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Peak-Flow Variability, Peak-Flow Informational Needs, and Consideration of Regional Regression Analyses in Managing the Crest-Stage Gage Network in Montana

Scientific Investigations Report 2021–5063

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

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U.S. Geological Survey, Reston, Virginia: 2021

Suggested citation:
Sando, S.K., 2021, Peak-flow variability, peak-flow informational needs, and consideration of regional regression analyses in managing the crest-stage gage network in Montana: U.S. Geological Survey Scientific Investigations Report 2021–5063, 124 p., https://doi.org/10.3133/sir20215063.

Associated data for this publication:
Dutton, D.D., Sando, R., and Sando, S.K., 2021, Drainage-basin characteristics associated with 12,639 road and stream intersections in Montana: U.S. Geological Survey data release, https://doi.org/10.5066/P9NZX5TM.

U.S. Geological Survey, 2018, 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 recognize the U.S. Geological Survey hydrologic technicians involved in the collection of streamflow data for their dedicated efforts. The authors also would like to recognize the valuable contributions to this report from the insightful technical reviews by Karen Ryberg, Nancy Barth, and Kathy Chase of the U.S. Geological Survey.

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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	
square mile (mi^2)	259.0	hectare (ha)
square mile (mi^2)	2.590	square kilometer (km^2)
	Flow rate	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)

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

°C = (°F – 32) / 1.8.

Datum

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

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 2015 is the period from October 1, 2014, through September 30, 2015.

Abbreviations

ABS	absolute value
AEP	annual exceedance probability
CDF	cumulative distribution function
CONTDA	contributing drainage area
CSG	crest-stage gage
EL_{5000}	percentage of basin above 5,000 feet elevation
EL_{6000}	percentage of basin above 6,000 feet elevation
*ET*0306*MOD*	mean spring (March–June) evapotranspiration
FOREST	percentage of basin that is forest
LOWESS	locally weighted scatterplot smooths
MDT	Montana Department of Transportation
PFVI	peak-flow variability index
PRECIP	mean annual precipitation
RRE	regional regression equation
SEP	mean standard error of prediction
*SLOP*30_30*M*	percentage of basin with slope greater than 30 percent
USGS	U.S. Geological Survey

Peak-Flow Variability, Peak-Flow Informational Needs, and Consideration of Regional Regression Analyses in Managing the Crest-Stage Gage Network in Montana

By Steven K. Sando

Abstract

The U.S. Geological Survey (USGS), in cooperation with the Montana Department of Transportation (MDT), has operated a crest-stage gage (CSG) network in Montana to collect peak-flow data since 1955. The CSG network is vital to collecting peak-flow data on small drainage basins that typically are not addressed by continuous streamflow operations. Discussions between USGS and MDT identified a need for evaluating the CSG network to allow for better decision making in the management of the network. The purpose of this report is to (1) generally describe peak-flow variability in Montana, (2) assess peak-flow informational needs relevant to MDT activities, and (3) consider the characteristics of the active CSG network in relation to addressing the informational needs. The evaluation of the CSG network is intended to assist in prioritization for discontinuation of CSGs and other activities involving changes to the CSG network.

Peak-flow variability was investigated by analysis of selected peak-flow characteristics of 659 unregulated streamgages in or near Montana. A generalized peak-flow variability index (*PFVI*) was developed to provide large-scale representation of peak-flow variability in Montana. For unregulated Montana streamgages, *PFVI* generally monotonically decreases with increasing drainage area, although there is somewhat large (but generally consistent) variability about the locally weighted scatterplot smooth line. Presumably, highly variable small-scale hydroclimatic processes are integrated with increasing drainage area such that variability in many hydrologic characteristics is reduced. *PFVI* also decreases with increasing mean basin elevation and mean annual precipitation. Presumably, higher elevation and wetter hydroclimatic settings in Montana contribute to reduced variability in hydrologic characteristics. Intuitively, *PFVI* might be expected to generally decrease with increasing years of record because the standard deviation might typically be expected to decrease with increasing sample size. However, relations among *PFVI* and years of record are more complex and variable than drainage area, elevation, and precipitation. *PFVI* variably increases from 10 to about 40 years of record and then generally monotonically decreases from about 40 to about 105 years of record. Relations among *PFVI* and the years of record might be confounded by effects of drainage area because streamgages with long periods of record (greater than about 60 years) generally have large drainage areas (greater than about 100 square miles).

The relations between *PFVI* and drainage area, mean basin elevation, mean annual precipitation, and years of record substantially differ among the eight hydrologic regions in Montana. As such, the *PFVI* relations were further investigated within each hydrologic region.

A major use of peak-flow information by MDT is for design of road and highway infrastructure, including bridges, culverts, and roadside drainage ditches. As such, basin characteristics (including drainage area, mean basin elevation, and mean annual precipitation) of the Montana streamgage network (735 regulated and unregulated streamgages) were statistically investigated in relation to basin characteristics of 12,639 road and stream intersections in Montana. Both regulated and unregulated streamgages were investigated because the road and stream intersections are on both regulated and unregulated streams. Exploratory analyses indicated that the various relations substantially differ among the hydrologic regions. As such, the relations between the Montana streamgage network and the road and stream intersections were further investigated within each hydrologic region.

An important objective of the CSG network is to provide data for developing regional regression equations (RREs) for estimating frequencies at ungaged sites in Montana. Various characteristics of the RREs substantially differ among the eight hydrologic regions in Montana. As such, the RRE characteristics were further investigated within each hydrologic region.

For each of the eight hydrologic regions, various characteristics of peak-flow variability, peak-flow informational needs, and regional regression analyses were investigated in detail. Possible shortcomings of the streamgage network in each hydrologic region are identified and possible future improvements to the CSG network are presented.

Introduction

The U.S. Geological Survey (USGS), in cooperation with the Montana Department of Transportation (MDT), has operated a crest-stage gage (CSG) network in Montana to collect peak-flow data since 1955. Description of CSG operations is provided in Sando and McCarthy (2018). Currently (2020) there are 88 CSGs being operated in Montana on drainage basins with areas ranging from 0.08 to 40.4 square miles (mi^2). The CSG network is vital to collecting peak-flow data on small drainage basins that typically are not addressed by continuous streamflow operations. For example, in eastern Montana (Northeast Plains, East-Central Plains, and Southeast Plains hydrologic regions) there are 29 active continuous streamgages and none are on drainage basins less than 110 mi^2 in area. However, within the three hydrologic regions, there are 63 CSGs and none are on drainage basins greater than 17 mi^2. Peak-flow data from the CSG network are essential to developing regional regression equations (RREs) for estimating peak-flow frequencies (hereinafter referred to as "frequencies") at ungaged sites in Montana. Without the CSG network, the RREs would not be valid for drainage areas less than about 100 mi^2. MDT and many other agencies and Tribes have continuing needs for peak-flow information for a large range of drainage basins, including small drainage basins.

The CSG network in Montana has fluctuated in size since its inception in 1955. The initial CSG network consisted of 45 CSGs but increased to 152 in 1959 and then to about 300 in the 1970s. Since the 1970s the CSG network generally decreased to the 88 active CSGs. The primary reason for the decrease in CSGs has been budgetary constraints. For about the past 10 years the funding for the network has remained constant while operational costs slowly have been increasing. Consequently, each year one or more CSGs have been discontinued. The selection of CSGs that are discontinued typically has been based on site-specific operational considerations. Sites that are more difficult and costly to accurately gage typically are prioritized for discontinuation. Generally, the peak-flow informational value of individual CSGs has not been strongly considered in prioritization for discontinuation.

Discussions between USGS and MDT identified a need for evaluating the CSG network to allow for better decision making in the management of the network. Investigation of peak-flow variability in Montana was considered an important part of the CSG network analysis because areas with high peak-flow variability might require dense peak-flow data collection to adequately describe peak-flow characteristics. Consideration of unregulated continuous streamgages also is an important part of the CSG network analysis because those streamgages contribute to the development of RREs. Future management of the CSG network might focus on improving the RREs by targeting hydroclimatic settings that are not well represented in the current (2020) combined CSG and unregulated continuous streamgage networks.

Purpose and Scope

The purpose of this report is to (1) generally describe peak-flow variability in Montana, (2) assess peak-flow informational needs relevant to MDT activities, and (3) consider the characteristics of the active CSG network in relation to addressing the informational needs. The evaluation of the CSG network is intended to assist in prioritization for discontinuation of CSGs and other activities involving changes to the CSG network.

Description of Study Area

The study area primarily consists of the State of Montana. Montana is a large State (147,000 mi^2) with large spatial variability in geologic, topographic, ecologic, and climatic characteristics; the large variability in these characteristics translates to large spatial variability in hydrologic regimes. Seven Level III ecoregions (U.S. Environmental Protection Agency, 2015) are represented in Montana (Canadian Rockies, Idaho Batholith, Middle Rockies, Northern Rockies, Northwestern Glaciated Plains, Northwestern Great Plains, and Wyoming Basin) with large variability in characteristics among the ecoregions. Somewhat abrupt transitions can exist among high-elevation mountains with intermontane valleys; well-drained, low-elevation plains; poorly drained, low-elevation glaciated prairies; and other complex geologic and hydroclimatic features.

Parrett and Johnson (2004) identified eight hydrologic regions in Montana to describe streamflow characteristics (fig. 1). Various topographic, climatic, and land-cover characteristics of the hydrologic regions are presented in table 1. The percentages of each hydrologic region within each Level III ecoregion are presented in table 2.

Major drivers of peak-flow events in Montana include snowmelt, rainfall, and snowmelt with rainfall. Across Montana, large variability in climatic and topographic characteristics affects the spatial dominance among the major drivers and results in large variability in the flood regimes of streamgages. A brief overview of climatic and topographic characteristics relevant to Montana flood hydrology is presented by Sando and McCarthy (2018).

With an area of 147,000 mi^2, Montana ranks fourth among States in the United States in size; however, Montana ranks 47th in population and 46th in tax base (U.S. Census Bureau, 2016). In conjunction with large variability in hydrologic regimes, the socioeconomic characteristics of Montana present substantial challenges for operating a large statewide streamgage network that consistently captures the hydrologic variability.

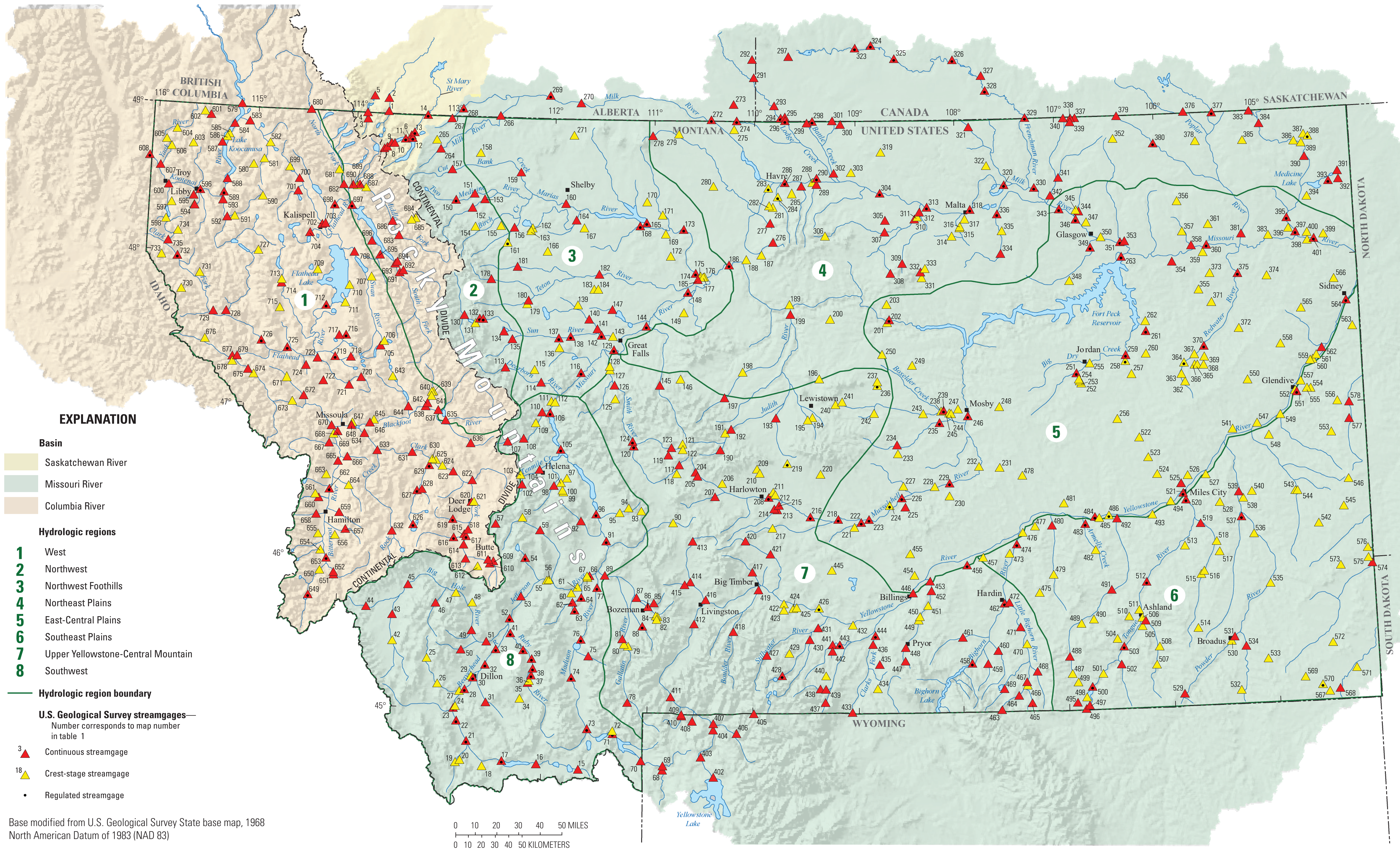


Figure 1. Locations of hydrologic regions (Sando, R., and others, 2018) and selected streamgages in or near Montana.

Table 1. Geographic, climatic, and land-cover characteristics of hydrologic regions in Montana.

[HR, hydrologic region; No., number; mi², square mile; elev., elevation; ft, foot; precip., precipitation; in., inch; LC, land cover; urb., urban; ag., agricultural; irr., irrigation; Jan., January; temp., air temperature; °F, degrees Fahrenheit; gages, streamgages; mixed-pop. chars., mixed-population characteristics]

HR	HR No. (fig. 1)	Area, in mi²	Maximum elev., in ft[1]	Minimum elev., in ft[1]	Mean elev., in ft[1]	Percent above 6,000 ft elev.[1]	Mean slope[1,2]	Mean annual precip., in in.[3]	Percent with forest LC[4]	Percent with urb. LC[4]	Percent with ag. LC[4]	Percent with irr.[5]	Mean Jan. temp., in °F[3]	Mean July temp., in °F[3]	Mean annual temp., in °F[3]	Percent of gages with mixed-pop. chars.[6]
West	1	21,371	10,635	1,807	4,867	21.7	29.2	30.1	67.7	1.5	4.5	2.3	21.6	60.6	40.3	12.5
Northwest	2	7,938	10,103	3,020	5,789	45.6	40.0	45.1	76.0	0.3	0.4	0.1	18.5	56.7	36.8	55.8
Northwest Foothills	3	10,624	6,981	2,511	3,607	0.1	5.3	13.2	1.2	2.3	53.1	4.2	20.2	65.6	43.2	22.2
Northeast Plains	4	22,059	7,666	1,922	2,928	0.1	6.4	13.5	2.2	1.6	34.0	1.1	15.1	67.6	42.5	1.4
East-Central Plains	5	28,451	5,339	1,863	2,786	0.0	6.6	13.1	3.7	1.2	18.0	0.9	16.8	70.1	44.4	2.2
Southeast Plains	6	18,520	5,353	1,880	3,189	0.0	9.9	14.7	9.8	0.7	4.8	0.8	18.7	70.7	44.9	0.0
Upper Yellowstone-Central Mountain	7	23,003	12,763	2,809	5,432	29.4	18.8	21.2	21.6	1.4	10.2	3.4	21.6	64.2	42.0	3.9
Southwest	8	14,891	11,268	3,389	6,376	61.0	20.5	19.8	34.8	1.6	5.4	3.4	19.4	60.2	38.7	17.2

[1]Elevation and related variables were determined or calculated from the National Elevation Dataset (NED; Gesch and others, 2002). Elevation refers to distance above North American Vertical Datum of 1988 (NAVD 88).

[2]Mean slope was computed as the first derivative of the 30-meter elevation dataset.

[3]Precipitation and air temperature variables determined from climatic datasets obtained from Parameter-elevation Regression on Independent Slopes Model (PRISM) data (PRISM Climate Group, 2004). Mean annual precipitation and air temperature values were determined from 1971–2000 data.

[4]Land-cover variables were determined from the 2001 National Land Cover Dataset (NLCD; Homer and others, 2007).

[5]Irrigated area was determined from the Final Land Unit classification (FLU; Montana Department of Revenue, 2014) and represents the area under some type of irrigation regime.

[6]Criteria for designating streamgage peak-flow datasets as having mixed-population characteristics are described by Sando and McCarthy (2018).

Table 2. Information on hydrologic regions and Level III ecoregions (U.S. Environmental Protection Agency, 2015) in Montana.

Hydrologic region (ordered clockwise from northwestern Montana)	Hydrologic region number (fig. 1)	Area, in square miles	Percentage of the hydrologic region within each Level III ecoregion[1]						
			Canadian Rockies	Idaho Batholith	Middle Rockies	Northern Rockies	Northwestern Glaciated Plains	Northwestern Great Plains	Wyoming Basin
West	1	21,371	9.5	8.2	29.9	52.5	0.0	0.0	0.0
Northwest	2	7,938	66.3	0.0	11.1	0.0	22.6	0.0	0.0
Northwest Foothills	3	10,624	0.0	0.0	1.8	0.0	98.1	0.2	0.0
Northeast Plains	4	22,059	0.0	0.0	2.2	0.0	81.2	16.6	0.0
East-Central Plains	5	28,451	0.0	0.0	0.0	0.0	23.6	76.4	0.0
Southeast Plains	6	18,520	0.0	0.0	0.0	0.0	0.0	100.0	0.0
Upper Yellowstone-Central Mountain	7	23,003	0.0	0.0	35.8	0.0	0.1	62.2	1.9
Southwest	8	14,891	0.0	1.8	95.5	0.0	0.8	1.9	0.0

[1]The percentage of the hydrologic region within each Level III ecoregion was determined by geospatial analysis of the hydrologic regions (Sando, R., and others, 2018) and Level III ecoregions (U.S. Environmental Protection Agency, 2015) geospatial datasets.

Peak-Flow Variability in Montana

Peak-flow variability was investigated by analysis of selected peak-flow characteristics of 659 unregulated streamgages in or near Montana. A generalized peak-flow variability index (*PFVI*) was developed to provide large-scale representation of peak-flow variability in Montana. The *PFVI* is a version of the coefficient of variation and was calculated for each unregulated streamgage using the following equation:

$$PFVI = 100\ X\ ABS(\frac{\hat{\sigma}}{\hat{\mu}}) \quad (1)$$

where

PFVI is the peak-flow variability index;

ABS indicates absolute value;

$\hat{\sigma}$ is the standard deviation of the base-10 logarithms of peak flows as calculated using Bulletin 17 procedures (U.S. Interagency Advisory Committee on Water Data, 1982; England and others, 2019); and

$\hat{\mu}$ is the mean of the base-10 logarithms of peak flows as calculated using Bulletin 17 procedures (U.S. Interagency Advisory Committee on Water Data, 1982; England and others, 2019).

The generalized *PFVI* is dimensionless and serves to normalize peak-flow variability among diverse streamgages. The primary purpose of the general *PFVI* is to allow large-scale relative comparison of peak-flow variability among numerous diverse streamgages.

For 649 of the unregulated streamgages, the mean and standard deviations of the base-10 logarithms of peak flows were taken from frequency analyses by Sando and others (2016) and were calculated using Bulletin 17B procedures (U.S. Interagency Advisory Committee on Water Data, 1982) based on peak-flow data (U.S. Geological Survey, 2018) through water year 2011. Ten of the unregulated streamgages were CSGs that were not reported by Sando and others (2016) because they had less than 10 years of peak-flow data through water year 2011 but have greater than 10 years of peak-flow data through water year 2017. The mean and standard deviations of the 10 previously unreported CSGs were determined based on peak-flow data (U.S. Geological Survey, 2018) through water year 2017 using Bulletin 17C procedures (England and others, 2019) as described by Sando and McCarthy (2018). Differences between the mean and standard deviation calculation methods for the 649 streamgages reported by Sando and others (2016) and the 10 previously unreported CSGs are not considered to substantially affect the investigation of large-scale patterns in peak-flow variability.

The *PFVI* for each of the 659 streamgages was based on the length and period of record of that streamgage. Among the 659 streamgages, lengths of record varied from 10 to 105 years. The starting years in the periods of record for the 659 streamgages ranged from 1872 through 2003 and the ending years ranged from 1915 through 2017.

Statistical summaries of the *PFVI*s and other selected characteristics of the 659 unregulated streamgages are presented in table 3; summaries are presented for all 659 streamgages, 336 continuous streamgages, and 323 CSGs. Further, summaries are presented for the 231 active streamgages that are among the following categories: 143 active continuous streamgages and 88 active CSGs. Of the 659 unregulated streamgages in or near Montana, 15 of the streamgages are in Canada or Yellowstone National Park on streams that flow into Montana; those streamgages are considered to be representative of hydroclimatic characteristics of streams in Montana, but they are located outside of the Montana border and are not within the boundaries of the eight hydrologic regions. Thus, 644 unregulated streamgages are used in various analyses in this report that apply to unregulated streamgages within the eight hydrologic regions.

Several basin and streamgage characteristics, including contributing drainage area, mean basin elevation, mean annual precipitation, and the number of years of peak-flow records, might be factors that affect *PFVI* and could be relevant to the management of the CSG network. Relations among *PFVI* and the selected characteristics for Montana streamgages are shown in figure 2 with distinction between CSGs and continuous streamgages. Locally weighted scatterplot smooths (LOWESS; Cleveland, 1985) are fitted through the relations between *PFVI* and drainage area (fig. 2*A*), mean basin elevation (fig. 2*B*), mean annual precipitation (fig. 2*C*), and years of peak-flow records relations (fig. 2*D*).

For unregulated Montana streamgages, *PFVI* generally monotonically decreases with increasing drainage area (fig. 2*A*), although there is somewhat large (but generally consistent) variability about the LOWESS line. Presumably, highly variable small-scale hydroclimatic processes are integrated with increasing drainage area such that variability in many hydrologic characteristics is reduced. *PFVI* also decreases with increasing mean basin elevation and mean annual precipitation (figs. 2*B* and 2*C*). Presumably, higher elevation and wetter hydroclimatic settings in Montana contribute to reduced variability in hydrologic characteristics.

Presumably, *PFVI* might be expected to generally decrease with increasing years of record because the standard deviation might typically be expected to decrease with increasing sample size. However, relations between *PFVI* and years of record (fig. 2*D*) are more complex and variable than drainage area, elevation, and precipitation. *PFVI* variably increases from 10 to about 40 years of record, and then generally monotonically decreases from about 40 to about 105 years of record.

Table 3. Statistical summaries of peak-flow variability indices and other selected characteristics of unregulated streamgages in or near Montana.

[For 649 streamgages, the standard deviations and means of the peak flows were calculated using Bulletin 17B procedures (U.S. Interagency Advisory Council on Water Data, 1982) for fitting the log-Pearson III distribution. For 10 streamgages, the standard deviations and means of the peak flows were calculated using Bulletin 17C procedures as described by Sando and McCarthy (2018) for fitting the log-Pearson III distribution. *CONTDA*, contributing drainage area, in square miles; *n*, number of years of unregulated peak-flow records; *PFVI*, peak-flow variability index calculated by 100 times the absolute value of the ratio of the standard deviation of the peak flows (base-10 logarithms) divided by the mean of the peak flows (base-10 logarithms); CSG, crest-stage gage; NA, not applicable; --, no data]

Summary statistic	All unregulated peak-flow frequency streamgages			Continuous unregulated peak-flow frequency streamgages			CSG unregulated peak-flow frequency streamgages		
	CONTDA	*n*	*PFVI*[1]	*CONTDA*	*n*	*PFVI*[1]	*CONTDA*	*n*	*PFVI*[1]
Summary statistics for unregulated streamgages in or near Montana									
NA	659 streamgages summarized			336 streamgages summarized			323 streamgages summarized		
Minimum	0.08	10	1.35	0.64	10	1.35	0.08	10	2.32
10th nonexceedance percentile	1.42	12	4.22	31.05	11	3.30	0.78	15	10.24
25th nonexceedance percentile	4.52	16	7.74	78.80	15	4.96	1.84	16	21.67
Median	37.30	23	18.26	259.00	26	8.32	4.52	20	38.09
Mean	1,184.08	30	58.51	2,295.75	34	13.11	27.67	26	105.74
75th nonexceedance percentile	311.00	39	40.18	961.75	46	16.01	14.50	38	61.29
90th nonexceedance percentile	1,301.40	56	72.06	4,830.00	73	27.33	38.74	40	110.58
Maximum	68,407.00	105	5,900.00	68,407.00	105	165.78	1,223.00	57	5,900.00
Summary statistics for active unregulated streamgages in Montana									
NA	231 streamgages summarized			143 streamgages summarized			88 streamgages summarized		
Minimum	0.08	10	1.96	7.61	10	1.96	0.08	12	5.92
10th nonexceedance percentile	1.45	15	3.88	92.46	15	3.25	0.73	15	22.56
25th nonexceedance percentile	4.47	29	5.80	243.00	26	4.40	1.42	38	36.12
Median	153.00	39	12.04	638.00	42	6.84	2.66	38	47.89
Mean	2,586.84	44	43.07	4,175.51	49	10.02	5.26	38	96.77
75th nonexceedance percentile	998.00	57	42.37	2,494.00	73	10.47	6.36	40	80.88
90th nonexceedance percentile	5,187.00	79	78.46	11,094.40	86	19.03	11.69	49	175.06
Maximum	68,407.00	105	1,126.98	68,407.00	105	73.77	40.40	57	1,126.98
Summary statistics for unregulated streamgages in the West hydrologic region (hydrologic region 1, fig. 1)									
NA	133 streamgages summarized			80 streamgages summarized			53 streamgages summarized		
Minimum	0.60	10	1.35	6.86	10	1.35	0.60	10	2.32
10th nonexceedance percentile	4.56	11	3.47	21.62	10	3.01	2.53	11	4.46
25th nonexceedance percentile	10.10	15	4.93	56.20	17	4.25	4.52	14	7.17
Median	52.00	21	7.63	277.00	28	6.42	8.07	18	14.01
Mean	995.88	28	11.42	1,642.81	34	8.00	19.39	20	16.60
75th nonexceedance percentile	383.00	33	12.92	917.00	41	8.65	22.60	22	23.53

Table 3. Statistical summaries of peak-flow variability indices and other selected characteristics of unregulated streamgages in or near Montana.—Continued

[For 649 streamgages, the standard deviations and means of the peak flows were calculated using Bulletin 17B procedures (U.S. Interagency Advisory Council on Water Data, 1982) for fitting the log-Pearson III distribution. For 10 streamgages, the standard deviations and means of the peak flows were calculated using Bulletin 17C procedures as described by Sando and McCarthy (2018) for fitting the log-Pearson III distribution. *CONTDA*, contributing drainage area, in square miles; *n*, number of years of unregulated peak-flow records; *PFVI*, peak-flow variability index calculated by 100 times the absolute value of the ratio of the standard deviation of the peak flows (base-10 logarithms) divided by the mean of the peak flows (base-10 logarithms); CSG, crest-stage gage; NA, not applicable; --, no data]

Summary statistic	All unregulated peak-flow frequency streamgages			Continuous unregulated peak-flow frequency streamgages			CSG unregulated peak-flow frequency streamgages		
	CONTDA	*n*	*PFVI*[1]	*CONTDA*	*n*	*PFVI*[1]	*CONTDA*	*n*	*PFVI*[1]
Summary statistics for unregulated streamgages in the West hydrologic region (hydrologic region 1, fig. 1)—Continued									
90th nonexceedance percentile	2,481.20	61	23.80	6,126.80	72	11.94	61.44	33	35.51
Maximum	19,964.00	96	84.69	19,964.00	96	84.69	109.00	43	47.08
Summary statistics for active unregulated streamgages in the West hydrologic region (hydrologic region 1, fig. 1)									
NA	41 streamgages summarized			41 streamgages summarized			0 streamgages summarized		
Minimum	7.61	14	1.96	7.61	14	1.96	--	--	--
10th nonexceedance percentile	70.50	23	3.44	70.50	23	3.44	--	--	--
25th nonexceedance percentile	182.00	28	4.82	182.00	28	4.82	--	--	--
Median	498.00	37	6.34	498.00	37	6.34	--	--	--
Mean	2,011.19	47	6.91	2,011.19	47	6.91	--	--	--
75th nonexceedance percentile	1,774.00	71	8.41	1,774.00	71	8.41	--	--	--
90th nonexceedance percentile	6,021.00	78	11.02	6,021.00	78	11.02	--	--	--
Maximum	19,964.00	96	20.69	19,964.00	96	20.69	--	--	--
Summary statistics for unregulated streamgages in Northwest hydrologic region (hydrologic region 2, fig. 1)									
NA	44 streamgages summarized			36 streamgages summarized			8 streamgages summarized		
Minimum	0.64	10	2.17	0.64	10	2.17	1.36	12	9.27
10th nonexceedance percentile	7.92	13	2.93	24.15	13	2.70	2.11	14	10.46
25th nonexceedance percentile	20.70	17	3.96	67.28	17	3.53	6.86	15	14.30
Median	112.50	24	6.04	159.00	25	4.92	12.59	17	24.17
Mean	284.95	31	11.56	345.59	33	6.73	12.06	20	33.29
75th nonexceedance percentile	286.25	40	11.76	420.75	44	8.12	18.60	25	32.84
90th nonexceedance percentile	952.80	65	21.79	1,041.00	70	12.31	20.52	27	58.92
Maximum	1,668.00	99	115.41	1,668.00	99	22.19	20.80	30	115.41
Summary statistics for active unregulated streamgages in Northwest hydrologic region (hydrologic region 2, fig. 1)									
NA	12 streamgages summarized			11 streamgages summarized			1 streamgages summarized		
Minimum	8.33	10	2.31	31.20	10	2.31	8.33	12	32.22
10th nonexceedance percentile	34.16	13	3.21	60.80	17	3.21	--	--	--
25th nonexceedance percentile	97.70	28	3.29	131.50	36	3.27	--	--	--

Table 3. Statistical summaries of peak-flow variability indices and other selected characteristics of unregulated streamgages in or near Montana.—Continued

[For 649 streamgages, the standard deviations and means of the peak flows were calculated using Bulletin 17B procedures (U.S. Interagency Advisory Council on Water Data, 1982) for fitting the log-Pearson III distribution. For 10 streamgages, the standard deviations and means of the peak flows were calculated using Bulletin 17C procedures as described by Sando and McCarthy (2018) for fitting the log-Pearson III distribution. *CONTDA*, contributing drainage area, in square miles; *n*, number of years of unregulated peak-flow records; *PFVI*, peak-flow variability index calculated by 100 times the absolute value of the ratio of the standard deviation of the peak flows (base-10 logarithms) divided by the mean of the peak flows (base-10 logarithms); CSG, crest-stage gage; NA, not applicable; --, no data]

Summary statistic	All unregulated peak-flow frequency streamgages			Continuous unregulated peak-flow frequency streamgages			CSG unregulated peak-flow frequency streamgages		
	CONTDA	*n*	*PFVI*[1]	*CONTDA*	*n*	*PFVI*[1]	*CONTDA*	*n*	*PFVI*[1]
Summary statistics for active unregulated streamgages in Northwest hydrologic region (hydrologic region 2, fig. 1)—Continued									
Median	267.00	44	4.88	275.00	46	4.73	--	--	--
Mean	572.28	49	8.80	623.55	53	6.67	--	--	--
75th nonexceedance percentile	1,133.50	72	10.17	1,142.00	73	7.66	--	--	--
90th nonexceedance percentile	1,516.30	88	19.19	1,556.00	90	12.05	--	--	--
Maximum	1,668.00	99	32.22	1,668.00	99	19.98	8.33	12	32.22
Summary statistics for unregulated streamgages in the Northwest Foothills hydrologic region (hydrologic region 3, fig. 1)									
NA	40 streamgages summarized			18 streamgages summarized			22 streamgages summarized		
Minimum	0.19	11	3.59	55.80	11	3.59	0.19	13	21.83
10th nonexceedance percentile	0.69	13	8.97	114.33	12	5.81	0.23	15	25.75
25th nonexceedance percentile	2.93	16	14.76	259.25	14	9.02	0.92	16	39.18
Median	20.85	20	27.17	526.50	29	12.63	3.39	18	46.54
Mean	1,491.20	30	37.52	3,304.38	39	13.87	7.69	23	56.86
75th nonexceedance percentile	380.25	38	48.29	1,773.75	59	16.75	13.58	29	71.45
90th nonexceedance percentile	1,981.60	61	89.56	9,634.40	77	22.58	20.02	38	92.39
Maximum	24,297.00	105	125.35	24,297.00	105	34.15	31.40	52	125.35
Summary statistics for active unregulated streamgages in the Northwest Foothills hydrologic region (hydrologic region 3, fig. 1)									
NA	15 streamgages summarized			9 streamgages summarized			6 streamgages summarized		
Minimum	0.21	13	3.59	256.00	13	3.59	0.21	13	21.88
10th nonexceedance percentile	2.22	13	6.06	308.80	14	4.14	0.49	14	23.75
25th nonexceedance percentile	9.12	26	9.90	405.00	43	8.74	1.68	20	30.33
Median	322.00	43	15.61	1,238.00	60	9.91	5.03	38	45.84
Mean	3,358.43	47	29.05	5,593.22	57	10.51	6.25	32	56.85
75th nonexceedance percentile	1,569.00	63	35.04	2,716.00	75	14.82	10.86	38	81.14
90th nonexceedance percentile	11,990.20	78	74.35	19,397.80	85	15.92	13.25	45	100.97
Maximum	24,297.00	105	109.49	24,297.00	105	17.12	13.90	52	109.49

Table 3. Statistical summaries of peak-flow variability indices and other selected characteristics of unregulated streamgages in or near Montana.—Continued

[For 649 streamgages, the standard deviations and means of the peak flows were calculated using Bulletin 17B procedures (U.S. Interagency Advisory Council on Water Data, 1982) for fitting the log-Pearson III distribution. For 10 streamgages, the standard deviations and means of the peak flows were calculated using Bulletin 17C procedures as described by Sando and McCarthy (2018) for fitting the log-Pearson III distribution. *CONTDA*, contributing drainage area, in square miles; *n*, number of years of unregulated peak-flow records; *PFVI*, peak-flow variability index calculated by 100 times the absolute value of the ratio of the standard deviation of the peak flows (base-10 logarithms) divided by the mean of the peak flows (base-10 logarithms); CSG, crest-stage gage; NA, not applicable; --, no data]

Summary statistic	All unregulated peak-flow frequency streamgages			Continuous unregulated peak-flow frequency streamgages			CSG unregulated peak-flow frequency streamgages		
	CONTDA	*n*	*PFVI*[1]	*CONTDA*	*n*	*PFVI*[1]	*CONTDA*	*n*	*PFVI*[1]
Summary statistics for unregulated streamgages in the Northeast Plains hydrologic region (hydrologic region 4, fig. 1)									
NA	76 streamgages summarized			42 streamgages summarized			34 streamgages summarized		
Minimum	0.08	10	3.67	2.11	10	3.67	0.08	11	15.00
10th nonexceedance percentile	1.66	12	13.33	13.56	10	11.34	0.80	14	30.25
25th nonexceedance percentile	3.22	16	20.69	68.98	14	17.62	1.76	18	34.87
Median	31.85	29	32.05	181.50	24	22.68	3.02	30	51.05
Mean	866.84	29	130.53	1,539.61	30	28.19	35.76	29	256.94
75th nonexceedance percentile	248.25	39	54.40	643.50	44	31.20	6.50	38	88.39
90th nonexceedance percentile	934.50	47	105.05	1,466.50	52	43.50	17.22	39	169.63
Maximum	33,326.00	80	5900.00	33,326.00	80	165.78	850.00	52	5900.00
Summary statistics for active unregulated streamgages in the Northeast Plains hydrologic region (hydrologic region 4, fig. 1)									
NA	26 streamgages summarized			12 streamgages summarized			14 streamgages summarized		
Minimum	0.08	11	4.37	135.00	11	4.37	0.08	14	33.24
10th nonexceedance percentile	1.48	18	9.76	236.50	17	7.37	0.95	29	33.84
25th nonexceedance percentile	2.39	29	17.83	349.00	23	10.50	1.64	38	39.41
Median	6.98	38	34.07	1,077.00	35	17.68	2.40	38	70.69
Mean	2,218.26	36	79.11	4,803.08	37	19.07	2.69	35	130.57
75th nonexceedance percentile	843.75	39	74.00	3,357.00	44	22.37	2.68	38	120.39
90th nonexceedance percentile	3,967.00	45	152.25	10,586.10	63	32.21	4.66	39	301.90
Maximum	33,326.00	80	598.60	33,326.00	80	48.20	8.90	39	598.60
Summary statistics for unregulated streamgages in the East-Central Plains hydrologic region (hydrologic region 5, fig. 1)									
NA	102 streamgages summarized			26 streamgages summarized			76 streamgages summarized		
Minimum	0.11	10	2.33	59.30	10	2.33	0.11	13	9.86
10th nonexceedance percentile	0.77	14	12.96	155.50	10	4.16	0.67	15	20.66
25th nonexceedance percentile	1.48	16	20.97	267.00	11	10.68	1.09	17	28.94
Median	6.76	21	36.00	659.00	19	16.28	3.17	23	40.48
Mean	2,644.41	28	45.74	10,256.93	25	20.42	40.13	28	54.40
75th nonexceedance percentile	211.75	38	49.61	3,035.25	34	26.21	9.99	38	56.53
90th nonexceedance percentile	1,173.10	49	73.59	43,710.50	52	39.88	33.40	49	82.62
Maximum	68,407.00	74	396.25	68,407.00	74	73.77	1,223.00	54	396.25

Table 3. Statistical summaries of peak-flow variability indices and other selected characteristics of unregulated streamgages in or near Montana.—Continued

[For 649 streamgages, the standard deviations and means of the peak flows were calculated using Bulletin 17B procedures (U.S. Interagency Advisory Council on Water Data, 1982) for fitting the log-Pearson III distribution. For 10 streamgages, the standard deviations and means of the peak flows were calculated using Bulletin 17C procedures as described by Sando and McCarthy (2018) for fitting the log-Pearson III distribution. *CONTDA*, contributing drainage area, in square miles; *n*, number of years of unregulated peak-flow records; *PFVI*, peak-flow variability index calculated by 100 times the absolute value of the ratio of the standard deviation of the peak flows (base-10 logarithms) divided by the mean of the peak flows (base-10 logarithms); CSG, crest-stage gage; NA, not applicable; --, no data]

Summary statistic	All unregulated peak-flow frequency streamgages			Continuous unregulated peak-flow frequency streamgages			CSG unregulated peak-flow frequency streamgages		
	CONTDA	*n*	*PFVI*[1]	*CONTDA*	*n*	*PFVI*[1]	*CONTDA*	*n*	*PFVI*[1]
Summary statistics for active unregulated streamgages in the East-Central Plains hydrologic region (hydrologic region 5, fig. 1)									
NA	36 streamgages summarized			9 streamgages summarized			27 streamgages summarized		
Minimum	0.46	10	2.33	110.00	10	2.33	0.46	15	14.06
10th nonexceedance percentile	0.86	19	7.61	462.80	11	2.43	0.73	38	28.88
25th nonexceedance percentile	1.59	38	22.39	551.00	18	3.63	1.43	38	38.44
Median	3.54	38	40.48	7,784.00	23	10.52	2.30	38	42.94
Mean	6,503.28	38	62.21	26,002.22	33	17.54	3.63	40	77.10
75th nonexceedance percentile	40.18	49	62.80	47,596.00	50	19.17	4.13	45	68.39
90th nonexceedance percentile	23,804.50	50	90.55	66,512.60	57	33.01	8.11	49	126.63
Maximum	68,407.00	74	396.25	68,407.00	74	73.77	16.90	54	396.25
Summary statistics for unregulated streamgages in the Southeast Plains hydrologic region (hydrologic region 6, fig. 1)									
NA	74 streamgages summarized			20 streamgages summarized			54 streamgages summarized		
Minimum	0.10	10	4.19	3.91	10	4.19	0.10	11	9.57
10th nonexceedance percentile	0.82	15	10.11	114.99	11	7.37	0.71	15	18.37
25th nonexceedance percentile	1.99	16	19.70	434.50	18	9.30	1.47	16	27.84
Median	7.14	30	35.21	852.50	27	17.09	3.57	30	44.05
Mean	887.54	30	55.72	3,226.24	32	19.68	21.36	30	69.07
75th nonexceedance percentile	123.50	39	60.34	1,687.50	43	27.20	9.91	39	74.98
90th nonexceedance percentile	1,244.00	49	95.45	9,103.60	55	36.55	19.45	40	102.92
Maximum	22,419.00	82	646.46	22,419.00	82	48.84	663.00	57	646.46
Summary statistics for active unregulated streamgages in the Southeast Plains hydrologic region (hydrologic region 6, fig. 1)									
NA	30 streamgages summarized			8 streamgages summarized			22 streamgages summarized		
Minimum	0.13	20	4.19	124.00	20	4.19	0.13	38	18.26
10th nonexceedance percentile	0.78	29	9.75	364.10	21	6.52	0.53	38	31.29
25th nonexceedance percentile	1.73	38	29.46	638.75	27	8.75	1.36	39	40.51
Median	4.28	39	47.00	1,080.50	31	14.74	2.68	39	49.89

Table 3. Statistical summaries of peak-flow variability indices and other selected characteristics of unregulated streamgages in or near Montana.—Continued

[For 649 streamgages, the standard deviations and means of the peak flows were calculated using Bulletin 17B procedures (U.S. Interagency Advisory Council on Water Data, 1982) for fitting the log-Pearson III distribution. For 10 streamgages, the standard deviations and means of the peak flows were calculated using Bulletin 17C procedures as described by Sando and McCarthy (2018) for fitting the log-Pearson III distribution. *CONTDA*, contributing drainage area, in square miles; *n*, number of years of unregulated peak-flow records; *PFVI*, peak-flow variability index calculated by 100 times the absolute value of the ratio of the standard deviation of the peak flows (base-10 logarithms) divided by the mean of the peak flows (base-10 logarithms); CSG, crest-stage gage; NA, not applicable; --, no data]

Summary statistic	All unregulated peak-flow frequency streamgages			Continuous unregulated peak-flow frequency streamgages			CSG unregulated peak-flow frequency streamgages		
	CONTDA	*n*	*PFVI*[1]	*CONTDA*	*n*	*PFVI*[1]	*CONTDA*	*n*	*PFVI*[1]
Summary statistics for active unregulated streamgages in the Southeast Plains hydrologic region (hydrologic region 6, fig. 1)—Continued									
Mean	1,568.06	41	72.01	5,869.50	42	20.26	3.90	41	90.83
75th nonexceedance percentile	95.90	40	74.40	1,443.59	32	19.56	5.72	40	85.51
90th nonexceedance percentile	2,108.80	52	98.28	15,867.70	76	39.90	8.52	49	103.62
Maximum	22,419.00	82	646.46	22,419.00	82	48.84	11.60	57	646.46
Summary statistics for unregulated streamgages in the Upper Yellowstone-Central Mountain hydrologic region (hydrologic region 7, fig. 1)									
NA	108 streamgages summarized			64 streamgages summarized			44 streamgages summarized		
Minimum	0.39	10	1.89	7.23	10	1.89	0.39	11	8.00
10th nonexceedance percentile	2.49	13	3.51	47.66	12	2.98	1.25	15	13.02
25th nonexceedance percentile	7.37	16	7.75	64.63	18	5.20	2.49	15	23.02
Median	56.35	27	14.48	157.00	31	8.05	5.44	19	42.53
Mean	737.13	35	94.01	1,227.78	41	10.34	23.48	26	215.70
75th nonexceedance percentile	226.25	46	33.48	547.75	63	13.58	18.48	38	61.01
90th nonexceedance percentile	1,121.20	75	61.09	1,728.70	87	18.97	45.68	47	231.89
Maximum	20,718.00	105	5,652.38	20,718.00	105	40.78	430.00	57	5,652.38
Summary statistics for active unregulated streamgages in the Upper Yellowstone-Central Mountain hydrologic region (hydrologic region 7, fig. 1)									
NA	35 streamgages summarized			25 streamgages summarized			10 streamgages summarized		
Minimum	0.39	10	2.71	48.50	10	2.71	0.39	15	15.13
10th nonexceedance percentile	3.23	20	2.93	71.52	24	2.80	1.16	15	19.99
25th nonexceedance percentile	25.65	36	4.24	198.00	33	3.29	1.58	38	23.47
Median	230.00	53	7.16	819.00	73	6.14	4.76	38	40.42
Mean	1,476.15	56	56.06	2,063.37	64	6.49	8.11	38	180.00
75th nonexceedance percentile	1,130.00	80	18.27	1,588.00	87	7.68	8.11	48	60.62
90th nonexceedance percentile	2,383.20	96	52.17	3,177.00	98	11.76	13.85	53	463.40
Maximum	19,672.00	105	1,126.98	19,672.00	105	16.02	40.40	57	1,126.98

Table 3. Statistical summaries of peak-flow variability indices and other selected characteristics of unregulated streamgages in or near Montana.—Continued

[For 649 streamgages, the standard deviations and means of the peak flows were calculated using Bulletin 17B procedures (U.S. Interagency Advisory Council on Water Data, 1982) for fitting the log-Pearson III distribution. For 10 streamgages, the standard deviations and means of the peak flows were calculated using Bulletin 17C procedures as described by Sando and McCarthy (2018) for fitting the log-Pearson III distribution. *CONTDA*, contributing drainage area, in square miles; *n*, number of years of unregulated peak-flow records; *PFVI*, peak-flow variability index calculated by 100 times the absolute value of the ratio of the standard deviation of the peak flows (base-10 logarithms) divided by the mean of the peak flows (base-10 logarithms); CSG, crest-stage gage; NA, not applicable; --, no data]

Summary statistic	All unregulated peak-flow frequency streamgages			Continuous unregulated peak-flow frequency streamgages			CSG unregulated peak-flow frequency streamgages		
	CONTDA	*n*	*PFVI*[1]	*CONTDA*	*n*	*PFVI*[1]	*CONTDA*	*n*	*PFVI*[1]
Summary statistics for unregulated streamgages in the Southwest hydrologic region (hydrologic region 8, fig. 1)									
NA	67 streamgages summarized			35 streamgages summarized			32 streamgages summarized		
Minimum	0.42	11	2.88	22.80	11	2.88	0.42	14	5.92
10th nonexceedance percentile	3.55	14	4.75	36.34	12	4.06	1.23	15	9.17
25th nonexceedance percentile	11.45	15	6.49	75.25	15	5.19	3.73	16	17.90
Median	44.60	19	9.30	316.00	24	6.74	10.17	18	35.34
Mean	1,235.29	30	88.22	2,330.66	35	7.02	37.22	25	177.04
75th nonexceedance percentile	334.50	38	32.60	1,873.50	43	8.68	31.20	38	99.98
90th nonexceedance percentile	2,692.80	71	123.12	8,781.20	77	9.33	79.75	40	174.27
Maximum	16,669.00	95	2,898.55	16,669.00	95	14.49	348.00	54	2,898.55
Summary statistics for active unregulated streamgages in the Southwest hydrologic region (hydrologic region 8, fig. 1)									
NA	29 streamgages summarized			21 streamgages summarized			8 streamgages summarized		
Minimum	1.37	14	3.91	33.00	14	3.91	1.37	14	5.92
10th nonexceedance percentile	10.62	14	4.93	85.90	15	4.43	2.95	14	7.24
25th nonexceedance percentile	30.50	15	5.89	192.00	22	5.79	5.02	14	21.79
Median	381.00	36	7.22	566.00	34	6.74	13.10	38	46.27
Mean	2,235.41	41	20.11	3,081.52	45	7.07	14.36	31	54.35
75th nonexceedance percentile	2,472.00	71	9.31	2,730.00	73	8.35	20.58	39	59.22
90th nonexceedance percentile	8,004.40	80	51.39	9,558.00	85	9.30	30.43	43	103.22
Maximum	16,669.00	95	174.75	16,669.00	95	14.49	30.50	52	174.75

[1]The peak-flow variability index for each streamgage summarized was based on the length and period of record of that streamgage. Among the 659 streamgages summarized, the starting years in the periods of record ranged from 1872 through 2003 and the ending years ranged from 1915 through 2017.

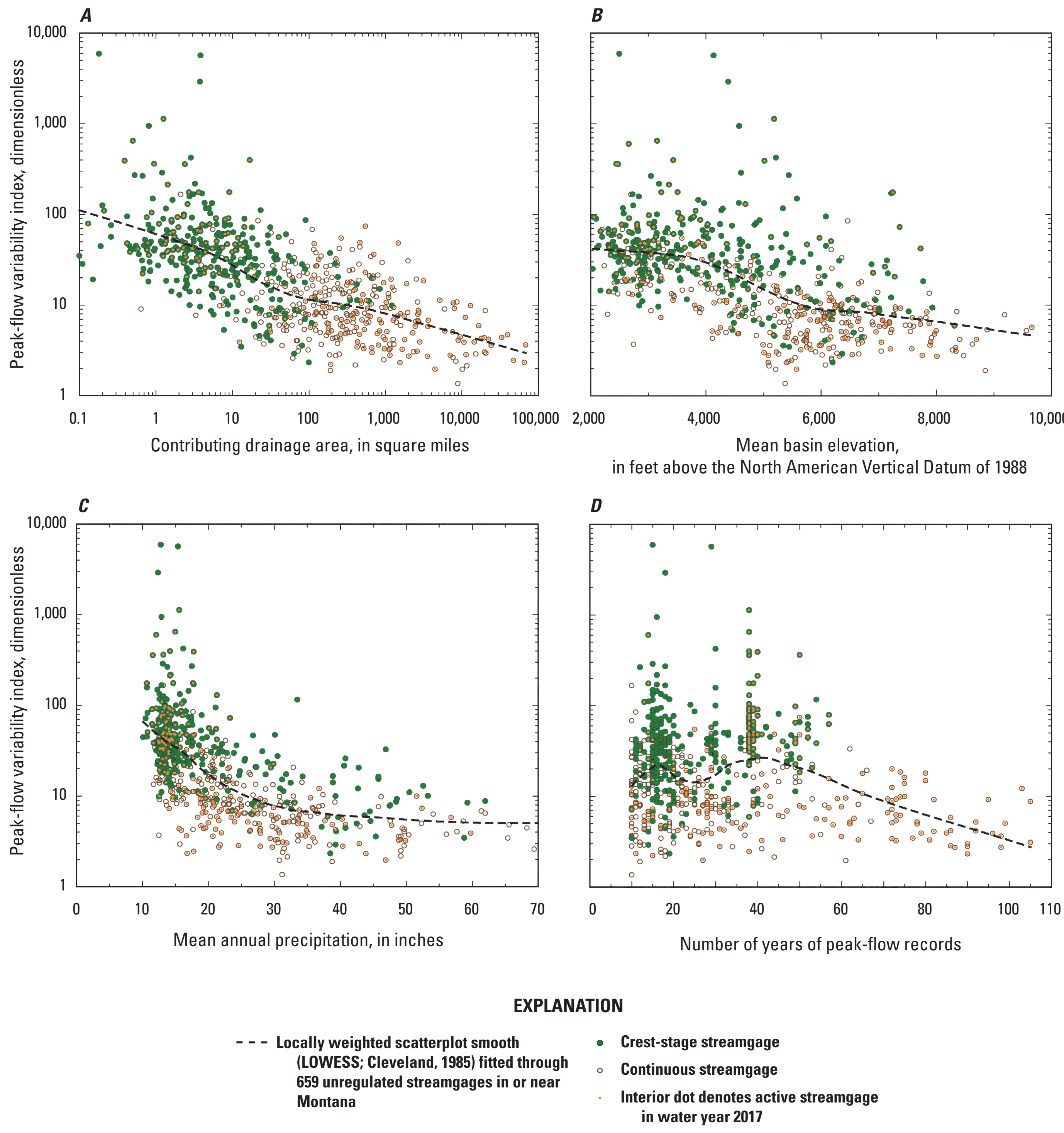


Figure 2. Relations between peak-flow variability index and selected drainage-basin and streamgage characteristics for 659 unregulated streamgages in or near Montana. *A*, Peak-flow variability and contributing drainage area relations. *B*, Peak-flow variability and mean basin elevation relations. *C*, Peak-flow variability and mean annual precipitation relations. *D*, Peak-flow variability and years of peak-flow records relations.

Relations among *PFVI* and the selected characteristics shown in figure 2 might be confounded by relations among drainage area and the other characteristics (fig. 3). Of particular note, streamgages with long periods of record (greater than about 60 years) generally have large drainage areas (greater than about 100 mi^2) as shown in figure 3*C*. Thus, general relations between *PFVI* and years of record are difficult to characterize when all 659 unregulated streamgages are evaluated on a statewide basis; better understanding of the relations might be achieved by evaluation within each hydrologic region. The hydrologic region of each streamgage is not indicated in figure 2, but LOWESS lines fitted through the streamgage data of each hydrologic region are shown in figure 4 to assist in evaluation of the various relations within each hydrologic region.

