristics for ungaged sites in Montana based on regression equations described in Chapter F (Sando, Roy, and others, 2016) and Chapter G (McCarthy and others, 2016); however, the regression equations developed for estimating streamflow characteristics are meant for use on unregulated streams. A tool for determining the percentage of basin area that is upstream from dams for a user-selected drainage basin is currently (2015) being developed for StreamStats. Users should carefully review the selected site for regulation as well as review Chapters F and G to understand how the regression equations were developed and how the equations should be applied, and to view any special instructions for estimating streamflow characteristics for ungaged sites in the State.

Methods for Estimating Peak-Flow Frequencies at Ungaged Sites

Updated methods for estimating peak-flow frequencies at ungaged sites in Montana based on peak-flow data at gaging stations through water year 2011 are presented in Chapter F (Sando, Roy, and others, 2016). The updated methods allow estimation of peak-flow frequencies (that is, peak-flow magnitudes for AEPs of 66.7, 50, 42.9, 20, 10, 4, 2, 1, 0.5, and 0.2 percent) at ungaged sites.

Regression equations based on analyses of peak-flow frequencies and basin characteristics were developed using GLS regression at 537 gaging stations in 8 hydrologic regions in Montana. The peak-flow frequencies for the 537 gaging stations used to develop regression equations are from gaging stations that are classified as unregulated or are from unregulated periods at gaging stations classified as regulated. In addition to the regression equations, two methods for estimating flood frequency at ungaged sites located on the same streams as gaging stations are described. Envelope curves relating maximum recorded peak flows to drainage area for each of the eight hydrologic regions in Montana also are presented and compared to a national envelope curve. In addition to providing general information on characteristics of large peak flows, the regional envelope curves can be used to assess the reasonableness of peak-flow frequency estimates determined using the regression equations.

The regression equations for estimating peak-flow frequencies and a description of the analyses and methods used to develop the regression equations are available in Chapter F (Sando, Roy, and others, 2016). StreamStats (http://streamstats.usgs.gov/; U.S. Geological Survey, 2015a) will solve the appropriate regression equations and provide peak-flow frequency estimates for user-selected sites in Montana.

Methods for Estimating Streamflow Characteristics at Ungaged Sites

Regional regression equations were developed to estimate 2 low-flow frequencies, mean annual and mean monthly streamflows, and the annual and monthly duration streamflows for 20-, 50-, and 80-percent exceedances for 4 hydrologic regions in western Montana using streamflow characteristics from 152 gaging stations (McCarthy and others, 2016). The GLS regression was used to develop the regression equations for low-flow frequencies, and OLS regression was used to develop regression equations for all other streamflow characteristics. The streamflow characteristics for the 152 gaging stations used to develop regression equations are from gaging stations that are classified as unregulated or from unregulated periods at gaging stations classified as regulated, and are based on analyses of daily mean streamflow data through water year 2009. It was not possible to develop reliable regional regression equations for the four hydrologic regions in eastern Montana due to the few unregulated gaging stations and extreme variability of streamflow characteristics that could not be explained with the existing basin characteristics.

Of the 40 basin characteristics initially used as explanatory variables in development of the equations, only 3 were significant in the final regression equations. These three basin characteristics are CONTDA, mean annual precipitation of the drainage basin, and percentage of basin with slopes greater than 50 percent. In addition to the regional regression equations, two methods for estimating streamflow characteristics based on drainage areas of a nearby gaging station are provided by McCarthy and others (2016).

Additional descriptions of the methods used to develop the regression equations, the equations, and analyses for streamflow characteristics are available in Chapter G (McCarthy and others, 2016). StreamStats (http://water.usgs.gov/osw/streamstats/; U.S. Geological Survey, 2015a) will solve the appropriate regression equations and provide streamflow estimates for user-selected sites in western Montana.

Summary

The U.S. Geological Survey (USGS) provides streamflow characteristics and other related information needed by water-resource managers to protect people and property from floods, plan and manage water-resource activities, and protect water quality. Streamflow characteristics provided by the USGS, such as peak-flow and low-flow frequencies for streamflow-gaging stations, are frequently used by engineers, flood forecasters, land managers, biologists, and others to guide their everyday decisions. In addition to providing streamflow characteristics at streamflow-gaging stations, the USGS also develops regional regression equations and drainage area-adjustment methods for estimating streamflow characteristics at locations on ungaged streams. Regional regression equations can be complex and often require users to determine several basin characteristics, which are physical and climatic characteristics of the stream and its drainage basin. Obtaining these basin characteristics for streamflow-gaging stations and ungaged sites traditionally has been time consuming and subjective, and led to inconsistent results.