LOWESS lines fitted through various relations between *PFVI* and the selected characteristics for each hydrologic region in Montana are shown in figure 4. The LOWESS lines in figure 4 are sometimes difficult to distinguish among the hydrologic regions and are sometimes confusing, but the primary purpose of figure 4 is to initially establish that the various relations have some general similarities but also substantially differ among hydrologic regions. For example, the LOWESS lines through the relations between *PFVI* and drainage area (fig. 4*A*) and years of record (fig. 4*D*) for the West and Northwest hydrologic regions are consistently below the LOWESS line through the data for all unregulated streamgages in Montana. The West and Northwest hydrologic regions have much lower median *PFVI* values (7.63 and 6.04, respectively; table 3) than the median for all unregulated streamgages in Montana (18.26, table 3). In contrast, the LOWESS lines through the relations between *PFVI* and drainage area (fig. 4*A*) and years of record (fig. 4*D*) for the Northeast Plains, East-Central Plains, and Southeast Plains hydrologic regions generally are above the LOWESS line through the data for all unregulated streamgages in Montana. The Northeast Plains, East-Central Plains, and Southeast Plains hydrologic regions have much higher median *PFVI* values (32.05, 36.00, and 35.21, respectively; table 3) than the median for all unregulated streamgages in Montana (18.26, table 3). The substantial differences in the various relations among the hydrologic regions provide evidence of the need to consider each hydrologic region independently when evaluating peak-flow variability and peak-flow informational needs. As such, these subjects are addressed for each hydrologic region in the section “Description of Peak-Flow Variability and Peak-Flow Informational Needs, and Consideration of Regional Regression Analyses by Hydrologic Region.”

In the previous paragraph and in various other sections of this report, the median *PFVI* is used as a single metric to make general comparisons of peak-flow variability among the hydrologic regions. It should be noted that this usage of the median *PFVI* is imprecise because the *PFVI* is affected by many factors (notably contributing drainage area and years of record) that vary in their representation within each hydrologic region. However, figures 4*A* and 4*D* show that the LOWESS lines for hydrologic regions with the lowest median *PFVI* values (the West and Northwest hydrologic regions) generally are below the LOWESS line for all unregulated streamgages in Montana throughout their full ranges in contributing drainage area (fig. 4*A*) and years of record (fig. 4*D*). Likewise, the LOWESS lines for hydrologic regions with the highest median *PFVI* values (the Northeast Plains, East-Central Plains, and Southeast Plains hydrologic regions) generally are above the LOWESS line for all unregulated streamgages in Montana throughout their full ranges in contributing drainage area (fig. 4*A*) and years of record (fig. 4*D*). Intuitively, the median *PFVI* values of the hydrologic regions would reasonably capture the relative variability in peak-flow variability among the hydrologic regions. However, given the complex interactions of various factors affecting the *PFVI* values and the acknowledged imprecision of the median *PFVI* value as a single metric, some other single metric might result in small differences in the relative ranking of peak-flow variability among the hydrologic regions.

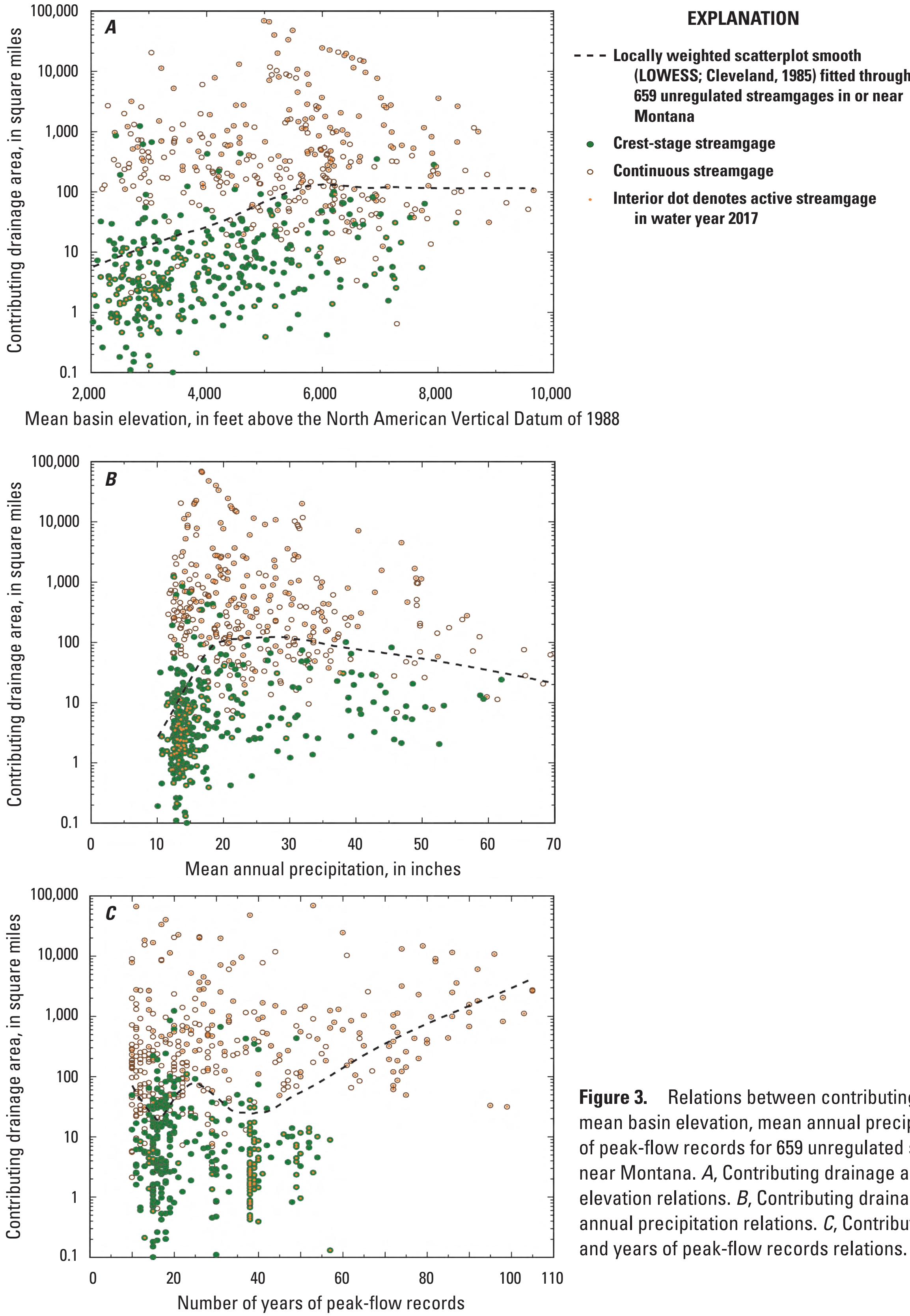


Figure 3. Relations between contributing drainage area and mean basin elevation, mean annual precipitation, and years of peak-flow records for 659 unregulated streamgages in or near Montana. *A*, Contributing drainage area and mean basin elevation relations. *B*, Contributing drainage area and mean annual precipitation relations. *C*, Contributing drainage area and years of peak-flow records relations.

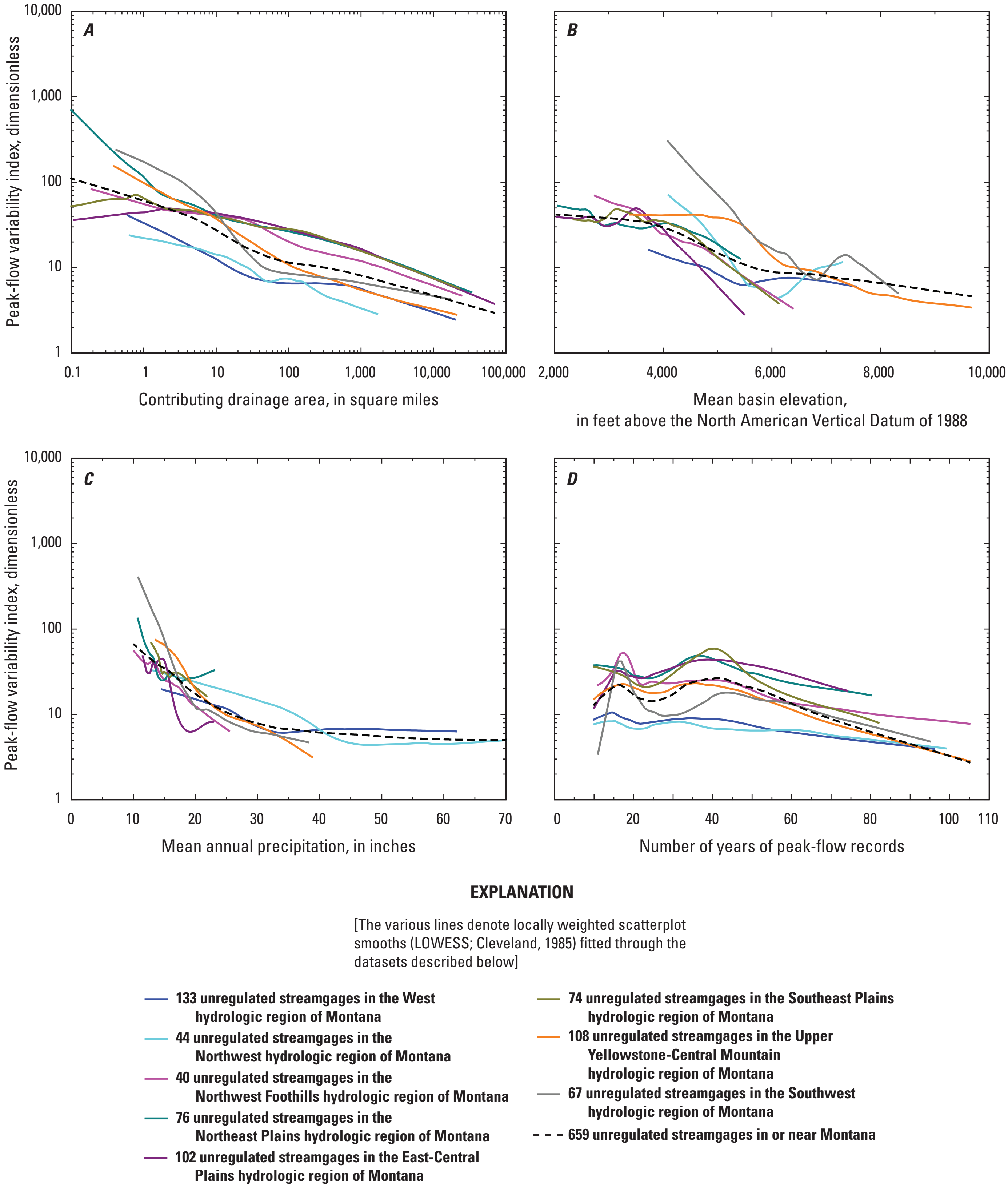


Figure 4. Locally weighted scatterplot smooths (LOWESS; Cleveland, 1985) fitted through relations between peak-flow variability index and contributing drainage area, mean basin elevation, mean annual precipitation, and years of peak-flow records for each hydrologic regions in Montana. *A*, Peak-flow variability and contributing drainage area relations. *B*, Peak-flow variability and mean basin elevation relations. *C*, Peak-flow variability and mean annual precipitation relations. *D*, Peak-flow variability and years of peak-flow records relations.

General Characterization of Peak-Flow Informational Needs in Montana

A major use of peak-flow information by MDT is for design of road and highway infrastructure, including bridges, culverts, and roadside drainage ditches. As such, characterization of the drainage basins associated with the intersections of roads and streams might provide useful information for guiding optimization of the CSG network.

The most complete Montana roads dataset (Montana State Library, 2019) was geospatially analyzed in conjunction with the NHD Plus Version 2 streams dataset (Horizon Systems Corporation, 2013) to identify 12,639 intersections of roads and streams in Montana. Basin characteristics that can be computed by the Montana StreamStats application (McCarthy and others, 2016) were determined for each road and stream intersection. The basin characteristics determined for each road and stream intersection represent the entire drainage basin upstream from the road and stream intersection rather than just the intervening area between nested road and stream intersections on the same stream channel. The data for the road and stream intersections were generated during this study and are available as a USGS data release (Dutton and others, 2021).

Statistical summaries of selected drainage-basin characteristics of the 12,639 road and stream intersections in Montana are presented in tables 4 and 5. Statistical summaries of selected drainage-basin characteristics of 735 streamgages that currently (2020) have 10 or more years of peak-flow records and include regulated and unregulated streamgages are also shown in tables 4 and 5. Regulated and unregulated streamgages are included because the road and stream intersections are on regulated and unregulated streams. The minimum drainage area for the road and stream intersections was 0.31 mi^2 and was a function of the spatial resolution of NHD Plus Version 2 streams dataset (Horizon Systems Corporation, 2013) that serves as the source of most basic data supporting the Montana StreamStats application (McCarthy and others, 2016). Intuitively, there are numerous road and stream intersections in Montana that have drainage areas less than 0.31 mi^2, but the 0.31-mi^2 resolution threshold serves as a constraint on the characterization of the road and stream intersections. There are only 11 CSGs on streams with drainage areas less than 0.31 mi^2, which accounts for about 3 percent of all CSGs in Montana. Various issues related to the 0.31-mi^2 resolution threshold are not considered to have a substantial effect on the investigation of peak-flow informational needs in Montana.

Of the 735 regulated and unregulated streamgages in or near Montana, 20 of the streamgages are in Canada or Yellowstone National Park on streams that flow into Montana; those streamgages are considered to be representative of hydroclimatic characteristics of streams in Montana, but they are located outside of the Montana border and are not within the boundaries of the eight hydrologic regions. Thus, 715 regulated and unregulated streamgages are used in various analyses in this report that apply to regulated and unregulated streamgages within the eight hydrologic regions.

Cumulative distribution functions (CDFs) of selected basin characteristics (drainage area, mean basin elevation, and mean annual precipitation) for the road and stream intersections and for the streamgages are shown in figure 5. The basin characteristics were selected for presentation because they are important factors affecting the large variability in streamflow characteristics across Montana.

For a hypothetical ideal streamgaging network, it might be desirable that the pattern of the streamgage CDFs in figure 5 would closely resemble the pattern of the road and stream intersection CDFs, but such a hypothetical ideal streamgaging network is not realistic for several reasons. For example, continuous streamgages, which comprise about 56 percent of the 735 streamgages represented in figure 5, generally are established based on specific needs for streamflow information to address various water-management issues and generally are not intended to provide reasonable representation of hydroclimatic settings across Montana. Also, although CSGs have been established with the intention of providing reasonable representation of hydroclimatic settings across Montana, the decisions concerning establishment and discontinuation of CSGs often are based on subjective professional judgement and (or) operational considerations unrelated to informational value in representation of hydroclimatic settings. Further, some basic statistical characteristics of the road and stream intersections dataset could make it an unrealistic model for managing the streamgaging network. For example, the median contributing drainage of the 12,639 road and stream intersections is 3.85 mi^2 (tables 4 and 5). Clearly, practical considerations would negate developing a streamgaging network with a median contributing drainage area less than 5 mi^2. But, evaluating the streamgaging network in relation to the road and stream intersections dataset still might have utility if it is recognized that the pattern of the streamgage CDFs (fig. 5) ideally would have general characteristics that reasonably represent the road and stream intersections general characteristics. For example, it might be desirable that the CDFs of the streamgaging network generally consistently vary across the range of the CDFs of the road and stream intersections dataset.

Brief guidance in interpreting the road and stream intersections and streamgage CDF relations in figure 5 might be useful. Where streamgage CDFs plot above the road and stream intersection CDFs, the basin characteristic values are overrepresented in the streamgage network; this pattern is rare. For example, in figure 5*A*, streamgage CDFs plot above the road and stream intersection CDFs in the range of contributing drainage area of 0.08–0.31 mi^2, primarily because of the resolution threshold of the road and stream intersections dataset. Where the streamgage CDFs plot below the road and stream intersection CDFs, the basin characteristic values are underrepresented in the streamgage network; this pattern is predominant. The streamgage CDFs plot below the road and stream

Table 4. Statistical summaries of contributing drainage area and elevation-related and slope-related drainage-basin characteristics associated with road and stream intersections, and streamgages (regulated and unregulated) in or near Montana.

[*CONTDA*, contributing drainage area, in square miles; *ELEV*, mean basin elevation, in feet; *ELEVMAX*, maximum basin elevation, in feet; *MINBELEV*, minimum basin elevation, in feet; *RELIEF*, maximum minus minimum elevation, in feet; EL_{5000}, percentage of basin above 5,000 feet elevation; EL_{6000}, percentage of basin above 6,000 feet elevation; *BSLDEM*30, mean basin slope; *SLOP*30_30*M*, percentage of basin with slopes greater than or equal to 30 percent; *NFSL*30_30*M*, percentage of basin with north-facing slopes greater than or equal to 30 percent; *SLOP*50_30*M*, percentage of basin with slopes greater than or equal to 50 percent; --, no data]

Summary statistic	Basin characteristics computed by the Montana StreamStats application (McCarthy and others, 2016) as indicated by the StreamStats abbreviations										
		Elevation-related basin characteristics						Slope-related basin characteristics			
	CONTDA	*ELEV*	*ELEVMAX*	*MINBELEV*	*RELIEF*	EL_{5000}	EL_{6000}	*BSLDEM*30	*SLOP*30_30*M*	*NFSL*30_30*M*	*SLOP*50_30*M*
Summary statistics for 12,639 road and stream intersections in Montana											
10th percentile[1]	0.44	2,689	2,863	2,458	162	0.00	0.00	2.3	0.00	0.00	0.00
Median	3.85	4,173	4,920	3,561	845	0.00	0.00	11.5	3.63	0.70	0.03
90th percentile[1]	125.92	6,735	9,140	5,639	4,565	100.00	89.79	33.8	54.91	17.74	19.94
Summary statistics for 735 streamgages (regulated and unregulated) in Montana											
10th percentile[1]	1.60	2,693	--	--	320	0.00	0.00	4.3	0.00	--	--
Median	59.30	4,641	--	--	3,090	27.27	3.99	16.0	13.02	--	--
90th percentile[1]	2,626.20	7,059	--	--	6,779	100.00	86.24	39.8	63.55	--	--
Summary statistics for 2,380 road and stream intersections in the West hydrologic region (hydrologic region 1, fig. 1)											
10th percentile[1]	0.50	3,400	4,142	2,630	606	0.00	0.00	8.6	1.08	0.00	0.00
Median	8.46	4,741	6,565	3,415	2,817	35.00	4.00	26.8	38.85	9.76	7.57
90th percentile[1]	254.98	6,239	9,056	4,965	5,360	100.00	60.67	44.9	79.67	27.62	40.43
Summary statistics for 141 streamgages (regulated and unregulated) in the West hydrologic region (hydrologic region 1, fig. 1)											
10th percentile[1]	4.71	4,412	--	--	2,801	22.41	0.79	20.8	25.30	--	--
Median	65.90	5,390	--	--	4,502	60.14	32.12	32.9	52.58	--	--
90th percentile[1]	2,824.00	6,568	--	--	7,039	98.06	70.55	46.9	78.79	--	--
Summary statistics for 356 road and stream intersections in Northwest hydrologic region (hydrologic region 2, fig. 1)											
10th percentile[1]	0.46	4,316	4,727	3,369	373	0.00	0.00	5.7	0.00	0.00	0.00
Median	4.19	5,493	7,377	4,400	2,788	72.00	21.23	28.5	41.24	11.60	12.06
90th percentile[1]	103.51	6,246	9,383	5,173	5,071	100.00	61.92	49.2	75.44	25.19	45.38
Summary statistics for 49 streamgages (regulated and unregulated) in the Northwest hydrologic region (hydrologic region 2, fig. 1)											
10th percentile[1]	8.21	5,060	--	--	2,587	35.33	0.95	10.3	3.94	--	--
Median	115.00	5,916	--	--	4,885	78.12	44.81	41.2	57.63	--	--
90th percentile[1]	945.80	6,479	--	--	6,218	97.49	68.65	52.8	73.02	--	--
Summary statistics for 1,043 road and stream intersections in the Northwest Foothills hydrologic region (hydrologic region 3, fig. 1)											
10th percentile[1]	0.42	3,225	3,315	3,034	78	0.00	0.00	1.2	0.00	0.00	10th percentile[1]
Median	2.25	3,735	3,931	3,484	276	0.00	0.00	3.5	0.00	0.00	Median
90th percentile[1]	75.15	4,414	6,122	4,029	2,549	4.00	0.00	11.6	7.02	2.73	90th percentile[1]

Table 4. Statistical summaries of contributing drainage area and elevation-related and slope-related drainage-basin characteristics associated with road and stream intersections, and streamgages (regulated and unregulated) in or near Montana.—Continued

[*CONTDA*, contributing drainage area, in square miles; *ELEV*, mean basin elevation, in feet; *ELEVMAX*, maximum basin elevation, in feet; *MINBELEV*, minimum basin elevation, in feet; *RELIEF*, maximum minus minimum elevation, in feet; EL_{5000}, percentage of basin above 5,000 feet elevation; EL_{6000}, percentage of basin above 6,000 feet elevation; *BSLDEM*30, mean basin slope; *SLOP*30_30*M*, percentage of basin with slopes greater than or equal to 30 percent; *NFSL*30_30*M*, percentage of basin with north-facing slopes greater than or equal to 30 percent; *SLOP*50_30*M*, percentage of basin with slopes greater than or equal to 50 percent; --, no data]

Summary statistic	Basin characteristics computed by the Montana StreamStats application (McCarthy and others, 2016) as indicated by the StreamStats abbreviations										
		Elevation-related basin characteristics						Slope-related basin characteristics			
	CONTDA	*ELEV*	*ELEVMAX*	*MINBELEV*	*RELIEF*	EL_{5000}	EL_{6000}	*BSLDEM*30	*SLOP*30_30*M*	*NFSL*30_30*M*	*SLOP*50_30*M*
Summary statistics for 46 streamgages (regulated and unregulated) in the Northwest Foothills hydrologic region (hydrologic region 3, fig. 1)											
10th percentile[1]	0.74	3,145	--	--	243	0.00	0.00	1.8	0.00	--	--
Median	60.95	3,938	--	--	937	0.00	0.00	7.3	1.95	--	--
90th percentile[1]	6,227.50	5,419	--	--	6,853	55.28	35.15	20.0	24.72	--	--
Summary statistics for 1,470 road and stream intersections in the Northeast Plains hydrologic region (hydrologic region 4, fig. 1)											
10th percentile[1]	0.41	2,376	2,525	2,218	81	0.00	0.00	1.4	0.00	0.00	0.00
Median	3.70	2,943	3,134	2,780	320	0.00	0.00	4.2	0.00	0.00	0.00
90th percentile[1]	109.41	4,339	5,995	3,727	2,768	4.91	0.00	16.5	14.81	5.23	2.10
Summary statistics for 88 streamgages (regulated and unregulated) in Northeast Plains hydrologic region (hydrologic region 4, fig. 1)											
10th percentile[1]	1.85	2,461	--	--	198	0.00	0.00	2.0	0.00	--	--
Median	86.85	3,035	--	--	758	0.00	0.00	4.9	0.08	--	--
90th percentile[1]	2,540.50	4,060	--	--	6,278	6.05	0.11	16.4	17.35	--	--
Summary statistics for 1,586 road and stream intersections in the East-Central Plains hydrologic region (hydrologic region 5, fig. 1)											
10th percentile[1]	0.42	2,244	2,416	2,053	146	0.00	0.00	2.7	0.00	0.00	0.00
Median	3.64	2,838	3,071	2,661	340	0.00	0.00	5.4	0.00	0.00	0.00
90th percentile[1]	107.66	3,862	4,174	3,564	1,002	0.00	0.00	10.8	2.61	0.86	0.04
Summary statistics for 114 streamgages (regulated and unregulated) in the East-Central Plains hydrologic region (hydrologic region 5, fig. 1)											
10th percentile[1]	0.79	2,314	--	--	186	0.00	0.00	4.2	0.00	--	--
Median	9.99	2,832	--	--	494	0.00	0.00	6.3	0.21	--	--
90th percentile[1]	4,373.20	4,222	--	--	6,192	21.40	9.27	14.0	9.73	--	--
Summary statistics for 1,371 road and stream intersections in the Southeast Plains hydrologic region (hydrologic region 6, fig. 1)											
10th percentile[1]	0.43	2,634	2,792	2,444	185	0.00	0.00	3.8	0.00	0.00	$10th percentile_{1}$
Median	2.37	3,194	3,442	2,967	442	0.00	0.00	9.7	1.22	0.36	Median
90th percentile[1]	77.05	3,940	4,352	3,543	1,089	0.00	0.00	17.0	13.28	4.50	90th percentile[1]
Summary statistics for 80 streamgages (regulated and unregulated) in the Southeast Plains hydrologic region (hydrologic region 6, fig. 1)											
10th percentile[1]	0.84	2,819	--	--	256	0.00	0.00	4.7	0.00	--	--
Median	8.96	3,396	--	--	673	0.00	0.00	11.6	2.64	--	--
90th percentile[1]	2,029.10	4,629	--	--	8,413	20.42	12.58	17.2	13.74	--	--

Table 4. Statistical summaries of contributing drainage area and elevation-related and slope-related drainage-basin characteristics associated with road and stream intersections, and streamgages (regulated and unregulated) in or near Montana.—Continued

[*CONTDA*, contributing drainage area, in square miles; *ELEV*, mean basin elevation, in feet; *ELEVMAX*, maximum basin elevation, in feet; *MINBELEV*, minimum basin elevation, in feet; *RELIEF*, maximum minus minimum elevation, in feet; EL_{5000}, percentage of basin above 5,000 feet elevation; EL_{6000}, percentage of basin above 6,000 feet elevation; *BSLDEM*30, mean basin slope; *SLOP*30_30*M*, percentage of basin with slopes greater than or equal to 30 percent; *NFSL*30_30*M*, percentage of basin with north-facing slopes greater than or equal to 30 percent; *SLOP*50_30*M*, percentage of basin with slopes greater than or equal to 50 percent; --, no data]

Summary statistic	Basin characteristics computed by the Montana StreamStats application (McCarthy and others, 2016) as indicated by the StreamStats abbreviations										
		Elevation-related basin characteristics						Slope-related basin characteristics			
	CONTDA	*ELEV*	*ELEVMAX*	*MINBELEV*	*RELIEF*	EL_{5000}	EL_{6000}	*BSLDEM*30	*SLOP*30_30*M*	*NFSL*30_30*M*	*SLOP*50_30*M*
Summary statistics for 2,166 road and stream intersections in the Upper Yellowstone-Central Mountain hydrologic region (hydrologic region 7, fig. 1)											
10th percentile[1]	0.45	3,634	3,955	3,300	259	0.00	0.00	3.0	0.00	0.00	0.00
Median	3.88	4,889	5,452	4,342	1,000	29.54	0.00	13.2	6.20	1.51	0.16
90th percentile[1]	104.79	7,290	10,005	5,517	4,861	100.00	92.02	31.4	46.63	16.20	18.15
Summary statistics for 113 streamgages (regulated and unregulated) in the Upper Yellowstone-Central Mountain hydrologic region (hydrologic region 7, fig. 1)											
10th percentile[1]	2.55	4,183	--	--	741	0.00	0.00	7.6	1.25	--	--
Median	61.30	5,807	--	--	4,162	80.40	32.57	18.5	18.90	--	--
90th percentile[1]	1,143.20	7,855	--	--	7,168	100.00	97.12	36.2	53.24	--	--
Summary statistics for 2,267 road and stream intersections in the Southwest hydrologic region (hydrologic region 8, fig. 1)											
10th percentile[1]	0.45	4,761	5,359	3,920	416	19.60	0.00	5.5	0.00	0.00	0.00
Median	2.90	6,347	7,778	5,440	2,002	100.00	71.61	20.1	22.52	6.60	2.90
90th percentile[1]	204.86	7,632	10,212	6,722	5,027	100.00	100.00	32.5	51.58	18.93	18.88
Summary statistics for 84 streamgages (regulated and unregulated) in the Southwest hydrologic region (hydrologic region 8, fig. 1)											
10th percentile[1]	3.81	5,274	--	--	1,544	55.99	2.74	14.0	9.79	--	--
Median	93.80	6,997	--	--	4,424	100.00	85.56	21.2	25.12	--	--
90th percentile[1]	2,843.40	7,671	--	--	6,285	100.00	100.00	30.7	49.03	--	--

[1]Nonexceedance percentile.

Table 5. Statistical summaries of climate-related and land use and land cover related drainage-basin characteristics associated with road and stream intersections, and streamgages (regulated and unregulated) in or near Montana.

[*CONTDA*, contributing drainage area; *PRECIP*, mean annual precipitation, in inches; *ET*0306*MOD*, spring mean monthly evapotranspiration, in inches per month; *ET*0710*MOD*, summer mean monthly evapotranspiration, in inches per month; *AG_OF_DA*, percentage of basin in agricultural land; *IRRIG_MT*, percentage of basin under some irrigation regime; *FOREST*, percentage of basin in forest; *LAKEAREA*, percentage of basin in lakes, ponds, and reservoirs; *URBAN*, percentage of basin in urban; *WETLAND*, percentage of basin in wetlands; --, no data]

Summary Statistic	Basin characteristics computed by the Montana StreamStats application (McCarthy and others, 2016) as indicated by the StreamStats abbreviations									
	CONTDA	Climate-related basin characteristics			Land use and land cover related basin characteristics					
		PRECIP	*ET*0306*MOD*	*ET*0710*MOD*	*AG_OF_DA*	*IRRIGAT_MT*	*FOREST*	*LAKEAREA*	*URBAN*	*WETLAND*
Summary statistics for 12,639 road and stream intersections in Montana										
10th percentile[1]	0.44	12.4	1.07	0.59	0.00	0.00	0.00	0.00	0.00	0.00
Median	3.85	15.7	1.38	0.99	2.00	0.00	4.16	0.00	1.00	0.00
90th percentile[1]	125.92	29.9	1.75	1.78	75.00	5.00	81.47	0.00	5.00	2.00
Summary statistics for 735 streamgages (regulated and unregulated) in Montana										
10th percentile[1]	1.60	12.9	1.06	0.60	0.00	--	0.00	--	0.00	--
Median	59.30	18.6	1.44	1.12	1.53	--	20.04	--	0.49	--
90th percentile[1]	2,626.20	39.2	1.78	1.86	42.34	--	82.32	--	3.17	--
Summary statistics for 2,380 road and stream intersections in the West hydrologic region (hydrologic region 1, fig. 1)										
10th percentile[1]	0.50	15.2	1.54	1.12	0.00	0.00	3.49	0.00	0.00	0.00
Median	8.46	23.4	1.71	1.64	0.00	0.00	72.61	0.00	0.00	0.00
90th percentile[1]	254.98	42.2	1.90	2.31	18.10	8.00	91.79	1.00	7.00	1.00
Summary statistics for 141 streamgages (regulated and unregulated) in the West hydrologic region (hydrologic region 1, fig. 1)										
10th percentile[1]	4.71	20.8	1.60	1.29	0.00	--	49.62	--	0.00	--
Median	65.90	31.5	1.72	1.78	0.08	--	76.38	--	0.19	--
90th percentile[1]	2,824.00	48.9	1.87	2.39	4.81	--	91.95	--	1.91	--
Summary statistics for 356 road and stream intersections in Northwest hydrologic region (hydrologic region 2, fig. 1)										
10th percentile[1]	0.46	16.3	1.52	1.11	0.00	0.00	0.00	0.00	0.00	0.00
Median	4.19	31.5	1.68	1.73	0.00	0.00	63.48	0.00	0.00	0.00
90th percentile[1]	103.51	56.6	1.86	2.27	2.00	0.00	94.66	1.00	3.00	1.00
Summary statistics for 49 streamgages (regulated and unregulated) in the Northwest hydrologic region (hydrologic region 2, fig. 1)										
10th percentile[1]	8.21	22.8	1.58	1.35	0.00	--	18.10	--	0.00	--
Median	115.00	48.6	1.70	1.66	0.05	--	55.90	--	0.03	--
90th percentile[1]	945.80	68.6	1.87	2.08	2.02	--	83.36	--	0.78	--
Summary statistics for 1,043 road and stream intersections in the Northwest Foothills hydrologic region (hydrologic region 3, fig. 1)										
10th percentile[1]	0.42	11.3	1.05	0.61	1.00	0.00	0.00	0.00	0.00	0.00
Median	2.25	13.0	1.21	0.77	66.00	0.00	0.00	0.00	2.00	0.00
90th percentile[1]	75.15	17.0	1.50	1.26	96.00	23.80	3.38	1.00	7.00	1.00

Table 5. Statistical summaries of climate-related and land use and land cover related drainage-basin characteristics associated with road and stream intersections, and streamgages (regulated and unregulated) in or near Montana.—Continued

[*CONTDA*, contributing drainage area; *PRECIP*, mean annual precipitation, in inches; *ET*0306*MOD*, spring mean monthly evapotranspiration, in inches per month; *ET*0710*MOD*, summer mean monthly evapotranspiration, in inches per month; *AG_OF_DA*, percentage of basin in agricultural land; *IRRIG_MT*, percentage of basin under some irrigation regime; *FOREST*, percentage of basin in forest; *LAKEAREA*, percentage of basin in lakes, ponds, and reservoirs; *URBAN*, percentage of basin in urban; *WETLAND*, percentage of basin in wetlands; --, no data]

Summary Statistic	Basin characteristics computed by the Montana StreamStats application (McCarthy and others, 2016) as indicated by the StreamStats abbreviations									
	CONTDA	Climate-related basin characteristics			Land use and land cover related basin characteristics					
		PRECIP	*ET*0306*MOD*	*ET*0710*MOD*	*AG_OF_DA*	*IRRIGAT_MT*	*FOREST*	*LAKEAREA*	*URBAN*	*WETLAND*
Summary statistics for 46 streamgages (regulated and unregulated) in the Northwest Foothills hydrologic region (hydrologic region 3, fig. 1)										
10th percentile[1]	0.74	12.3	1.11	0.61	5.78	--	0.00	--	0.33	--
Median	60.95	14.8	1.31	0.95	42.61	--	0.01	--	1.78	--
90th percentile[1]	6,227.50	21.9	1.52	1.24	85.70	--	34.87	--	3.97	--
Summary statistics for 1,470 road and stream intersections in the Northeast Plains hydrologic region (hydrologic region 4, fig. 1)										
10th percentile[1]	0.41	11.3	1.05	0.61	0.00	0.00	0.00	0.00	0.00	0.00
Median	3.70	13.4	1.17	0.88	42.00	0.00	0.00	0.00	2.00	0.00
90th percentile[1]	109.41	18.4	1.57	1.39	95.00	0.00	12.02	1.00	5.00	3.00
Summary statistics for 88 streamgages (regulated and unregulated) in Northeast Plains hydrologic region (hydrologic region 4, fig. 1)										
10th percentile[1]	1.85	12.3	1.05	0.63	0.39	--	0.00	--	0.00	--
Median	86.85	13.9	1.19	0.91	25.31	--	0.10	--	0.50	--
90th percentile[1]	2,540.50	18.8	1.42	1.30	69.45	--	10.94	--	3.47	--
Summary statistics for 1,586 road and stream intersections in the East-Central Plains hydrologic region (hydrologic region 5, fig. 1)										
10th percentile[1]	0.42	12.5	0.98	0.49	0.00	0.00	0.00	0.00	0.00	0.00
Median	3.64	13.4	1.11	0.70	16.00	0.00	0.02	0.00	1.00	0.98
90th percentile[1]	107.66	14.7	1.24	0.99	74.50	1.00	13.85	0.00	4.00	2.00
Summary statistics for 114 streamgages (regulated and unregulated) in the East-Central Plains hydrologic region (hydrologic region 5, fig. 1)										
10th percentile[1]	0.79	12.4	0.95	0.48	0.00	--	0.00	--	0.00	--
Median	9.99	13.4	1.10	0.70	12.62	--	0.12	--	0.95	--
90th percentile[1]	4,373.20	16.7	1.27	0.98	54.02	--	16.37	--	5.53	--
Summary statistics for 1,371 road and stream intersections in the Southeast Plains hydrologic region (hydrologic region 6, fig. 1)										
10th percentile[1]	0.43	13.5	1.04	0.53	0.00	0.00	0.00	0.00	0.00	0.00
Median	2.37	14.5	1.17	0.67	0.00	0.00	3.41	0.00	0.60	1.07
90th percentile[1]	77.05	16.1	1.38	0.99	24.00	0.00	36.50	0.00	1.18	2.00
Summary statistics for 80 streamgages (regulated and unregulated) in the Southeast Plains hydrologic region (hydrologic region 6, fig. 1)										
10th percentile[1]	0.84	13.9	1.04	0.54	0.00	--	0.00	--	0.00	--
Median	8.96	14.9	1.22	0.70	0.64	--	7.92	--	0.39	--
90th percentile[1]	2,029.10	18.2	1.43	1.00	4.91	--	26.43	--	1.99	--

Table 5. Statistical summaries of climate-related and land use and land cover related drainage-basin characteristics associated with road and stream intersections, and streamgages (regulated and unregulated) in or near Montana.—Continued

[*CONTDA*, contributing drainage area; *PRECIP*, mean annual precipitation, in inches; *ET*0306*MOD*, spring mean monthly evapotranspiration, in inches per month; *ET*0710*MOD*, summer mean monthly evapotranspiration, in inches per month; *AG_OF_DA*, percentage of basin in agricultural land; *IRRIG_MT*, percentage of basin under some irrigation regime; *FOREST*, percentage of basin in forest; *LAKEAREA*, percentage of basin in lakes, ponds, and reservoirs; *URBAN*, percentage of basin in urban; *WETLAND*, percentage of basin in wetlands; --, no data]

Summary Statistic	Basin characteristics computed by the Montana StreamStats application (McCarthy and others, 2016) as indicated by the StreamStats abbreviations									
	CONTDA	Climate-related basin characteristics			Land use and land cover related basin characteristics					
		PRECIP	*ET*0306*MOD*	*ET*0710*MOD*	*AG_OF_DA*	*IRRIGAT_MT*	*FOREST*	*LAKEAREA*	*URBAN*	*WETLAND*
Summary statistics for 2,166 road and stream intersections in the Upper Yellowstone-Central Mountain hydrologic region (hydrologic region 7, fig. 1)										
10th percentile[1]	0.45	14.7	1.18	0.61	0.00	0.00	0.00	0.00	0.00	0.00
Median	3.88	17.7	1.55	1.09	4.00	0.00	5.62	0.00	0.92	1.04
90th percentile[1]	104.79	29.8	1.77	1.59	60.00	16.00	63.41	0.00	3.00	3.00
Summary statistics for 113 streamgages (regulated and unregulated) in the Upper Yellowstone-Central Mountain hydrologic region (hydrologic region 7, fig. 1)										
10th percentile[1]	2.55	16.2	1.30	0.67	0.00	--	0.15	--	0.00	--
Median	61.30	21.4	1.63	1.19	2.77	--	27.95	--	0.50	--
90th percentile[1]	1,143.20	32.2	1.78	1.64	17.76	--	75.28	--	2.34	--
Summary statistics for 2,267 road and stream intersections in the Southwest hydrologic region (hydrologic region 8, fig. 1)										
10th percentile[1]	0.45	11.8	1.25	0.70	0.00	0.00	0.00	0.00	0.00	0.00
Median	2.90	18.4	1.41	1.08	0.00	0.00	24.75	0.00	1.00	0.00
90th percentile[1]	204.86	27.1	1.59	1.43	9.00	5.00	80.74	0.00	6.00	1.00
Summary statistics for 84 streamgages (regulated and unregulated) in the Southwest hydrologic region (hydrologic region 8, fig. 1)										
10th percentile[1]	3.81	14.4	1.27	0.76	0.00	--	3.32	--	0.00	--
Median	93.80	21.2	1.46	1.16	0.49	--	36.36	--	0.62	--
90th percentile[1]	2,843.40	30.5	1.62	1.46	5.76	--	83.60	--	2.00	--

[1]Nonexceedance percentile.

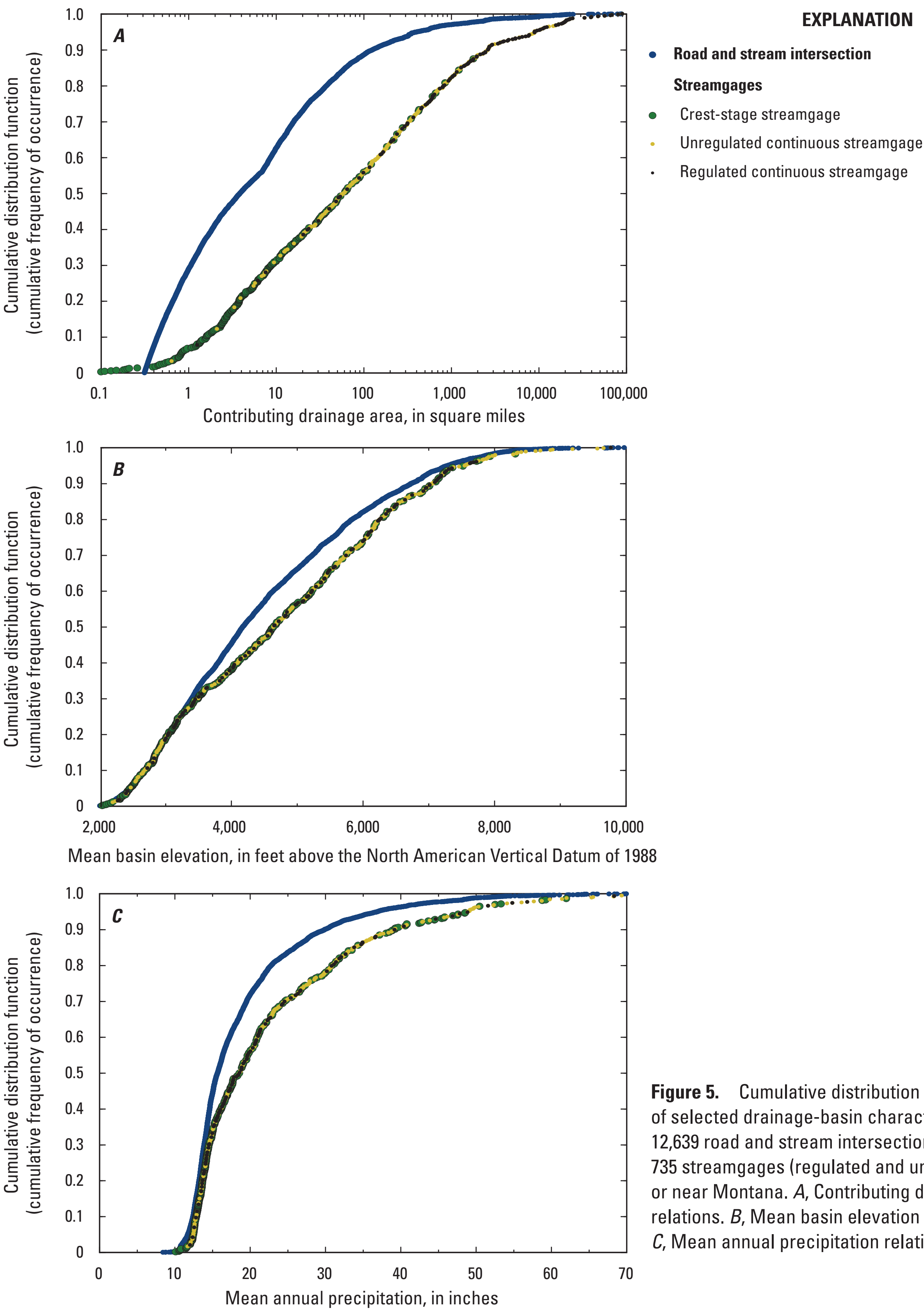


Figure 5. Cumulative distribution functions of selected drainage-basin characteristics for 12,639 road and stream intersections and for 735 streamgages (regulated and unregulated) in or near Montana. *A*, Contributing drainage area relations. *B*, Mean basin elevation relations. *C*, Mean annual precipitation relations.

intersection CDFs from 0.32 to about 88,000 mi^2. In the range from 0.32 to about 3 mi^2, the deviation of the streamgage CDFs from the road and stream intersection CDFs strongly increases, denoting strong underrepresentation. From about 3 to about 100 mi^2, the deviation of the streamgage CDFs from the road and stream intersection CDFs moderately increases but is considered to generally provide reasonable representation. From about 100 to about 88,000 mi^2, the deviation of the streamgage CDFs from the road and stream intersection CDFs moderately decreases and is considered to provide better representation than for contributing drainage areas less than 100 mi^2. The general interpretation described for road and stream intersections and streamgage CDF relations with respect to contributing drainage area (fig. 5*A*) also can be applied to relations with respect to mean basin elevation (fig. 5*B*) and mean annual precipitation (fig. 5*C*).

The road and stream intersection and streamgage CDF relations shown in figure 5 are based on statewide datasets with no distinction between hydrologic regions. Exploratory analyses indicated that the CDF relations are substantially different among the hydrologic regions and determined the need to consider each hydrologic region independently when evaluating the CDF relations. As such, the CDF relations are addressed for each hydrologic region in the section "Description of Peak-Flow Variability and Peak-Flow Informational Needs, and Consideration of Regional Regression Analyses by Hydrologic Region."

Consideration of Regional Regression Analyses in Managing the Crest-Stage Gage Network

An important objective of the CSG network is to provide data for developing RREs for estimating frequencies at ungaged sites in Montana. In providing regional information, the CSG network is vital to collecting peak-flow data on small drainage basins that typically are not addressed by continuous streamflow operations. As such, consideration of regional regression analyses is important in investigating and managing the CSG network.

Selected information concerning RREs for Montana (Sando, R., and others, 2018) is presented in table 6. The mean standard error of prediction (SEP) is an important metric for confidence in RRE results and varies substantially among the hydrologic regions. For example, the 1-percent annual exceedance probability (AEP) RRE for the West hydrologic region has an SEP of 56.0 percent, which is somewhat less than the area-weighted mean SEP for all hydrologic regions in Montana (63.3 percent) (table 6). In contrast, the 1-percent AEP RRE for the East-Central Plains hydrologic region has an SEP of 73.5 percent, which is somewhat higher than the statewide mean.

Diagnostic statistics, including leverage and influence, from regional regression analyses also might be important in evaluating the peak-flow informational value of individual streamgages. Information on streamgages with significant leverage and influence statistics from regional regression

Table 6. Selected information concerning regional regression equations for Montana (Sando, R., and others, 2018).

[*n*, number of streamgages in regression analysis; *SEP*, mean standard error of prediction; Q_{AEP}, peak-flow magnitude, in cubic feet per second, for annual exceedance probability (AEP), in percent (where AEP equals 10, 4, or 1 percent); *CONTDA*, contributing drainage area, in square miles; *PRECIP*, mean annual precipitation, in inches; *FOREST*, percentage of basin that is forest; EL_{5000}, percentage of basin above 5,000 feet elevation; *SLOP*30_30*M*, percentage of basin with slope greater than 30 percent; *ET*0306*MOD*, mean spring (March–June) evapotranspiration, in inches per month; EL_{6000}, percentage of basin above 6,000 feet elevation; --, not applicable]

Hydrologic region (ordered clockwise from northwestern Montana)	Hydrologic region number (fig. 1)	*n*	Explanatory variables in regression analysis	*SEP*, in percent		
				Q_{10}	Q_4	Q_1
West[1]	1	113	*CONTDA*, *PRECIP*, *FOREST*	52.8	53.2	56.0
Northwest[2]	2	32	*CONTDA*	34.4	9.1	13.6
Northwest Foothills[1]	3	31	*CONTDA*, *PRECIP*	56.4	55.2	65.8
Northeast Plains[1]	4	64	*CONTDA*, EL_{5000}	53.1	49.2	54.5
East-Central Plains[1]	5	90	*CONTDA*, *SLOP*30_30*M*, *ET*0306*MOD*	60.9	62.7	73.5
Southeast Plains[1]	6	68	*CONTDA*, *FOREST*, *ET*0306*MOD*	83.4	72.1	71.1
Upper Yellowstone-Central Mountain[1]	7	91	*CONTDA*, EL_{6000}	73.0	68.4	69.0
Southwest[1]	8	48	*CONTDA*, EL_{6000}	72.1	71.3	73.8
Area-weighted mean for Montana	--	--	--	62.6	58.8	63.3

[1]Regression equations were developed using generalized least squares regression analyses.

[2]Regression equations were developed using weighted least squares regression analyses.

analyses (Sando, R., and others, 2018) is presented in table 7. A leverage statistic expresses the distance of the basin characteristics of an individual streamgage from the center of the basin characteristics of all streamgages in the regression analysis. A significant leverage value indicates that a streamgage is unusual in the regression analysis and has basin characteristics that are not well represented. An influence statistic expresses how much the inclusion of an individual streamgage affects the regression predictions. A significant influence value indicates that a streamgage has greater than typical effect on the regression predictions. The leverage and influence statistics vary among the hydrologic regions. For example, for the 1-percent AEP regression for the West hydrologic region, 8.0 percent of the streamgages have significant leverage and 10.6 percent of the streamgages have significant influence; these percentages are similar to significant leverage and influence percentages (8.2 and 10.4 percent, respectively) for all of the streamgages in Montana included in the regional regression analyses (table 7). In contrast, for the 1-percent AEP regression for the Upper Yellowstone-Central Mountain hydrologic region, 11.0 percent of the streamgages have significant leverage and 14.3 percent of the streamgages have significant influence; these percentages are somewhat higher than significant leverage and influence percentages (8.2 and 10.4 percent, respectively) for all of the streamgages in Montana included in the regional regression analyses.

The SEPs of the RREs and the leverage and influence statistics vary considerably among the hydrologic regions, which further supports a need to consider each hydrologic region independently when evaluating the Montana streamgage network. As such, consideration of regional regression analyses for each hydrologic region is included in the section “Description of Peak-Flow Variability and Peak-Flow Informational Needs, and Consideration of Regional Regression Analyses by Hydrologic Region.”

Consideration of regional regression analyses in managing the CSG network is complex and might involve various approaches or a combination of approaches. Various information from the regional regression analyses might assist in identifying needed additional peak-flow information from under-represented hydroclimatic settings that might improve the coverage and accuracy of the RREs. However, additional streamgaging generally would require additional funding and substantial time before adequate data are collected to provide frequency estimates. Establishing new CSGs in targeted hydroclimatic settings would require at least a decade of data collection. In some cases, useful data might be obtained by reactivating discontinued streamgages in targeted hydroclimatic settings, especially for discontinued streamgages with less than 10 years of record that currently are not analyzed for frequencies. The approach of managing the CSG network in relation to regional regression analyses by collecting additional information would attempt to improve the RREs by reducing sampling error. Another approach of managing the CSG network in relation to regional regression analyses might involve attempting to improve the RREs by reducing the model error. Such an approach might involve investigating the streamgages with significant leverage and influence and considering whether to exclude those streamgages from the regional regression analyses. Excluding significant leverage and influence streamgages might reduce the model error but might also reduce the coverage of some hydroclimatic settings. Reducing the coverage of some hydroclimatic settings might result in users of the RREs needing to consider other methods (for example, rainfall and runoff modeling) for estimating frequencies at ungaged sites. Managing the CSG network in relation to regional regression analyses might best be accomplished by a combination of the approaches that attempt to reduce sampling error or model error.

Table 7. Information on streamgages with significant leverage and influence statistics from regional regression analyses (Sando, R., and others, 2018).

[AEP, annual exceedance probability; %, percent; NA, not applicable]

Summary statistic	Information for all streamgages (both continuous streamgages and crest-stage gages)				Information for continuous streamgages				Information for crest-stage gages			
	Information on streamgages with significant leverage	Information on streamgages with significant influence for the percentage AEP regression analyses			Information on streamgages with significant leverage	Information on streamgages with significant influence for the percentage AEP regression analyses			Information on streamgages with significant leverage	Information on streamgages with significant influence for the percentage AEP regression analyses		
		10%	4%	1%		10%	4%	1%		10%	4%	1%
Montana streamgages (all hydrologic regions combined) included in the regional regression analyses (Sando, R., and others, 2018)												
NA	537 streamgages summarized				236 streamgages summarized				301 streamgages summarized			
Number of streamgages with significance	44	49	54	56	19	12	15	15	25	37	39	41
Percentage of streamgages with significance	8.2	9.1	10.1	10.4	8.1	5.1	6.4	6.4	8.3	12.3	13.0	13.6
Active Montana streamgages (all hydrologic regions combined) included in the regional regression analyses (Sando, R., and others, 2018)												
NA	162 streamgages summarized				86 streamgages summarized				76 streamgages summarized			
Number of streamgages with significance	20	19	18	22	12	5	6	8	8	14	12	14
Percentage of streamgages with significance	12.3	11.7	11.1	13.6	14.0	5.8	7.0	9.3	10.5	18.4	15.8	18.4
Streamgages in the West hydrologic region included in the regional regression analyses (Sando, R., and others, 2018)												
NA	113 streamgages summarized				62 streamgages summarized				51 streamgages summarized			
Number of streamgages with significance	9	12	12	12	5	4	3	4	4	8	9	8
Percentage of streamgages with significance	8.0	10.6	10.6	10.6	8.1	6.5	4.8	6.5	7.8	15.7	17.6	15.7
Active streamgages in the West hydrologic region included in the regional regression analyses (Sando, R., and others, 2018)												
NA	29 streamgages summarized				29 streamgages summarized				0 streamgages summarized			
Number of streamgages with significance	4	2	2	3	4	2	2	3	0	0	0	0
Percentage of streamgages with significance	13.8	6.9	6.9	10.3	13.8	6.9	6.9	10.3	0.0	0.0	0.0	0.0
Streamgages in the Northwest hydrologic region included in the regional regression analyses (Sando, R., and others, 2018)												
NA	32 streamgages summarized				26 streamgages summarized				6 streamgages summarized			
Number of streamgages with significance	4	2	4	2	3	1	3	1	4	1	1	1
Percentage of streamgages with significance	12.5	6.3	12.5	6.3	11.5	3.8	11.5	3.8	66.7	16.7	16.7	16.7

Table 7. Information on streamgages with significant leverage and influence statistics from regional regression analyses (Sando, R., and others, 2018).—Continued

[AEP, annual exceedance probability; %, percent; NA, not applicable]

Summary statistic	Information for all streamgages (both continuous streamgages and crest-stage gages)				Information for continuous streamgages				Information for crest-stage gages			
	Information on streamgages with significant leverage	Information on streamgages with significant influence for the percentage AEP regression analyses			Information on streamgages with significant leverage	Information on streamgages with significant influence for the percentage AEP regression analyses			Information on streamgages with significant leverage	Information on streamgages with significant influence for the percentage AEP regression analyses		
		10%	4%	1%		10%	4%	1%		10%	4%	1%
Active streamgages in the Northwest hydrologic region included in the regional regression analyses (Sando, R., and others, 2018)												
NA	8 streamgages summarized				8 streamgages summarized				0 streamgages summarized			
Number of streamgages with significance	4	2	4	2	4	1	3	1	0	0	0	0
Percentage of streamgages with significance	50.0	25.0	50.0	25.0	50.0	12.5	37.5	12.5	0.0	0.0	0.0	0.0
Streamgages in the Northwest Foothills hydrologic region included in the regional regression analyses (Sando, R., and others, 2018)												
NA	31 streamgages summarized				11 streamgages summarized				20 streamgages summarized			
Number of streamgages with significance	3	2	2	3	2	1	1	1	1	1	1	2
Percentage of streamgages with significance	9.7	6.5	6.5	9.7	18.2	9.1	9.1	9.1	5.0	5.0	5.0	10.0
Active streamgages in the Northwest Foothills hydrologic region included in the regional regression analyses (Sando, R., and others, 2018)												
NA	9 streamgages summarized				5 streamgages summarized				4 streamgages summarized			
Number of streamgages with significance	3	0	0	1	2	0	0	0	1	0	0	1
Percentage of streamgages with significance	33.3	0.0	0.0	11.1	40.0	0.0	0.0	0.0	25.0	0.0	0.0	25.0
Streamgages in the Northeast Plains hydrologic region included in the regional regression analyses (Sando, R., and others, 2018)												
NA	64 streamgages summarized				33 streamgages summarized				31 streamgages summarized			
Number of streamgages with significance	6	8	7	7	5	2	1	2	1	6	6	5
Percentage of streamgages with significance	9.4	12.5	10.9	10.9	15.2	6.1	3.0	6.1	3.2	19.4	19.4	16.1
Active streamgages in the Northeast Plains hydrologic region included in the regional regression analyses (Sando, R., and others, 2018)												
NA	21 streamgages summarized				8 streamgages summarized				13 streamgages summarized			
Number of streamgages with significance	3	5	5	6	2	1	1	2	1	4	4	4
Percentage of streamgages with significance	14.3	23.8	23.8	28.6	25.0	12.5	12.5	25.0	7.7	30.8	30.8	30.8

Table 7. Information on streamgages with significant leverage and influence statistics from regional regression analyses (Sando, R., and others, 2018).—Continued

[AEP, annual exceedance probability; %, percent; NA, not applicable]

Summary statistic	Information for all streamgages (both continuous streamgages and crest-stage gages)				Information for continuous streamgages				Information for crest-stage gages			
	Information on streamgages with significant leverage	Information on streamgages with significant influence for the percentage AEP regression analyses			Information on streamgages with significant leverage	Information on streamgages with significant influence for the percentage AEP regression analyses			Information on streamgages with significant leverage	Information on streamgages with significant influence for the percentage AEP regression analyses		
		10%	4%	1%		10%	4%	1%		10%	4%	1%
Streamgages in the East-Central Plains hydrologic region included in the regional regression analyses (Sando, R., and others, 2018)												
NA	90 streamgages summarized				16 streamgages summarized				74 streamgages summarized			
Number of streamgages with significance	7	6	7	9	2	1	2	2	5	5	5	7
Percentage of streamgages with significance	7.8	6.7	7.8	10.0	12.5	6.3	12.5	12.5	6.8	6.8	6.8	9.5
Active streamgages in the East-Central Plains hydrologic region included in the regional regression analyses (Sando, R., and others, 2018)												
NA	27 streamgages summarized				2 streamgages summarized				25 streamgages summarized			
Number of streamgages with significance	1	2	1	2	0	0	0	0	1	2	1	2
Percentage of streamgages with significance	3.7	7.4	3.7	7.4	0.0	0.0	0.0	0.0	4.0	8.0	4.0	8.0
Streamgages in the Southeast Plains hydrologic region included in the regional regression analyses (Sando, R., and others, 2018)												
NA	68 streamgages summarized				14 streamgages summarized				54 streamgages summarized			
Number of streamgages with significance	4	8	10	10	1	2	5	4	3	6	5	6
Percentage of streamgages with significance	5.9	11.8	14.7	14.7	7.1	14.3	35.7	28.6	5.6	11.1	9.3	11.1
Active streamgages in the Southeast Plains hydrologic region included in the regional regression analyses (Sando, R., and others, 2018)												
NA	27 streamgages summarized				5 streamgages summarized				22 streamgages summarized			
Number of streamgages with significance	3	6	5	5	1	2	2	2	2	4	3	3
Percentage of streamgages with significance	11.1	22.2	18.5	18.5	20.0	40.0	40.0	40.0	9.1	18.2	13.6	13.6
Streamgages in the Upper Yellowstone-Central Mountain hydrologic region included in the regional regression analyses (Sando, R., and others, 2018)												
NA	91 streamgages summarized				50 streamgages summarized				41 streamgages summarized			
Number of streamgages with significance	10	12	13	13	3	2	3	2	7	10	10	11
Percentage of streamgages with significance	11.0	13.2	14.3	14.3	6.0	4.0	6.0	4.0	17.1	24.4	24.4	26.8

Table 7. Information on streamgages with significant leverage and influence statistics from regional regression analyses (Sando, R., and others, 2018).—Continued

[AEP, annual exceedance probability; %, percent; NA, not applicable]

Summary statistic	Information for all streamgages (both continuous streamgages and crest-stage gages)				Information for continuous streamgages				Information for crest-stage gages			
	Information on streamgages with significant leverage	Information on streamgages with significant influence for the percentage AEP regression analyses			Information on streamgages with significant leverage	Information on streamgages with significant influence for the percentage AEP regression analyses			Information on streamgages with significant leverage	Information on streamgages with significant influence for the percentage AEP regression analyses		
		10%	4%	1%		10%	4%	1%		10%	4%	1%
Active streamgages in the Upper Yellowstone-Central Mountain hydrologic region included in the regional regression analyses (Sando, R., and others, 2018)												
NA	23 streamgages summarized				16 streamgages summarized				7 streamgages summarized			
Number of streamgages with significance	5	3	4	4	2	0	1	1	3	3	3	3
Percentage of streamgages with significance	21.7	13.0	17.4	17.4	12.5	0.0	6.3	6.3	42.9	42.9	42.9	42.9
Streamgages in the Southwest hydrologic region included in the regional regression analyses (Sando, R., and others, 2018)												
NA	48 streamgages summarized				24 streamgages summarized				24 streamgages summarized			
Number of streamgages with significance	5	1	3	2	1	0	0	0	4	1	3	2
Percentage of streamgages with significance	10.4	2.1	6.3	4.2	4.2	0.0	0.0	0.0	16.7	4.2	12.5	8.3
Active streamgages in the Southwest hydrologic region included in the regional regression analyses (Sando, R., and others, 2018)												
NA	18 streamgages summarized				13 streamgages summarized				5 streamgages summarized			
Number of streamgages with significance	1	1	1	1	1	0	0	0	0	1	1	1
Percentage of streamgages with significance	5.6	5.6	5.6	5.6	7.7	0.0	0.0	0.0	0.0	20.0	20.0	20.0

Description of Peak-Flow Variability and Peak-Flow Informational Needs, and Consideration of Regional Regression Analyses by Hydrologic Region

In the sections "Peak-Flow Variability in Montana," "General Characterization of Peak-Flow Informational Needs in Montana," and "Consideration of Regional Regression Analyses in Managing the Crest-Stage Gage Network," various datasets were investigated on a statewide basis with a primary conclusion that individual hydrologic regions substantially differ from statewide patterns and among each other. The following sections discuss peak-flow variability and informational needs, and regional regression analyses for each hydrologic region. In the discussion, comparisons are made between the characteristics for each hydrologic region and statewide patterns. The comparisons might be useful in identifying hydroclimatic settings needing more and less representation in the statewide CSG network.

In support of some of the discussion for the hydrologic regions, table 8 presents statistical summaries of precipitation characteristics for the drainage basins of unregulated streamgages in the hydrologic regions. Also, tables 9–11 presents statistical summaries of selected streamgage characteristics and drainage-basin characteristics for streamgages included in regional regression analyses (Sando, R., and others, 2018).

Peak-Flow Variability, Peak-Flow Informational Needs, and Consideration of Regional Regression Analyses in the West Hydrologic Region

The West hydrologic region has an area of 21,371 mi^2 (table 1), which ranks fourth largest among the eight hydrologic regions. Level III ecoregions (table 2) represented in the West hydrologic region include the Canadian Rockies (9.5 percent), Idaho Batholith (8.2 percent), Middle Rockies (29.9 percent), and Northern Rockies (52.5 percent). The 2,380 road and stream intersections in the West hydrologic region (tables 4 and 5) represent a density of 0.111 road and stream intersection per mi^2, which ranks second among the hydrologic regions. The 141 streamgages (both regulated and unregulated; tables 4 and 5) represent an areal density of 0.00660 streamgage per mi^2 (ranking first among hydrologic regions) and a density of 0.05924 streamgage per road and stream intersection (ranking fourth among hydrologic regions).

Relations between *PFVI* and contributing drainage area, mean basin elevation, mean annual precipitation, and years of peak-flow records for 133 unregulated streamgages in the West hydrologic region (table 3) are presented in figure 6. For the 133 unregulated streamgages, *PFVI* generally monotonically decreases with increasing drainage area (fig. 6*A*) with generally small and consistent variability about the LOWESS line. Intuitively, highly variable small-scale hydroclimatic processes are integrated with increasing drainage area such that variability in many hydrologic characteristics is reduced. *PFVI* also decreases with increasing elevation (fig. 6*B*), precipitation (fig. 6*C*), and years of record (fig. 6*D*). For the relations between *PFVI* and drainage area (fig. 6*A*), elevation (fig. 6*B*), and years of record (fig. 6*D*), the LOWESS lines for the West hydrologic region are consistently below the LOWESS lines for all unregulated streamgages in Montana.

Relations between contributing drainage area and mean basin elevation, mean annual precipitation, and years of peak-flow records for the unregulated streamgages are presented in figure 7. Streamgages with greater than about 50 years of record are predominantly located on streams with contributing drainage areas greater than about 100 mi^2 (fig. 7*C*), which likely strongly contributes to the *PFVI* and years of record relations (fig. 6*D*).

The median *PFVI* value for streamgages in the West hydrologic region (7.63, table 3) is substantially less than the median for all unregulated streamgages in Montana (18.26, table 3) and ranks as the seventh largest median *PFVI* among the eight hydrologic regions. A major factor contributing to low peak-flow variability in the West hydrologic region might be the strong dominance of snowmelt runoff in the annual hydrograph of the streamgages. For unregulated streamgages in the West hydrologic region, fall and winter (October–February) precipitation accounts for about 40 percent of annual precipitation (table 8), which can result in large accumulated snowpacks (Sando and McCarthy, 2018) that contribute to streamflows during the typical snowmelt runoff period of May through mid-July. May–June precipitation accounts for about 24.4 percent of annual precipitation (table 8), which ranks eighth among the hydrologic regions, and July–August precipitation accounts for 13.3 percent of annual precipitation, which ranks seventh among the eight hydrologic regions. In the West hydrologic region, annual peak flows predominantly are in May and June (fig. 2 of Sando, R., and others, 2018). Dominance of snowmelt in the annual hydrograph tends to provide temporal integration of a substantial part of the annual precipitation inputs and contributes to the low *PFVI*s for streamgages in the West hydrologic region.

Although streamgages in the West hydrologic region have less than typical *PFVI*s, about 12.5 percent of the streamgages are considered to have mixed-population characteristics (table 1) that result in a small number of unusually large peak flows that are substantially larger than the main body of peak flows. Typically, the unusually large peak-flow events result from extremely intense rainfall events in May and June that happen near the peak of snowmelt runoff. Mixed-population peak-flow datasets often are in streamgages with drainage basins along or near the Continental Divide. In other areas of the West hydrologic region, some mixed-population peak-flow

Table 8. Statistical summaries of precipitation characteristics for the drainage basins of unregulated streamgages in the hydrologic regions in Montana.

[*n*, number of unregulated streamgages]

Hydrologic region (ordered clockwise from northwestern Montana)	Hydrologic region number (fig. 1)	*n*	Mean percentage of annual precipitation that occurs in each month or selected groups of months for the drainage basins of unregulated streamgages																Mean (1981–2010) annual precipitation, in inches[1]
			Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.–Feb.	Feb.–Apr.	May–June	July–Aug.	
West	1	133	7.1	9.7	8.8	8.2	6.4	7.1	7.5	11.5	12.9	6.9	6.4	7.3	40.3	21.1	24.4	13.3	19.3
Northwest	2	44	6.8	9.0	7.9	8.0	6.1	7.7	7.8	11.7	13.6	6.8	6.3	8.2	37.8	21.6	25.4	13.1	29.0
Northwest Foothills	3	40	5.5	3.6	3.0	2.8	2.5	5.4	8.8	16.3	20.4	10.5	10.6	10.6	17.5	16.6	36.7	21.1	12.4
Northeast Plains	4	76	5.9	3.9	3.2	3.4	2.2	4.3	7.0	16.3	20.8	14.1	9.4	9.4	18.7	13.6	37.1	23.5	12.9
East-Central Plains	5	102	7.1	3.2	2.8	2.7	1.9	4.5	8.7	17.0	19.4	14.8	9.1	8.9	17.7	15.1	36.4	23.9	12.6
Southeast Plains	6	74	8.3	3.9	3.0	2.9	2.5	5.8	10.2	17.0	17.7	12.4	7.4	8.9	20.7	18.6	34.6	19.8	13.6
Upper Yellowstone-Central Mountain	7	108	7.9	4.8	4.2	3.7	3.5	6.5	10.5	16.8	16.1	9.9	7.6	8.5	24.1	20.5	32.9	17.5	16.4
Southwest	8	67	7.0	5.3	4.7	4.2	3.7	6.0	9.7	16.0	16.6	9.8	8.8	8.3	24.8	19.4	32.6	18.6	14.5

[1]Precipitation variables determined from geospatial analysis of climatic datasets obtained from Parameter-elevation Regression on Independent Slopes Model (PRISM) data (PRISM Climate Group, 2004).

Table 9. Statistical summaries of selected streamgage characteristics and drainage-basin characteristics for all streamgages (both continuous streamgages and crest-stage gages) included in the Montana regional regression analyses (Sando, R., and others, 2018).

[No., number; *PFVI*, peak-flow variability index calculated by 100 times the standard deviation of the peak flows (base-10 logarithms) divided by the mean of the peak flows (base-10 logarithms); the standard deviations and means of the peak flows were calculated using Bulletin 17B procedures (U.S. Interagency Advisory Council on Water Data, 1982) for fitting the log-Pearson III distribution. *CONTDA*, contributing drainage area, in square miles; EL_{5000}, percentage of basin above 5,000 feet elevation; EL_{6000}, percentage of basin above 6,000 feet elevation; *SLOP*30_30*M*, percentage of basin with slopes greater than or equal to 30 percent; *PRECIP*, mean annual precipitation, in inches; *ET*0306*MOD*, spring mean monthly evapotranspiration, in inches per month; *FOREST*, Percent of basin in forest]

Summary statistic	Statistical summaries for all streamgages (both continuous streamgages and crest-stage gages)								
	Streamgage characteristics		Basin and climatic used as explanatory variables in regional regression equations						
	No.	*PFVI*	*CONTDA*	EL_{5000}	EL_{6000}	*SLOP*30_30*M*	*PRECIP*	*ET*0306*MOD*	*FOREST*
Summary statistics for streamgages in Montana									
537 streamgages summarized									
10th percentile[1]	12	5.18	1.38	0.00	0.00	0.00	12.72	1.04	0.00
Median	24	21.33	22.60	14.26	0.00	10.59	17.70	1.43	19.07
90th percentile[1]	56	71.88	528.60	100.00	79.46	66.37	39.94	1.79	84.96
Summary statistics for active streamgages in Montana									
162 streamgages summarized									
10th percentile[1]	31	4.94	1.40	0.00	0.00	0.00	12.94	1.02	0.00
Median	44	19.82	38.85	11.18	0.00	10.10	17.68	1.41	16.91
90th percentile[1]	80	85.99	1,102.20	100.00	90.51	52.95	35.46	1.74	78.90
Summary statistics for streamgages in the West hydrologic region									
113 streamgages summarized									
10th percentile[1]	10	4.04	3.76	19.77	0.50	25.71	21.62	1.60	55.42
Median	20	8.01	28.90	56.90	24.15	55.91	33.04	1.73	80.08
90th percentile[1]	57	24.35	576.40	94.57	70.34	80.01	50.22	1.89	92.85
Summary statistics for active streamgages in the West hydrologic region									
29 streamgages summarized									
10th percentile[1]	19	4.63	50.00	27.63	3.88	24.93	19.44	1.59	47.99
Median	44	6.57	419.00	80.00	41.50	42.84	29.56	1.72	72.36
90th percentile[1]	80	11.06	1,010.80	98.13	78.42	73.88	44.61	1.83	92.41
Summary statistics for streamgages in the Northwest hydrologic region									
32 streamgages summarized									
10th percentile[1]	13	3.22	16.92	52.85	11.63	5.46	23.39	1.60	28.26
Median	27	7.08	102.55	77.92	41.43	60.33	46.69	1.71	60.75
90th percentile[1]	76	20.77	599.00	97.95	67.07	74.68	68.01	1.85	83.20
Summary statistics for active streamgages in the Northwest hydrologic region									
8 streamgages summarized									
10th percentile[1]	33	2.94	51.92	49.42	21.74	32.02	31.74	1.60	26.88
Median	64	4.63	206.00	78.34	49.41	59.09	41.57	1.73	69.44
90th percentile[1]	98	14.43	1,278.10	98.21	69.80	73.58	59.89	1.82	78.45
Summary statistics for streamgages in the Northwest Foothills hydrologic region									
31 streamgages summarized									
10th percentile[1]	15	14.61	0.72	0.00	0.00	0.00	11.94	1.08	0.00
Median	18	38.87	14.40	0.00	0.00	0.28	13.20	1.22	0.00
90th percentile[1]	62	89.31	405.00	27.82	11.47	11.48	20.55	1.51	10.75

Table 9. Statistical summaries of selected streamgage characteristics and drainage-basin characteristics for all streamgages (both continuous streamgages and crest-stage gages) included in the Montana regional regression analyses (Sando, R., and others, 2018).—Continued

[No., number; *PFVI*, peak-flow variability index calculated by 100 times the standard deviation of the peak flows (base-10 logarithms) divided by the mean of the peak flows (base-10 logarithms); the standard deviations and means of the peak flows were calculated using Bulletin 17B procedures (U.S. Interagency Advisory Council on Water Data, 1982) for fitting the log-Pearson III distribution. *CONTDA*, contributing drainage area, in square miles; EL_{5000}, percentage of basin above 5,000 feet elevation; EL_{6000}, percentage of basin above 6,000 feet elevation; *SLOP*30_30*M*, percentage of basin with slopes greater than or equal to 30 percent; *PRECIP*, mean annual precipitation, in inches; *ET*0306*MOD*, spring mean monthly evapotranspiration, in inches per month; *FOREST*, Percent of basin in forest]

Summary statistic	Statistical summaries for all streamgages (both continuous streamgages and crest-stage gages)								
	Streamgage characteristics		Basin and climatic used as explanatory variables in regional regression equations						
	No.	*PFVI*	*CONTDA*	EL_{5000}	EL_{6000}	*SLOP*30_30*M*	*PRECIP*	*ET*0306*MOD*	*FOREST*
Summary statistics for active streamgages in the Northwest Foothills hydrologic region									
9 streamgages summarized									
10th percentile[1]	43	9.91	4.66	0.00	0.00	0.00	12.50	1.26	0.00
Median	57	15.61	256.00	0.00	0.00	0.38	16.66	1.35	0.01
90th percentile[1]	81	56.25	1,073.20	34.64	14.71	17.47	23.19	1.51	17.15
Summary statistics for streamgages in the Northeast Plains hydrologic region									
64 streamgages summarized									
10th percentile[1]	11	18.14	1.64	0.00	0.00	0.00	12.21	1.05	0.00
Median	34	33.84	14.15	0.00	0.00	0.01	13.70	1.19	0.03
90th percentile[1]	50	109.80	443.80	6.41	0.00	15.95	18.85	1.46	11.90
Summary statistics for active streamgages in the Northeast Plains hydrologic region									
21 streamgages summarized									
10th percentile[1]	34	17.81	1.62	0.00	0.00	0.00	11.64	1.05	0.00
Median	43	36.32	3.76	0.00	0.00	0.15	13.80	1.18	0.00
90th percentile[1]	50	129.45	1,199.00	5.79	0.00	14.45	18.76	1.42	10.23
Summary statistics for streamgages in the East-Central Plains hydrologic region									
90 streamgages summarized									
10th percentile[1]	15	16.51	0.76	0.00	0.00	0.00	12.38	0.95	0.00
Median	22	38.20	4.26	0.00	0.00	0.05	13.12	1.06	0.02
90th percentile[1]	51	72.31	436.70	0.00	0.00	4.33	14.48	1.21	12.75
Summary statistics for active streamgages in the East-Central Plains hydrologic region									
27 streamgages summarized									
10th percentile[1]	42	22.34	0.88	0.00	0.00	0.00	12.48	0.95	0.00
Median	43	42.75	2.30	0.00	0.00	0.00	13.34	1.04	0.00
90th percentile[1]	54	89.80	9.49	0.00	0.00	2.40	14.57	1.13	5.69
Summary statistics for streamgages in the Southeast Plains hydrologic region									
68 streamgages summarized									
10th percentile[1]	15	13.84	0.81	0.00	0.00	0.00	13.84	1.03	0.00
Median	30	37.29	5.78	0.00	0.00	1.46	14.83	1.21	6.74
90th percentile[1]	46	98.25	672.90	0.00	0.00	13.44	16.55	1.38	26.82
Summary statistics for active streamgages in the Southeast Plains hydrologic region									
27 streamgages summarized									
10th percentile[1]	35	23.97	0.69	0.00	0.00	0.00	13.57	1.01	0.00
Median	44	47.77	3.64	0.00	0.00	2.61	14.35	1.16	9.72
90th percentile[1]	54	100.28	558.60	0.00	0.00	13.63	15.93	1.37	25.15

Table 9. Statistical summaries of selected streamgage characteristics and drainage-basin characteristics for all streamgages (both continuous streamgages and crest-stage gages) included in the Montana regional regression analyses (Sando, R., and others, 2018).—Continued

[No., number; *PFVI*, peak-flow variability index calculated by 100 times the standard deviation of the peak flows (base-10 logarithms) divided by the mean of the peak flows (base-10 logarithms); the standard deviations and means of the peak flows were calculated using Bulletin 17B procedures (U.S. Interagency Advisory Council on Water Data, 1982) for fitting the log-Pearson III distribution. *CONTDA*, contributing drainage area, in square miles; EL_{5000}, percentage of basin above 5,000 feet elevation; EL_{6000}, percentage of basin above 6,000 feet elevation; *SLOP30_30M*, percentage of basin with slopes greater than or equal to 30 percent; *PRECIP*, mean annual precipitation, in inches; *ET0306MOD*, spring mean monthly evapotranspiration, in inches per month; *FOREST*, Percent of basin in forest]

Summary statistic	Statistical summaries for all streamgages (both continuous streamgages and crest-stage gages)								
	Streamgage characteristics		Basin and climatic used as explanatory variables in regional regression equations						
	No.	*PFVI*	*CONTDA*	EL_{5000}	EL_{6000}	*SLOP30_30M*	*PRECIP*	*ET0306MOD*	*FOREST*
Summary statistics for streamgages in the Upper Yellowstone-Central Mountain hydrologic region									
91 streamgages summarized									
10th percentile[1]	13	5.20	2.38	0.00	0.00	0.56	16.18	1.32	0.02
Median	28	16.22	49.50	77.10	26.75	17.16	20.62	1.64	28.09
90th percentile[1]	68	62.17	430.00	100.00	96.94	53.28	32.93	1.79	77.61
Summary statistics for active streamgages in the Upper Yellowstone-Central Mountain hydrologic region									
23 streamgages summarized									
10th percentile[1]	41	3.35	3.07	6.69	0.00	0.59	17.17	1.40	0.07
Median	65	8.00	182.00	80.23	45.42	21.56	23.78	1.64	28.09
90th percentile[1]	88	54.08	1,529.20	100.00	98.53	53.69	33.32	1.68	76.08
Summary statistics for streamgages in the Southwest hydrologic region									
48 streamgages summarized									
10th percentile[1]	15	5.67	4.36	56.60	21.96	11.85	16.31	1.31	15.45
Median	24	9.33	43.50	100.00	88.12	33.48	21.81	1.47	59.32
90th percentile[1]	77	73.83	404.20	100.00	100.00	50.92	31.31	1.63	86.57
Summary statistics for active streamgages in the Southwest hydrologic region									
18 streamgages summarized									
10th percentile[1]	20	5.67	16.40	73.46	34.09	13.75	18.88	1.44	33.93
Median	49	8.09	111.85	100.00	92.68	33.48	23.43	1.48	57.95
90th percentile[1]	91	34.95	792.70	100.00	100.00	47.92	35.37	1.64	88.63

[1]Nonexceedance percentile.

datasets result from ice jams and associated releases, and unusual rapid snowmelt events during winter, sometimes in association with rainfall. The large peak-flow variability of mixed-population peak-flow datasets might not be well represented in the *PFVI* values because the unusually large peak-flow events are infrequent and might not substantially affect the calculation of the *PFVI* values. Nearly all (11 out of 12) of the mixed-population streamgages in the West hydrologic region that were included in the regional regression analysis (Sando, R., and others, 2018) had positive residuals for the 1-percent AEP regression; however, none of those mixed-population streamgages had significant influence. Among the candidate explanatory variables included in the regional regression analyses, there are no variables that represent spatial variability in precipitation intensity (such as indices of the 100-year 24-hour precipitation; for example, U.S. Weather Bureau, 1961). Inclusion of variables that represent spatial variability in precipitation intensity might help address some mixed-population issues and improve potential future regional regression analyses in the West hydrologic region.

The CDFs of selected basin characteristics (drainage area, mean basin elevation, and mean annual precipitation) for the road and stream intersections and for the streamgages in the West hydrologic region are shown in figure 8. With respect to drainage area, the CDF of road and stream intersections for the West hydrologic region generally is similar to the CDF of road and stream intersections for all of Montana (fig. 8*A*), but with smaller representation of drainage areas between about 1–7 mi^2. In the West hydrologic region, the CDF of streamgages diverges from the CDF of road and stream intersections in the range of drainage areas less than about 5 mi^2, indicating underrepresentation of those small drainage areas.

Mean basin elevation for road and stream intersections in the West hydrologic region ranges from 2,236 to 8,006 feet (ft; Dutton and others, 2021) with a median of 4,741 ft (table 4), which generally are similar to the range (1,951–9,974 ft; Dutton and others, 2021) and median (4,173 ft; table 4) for all of Montana . However, the West hydrologic region has a somewhat lower proportion of road and stream intersections less than about 4,000 ft than Montana as a whole (fig. 8*B*). With respect to mean basin elevation, the pattern of the streamgage CDF reasonably represents the road and stream intersections CDF but with underrepresentation at elevations less than about 4,000 ft. Although about 20 percent of the road and stream intersections have mean basin elevations less than about 4,000 ft, only one streamgage falls within that range.

The West hydrologic region is somewhat wetter than Montana as a whole. Mean annual precipitation for road and stream intersections in the West hydrologic region ranges from 10.4 to 75.1 inches (Dutton and others, 2021) with a median of 23.4 inches (table 5). The range for the West hydrologic region is somewhat smaller than for all of Montana (8.4–91.3 inches; Dutton and others, 2021) and the median for the West hydrologic region is larger than for all of Montana (15.7 inches; table 5). The West hydrologic region has a somewhat lower proportion of road and stream intersections with mean annual precipitation less than about 25 inches than Montana as a whole (fig. 8*C*). With respect to mean annual precipitation, the pattern of the streamgage CDF reasonably represents the road and stream intersections CDF, but the CDF of streamgages diverges from the CDF of road and stream intersections in the range of mean annual precipitation less than about 25 inches, indicating underrepresentation of drier parts of the West hydrologic region.

The explanatory variables for the West hydrologic region RREs are contributing drainage area (*CONTDA*), mean annual precipitation (*PRECIP*), and percentage of basin that is forest (*FOREST*; table 6). The 1-percent AEP RRE for the West hydrologic region has an SEP of 56.0 percent, which is somewhat less than the area-weighted mean SEP for all hydrologic regions in Montana (63.3 percent; table 6). For the 1-percent AEP regression for the West hydrologic region, 8.0 percent of the streamgages have significant leverage and 10.6 percent of the streamgages have significant influence (table 7); these percentages are similar to significant leverage and influence percentages (8.2 and 10.4 percent, respectively; table 7) for all of the streamgages in Montana used in the regional regression analyses.

Information on streamgages in the West hydrologic region with significant leverage and influence is presented in table 12. All of the nine significant leverage streamgages have low *FOREST* values (nonexceedance percentiles less than about 10 percent), generally in association with unusually low or high *PRECIP* values and (or) unusually low or high *CONTDA* values. Most (six out of nine) of the significant leverage streamgages are in a somewhat small part of the West hydrologic region in the Clark Fork basin upstream from Drummond, Montana. Five of the significant leverage streamgages also have significant influence. The 14 streamgages with significant influence vary with respect to the residuals for the 1-percent AEP RRE; eight of the streamgages have negative residuals, and six have positive residuals. All of the five streamgages with significant leverage and significant influence are in the upper Clark Fork Basin. Two of the streamgages are on main-stem channels with generally large drainage basins and have negative residuals. Three of the streamgages are on tributary channels with generally small drainage basins and have positive residuals.

In general, the streamgage network in the West hydrologic region is considered to provide reasonable representation of the hydroclimatic settings of that hydrologic region. The RREs of the West hydrologic region are considered to be reasonably reliable. Possible shortcomings of the streamgage network in the West hydrologic region include no active CSGs, and possible underrepresentation of basins with drainage area less than about 5 mi^2, mean elevation less than about 4,000 ft, and (or) mean annual precipitation less than about 25 inches. The lack of active CSGs might contribute to poor understanding of effects of future climatic variability on small drainage basins in the West hydrologic region. Future improvements to the streamgage network in the West hydrologic region might include establishing new CSGs or reactivating discontinued streamgages as CSGs on basins with the underrepresented characteristics. Information on discontinued streamgages in the West hydrologic region that might be candidates for reactivation to improve the streamgage network is presented in table 13.

Peak-Flow Variability, Peak-Flow Informational Needs, and Consideration of Regional Regression Analyses in the Northwest Hydrologic Region

The Northwest hydrologic region has an area of 7,938 mi^2 (table 1), which ranks eighth largest among the eight hydrologic regions. Level III ecoregions (table 2) represented in the Northwest hydrologic region include the Canadian Rockies (66.3 percent), Middle Rockies (11.1 percent), and Northwestern Glaciated Plains (22.6 percent). The 356 road and stream intersections in the Northwest hydrologic region (tables 4 and 5) represent a density of 0.045 road and stream intersection per mi^2, which ranks eighth among the hydrologic regions. The 49 streamgages (both regulated and unregulated; tables 4 and 5) represent an areal density of 0.00617 streamgage per mi^2 (ranking second among hydrologic regions) and a density of 0.13764 streamgage per road and stream intersection (ranking first among hydrologic regions).

Relations between *PFVI* and contributing drainage area, mean basin elevation, mean annual precipitation, and years of peak-flow records for 44 unregulated streamgages in the Northwest hydrologic region (table 3) are presented in figure 9. In general, the small number of unregulated streamgages in the

Table 10. Statistical summaries of selected streamgage characteristics and drainage-basin characteristics for continuous streamgages included in the Montana regional regression analyses (Sando, R., and others, 2018).

[*PFVI*, peak-flow variability index calculated by 100 times the standard deviation of the peak flows (base-10 logarithms) divided by the mean of the peak flows (base-10 logarithms); the standard deviations and means of the peak flows were calculated using Bulletin 17B procedures (U.S. Interagency Advisory Council on Water Data, 1982) for fitting the log-Pearson III distribution. *CONTDA*, contributing drainage area, in square miles; EL_{5000}, percentage of basin above 5,000 feet elevation; EL_{6000}, percentage of basin above 6,000 feet elevation; *SLOP*30_30*M*, percentage of basin with slopes greater than or equal to 30 percent; *PRECIP*, mean annual precipitation, in inches; *ET*0306*MOD*, spring mean monthly evapotranspiration, in inches per month; *FOREST*, percentage of basin in forest]

Summary statistic	Statistical summaries for continuous streamgages								
	Streamgage characteristics		Basin and climatic used as explanatory variables in regional regression equations						
	No.	*PFVI*	*CONTDA*	EL_{5000}	EL_{6000}	*SLOP*30_30*M*	*PRECIP*	*ET*0306*MOD*	*FOREST*
Summary statistics for continuous streamgages in Montana									
236 continuous streamgages summarized									
10th percentile[1]	11	3.90	26.65	0.00	0.00	0.15	13.56	1.15	0.13
Median	27	9.36	172.50	59.78	28.12	28.39	23.21	1.61	47.89
90th percentile[1]	78	28.50	1,102.50	100.00	92.10	68.32	46.91	1.79	85.23
Summary statistics for active continuous streamgages in Montana									
86 continuous streamgages summarized									
10th percentile[1]	24	3.74	59.20	0.00	0.00	2.04	15.04	1.28	3.24
Median	58	7.75	409.50	76.78	39.81	31.13	23.94	1.62	52.48
90th percentile[1]	87	19.82	1,459.50	100.00	94.84	66.41	40.56	1.78	84.18
Summary statistics for continuous streamgages in the West hydrologic region									
62 continuous streamgages summarized									
10th percentile[1]	10	3.73	19.73	28.00	4.03	25.94	21.30	1.61	55.41
Median	24	6.58	175.00	69.37	38.07	49.43	32.64	1.73	76.48
90th percentile[1]	77	11.85	884.30	97.70	77.29	77.88	50.29	1.86	90.31
Summary statistics for active continuous streamgages in the West hydrologic region									
29 continuous streamgages summarized									
10th percentile[1]	19	4.63	50.00	27.63	3.88	24.93	19.44	1.59	47.99
Median	44	6.57	419.00	80.00	41.50	42.84	29.56	1.72	72.36
90th percentile[1]	80	11.06	1,010.80	98.13	78.42	73.88	44.61	1.83	92.41
Summary statistics for continuous streamgages in the Northwest hydrologic region									
26 continuous streamgages summarized									
10th percentile[1]	13	3.01	29.55	55.83	19.19	22.43	26.86	1.58	30.93
Median	29	5.28	122.00	77.92	46.67	64.19	48.38	1.70	61.15
90th percentile[1]	78	13.36	867.00	97.69	67.94	73.99	68.82	1.88	82.82
Summary statistics for active continuous streamgages in the Northwest hydrologic region									
8 continuous streamgages summarized									
10th percentile[1]	33	2.94	51.92	49.42	21.74	32.02	31.74	1.60	26.88
Median	64	4.63	206.00	78.34	49.41	59.09	41.57	1.73	69.44
90th percentile[1]	98	14.43	1,278.10	98.21	69.80	73.58	59.89	1.82	78.45
Summary statistics for continuous streamgages in the Northwest Foothills hydrologic region									
11 continuous streamgages summarized									
10th percentile[1]	11	9.91	66.10	0.00	0.00	0.03	12.40	1.14	0.00
Median	26	14.82	322.00	18.03	2.97	3.26	18.52	1.40	9.36
90th percentile[1]	80	30.12	1,032.00	29.65	15.46	16.39	23.15	1.52	20.00

Table 10. Statistical summaries of selected streamgage characteristics and drainage-basin characteristics for continuous streamgages included in the Montana regional regression analyses (Sando, R., and others, 2018).—Continued

[*PFVI*, peak-flow variability index calculated by 100 times the standard deviation of the peak flows (base-10 logarithms) divided by the mean of the peak flows (base-10 logarithms); the standard deviations and means of the peak flows were calculated using Bulletin 17B procedures (U.S. Interagency Advisory Council on Water Data, 1982) for fitting the log-Pearson III distribution. *CONTDA*, contributing drainage area, in square miles; EL_{5000}, percentage of basin above 5,000 feet elevation; EL_{6000}, percentage of basin above 6,000 feet elevation; *SLOP*30_30*M*, percentage of basin with slopes greater than or equal to 30 percent; *PRECIP*, mean annual precipitation, in inches; *ET*0306*MOD*, spring mean monthly evapotranspiration, in inches per month; *FOREST*, percentage of basin in forest]

Summary statistic	Statistical summaries for continuous streamgages								
	Streamgage characteristics		Basin and climatic used as explanatory variables in regional regression equations						
	No.	*PFVI*	*CONTDA*	EL_{5000}	EL_{6000}	*SLOP*30_30*M*	*PRECIP*	*ET*0306*MOD*	*FOREST*
Summary statistics for active continuous streamgages in the Northwest Foothills hydrologic region									
5 continuous streamgages summarized									
10th percentile[1]	54	9.90	282.40	4.03	0.84	0.55	14.64	1.37	1.78
Median	67	10.64	405.00	18.03	2.97	3.26	18.52	1.40	10.63
90th percentile[1]	83	15.30	1,155.60	44.64	21.18	29.44	23.27	1.52	29.96
Summary statistics for continuous streamgages in the Northeast Plains hydrologic region									
33 continuous streamgages summarized									
10th percentile[1]	10	14.26	8.52	0.00	0.00	0.00	12.50	1.05	0.00
Median	24	26.74	145.00	0.00	0.00	0.15	14.13	1.21	0.23
90th percentile[1]	53	47.29	1,150.20	7.31	0.03	37.44	19.09	1.53	27.11
Summary statistics for active continuous streamgages in the Northeast Plains hydrologic region									
8 continuous streamgages summarized									
10th percentile[1]	28	14.77	199.40	0.00	0.00	0.11	13.45	1.12	0.22
Median	44	18.56	656.50	0.02	0.00	0.83	14.55	1.27	1.96
90th percentile[1]	75	37.04	1,851.70	12.75	4.32	15.09	18.80	1.49	13.60
Summary statistics for continuous streamgages in the East-Central Plains hydrologic region									
16 continuous streamgages summarized									
10th percentile[1]	11	14.17	117.00	0.00	0.00	0.08	12.32	1.02	0.01
Median	19	20.11	327.50	0.00	0.00	0.40	12.86	1.12	0.45
90th percentile[1]	57	39.88	1,353.00	10.02	2.42	6.57	16.34	1.27	31.00
Summary statistics for active continuous streamgages in the East-Central Plains hydrologic region									
2 continuous streamgages summarized									
10th percentile[1]	33	19.54	154.10	0.00	0.00	0.27	12.61	1.03	0.14
Median	54	21.00	330.50	0.00	0.00	0.29	12.71	1.07	0.69
90th percentile[1]	75	22.46	506.90	0.00	0.00	0.31	12.80	1.11	1.24
Summary statistics for continuous streamgages in the Southeast Plains hydrologic region									
14 continuous streamgages summarized									
10th percentile[1]	12	8.56	60.93	0.00	0.00	0.23	14.61	1.16	1.56
Median	29	25.66	581.50	0.00	0.00	4.62	15.17	1.27	10.19
90th percentile[1]	49	39.42	1,407.80	0.79	0.00	11.46	20.35	1.61	24.10
Summary statistics for active continuous streamgages in the Southeast Plains hydrologic region									
5 continuous streamgages summarized									
10th percentile[1]	29	12.38	261.20	0.00	0.00	3.85	14.60	1.16	10.09
Median	34	26.84	696.00	0.00	0.00	7.68	15.86	1.26	20.99
90th percentile[1]	48	43.73	1,154.60	21.82	19.27	13.35	20.82	1.65	25.53

Table 10. Statistical summaries of selected streamgage characteristics and drainage-basin characteristics for continuous streamgages included in the Montana regional regression analyses (Sando, R., and others, 2018).—Continued

[*PFVI*, peak-flow variability index calculated by 100 times the standard deviation of the peak flows (base-10 logarithms) divided by the mean of the peak flows (base-10 logarithms); the standard deviations and means of the peak flows were calculated using Bulletin 17B procedures (U.S. Interagency Advisory Council on Water Data, 1982) for fitting the log-Pearson III distribution. *CONTDA*, contributing drainage area, in square miles; EL_{5000}, percentage of basin above 5,000 feet elevation; EL_{6000}, percentage of basin above 6,000 feet elevation; *SLOP*30_30*M*, percentage of basin with slopes greater than or equal to 30 percent; *PRECIP*, mean annual precipitation, in inches; *ET*0306*MOD*, spring mean monthly evapotranspiration, in inches per month; *FOREST*, percentage of basin in forest]

Summary statistic	Statistical summaries for continuous streamgages								
	Streamgage characteristics		Basin and climatic used as explanatory variables in regional regression equations						
	No.	*PFVI*	*CONTDA*	EL_{5000}	EL_{6000}	*SLOP*30_30*M*	*PRECIP*	*ET*0306*MOD*	*FOREST*
Summary statistics for continuous streamgages in the Upper Yellowstone-Central Mountain hydrologic region									
50 continuous streamgages summarized									
10th percentile[1]	12	3.29	44.00	22.81	4.13	8.39	19.01	1.46	8.40
Median	34	8.18	132.50	90.05	53.24	28.39	24.52	1.66	37.33
90th percentile[1]	80	19.60	989.20	100.00	97.83	53.89	33.63	1.75	76.74
Summary statistics for active continuous streamgages in the Upper Yellowstone-Central Mountain hydrologic region									
16 continuous streamgages summarized									
10th percentile[1]	38	3.29	77.10	50.66	20.11	14.17	20.11	1.52	19.18
Median	74	6.55	440.00	84.67	56.26	30.89	25.82	1.64	37.79
90th percentile[1]	93	12.98	1,688.50	100.00	99.09	53.54	33.71	1.68	73.97
Summary statistics for continuous streamgages in the Southwest hydrologic region									
24 continuous streamgages summarized									
10th percentile[1]	13	4.54	36.18	76.17	33.12	15.17	20.55	1.38	27.51
Median	29	7.53	153.50	100.00	93.87	33.16	24.02	1.49	61.76
90th percentile[1]	86	9.44	570.40	100.00	100.00	50.28	34.51	1.64	85.84
Summary statistics for active continuous streamgages in the Southwest hydrologic region									
13 continuous streamgages summarized									
10th percentile[1]	19	5.43	47.02	71.59	30.15	11.90	19.42	1.45	34.75
Median	76	7.83	381.00	100.00	90.52	30.75	23.52	1.48	56.51
90th percentile[1]	92	9.31	1,137.20	100.00	100.00	40.38	34.72	1.64	77.77

[1]Nonexceedance percentile.

Northwest hydrologic region relative to the other hydrologic regions makes it more difficult to discern clear patterns in the various relations.

For 44 unregulated streamgages in the Northwest hydrologic region, *PFVI* generally monotonically decreases with increasing drainage area (fig. 9*A*). Variability about the LOWESS line is larger for drainage areas less than about 10 mi^2, but there are few streamgages in that range. Intuitively, highly variable small-scale hydroclimatic processes are integrated with increasing drainage area such that variability in many hydrologic characteristics is reduced. *PFVI* also generally decreases with increasing elevation (fig. 9*B*), precipitation (fig. 9*C*), and years of record (fig. 9*D*). For the relations between *PFVI* and drainage area (fig. 9*A*), elevation (fig. 9*B*), and years of record (fig. 9*D*), the LOWESS lines for the Northwest hydrologic region generally are below or near the LOWESS lines for all unregulated streamgages in Montana.

Relations between contributing drainage area and mean basin elevation, mean annual precipitation, and years of peak-flow records for the unregulated streamgages are presented in figure 10. Streamgages with greater than about 40 years of record are predominantly located on streams with contributing drainage areas greater than about 100 mi^2 (fig. 10*C*), which might contribute to the *PFVI* and years of record relations (fig. 9*D*).

The median *PFVI* value for streamgages in the Northwest hydrologic region (6.04, table 3) is substantially less than the median for all unregulated streamgages in Montana (18.26, table 3) and ranks as the eighth largest median *PFVI* among the eight hydrologic regions. A major factor contributing to low peak-flow variability in the Northwest hydrologic region might be the strong dominance of snowmelt runoff in the annual hydrograph of the streamgages. For unregulated streamgages in the Northwest hydrologic region, fall and winter

Table 11. Statistical summaries of selected streamgage characteristics and drainage-basin characteristics for crest-stage gages included in the Montana regional regression analyses (Sando, R., and others, 2018).

[*PFVI*, peak-flow variability index calculated by 100 times the standard deviation of the peak flows (base-10 logarithms) divided by the mean of the peak flows (base-10 logarithms); the standard deviations and means of the peak flows were calculated using Bulletin 17B procedures (U.S. Interagency Advisory Council on Water Data, 1982) for fitting the log-Pearson III distribution. *CONTDA*, contributing drainage area, in square miles; EL_{5000}, percentage of basin above 5,000 feet elevation; EL_{6000}, percentage of basin above 6,000 feet elevation; *SLOP*30_30*M*, percentage of basin with slopes greater than or equal to 30 percent; *PRECIP*, mean annual precipitation, in inches; *ET*0306*MOD*, spring mean monthly evapotranspiration, in inches per month; *FOREST*, percentage of basin in forest]

Summary statistic	Statistical summaries for crest-stage gages								
	Streamgage characteristics		Basin and climatic used as explanatory variables in regional regression equations						
	No.	*PFVI*	*CONTDA*	EL_{5000}	EL_{6000}	*SLOP*30_30*M*	*PRECIP*	*ET*0306*MOD*	*FOREST*
Summary statistics for crest-stage gages in Montana									
301 crest-stage gages summarized									
10th percentile[1]	15	9.96	0.80	0.00	0.00	0.00	12.63	1.00	0.00
Median	20	36.32	5.05	0.00	0.00	2.16	14.86	1.24	3.52
90th percentile[1]	45	92.45	39.10	98.08	52.50	63.89	37.19	1.80	84.67
Summary statistics for active crest-stage gages in Montana									
76 crest-stage gages summarized									
10th percentile[1]	42	24.28	0.78	0.00	0.00	0.00	12.44	0.98	0.00
Median	44	47.89	2.57	0.00	0.00	0.22	14.01	1.11	0.00
90th percentile[1]	55	116.87	11.75	62.11	2.19	26.67	17.75	1.44	28.01
Summary statistics for crest-stage gages in the West hydrologic region									
51 crest-stage gages summarized									
10th percentile[1]	11	4.56	2.53	16.80	0.00	24.18	22.12	1.60	56.36
Median	18	14.01	7.77	43.44	10.89	63.01	38.87	1.77	84.62
90th percentile[1]	33	36.25	49.20	91.73	68.04	82.06	48.51	1.93	93.62
Summary statistics for active crest-stage gages in the West hydrologic region									
0 crest-stage gages summarized									
10th percentile[1]	--	--	--	--	--	--	--	--	--
Median	--	--	--	--	--	--	--	--	--
90th percentile[1]	--	--	--	--	--	--	--	--	--
Summary statistics for crest-stage gages in the Northwest hydrologic region									
6 crest-stage gages summarized									
10th percentile[1]	16	10.12	5.41	44.57	0.65	2.04	24.08	1.63	33.10
Median	21	18.13	17.40	85.10	33.78	47.19	38.11	1.77	59.79
90th percentile[1]	28	31.10	20.60	98.03	44.67	74.49	49.53	1.80	82.08
Summary statistics for active crest-stage gages in the Northwest hydrologic region									
0 crest-stage gages summarized									
10th percentile[1]	--	--	--	--	--	--	--	--	--
Median	--	--	--	--	--	--	--	--	--
90th percentile[1]	--	--	--	--	--	--	--	--	--
Summary statistics for crest-stage gages in the Northwest Foothills hydrologic region									
20 crest-stage gages summarized									
10th percentile[1]	0.00	16	26.51	0.43	0.00	0.00	0.00	10.65	1.07
Median	9.36	18	46.54	3.39	0.00	0.00	0.01	13.05	1.19
90th percentile[1]	20.00	43	91.89	20.49	0.00	0.00	3.01	16.61	1.37

Table 11. Statistical summaries of selected streamgage characteristics and drainage-basin characteristics for crest-stage gages included in the Montana regional regression analyses (Sando, R., and others, 2018).—Continued

[*PFVI*, peak-flow variability index calculated by 100 times the standard deviation of the peak flows (base-10 logarithms) divided by the mean of the peak flows (base-10 logarithms); the standard deviations and means of the peak flows were calculated using Bulletin 17B procedures (U.S. Interagency Advisory Council on Water Data, 1982) for fitting the log-Pearson III distribution. *CONTDA*, contributing drainage area, in square miles; EL_{5000}, percentage of basin above 5,000 feet elevation; EL_{6000}, percentage of basin above 6,000 feet elevation; *SLOP*30_30*M*, percentage of basin with slopes greater than or equal to 30 percent; *PRECIP*, mean annual precipitation, in inches; *ET*0306*MOD*, spring mean monthly evapotranspiration, in inches per month; *FOREST*, percentage of basin in forest]

Summary statistic	Statistical summaries for crest-stage gages								
	Streamgage characteristics		Basin and climatic used as explanatory variables in regional regression equations						
	No.	*PFVI*	*CONTDA*	EL_{5000}	EL_{6000}	*SLOP*30_30*M*	*PRECIP*	*ET*0306*MOD*	*FOREST*
Summary statistics for active crest-stage gages in the Northwest Foothills hydrologic region									
4 crest-stage gages summarized									
10th percentile[1]	42	28.66	2.22	0.00	0.00	0.00	12.43	1.18	0.00
Median	43	45.84	9.12	0.00	0.00	0.00	14.71	1.31	0.00
90th percentile[1]	53	78.88	13.51	0.00	0.00	0.27	16.54	1.34	0.00
Summary statistics for crest-stage gages in the Northeast Plains hydrologic region									
31 crest-stage gages summarized									
10th percentile[1]	15	31.84	0.83	0.00	0.00	0.00	11.50	1.04	0.00
Median	39	53.43	2.93	0.00	0.00	0.00	13.28	1.16	0.00
90th percentile[1]	44	157.01	15.40	0.00	0.00	1.22	15.38	1.30	0.07
Summary statistics for active crest-stage gages in the Northeast Plains hydrologic region									
13 crest-stage gages summarized									
10th percentile[1]	35	33.73	1.40	0.00	0.00	0.00	11.53	1.03	0.00
Median	43	64.07	2.40	0.00	0.00	0.00	13.26	1.13	0.00
90th percentile[1]	44	165.93	4.79	0.00	0.00	0.56	15.80	1.31	1.34
Summary statistics for crest-stage gages in the East-Central Plains hydrologic region									
74 crest-stage gages summarized									
10th percentile[1]	15	20.52	0.68	0.00	0.00	0.00	12.39	0.94	0.00
Median	24	39.98	3.17	0.00	0.00	0.00	13.14	1.05	0.00
90th percentile[1]	50	77.62	33.27	0.00	0.00	3.62	14.17	1.16	8.90
Summary statistics for active crest-stage gages in the East-Central Plains hydrologic region									
25 crest-stage gages summarized									
10th percentile[1]	42	26.75	0.84	0.00	0.00	0.00	12.45	0.94	0.00
Median	43	42.94	2.30	0.00	0.00	0.00	13.34	1.04	0.00
90th percentile[1]	54	91.30	7.15	0.00	0.00	2.43	14.61	1.13	6.38
Summary statistics for crest-stage gages in the Southeast Plains hydrologic region									
54 crest-stage gages summarized									
10th percentile[1]	15	18.37	0.71	0.00	0.00	0.00	13.80	1.02	0.00
Median	30	44.05	3.57	0.00	0.00	1.16	14.47	1.16	5.39
90th percentile[1]	45	102.92	19.45	0.00	0.00	13.55	15.93	1.32	28.28
Summary statistics for active crest-stage gages in the Southeast Plains hydrologic region									
22 crest-stage gages summarized									
10th percentile[1]	43	31.29	0.53	0.00	0.00	0.00	13.49	1.01	0.00
Median	44	49.89	2.68	0.00	0.00	1.29	14.26	1.10	8.63
90th percentile[1]	54	103.62	8.52	0.00	0.00	12.93	15.03	1.26	20.69

Table 11. Statistical summaries of selected streamgage characteristics and drainage-basin characteristics for crest-stage gages included in the Montana regional regression analyses (Sando, R., and others, 2018).—Continued

[*PFVI*, peak-flow variability index calculated by 100 times the standard deviation of the peak flows (base-10 logarithms) divided by the mean of the peak flows (base-10 logarithms); the standard deviations and means of the peak flows were calculated using Bulletin 17B procedures (U.S. Interagency Advisory Council on Water Data, 1982) for fitting the log-Pearson III distribution. *CONTDA*, contributing drainage area, in square miles; EL_{5000}, percentage of basin above 5,000 feet elevation; EL_{6000}, percentage of basin above 6,000 feet elevation; *SLOP*30_30*M*, percentage of basin with slopes greater than or equal to 30 percent; *PRECIP*, mean annual precipitation, in inches; *ET*0306*MOD*, spring mean monthly evapotranspiration, in inches per month; *FOREST*, percentage of basin in forest]

Summary statistic	Statistical summaries for crest-stage gages								
	Streamgage characteristics		Basin and climatic used as explanatory variables in regional regression equations						
	No.	*PFVI*	*CONTDA*	EL_{5000}	EL_{6000}	*SLOP*30_30*M*	*PRECIP*	*ET*0306*MOD*	*FOREST*
Summary statistics for crest-stage gages in the Upper Yellowstone-Central Mountain hydrologic region									
41 crest-stage gages summarized									
10th percentile[1]	15	12.11	1.25	0.00	0.00	0.00	15.12	1.20	0.00
Median	19	43.27	5.65	19.57	0.00	6.53	17.49	1.49	13.07
90th percentile[1]	49	144.13	47.90	100.00	85.94	48.28	29.55	1.80	77.61
Summary statistics for active crest-stage gages in the Upper Yellowstone-Central Mountain hydrologic region									
7 crest-stage gages summarized									
10th percentile[1]	43	23.87	0.91	0.00	0.00	0.00	14.90	1.23	0.00
Median	45	46.45	5.23	58.22	0.00	2.89	17.66	1.42	0.33
90th percentile[1]	60	193.17	22.70	100.00	48.28	45.36	23.86	1.72	47.81
Summary statistics for crest-stage gages in the Southwest hydrologic region									
24 crest-stage gages summarized									
10th percentile[1]	16	8.21	3.59	28.48	2.74	11.06	14.62	1.26	3.32
Median	19	25.10	16.75	100.00	71.11	33.59	19.51	1.45	54.79
90th percentile[1]	45	90.52	86.71	100.00	100.00	52.20	24.35	1.59	85.54
Summary statistics for active crest-stage gages in the Southwest hydrologic region									
5 crest-stage gages summarized									
10th percentile[1]	43	6.68	12.86	99.02	63.99	33.91	19.09	1.38	44.52
Median	44	26.45	17.30	100.00	95.27	36.41	23.33	1.46	79.34
90th percentile[1]	51	65.44	30.46	100.00	99.52	51.17	34.10	1.65	89.62

[1]Nonexceedance percentile.