StreamStats is a Web-based geographic information system application that was created by the USGS to provide users with access to an assortment of analytical tools that are useful for water-resource planning and management. StreamStats allows users to easily obtain streamflow and basin characteristics for USGS streamflow-gaging stations (hereinafter referred to as gaging stations) and user-selected locations on ungaged streams. The USGS, in cooperation with Montana Department of Transportation, Montana Department of Environmental Quality, and Montana Department of Natural Resources and Conservation, completed a study to develop a StreamStats application for Montana, compute streamflow characteristics at gaging stations, and develop regional regression equations to estimate streamflow characteristics at ungaged sites. Chapter A of this Scientific Investigations Report describes the Montana StreamStats application and the datasets, gaging stations, streamflow characteristics, and regression equations (as described fully in Chapters B through G of this report) that are used for development of the StreamStats application for Montana.

The Montana StreamStats application uses the National Hydrography Dataset Plus Version 2 (NHDPlusV2), which is an integrated suite of application-ready geospatial datasets incorporating the National Hydrography Dataset stream network (1:100,000-scale), derived hydrologic units (12-digit) from the Watershed Boundary Dataset, and the 30-meter digital elevation model from the National Elevation Dataset as well as various other value-added attributes to enhance stream-network navigation, analysis, and display.

StreamStats functionality and NHDPlusV2 were used to determine drainage-basin boundaries. The drainage-basin boundaries were processed with georeferenced datasets to determine basin characteristics (physical and climatic). Basin characteristics were developed for use in regional regression equations and StreamStats. Basin characteristics investigated as potential explanatory variables in the regional regression analyses were selected based on previous studies performed in Montana, theoretical relations with streamflow characteristics, and the ability to generate the characteristics using geographic information system analyses and digital datasets.

Various streamflow characteristics were computed for 755 gaging stations operated by the USGS in and near Montana that had 10 or more years of record. Each gaging station also was classified as regulated or unregulated for this study. A total of 2,817 dams, which were obtained from the National Hydrography Dataset point layer for dams, were used to classify regulation for the gaging stations in Montana. A gaging station was considered to be regulated if the cumulative drainage area of all upstream dams exceeded 20 percent of the drainage area for the gaging station.

A complementary study was completed to determine general patterns in peak-flow temporal trends and stationarity for 24 long-term gaging stations in Montana. The primary focus of the study was to identify general patterns in peak-flow temporal trends and stationarity that are relevant to application of peak-flow frequency analyses within a statewide gaging-station network. Study results provided evidence that annual peak flow for most of the long-term gaging stations can be reasonably considered as stationary for application of peak-flow frequency analyses within a statewide gaging-station network. Thus, at-site peak-flow frequency analyses were computed for 725 gaging stations in or near Montana based on data through water year 2011. Of these, 537 gaging stations had peak-flow frequency analyses that were classified as unregulated and were used to develop regional regression equations to estimate peak-flow frequencies at ungaged and unregulated sites in Montana. Regional regression equations were then used to adjust at-site frequency estimates for 438 selected gaging stations in Montana by weighting results from regression equations with at-site peak-flow estimates using the Weighted Independent Estimate (WIE) program. At-site adjustments to peak-flow frequencies were performed for 66 selected gaging stations using record extension methods where the WIE program could not be used because of regulation or drainage areas that were greater than the applicable limits of the regression equations.

Low-flow frequencies, high-flow frequencies, and streamflow characteristics for monthly and annual periods were computed for 408 gaging stations in or near Montana with 10 or more years of daily mean streamflow records through water year 2009. Regional regression equations for estimating streamflow characteristics at ungaged sites were developed for 4 hydrologic regions in western Montana using streamflow characteristics classified as unregulated from 152 gaging stations. Regression equations were developed for 2 low-flow frequencies, mean annual and mean monthly streamflows, and the annual and monthly duration streamflows for 20-, 50-, and 80-percent exceedances in each of the 4 hydrologic regions. Similar regression equations for eastern Montana were not developed because of the few unregulated gaging stations and extreme variability of streamflow characteristics that could not be explained with the existing basin characteristics.

Applicable streamflow characteristics are reported for the 755 gaging stations included in this study and are available in StreamStats. The geospatial datasets required for computing basin characteristics and the regional regression equations for estimating streamflow characteristics at ungaged and unregulated sites in Montana also are included in StreamStats. Users can select a stream location where streamflow characteristics are desired and StreamStats will compute estimates of streamflow characteristics.