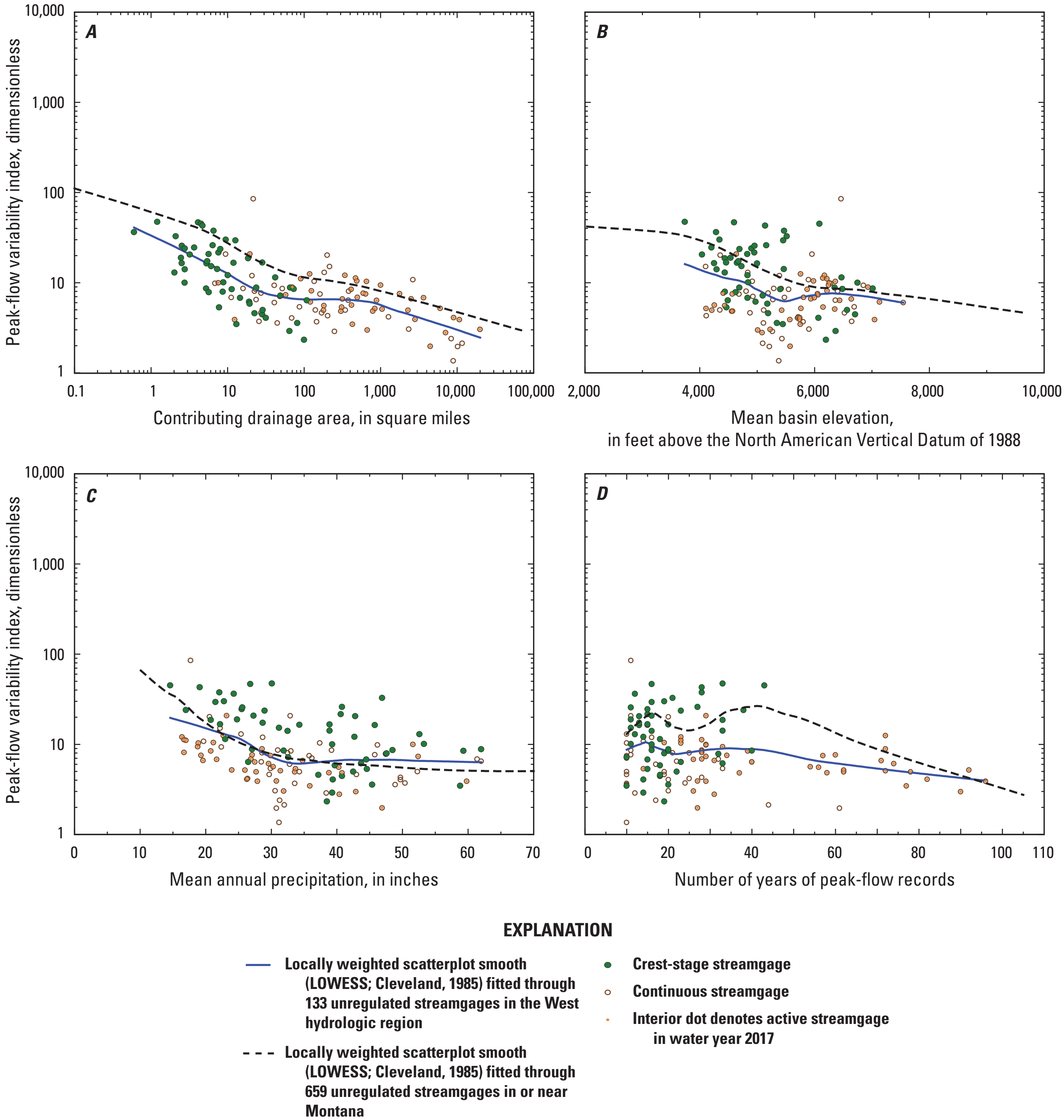
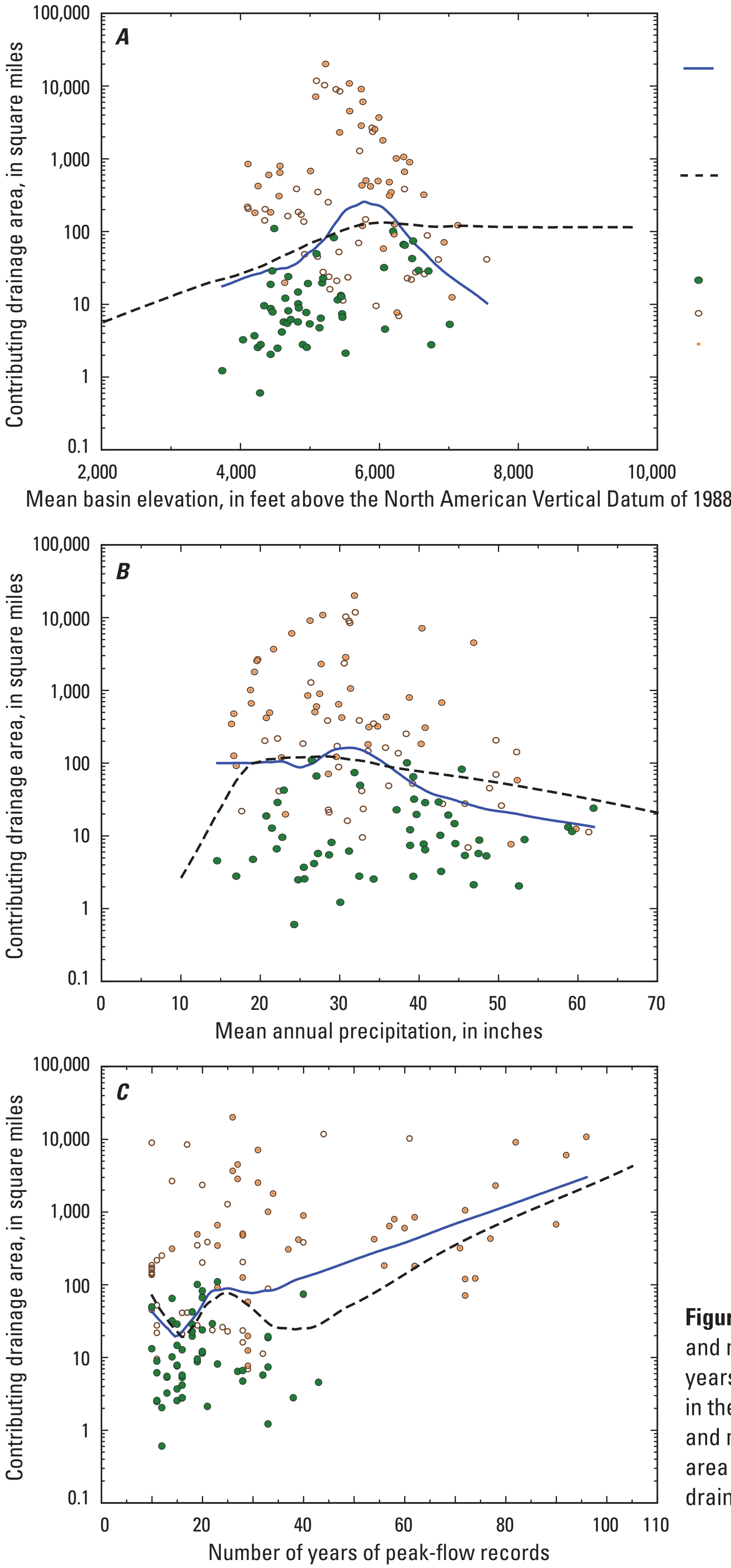


Figure 6. Relations between peak-flow variability index and contributing drainage area, mean basin elevation, mean annual precipitation, and years of peak-flow records for 133 unregulated streamgages in the West hydrologic region. *A*, Peak-flow variability and contributing drainage area relations. *B*, Peak-flow variability and mean basin elevation relations. *C*, Peak-flow variability and mean annual precipitation relations. *D*, Peak-flow variability and years of peak-flow records relations.



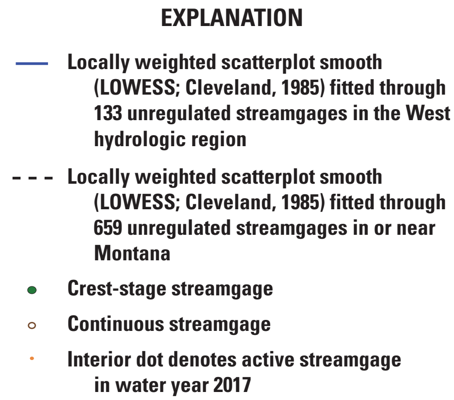


Figure 7. Relations between contributing drainage area and mean basin elevation, mean annual precipitation, and years of peak-flow records for 133 unregulated streamgages in the West hydrologic region. *A*, Contributing drainage area and mean basin elevation relations. *B*, Contributing drainage area and mean annual precipitation relations. *C*, Contributing drainage area and years of peak-flow records relations.

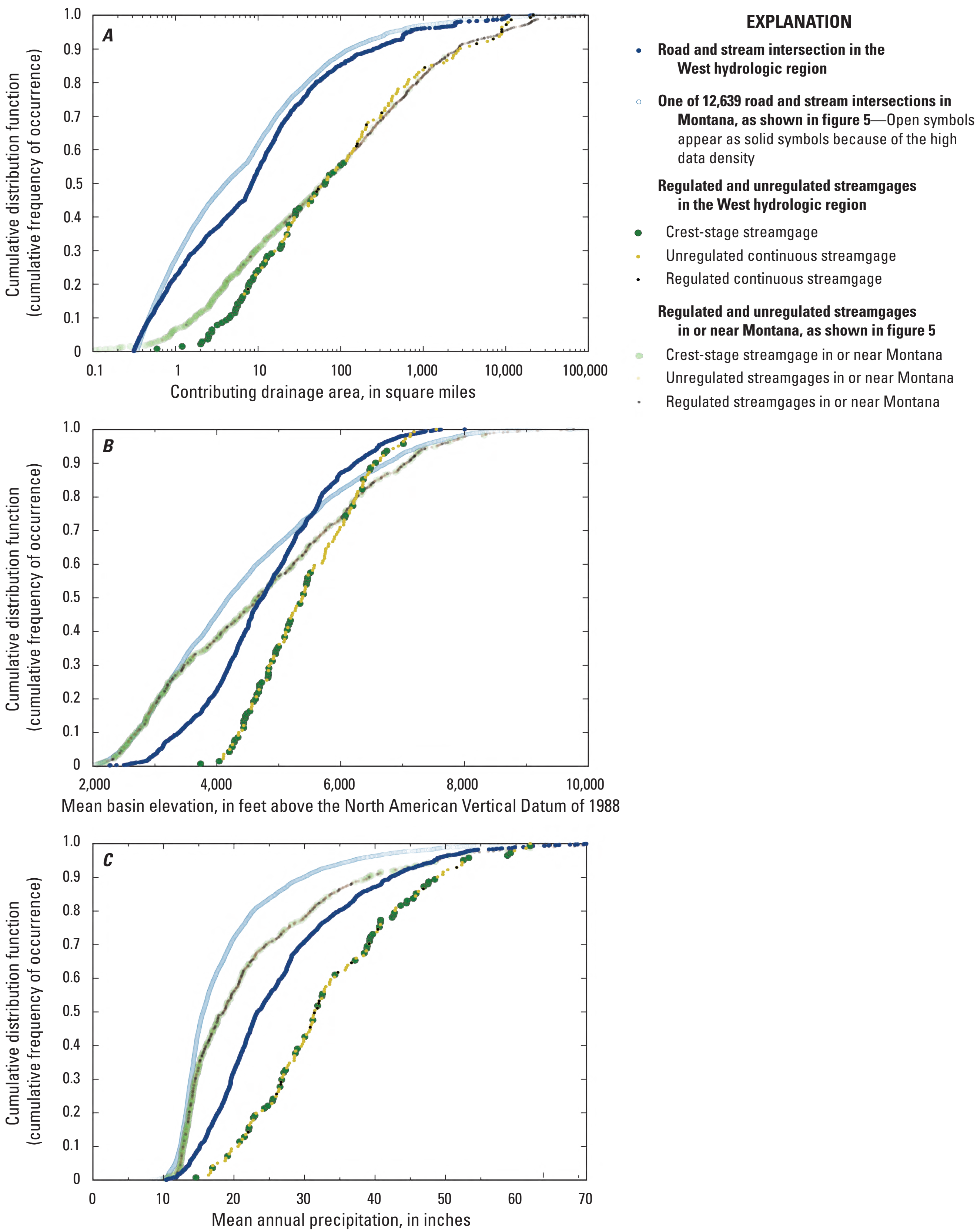


Figure 8. Cumulative distribution functions of selected drainage-basin characteristics for 2,380 road and stream intersections and for 141 streamgages (regulated and unregulated) in the West hydrologic region. *A*, Contributing drainage area relations. *B*, Mean basin elevation relations. *C*, Mean annual precipitation relations.

(October–February) precipitation accounts for about 38 percent of annual precipitation (table 8), which can result in large accumulated snowpacks (Sando and McCarthy, 2018) that contribute to streamflows during the typical snowmelt runoff period of May through mid-July. May–June precipitation accounts for about 25.4 percent of annual precipitation (table 8), which ranks seventh among the hydrologic regions, and July–August precipitation accounts for 13.1 percent of annual precipitation, which ranks eighth among the eight hydrologic regions. In the Northwest hydrologic region, annual peak flows predominantly are in May and June (fig. 2 of Sando, R., and others, 2018). Dominance of snowmelt in the annual hydrograph tends to provide temporal integration of a substantial part of the annual precipitation inputs and contributes to the low *PFVI*s for streamgages in the Northwest hydrologic region.

Although streamgages in the Northwest hydrologic region have less than typical *PFVI*s, about 56 percent of the streamgages are considered to have mixed-population characteristics (table 1) that result in a small number of unusually large peak flows that are substantially larger than the main body of peak flows. Typically, the unusually large peak-flow events result from extremely intense rainfall events in May and June that happen near the peak of snowmelt runoff. Mixed-population peak-flow datasets often are in streamgages with drainage basins along or near the Continental Divide, which closely corresponds to the general location of the Northwest hydrologic region. In some areas of the Northwest hydrologic region, some mixed-population peak-flow datasets result from unusual rapid snowmelt events during winter, sometimes in association with rainfall. The large peak-flow variability of mixed-population peak-flow datasets might not be well represented in the *PFVI* values because the unusually large peak-flow events are infrequent and might not substantially affect the calculation of the *PFVI* values. Partly because of the large proportion of mixed-population streamgages in the Northwest hydrologic region, those streamgages do not have disproportionally strong positive residuals for the 1-percent AEP regression or significant influence. Among the candidate explanatory variables included in the regional regression analyses, there are no variables that represent spatial variability in precipitation intensity (such as indices of the 100-year 24-hour precipitation; for example, U.S. Weather Bureau, 1961). Inclusion of variables that represent spatial variability in precipitation intensity might help address some mixed-population issues and improve potential future regional regression analyses in the Northwest hydrologic region.

The CDFs of selected basin characteristics (drainage area, mean basin elevation, and mean annual precipitation) for the road and stream intersections and for the streamgages in the Northwest hydrologic region are shown in figure 11. With respect to drainage area, the CDF of road and stream intersections for the Northwest hydrologic region is similar to the CDF of road and stream intersections for all of Montana (fig. 11*A*), but with greater representation of drainage areas greater than about 100 mi^2. In the Northwest hydrologic region, the CDF of streamgages diverges from the CDF of road and stream intersections in the range of drainage areas less than about 60 mi^2, indicating underrepresentation in that range.

The Northwest hydrologic region generally is higher in elevation than Montana as a whole. Mean basin elevation for road and stream intersections in the Northwest hydrologic region ranges from 3,355 to 7,458 ft (Dutton and others, 2021) with a median of 5,493 ft (table 4). The range for the Northwest hydrologic region is smaller than for all of Montana (1,951–9,974 ft; Dutton and others, 2021) and the median for the Northwest hydrologic region is higher than for all of Montana (4,173 ft; table 4). There are substantial differences between the CDFs of road and stream intersections for the Northwest hydrologic region relative to the CDFs of road and stream intersections for all of Montana (fig. 11*B*). With respect to mean basin elevation, the pattern of the streamgage CDFs reasonably represents the road and stream intersection CDF but with some underrepresentation at elevations less than about 5,400 ft.

The Northwest hydrologic region generally is wetter than Montana as a whole. Mean annual precipitation for road and stream intersections in the Northwest hydrologic region ranges from 13.2 to 91.3 inches (Dutton and others, 2021) with a median of 31.5 inches (table 5). The range for the Northwest hydrologic region is smaller than for all of Montana (8.4–91.3 inches; Dutton and others, 2021) and the median for the Northwest hydrologic region is larger than for all of Montana (15.7 inches; table 5). There are substantial differences between the CDFs of road and stream intersections for the Northwest hydrologic region relative to the CDFs of road and stream intersections for all of Montana (fig. 11*C*). With respect to mean annual precipitation, the pattern of the streamgage CDFs reasonably represents the road and stream intersection CDF but with some underrepresentation of mean annual precipitation less than about 37 inches.

The explanatory variable for the Northwest hydrologic region RREs is *CONTDA* (table 6). The 1-percent AEP RRE for the West hydrologic region has an SEP of 13.6 percent, which is substantially less than the area-weighted mean SEP for all hydrologic regions in Montana (63.3 percent; table 6). The RREs for the Northwest hydrologic region were developed using weighted least squares regression to better handle complexities introduced by the large proportion of mixed-population peak-flow datasets (Sando, R., and others, 2018); the use of weighted least squares regression might contribute to the low SEP. For the 1-percent AEP regression for the Northwest hydrologic region, 12.5 percent of the streamgages have significant leverage and 6.3 percent of the streamgages have significant influence (table 7). The significant leverage percentage is somewhat larger the significant leverage percentage for all of the streamgages in Montana used in the regional regression analyses (8.2 percent; table 7) and the significant influence percentage is somewhat smaller than the significant influence percentage for all of the streamgages in Montana used in the regional regression analyses (10.4 percent; table 7).

Table 12. Information on streamgages in the West hydrologic region with significant leverage and influence in the Montana regional regression analyses (Sando, R., and others, 2018).

[ID, identification; NAD 83, North American Datum of 1983; *n*, total number of years of peak-flow records; *CONTDA*, contributing drainage area, in square miles; *PRECIP*, mean annual precipitation, in inches; *FOREST*, percentage of basin in forest; AEP, annual exceedance probability; CSG, crest-stage gage; CONT, continuous streamgage]

Map number (fig. 1)	Station ID number	Station name	Latitude, in decimal degrees (NAD 83)	Longitude, in decimal degrees (NAD 83)	Type of streamgage	Status of streamgage in water year 2017	*n*
		Streamgages with significant leverage					
598	12301700	Kootenai River tributary near Rexford, Montana	48.7985	−115.2964	CSG	Discontinued	12
626	[2]12323300	Smith Gulch near Silver Bow, Montana	45.9570	−12.6637	CSG	Discontinued	43
629	[2]12323750	Silver Bow Creek at Warm Springs, Montana	46.1795	−112.7806	CONT	Active	33
634	[2]12324200	Clark Fork at Deer Lodge, Montana	46.3977	−112.7425	CONT	Active	38
638	[2]12324700	Clark Fork tributary near Drummond, Montana	46.6196	−113.0339	CSG	Discontinued	38
645	[2]12331700	Edwards Gulch at Drummond, Montana	46.6701	−113.1456	CSG	Discontinued	28
646	12331800	Clark Fork near Drummond, Montana	46.7119	−113.3308	CONT	Active	24
676	12347500	Blodgett Creek near Corvallis, Montana	46.2694	−114.2371	CONT	Discontinued	24
738	12377150	Mission Creek above reservoir, near St. Ignatius, Montana	47.3228	−113.9794	CONT	Active	34
		Streamgages with significant influence					
608	12302400	Shaughnessy Creek near Libby, Montana	48.3031	−115.5948	CSG	Discontinued	33
612	12303400	Ross Creek near Troy, Montana	48.2071	−115.8709	CSG	Discontinued	20
624	12323240	Blacktail Creek at Butte, Montana	45.9947	−112.5357	CONT	Active	28
626	[2]12323300	Smith Gulch near Silver Bow, Montana	45.9570	−112.6637	CSG	Discontinued	43
629	[2]12323750	Silver Bow Creek at Warm Springs, Montana	46.1795	−112.7806	CONT	Active	33
634	[2]12324200	Clark Fork at Deer Lodge, Montana	46.3977	−112.7425	CONT	Active	38
638	[2]12324700	Clark Fork tributary near Drummond, Montana	46.6196	−113.0339	CSG	Discontinued	38
639	12324800	Morris Creek near Drummond, Montana	46.6655	−113.0999	CSG	Discontinued	16
645	[2]12331700	Edwards Gulch at Drummond, Montana	46.6701	−113.1456	CSG	Discontinued	28
672	12344300	Burke Gulch near Darby, Montana	46.0242	−114.1511	CSG	Discontinued	28
679	12350200	Gash Creek near Victor, Montana	46.4055	−114.2566	CSG	Discontinued	16
717	12363900	Rock Creek near Olney, Montana	48.6122	−114.6519	CSG	Discontinued	15
724	12367500	Ashley Creek near Kalispell, Montana	48.1650	−114.4324	CONT	Discontinued	20
741	12383500	Big Knife Creek near Arlee, Montana	47.1473	−113.9745	CONT	Discontinued	29

[1]The nonexceedance percentile for the basin or climatic variable value was calculated in relation to the values for all streamgages included in the regional regression analyses for the indicated hydrologic region.

[2]Streamgages having both significant leverage and significant influence.

CONTDA	Nonexceedance percentile[1] for *CONTDA*	*PRECIP*	Nonexceedance percentile[1] for *PRECIP*	*FOREST*	Nonexceedance percentile[1] for *FOREST*	Regression residuals for the specified AEP regression analyses		
						10-percent AEP	4-percent AEP	1-percent AEP
Streamgages with significant leverage								
0.60	0.9	24.3	17.7	46.2	6.2	0.049	−0.011	−0.086
4.52	12.4	14.6	0.9	29.8	1.8	0.245	0.301	0.379
473	87.6	16.7	1.8	45.1	5.3	−0.310	−0.327	−0.347
1,001	95.6	18.8	4.4	44.1	4.4	−0.381	−0.386	−0.391
2.77	8.0	17.0	2.7	20.4	0.9	0.469	0.458	0.451
4.71	13.3	19.1	5.3	32.5	2.7	0.169	0.247	0.348
2,516	100.0	19.6	6.2	47.7	7.1	−0.126	−0.090	−0.020
25.9	46.9	50.4	90.3	49.3	8.8	−0.073	−0.100	−0.127
12.4	33.6	59.8	97.3	48.1	8.0	−0.117	−0.148	−0.183
Streamgages with significant influence								
1.21	1.8	30.1	39.8	89.2	80.5	0.448	0.563	0.732
23.8	46.0	62.0	99.1	86.0	72.6	0.407	0.499	0.628
90.9	65.5	17.0	3.5	57.4	13.3	−0.230	−0.288	−0.361
4.52	12.4	14.6	0.9	29.8	1.8	0.245	0.301	0.379
473	87.6	16.7	1.8	45.1	5.3	−0.310	−0.327	−0.347
1,001	95.6	18.8	4.4	44.1	4.4	−0.381	−0.386	−0.391
2.77	8.0	17.0	2.7	20.4	0.9	0.469	0.458	0.451
12.7	34.5	21.5	10.6	43.9	3.5	−0.831	−0.840	−0.836
4.71	13.3	19.1	5.3	32.5	2.7	0.169	0.247	0.348
6.58	20.4	22.1	11.5	76.3	40.7	−0.347	−0.347	−0.325
2.76	7.1	39.3	66.4	79.3	49.6	0.465	0.432	0.393
7.64	23.9	40.6	69.9	88.6	77.9	−0.672	−0.666	−0.643
201	76.1	20.6	7.1	71.6	31.0	−0.444	−0.356	−0.234
6.86	21.2	46.2	83.2	97.0	98.2	−0.359	−0.372	−0.386

Table 13. Information on discontinued streamgages in the West hydrologic region that might be candidates for reactivation to improve the streamgage network.

[NAD 83, North American Datum of 1983; *n*, total number of years of peak-flow records; *CONTDA*, contributing drainage area, in square miles; *PRECIP*, mean annual precipitation, in inches; *FOREST*, percentage of basin in forest; CSG, crest-stage gage; CONT, continuous streamgage]

Map number (fig. 1)	Station identification number	Station name	Latitude, in decimal degrees (NAD 83)	Longitude, in decimal degrees (NAD 83)	Type of streamgage	*n*	*CONTDA*	Nonexceedance percentile[1] for *CONTDA*	*PRECIP*	Nonexceedance percentile[1] for *PRECIP*	*FOREST*	Nonexceedance percentile[1] for *FOREST*
593	12300400	Cayuse Creek near Trego, Montana	48.6092	−115.0296	CSG	13	5.44	15.9	28.7	33.6	84.8	63.7
594	12300500	Fortine Creek near Trego, Montana	48.6440	−114.9112	CONT, CSG	23	109	66.4	26.5	23.9	75.7	39.8
598	12301700	Kootenai River tributary near Rexford, Montana	48.7985	−115.2964	CSG	12	0.60	0.9	24.3	17.7	46.2	6.2
599	12301800	Gold Creek near Rexford, Montana	48.7855	−115.3170	CSG	11	6.13	18.6	31.2	43.4	84.6	61.9
600	12301810	Big Creek near Rexford, Montana	48.7478	−115.3537	CONT	10	136	69.0	37.4	60.2	85.7	69.0
603	12301993	Wolf Creek tributary near Libby, Montana	48.3980	−114.9189	CSG	11	2.47	4.4	24.8	18.6	93.6	92.0
604	12301997	Richards Creek near Libby, Montana	48.2586	−115.1999	CSG	19	9.48	29.2	22.8	15.0	56.4	11.5
605	12301999	Wolf Creek near Libby, Montana	48.2336	−115.2849	CONT	11	216	77.9	22.2	12.4	68.1	23.9
609	12302500	Granite Creek near Libby, Montana	48.3018	−115.5924	CONT	22	23.7	45.1	62.0	100.0	80.4	51.3
612	12303400	Ross Creek near Troy, Montana	48.2071	−115.8709	CSG	20	23.8	46.0	62.0	99.1	86.0	72.6

Table 13. Information on discontinued streamgages in the West hydrologic region that might be candidates for reactivation to improve the streamgage network.—Continued

[NAD 83, North American Datum of 1983; *n*, total number of years of peak-flow records; *CONTDA*, contributing drainage area, in square miles; *PRECIP*, mean annual precipitation, in inches; *FOREST*, percentage of basin in forest; CSG, crest-stage gage; CONT, continuous streamgage]

Map number (fig. 1)	Station identification number	Station name	Latitude, in decimal degrees (NAD 83)	Longitude, in decimal degrees (NAD 83)	Type of streamgage	*n*	*CONTDA*	Nonexceedance percentile[1] for *CONTDA*	*PRECIP*	Nonexceedance percentile[1] for *PRECIP*	*FOREST*	Nonexceedance percentile[1] for *FOREST*
613	12303440	Camp Creek near Troy, Montana	48.3210	−115.8245	CSG	20	11.4	31.9	59.3	96.5	84.7	62.8
615	12304040	Basin Creek near Yaak, Montana	48.9305	−115.4816	CONT	11	27.5	48.7	45.8	81.4	89.9	82.3
616	12304060	Blacktail Creek near Yaak, Montana	48.9508	−115.5420	CSG	14	10.1	30.1	42.7	74.3	85.9	69.9
617	12304120	Zulu Creek near Yaak, Montana	48.7302	−115.6427	CSG	13	5.33	15.0	45.8	82.3	94.7	93.8
618	12304250	Whitetail Creek near Yaak, Montana	48.8287	−115.8139	CSG	15	2.53	5.3	34.3	54.9	90.9	85.8
620	12304400	Fourth of July Creek near Yaak, Montana	48.7011	−115.8687	CSG	15	7.77	24.8	44.6	79.6	59.9	15.9
627	12323500	German Gulch Creek near Ramsay, Montana	46.0146	−112.7932	CONT	16	40.9	52.2	22.4	13.3	80.7	52.2
633	12324100	Racetrack Creek below Granite Creek, near Anaconda, Montana	46.2789	−112.9192	CONT	17	41.1	53.1	32.8	48.7	86.2	74.3
635	12324250	Cottonwood Creek at Deer Lodge, Montana	46.3997	−112.7167	CSG	18	43.7	54.0	23.0	15.9	67.2	23.0

Table 13. Information on discontinued streamgages in the West hydrologic region that might be candidates for reactivation to improve the streamgage network.—Continued

[NAD 83, North American Datum of 1983; *n*, total number of years of peak-flow records; *CONTDA*, contributing drainage area, in square miles; *PRECIP*, mean annual precipitation, in inches; *FOREST*, percentage of basin in forest; CSG, crest-stage gage; CONT, continuous streamgage]

Map number (fig. 1)	Station identification number	Station name	Latitude, in decimal degrees (NAD 83)	Longitude, in decimal degrees (NAD 83)	Type of streamgage	*n*	*CONTDA*	Nonexceedance percentile[1] for *CONTDA*	*PRECIP*	Nonexceedance percentile[1] for *PRECIP*	*FOREST*	Nonexceedance percentile[1] for *FOREST*
639	12324800	Morris Creek near Drummond, Montana	46.6655	−113.0999	CSG	16	12.7	34.5	21.5	10.6	43.9	3.5
655	12338500	Blackfoot River near Ovando, Montana	47.0156	−113.2288	CONT	25	1,270	97.3	26.4	23.0	65.8	20.4
656	12338540	Monture Creek above Dunham Creek, near Ovando, Montana	47.1184	−113.1464	CSG	14	64.5	59.3	39.3	65.5	77.1	45.1
657	12338550	Dunham Creek at mouth, near Ovando, Montana	47.1233	−113.1645	CSG	14	31.7	51.3	39.4	67.3	90.3	84.1
659	12338690	Monture Creek near Ovando, Montana	47.0453	−113.1902	CONT	10	146	70.8	33.6	51.3	74.7	38.9
660	12339300	Deer Creek near Seeley Lake, Montana	47.2101	−113.5416	CSG	18	19.5	39.8	39.7	68.1	83.4	59.3
661	12339450	Clearwater River near Clearwater, Montana	47.0187	−113.3877	CONT	19	346	82.3	34.3	54.0	83.3	58.4
664	12340200	Marshall Creek near Missoula, Montana	46.8877	−113.9249	CSG	16	5.67	16.8	27.3	28.3	84.8	64.6
667	12342950	Trapper Creek near Conner, Montana	45.8951	−114.1819	CSG	18	28.4	49.6	40.8	71.7	61.6	16.8

Table 13. Information on discontinued streamgages in the West hydrologic region that might be candidates for reactivation to improve the streamgage network.—Continued

[NAD 83, North American Datum of 1983; *n*, total number of years of peak-flow records; *CONTDA*, contributing drainage area, in square miles; *PRECIP*, mean annual precipitation, in inches; *FOREST*, percentage of basin in forest; CSG, crest-stage gage; CONT, continuous streamgage]

Map number (fig. 1)	Station identification number	Station name	Latitude, in decimal degrees (NAD 83)	Longitude, in decimal degrees (NAD 83)	Type of streamgage	*n*	*CONTDA*	Nonexceedance percentile[1] for *CONTDA*	*PRECIP*	Nonexceedance percentile[1] for *PRECIP*	*FOREST*	Nonexceedance percentile[1] for *FOREST*
668	12343300	Laird Creek near Sula, Montana	45.8736	−114.0535	CONT	12	9.45	28.3	32.9	49.6	71.3	30.1
673	12345800	Camas Creek near Hamilton, Montana	46.1445	−114.2136	CSG	16	5.27	14.2	48.5	86.7	58.9	14.2
674	12345850	Sleeping Child Creek near Hamilton, Montana	46.1324	−114.0582	CONT, CSG	20	65.9	60.2	27.1	27.4	87.8	76.1
676	12347500	Blodgett Creek near Corvallis, Montana	46.2694	−114.2371	CONT	24	25.9	46.9	50.4	90.3	49.3	8.8
677	12348500	Willow Creek near Corvallis, Montana	46.2954	−113.9955	CONT	19	22.6	42.5	28.6	32.7	88.7	79.6
678	12350000	Bear Creek near Victor, Montana	46.3809	−114.2204	CONT	19	27.4	47.8	43.0	77.0	66.8	22.1
679	12350200	Gash Creek near Victor, Montana	46.4055	−114.2566	CSG	16	2.76	7.1	39.3	66.4	79.3	49.6
681	12350500	Kootenai Creek near Stevensville, Montana	46.5368	−114.1596	CONT, CSG	22	28.9	50.4	42.5	73.5	66.1	21.2
683	12351200	Bitterroot River near Florence, Montana	46.6331	−114.0510	CONT	20	2,342	99.1	30.6	41.6	61.7	17.7

Table 13. Information on discontinued streamgages in the West hydrologic region that might be candidates for reactivation to improve the streamgage network.—Continued

[NAD 83, North American Datum of 1983; *n*, total number of years of peak-flow records; *CONTDA*, contributing drainage area, in square miles; *PRECIP*, mean annual precipitation, in inches; *FOREST*, percentage of basin in forest; CSG, crest-stage gage; CONT, continuous streamgage]

Map number (fig. 1)	Station identification number	Station name	Latitude, in decimal degrees (NAD 83)	Longitude, in decimal degrees (NAD 83)	Type of streamgage	*n*	*CONTDA*	Nonexceedance percentile[1] for *CONTDA*	*PRECIP*	Nonexceedance percentile[1] for *PRECIP*	*FOREST*	Nonexceedance percentile[1] for *FOREST*
684	12351400	Eightmile Creek near Florence, Montana	46.6486	−113.9582	CONT	16	20.9	41.6	28.7	34.5	70.1	27.4
685	12352000	Lolo Creek above Sleeman Creek, near Lolo, Montana	46.7441	−114.1434	CONT	12	250	78.8	38.4	61.1	81.7	55.8
686	12352200	Hays Creek near Missoula, Montana	46.8132	−114.0939	CSG	16	4.13	11.5	26.8	24.8	86.7	75.2
689	12353250	Ninemile Creek near Alberton, Montana	47.1859	−114.5872	CSG	10	49.2	56.6	32.6	47.8	79.1	48.7
690	12353280	Ninemile Creek near Huson, Montana	47.0634	−114.4138	CONT	10	170	72.6	29.7	37.2	85.2	66.4
691	12353400	Negro Gulch near Alberton, Montana	47.0207	−114.5229	CSG	23	8.07	25.7	29.0	35.4	76.7	43.4
692	12353800	Thompson Creek near Superior, Montana	47.1991	−114.9171	CSG	20	12.0	32.7	38.9	62.8	78.2	46.9
693	12353820	Dry Creek near Superior, Montana	47.2214	−114.9732	CONT	10	44.8	54.9	48.9	87.6	77.0	44.2

Table 13. Information on discontinued streamgages in the West hydrologic region that might be candidates for reactivation to improve the streamgage network.—Continued

[NAD 83, North American Datum of 1983; *n*, total number of years of peak-flow records; *CONTDA*, contributing drainage area, in square miles; *PRECIP*, mean annual precipitation, in inches; *FOREST*, percentage of basin in forest; CSG, crest-stage gage; CONT, continuous streamgage]

Map number (fig. 1)	Station identification number	Station name	Latitude, in decimal degrees (NAD 83)	Longitude, in decimal degrees (NAD 83)	Type of streamgage	*n*	*CONTDA*	Nonexceedance percentile[1] for *CONTDA*	*PRECIP*	Nonexceedance percentile[1] for *PRECIP*	*FOREST*	Nonexceedance percentile[1] for *FOREST*
694	12353850	East Fork Timber Creek near Haugan, Montana	47.4133	−115.4134	CSG	16	2.77	8.0	32.5	46.9	90.0	83.2
696	12354100	North Fork Little Joe Creek near St. Regis, Montana	47.2700	−115.1428	CSG	15	14.6	36.3	44.5	78.8	88.2	77.0
699	12355350	Big Creek at Big Creek Ranger Station, near Columbia Falls, Montana	48.6017	−114.1667	CSG	20	81.8	63.7	45.4	80.5	92.8	89.4
717	12363900	Rock Creek near Olney, Montana	48.6122	−114.6519	CSG	15	7.64	23.9	40.6	69.9	88.6	77.9
718	12363920	Stillwater River at Olney, Montana	48.5355	−114.5717	CONT	10	162	71.7	35.8	56.6	84.3	61.1
719	12364000	Logan Creek at Tally Lake, near Whitefish, Montana	48.4507	−114.5686	CONT	10	184	75.2	25.4	19.5	76.4	41.6
724	12367500	Ashley Creek near Kalispell, Montana	48.1650	−114.4324	CONT	20	201	76.1	20.6	7.1	71.6	31.0
725	12369200	Swan River near Condon, Montana	47.4224	−113.6710	CONT	20	69.1	61.1	49.7	89.4	74.1	38.1

Table 13. Information on discontinued streamgages in the West hydrologic region that might be candidates for reactivation to improve the streamgage network.—Continued

[NAD 83, North American Datum of 1983; *n*, total number of years of peak-flow records; *CONTDA*, contributing drainage area, in square miles; *PRECIP*, mean annual precipitation, in inches; *FOREST*, percentage of basin in forest; CSG, crest-stage gage; CONT, continuous streamgage]

Map number (fig. 1)	Station identification number	Station name	Latitude, in decimal degrees (NAD 83)	Longitude, in decimal degrees (NAD 83)	Type of streamgage	*n*	*CONTDA*	Nonexceedance percentile[1] for *CONTDA*	*PRECIP*	Nonexceedance percentile[1] for *PRECIP*	*FOREST*	Nonexceedance percentile[1] for *FOREST*
726	12369250	Holland Creek near Condon, Montana	47.4389	−113.6704	CSG	18	22.6	42.5	37.2	59.3	81.5	54.9
727	12369650	North Fork Lost Creek near Swan Lake, Montana	47.8848	−113.7989	CONT, CSG	10	13.1	35.4	58.8	95.6	80.1	50.4
730	12370900	Teepee Creek near Polson, Montana	47.8215	−114.0234	CONT, CSG	21	2.11	3.5	46.9	84.1	88.7	78.8
735	12375700	Garden Creek near Hot Springs, Montana	47.6484	−114.6930	CSG	15	3.67	10.6	25.5	20.4	95.6	96.5
737	12376000	Crow Creek near Ronan, Montana	47.4866	−114.0944	CONT	10	48.4	55.8	36.2	58.4	71.8	33.6
743	12388200	Jocko River at Dixon, Montana	47.3121	−114.2974	CONT	21	383	84.1	32.5	46.0	71.6	32.7
747	12389150	McGregor Creek tributary near Marion, Montana	48.0283	−114.9324	CSG	11	2.54	6.2	25.6	21.2	70.0	26.5
750	12391100	White Pine Creek near Trout Creek, Montana	47.7394	−115.6738	CSG	11	8.85	27.4	53.3	94.7	93.8	92.9
751	12391200	Canyon Creek near Trout Creek, Montana	47.8545	−115.5004	CSG	19	8.67	26.5	47.6	85.8	92.0	87.6

Table 13. Information on discontinued streamgages in the West hydrologic region that might be candidates for reactivation to improve the streamgage network.—Continued

[NAD 83, North American Datum of 1983; *n*, total number of years of peak-flow records; *CONTDA*, contributing drainage area, in square miles; *PRECIP*, mean annual precipitation, in inches; *FOREST*, percentage of basin in forest; CSG, crest-stage gage; CONT, continuous streamgage]

Map number (fig. 1)	Station identification number	Station name	Latitude, in decimal degrees (NAD 83)	Longitude, in decimal degrees (NAD 83)	Type of streamgage	*n*	*CONTDA*	Nonexceedance percentile[1] for *CONTDA*	*PRECIP*	Nonexceedance percentile[1] for *PRECIP*	*FOREST*	Nonexceedance percentile[1] for *FOREST*
753	12391430	Skeleton Creek near Noxon, Montana	47.9628	−115.8910	CSG	12	2.03	2.7	52.6	93.8	97.0	99.1
754	12391525	Snake Creek near Noxon, Montana	48.1230	−115.7544	CSG	13	3.22	9.7	42.8	75.2	99.0	100.0
755	12391550	Bull River near Noxon, Montana	48.0474	−115.8350	CONT	10	141	69.9	52.3	92.0	85.3	67.3

[1]The nonexceedance percentile for the basin or climatic variable value was calculated in relation to the values for all streamgages included in the regional regression analyses for the indicated hydrologic region.

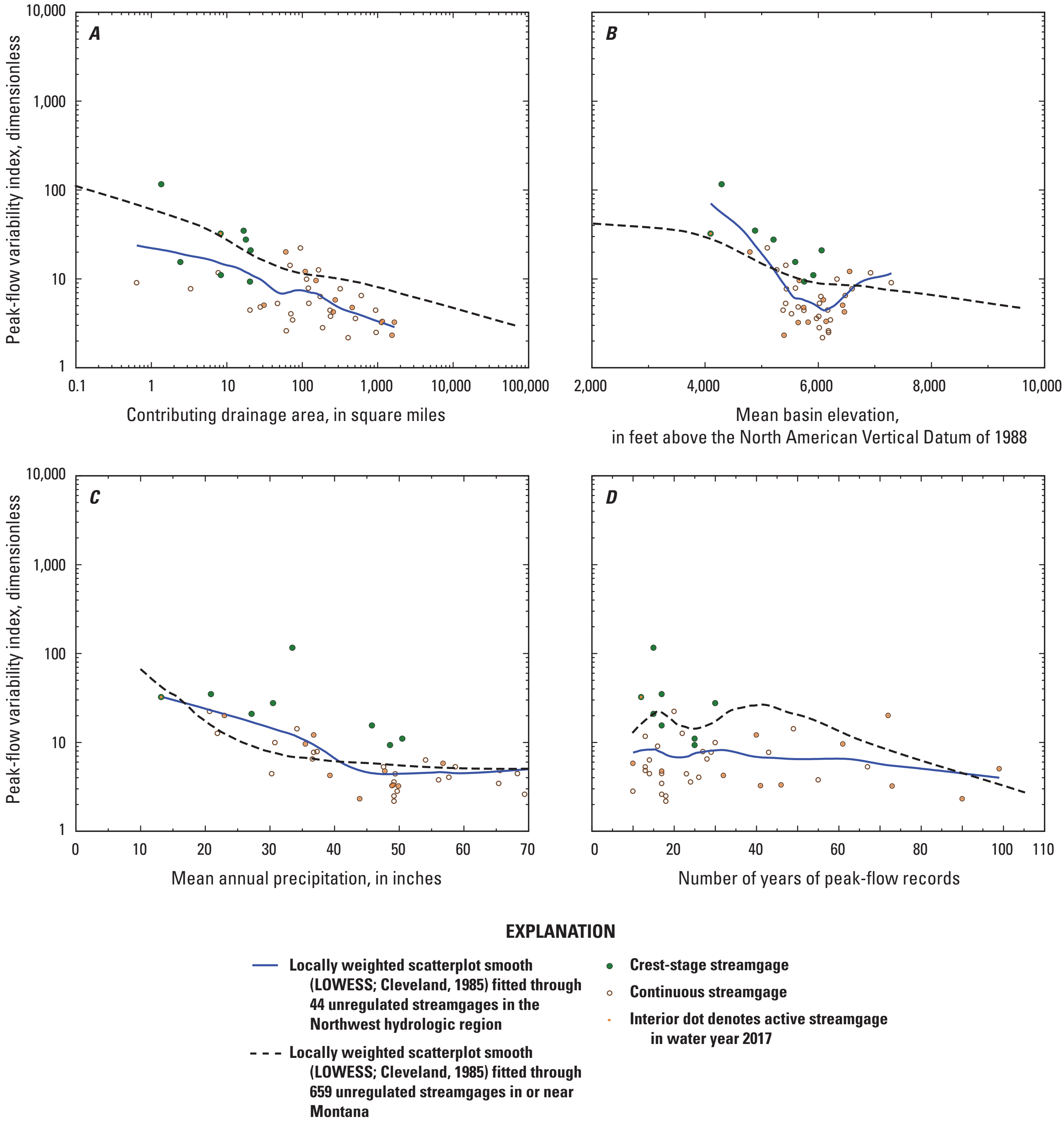


Figure 9. Relations between peak-flow variability index and contributing drainage area, mean basin elevation, mean annual precipitation, and years of peak-flow records for 44 unregulated streamgages in the Northwest hydrologic region. *A*, peak-flow variability and contributing drainage area relations. *B*, Peak-flow variability and mean basin elevation relations. *C*, Peak-flow variability and mean annual precipitation relations. *D*, Peak-flow variability and years of peak-flow records relations.

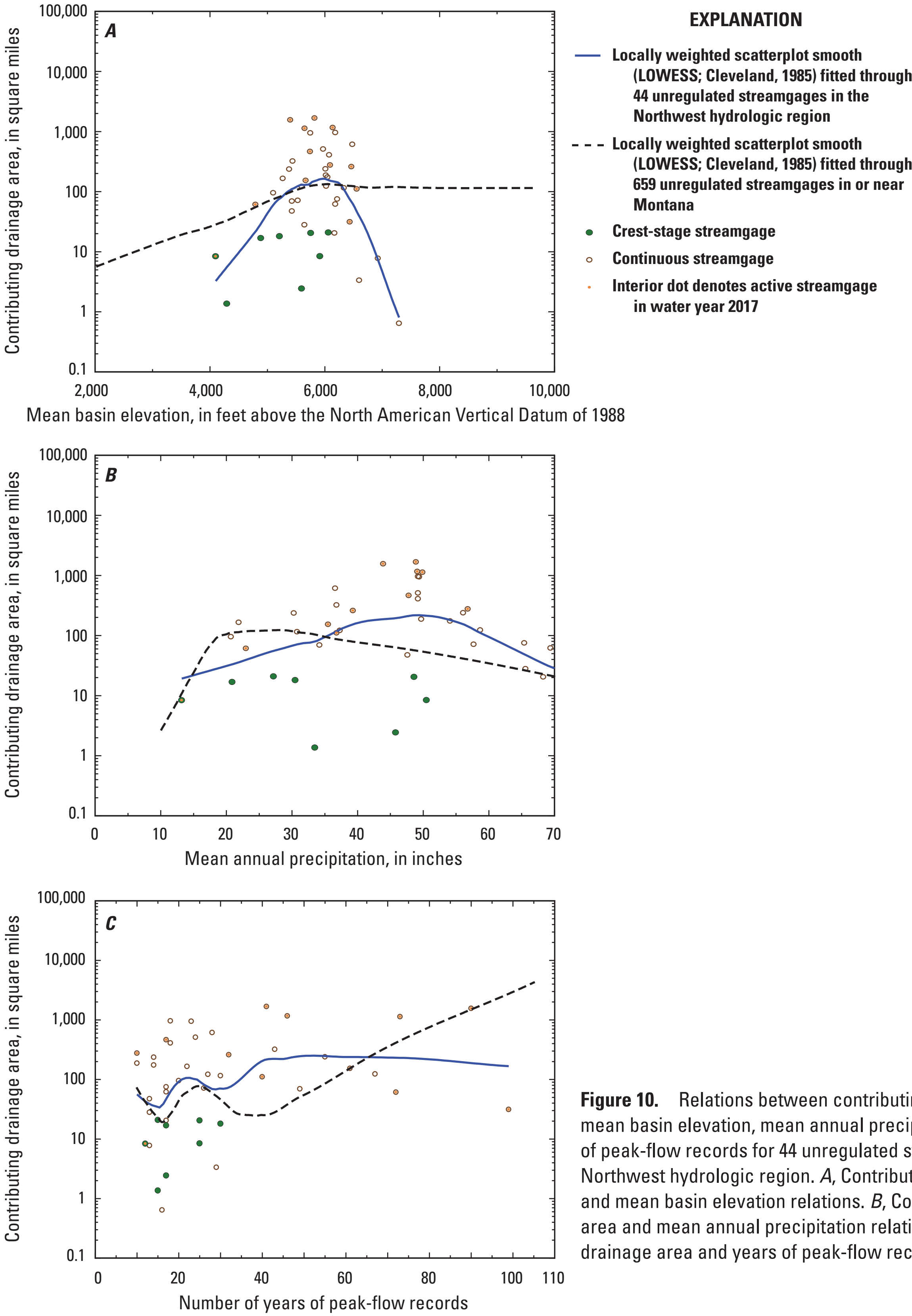


Figure 10. Relations between contributing drainage area and mean basin elevation, mean annual precipitation, and years of peak-flow records for 44 unregulated streamgages in the Northwest hydrologic region. *A*, Contributing drainage area and mean basin elevation relations. *B*, Contributing drainage area and mean annual precipitation relations. *C*, Contributing drainage area and years of peak-flow records relations.

Information on streamgages in the Northwest hydrologic region with significant leverage and influence is presented in table 14. Three of the four significant leverage streamgages have high *CONTDA* values (nonexceedance percentiles greater than about 93 percent) and one streamgage has a low *CONTDA* value (nonexceedance percentile less than about 4 percent). Three of the four streamgages with significant influence have positive residuals for the 1-percent AEP RRE.

In general, the streamgage network in the Northwest hydrologic region is considered to provide generally reasonable representation of the hydroclimatic settings of that hydrologic region. The RREs of the Northwest hydrologic region are considered to be generally reliable but are affected by a large proportion of mixed-population peak-flow datasets that currently (2020) are not well handled in the Bulletin 17C frequency-analysis approaches and are noted as needing further research (England and others, 2019). Possible shortcomings of the streamgage network in the Northwest hydrologic region include possible underrepresentation of basins with drainage area less than about 125 mi^2, mean basin elevation less than about 5,400 ft, and (or) mean annual precipitation less than about 37 inches. Future improvements to the streamgage network in the Northwest hydrologic region might include establishing new CSGs or reactivating discontinued streamgages as CSGs on drainage basins with the specified characteristics. Information on discontinued streamgages in the Northwest hydrologic region that might be candidates for reactivation to improve the streamgage network is presented in table 15.

Peak-Flow Variability, Peak-Flow Informational Needs, and Consideration of Regional Regression Analyses in the Northwest Foothills Hydrologic Region

The Northwest Foothills hydrologic region has an area of 10,624 mi^2 (table 1), which ranks seventh largest among the eight hydrologic regions. Level III ecoregions (table 2) represented in the Northwest Foothills hydrologic region include the Middle Rockies (1.8 percent), Northwestern Glaciated Plains (98.1 percent), and Northwestern Great Plains (0.2 percent). The 1,043 road and stream intersections in the Northwest Foothills hydrologic region (tables 4 and 5) represent a density of 0.098 road and stream intersection per mi^2, which ranks third among the hydrologic regions. The 46 streamgages (both regulated and unregulated; tables 4 and 5) represent an areal density of 0.00433 streamgage per mi^2 (ranking fifth among hydrologic regions) and a density of 0.04410 streamgage per road and stream intersection (ranking seventh among hydrologic regions).

Relations between *PFVI* and contributing drainage area, mean basin elevation, mean annual precipitation, and years of peak-flow records for 40 unregulated streamgages in the Northwest Foothills hydrologic region (table 3) are presented in figure 12. In general, the small number of unregulated streamgages in the Northwest Foothills hydrologic region relative to the other hydrologic regions makes it more difficult to discern clear patterns in the various relations.

For 40 unregulated streamgages in the Northwest Foothills hydrologic region, *PFVI* generally monotonically decreases with increasing drainage area (fig. 12*A*) with generally small and consistent variability about the LOWESS line. Intuitively, highly variable small-scale hydroclimatic processes are integrated with increasing drainage area such that variability in many hydrologic characteristics is reduced. *PFVI* also generally decreases with increasing elevation (fig. 12*B*), and precipitation (fig. 12*C*). The small number of streamgages with more than 40 years of peak-flow records makes it difficult to discern clear patterns in the *PFVI* and years of record relations (fig. 12*D*). For the relations between *PFVI* and drainage area (fig. 12*A*), elevation (fig. 12*B*), and years of record (fig. 12*D*), the LOWESS lines for the Northwest Foothills hydrologic region generally are similar to the LOWESS lines for all unregulated streamgages in Montana.

Relations between contributing drainage area and mean basin elevation, mean annual precipitation, and years of peak-flow records for the unregulated streamgages are presented in figure 13. Relations between contributing drainage area and mean basin elevation (fig. 13*A*) indicate that streamgages with smaller drainage areas (less than about 30 mi^2) are predominantly located at lower elevations (ranging from about 2,740 to 4,550 ft) and streamgages with larger drainage areas (greater than about 50 mi^2) are predominantly located at higher elevations (ranging from about 3,440 to 6,385 ft). Similarly, relations between contributing drainage area and mean annual precipitation (fig. 13*B*) indicate that streamgages with smaller drainage areas (less than about 30 mi^2) are predominantly located in lower mean annual precipitation areas (ranging from about 10 to 17 inches) and streamgages with larger drainage areas (greater than about 50 mi^2) are predominantly located at higher elevations (ranging from about 12 to 25 inches). Streamgages with greater than about 40 years of record are predominantly located on streams with contributing drainage areas greater than about 100 mi^2 (fig. 13*C*).

The median *PFVI* value for streamgages in the Northwest Foothills hydrologic region (27.17, table 3) is larger than the median for all unregulated streamgages in Montana (18.26, table 3) and ranks as the fourth largest median *PFVI* among the eight hydrologic regions. For unregulated streamgages in the Northwest Foothills hydrologic region, fall and winter (October–February) precipitation accounts for about 17.5 percent of annual precipitation (table 8), which is less than any other hydrologic region. May–June precipitation accounts for about 36.7 percent of annual precipitation (table 8), which ranks second among the hydrologic regions, and July–August precipitation accounts for 21.1 percent of annual precipitation, which ranks third among the eight hydrologic regions. In the Northwest Foothills hydrologic region, annual peak flows are most frequently in March and June (fig. 2 of Sando, R., and others, 2018), probably resulting from low-elevation snowmelt runoff and springtime rainfall runoff, respectively;

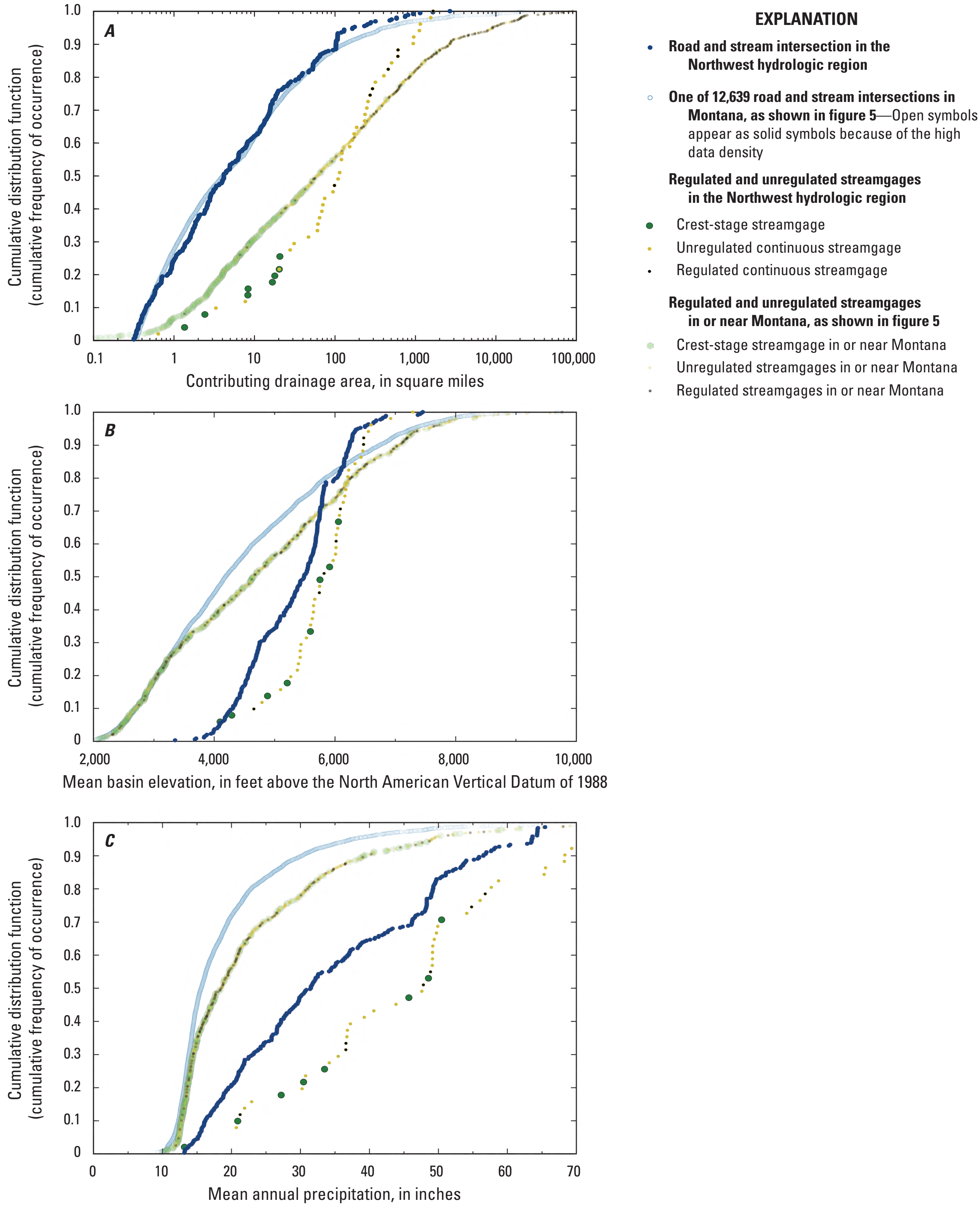


Figure 11. Cumulative distribution functions of selected drainage-basin characteristics for 356 road and stream intersections and for 49 streamgages (regulated and unregulated) in the Northwest hydrologic region. *A*, Contributing drainage area relations. *B*, Mean basin elevation relations. *C*, Mean annual precipitation relations.

Table 14. Information on streamgages in the Northwest hydrologic region with significant leverage and influence in the Montana regional regression analyses (Sando, R., and others, 2018).

[NAD 83, North American Datum of 1983; *n*, total number of years of peak-flow records; *CONTDA*, contributing drainage area, in square miles; AEP, annual exceedance probability; CONT, continuous streamgage; CSG, crest-stage gage]

Map number (fig. 1)	Station identification number	Station name	Latitude, in decimal degrees (NAD 83)	Longitude, in decimal degrees (NAD 83)	Type of streamgage	Status of streamgage in water year 2017	*n*	*CONTDA*	Nonexceedance percentile[1] for *CONTDA*	Regression residuals for the specified annual AEP regression analyses		
										10-percent AEP	4-percent AEP	1-percent AEP
Streamgages with significant leverage												
700	12355500	North Fork Flathead River near Columbia Falls, Montana	48.4958	−114.1268	CONT	Active	95	1,556	100.0	0.035	−0.023	−0.063
705	[2]12357300	Moccasin Creek near West Glacier, Montana	48.4811	−113.8479	CSG	Discontinued	17	2.43	3.1	0.363	0.409	0.465
708	[2]12358500	Middle Fork Flathead River near West Glacier, Montana	48.4955	−114.0102	CONT	Active	78	1,125	93.8	0.198	0.177	0.191
711	12359800	South Fork Flathead River above Twin Creek, near Hungry Horse, Montana	47.9791	−113.5607	CONT	Active	51	1,159	96.9	0.105	0.009	−0.119
Streamgages with significant influence												
9	05014500	Swiftcurrent Creek at Many Glacier, Montana	48.7988	−113.6567	CONT	Active	104	31.2	31.3	0.181	0.117	0.032
272	06133500	North Fork Milk River above St. Mary Canal, near Browning, Montana	48.9708	−113.0560	CONT	Active	77	60.8	37.5	−0.234	−0.189	−0.168
705	[2]12357300	Moccasin Creek near West Glacier, Montana	48.4811	−113.8479	CSG	Discontinued	17	2.43	3.1	0.363	0.409	0.465
708	[2]12358500	Middle Fork Flathead River near West Glacier, Montana	48.4955	−114.0102	CONT	Active	78	1,125	93.8	0.198	0.177	0.191

[1]The nonexceedance percentile for the basin or climatic variable value was calculated in relation to the values for all streamgages included in the regional regression analyses for the indicated hydrologic region.

[2]Streamgages having both significant leverage and significant influence.

Table 15. Information on discontinued streamgages in the Northwest hydrologic region that might be candidates for reactivation to improve the streamgage network.

[NAD 83, North American Datum of 1983; *n*, total number of years of peak-flow records; *CONTDA*, contributing drainage area, in square miles; CONT, continuous streamgage; CSG, crest-stage gage]

Map number (fig. 1)	Station identification number	Station name	Latitude, in decimal degrees (NAD 83)	Longitude, in decimal degrees (NAD 83)	Type of streamgage	*n*	*CONTDA*	Nonexceedance percentile[1] for *CONTDA*
3	05011500	Waterton River near international boundary	48.9550	−113.8999	CONT	17	61.8	40.6
4	05012500	Boundary Creek at international boundary	48.9958	−113.9077	CONT	17	20.4	18.8
6	05013700	St. Mary River above Swiftcurrent Creek, near Babb, Montana	48.8509	−113.4162	CONT	14	174	71.9
10	05015000	Canyon Creek near Many Glacier, Montana	48.7960	−113.6242	CONT	13	7.74	6.3
130	06079600	Beaver Creek at Gibson Dam, near Augusta, Montana	47.6023	−112.7575	CSG	15	20.8	25.0
133	06081500	Willow Creek near Augusta, Montana	47.5455	−112.4737	CONT	20	95.1	50.0
134	06084500	Elk Creek at Augusta, Montana	47.4854	−112.3875	CONT	22	165	68.8
156	06097100	Blacktail Creek near Heart Butte, Montana	48.2488	−112.7891	CSG	17	16.8	12.5
702	12356000	Skyland Creek near Essex, Montana	48.2919	−113.3871	CONT, CSG	25	8.38	9.4
703	12356500	Bear Creek near Essex, Montana	48.2800	−113.4253	CONT, CSG	25	20.4	18.8
704	12357000	Middle Fork Flathead River at Essex, Montana	48.2751	−113.6051	CONT	24	509	87.5
705	12357300	Moccasin Creek near West Glacier, Montana	48.4811	−113.8479	CSG	17	2.43	3.1
710	12359500	Spotted Bear River near Hungry Horse, Montana	47.9280	−113.5206	CONT	10	187	75.0
712	12360000	Twin Creek near Hungry Horse, Montana	47.9848	−113.5613	CONT	13	47.2	34.4
714	12361500	Graves Creek near Hungry Horse, Montana	48.1279	−113.8121	CONT	13	27.9	28.1

[1]The nonexceedance percentile for the basin or climatic variable value was calculated in relation to the values for all streamgages included in the regional regression analyses for the indicated hydrologic region.

however, substantial proportions of annual peak flows also are in February, April–May, and July. Generally small accumulated snowpacks, variability in the timing and magnitude of low-elevation snowmelt runoff, and variability in spring and summer rainfall might contribute to greater peak-flow variability in the Northwest Foothills hydrologic region than for Montana as a whole.

About 22 percent of the streamgages in the Northwest Foothills hydrologic region are considered to have mixed-population characteristics (table 1) that result in a small number of unusually large peak flows that are substantially larger than the main body of peak flows. Typically, the unusually large peak-flow events result from extremely intense rainfall events in May and June. Mixed-population peak-flow datasets often are in streamgages with headwaters on or near the Continental Divide, which applies to some of the streamgages with larger drainage areas in the Northwest Foothills hydrologic region. For some streamgages in the Northwest Foothills hydrologic region, unusual rapid snowmelt events during winter, sometimes in association with rainfall, can contribute to the mixed-population peak-flow datasets. All of the mixed-population streamgages in the Northwest Foothills hydrologic region that were included in the regional regression analysis (Sando, R., and others, 2018) had positive residuals for the 1-percent AEP regression; however, none of those mixed-population streamgages had significant influence. Among the candidate explanatory variables included in the regional regression analyses, there are no variables that represent spatial variability in precipitation intensity (such as indices of the 100-year 24-hour precipitation; for example, U.S. Weather Bureau, 1961). Inclusion of variables that represent spatial variability in precipitation intensity might help address some mixed-population issues and improve potential future regional regression analyses in the Northwest Foothills hydrologic region.

The CDFs of selected basin characteristics (drainage area, mean basin elevation, and mean annual precipitation) for the road and stream intersections and for the streamgages in the Northwest Foothills hydrologic region are shown in figure 14. With respect to drainage area, the CDF of road and stream intersections for the Northwest Foothills hydrologic region generally is similar to the CDF of road and stream intersections for all of Montana (fig. 14*A*). In the Northwest Foothills hydrologic region, the CDF of streamgages diverges from the CDF of road and stream intersections in the range of drainage areas less than about 225 mi^2, indicating underrepresentation in that range. But, for drainage areas less than about 30 mi^2, the Northwest Foothills streamgage CDF indicates greater representation than for the Montana streamgage CDF. Thus, the strongest underrepresentation in the Northwest Foothills hydrologic region might be in the range of drainage areas from about 30 to 225 mi^2.

The Northwest Foothills hydrologic region generally is lower in elevation than Montana as a whole. Mean basin elevation for road and stream intersections in the Northwest Foothills hydrologic region ranges from 2,780 to 6,401 ft (Dutton and others, 2021) with a median of 3,735 ft (table 4). The range for the Northwest Foothills hydrologic region is smaller than for all of Montana (1,951–9,974 ft; Dutton and others, 2021) and the median for the Northwest Foothills hydrologic region is less than for all of Montana (4,173 ft; table 4). There are substantial differences between the CDFs of road and stream intersections for the Northwest Foothills hydrologic region relative to the CDFs of road and stream intersections for all of Montana (fig. 14*B*). In the Northwest Foothills hydrologic region, the CDF of streamgages diverges from the CDF of road and stream intersections in the range of mean basin elevations from about 4,000 to 4,600 ft, indicating underrepresentation in that range.

The Northwest Foothills hydrologic region generally is drier than Montana as a whole. Mean annual precipitation for road and stream intersections in the Northwest Foothills hydrologic region ranges from 9.9 to 31.2 inches (Dutton and others, 2021) with a median of 13.0 inches (table 5). The range for the Northwest Foothills hydrologic region is smaller than for all of Montana (8.4–91.3 inches; Dutton and others, 2021) and the median for the Northwest Foothills hydrologic region is somewhat smaller than for all of Montana (15.7 inches; table 5). There are substantial differences between the CDFs of road and stream intersections for the Northwest Foothills hydrologic region relative to the CDFs of road and stream intersections for all of Montana (fig. 14*C*). In the Northwest Foothills hydrologic region, the CDF of streamgages diverges from the CDF of road and stream intersections in the range of mean annual precipitation from about 14 to 18 inches, indicating underrepresentation in that range.

The explanatory variables for the Northwest Foothills hydrologic region RREs are *CONTDA* and *PRECIP* (table 6). The 1-percent AEP RRE for the Northwest Foothills hydrologic region has an SEP of 65.8 percent, which is similar the area-weighted mean SEP for all hydrologic regions in Montana (63.3 percent; table 6). For the 1-percent AEP regression for the Northwest Foothills hydrologic region, 9.7 percent of the streamgages have significant leverage and 9.7 percent of the streamgages have significant influence (table 7); these percentages generally are similar to significant leverage and influence percentages (8.2 and 10.4 percent, respectively; table 7) for all of the streamgages in Montana used in the regional regression analyses.

Information on streamgages in the Northwest Foothills hydrologic region with significant leverage and influence is presented in table 16. Two of the four significant leverage streamgages have high *CONTDA* values (nonexceedance percentiles greater than about 83 percent) in conjunction with large *PRECIP* values (nonexceedance percentiles greater than about 96 percent). One streamgage has a small *CONTDA* value in conjunction with a small *PRECIP* value (nonexceedance percentile less than about 16 percent). The three streamgages with significant influence vary with respect to the residuals for the 1-percent AEP RRE; two of the streamgages have negative residuals, and one has a positive residual. The

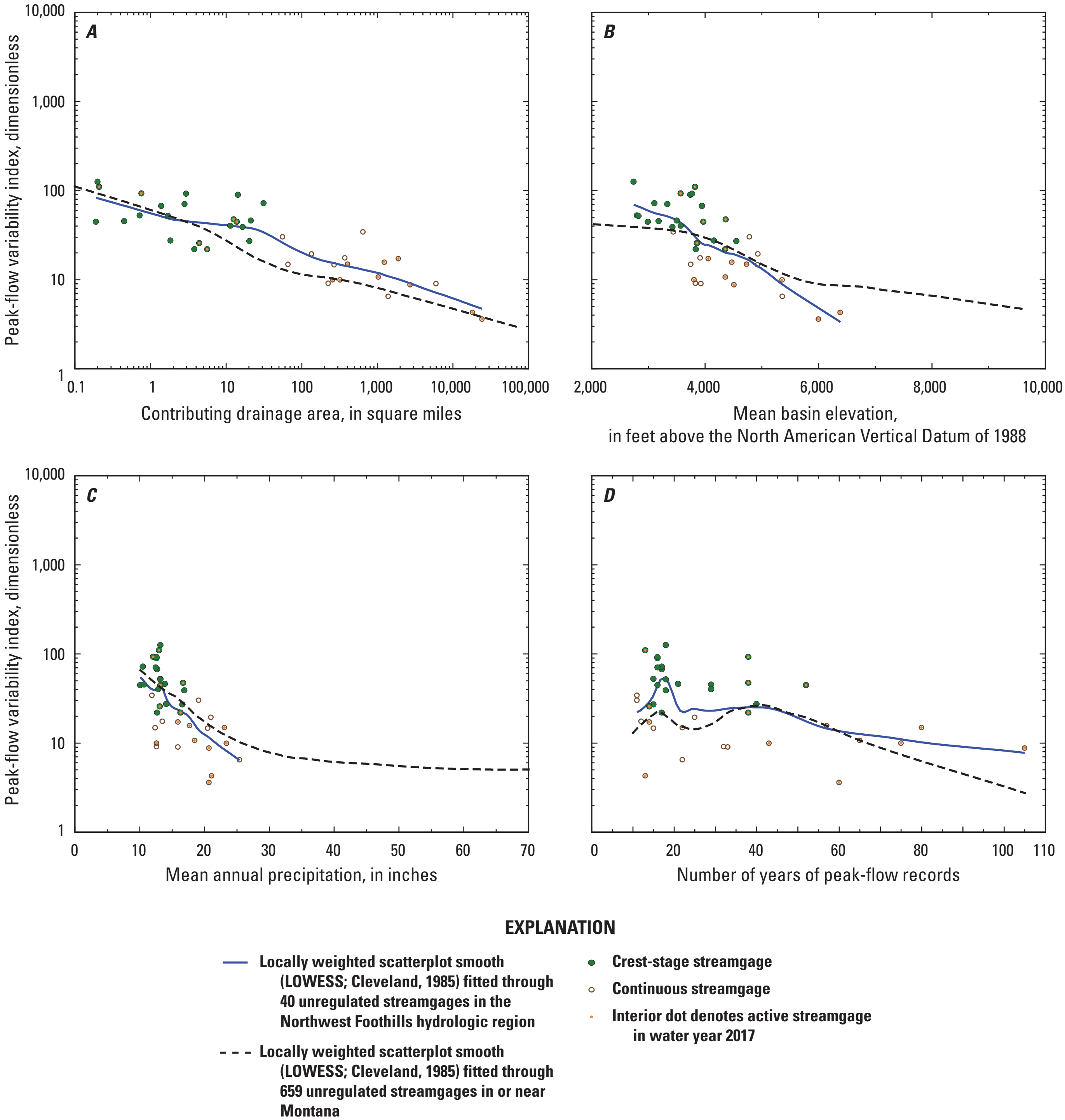


Figure 12. Relations between peak-flow variability index and contributing drainage area, mean basin elevation, mean annual precipitation, and years of peak-flow records for 40 unregulated streamgages in the Northwest Foothills hydrologic region. *A*, Peak-flow variability and contributing drainage area relations. *B*, Peak-flow variability and mean basin elevation relations. *C*, Peak-flow variability and mean annual precipitation relations. *D*, Peak-flow variability and years of peak-flow records relations.

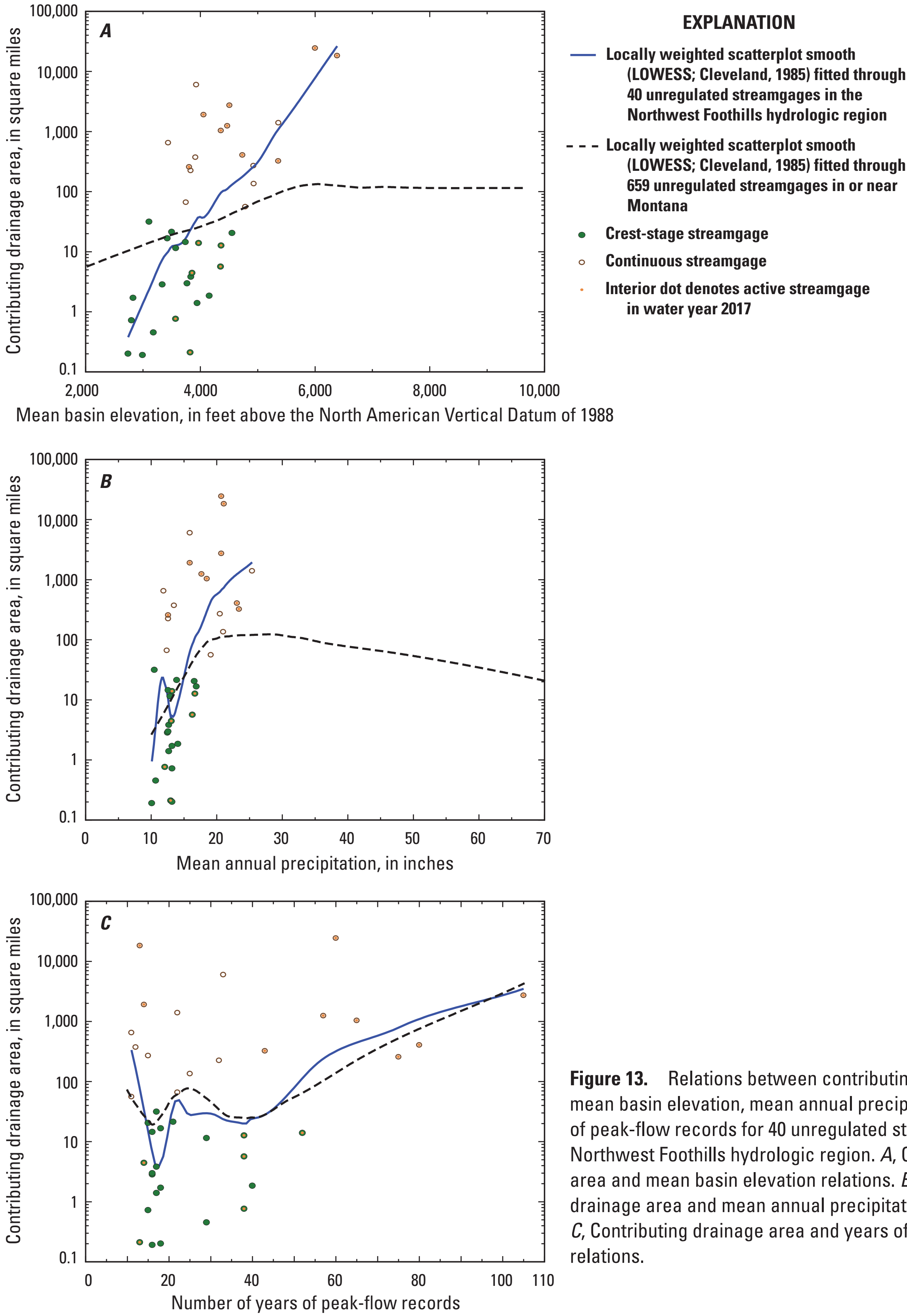


Figure 13. Relations between contributing drainage area and mean basin elevation, mean annual precipitation, and years of peak-flow records for 40 unregulated streamgages in the Northwest Foothills hydrologic region. *A*, Contributing drainage area and mean basin elevation relations. *B*, Contributing drainage area and mean annual precipitation relations. *C*, Contributing drainage area and years of peak-flow records relations.

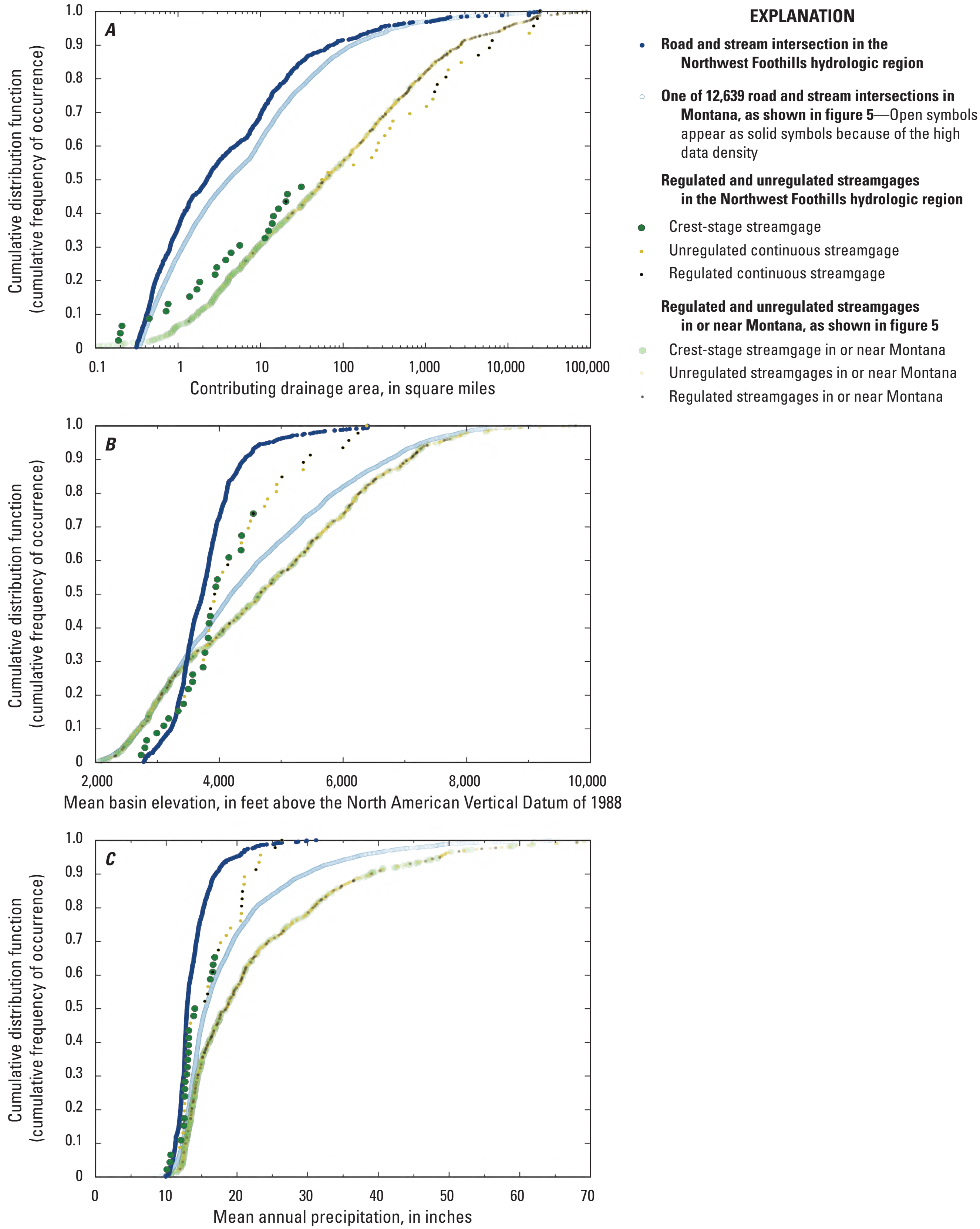


Figure 14. Cumulative distribution functions of selected drainage-basin characteristics for 1,043 road and stream intersections and for 46 streamgages (regulated and unregulated) in the Northwest Foothills hydrologic region. *A*, Contributing drainage area relations. *B*, Mean basin elevation relations. *C*, Mean annual precipitation relations.

streamgage with both significant leverage and significant influence has a small drainage area, low precipitation, and a negative residual.

In general, the streamgage network in the Northwest Foothills hydrologic region is considered to provide generally reasonable representation of the hydroclimatic settings of that hydrologic region. The RREs of the Northwest Foothills hydrologic region are considered to be reasonably reliable. Possible shortcomings of the streamgage network in the Northwest Foothills hydrologic region include possible underrepresentation of basins with drainage area from about 30 to 225 mi^2, mean elevation from about 4,000 to 4,600 ft, and (or) mean annual precipitation from about 14 to 18 inches. Future improvements to the streamgage network in the Northwest Foothills hydrologic region might include establishing new CSGs or reactivating discontinued streamgages as CSGs on drainage basins with the specified characteristics. Information on discontinued streamgages in the Northwest Foothills hydrologic region that might be candidates for reactivation to improve the streamgage network is presented in table 17.

Peak-Flow Variability, Peak-Flow Informational Needs, and Consideration of Regional Regression Analyses in the Northeast Plains Hydrologic Region

The Northeast Plains hydrologic region has an area of 22,059 mi^2 (table 1), which ranks third largest among the eight hydrologic regions. Level III ecoregions (table 2) represented in the Northeast Plains hydrologic region include the Middle Rockies (2.2 percent), Northwestern Glaciated Plains (81.2 percent), and Northwestern Great Plains (16.6 percent). The 1,470 road and stream intersections in the Northeast Plains hydrologic region (tables 4 and 5) represent a density of 0.067 road and stream intersection per mi^2, which ranks sixth among the hydrologic regions. The 88 streamgages (both regulated and unregulated; tables 4 and 5) represent an areal density of 0.00399 streamgage per mi^2 (ranking eighth among hydrologic regions) and a density of 0.05986 streamgage per road and stream intersection (ranking third among hydrologic regions).

Relations between *PFVI* and contributing drainage area, mean basin elevation, mean annual precipitation, and years of peak-flow records for 76 unregulated streamgages in the Northeast Plains hydrologic region (table 3) are presented in figure 15. For the 76 unregulated streamgages, *PFVI* generally monotonically decreases with increasing drainage area (fig. 15*A*) with generally small and consistent variability about the LOWESS line. Intuitively, highly variable small-scale hydroclimatic processes are integrated with increasing drainage area such that variability in many hydrologic characteristics is reduced. For the relation between *PFVI* and drainage area (fig. 15*A*), the LOWESS line for the Northeast Plains hydrologic region is consistently above the LOWESS line for all unregulated streamgages in Montana. For streamgages in the Northeast Plains hydrologic region, mean basin elevation and mean annual precipitation are within small ranges, and it is difficult to discern clear patterns in the relations between *PFVI* and those variables (figs. 15*B* and 15*C*); however, within the small ranges, the LOWESS lines for the Northeast Plains region generally are similar to the LOWESS lines for all unregulated streamgages in Montana. The relation between *PFVI* and years of peak-flow records for the Northeast Plains hydrologic region generally is similar to the relation for all unregulated streamgages in Montana, but the LOWESS line for the Northeast Plains hydrologic region is consistently above the LOWESS line for all unregulated streamgages in Montana (fig. 15*D*).

Relations between contributing drainage area and mean basin elevation, mean annual precipitation, and years of peak-flow records for the unregulated streamgages are presented in figure 16. In the various relations, the LOWESS lines for the Northeast Plains hydrologic region generally are similar to the LOWESS lines for all unregulated streamgages in Montana.

The median *PFVI* value for streamgages in the Northeast Plains hydrologic region (32.05, table 3) is substantially larger than the median for all unregulated streamgages in Montana (18.26, table 3) and ranks as the third largest median *PFVI* among the eight hydrologic regions. For unregulated streamgages in the Northeast Plains hydrologic region, fall and winter (October–February) precipitation accounts for about 18.7 percent of annual precipitation (table 8), which ranks sixth largest among the eight hydrologic regions. May–June precipitation accounts for about 37.1 percent of annual precipitation (table 8), which ranks first among the hydrologic regions, and July–August precipitation accounts for 23.5 percent of annual precipitation, which ranks second among the eight hydrologic regions. In the Northeast Plains hydrologic region, annual peak flows are most frequently in March (fig. 2 of Sando, R., and others, 2018), probably resulting from low-elevation snowmelt runoff; however, substantial proportions of annual peak flows also are in April–July. Generally small accumulated snowpacks, variability in the timing and magnitude of low-elevation snowmelt runoff, and variability in spring and summer rainfall might contribute to greater peak-flow variability in the Northeast Plains hydrologic region than for Montana as a whole.

About 1.4 percent of the streamgages in the Northeast Plains hydrologic region are considered to have mixed-population characteristics (table 1) that result in a small number of unusually large peak flows that are substantially larger than the main body of peak flows. Mixed-population peak-flow datasets are not a substantial consideration in the Northeast Plains hydrologic region.

The CDFs of selected basin characteristics (drainage area, mean basin elevation, and mean annual precipitation) for the road and stream intersections and for the streamgages in the Northeast Plains hydrologic region are shown in figure 17. With respect to drainage area, the CDF of road and stream intersections for the Northeast Plains hydrologic region is similar to the CDF of road and stream intersections for all

Table 16. Information on streamgages in the Northwest Foothills hydrologic region with significant leverage and influence in the Montana regional regression analyses (Sando, R., and others, 2018).

[ID, identification; NAD 83, North American Datum of 1983; n, total number of years of peak-flow records; *CONTDA*, contributing drainage area, in square miles; *PRECIP*, mean annual precipitation, in inches; AEP, annual exceedance probability; CONT, continuous streamgage; CSG, crest-stage gage]

Map number (fig. 1)	Streamgage ID number	Streamgage name	Latitude, in decimal degrees (NAD 83)	Longitude, in decimal degrees (NAD 83)	Type of streamgage	Status of streamgage in water year 2017	*n*	*CONTDA*, in square miles	Non-exceedance percentile[1] for *CONTDA*	*PRECIP*	Non-exceedance percentile[1] for *PRECIP*	Regression residuals for the specified AEP regression analyses		
												10-percent AEP	4-percent AEP	1-percent AEP
Streamgages with significant leverage														
113	06073500	Dearborn River near Craig, Montana	47.1990	−112.0959	CONT	Active	48	322	83.9	23.4	100.0	0.143	0.081	0.015
139	06088500	Muddy Creek at Vaughn, Montana	47.5613	−111.5418	CONT	Active	80	256	77.4	12.6	29.0	0.215	0.107	−0.002
167	[2]06101520	Favot Coulee tributary near Ledger, Montana	48.2630	−111.7034	CSG	Active	43	0.76	16.1	12.1	16.1	−0.091	−0.189	−0.347
271	06133000	Milk River at western crossing of international boundary	49.0075	−112.5453	CONT	Active	85	405	90.3	23.1	96.8	−0.023	−0.056	−0.101
Streamgages with significant influence														
145	06090650	Lake Creek near Power, Montana	47.7079	−111.4092	CONT	Discontinued	26	66.1	71.0	12.4	19.4	−0.482	−0.625	−0.795
167	[2]06101520	Favot Coulee tributary near Ledger, Montana	48.2630	−111.7034	CSG	Active	43	0.76	16.1	12.1	16.1	−0.091	−0.189	−0.347
170	06101700	Fey Coulee tribuary near Chester, Montana	48.4479	−111.0805	CSG	Discontinued	29	0.45	9.7	10.7	9.7	0.695	0.718	0.758

[1]The nonexceedance percentile for the basin or climatic variable value was calculated in relation to the values for all streamgages included in the regional regression analyses for the indicated hydrologic region.

[2]Streamgages having both significant leverage and significant influence.

Table 17. Information on discontinued streamgages in the Northwest Foothills hydrologic region that might be candidates for reactivation to improve the streamgage network.

[NAD 83, North American Datum of 1983; *n*, total number of years of peak-flow records; *CONTDA*, contributing drainage area, in square miles; *PRECIP*, mean annual precipitation, in inches; CSG, crest-stage gage; CONT, continuous streamgage]

Map number (fig. 1)	Station identification number	Station name	Latitude, in decimal degrees (NAD 83)	Longitude, in decimal degrees (NAD 83)	Type of streamgage	*n*	*CONTDA*	Nonexceedance percentile[1] for *CONTDA*	*PRECIP*	Nonexceedance percentile[1] for *PRECIP*
137	06087900	Muddy Creek tributary near Power, Montana	47.7557	−111.7296	CSG	17	3.81	35.5	12.7	35.5
141	06089300	Sun River tributary near Great Falls, Montana	47.5271	−111.4019	CSG	21	21.3	61.3	13.9	61.3
145	06090650	Lake Creek near Power, Montana	47.7079	−111.4092	CONT	26	66.1	71.0	12.4	19.4
147	06090810	Ninemile Coulee near Fort Benton, Montana	47.7005	−110.7041	CSG	18	16.6	54.8	16.9	77.4
157	06098000	Dupuyer Creek near Valier, Montana	48.2350	−112.3982	CONT	25	135	74.2	21.0	93.5
163	06100200	Heines Coulee tributary near Valier, Montana	48.2489	−112.2290	CSG	17	1.39	19.4	12.7	38.7
165	06100500	Dry Fork Marias River at Fowler, Montana	48.3157	−111.7825	CONT	12	372	87.1	13.5	58.1
168	06101560	Pondera Coulee near Chester, Montana	48.2705	−111.1458	CONT	11	648	93.5	11.9	12.9
169	06101600	Marias River tributary No. 3 near Chester, Montana	48.2310	−110.8917	CSG	16	0.19	3.2	10.1	3.2
171	06101800	Sixmile Coulee near Chester, Montana	48.3305	−110.9453	CSG	17	31.4	64.5	10.5	6.5
172	06101900	Dead Indian Coulee near Fort Benton, Montana	48.0815	−110.8379	CSG	16	2.83	29.0	12.5	22.6
175	06102100	Dry Fork Coulee tributary near Loma, Montana	47.9486	−110.5441	CSG	15	0.72	12.9	13.2	54.8
176	06102200	Marias River tributary at Loma, Montana	47.9439	−110.5146	CSG	18	1.70	22.6	13.2	51.6
177	06102300	Maris River tributary No. 2 at Loma, Montana	47.9413	−110.5058	CSG	18	0.20	6.5	13.2	48.4
181	06106000	Deep Creek near Choteau, Montana	47.7520	−112.2395	CONT	15	269	80.6	20.5	90.3
182	06107000	North Fork Muddy Creek near Bynum, Montana	47.9919	−112.3574	CONT	11	55.8	67.7	19.1	87.1
184	06108200	Kinley Coulee near Dutton, Montana	47.8428	−111.5917	CSG	16	14.4	51.6	12.6	25.8
185	06108300	Kinley Coulee tributary near Dutton, Montana	47.8428	−111.5521	CSG	16	2.96	32.3	12.6	32.3

[1]The nonexceedance percentile for the basin or climatic variable value was calculated in relation to the values for all streamgages included in the regional regression analyses for the indicated hydrologic region.

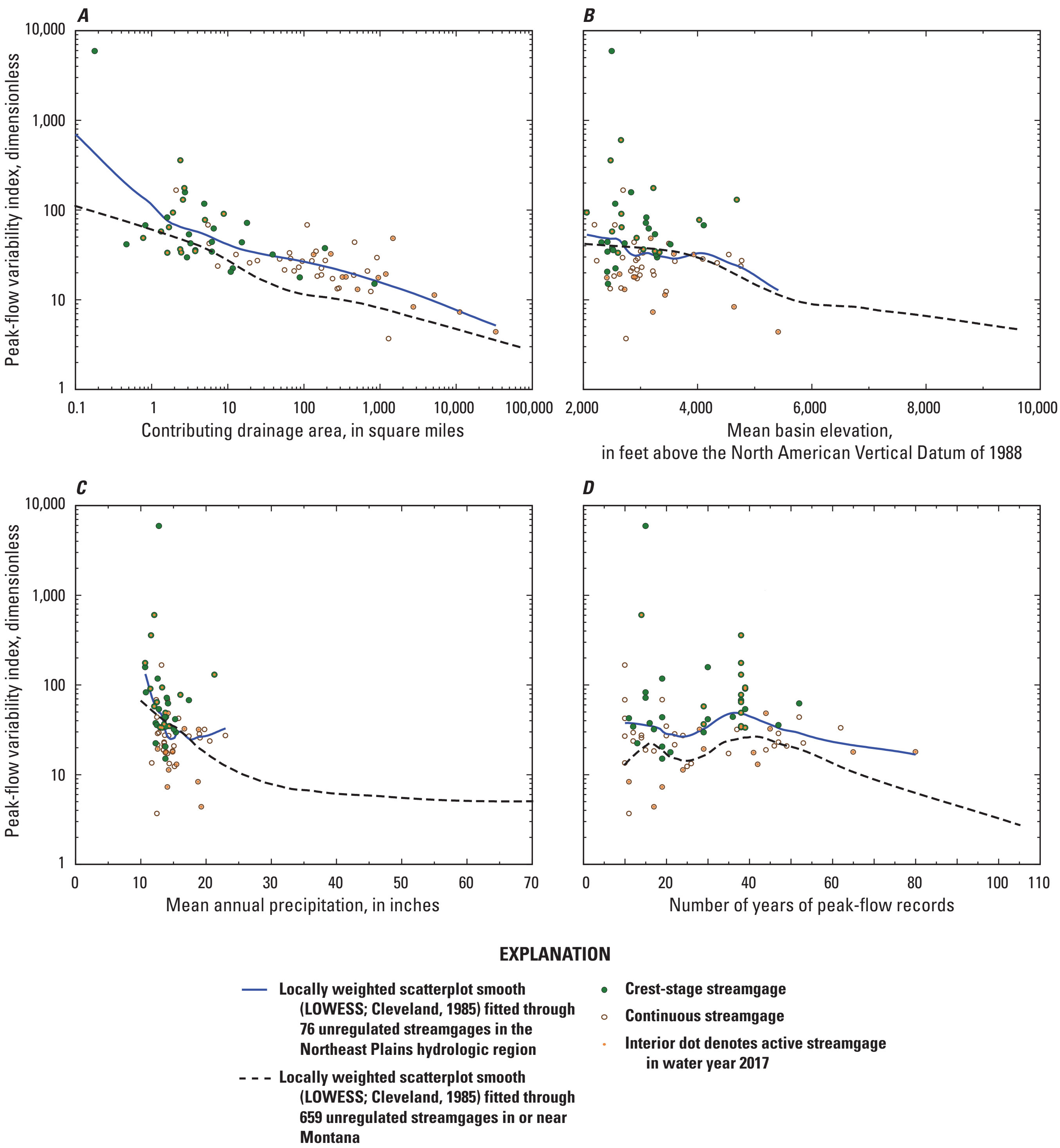


Figure 15. Relations between peak-flow variability index and contributing drainage area, mean basin elevation, mean annual precipitation, and years of peak-flow records for 76 unregulated streamgages in the Northeast Plains hydrologic region. *A*, peak-flow variability and contributing drainage area relations; *B*, peak-flow variability and mean basin elevation relations; *C*, peak-flow variability and mean annual precipitation relations; *D*, peak-flow variability and years of peak-flow records relations.

of Montana (fig. 17*A*). In the Northeast Plains hydrologic region, the CDF of streamgages diverges from the CDF of road and stream intersections in the range of drainage areas less than about 100 mi^2, indicating underrepresentation in that range, but throughout that range, the Northeast Plains streamgage CDF indicates similar representation as for the Montana streamgage CDF. Thus, with respect to drainage area, underrepresentation probably is not a substantial issue in the Northeast Plains hydrologic region.

The Northeast Plains hydrologic region generally is lower in elevation than Montana as a whole. Mean basin elevation for road and stream intersections in the Northeast Plains hydrologic region ranges from 1,984 to 6,150 ft (Dutton and others, 2021) with a median of 2,943 ft (table 4). The range for the Northeast Plains hydrologic region is smaller than for all of Montana (1,951–9,974 ft; Dutton and others, 2021) and the median for the Northeast Plains hydrologic region is less than for all of Montana (4,173 ft; table 4). There are substantial differences between the CDFs of road and stream intersections for the Northeast Plains hydrologic region relative to the CDFs of road and stream intersections for all of Montana (fig. 17*B*). With respect to mean basin elevation, the pattern of the streamgage CDF reasonably represents the road and stream intersection CDF but with small overrepresentation at elevations higher than about 3,400 ft.

The Northeast Plains hydrologic region generally is drier than Montana as a whole. Mean annual precipitation for road and stream intersections in the Northeast Plains hydrologic region ranges from 10.2 to 32.3 inches (Dutton and others, 2021) with a median of 13.4 inches (table 5). The range for the Northeast Plains hydrologic region is smaller than for all of Montana (8.4–91.3 ft; Dutton and others, 2021) and the median for the Northeast Plains hydrologic region is somewhat smaller than for all of Montana (15.7 inches; table 5). There are substantial differences between the CDFs of road and stream intersections for the Northeast Plains hydrologic region relative to the CDFs of road and stream intersections for all of Montana (fig. 17*C*). With respect to mean annual precipitation, the pattern of the streamgage CDF reasonably represents the road and stream intersection CDF but with small overrepresentation at mean annual precipitation greater than about 20 inches.

The explanatory variables for the Northeast Plains hydrologic region RREs are *CONTDA* and percentage of basin above 5,000 ft elevation (EL_{5000}; table 6). The 1-percent AEP RRE for the Northeast Plains hydrologic region has an SEP of 54.5 percent, which is less than the area-weighted mean SEP for all hydrologic regions in Montana (63.3 percent; table 6). For the 1-percent AEP regression for the Northeast Plains hydrologic region, 9.4 percent of the streamgages have significant leverage and 10.9 percent of the streamgages have significant influence (table 7); these percentages generally are similar to significant leverage and influence percentages (8.2 and 10.4 percent, respectively; table 7) for all of the streamgages in Montana used in the regional regression analyses.

Information on streamgages in the Northeast Plains hydrologic region with significant leverage and influence is presented in table 18. Five of the six significant leverage streamgages have high EL_{5000} values (nonexceedance percentiles greater than about 94 percent) and one of the six has a low EL_{5000} value (nonexceedance percentile of 1.6 percent). Five of the six streamgages with significant leverage have positive residuals for the 1-percent AEP RRE. The 10 streamgages with significant influence vary with respect to the residuals for the 1-percent AEP RRE; five of the streamgages have negative residuals, and five have positive residuals. The two streamgages with both significant leverage and significant influence have positive residuals.

In general, the streamgage network in the Northeast Plains hydrologic region is considered to provide generally reasonable representation of the hydroclimatic settings of that hydrologic region. The RREs of the Northeast Plains hydrologic region are considered to be reasonably reliable. Possible shortcomings of the streamgage network in the Northeast Plains hydrologic region include small overrepresentation of basins with mean basin elevation higher than about 3,400 ft, and (or) mean annual precipitation greater than about 20 inches. Future improvements to the streamgage network in the Northeast Plains hydrologic region might include discontinuing CSGs with the specified characteristics and (or) reactivating discontinued streamgages as CSGs on drainage basins outside of the specified characteristics. Information on discontinued streamgages in the Northeast Plains hydrologic region that might be candidates for reactivation to improve the streamgage network is presented in table 19.

Peak-Flow Variability, Peak-Flow Informational Needs, and Consideration of Regional Regression Analyses in the East-Central Plains Hydrologic Region

The East-Central Plains hydrologic region has an area of 28,451 mi^2 (table 1), which ranks first largest among the eight hydrologic regions. Level III ecoregions (table 2) represented in the East-Central Plains hydrologic region include the Northwestern Glaciated Plains (23.6 percent) and Northwestern Great Plains (76.4 percent). The 1,586 road and stream intersections in the East-Central Plains hydrologic region (tables 4 and 5) represent a density of 0.056 road and stream intersection per mi^2, which ranks seventh among the hydrologic regions. The 114 streamgages (both regulated and unregulated; tables 4 and 5) represent an areal density of 0.00401 streamgage per mi^2 (ranking seventh among hydrologic regions) and a density of 0.07188 streamgage per road and stream intersection (ranking second among hydrologic regions).

Relations between *PFVI* and contributing drainage area, mean basin elevation, mean annual precipitation, and years of peak-flow records for 102 unregulated streamgages in the East-Central Plains hydrologic region (table 3) are presented

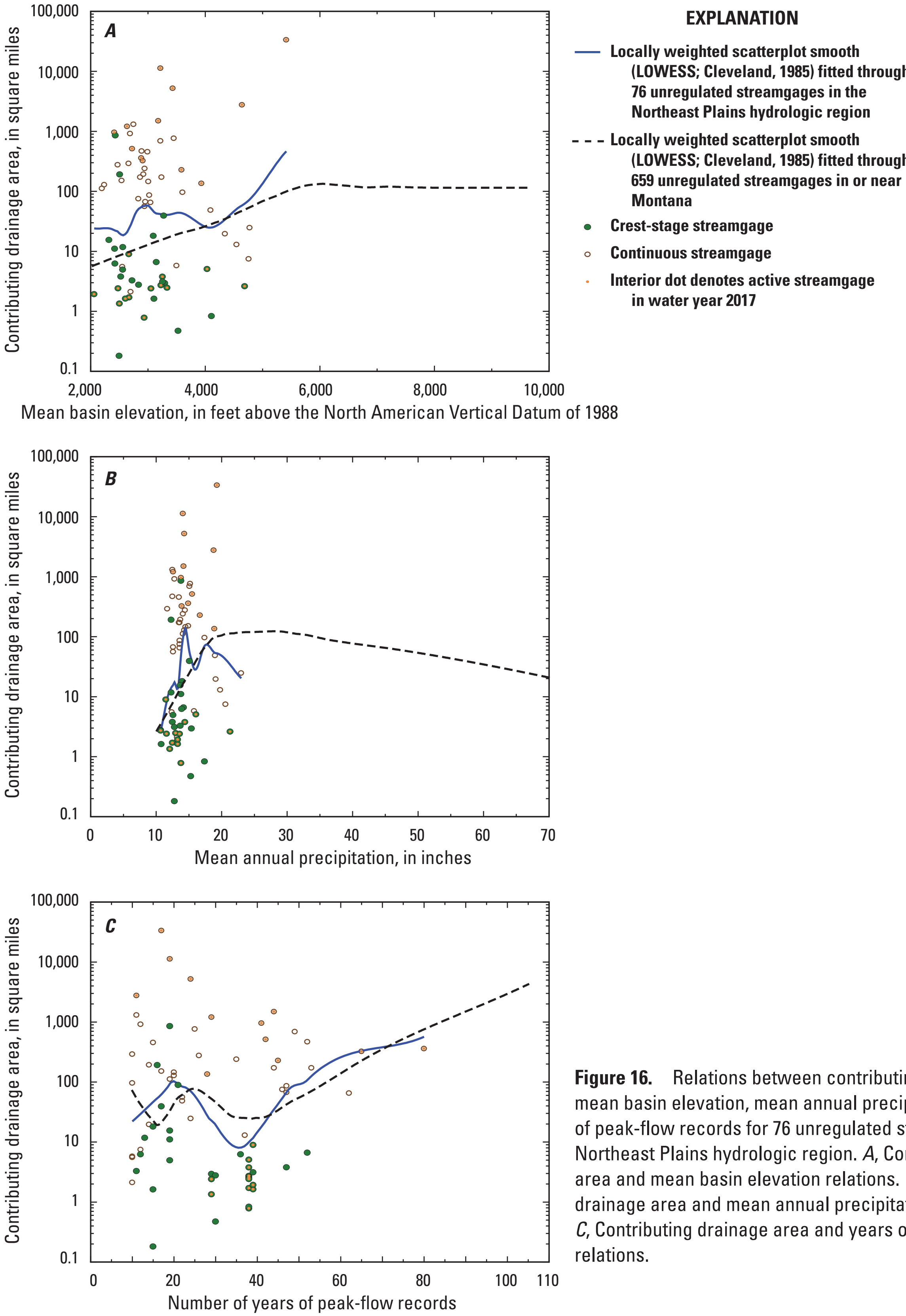


Figure 16. Relations between contributing drainage area and mean basin elevation, mean annual precipitation, and years of peak-flow records for 76 unregulated streamgages in the Northeast Plains hydrologic region. *A*, Contributing drainage area and mean basin elevation relations. *B*, Contributing drainage area and mean annual precipitation relations. *C*, Contributing drainage area and years of peak-flow records relations.

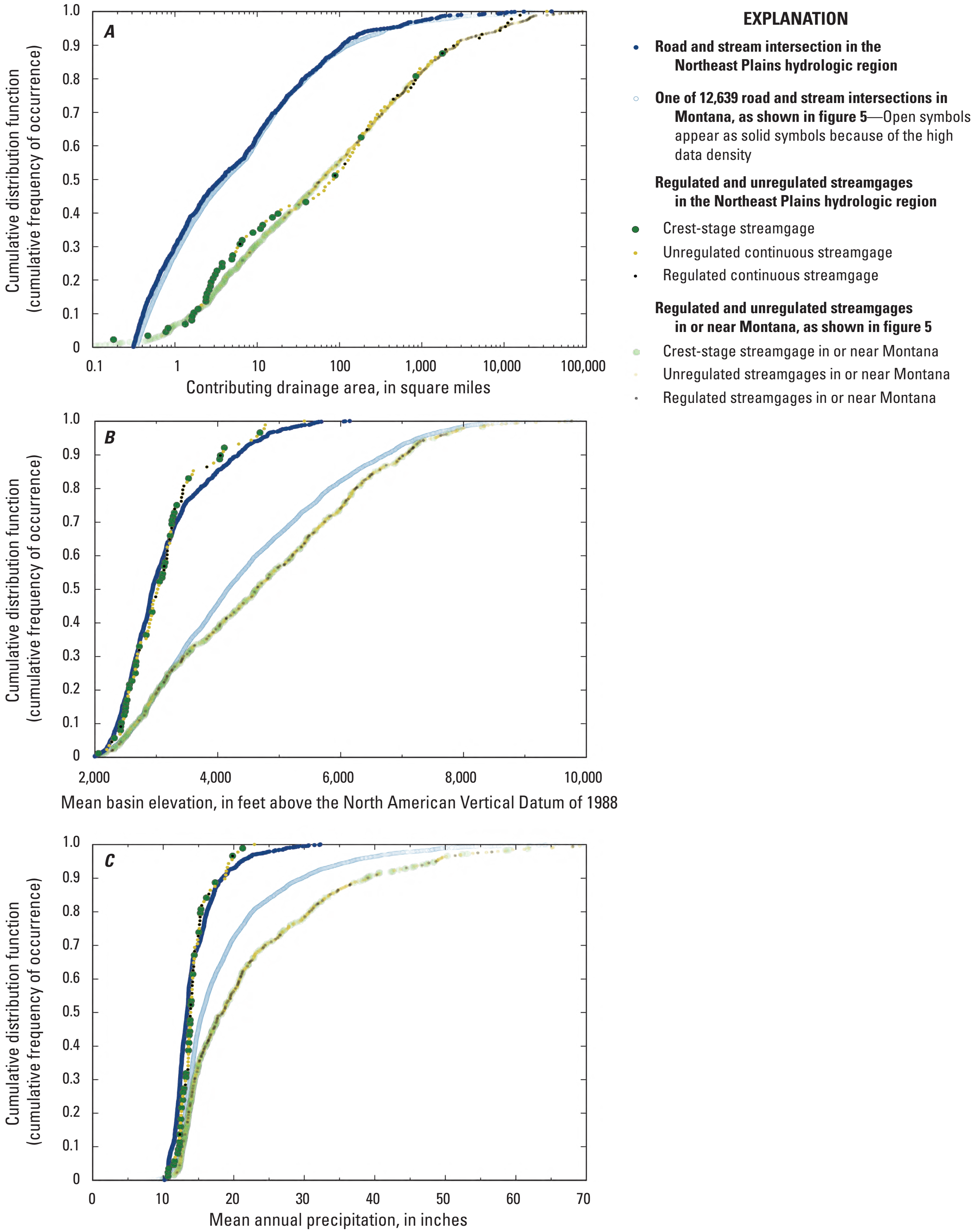


Figure 17. Cumulative distribution functions of selected drainage-basin characteristics for 1,470 road and stream intersections and for 88 streamgages (regulated and unregulated) in the Northeast Plains hydrologic region. *A*, Contributing drainage area relations. *B*, Mean basin elevation relations. *C*, Mean annual precipitation relations.

in figure 18. For the 102 unregulated streamgages, *PFVI* generally monotonically decreases with increasing drainage area (fig. 18*A*) with generally small and consistent variability about the LOWESS line. Intuitively, highly variable small-scale hydroclimatic processes are integrated with increasing drainage area such that variability in many hydrologic characteristics is reduced. For the relation between *PFVI* and drainage area (fig. 18*A*), the LOWESS line for the East-Central Plains hydrologic region generally is above the LOWESS line for all unregulated streamgages in Montana. For streamgages in the East-Central Plains hydrologic region, mean basin elevation and mean annual precipitation generally are within small ranges, and it is difficult to discern clear patterns in the relations between *PFVI* and those variables (figs. 18*B* and 18*C*); however, within the small ranges, the LOWESS lines for the East-Central Plains region generally are similar to the LOWESS lines for all unregulated streamgages in Montana. The relation between *PFVI* and years of peak-flow records for the East-Central Plains hydrologic region generally is similar to the relation for all unregulated streamgages in Montana, but the LOWESS line for the East-Central Plains hydrologic region is consistently above the LOWESS line for all unregulated streamgages in Montana (fig. 18*D*).