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Appendix 1

Appendix 1. Streamflow-Gaging Stations, Dams, and Major Regulation Structures Used in this Study

This appendix presents information on streamflow-gaging stations for which streamflow characteristics and regulation status are reported (table 1–1). This appendix also provides information on dams (table 1–2) and major regulation structures (table 1–3) in Montana.

An Excel file containing the tables is available at http://dx.doi.org/10.3133/sir20155019A.

Table 1–1. Streamflow-gaging stations in or near Montana for which streamflow characteristics and regulation status are reported.

Table 1–2. Dams in Montana that were used to classify regulation status for streamflow-gaging stations.

Table 1–3. Information on major regulation structures affecting streamflow records.

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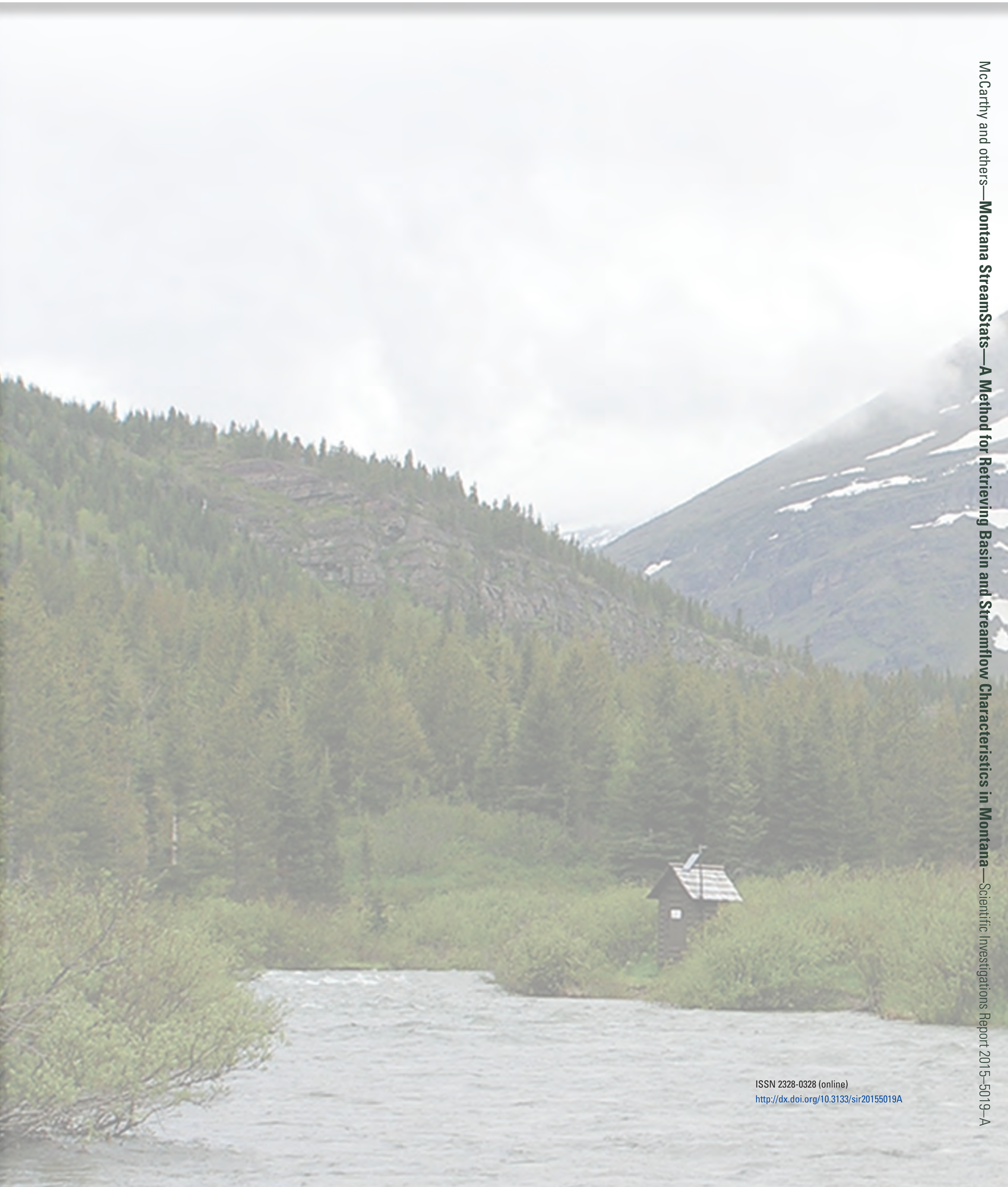

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