Relations between contributing drainage area and mean basin elevation, mean annual precipitation, and years of peak-flow records for the unregulated streamgages are presented in figure 19. In the relations between contributing drainage area and mean basin elevation and mean annual precipitation (figs. 19*A* and 19*B*), the small ranges in mean basin elevation and mean annual precipitation in the East-Central Plains hydrologic region make it difficult to discern clear patterns in the relations. In the relation between contributing drainage area and years of peak-flow records (fig. 19*C*), the LOWESS line for the East-Central Plains hydrologic region generally is below the LOWESS line for all unregulated streamgages in Montana, indicating that streamgages on small basins generally have longer periods of record in the East-Central Plains hydrologic region than in Montana as a whole.

The median *PFVI* value for streamgages in the East-Central Plains hydrologic region (36.00, table 3) is substantially larger than the median for all unregulated streamgages in Montana (18.26, table 3) and ranks as the first largest median *PFVI* among the eight hydrologic regions. For unregulated streamgages in the East-Central Plains hydrologic region, fall and winter (October–February) precipitation accounts for about 17.7 percent of annual precipitation (table 8), which ranks seventh largest among the eight hydrologic regions. May–June precipitation accounts for about 36.4 percent of annual precipitation (table 8), which ranks third among the hydrologic regions, and July–August precipitation accounts for 23.9 percent of annual precipitation, which ranks first among the eight hydrologic regions. In the East-Central Plains hydrologic region, annual peak flows are most frequently in March and June (fig. 2 of Sando, R., and others, 2018), probably resulting from low-elevation snowmelt runoff and springtime rainfall runoff, respectively; however, substantial proportions of annual peak flows also are in February, April–May, and July. Generally small accumulated snowpacks, variability in the timing and magnitude of low-elevation snowmelt runoff, and variability in spring and summer rainfall might contribute to greater peak-flow variability in the East-Central Plains hydrologic region than for Montana as a whole.

About 2.2 percent of the streamgages in the East-Central Plains hydrologic region are considered to have mixed-population characteristics (table 1) that result in a small number of unusually large peak flows that are substantially larger than the main body of peak flows. Mixed-population peak-flow datasets are not a substantial consideration in the East-Central Plains hydrologic region.

The CDFs of selected basin characteristics (drainage area, mean basin elevation, and mean annual precipitation) for the road and stream intersections and for the streamgages in the East-Central Plains hydrologic region are shown in figure 20. With respect to drainage area, the CDF of road and stream intersections for the East-Central Plains hydrologic region is similar to the CDF of road and stream intersections for all of Montana (fig. 20*A*). In the East-Central Plains hydrologic region, the CDF of streamgages diverges from and is substantially above the CDF of streamgages for Montana as a whole in the range of drainage areas less than about 17 mi^2, indicating that small basins are more strongly represented in the East-Central Plains hydrologic region. It is noteworthy that about 58 percent of the streamgages (both regulated and unregulated) in the East-Central Plains hydrologic region are on basins with drainage areas less than about 17 mi^2, whereas the other 42 percent of the streamgages are distributed over a large range in drainage areas from about 17 to several thousand square miles. In the East-Central Plains hydrologic region, the CDF of streamgages diverges from the CDF of road and stream intersections in the range of drainage areas from about 17 to 220 mi^2, indicating underrepresentation in that range.

The East-Central Plains hydrologic region generally is lower in elevation than Montana as a whole. Mean basin elevation for road and stream intersections in the East-Central Plains hydrologic region ranges from 1,951 to 6,385 ft (Dutton and others, 2021) with a median of 2,838 ft (table 4). The range for the East-Central Plains hydrologic region is smaller than for all of Montana (1,951–9,974 ft; Dutton and others, 2021) and the median for the East-Central Plains hydrologic region is less than for all of Montana (4,173 ft; table 4). There are substantial differences between the CDFs of road and stream intersections for the East-Central Plains hydrologic region relative to the CDFs of road and stream intersections for all of Montana (fig. 20*B*). With respect to mean basin elevation, the pattern of the streamgage CDF reasonably represents the road and stream intersection CDF but with small underrepresentation in a small range of elevations from about 3,600 to 4,000 ft.

The East-Central Plains hydrologic region generally is drier than Montana as a whole. Mean annual precipitation for road and stream intersections in the East-Central Plains hydrologic region ranges from 11.1 to 24.1 inches (Dutton

Table 18. Information on streamgages in the Northeast Plains hydrologic region with significant leverage and influence in the Montana regional regression analyses (Sando, R., and others, 2018).

[ID, identification; NAD 83, North American Datum of 1983; *n*, total number of years of peak-flow records; *CONTDA*, contributing drainage area, in square miles; EL_{5000}, percentage of basin above 5,000 feet elevation; AEP, annual exceedance probability; CONT, continuous streamgage; CSG, crest-stage gage]

Map number (fig. 1)	Streamgage ID number	Streamgage name	Latitude, in decimal degrees (NAD 83)	Longitude, in decimal degrees (NAD 83)	Type of streamgage	Status of streamgage in water year 2017	*n*	*CONTDA*	Non-exceedance percentile[1] for *CONTDA*	EL_{5000}	Non-exceedance percentile[1] for EL_{5000}	Regression residuals for the specified AEP regression analyses		
												10-percent AEP	4-percent AEP	1-percent AEP
Streamgages with significant leverage														
199	06114700	Judith River near mouth, near Winifred, Montana	47.6684	−109.6526	CONT	Active	16	2,747	100.0	29.0	96.9	0.171	0.184	0.233
281	06137400	Big Sandy Creek at reservation boundary, near Rocky Boy, Montana	48.1724	−109.8260	CONT	Discontinued	24	24.6	56.3	29.3	98.4	0.095	0.119	0.163
283	06137580	Sage Creek near Whitlash, Montana	48.8914	−111.0311	CONT	Discontinued	12	7	43.8	30.5	100.0	−0.043	−0.110	−0.191
311	[2]06151500	Battle Creek near Chinook, Montana	48.6495	−109.2317	CONT	Active	49	1,468	98.4	0.0	1.6	0.032	0.164	0.287
315	[2]06154350	Peoples Creek tributary near Lloyd, Montana	48.1922	−109.3076	CSG	Active	41	2.60	21.9	14.6	95.3	−0.174	−0.058	0.103
317	06154410	Little Peoples Creek near Hays, Montana	47.9658	−108.6607	CONT	Discontinued	37	12.9	50.0	7.4	93.8	0.070	0.059	0.051
Streamgages with significant influence														
188	06109530	Little Sandy Creek tributary near Virgelle, Montana	48.0864	−109.9418	CSG	Discontinued	30	0.47	3.1	0.0	1.6	−0.549	−0.681	−0.775
280	06136400	Spring Coulee tributary near Simpson, Montana	48.9443	−110.2160	CSG	Discontinued	30	2.76	25.0	0.0	1.6	−0.563	−0.559	−0.573

Table 18. Information on streamgages in the Northeast Plains hydrologic region with significant leverage and influence in the Montana regional regression analyses (Sando, R., and others, 2018).—Continued

[ID, identification; NAD 83, North American Datum of 1983; *n*, total number of years of peak-flow records; *CONTDA*, contributing drainage area, in square miles; EL_{5000}, percentage of basin above 5,000 feet elevation; AEP, annual exceedance probability; CONT, continuous streamgage; CSG, crest-stage gage]

Map number (fig. 1)	Streamgage ID number	Streamgage name	Latitude, in decimal degrees (NAD 83)	Longitude, in decimal degrees (NAD 83)	Type of streamgage	Status of streamgage in water year 2017	*n*	*CONTDA*	Non-exceedance percentile[1] for *CONTDA*	EL_{5000}	Non-exceedance percentile[1] for EL_{5000}	Regression residuals for the specified AEP regression analyses: 10-percent AEP	4-percent AEP	1-percent AEP
Streamgages with significant influence—Continued														
294	06142400	Clear Creek near Chinook, Montana	48.5789	−109.3911	CONT	Active	33	135	71.9	5.8	89.1	−0.355	−0.382	−0.430
311	[2]06151500	Battle Creek near Chinook, Montana	48.6495	−109.2317	CONT	Active	49	1,468	98.4	0.0	1.6	0.032	0.164	0.287
315	[2]06154350	Peoples Creek tributary near Lloyd, Montana	48.1922	−109.3076	CSG	Active	41	2.60	21.9	14.6	95.3	−0.174	−0.058	0.103
341	06164600	Beaver Creek tributary near Zortman, Montana	47.9275	−108.3527	CSG	Active	43	3.76	31.3	0.0	1.6	0.487	0.549	0.668
343	06164623	Little Warm Creek tributary near Lodge Pole, Montana	47.9952	−108.3202	CONT, CSG	Active	34	2.39	17.2	0.0	1.6	0.573	0.567	0.572
345	06165200	Guston Coulee near Malta, Montana	48.2419	−107.5486	CSG	Active	43	2.40	18.8	0.0	1.6	−0.583	−0.560	−0.572
403	06183750	Lake Creek near Dagmar, Montana	48.5641	−104.1776	CONT	Discontinued	19	111	68.8	0.0	1.6	−0.668	−0.572	−0.459
406	06184200	Lost Creek tributary near Homestead, Montana	48.4025	−104.4975	CSG	Active	44	1.92	14.1	0.0	1.6	0.262	0.382	0.537

[1]The nonexceedance percentile for the basin or climatic variable value was calculated in relation to the values for all streamgages included in the regional regression analyses for the indicated hydrologic region.

[2]Streamgages having both significant leverage and significant influence.

Table 19. Information on discontinued streamgages in the Northeast Plains hydrologic region that might be candidates for reactivation to improve the streamgage network.

[NAD 83, North American Datum of 1983; *n*, total number of years of peak-flow records; *CONTDA*, contributing drainage area, in square miles; EL_{5000}, percentage of basin above 5,000 feet elevation; CONT, continuous streamgage; CSG, crest-stage gage]

Map number (fig. 1)	Station identification number	Station name	Latitude, in decimal degrees (NAD 83)	Longitude, in decimal degrees (NAD 83)	Type of streamgage	*n*	*CONTDA*	Non-exceedance percentile[1] for *CONTDA*	EL_{5000}	Non-exceedance percentile[1] for EL_{5000}
281	06137400	Big Sandy Creek at reservation boundary, near Rocky Boy, Montana	48.1724	−109.8260	CONT	24	24.6	56.3	29.3	98.4
282	06137570	Boxelder Creek near Rocky Boy, Montana	48.3019	−109.8443	CONT	22	48.3	59.4	5.7	87.5
283	06137580	Sage Creek near Whitlash, Montana	48.8914	−111.0311	CONT	12	7.43	43.8	30.5	100.0
285	06137900	England Coulee at Hingham, Montana	48.5595	−110.4217	CSG	15	1.61	9.4	0.0	1.6
287	06138800	Spring Coulee near Havre, Montana	48.4208	−109.8652	CSG	15	18.0	53.1	0.0	1.6
290	06140400	Bullhook Creek near Havre, Montana	48.5076	−109.6389	CSG	17	39.1	57.8	0.0	1.6
292	06141600	Little Boxelder Creek at mouth, near Havre, Montana	48.5621	−109.5323	CONT	10	95.9	67.2	6.7	90.6
293	06141900	Milk River tributary near Lohman, Montana	48.5849	−109.4295	CSG	15	0.18	1.6	0.0	1.6
314	06154140	Fifteenmile Creek tributary near Harlem, Montana	48.3248	−108.7083	CONT	10	2.11	15.6	0.0	1.6
318	06154430	Lodge Pole Creek at Lodge Pole, Montana	48.0311	−108.5326	CONT	14	19.5	54.7	6.9	92.2
319	06154490	Willow Creek near Dodson, Montana	48.3251	−108.4154	CONT	10	5.53	37.5	0.0	1.6
323	06155100	Black Coulee near Malta, Montana	48.2121	−108.0471	CSG	13	11.7	48.4	0.0	1.6
324	06155200	Alkali Creek near Malta, Montana	48.2681	−107.9662	CSG	18	184	78.1	0.0	1.6
326	06155400	South Fork Taylor Coulee near Malta, Montana	48.3262	−107.9147	CSG	19	4.93	34.4	0.0	1.6
337	06163400	Denniel Creek near Val Marie, Saskatchewan	49.3073	−107.7035	CONT	14	192	79.7	0.0	1.6
342	06164615	Little Warm Creek at reservation boundary, near Zortman, Montana	47.9730	−108.3629	CONT	10	5.75	39.1	0.0	1.6
351	06170200	Willow Creek near Hinsdale, Montana	48.5650	−106.9825	CONT	10	290	84.4	0.0	1.6
352	06171000	Rock Creek near Hinsdale, Montana	48.4527	−107.0365	CONT	11	1,300	96.9	0.0	1.6
390	06179500	West Fork Poplar River at international boundary	49.0000	−106.3683	CONT	20	145	73.4	0.0	1.6
397	06182700	Middle Fork Big Muddy Creek near Flaxville, Montana	48.8022	−105.1139	CSG	11	3.26	29.7	0.0	1.6
399	06183100	Box Elder Creek near Plentywood, Montana	48.8238	−104.4997	CSG	19	11.0	46.9	0.0	1.6
401	06183400	Spring Creek at Highway 16, near Plentywood, Montana	48.7666	−104.5252	CSG	19	15.4	51.6	0.0	1.6
403	06183750	Lake Creek near Dagmar, Montana	48.5641	−104.1776	CONT	19	111	68.8	0.0	1.6
404	06183800	Cottonwood Creek near Dagmar, Montana	48.5092	−104.1734	CONT	20	128	70.3	0.0	1.6

[1]The nonexceedance percentile for the basin or climatic variable value was calculated in relation to the values for all streamgages included in the regional regression analyses for the indicated hydrologic region.

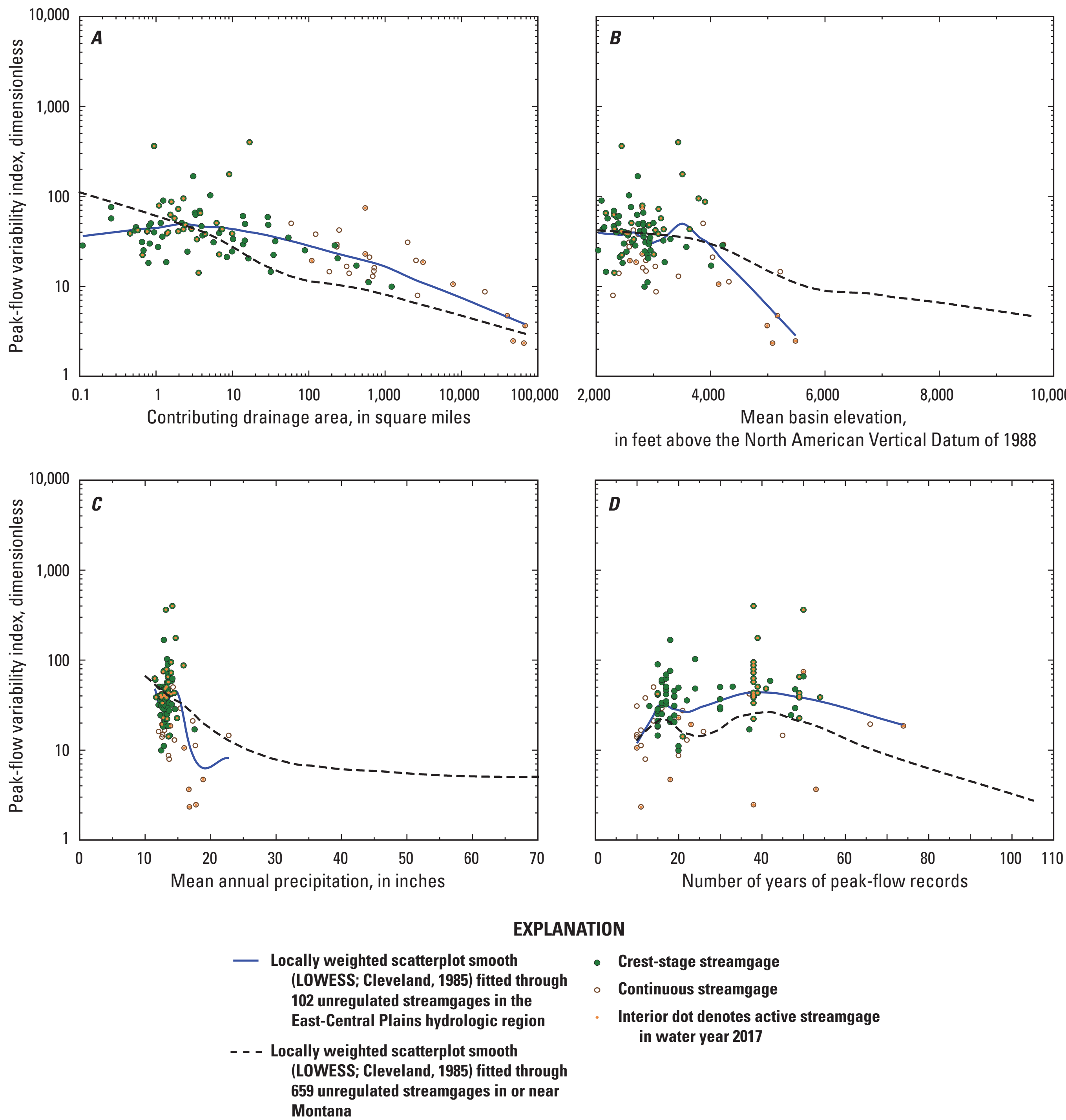


Figure 18. Relations between peak-flow variability index and contributing drainage area, mean basin elevation, mean annual precipitation, and years of peak-flow records for 102 unregulated streamgages in the East-Central Plains hydrologic region. *A*, Peak-flow variability and contributing drainage area relations. *B*, Peak-flow variability and mean basin elevation relations. *C*, Peak-flow variability and mean annual precipitation relations. *D*, Peak-flow variability and years of peak-flow records relations.

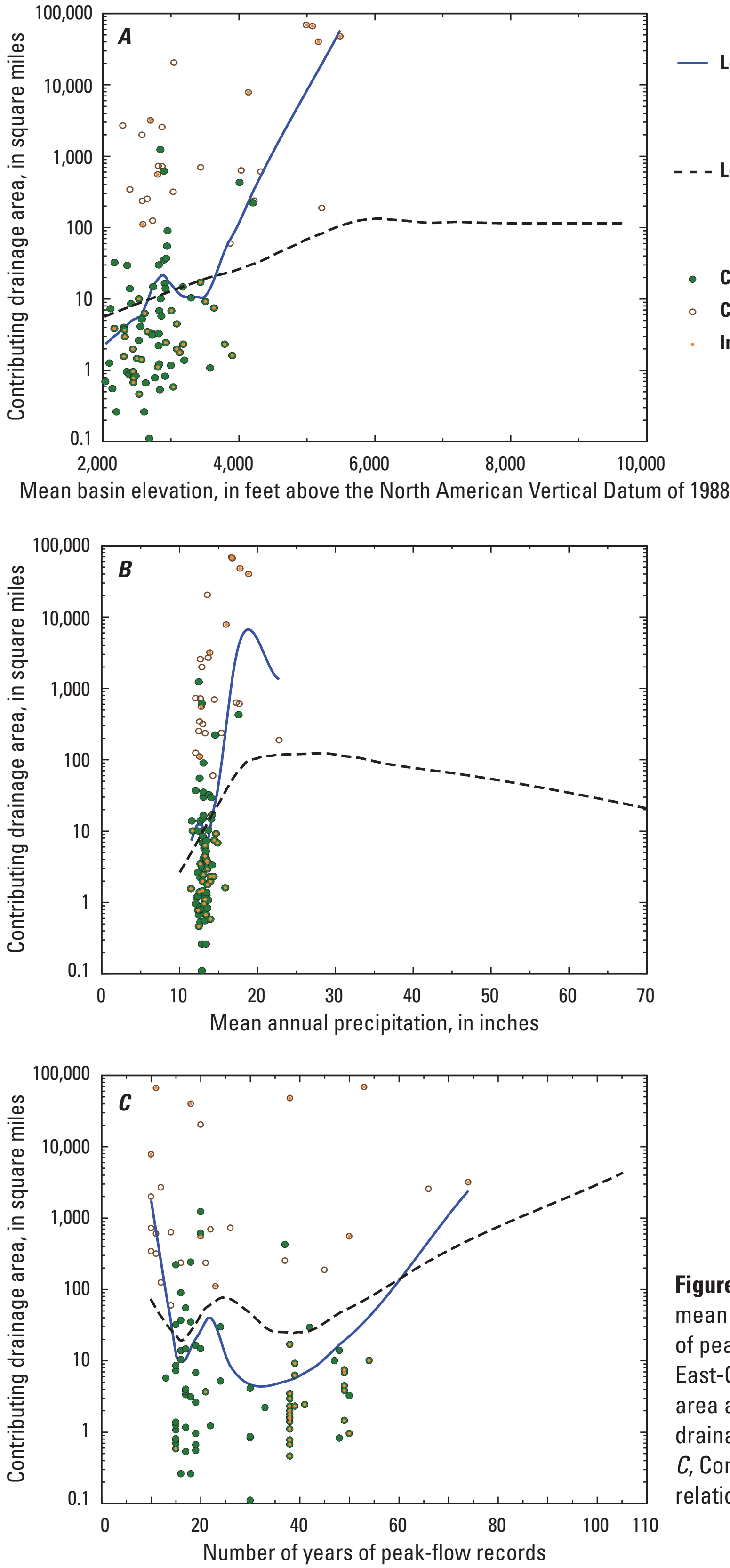


Figure 19. Relations between contributing drainage area and mean basin elevation, mean annual precipitation, and years of peak-flow records for 102 unregulated streamgages in the East-Central Plains hydrologic region. *A*, Contributing drainage area and mean basin elevation relations. *B*, Contributing drainage area and mean annual precipitation relations. *C*, Contributing drainage area and years of peak-flow records relations.

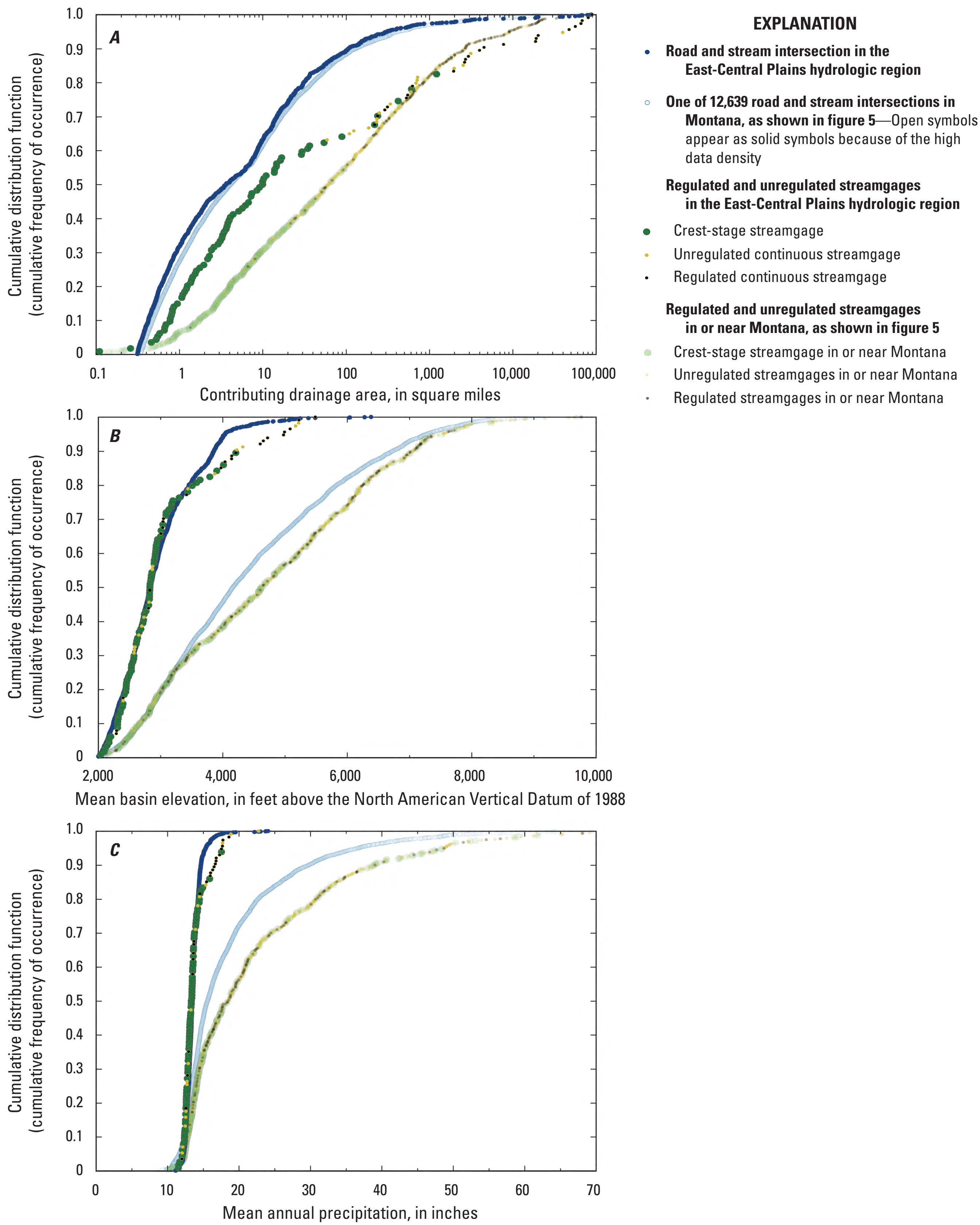


Figure 20. Cumulative distribution functions of selected drainage-basin characteristics for 1,586 road and stream intersections and for 114 streamgages (regulated and unregulated) in the East-Central Plains hydrologic region. *A*, Contributing drainage area relations. *B*, Mean basin elevation relations. *C*, Mean annual precipitation relations.

and others, 2021) with a median of 13.4 inches (table 5). The range for the East-Central Plains hydrologic region is smaller than for all of Montana (8.4–91.3 ft; Dutton and others, 2021) and the median for the East-Central Plains hydrologic region is somewhat smaller than for all of Montana (15.7 inches; table 5). There are substantial differences between the CDFs of road and stream intersections for the East-Central Plains hydrologic region relative to the CDFs of road and stream intersections for all of Montana (fig. 20*C*). With respect to mean annual precipitation, the pattern of the streamgage CDF reasonably represents the road and stream intersection CDF but with small underrepresentation in a small range of mean annual precipitation from about 15 to 16 inches.

The explanatory variables for the East-Central Plains hydrologic region RREs are *CONTDA*, percentage of basin with slope greater than 30 percent (*SLOP*30_30*M*), and mean spring (March–June) evapotranspiration (*ET*0306*MOD*; table 6). The 1-percent AEP RRE for the East-Central Plains hydrologic region has an SEP of 73.5 percent, which is higher than the area-weighted mean SEP for all hydrologic regions in Montana (63.3 percent; table 6). For the 1-percent AEP regression for the East-Central Plains hydrologic region, 7.8 percent of the streamgages have significant leverage and 10.0 percent of the streamgages have significant influence (table 7); these percentages generally are similar to significant leverage and influence percentages (8.2 and 10.4 percent, respectively; table 7) for all of the streamgages in Montana used in the regional regression analyses.

Information on streamgages in the East-Central Plains hydrologic region with significant leverage and influence is presented in table 20. One of the seven significant leverage streamgages has the largest *CONTDA* (nonexceedance percentile equal to 100 percent). Four of the seven significant leverage streamgages have high *SLOP*30_30*M* values (nonexceedance percentiles greater than about 97 percent). Two of the seven significant leverages streamgages has a high *ET*0306*MOD* value (nonexceedance percentile greater than about 99 percent), and one has a low *ET*0306*MOD* value (nonexceedance percentile less than about 6 percent). The 11 streamgages with significant influence vary with respect to the residuals for the 1-percent AEP RRE; five of the streamgages have negative residuals, and six have positive residuals. The three streamgages with both significant leverage and significant influence have negative residuals.

In general, the streamgage network in the East-Central Plains hydrologic region is considered to provide generally reasonable representation of the hydroclimatic settings of that hydrologic region. The RREs of the East-Central Plains hydrologic region are considered to be reasonably reliable. However, small basins (*CONTDA* less than about 17 mi^2) are more strongly represented in the East-Central Plains hydrologic region than the other hydrologic regions; greater variability in annual peak flows in small basins might contribute to the large SEP (73.5 percent) for the 1-percent AEP RRE for the East-Central Plains hydrologic region. Possible shortcomings of the streamgage network in the East-Central Plains hydrologic region include underrepresentation of basins with *CONTDA* from about 17 to 220 mi^2, mean elevation from about 3,600 to 4,000 ft, and (or) mean annual precipitation from about 15 to 16 inches. Future improvements to the streamgage network in the East-Central Plains hydrologic region might include discontinuing some CSGs on basins with drainage areas less than about 17 mi^2 and reactivating discontinued streamgages as CSGs on drainage basins within the specified underrepresented characteristics. Establishing new CSGs on basins with drainage areas from about 17 to 220 mi^2 might also be warranted to appropriately distribute *CONTDA* representation in the streamgage network. In addition to possibly providing better representation of the road and stream intersections network, redistributing some CSGs from smaller to larger basins might be beneficial for regional regression analyses. Because larger basins integrate hydroclimatic characteristics of multiple smaller basins, appropriate representation of larger basins might assist in developing efficient regression relations. Information on discontinued streamgages in the East-Central Plains hydrologic region that might be candidates for reactivation to improve the streamgage network is presented in table 21.

Peak-Flow Variability, Peak-Flow Informational Needs, and Consideration of Regional Regression Analyses in the Southeast Plains Hydrologic Region

The Southeast Plains hydrologic region has an area of 18,520 mi^2 (table 1), which ranks fifth largest among the eight hydrologic regions. The Level III ecoregion (table 2) represented in the Southeast Plains hydrologic region is the Northwestern Great Plains (100.0 percent). The 1,371 road and stream intersections in the Southeast Plains hydrologic region (tables 4 and 5) represent a density of 0.074 road and stream intersection per mi^2, which ranks fifth among the hydrologic regions. The 80 streamgages (both regulated and unregulated; tables 4 and 5) represent an areal density of 0.00432 streamgage per mi^2 (ranking sixth among hydrologic regions) and a density of 0.05835 streamgage per road and stream intersection (ranking fifth among hydrologic regions).

Relations between *PFVI* and contributing drainage area, mean basin elevation, mean annual precipitation, and years of peak-flow records for 74 unregulated streamgages in the Southeast Plains hydrologic region (table 3) are presented in figure 21. For the 74 unregulated streamgages, *PFVI* generally monotonically decreases with increasing drainage area (fig. 21*A*) with somewhat inconsistent variability about the LOWESS line, possibly affected by poor representation of basins with drainage areas greater than about 20 mi^2. Intuitively, highly variable small-scale hydroclimatic processes are integrated with increasing drainage area such that variability in many hydrologic characteristics is reduced. For the relation between *PFVI* and drainage area (fig. 21*A*), the LOWESS line for the Southeast Plains hydrologic region generally is above the LOWESS line for all unregulated streamgages in Montana. For streamgages in the Southeast Plains hydrologic region, mean basin elevation and mean annual precipitation generally are within small ranges, and it is difficult to discern clear patterns in the relations between *PFVI* and those variables (figs. 21*B* and 21*C*); however, within the small ranges, the LOWESS lines for the Southeast Plains region generally are similar to the LOWESS lines for all unregulated streamgages in Montana. The relation between *PFVI* and years of peak-flow records for the Southeast Plains hydrologic region generally is similar to the relation for all unregulated streamgages in Montana, but the LOWESS line for the Southeast Plains hydrologic region is consistently above the LOWESS line for all unregulated streamgages in Montana (fig. 21*D*).

Relations between contributing drainage area and mean basin elevation, mean annual precipitation, and years of peak-flow records for the unregulated streamgages are presented in figure 22. In the relations between contributing drainage area and mean basin elevation and mean annual precipitation (figs. 22*A* and 22*B*), the small ranges in mean basin elevation and mean annual precipitation in the Southeast Plains hydrologic region make it difficult to discern clear patterns in the relations. Relations between contributing drainage area and mean basin elevation (fig. 22*A*) indicate that all streamgages at lower elevations (less than about 3,000 ft) have smaller drainage areas (less than about 20 mi^2). In the relation between contributing drainage area and years of peak-flow records (fig. 22*C*), the LOWESS line for the Southeast Plains hydrologic region generally is below the LOWESS line for all unregulated streamgages in Montana, indicating that streamgages on small basins generally have longer periods of record in the Southeast Plains hydrologic region than in Montana as a whole.

The median *PFVI* value for streamgages in the Southeast Plains hydrologic region (35.21, table 3) is substantially larger than the median for all unregulated streamgages in Montana (18.26, table 3) and ranks as the second largest median *PFVI* among the eight hydrologic regions. For unregulated streamgages in the Southeast Plains hydrologic region, fall and winter (October–February) precipitation accounts for about 20.7 percent of annual precipitation (table 8), which ranks fifth largest among the eight hydrologic regions. May–June precipitation accounts for about 34.6 percent of annual precipitation (table 8), which ranks fourth among the hydrologic regions, and July–August precipitation accounts for 19.8 percent of annual precipitation, which ranks fourth among the eight hydrologic regions. In the Southeast Plains hydrologic region, annual peak flows are most frequently in March and June (fig. 2 of Sando, R., and others, 2018), probably resulting from low-elevation snowmelt runoff and springtime rainfall runoff, respectively; however, substantial proportions of annual peak flows also are in February, April–May, and July–September. Generally small accumulated snowpacks, variability in the timing and magnitude of low-elevation snowmelt runoff, and variability in spring and summer rainfall might contribute to greater peak-flow variability in the Northwest Foothills hydrologic region than for Montana as a whole.

No streamgages in the Southeast Plains hydrologic region are considered to have mixed-population characteristics (table 1) that result in a small number of unusually large peak flows that are substantially larger than the main body of peak flows. Mixed-population peak-flow datasets are not a substantial consideration in the Southeast Plains hydrologic region.

The CDFs of selected basin characteristics (drainage area, mean basin elevation, and mean annual precipitation) for the road and stream intersections and for the streamgages in the Southeast Plains hydrologic region are shown in figure 23. With respect to drainage area, the CDF of road and stream intersections for the Southeast Plains hydrologic region is similar to the CDF of road and stream intersections for all of Montana (fig. 23*A*). In the Southeast Plains hydrologic region, the CDF of streamgages diverges from and is substantially above the CDF of streamgages for Montana as a whole in the range of drainage areas less than about 20 mi^2, indicating that small basins are more strongly represented in the Southeast Plains hydrologic region. It is noteworthy that about 63 percent of the streamgages (both regulated and unregulated) in the Southeast Plains hydrologic region are on basins with drainage areas less than about 20 mi^2, whereas the other 37 percent of the streamgages are distributed over a large range in drainage areas from about 20 to several thousand square miles. In the Southeast Plains hydrologic region, the CDF of streamgages diverges from the CDF of road and stream intersections in the range of drainage areas from about 20 to 370 mi^2, indicating underrepresentation in that range.

The Southeast Plains hydrologic region generally is lower in elevation than Montana as a whole. Mean basin elevation for road and stream intersections in the Southeast Plains hydrologic region ranges from 2,092 to 6,128 ft (Dutton and others, 2021) with a median of 3,194 ft (table 4). The range for the Southeast Plains hydrologic region is smaller than for all of Montana (1,951–9,974 ft; Dutton and others, 2021) and the median for the Southeast Plains hydrologic region is less than for all of Montana (4,173 ft; table 4). There are substantial differences between the CDFs of road and stream intersections for the Southeast Plains hydrologic region relative to the CDFs of road and stream intersections for all of Montana (fig. 23*B*). With respect to mean basin elevation, the pattern of the streamgage CDF reasonably represents the road and stream intersection CDF but with small underrepresentation in a small range of elevations from about 3,600 to 4,200 ft.

The Southeast Plains hydrologic region generally is drier than Montana as a whole. Mean annual precipitation for road and stream intersections in the Southeast Plains hydrologic region ranges from 12.1 to 21.6 inches (Dutton and others, 2021) with a median of 14.5 inches (table 5). The range for the Southeast Plains hydrologic region is smaller than for all of Montana (8.4–91.3 ft; Dutton and others, 2021) and the median for the Southeast Plains hydrologic region is somewhat smaller than for all of Montana (15.7 inches; table 5).

Table 20. Information on streamgages in the East-Central Plains hydrologic region with significant leverage and influence in the Montana regional regression analyses (Sando, R., and others, 2018).

[ID, identification; NAD 83, North American Datum of 1983; *n*, total number of years of peak-flow records; *CONTDA*, contributing drainage area, in square miles; *SLOP*30_30*M*, percentage of basin in slopes greater than or equal to 30 percent; *ET*0306*MOD*, spring mean monthly evapotranspiration, in inches per month; AEP, annual exceedance probability; CONT, continuous streamgage; CSG, crest-stage gage]

Map number (fig. 1)	Streamgage ID number	Streamgage name	Latitude, in decimal degrees (NAD 83)	Longitude, in decimal degrees (NAD 83)	Type of streamgage	Status of streamgage in water year 2017	*n*
		Streamgages with significant leverage					
239	[2]06127900	Flatwillow Creek near Flatwillow, Montana	46.7912	−108.6142	CONT	Discontinued	45
248	06129500	McDonald Creek at Winnett, Montana	46.9936	−108.3564	CONT, CSG	Discontinued	37
263	06131000	Big Dry Creek near Van Norman, Montana	47.3494	−106.3578	CONT	Discontinued	69
489	06294800	Unknown Creek near Bighorn, Montana	46.1970	−107.4092	CSG	Discontinued	17
499	06295050	Little Porcupine Creek near Forsyth, Montana	46.3044	−106.5751	CSG	Discontinued	20
554	[2]06326550	Cherry Creek tributary near Terry, Montana	46.8551	−105.3412	CSG	Discontinued	19
564	[2]06327450	Cains Coulee at Glendive, Montana	47.0942	−104.7133	CONT, CSG	Active	26
		Streamgages with significant influence					
202	06115100	Missouri River tributary near Landusky, Montana	47.6262	−108.6986	CSG	Discontinued	17
239	[2]06127900	Flatwillow Creek near Flatwillow, Montana	46.7912	−108.6142	CONT	Discontinued	45
367	06175900	Wolf Creek tributary No. 2 near Wolf Point, Montana	48.2017	−105.7538	CSG	Discontinued	30
368	06176500	Wolf Creek near Wolf Point, Montana	48.0972	−105.6802	CONT	Discontinued	37
369	06176950	Missouri River tributary No. 6 near Wolf Point, Montana	48.0563	−105.5569	CSG	Discontinued	19
371	06177020	Tule Creek tributary near Wolf Point, Montana	48.2446	−105.4927	CSG	Active	43
381	06177700	Cow Creek tributary near Vida, Montana	47.7158	−105.4945	CONT, CSG	Active	53
383	06177800	Gady Coulee near Vida, Montana	47.9127	−105.4971	CSG	Discontinued	30
412	06185400	Missouri River tributary No. 5 at Culbertson, Montana	48.1587	−104.5161	CSG	Active	54
554	[2]06326550	Cherry Creek tributary near Terry, Montana	46.8551	−105.3412	CSG	Discontinued	19
564	[2]06327450	Cains Coulee at Glendive, Montana	47.0942	−104.7133	CONT, CSG	Active	26

[1]The nonexceedance percentile for the basin or climatic variable value was calculated in relation to the values for all streamgages included in the regional regression analyses for the indicated hydrologic region.

[2]Streamgages having both significant leverage and significant influence.

CONTDA	Nonexceedance percentile[1] for *CONTDA*	*SLOP*30_30*M*	Nonexceedance percentile[1] for *SLOP*30_30*M*	*ET*0306*MOD*	Nonexceedance percentile[1] for *ET*0306*MOD*	Regression residuals for the specified AEP regression analyses		
						10-percent AEP	4-percent AEP	1-percent AEP
Streamgages with significant leverage								
187	82.2	16.47	98.9	1.57	100.0	−0.200	−0.327	−0.429
424	90.0	3.81	87.8	1.45	98.9	0.009	−0.104	−0.222
2,551	100.0	0.13	56.7	1.05	45.6	0.197	0.203	0.207
14.6	68.9	13.10	97.8	1.11	68.9	0.135	0.112	0.105
611	92.2	0.22	61.1	0.91	5.6	−0.068	−0.097	−0.098
2.60	38.9	10.45	96.7	0.93	6.7	−0.456	−0.585	−0.720
3.64	45.6	31.87	100.0	0.95	11.1	0.216	0.034	−0.168
Streamgages with significant influence								
3.32	43.3	8.09	95.6	1.09	60.0	0.392	0.514	0.677
187	82.2	16.47	98.9	1.57	100.0	−0.200	−0.327	−0.429
0.86	16.7	0.00	1.1	1.00	27.8	0.685	0.715	0.741
251	86.7	0.01	43.3	1.12	72.2	0.391	0.518	0.660
0.55	6.7	0.05	51.1	1.02	35.6	−0.427	−0.567	−0.737
1.97	32.2	0.00	1.1	1.15	80.0	−0.186	−0.324	−0.497
1.45	27.8	0.00	1.1	1.11	64.4	0.437	0.424	0.415
0.83	15.6	0.00	1.1	1.16	85.6	0.851	0.792	0.726
3.82	47.8	0.30	65.6	1.19	88.9	0.355	0.422	0.499
2.60	38.9	10.45	96.7	0.93	6.7	−0.456	−0.585	−0.720
3.64	45.6	31.87	100.0	0.95	11.1	0.216	0.034	−0.168

Table 21. Information on discontinued streamgages in the East-Central Plains hydrologic region that might be candidates for reactivation to improve the streamgage network.

[NAD 83, North American Datum of 1983; *n*, total number of years of peak-flow records; *CONTDA*, contributing drainage area, in square miles; *SLOP*30_30*M*, percentage of basin in slopes greater than or equal to 30 percent; *ET*0306*MOD*, spring mean monthly evapotranspiration, in inches per month; CSG, crest-stage gage; CONT, continuous streamgage]

Map number (fig. 1)	Station identification number	Station name	Latitude, in decimal degrees (NAD 83)	Longitude, in decimal degrees (NAD 83)	Type of streamgage	*n*	*CONTDA*	Non-exceedance percentile[1] for *CONTDA*	*SLOP*30_30*M*	Non-exceedance percentile[1] for *SLOP*30_30*M*	*ET*0306*MOD*	Non-exceedance percentile[1] for *ET*0306*MOD*
202	06115100	Missouri River tributary near Landusky, Montana	47.6262	−108.6986	CSG	17	3.32	43.3	8.1	95.6	1.090	60.0
227	06125700	Big Coulee Creek near Lavina, Montana	46.2645	−108.9478	CONT	16	235	85.6	5.3	91.1	1.169	87.8
230	06126470	Halfbreed Creek near Klein, Montana	46.3872	−108.5418	CONT	14	59.30	77.8	7.6	94.4	1.206	90.0
232	06127100	South Willow Creek tributary near Roundup, Montana	46.5147	−108.5783	CSG	15	1.07	20.0	0.0	1.1	1.001	26.7
233	06127200	Musselshell River tributary near Musselshell, Montana	46.5071	−108.2549	CSG	16	10.3	64.4	0.1	51.1	1.070	52.2
243	06128900	Box Elder Creek tributary near Winnett, Montana	47.0163	−108.1599	CSG	19	16.3	71.1	0.0	43.3	1.021	34.4
244	06129000	Box Elder Creek near Winnett, Montana	47.0125	−108.1553	CONT	22	691	94.4	2.9	85.6	1.210	91.1
252	06130600	Cat Creek near Cat Creek, Montana	47.0432	−108.0158	CSG	18	34.8	74.4	0.3	67.8	1.030	37.8
256	06130800	Second Creek tributary near Jordan, Montana	47.1919	−106.8024	CSG	17	0.53	5.6	0.0	1.1	0.942	10.0
258	06130900	Second Creek tributary No. 3 near Jordan, Montana	47.2193	−106.8260	CSG	15	0.78	12.2	0.0	1.1	1.147	78.9

Table 21. Information on discontinued streamgages in the East-Central Plains hydrologic region that might be candidates for reactivation to improve the streamgage network.—Continued

[NAD 83, North American Datum of 1983; *n*, total number of years of peak-flow records; *CONTDA*, contributing drainage area, in square miles; *SLOP*30_30*M*, percentage of basin in slopes greater than or equal to 30 percent; *ET*0306*MOD*, spring mean monthly evapotranspiration, in inches per month; CSG, crest-stage gage; CONT, continuous streamgage]

Map number (fig. 1)	Station identification number	Station name	Latitude, in decimal degrees (NAD 83)	Longitude, in decimal degrees (NAD 83)	Type of streamgage	*n*	*CONTDA*	Non-exceedance percentile[1] for *CONTDA*	*SLOP*30_30*M*	Non-exceedance percentile[1] for *SLOP*30_30*M*	*ET*0306*MOD*	Non-exceedance percentile[1] for *ET*0306*MOD*
260	06130925	Thompson Creek tributary near Cohagen, Montana	46.9513	−106.4613	CSG	22	1.22	23.3	0.0	1.1	0.997	24.4
262	06130950	Little Dry Creek near Van Norman, Montana	47.3394	−106.3636	CSG	20	1,223	97.8	0.1	54.4	1.041	43.3
354	06172200	Buggy Creek near Tampico, Montana	48.3608	−106.7779	CONT	12	124	81.1	0.1	57.8	1.081	56.7
357	06172350	Mooney Coulee near Tampico, Montana	48.2859	−106.7092	CSG	16	13.8	66.7	0.0	1.1	1.038	40.0
358	06173300	Willow Creek tributary near Fort Peck, Montana	47.8931	−106.8903	CSG	19	0.95	17.8	0.0	1.1	0.896	1.1
364	06175540	Prairie Elk Creek near Oswego, Montana	47.9990	−105.8674	CONT	10	340	88.9	0.5	74.4	1.017	31.1
365	06175550	East Fork Sand Creek near Vida, Montana	47.8042	−105.6143	CSG	15	8.51	60.0	0.0	1.1	1.045	44.4
369	06176950	Missouri River tributary No. 6 near Wolf Point, Montana	48.0563	−105.5569	CSG	19	0.55	6.7	0.1	51.1	1.024	35.6
373	06177100	Duck Creek near Brockway, Montana	47.2391	−105.8171	CSG	17	54.6	76.7	0.4	71.1	1.114	67.8
375	06177200	Tusler Creek near Brockway, Montana	47.2972	−105.6635	CSG	16	89.4	78.9	0.4	68.9	1.154	84.4

Table 21. Information on discontinued streamgages in the East-Central Plains hydrologic region that might be candidates for reactivation to improve the streamgage network.—Continued

[NAD 83, North American Datum of 1983; *n*, total number of years of peak-flow records; *CONTDA*, contributing drainage area, in square miles; *SLOP*30_30*M*, percentage of basin in slopes greater than or equal to 30 percent; *ET*0306*MOD*, spring mean monthly evapotranspiration, in inches per month; CSG, crest-stage gage; CONT, continuous streamgage]

Map number (fig. 1)	Station identification number	Station name	Latitude, in decimal degrees (NAD 83)	Longitude, in decimal degrees (NAD 83)	Type of streamgage	*n*	*CONTDA*	Non-exceedance percentile[1] for *CONTDA*	*SLOP*30_30*M*	Non-exceedance percentile[1] for *SLOP*30_30*M*	*ET*0306*MOD*	Non-exceedance percentile[1] for *ET*0306*MOD*
376	06177250	Tusler Creek tributary near Brockway, Montana	47.2978	−105.6785	CSG	18	3.09	41.1	0.0	1.1	1.077	54.4
377	06177300	Redwater River tributary near Brockway, Montana	47.3463	−105.6850	CSG	18	0.26	2.2	0.0	1.1	1.040	42.2
378	06177350	South Fork Dry Ash Creek near Circle, Montana	47.2954	−105.5973	CSG	19	6.76	55.6	0.0	1.1	1.130	74.4
379	06177400	McCune Creek near Circle, Montana	47.3498	−105.5860	CONT, CSG	24	29.7	73.3	3.2	86.7	1.099	62.2
382	06177720	West Fork Sullivan Creek near Richey, Montana	47.5322	−105.2351	CSG	20	14.7	70.0	0.4	70.0	1.127	73.3
385	06177825	Redwater River near Vida, Montana	47.9022	−105.2128	CONT	13	1,982	98.9	0.3	64.4	1.123	71.1
394	06181200	Missouri River tributary No. 2 near Brockton, Montana	48.1520	−104.9019	CSG	15	0.69	10.0	2.7	84.4	1.052	47.8
408	06185100	Big Muddy Creek tributary near Culbertson, Montana	48.1928	−104.6979	CSG	15	7.24	57.8	0.0	1.1	1.135	75.6
410	06185200	Missouri River tributary No. 3 near Culbertson, Montana	48.1042	−104.5158	CSG	15	1.25	24.4	7.1	93.3	1.073	53.3

Table 21. Information on discontinued streamgages in the East-Central Plains hydrologic region that might be candidates for reactivation to improve the streamgage network.—Continued

[NAD 83, North American Datum of 1983; *n*, total number of years of peak-flow records; *CONTDA*, contributing drainage area, in square miles; *SLOP*30_30*M*, percentage of basin in slopes greater than or equal to 30 percent; *ET*0306*MOD*, spring mean monthly evapotranspiration, in inches per month; CSG, crest-stage gage; CONT, continuous streamgage]

Map number (fig. 1)	Station identification number	Station name	Latitude, in decimal degrees (NAD 83)	Longitude, in decimal degrees (NAD 83)	Type of streamgage	*n*	*CONTDA*	Non-exceedance percentile[1] for *CONTDA*	*SLOP*30_30*M*	Non-exceedance percentile[1] for *SLOP*30_30*M*	*ET*0306*MOD*	Non-exceedance percentile[1] for *ET*0306*MOD*
411	06185300	Missouri River tributary No. 4 near Bainville, Montana	48.1419	−104.3528	CSG	15	11.0	65.6	0.0	42.2	1.299	96.7
489	06294800	Unknown Creek near Bighorn, Montana	46.1970	−107.4092	CSG	17	14.6	68.9	13.1	97.8	1.114	68.9
491	06294900	Middle Fork Froze to Death Creek tributary near Ingomar, Montana	46.5813	−107.4005	CSG	15	1.37	25.6	0.5	75.6	0.950	12.2
494	06294960	Anderson Creek at Vananda, Montana	46.3930	−107.0081	CSG	13	5.70	53.3	0.0	1.1	0.975	16.7
499	06295050	Little Porcupine Creek near Forsyth, Montana	46.3044	−106.5751	CSG	20	611	92.2	0.2	61.1	0.913	5.6
535	06309020	Rock Springs Creek tributary at Rock Springs, Montana	46.8222	−106.2544	CSG	17	1.16	22.2	0.0	1.1	1.018	33.3
536	06309040	Dry House Creek near Angela, Montana	46.6872	−106.1748	CSG	16	36.7	75.6	0.0	1.1	1.005	28.9
538	06309075	Sunday Creek near Miles City, Montana	46.4727	−105.8435	CONT	10	717	95.6	0.1	55.6	0.951	13.3
554	06326550	Cherry Creek tributary near Terry, Montana	46.8551	−105.3412	CSG	19	2.60	38.9	10.5	96.7	0.931	6.7

Table 21. Information on discontinued streamgages in the East-Central Plains hydrologic region that might be candidates for reactivation to improve the streamgage network.—Continued

[NAD 83, North American Datum of 1983; *n*, total number of years of peak-flow records; *CONTDA*, contributing drainage area, in square miles; *SLOP*30_30*M*, percentage of basin in slopes greater than or equal to 30 percent; *ET*0306*MOD*, spring mean monthly evapotranspiration, in inches per month; CSG, crest-stage gage; CONT, continuous streamgage]

Map number (fig. 1)	Station identification number	Station name	Latitude, in decimal degrees (NAD 83)	Longitude, in decimal degrees (NAD 83)	Type of streamgage	*n*	*CONTDA*	Non-exceedance percentile[1] for *CONTDA*	*SLOP*30_30*M*	Non-exceedance percentile[1] for *SLOP*30_30*M*	*ET*0306*MOD*	Non-exceedance percentile[1] for *ET*0306*MOD*
560	06326900	Yellowstone River tributary No. 4 near Fallon, Montana	46.8658	−105.1018	CSG	15	0.80	13.3	0.0	1.1	1.012	30.0
571	06328400	Thirteenmile Creek tributary near Bloomfield, Montana	47.4128	−104.8316	CSG	19	0.66	7.8	0.0	1.1	1.150	81.1
572	06328700	Linden Creek at Intake, Montana	47.2974	−104.5258	CSG	17	3.97	48.9	0.0	1.1	1.151	83.3
573	06328800	Indian Creek at Intake, Montana	47.2916	−104.5405	CSG	16	0.26	2.2	0.0	1.1	1.103	63.3
574	06328900	War Dance Creek near Intake, Montana	47.3270	−104.4883	CSG	17	3.74	46.7	0.1	53.3	1.143	77.8
575	06329200	Burns Creek near Savage, Montana	47.3723	−104.4300	CONT	21	234	84.4	1.6	77.8	1.169	86.7
578	06329510	Fox Creek tributary near Lambert, Montana	47.6493	−104.6149	CSG	24	5.16	52.2	0.2	60.0	1.236	94.4

[1]The nonexceedance percentile for the basin or climatic variable value was calculated in relation to the values for all streamgages included in the regional regression analyses for the indicated hydrologic region.

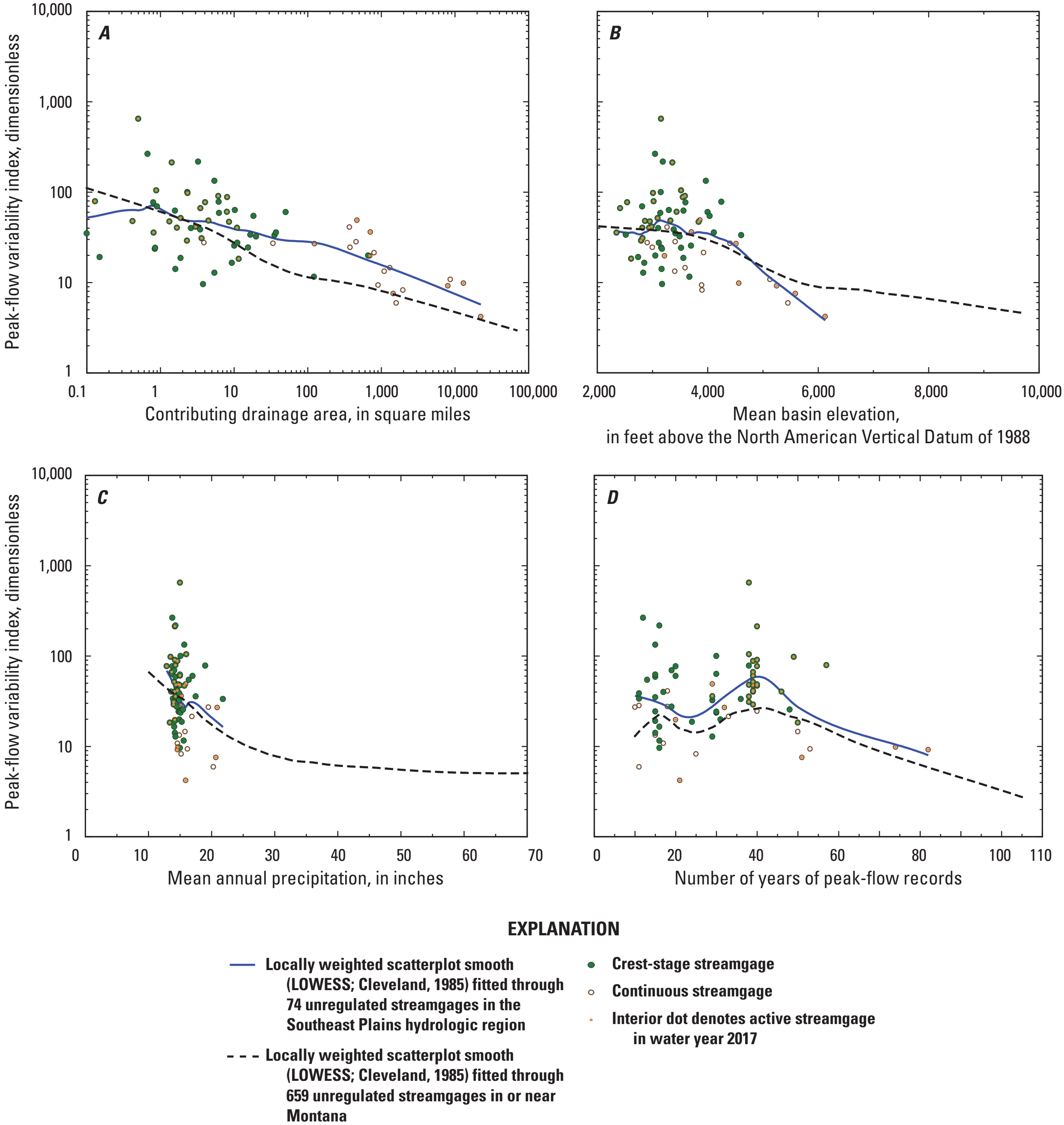
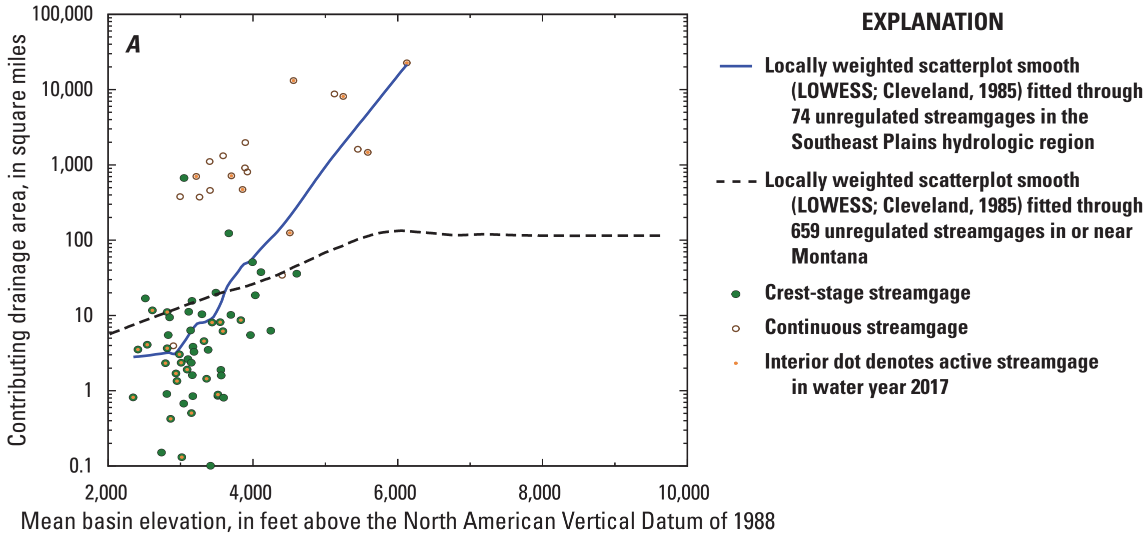
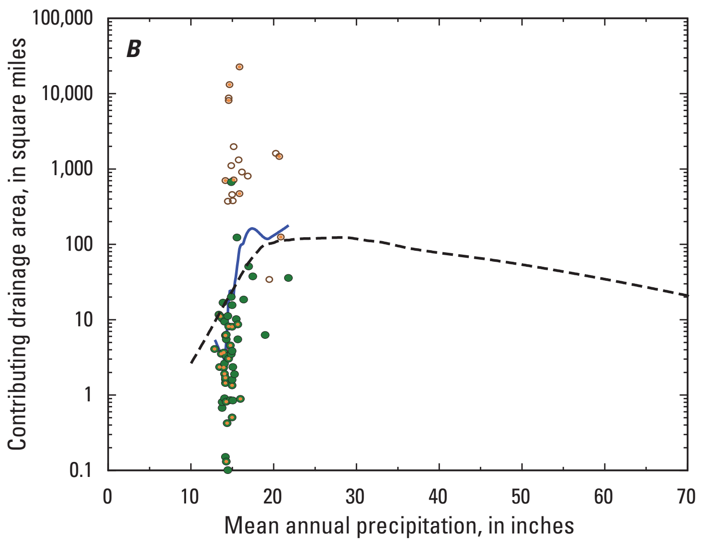


Figure 21. Relations between peak-flow variability index and contributing drainage area, mean basin elevation, mean annual precipitation, and years of peak-flow records for 74 unregulated streamgages in the Southeast Plains hydrologic region. *A*, Peak-flow variability and contributing drainage area relations. *B*, Peak-flow variability and mean basin elevation relations. *C*, Peak-flow variability and mean annual precipitation relations. *D*, Peak-flow variability and years of peak-flow records relations.





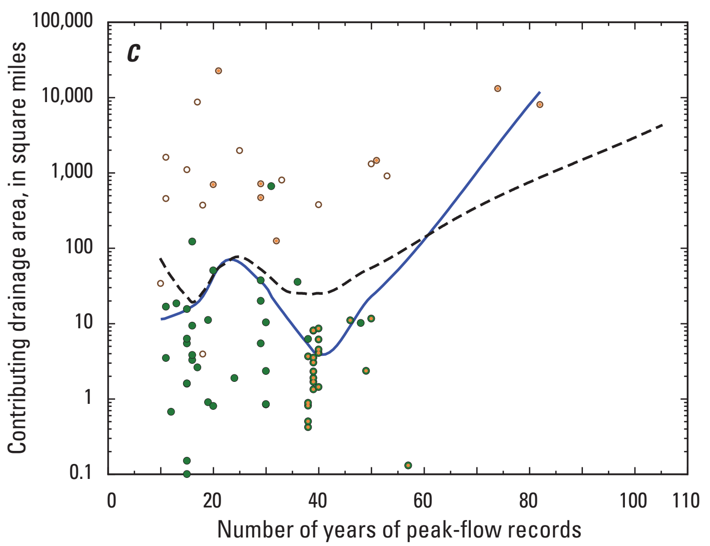


Figure 22. Relations between contributing drainage area and mean basin elevation, mean annual precipitation, and years of peak-flow records for 74 unregulated streamgages in the Southeast Plains hydrologic region. *A*, Contributing drainage area and mean basin elevation relations. *B*, Contributing drainage area and mean annual precipitation relations. *C*, Contributing drainage area and years of peak-flow records relations.

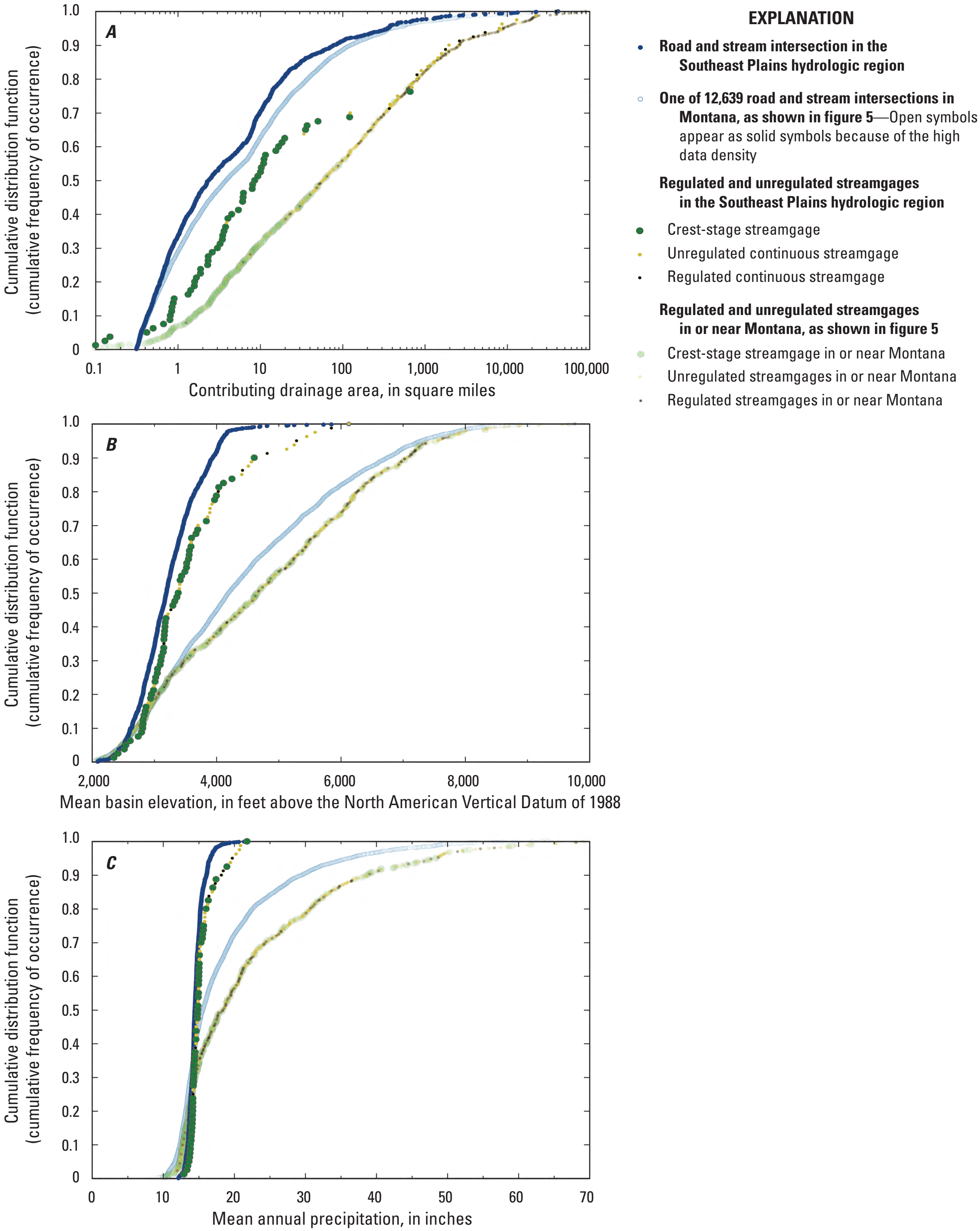


Figure 23. Cumulative distribution functions of selected drainage-basin characteristics for 1,371 road and stream intersections and for 80 streamgages (regulated and unregulated) in the Southeast Plains hydrologic region. *A*, Contributing drainage area relations. *B*, Mean basin elevation relations. *C*, Mean annual precipitation relations.

There are substantial differences between the CDFs of road and stream intersections for the Southeast Plains hydrologic region relative to the CDFs of road and stream intersections for all of Montana (fig. 23*C*). With respect to mean annual precipitation, the pattern of the streamgage CDF reasonably represents the road and stream intersection CDF but with small underrepresentation in a small range of mean annual precipitation from about 15 to 16 inches.

The explanatory variables for the Southeast Plains hydrologic region RREs are *CONTDA*, *FOREST*, and *ET*0306*MOD* (table 6). The 1-percent AEP RRE for the Southeast Plains hydrologic region has an SEP of 71.1 percent, which is higher than the area-weighted mean SEP for all hydrologic regions in Montana (63.3 percent; table 6). For the 1-percent AEP regression for the Southeast Plains hydrologic region, 5.9 percent of the streamgages have significant leverage and 14.7 percent of the streamgages have significant influence (table 7). The significant leverage percentage is somewhat smaller than the significant leverage percentage for all of the streamgages in Montana used in the regional regression analyses (8.2 percent; table 7) and the significant influence percentage is somewhat larger than the significant influence percentage for all of the streamgages in Montana used in the regional regression analyses (10.4 percent; table 7).

Information on streamgages in the Southeast Plains hydrologic region with significant leverage and influence is presented in table 22. Three of the five significant leverage streamgages have high *ET*0306*MOD* values (nonexceedance percentiles greater than about 96 percent). Two of the five significant leverage streamgages have small *CONTDA* values (nonexceedance percentiles less than about 6 percent). The 15 streamgages with significant influence vary with respect to the residuals for the 1-percent AEP RRE; nine of the streamgages have negative residuals, and six have positive residuals. The one streamgage with both significant leverage and significant influence has a positive residual.

In general, the streamgage network in the Southeast Plains hydrologic region is considered to provide generally reasonable representation of the hydroclimatic settings of that hydrologic region. The RREs of the Southeast Plains hydrologic region are considered to be reasonably reliable. However, small basins (*CONTDA* less than about 20 mi^2) are more strongly represented in the Southeast Plains hydrologic region than the other hydrologic regions; greater variability in annual peak flows in small basins might contribute to the large SEP (71.1 percent) for the 1-percent AEP RRE for the Southeast Plains hydrologic region. Possible shortcomings of the streamgage network in the Southeast Plains hydrologic region include underrepresentation of basins with *CONTDA* from about 20 to 370 mi^2, mean elevation from about 3,600 to 4,200 ft, and (or) mean annual precipitation from about 15 to 16 inches. Future improvements to the streamgage network in the Southeast Plains hydrologic region might include discontinuing some CSGs on basins with drainage areas less than about 20 mi^2 and reactivating discontinued streamgages as CSGs on drainage basins within the specified underrepresented characteristics. Establishing new CSGs on basins with drainage areas from about 20 to 370 mi^2 might also be warranted to appropriately distribute *CONTDA* representation in the streamgage network. In addition to possibly providing better representation of the road and stream intersections network, redistributing some CSGs from smaller to larger basins might be beneficial for regional regression analyses. Because larger basins integrate hydroclimatic characteristics of multiple smaller basins, appropriate representation of larger basins might assist in developing efficient regression relations. Information on discontinued streamgages in the Southeast Plains hydrologic region that might be candidates for reactivation to improve the streamgage network is presented in table 23.

Peak-Flow Variability, Peak-Flow Informational Needs, and Consideration of Regional Regression Analyses in the Upper Yellowstone-Central Mountain Hydrologic Region

The Upper Yellowstone-Central Mountain hydrologic region has an area of 23,003 mi^2 (table 1), which ranks second largest among the eight hydrologic regions. Level III ecoregions (table 2) represented in the Upper Yellowstone-Central Mountain hydrologic region include the Middle Rockies (35.8 percent), Northwestern Glaciated Plains (0.1 percent), Northwestern Great Plains (62.2 percent), and Wyoming Basin (1.9 percent). The 2,166 road and stream intersections in the Upper Yellowstone-Central Mountain hydrologic region (tables 4 and 5) represent a density of 0.094 road and stream intersection per mi^2, which ranks fourth among the hydrologic regions. The 113 streamgages (both regulated and unregulated; table 4 and 5) represent an areal density of 0.00491 streamgage per mi^2 (ranking fourth among hydrologic regions) and a density of 0.05217 streamgage per road and stream intersection (ranking sixth among hydrologic regions).

Relations between *PFVI* and contributing drainage area, mean basin elevation, mean annual precipitation, and years of peak-flow records for 108 unregulated streamgages in the Upper Yellowstone-Central Mountain hydrologic region (table 3) are presented in figure 24. For the 108 unregulated streamgages, *PFVI* generally monotonically decreases with increasing drainage area (fig. 24*A*). Intuitively, highly variable small-scale hydroclimatic processes are integrated with increasing drainage area such that variability in many hydrologic characteristics is reduced. For drainage areas smaller than about 50 mi^2, variability in *PFVI* is large and the LOWESS line for the streamgages in the Upper Yellowstone-Central Mountain hydrologic region is above the LOWESS line for all unregulated streamgages in Montana. For drainage areas larger than about 50 mi^2, variability in *PFVI* is moderate and the LOWESS line for the streamgages in the Upper Yellowstone-Central Mountain hydrologic region is below the

LOWESS line for all unregulated streamgages in Montana. *PFVI* also decreases with increasing elevation (fig. 24*B*), precipitation (fig. 24*C*), and years of record (fig. 24*D*). For the relations between *PFVI* and elevation (fig. 24*B*) and precipitation (fig. 24*C*), the LOWESS lines for the Upper Yellowstone-Central Mountain hydrologic region are above the LOWESS lines for all unregulated streamgages in Montana at elevations less than about 6,000 ft and precipitation less than about 20 inches.

Relations between contributing drainage area and mean basin elevation, mean annual precipitation, and years of peak-flow records for the unregulated streamgages are presented in figure 25. Streamgages with greater than about 60 years of record are predominantly located on streams with contributing drainage areas greater than about 100 mi^2 (fig. 25*C*), which likely strongly contributes to the *PFVI* and years of record relations (fig. 24*D*).

The median *PFVI* value for streamgages in the Upper Yellowstone-Central Mountain hydrologic region (14.48, table 3) is somewhat less than the median for all unregulated streamgages in Montana (18.26, table 3) and ranks as the fifth largest median *PFVI* among the eight hydrologic regions. A major factor contributing to low peak-flow variability in the Upper Yellowstone-Central Mountain hydrologic region might be the dominance of snowmelt runoff in the annual hydrograph of many of the streamgages. For unregulated streamgages in the Upper Yellowstone-Central Mountain hydrologic region, fall and winter (October–February) precipitation accounts for 24.1 percent of annual precipitation (table 8), which can result in large accumulated snowpacks (Sando and McCarthy, 2018) that contribute to streamflows during the typical snowmelt runoff period of May through mid-July. May–June precipitation accounts for about 32.9 percent of annual precipitation (table 8), which ranks fifth among the hydrologic regions, and July–August precipitation accounts for 17.5 percent of annual precipitation, which ranks sixth among the eight hydrologic regions. In the Upper Yellowstone-Central Mountain hydrologic region, annual peak flows predominantly are in May and June (fig. 2 of Sando, R., and others, 2018). Dominance of snowmelt in the annual hydrograph tends to provide temporal integration of a substantial part of the annual precipitation inputs and contributes to the low *PFVI*s for streamgages in the Upper Yellowstone-Central Mountain hydrologic region.

About 3.9 percent of the streamgages in the Upper Yellowstone-Central Mountain hydrologic region are considered to have mixed-population characteristics (table 1) that result in a small number of unusually large peak flows that are substantially larger than the main body of peak flows. Mixed-population peak-flow datasets are not a substantial consideration in the Upper Yellowstone-Central Mountain hydrologic region. However, possible future advances in understanding of mixed-population characteristics might result in identification of more mixed-population peak-flow datasets in the Upper Yellowstone-Central Mountain hydrologic region.

The CDFs of selected basin characteristics (drainage area, mean basin elevation, and mean annual precipitation) for the road and stream intersections and for the streamgages in the Upper Yellowstone-Central Mountain hydrologic region are shown in figure 26. With respect to drainage area, the CDF of road and stream intersections for the Upper Yellowstone-Central Mountain hydrologic region generally is similar to the CDF of road and stream intersections for all of Montana (fig. 26*A*). In the Upper Yellowstone-Central Mountain hydrologic region, the CDF of streamgages diverges from the CDF of road and stream intersections in the range of drainage areas less than about 32 mi^2. In the range of drainage areas less than about 10 mi^2, the CDF of streamgages in the Upper Yellowstone-Central Mountain hydrologic region is similar to the CDF of streamgages for all of Montana; thus, streamgages with drainage areas in that range are not considered to be underrepresented in the Upper Yellowstone-Central Mountain hydrologic region. In the range of drainage areas between about 10 and 32 mi^2, the CDF of streamgages in the Upper Yellowstone-Central Mountain hydrologic region diverges from the CDF of road and stream intersections and also diverges from the CDF of streamgages for all of Montana; thus, streamgages with drainage areas in that range are considered to be underrepresented in the Upper Yellowstone-Central Mountain hydrologic region.

Mean basin elevation for road and stream intersections in the Upper Yellowstone-Central Mountain hydrologic region ranges from 2,839 to 9,890 ft (Dutton and others, 2021) with a median of 4,889 ft (table 4), which generally are similar to the range (1,951–9,974 ft; Dutton and others, 2021) and median (4,173 ft; table 4) for all of Montana. However, the Upper Yellowstone-Central Mountain hydrologic region has a somewhat lower proportion of road and stream intersections less than about 4,000 ft than Montana as a whole (fig. 26*B*). With respect to mean basin elevation, the pattern of the streamgage CDF reasonably represents the road and stream intersection CDF but with some underrepresentation at elevations less than about 5,100 ft.

The Upper Yellowstone-Central Mountain hydrologic region is somewhat wetter than Montana as a whole. Mean annual precipitation for road and stream intersections in the Upper Yellowstone-Central Mountain hydrologic region ranges from 8.4 to 45.6 inches (Dutton and others, 2021) with a median of 17.7 inches (table 5). The range for the Upper Yellowstone-Central Mountain hydrologic region is smaller than for all of Montana (8.4–91.3 ft; Dutton and others, 2021) and the median for the Upper Yellowstone-Central Mountain hydrologic region is somewhat larger than for all of Montana (15.7 inches; table 5). The Upper Yellowstone-Central Mountain hydrologic region has a somewhat lower proportion of road and stream intersections with mean annual precipitation less than about 15 inches than Montana as a whole (fig. 26*C*). With respect to mean annual precipitation, the pattern of the streamgage CDF reasonably represents the road and stream intersection CDF but the CDF of streamgages slightly

Table 22. Information on streamgages in the Southeast Plains hydrologic region with significant leverage and influence in the Montana regional regression analyses (Sando, R., and others, 2018).

[ID, identification; NAD 83, North American Datum of 1983; *n*, total number of years of peak-flow records; *CONTDA*, contributing drainage area, in square miles; *FOREST*, percentage of basin in forest; *ET*0306*MOD*, spring mean monthly evapotranspiration, in inches per month; AEP, annual exceedance probability; CONT, continuous streamgage; CSG, crest-stage gage]

Map number (fig. 1)	Streamgage ID number	Streamgage name	Latitude, in decimal degrees (NAD 83)	Longitude, in decimal degrees (NAD 83)	Type of streamgage	Status of streamgage in water year 2017	*n*
		Streamgages with significant leverage					
500	06295100	Rosebud Creek near Kirby, Montana	45.2457	−106.9679	CONT, CSG	Discontinued	36
501	06295113	Rosebud Creek at reservation boundary, near Kirby, Montana	45.3612	−106.9904	CONT	Active	35
509	[2]06306300	Tongue River at State line, near Decker, Montana	45.0091	−106.8359	CONT	Active	57
528	06308200	Basin Creek tributary near Volborg, Montana	45.8856	−105.6824	CSG	Active	62
569	06327790	Krug Creek tributary No. 2 near Wibaux, Montana	47.0083	−104.3060	CSG	Active	43
		Streamgages with significant influence					
469	06217800	Yellowstone River tributary No. 2 near Pompeys Pillar, Montana	46.0418	−107.7968	CSG	Discontinued	12
485	06294400	Andresen Coulee near Custer, Montana	46.0651	−107.5429	CSG	Active	54
502	06295130	Rosebud Creek tributary near Busby, Montana	45.5801	−106.8690	CSG	Discontinued	15
505	06296003	Rosebud Creek at mouth, near Rosebud, Montana	46.2646	−106.4752	CONT	Discontinued	33
509	[2]06306300	Tongue River at State line, near Decker, Montana	45.0091	−106.8359	CONT	Active	57
522	06307740	Otter Creek at Ashland, Montana	45.5884	−106.2551	CONT	Active	34
526	06307930	Jack Creek near Volborg, Montana	46.0819	−105.8528	CSG	Discontinued	29
540	06309080	Deep Creek near Kinsey, Montana	46.5568	−105.6207	CSG	Active	55
547	06325500	Little Powder River near Broadus, Montana	45.3898	−105.3054	CONT	Discontinued	25
549	06325950	Cut Coulee near Mizpah, Montana	46.1439	−105.1687	CSG	Active	44
555	06326580	Lame Jones Creek tributary near Willard, Montana	46.1941	−104.5522	CSG	Active	43
568	06327720	Griffith Creek tributary near Glendive, Montana	47.1055	−104.5973	CSG	Active	44
580	06333850	North Creek near Alzada, Montana	45.0613	−104.5293	CONT, CSG	Discontinued	24
584	06334330	Little Missouri River tributary near Albion, Montana	45.2106	−104.2618	CSG	Active	44
591	06336500	Beaver Creek at Wibaux, Montana	46.9899	−104.1838	CONT	Discontinued	40

[1]The nonexceedance percentile for the basin or climatic variable value was calculated in relation to the values for all streamgages included in the regional regression analyses for the indicated hydrologic region.

[2]Streamgages having both significant leverage and significant influence.

CONTDA	Nonexceedance percentile[1] for *CONTDA*	*FOREST*	Nonexceedance percentile[1] for *FOREST*	*ET*0306*MOD*	Nonexceedance percentile[1] for *ET*0306*MOD*	Regression residuals for the specified AEP regression analyses		
						10-percent AEP	4-percent AEP	1-percent AEP
Streamgages with significant leverage								
35.5	76.5	5.59	47.1	1.58	95.6	0.073	0.048	0.014
124	82.4	20.99	82.4	1.67	100.0	−0.098	−0.071	0.011
1,451	98.5	26.29	89.7	1.62	98.5	0.698	0.575	0.452
0.13	2.9	19.07	77.9	1.08	23.5	0.190	0.132	0.100
0.42	5.9	17.25	72.1	1.31	83.8	0.282	0.106	−0.100
Streamgages with significant influence								
0.67	8.8	28.37	92.6	1.03	11.8	−0.640	−0.456	−0.240
2.34	32.4	14.87	69.1	1.02	7.4	−0.602	−0.581	−0.497
0.10	1.5	0.00	1.5	1.24	61.8	−0.352	−0.479	−0.645
1,307	97.1	21.88	83.8	1.30	82.4	−0.386	−0.429	−0.432
1,451	98.5	26.29	89.7	1.62	98.5	0.698	0.575	0.452
710	92.6	24.39	86.8	1.26	72.1	−0.909	−0.899	−0.853
5.43	48.5	4.69	44.1	0.97	2.9	0.008	−0.209	−0.466
11.6	67.6	4.65	42.6	0.96	1.5	0.417	0.330	0.238
1,962	100.0	3.97	41.2	1.20	47.1	−0.386	−0.494	−0.612
2.30	29.4	0.08	25.0	0.99	4.4	0.392	0.441	0.525
0.50	7.4	0.83	27.9	1.24	55.9	−0.575	−0.476	−0.377
3.50	39.7	9.58	58.8	1.06	14.7	0.314	0.442	0.628
1.88	26.5	0.00	1.5	1.15	38.2	0.716	0.659	0.586
1.43	20.6	0.00	1.5	1.27	73.5	−0.579	−0.435	−0.252
376	85.3	0.97	29.4	1.36	88.2	0.413	0.445	0.458

Table 23. Information on discontinued streamgages in the Southeast Plains hydrologic region that might be candidates for reactivation to improve the streamgage network.

[NAD 83, North American Datum of 1983; *n*, total number of years of peak-flow records; *CONTDA*, contributing drainage area, in square miles; *FOREST*, percentage of basin in forest; *ET*0306*MOD*, spring mean monthly evapotranspiration, in inches per month; CSG, crest-stage gage; CONT, continuous streamgage]

Map number (fig. 1)	Station identification number	Station name	Latitude, in decimal degrees (NAD 83)	Longitude, in decimal degrees (NAD 83)	Type of streamgage	*n*	*CONTDA*, in square miles	Non-exceedance percentile[1] for *CONTDA*	*FOREST*	Non-exceedance percentile[1] for *FOREST*	*ET*0306*MOD*	Non-exceedance percentile[1] for *ET*0306*MOD*
469	06217800	Yellowstone River tributary No. 2 near Pompeys Pillar, Montana	46.0418	−107.7968	CSG	12	0.67	8.8	28.4	92.6	1.03	11.8
490	06294850	Buckingham Coulee near Myers, Montana	46.2362	−107.2905	CSG	17	2.61	33.8	57.6	100.0	1.07	19.1
493	06294940	Sarpy Creek near Hysham, Montana	46.2386	−107.1371	CONT	11	454	86.8	23.4	85.3	1.21	51.5
502	06295130	Rosebud Creek tributary near Busby, Montana	45.5801	−106.8690	CSG	15	0.10	1.5	0.0	1.5	1.24	61.8
503	06295200	Whitedirt Creek near Lame Deer, Montana	45.6081	−106.7507	CSG	15	1.58	22.1	45.7	95.6	1.32	86.8
508	06306100	Squirrel Creek near Decker, Montana	45.0515	−106.9272	CONT	10	33.9	75.0	6.5	48.5	1.59	97.1
514	06307520	Canyon Creek near Birney, Montana	45.2411	−106.6762	CSG	20	50.4	79.4	18.9	76.5	1.26	69.1
517	06307620	Tie Creek near Birney, Montana	45.4727	−106.5307	CSG	13	18.4	72.1	46.5	97.1	1.38	91.2
518	06307640	Spring Creek near Ashland, Montana	45.5516	−106.2857	CSG	15	1.60	23.5	18.4	73.5	1.08	25.0
519	06307660	Walking Horse Creek near Ashland, Montana	45.6080	−106.2882	CSG	16	3.26	36.8	9.3	55.9	1.10	26.5
523	06307760	Stebbins Creek near Ashland, Montana	45.6199	−106.4100	CSG	15	5.43	48.5	48.7	98.5	1.43	92.6
527	06308100	Sixmile Creek tributary near Epsie, Montana	45.5242	−105.7533	CSG	20	0.80	10.3	0.0	1.5	1.03	10.3
529	06308300	Basin Creek near Volborg, Montana	45.8861	−105.6647	CSG	19	11.1	66.2	12.4	66.2	1.16	41.2
541	06309090	Ash Creek near Locate, Montana	46.3659	−105.4974	CSG	15	6.27	54.4	20.6	79.4	1.25	63.2
546	06325400	East Fork Little Powder River tributary near Hammond, Montana	45.3003	−105.0992	CSG	11	3.47	38.2	0.0	1.5	1.27	75.0

Table 23. Information on discontinued streamgages in the Southeast Plains hydrologic region that might be candidates for reactivation to improve the streamgage network.—Continued

[NAD 83, North American Datum of 1983; *n*, total number of years of peak-flow records; *CONTDA*, contributing drainage area, in square miles; *FOREST*, percentage of basin in forest; *ET*0306*MOD*, spring mean monthly evapotranspiration, in inches per month; CSG, crest-stage gage; CONT, continuous streamgage]

Map number (fig. 1)	Station identification number	Station name	Latitude, in decimal degrees (NAD 83)	Longitude, in decimal degrees (NAD 83)	Type of streamgage	*n*	*CONTDA*, in square miles	Non-exceedance percentile[1] for *CONTDA*	*FOREST*	Non-exceedance percentile[1] for *FOREST*	*ET*0306*MOD*	Non-exceedance percentile[1] for *ET*0306*MOD*
547	06325500	Little Powder River near Broadus, Montana	45.3898	−105.3054	CONT	25	1,962	100.0	4.0	41.2	1.20	47.1
551	06326400	Meyers Creek near Locate, Montana	46.3880	−105.2789	CSG	16	9.35	60.3	9.5	57.4	1.07	22.1
553	06326510	Locate Creek tributary near Locate, Montana	46.4311	−105.1819	CSG	19	0.90	17.6	6.7	50.0	1.12	30.9
557	06326650	O'Fallon Creek tributary near Ismay, Montana	46.4193	−104.7424	CSG	15	0.15	4.4	0.0	1.5	1.13	33.8
558	06326700	Deep Creek near Baker, Montana	46.2990	−104.3010	CSG	16	3.80	42.6	0.1	23.5	1.25	66.2
567	06327700	Griffith Creek near Glendive, Montana	47.1034	−104.5618	CSG	12	16.7	70.6	6.8	52.9	1.13	32.4
580	06333850	North Creek near Alzada, Montana	45.0613	−104.5293	CONT, CSG	24	1.88	26.5	0.0	1.5	1.15	38.2
583	06334200	Willow Creek near Alzada, Montana	45.1076	−104.5943	CSG	16	122	80.9	0.0	20.6	1.24	58.8
587	06334630	Boxelder Creek at Webster, Montana	45.9068	−104.0576	CONT	15	1,097	95.6	2.9	38.2	1.26	70.6
588	06334640	North Fork Coal Bank Creek near Mill Iron, Montana	45.9431	−104.0928	CSG	15	15.5	69.1	0.0	22.1	1.30	80.9
590	06336450	Spring Creek near Wibaux, Montana	46.8844	−104.2004	CONT	18	3.91	44.1	0.0	1.5	1.27	76.5

[1]The nonexceedance percentile for the basin or climatic variable value was calculated in relation to the values for all streamgages included in the regional regression analyses for the indicated hydrologic region.

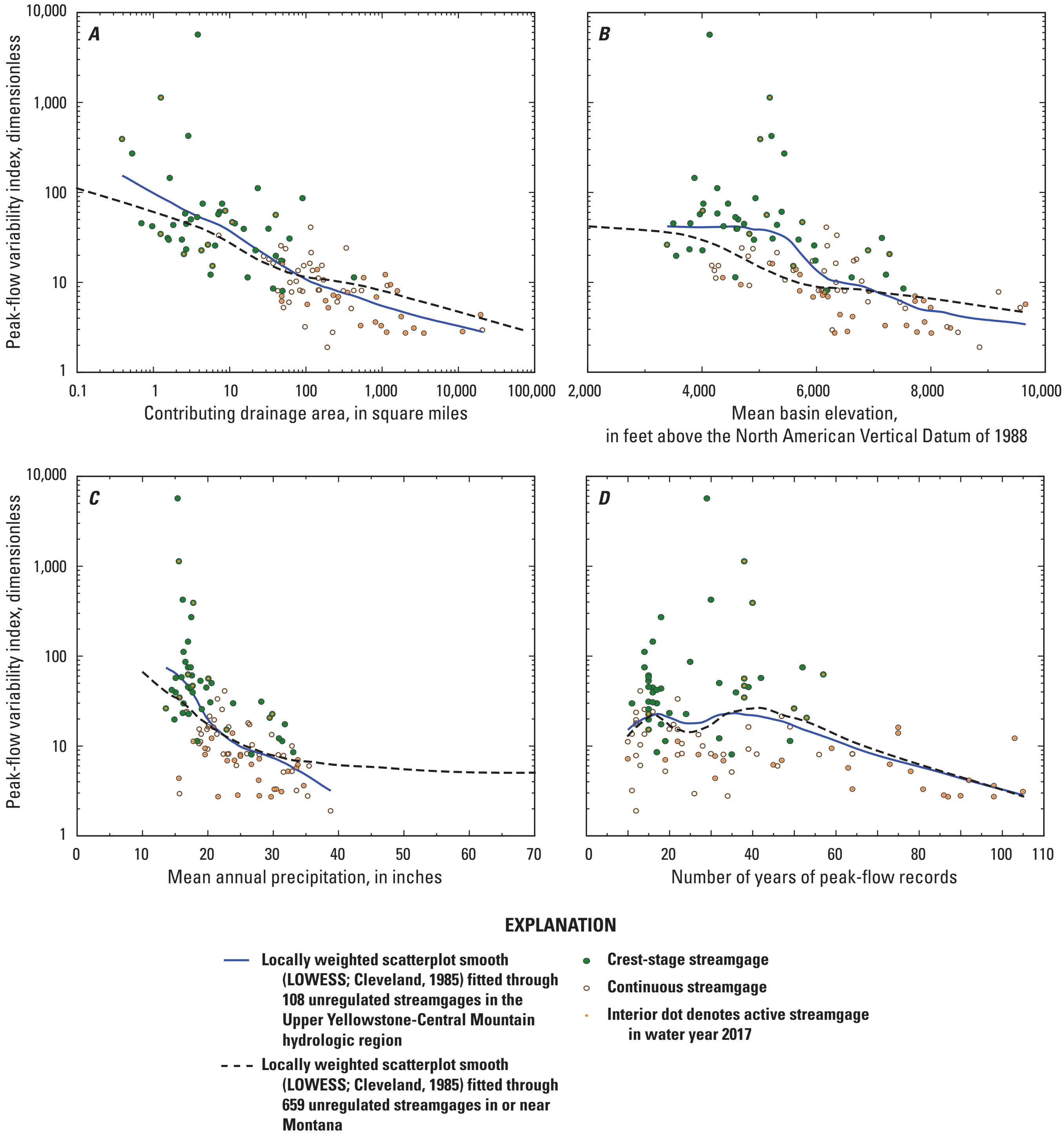


Figure 24. Relations between peak-flow variability index and contributing drainage area, mean basin elevation, mean annual precipitation, and years of peak-flow records for 108 unregulated streamgages in the Upper Yellowstone-Central Mountain hydrologic region. *A*, Peak-flow variability and contributing drainage area relations. *B*, Peak-flow variability and mean basin elevation relations. *C*, Peak-flow variability and mean annual precipitation relations. *D*, Peak-flow variability and years of peak-flow records relations.

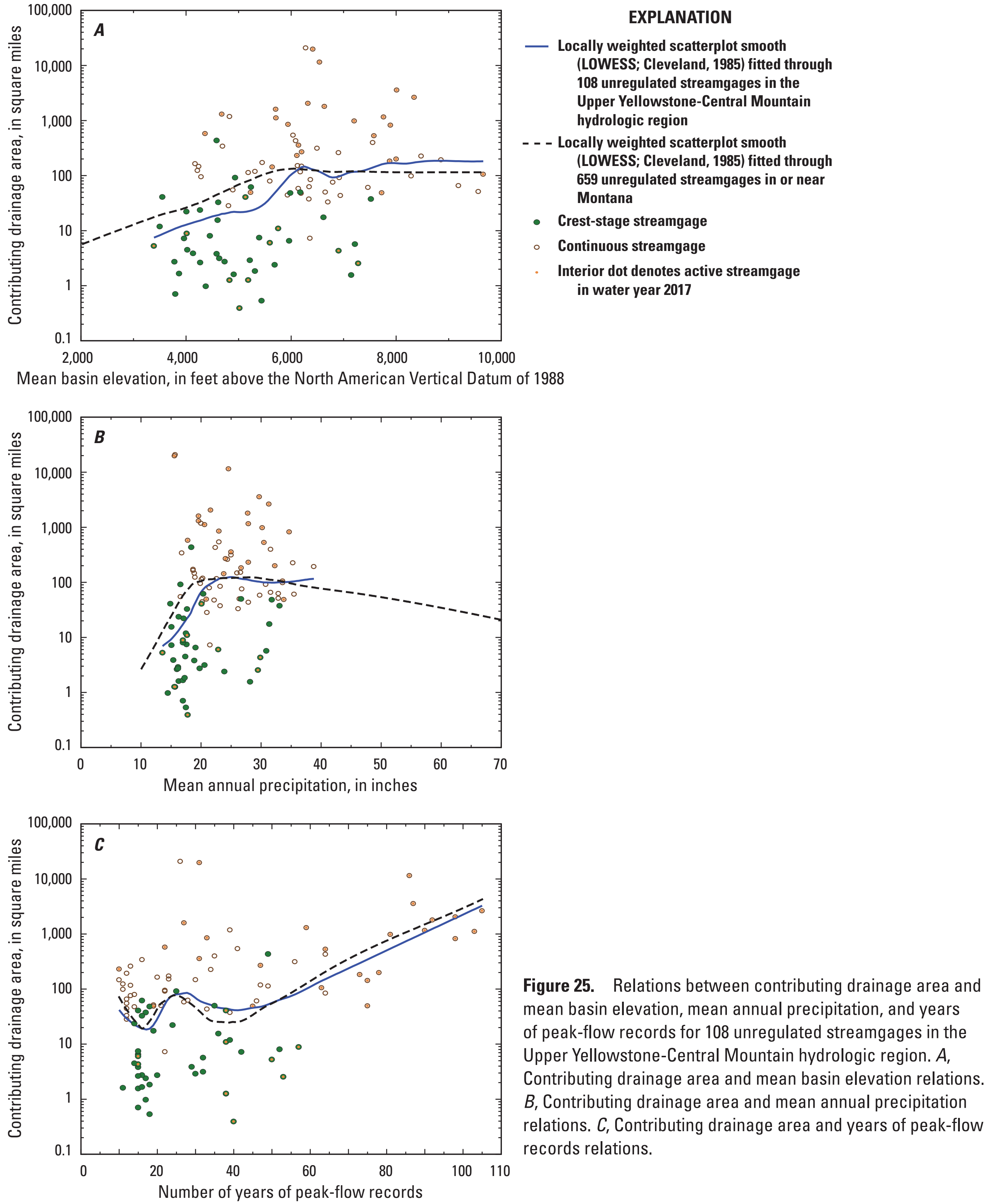


Figure 25. Relations between contributing drainage area and mean basin elevation, mean annual precipitation, and years of peak-flow records for 108 unregulated streamgages in the Upper Yellowstone-Central Mountain hydrologic region. *A*, Contributing drainage area and mean basin elevation relations. *B*, Contributing drainage area and mean annual precipitation relations. *C*, Contributing drainage area and years of peak-flow records relations.

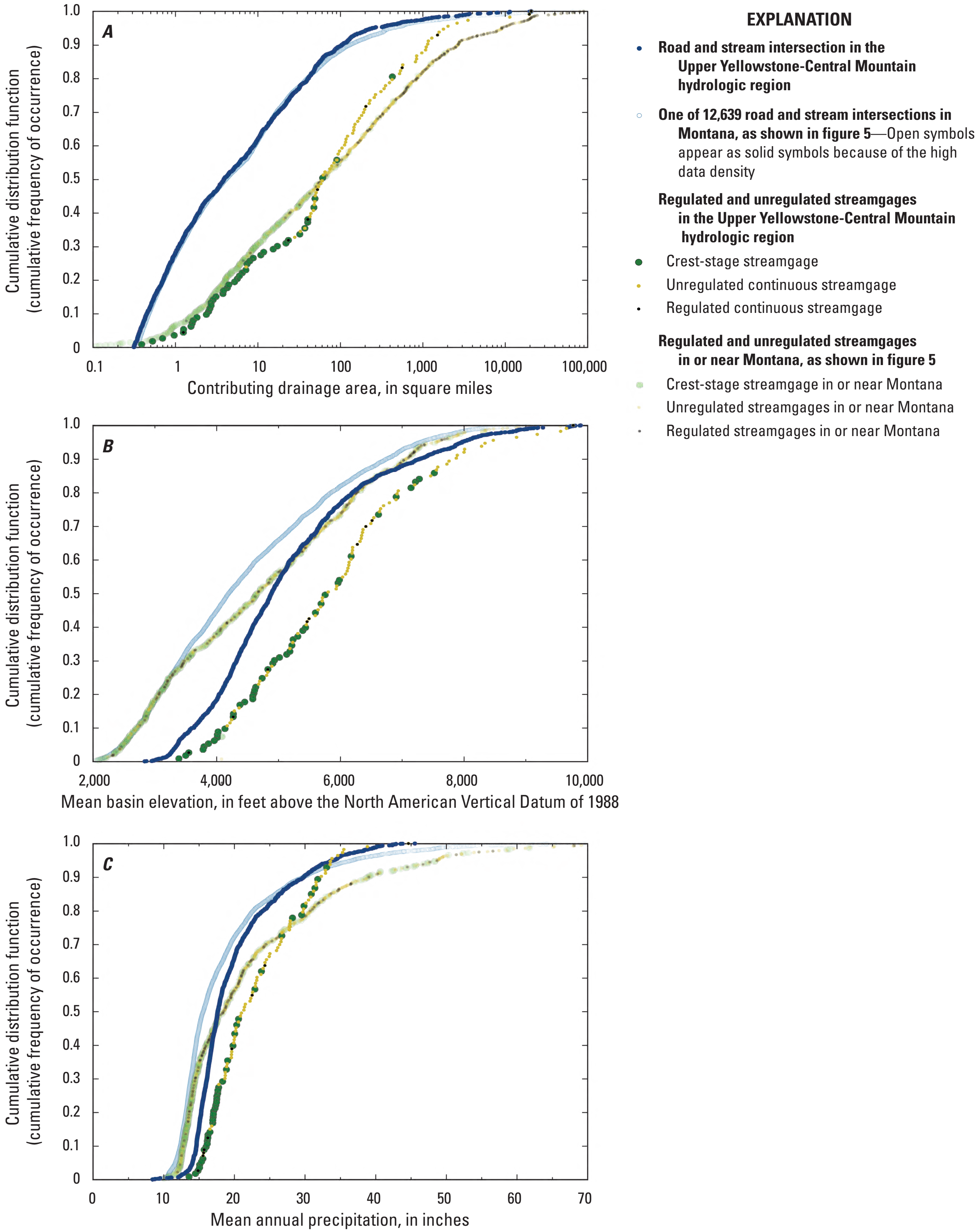


Figure 26. Cumulative distribution functions of selected drainage-basin characteristics for 2,166 road and stream intersections and for 113 streamgages (regulated and unregulated) in the Upper Yellowstone-Central Mountain hydrologic region. *A*, Contributing drainage area relations. *B*, Mean basin elevation relations. *C*, Mean annual precipitation relations.

diverges from the CDF of road and stream intersections in the range of mean annual precipitation from about 18 to 22 inches, indicating small underrepresentation in that range.

The explanatory variables for the Upper Yellowstone-Central Mountain hydrologic region RREs are *CONTDA* and percent of basin above 6,000 ft elevation (EL_{6000}; table 6). The 1-percent AEP RRE for the Upper Yellowstone-Central Mountain hydrologic region has an SEP of 69.0 percent, which is somewhat higher than the area-weighted mean SEP for all hydrologic regions in Montana (63.3 percent; table 6). For the 1-percent AEP regression for the Upper Yellowstone-Central Mountain hydrologic region, 11.0 percent of the streamgages have significant leverage and 14.3 percent of the streamgages have significant influence (table 7); these percentages are higher than significant leverage and influence percentages (8.2 and 10.4 percent, respectively; table 7) for all of the streamgages in Montana used in the regional regression analyses.

Information on streamgages in the Upper Yellowstone-Central Mountain hydrologic region with significant leverage and influence is presented in table 24. One of the 10 significant leverage streamgages has the largest *CONTDA* value (nonexceedance percentile equal to 100 percent). Three of the 10 significant leverage streamgages have high EL_{6000} values (nonexceedance percentiles greater than about 88 percent) in association with small *CONTDA* values (nonexceedance percentiles less than about 23 percent). Four of the 10 significant leverage streamgages have low EL_{6000} values (nonexceedance percentiles equal to 1.1 percent). The 15 streamgages with significant influence vary with respect to the residuals for the 1-percent AEP RRE; 10 of the streamgages have negative residuals, and five have positive residuals. Three of the five streamgages with both significant leverage and significant influence have negative residuals and two have positive residuals.

In general, the streamgage network in the Upper Yellowstone-Central Mountain hydrologic region is considered to provide reasonable representation of the hydroclimatic settings of that hydrologic region. The RREs of the Upper Yellowstone-Central Mountain hydrologic region are considered to be reasonably reliable. Possible shortcomings of the streamgage network in the Upper Yellowstone-Central Mountain hydrologic region include small underrepresentation of basins with drainage areas from 10 to 32 mi^2, mean basin elevation less than about 5,100 ft, and (or) mean annual precipitation from 18 to 22 inches. Future improvements to the streamgage network in the Upper Yellowstone-Central Mountain hydrologic region might include establishing new CSGs or reactivating discontinued streamgages as CSGs on drainage basins with the specified characteristics. Information on discontinued streamgages in the Upper Yellowstone-Central Mountain hydrologic region that might be candidates for reactivation to improve the streamgage network is presented in table 25.

Peak-Flow Variability, Peak-Flow Informational Needs, and Consideration of Regional Regression Analyses in the Southwest Hydrologic Region

The Southwest hydrologic region has an area of 14,891 mi^2 (table 1), which ranks sixth largest among the eight hydrologic regions. Level III ecoregions (table 2) represented in the Southwest hydrologic region include the Idaho Batholith (1.8 percent), Middle Rockies (95.5 percent), Northwestern Glaciated Plains (0.8 percent), and Northwestern Great Plains (1.9 percent). The 2,267 road and stream intersections in the Southwest hydrologic region (tables 4 and 5) represent a density of 0.152 road and stream intersection per mi^2, which ranks first among the hydrologic regions. The 84 streamgages (both regulated and unregulated; tables 4 and 5) represent an areal density of 0.00564 streamgage per mi^2 (ranking third among hydrologic regions) and a density of 0.03705 streamgage per road and stream intersection (ranking eighth among hydrologic regions).

Relations between *PFVI* and contributing drainage area, mean basin elevation, mean annual precipitation, and years of peak-flow records for 67 unregulated streamgages in the Southwest hydrologic region (table 3) are presented in figure 27. For the 67 unregulated streamgages, *PFVI* generally monotonically decreases with increasing drainage area (fig. 27*A*). Intuitively, highly variable small-scale hydroclimatic processes are integrated with increasing drainage area such that variability in many hydrologic characteristics is reduced. For drainage areas smaller than about 20 mi^2, variability in *PFVI* is large and the LOWESS line for the streamgages in the Southwest hydrologic region is above the LOWESS line for all unregulated streamgages in Montana. For drainage areas larger than about 20 mi^2, variability in *PFVI* is small and the LOWESS line for the streamgages in the Southwest hydrologic region is near or below the LOWESS line for all unregulated streamgages in Montana. *PFVI* also decreases with increasing elevation (fig. 27*B*), precipitation (fig. 27*C*), and years of record (fig. 27*D*). For the relations between *PFVI* and elevation (fig. 27*B*) and precipitation (fig. 27*C*), the LOWESS lines for the Southwest hydrologic region are above the LOWESS lines for all unregulated streamgages in Montana at elevations less than about 6,500 ft and precipitation less than about 18 inches.

Relations between contributing drainage area and mean basin elevation, mean annual precipitation, and years of peak-flow records for the unregulated streamgages are presented in figure 28. Streamgages with greater than about 60 years of record are predominantly located on streams with contributing drainage areas greater than about 100 mi^2 (fig. 28*C*), which likely contributes to the *PFVI* and years of record relations (fig. 27*D*).

The median *PFVI* value for streamgages in the Southwest hydrologic region (9.30, table 3) is less than the median for all unregulated streamgages in Montana (18.26, table 3)

Table 24. Information on streamgages in the Upper Yellowstone-Central Mountain hydrologic region with significant leverage and influence in the Montana regional regression analyses (Sando, R., and others, 2018).

[ID, identification; NAD 83, North American Datum of 1983; n, total number of years of peak-flow records; *CONTDA*, contributing drainage area, in square miles; EL_{6000}, percentage of basin above 6,000 feet elevation; AEP, annual exceedance probability; CSG, crest-stage gage; CONT, continuous streamgage]

Map number (fig. 1)	Streamgage ID number	Streamgage name	Latitude, in decimal degrees (NAD 83)	Longitude, in decimal degrees (NAD 83)	Type of streamgage	Status of streamgage in water year 2017	*n*	*CONTDA*	Non-exceedance percentile[1] for *CONTDA*	EL_{6000}	Non-exceedance percentile[1] for EL_{6000}	Regression residuals for the specified AEP regression analyses: 10-percent AEP	4-percent AEP	1-percent AEP
Streamgages with significant leverage														
79	[2]06043300	Logger Creek near Gallatin Gateway, Montana	45.4540	−111.2449	CSG	Active	58	2.53	12.1	90.39	88.5	−0.319	−0.319	−0.298
88	06052500	Gallatin River at Logan, Montana	45.8854	−111.4383	CONT	Active	97	1,789	98.9	60.30	78.2	−0.043	−0.102	−0.162
120	06076700	Sheep Creek near Neihart, Montana	46.7996	−110.7037	CSG	Discontinued	32	5.65	23.1	100.00	100.0	−0.038	−0.095	−0.164
121	[2]06076800	Nugget Creek near Neihart, Montana	46.7749	−110.7015	CSG	Discontinued	15	1.55	6.6	100.00	100.0	−0.328	−0.336	−0.329
193	06111000	Ross Fork Creek near Hobson, Montana	46.9927	−109.7951	CONT	Discontinued	16	340	85.7	3.11	35.6	−0.234	−0.270	−0.318
208	[2]06117800	Big Coulee near Martinsdale, Montana	46.5499	−110.3151	CSG	Discontinued	30	2.88	16.5	0.00	1.1	0.343	0.398	0.376
222	[2]06123200	Sadie Creek tributary near Harlowton, Montana	46.1912	−109.9005	CSG	Active	45	0.39	1.1	0.00	1.1	0.589	0.735	0.901
448	06208500	Clarks Fork Yellowstone River at Edgar, Montana	45.4657	−108.8441	CONT	Active	78	2,034	100.0	45.42	62.1	0.047	−0.032	−0.113

Table 24. Information on streamgages in the Upper Yellowstone-Central Mountain hydrologic region with significant leverage and influence in the Montana regional regression analyses (Sando, R., and others, 2018).—Continued

[ID, identification; NAD 83, North American Datum of 1983; n, total number of years of peak-flow records; *CONTDA*, contributing drainage area, in square miles; EL_{6000}, percentage of basin above 6,000 feet elevation; AEP, annual exceedance probability; CSG, crest-stage gage; CONT, continuous streamgage]

Map number (fig. 1)	Streamgage ID number	Streamgage name	Latitude, in decimal degrees (NAD 83)	Longitude, in decimal degrees (NAD 83)	Type of streamgage	Status of streamgage in water year 2017	*n*	*CONTDA*	Non-exceedance percentile[1] for *CONTDA*	EL_{6000}	Non-exceedance percentile[1] for EL_{6000}	Regression residuals for the specified AEP regression analyses		
												10-percent AEP	4-percent AEP	1-percent AEP
						Streamgages with significant leverage—Continued								
461	06216200	West Wets Creek near Billings, Montana	45.6270	−108.4045	CSG	Active	62	8.82	29.7	0.00	1.1	0.220	0.204	0.169
482	[2]06293300	Long Otter Creek near Lodge Grass, Montana	45.4540	−107.3959	CSG	Discontinued	40	11.8	31.9	0.00	1.1	−0.187	−0.265	−0.357
						Streamgages with significant influence								
79	[2]06043300	Logger Creek near Gallatin Gateway, Montana	45.4540	−111.2449	CSG	Active	58	2.53	12.1	90.39	88.5	−0.319	−0.319	−0.298
117	06075600	Fivemile Creek near White Sulphur Springs, Montana	46.6128	−110.7567	CSG	Discontinued	15	6.48	24.2	40.08	59.8	−0.600	−0.612	−0.607
118	06076000	Newlan Creek near White Sulphur Springs, Montana	46.7316	−110.8387	CONT	Discontinued	22	7.23	26.4	80.67	83.9	−0.560	−0.530	−0.482
121	[2]06076800	Nugget Creek near Neihart, Montana	46.7749	−110.7015	CSG	Discontinued	15	1.55	6.6	100.00	100.0	−0.328	−0.336	−0.329
144	06090550	Little Otter Creek near Raynesford, Montana	47.2518	−110.7316	CSG	Active	43	40.4	42.9	4.37	37.9	−0.774	−0.677	−0.514

Table 24. Information on streamgages in the Upper Yellowstone-Central Mountain hydrologic region with significant leverage and influence in the Montana regional regression analyses (Sando, R., and others, 2018).—Continued

[ID, identification; NAD 83, North American Datum of 1983; n, total number of years of peak-flow records; *CONTDA*, contributing drainage area, in square miles; EL_{6000}, percentage of basin above 6,000 feet elevation; AEP, annual exceedance probability; CSG, crest-stage gage; CONT, continuous streamgage]

Map number (fig. 1)	Streamgage ID number	Streamgage name	Latitude, in decimal degrees (NAD 83)	Longitude, in decimal degrees (NAD 83)	Type of streamgage	Status of streamgage in water year 2017	*n*	*CONTDA*	Non-exceedance percentile[1] for *CONTDA*	EL_{6000}	Non-exceedance percentile[1] for EL_{6000}	Regression residuals for the specified AEP regression analyses		
												10-percent AEP	4-percent AEP	1-percent AEP
Streamgages with significant influence—Continued														
197	06114500	Wolf Creek near Stanford, Montana	47.1190	−110.2872	CONT	Discontinued	13	116	69.2	53.86	70.1	−1.066	−0.851	−0.519
208	[2]06117800	Big Coulee near Martinsdale, Montana	46.5499	−110.3151	CSG	Discontinued	30	2.88	16.5	0.00	1.1	0.343	0.398	0.376
212	06120500	Musselshell River at Harlowton, Montana	46.4288	−109.8412	CONT	Active	108	1,108	95.6	31.86	56.3	−0.352	−0.350	−0.336
214	06120700	Antelope Creek tributary near mouth, near Harlowton, Montana	46.6192	−109.9519	CSG	Discontinued	18	1.83	9.9	0.00	1.1	0.554	0.506	0.459
215	06120800	Alkali Creek near Harlowton, Montana	46.4643	−109.8229	CSG	Discontinued	36	15.4	33.0	0.00	1.1	0.477	0.566	0.719
216	06120900	Antelope Creek at Harlowton, Montana	46.4385	−109.8225	CSG	Discontinued	25	90.9	62.6	6.91	39.1	0.406	0.676	0.963
222	[2]06123200	Sadie Creek tributary near Harlowton, Montana	46.1912	−109.9005	CSG	Active	45	0.39	1.1	0.00	1.1	0.589	0.735	0.901

Table 24. Information on streamgages in the Upper Yellowstone-Central Mountain hydrologic region with significant leverage and influence in the Montana regional regression analyses (Sando, R., and others, 2018).—Continued

[ID, identification; NAD 83, North American Datum of 1983; n, total number of years of peak-flow records; *CONTDA*, contributing drainage area, in square miles; EL_{6000}, percentage of basin above 6,000 feet elevation; AEP, annual exceedance probability; CSG, crest-stage gage; CONT, continuous streamgage]

Map number (fig. 1)	Streamgage ID number	Streamgage name	Latitude, in decimal degrees (NAD 83)	Longitude, in decimal degrees (NAD 83)	Type of streamgage	Status of streamgage in water year 2017	*n*	*CONTDA*	Non-exceedance percentile[1] for *CONTDA*	EL_{6000}	Non-exceedance percentile[1] for EL_{6000}	Regression residuals for the specified AEP regression analyses		
												10-percent AEP	4-percent AEP	1-percent AEP
Streamgages with significant influence—Continued														
245	06129100	North Fork McDonald Creek tributary near Heath, Montana	47.0684	−109.2137	CSG	Discontinued	16	2.72	15.4	0.00	1.1	−0.322	−0.441	−0.554
457	06214150	Mills Creek at Rapelje, Montana	45.9674	−109.2554	CSG	Discontinued	29	3.85	19.8	0.00	1.1	−0.585	−0.468	−0.342
482	[2]06293300	Long Otter Creek near Lodge Grass, Montana	45.4540	−107.3959	CSG	Discontinued	40	11.8	31.9	0.00	1.1	−0.187	−0.265	−0.357

[1]The nonexceedance percentile for the basin or climatic variable value was calculated in relation to the values for all streamgages included in the regional regression analyses for the indicated hydrologic region.

[2]Streamgages having both significant leverage and significant influence.

Table 25. Information on discontinued streamgages in the Upper Yellowstone-Central Mountain hydrologic region that might be candidates for reactivation to improve the streamgage network.

[NAD 83, North American Datum of 1983; *n*, total number of years of peak-flow records; *CONTDA*, contributing drainage area, in square miles; EL_{6000}, percentage of basin above 6,000 feet elevation; CONT, continuous streamgage; CSG, crest-stage gage]

Map number (fig. 1)	Station identification number	Station name	Latitude, in decimal degrees (NAD 83)	Longitude, in decimal degrees (NAD 83)	Type of streamgage	*n*	*CONTDA*	Nonexceedance percentile[1] for *CONTDA*	EL_{6000}	Nonexceedance percentile[1] for EL_{6000}
77	06043000	Taylor Creek near Grayling, Montana	45.0709	−111.2052	CONT	11	98.0	65.9	100.0	95.6
78	06043200	Squaw Creek near Gallatin Gateway, Montana	45.4414	−111.2067	CSG	17	37.3	40.7	97.2	91.2
82	06046700	Pitcher Creek near Bozeman, Montana	45.6549	−110.9426	CSG	17	2.38	11.0	16.3	45.1
83	06047000	Bear Canyon near Bozeman, Montana	45.6241	−110.9349	CONT, CSG	19	17.3	34.1	85.9	82.4
84	06048000	East Gallatin River at Bozeman, Montana	45.7005	−111.0293	CONT	23	151	75.8	51.5	64.8
116	06074500	Smith River near White Sulphur Springs, Montana	46.6717	−110.7234	CONT	12	32.9	39.6	80.4	79.1
117	06075600	Fivemile Creek near White Sulphur Springs, Montana	46.6128	−110.7567	CSG	15	6.48	24.2	40.1	57.1
118	06076000	Newlan Creek near White Sulphur Springs, Montana	46.7316	−110.8387	CONT	22	7.23	26.4	80.7	80.2
121	06076800	Nugget Creek near Neihart, Montana	46.7749	−110.7015	CSG	15	1.55	6.6	100.0	95.6
124	06077300	Trout Creek near Eden, Montana	47.1109	−111.3668	CSG	11	1.60	7.7	0.0	1.1
126	06077700	Smith River tributary near Eden, Montana	47.3064	−111.4245	CSG	16	1.65	8.8	0.0	1.1
127	06077800	Goodman Coulee near Eden, Montana	47.3237	−111.4272	CSG	24	22.0	35.2	0.0	1.1
190	06109800	South Fork Judith River near Utica, Montana	46.7534	−110.3232	CONT	21	49.9	51.6	92.2	85.7
191	06109900	Judith River tributary near Utica, Montana	46.8824	−110.2659	CSG	15	7.42	27.5	7.5	38.5
193	06111000	Ross Fork Creek near Hobson, Montana	46.9927	−109.7951	CONT	16	340	85.7	3.1	34.1
195	06112100	Cottonwood Creek near Moore, Montana	46.9790	−109.4939	CONT, CSG	18	47.9	47.3	43.6	58.2
197	06114500	Wolf Creek near Stanford, Montana	47.1190	−110.2872	CONT	13	116	69.2	53.9	67.0
213	06120600	Antelope Creek tributary near Harlowton, Montana	46.6411	−109.9776	CSG	18	0.53	2.2	0.0	1.1
214	06120700	Antelope Creek tributary near mouth, near Harlowton, Montana	46.6192	−109.9519	CSG	18	1.83	9.9	0.0	1.1
216	06120900	Antelope Creek at Harlowton, Montana	46.4385	−109.8225	CSG	25	90.9	62.6	6.9	37.4
217	06121000	American Fork near Harlowton, Montana	46.3740	−109.7921	CONT	14	79.1	60.4	26.8	50.5
218	06121500	Lebo Creek near Harlowton, Montana	46.3804	−109.7993	CONT	12	54.6	53.8	0.0	1.1

Table 25. Information on discontinued streamgages in the Upper Yellowstone-Central Mountain hydrologic region that might be candidates for reactivation to improve the streamgage network.—Continued

[NAD 83, North American Datum of 1983; *n*, total number of years of peak-flow records; *CONTDA*, contributing drainage area, in square miles; EL_{6000}, percentage of basin above 6,000 feet elevation; CONT, continuous streamgage; CSG, crest-stage gage]

Map number (fig. 1)	Station identification number	Station name	Latitude, in decimal degrees (NAD 83)	Longitude, in decimal degrees (NAD 83)	Type of streamgage	*n*	*CONTDA*	Nonexceedance percentile[1] for *CONTDA*	EL_{6000}	Nonexceedance percentile[1] for EL_{6000}
219	06122000	American Fork below Lebo Creek, near Harlowton, Montana	46.3962	−109.7421	CONT	23	171	78.0	13.2	44.0
245	06129100	North Fork McDonald Creek tributary near Heath, Montana	47.0684	−109.2137	CSG	16	2.72	15.4	0.0	1.1
246	06129200	Alkali Creek near Heath, Montana	47.0790	−109.1479	CSG	15	3.78	18.7	0.0	1.1
247	06129400	South Fork McDonald Creek tributary near Grass Range, Montana	47.0054	−108.7911	CSG	15	0.70	3.3	0.0	1.1
426	06193000	Shields River near Wilsall, Montana	46.1526	−110.5868	CONT	22	90.9	62.6	88.6	83.5
430	06197000	Big Timber Creek near Big Timber, Montana	45.9543	−110.0295	CONT	13	75.3	59.3	56.0	69.2
435	06201550	Yellowstone River tributary near Greycliff, Montana	45.7343	−109.7151	CSG	15	2.62	13.2	0.0	1.1
436	06201600	Bridger Creek near Greycliff, Montana	45.6914	−109.7163	CSG	16	61.3	57.1	10.9	41.8
437	06201650	Work Creek near Reed Point, Montana	45.7031	−109.6251	CSG	16	32.4	38.5	0.0	1.1
440	06202510	Stillwater River above Nye Creek, near Nye, Montana	45.3943	−109.8695	CONT	12	192	80.2	96.2	89.0
446	06207600	Jack Creek tributary near Belfry, Montana	45.1622	−108.8240	CSG	17	0.97	4.4	0.0	1.1
447	06207800	Bluewater Creek near Bridger, Montana	45.3314	−108.8015	CONT	12	28.1	37.4	0.5	33.0
451	06210000	West Fork Rock Creek below Basin Creek, near Red Lodge, Montana	45.1545	−109.3674	CONT	19	51.1	52.7	100.0	95.6
459	06215000	Pryor Creek above Pryor, Montana	45.3507	−108.5660	CONT	12	44.1	46.2	50.9	63.7
462	06216300	West Buckeye Creek near Billing, Montana	45.6498	−108.3923	CSG	20	2.71	14.3	0.0	1.1
471	06287500	Soap Creek near St. Xavier, Montana	45.3269	−107.7698	CONT	22	94.4	64.8	4.2	35.2
472	06288000	Rotten Grass Creek near St. Xavier, Montana	45.4122	−107.6831	CONT	10	146	73.6	8.1	39.6
473	06288200	Beauvais Creek near St. Xavier, Montana	45.4770	−108.0080	CONT	11	123	71.4	0.2	31.9
478	06290200	Little Bighorn River tributary near Wyola, Montana	45.1393	−107.3889	CSG	14	4.45	20.9	0.0	1.1
480	06291000	Owl Creek near Lodge Grass, Montana	45.2680	−107.3014	CONT	20	163	76.9	0.0	1.1

[1]The nonexceedance percentile for the basin or climatic variable value was calculated in relation to the values for all streamgages included in the regional regression analyses for the indicated hydrologic region.

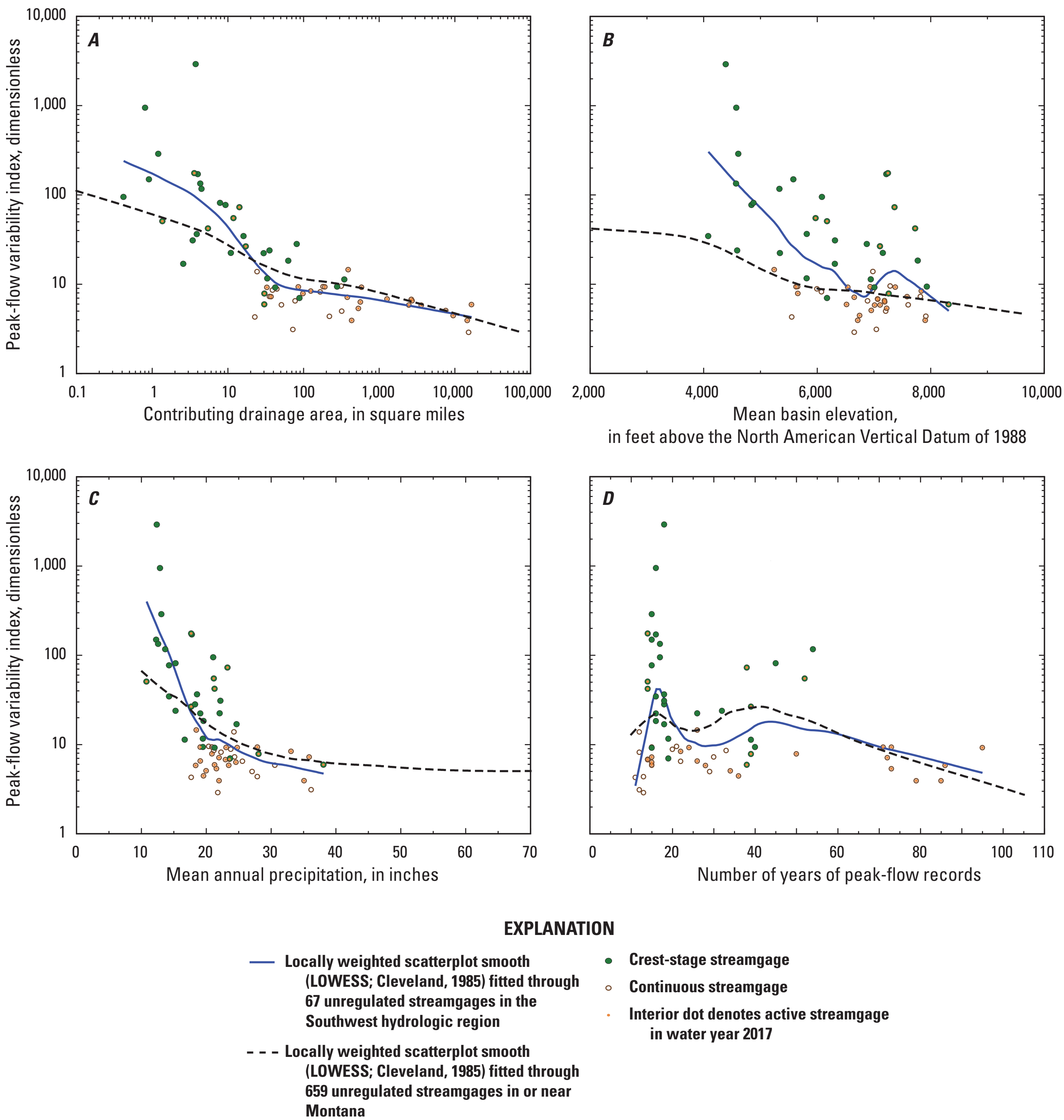


Figure 27. Relations between peak-flow variability index and contributing drainage area, mean basin elevation, mean annual precipitation, and years of peak-flow records for 67 unregulated streamgages in the Southwest hydrologic region. *A*, Peak-flow variability and contributing drainage area relations. *B*, Peak-flow variability and mean basin elevation relations. *C*, Peak-flow variability and mean annual precipitation relations. *D*, Peak-flow variability and years of peak-flow records relations.

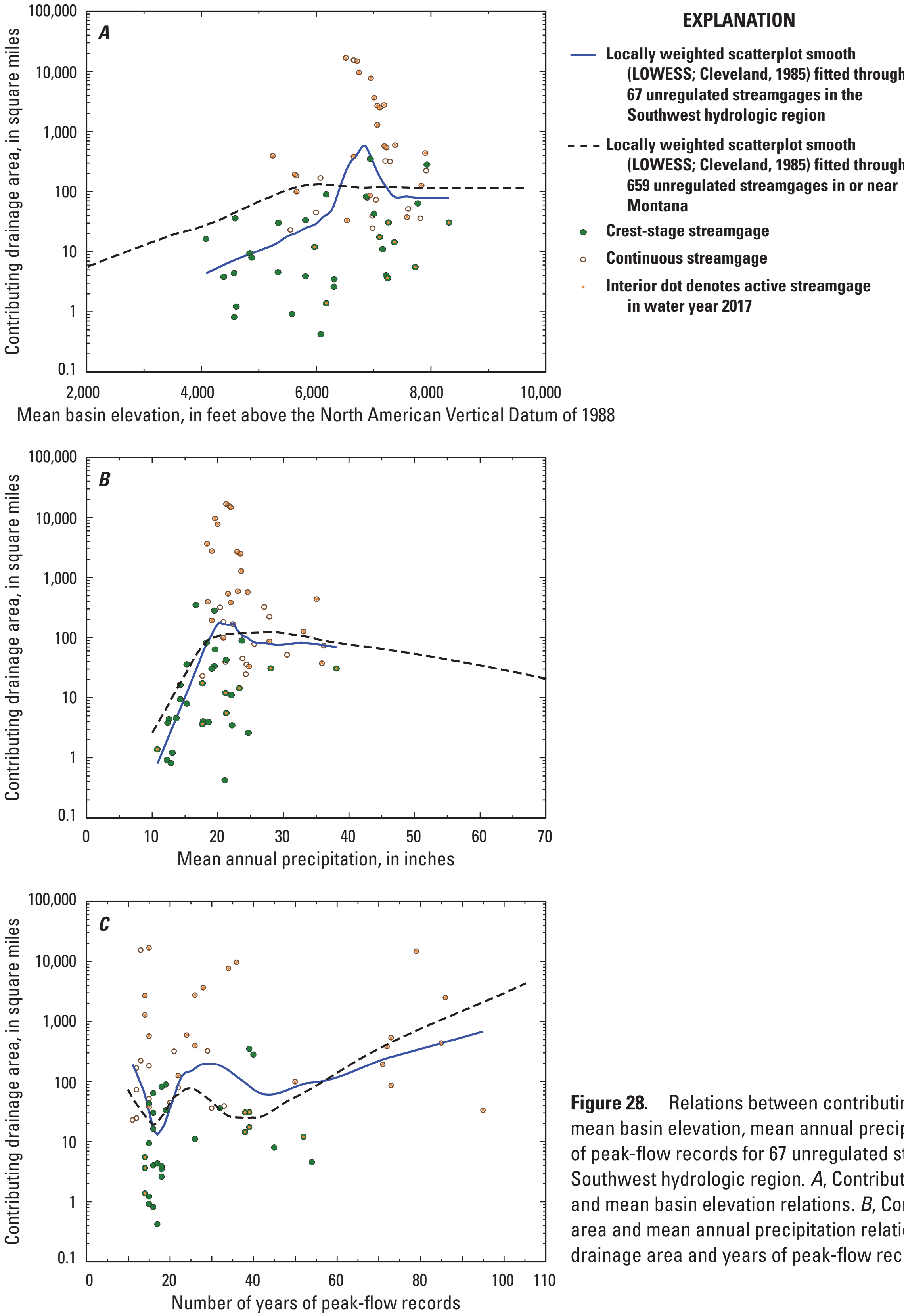


Figure 28. Relations between contributing drainage area and mean basin elevation, mean annual precipitation, and years of peak-flow records for 67 unregulated streamgages in the Southwest hydrologic region. *A*, Contributing drainage area and mean basin elevation relations. *B*, Contributing drainage area and mean annual precipitation relations. *C*, Contributing drainage area and years of peak-flow records relations.

and ranks as the sixth largest median *PFVI* among the eight hydrologic regions. A major factor contributing to low peak-flow variability in the Southwest hydrologic region might be the dominance of snowmelt runoff in the annual hydrograph of many of the streamgages. For unregulated streamgages in the Southwest hydrologic region, fall and winter (October–February) precipitation accounts for 24.8 percent of annual precipitation (table 8), which can result in large accumulated snowpacks (Sando and McCarthy, 2018) that contribute to streamflows during the typical snowmelt runoff period of May through mid-July. May–June precipitation accounts for about 32.6 percent of annual precipitation (table 8), which ranks sixth among the hydrologic regions, and July–August precipitation accounts for 18.6 percent of annual precipitation, which ranks fifth among the eight hydrologic regions. In the Southwest hydrologic region, annual peak flows predominantly are in May and June (fig. 2 of Sando, R., and others, 2018). Dominance of snowmelt in the annual hydrograph tends to provide temporal integration of a substantial part of the annual precipitation inputs and contributes to the low *PFVI*s for streamgages in the Southwest hydrologic region.

About 17.2 percent of the streamgages in the Southwest hydrologic region are considered to have mixed-population characteristics (table 1) that result in a small number of unusually large peak flows that are substantially larger than the main body of peak flows. Typically, the unusually large peak-flow events result from extremely intense rainfall events in May and June. Mixed-population peak-flow datasets often are in streamgages with headwaters on or near the Continental Divide. In the Southwest hydrologic region, the mixed-population streamgages predominantly are located in a generally small area west of the Missouri River in the northern part of the hydrologic region. Most (8 out of 11) of the mixed-population streamgages in the Southwest hydrologic region that were included in the regional regression analysis (Sando, R., and others, 2018) had positive residuals for the 1-percent AEP regression; however, none of those mixed-population streamgages had significant influence. Among the candidate explanatory variables included in the regional regression analyses, there are no variables that represent spatial variability in precipitation intensity (such as indices of the 100-year 24-hour precipitation; for example, U.S. Weather Bureau, 1961). Inclusion of variables that represent spatial variability in precipitation intensity might help address some mixed-population issues and improve potential future regional regression analyses in the Southwest hydrologic region.

The CDFs of selected basin characteristics (drainage area, mean basin elevation, and mean annual precipitation) for the road and stream intersections and for the streamgages in the Southwest hydrologic region are shown in figure 29. With respect to drainage area, the CDF of road and stream intersections for the Southwest hydrologic region generally is similar to the CDF of road and stream intersections for all of Montana (fig. 29*A*). In the Southwest hydrologic region, the CDF of streamgages diverges from the CDF of road and stream intersections in the range of drainage areas less than about 30 mi^2 and in that range, the CDF of streamgages in the Southwest hydrologic region diverges from the CDF of streamgages for all of Montana; thus, streamgages with drainage areas in that range are considered to be underrepresented in the Southwest hydrologic region.

The Southwest hydrologic region generally is higher in elevation than Montana as a whole. Mean basin elevation for road and stream intersections in the Southwest hydrologic region ranges from 3,618 to 9,974 ft (Dutton and others, 2021) with a median of 6,347 ft (table 4). The range for the Southwest hydrologic region is smaller than for all of Montana (1,951–9,974 ft; Dutton and others, 2021) and the median for the Southwest hydrologic region is substantially higher than for all of Montana (4,173 ft; table 4). There are substantial differences between the CDFs of road and stream intersections for the Southwest hydrologic region relative to the CDFs of road and stream intersections for all of Montana (fig. 29*B*). In the Southwest hydrologic region, the CDF of streamgages diverges from the CDF of road and stream intersections in the range of mean basin elevations from about 5,000 to 6,800 ft, indicating underrepresentation in that range.

The Southwest hydrologic region is somewhat wetter than Montana as a whole. Mean annual precipitation for road and stream intersections in the Southwest hydrologic region ranges from 9.5 to 47.6 inches (Dutton and others, 2021) with a median of 18.4 inches (table 5). The range for the Southwest hydrologic region is smaller than for all of Montana (8.4–91.3 inches; Dutton and others, 2021) and the median for the Southwest hydrologic region is somewhat larger than for all of Montana (15.7 inches; table 5). The Southwest hydrologic region has a somewhat lower proportion of road and stream intersections with mean annual precipitation from about 15 to 18 inches than Montana as a whole (fig. 29*C*). In the Southwest hydrologic region, the CDF of streamgages diverges from the CDF of road and stream intersections in the range of mean annual precipitation from about 12 to 17 inches, indicating underrepresentation in that range.

The explanatory variables for the Southwest hydrologic region RREs are *CONTDA* and EL_{6000} (table 6). The 1-percent AEP RRE for the Southwest hydrologic region has an SEP of 73.8 percent, which is higher than the area-weighted mean SEP for all hydrologic regions in Montana (63.3 percent; table 6). For the 1-percent AEP regression for the Southwest hydrologic region, 10.4 percent of the streamgages have significant leverage and 4.2 percent of the streamgages have significant influence (table 7). The significant leverage percentage is similar to the significant leverage percentage for all of the streamgages in Montana used in the regional regression analyses (8.2 percent; table 7) and the significant influence percentage is smaller than the significant influence percentage for all of the streamgages in Montana used in the regional regression analyses (10.4 percent; table 7).

Information on streamgages in the Southwest hydrologic region with significant leverage and influence is presented in table 26. One of the six significant leverage streamgages has the largest *CONTDA* value (nonexceedance percentile

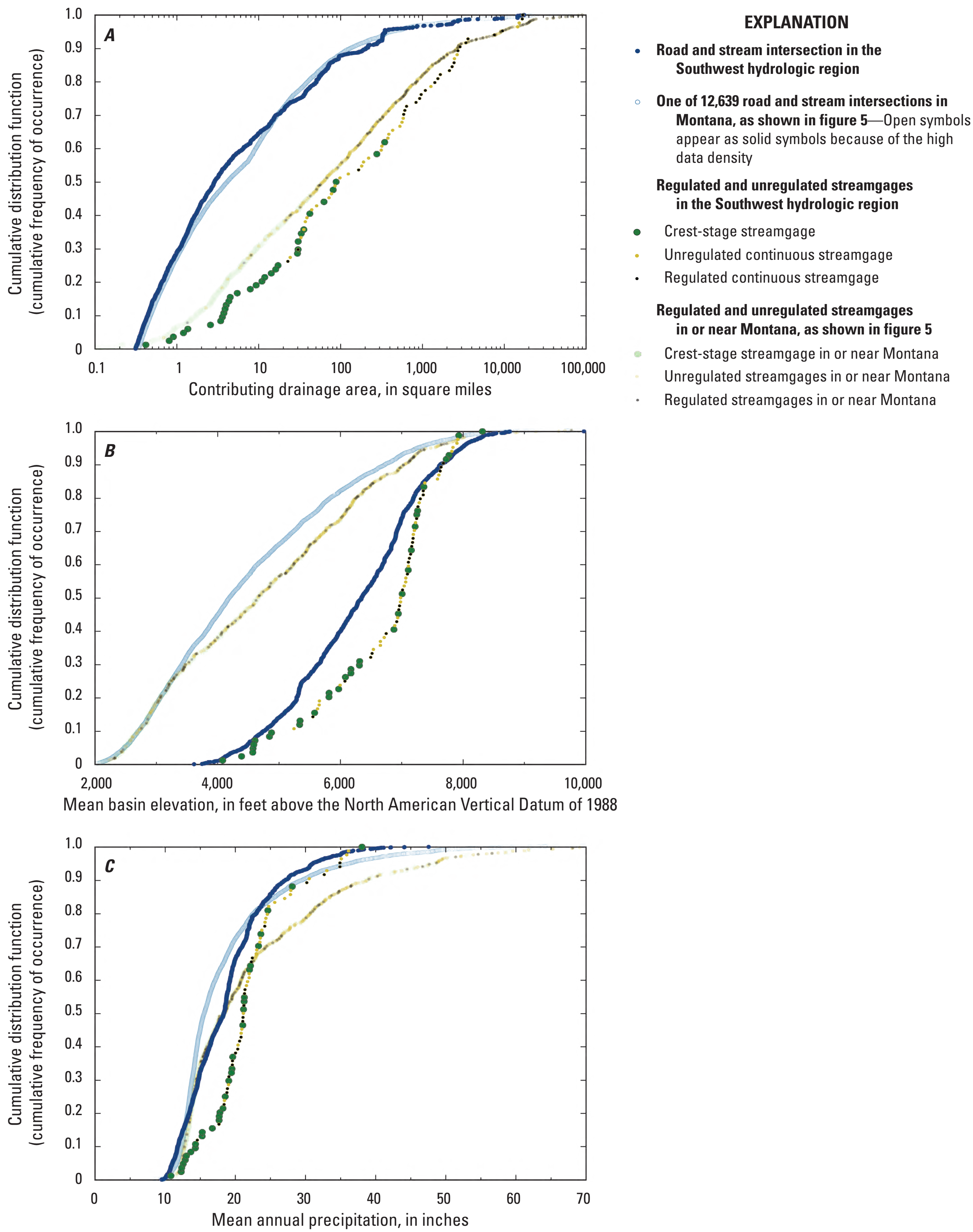


Figure 29. Cumulative distribution functions of selected drainage-basin characteristics for 2,267 road and stream intersections and for 84 streamgages (regulated and unregulated) in the Southwest hydrologic region. *A*, Contributing drainage area relations. *B*, Mean basin elevation relations. *C*, Mean annual precipitation relations.

equal to 100 percent) and one of the six significant leverage streamgages has a small *CONTDA* value (nonexceedance percentile less than about 2 percent). Three of the six significant leverage streamgages have low EL_{6000} values (nonexceedance percentiles less than about 8 percent). One of the six significant leverage streamgages has a low EL_{6000} value (nonexceedance percentiles less than about 11 percent) in association with a small *CONTDA* value (nonexceedance percentile less than about 15 percent). The three streamgages with significant influence vary with respect to the residuals for the 1-percent AEP RRE; one of the streamgages has a negative residual, and two have positive residuals. The streamgage with both significant leverage and significant influence has a positive residual.

In general, the streamgage network in the Southwest hydrologic region is considered to provide reasonable representation of the hydroclimatic settings of that hydrologic region. The RREs of the Southwest hydrologic region are considered to be reasonably reliable. Possible shortcomings of the streamgage network in the Southwest hydrologic region include small underrepresentation of basins with drainage areas less than about 30 mi^2, mean elevation from about 5,000 to 6,800 ft, and (or) mean annual precipitation from 12 to 17 inches. Future improvements to the streamgage network in the Southwest hydrologic region might include establishing new CSGs or reactivating discontinued streamgages as CSGs on drainage basins with the specified characteristics. Information on discontinued streamgages in the Southwest hydrologic region that might be candidates for reactivation to improve the streamgage network is presented in table 27.

Synopsis of Possible Shortcomings of and Future Improvements to the Streamgaging Network in Montana

This section describes possible shortcomings of and future improvements to the streamgage network. The descriptions are provided by hydrologic region.

Synopsis for the West Hydrologic Region

The median *PFVI* value for unregulated streamgages in the West hydrologic region (7.63, table 3) ranks as the seventh largest among the eight hydrologic regions. The 1-percent AEP RRE for the West hydrologic region has an SEP of 56.0 percent (table 6), which ranks sixth largest among the eight hydrologic regions. The 41 active unregulated streamgages (with no CSGs; table 3) represent an areal density of 0.00192 streamgage per mi^2 (ranking second largest among hydrologic regions) and a density of 0.01723 streamgage per road and stream intersection (ranking fifth among hydrologic regions). These various characteristics might indicate that the streamgage network in the West hydrologic region has a smaller need for improvements than most of the other hydrologic regions.

The indicated possible shortcomings of the streamgage network in the West hydrologic region include no active CSGs, and possible underrepresentation of basins with drainage area less than about 5 mi^2, mean elevation less than about 4,000 ft, and (or) mean annual precipitation less than about 25 inches. The lack of active CSGs might contribute to poor understanding of effects of future climatic variability on small drainage basins in the West hydrologic region. Intuitively, the streamgage network in the West hydrologic region might benefit from establishing a CSG on a basin with the specified characteristics.

About 12.5 percent of the streamgages in the West hydrologic region are considered to have mixed-population characteristics (table 1). Identification and treatment of mixed-population datasets are specifically noted in Bulletin 17C (England and others, 2019) as a topic needing further study. Potential future advances in understanding and treatment of mixed-population datasets in frequency analysis might contribute to improvements in frequency analyses in the West hydrologic region. Among the candidate explanatory variables included in the regional regression analyses, there are no variables that represent spatial variability in precipitation intensity (such as indices of the 100-year 24-hour precipitation; for example, U.S. Weather Bureau, 1961). Inclusion of variables that represent spatial variability in precipitation intensity might help address some mixed-population issues and improve potential future regional regression analyses in the West hydrologic region.

Synopsis for the Northwest hydrologic region

The median *PFVI* value for streamgages in the Northwest hydrologic region (6.04, table 3) ranks as the eighth largest among the eight hydrologic regions. The 1-percent AEP RRE for the Northwest hydrologic region has an SEP of 13.6 percent (table 6), which ranks eighth largest among the eight hydrologic regions. The RREs for the Northwest hydrologic region were developed using weighted least squares regression to better handle complexities introduced by the large proportion of mixed-population peak-flow datasets (Sando, R., and others, 2018); the use of weighted least squares regression might contribute to the low SEP. The 12 active unregulated streamgages (including 1 CSG; table 3) represent an areal density of 0.00151 streamgage per mi^2 (ranking fifth largest among hydrologic regions) and a density of 0.03371 streamgage per road and stream intersection (ranking first among hydrologic regions). These various characteristics might indicate that the streamgage network in the Northwest hydrologic region has a smaller need for improvements than most of the other hydrologic regions.

The indicated possible shortcomings of the streamgage network in the Northwest hydrologic region include possible underrepresentation of basins with drainage area less than about 125 mi^2, mean basin elevation less than about 5,400 ft, and (or) mean annual precipitation less than about 37 inches.

Table 26. Information on streamgages in the Southwest hydrologic region with significant leverage and influence in the Montana regional regression analyses (Sando, R., and others, 2018).

[ID, identification; NAD 83, North American Datum of 1983; *n*, total number of years of peak-flow records; *CONTDA*, contributing drainage area, in square miles; EL_{6000}, percentage of basin above 6,000 feet elevation; AEP, annual exceedance probability; CONT, continuous streamgage; CSG, crest-stage gage]

Map number (fig. 1)	Streamgage ID number	Streamgage name	Latitude, in decimal degrees (NAD 83)	Longitude, in decimal degrees (NAD 83)	Type of streamgage	Status of streamgage in water year 2017	*n*	*CONTDA*	Non-exceedance percentile[1] for *CONTDA*	EL_{6000}	Non-exceedance percentile[1] for EL_{6000}	Regression residuals for the specified AEP regression analyses: 10-percent AEP	4-percent AEP	1-percent AEP
						Streamgages with significant leverage								
45	06025500	Big Hole River near Melrose, Montana	45.5266	−112.7017	CONT	Active	92	2,472	100.0	92.04	73.0	0.231	0.253	0.270
58	[2]06034700	Sand Creek at Sappington, Montana	45.7914	−111.7555	CSG	Discontinued	15	9.34	16.7	0.00	2.7	0.217	0.249	0.271
96	06058700	Mitchell Gulch near East Helena, Montana	46.5713	−111.8235	CSG	Discontinued	45	7.93	14.6	7.54	10.8	0.032	0.041	0.015
102	06062700	Little Porcupine Creek tributary near Helena, Montana	46.5879	−112.2701	CSG	Discontinued	17	0.42	2.1	58.08	45.9	0.026	−0.017	−0.004
110	06071400	Dog Creek near Craig, Montana	47.0865	−111.9936	CSG	Discontinued	16	16.2	25.0	0.00	2.7	0.202	0.179	0.170
111	06071600	Wegner Creek at Craig, Montana	47.0762	−111.9555	CSG	Discontinued	32	35.7	41.7	0.68	8.1	−0.106	−0.156	−0.196

Table 26. Information on streamgages in the Southwest hydrologic region with significant leverage and influence in the Montana regional regression analyses (Sando, R., and others, 2018).—Continued

[ID, identification; NAD 83, North American Datum of 1983; *n*, total number of years of peak-flow records; *CONTDA*, contributing drainage area, in square miles; EL_{6000}, percentage of basin above 6,000 feet elevation; AEP, annual exceedance probability; CONT, continuous streamgage; CSG, crest-stage gage]

Map number (fig. 1)	Streamgage ID number	Streamgage name	Latitude, in decimal degrees (NAD 83)	Longitude, in decimal degrees (NAD 83)	Type of streamgage	Status of streamgage in water year 2017	*n*	*CONTDA*	Non-exceedance percentile[1] for *CONTDA*	EL_{6000}	Non-exceedance percentile[1] for EL_{6000}	Regression residuals for the specified AEP regression analyses		
												10-percent AEP	4-percent AEP	1-percent AEP
Streamgages with significant influence														
43	06025100	Quartz Hill Gulch near Wise River, Montana	45.7764	−112.8619	CSG	Active	43	14.3	22.9	95.27	81.1	−0.794	−0.692	−0.548
53	06030300	Jefferson River tributary No. 2 near Whitehall, Montana	45.8803	−111.9743	CSG	Discontinued	55	4.51	12.5	23.42	16.2	0.352	0.520	0.704
58	[2]06034700	Sand Creek at Sappington, Montana	45.7914	−111.7555	CSG	Discontinued	15	9.34	16.7	0.00	2.7	0.217	0.249	0.271

[1]The nonexceedance percentile for the basin or climatic variable value was calculated in relation to the values for all streamgages included in the regional regression analyses for the indicated hydrologic region.

[2]Streamgages having both significant leverage and significant influence.

Table 27. Information on discontinued streamgages in the Southwest hydrologic region that might be candidates for reactivation to improve the streamgage network.

[NAD 83, North American Datum of 1983; *n*, total number of years of peak-flow records; *CONTDA*, contributing drainage area, in square miles; EL_{6000}, percentage of basin above 6,000 feet elevation CSG, crest-stage gage; CONT, continuous streamgage]

Map number (fig. 1)	Station identification number	Station name	Latitude, in decimal degrees (NAD 83)	Longitude, in decimal degrees (NAD 83)	Type of streamgage	*n*	*CONTDA*	Nonexceedance percentile[1] for *CONTDA*	EL_{6000}	Nonexceedance percentile[1] for EL_{6000}
18	06013200	Traux Creek near Lima, Montana	44.6175	−112.5674	CSG	16	4.02	10.4	100.0	77.1
19	06013400	Muddy Creek near Dell, Montana	44.6395	−112.8094	CSG	16	63.1	56.3	100.0	77.1
29	06017500	Blacktail Deer Creek near Dillon, Montana	45.0461	−112.5497	CONT	21	316	81.3	95.7	64.6
32	06019400	Sweetwater Creek near Alder, Montana	45.0774	−112.2263	CSG	18	81.6	62.5	99.9	75.0
40	06024500	Trail Creek near Wisdom, Montana	45.6564	−113.7167	CONT	12	72.6	58.3	100.0	77.1
42	06024590	Wise River near Wise River, Montana	45.7046	−113.0316	CONT	13	221	77.1	100.0	77.1
44	06025300	Moose Creek near Divide, Montana	45.7136	−112.7053	CSG	15	42.4	50.0	94.7	60.4
54	06030500	Boulder River above Rock Creek, near Basin, Montana	46.2543	−112.5009	CONT	12	24.4	29.2	100.0	77.1
58	06034700	Sand Creek at Sappington, Montana	45.7914	−111.7555	CSG	15	9.34	16.7	0.0	2.1
74	06040300	Jack Creek near Ennis, Montana	45.3563	−111.5816	CONT	15	51.3	54.2	97.9	66.7
91	06055500	Crow Creek near Radersburg, Montana	46.2623	−111.6871	CONT	22	77.9	60.4	82.3	45.8
92	06056200	Castle Creek tributary near Ringling, Montana	46.3585	−111.0968	CSG	18	2.59	4.2	84.1	47.9
94	06056600	Deep Creek below North Fork Deep Creek, near Townsend, Montana	46.3247	−111.2935	CSG	19	88.9	66.7	52.7	31.3
98	06061700	Jackson Creek near East Helena, Montana	46.4718	−111.8531	CSG	18	3.45	6.3	58.0	33.3
99	06061800	Crystal Creek near East Helena, Montana	46.4832	−111.8610	CSG	18	3.90	8.3	32.3	20.8
100	06061900	McClellan Creek near East Helena, Montana	46.5331	−111.8791	CSG	19	33.3	39.6	33.7	22.9
102	06062700	Little Porcupine Creek tributary near Helena, Montana	46.5879	−112.2701	CSG	17	0.42	2.1	58.1	35.4
106	06068500	Little Prickly Pear Creek near Marysville, Montana	46.7877	−112.4067	CONT	20	44.6	52.1	46.1	29.2
107	06071000	Little Prickly Pear Creek near Canyon Creek, Montana	46.8189	−112.2505	CONT	15	182	72.9	31.7	18.8
108	06071200	Lyons Creek near Wolf Creek, Montana	46.9394	−112.1264	CSG	16	29.9	31.3	23.6	14.6
110	06071400	Dog Creek near Craig, Montana	47.0865	−111.9936	CSG	16	16.2	25.0	0.0	2.1

[1]The nonexceedance percentile for the basin or climatic variable value was calculated in relation to the values for all streamgages included in the regional regression analyses for the indicated hydrologic region.

Intuitively, the streamgage network in the Northwest hydrologic region might benefit from establishing a CSG on a basin with the specified characteristics.

About 56 percent of the streamgages in the Northwest hydrologic region are considered to have mixed-population characteristics (table 1). Identification and treatment of mixed-population datasets are specifically noted in Bulletin 17C (England and others, 2019) as a topic needing further study. Potential future advances in understanding and treatment of mixed-population datasets in frequency analysis might contribute to improvements in frequency analyses in the Northwest hydrologic region. Among the candidate explanatory variables included in the regional regression analyses, there are no variables that represent spatial variability in precipitation intensity (such as indices of the 100-year 24-hour precipitation; for example, U.S. Weather Bureau, 1961). Inclusion of variables that represent spatial variability in precipitation intensity might help address some mixed-population issues and improve potential future regional regression analyses in the Northwest hydrologic region. Future regional regression analyses for the Northwest hydrologic region might benefit from focused evaluation of appropriate regression methods for treatment of mixed-population datasets.

Synopsis for the Northwest Foothills hydrologic region

The median *PFVI* value for unregulated streamgages in the Northwest Foothills hydrologic region (27.17, table 3) ranks as the fourth largest among the eight hydrologic regions. The 1-percent AEP RRE for the Northwest Foothills hydrologic region has an SEP of 65.8 percent (table 6), which ranks fifth largest among the eight hydrologic regions. The 15 active unregulated streamgages (including six CSGs; table 3) represent an areal density of 0.00141 streamgage per mi^2 (ranking sixth largest among hydrologic regions) and a density of 0.01438 streamgage per road and stream intersection (ranking seventh among hydrologic regions). These various characteristics might indicate that the streamgage network in the Northwest Foothills hydrologic region has a somewhat larger need for improvements than some of the other hydrologic regions.

The indicated possible shortcomings of the streamgage network in the Northwest Foothills hydrologic region include possible underrepresentation of basins with drainage area from about 30 to 225 mi^2, mean elevation from about 4,000 to 4,600 ft, and (or) mean annual precipitation from about 14 to 18 inches. Intuitively, the streamgage network in the Northwest hydrologic region might benefit from establishing several (possibly about four) CSGs on basins with the specified characteristics.

About 22 percent of the streamgages in the Northwest Foothills hydrologic region are considered to have mixed-population characteristics (table 1). Identification and treatment of mixed-population datasets are specifically noted in Bulletin 17C (England and others, 2019) as a topic needing further study. Potential future advances in understanding and treatment of mixed-population datasets in frequency analysis might contribute to improvements in frequency analyses in the Northwest Foothills hydrologic region. Among the candidate explanatory variables included in the regional regression analyses, there are no variables that represent spatial variability in precipitation intensity (such as indices of the 100-year 24-hour precipitation; for example, U.S. Weather Bureau, 1961). Inclusion of variables that represent spatial variability in precipitation intensity might help address some mixed-population issues and improve potential future regional regression analyses in the Northwest Foothills hydrologic region.

Synopsis for the Northeast Plains hydrologic region

The median *PFVI* value for unregulated streamgages in the Northeast Plains hydrologic region (32.05, table 3) ranks as the third largest among the eight hydrologic regions. The 1-percent AEP RRE for the Northeast Plains hydrologic region has an SEP of 54.5 percent (table 6), which ranks seventh largest among the eight hydrologic regions. The 26 active unregulated streamgages (including 14 CSGs; table 3) represent an areal density of 0.00118 streamgage per mi^2 (ranking eighth largest among hydrologic regions) and a density of 0.01769 streamgage per road and stream intersection (ranking fourth among hydrologic regions). These various characteristics might indicate that the streamgage network in the Northeast Plains hydrologic region has a smaller need for improvements than some of the other hydrologic regions.

The indicated possible shortcomings of the streamgage network in the Northeast Plains hydrologic region are minor and do not include clear underrepresentation of important basin characteristics. Intuitively, the Northeast Plains hydrologic region would not substantially benefit from revisions to the streamgaging network.

Synopsis for the East-Central Plains hydrologic region

The median *PFVI* value for unregulated streamgages in the East-Central Plains hydrologic region (36.00, table 3) ranks as the first largest among the eight hydrologic regions. The 1-percent AEP RRE for the East-Central Plains hydrologic region has an SEP of 73.5 percent (table 6), which ranks second largest among the eight hydrologic regions. The 36 active unregulated streamgages (including 27 CSGs; table 3) represent an areal density of 0.00127 streamgage per mi^2 (ranking seventh largest among hydrologic regions) and a density of 0.02270 streamgage per road and stream intersection (ranking second among hydrologic regions). These various characteristics might indicate that the streamgage network in the East-Central Plains hydrologic region has a larger need for improvements than most of the other hydrologic regions.

Small basins are more strongly represented in the East-Central Plains hydrologic region than most other hydrologic regions. It is noteworthy that about 58 percent of the streamgages (both regulated and unregulated) in the East-Central Plains hydrologic region are on basins with drainage areas less than about 17 mi^2, whereas the other 42 percent of the streamgages are distributed over a large range in drainage areas from about 17 to several thousand square miles. In the East-Central Plains hydrologic region, the relatively large median *PFVI* value and high SEP for the 1-percent AEP RRE might be affected by strong representation of small basins. Intuitively, many (possibly about one-half) of the 27 active CSGs might be discontinued to free resources for redistributing CSGs to underrepresented hydroclimatic settings. The indicated possible shortcomings of the streamgage network in the East-Central Plains hydrologic region include underrepresentation of basins with drainage area from about 17 to 220 mi^2, mean elevation from about 3,600 to 4,000 ft, and (or) mean annual precipitation from about 15 to 16 inches. Intuitively, the streamgage network in the East-Central Plains hydrologic region might benefit from establishing several (possibly about four) CSGs on basins with the specified characteristics.

Synopsis for the Southeast Plains hydrologic region

The median *PFVI* value for unregulated streamgages in the Southeast Plains hydrologic region (35.21, table 3) ranks as the second largest among the eight hydrologic regions. The 1-percent AEP RRE for the Southeast Plains hydrologic region has an SEP of 71.1 percent (table 6), which ranks third largest among the eight hydrologic regions. The 30 active unregulated streamgages (including 22 CSGs; table 3) represent an areal density of 0.00162 streamgage per mi^2 (ranking third largest among hydrologic regions) and a density of 0.02188 streamgage per road and stream intersection (ranking third among hydrologic regions). These various characteristics might indicate that the streamgage network in the Southeast Plains hydrologic region has a larger need for improvements than most of the other hydrologic regions.

Small basins are more strongly represented in the Southeast Plains hydrologic region than most other hydrologic regions. It is noteworthy that about 63 percent of the streamgages (both regulated and unregulated) in the Southeast Plains hydrologic region are on basins with drainage areas less than about 20 mi^2, whereas the other 37 percent of the streamgages are distributed over a large range in drainage areas from about 20 to several thousand square miles. In the Southeast Plains hydrologic region, the relatively large median *PFVI* value and high SEP for the 1-percent AEP RRE might be affected by strong representation of small basins. Intuitively, many (possibly about one-half) of the 22 active CSGs might be discontinued to free resources for redistributing CSGs to underrepresented hydroclimatic settings. The indicated possible shortcomings of the streamgage network in the Southeast Plains hydrologic region include underrepresentation of basins with drainage area from about 20 to 370 mi^2, mean elevation from about 3,600 to 4,200 ft, and (or) mean annual precipitation from about 15 to 16 inches. Intuitively, the streamgage network in the Southeast Plains hydrologic region might benefit from establishing several (possibly about four) CSGs on basins with the specified characteristics.

Synopsis for the Upper Yellowstone-Central Mountain hydrologic region

The median *PFVI* value for unregulated streamgages in the Upper Yellowstone-Central Mountain hydrologic region (14.48, table 3) ranks as the fifth largest among the eight hydrologic regions. The 1-percent AEP RRE for the Upper Yellowstone-Central Mountain hydrologic region has an SEP of 69.0 percent (table 6), which ranks fourth largest among the eight hydrologic regions. The 35 active unregulated streamgages (including 10 CSGs; table 3) represent an areal density of 0.00152 streamgage per mi^2 (ranking fourth largest among hydrologic regions) and a density of 0.01616 streamgage per road and stream intersection (ranking sixth among hydrologic regions). These various characteristics might indicate that the streamgage network in the Upper Yellowstone-Central Mountain hydrologic region has a somewhat smaller need for improvements than some of the other hydrologic regions.

The indicated possible shortcomings of the streamgage network in the Upper Yellowstone-Central Mountain hydrologic region include small underrepresentation of basins with drainage areas from 10 to 32 mi^2, mean elevation less than about 5,100 ft, and (or) mean annual precipitation from 18 to 22 inches. Intuitively, the streamgage network in the Upper Yellowstone-Central Mountain hydrologic region might benefit from establishing a CSG on a basin with the specified characteristics.

Synopsis for the Southwest hydrologic region

The median *PFVI* value for unregulated streamgages in the Southwest hydrologic region (9.30, table 3) ranks as the sixth largest among the eight hydrologic regions. The 1-percent AEP RRE for the Southwest hydrologic region has an SEP of 73.8 percent (table 6), which ranks first largest among the eight hydrologic regions. The 29 active unregulated streamgages (including 8 CSGs; table 3) represent an areal density of 0.00195 streamgage per mi^2 (ranking first largest among hydrologic regions) and a density of 0.01279 streamgage per road and stream intersection (ranking eighth among hydrologic regions). These various characteristics might indicate that the streamgage network in the Southwest hydrologic region has a somewhat larger need for improvements than some of the other hydrologic regions.

The indicated possible shortcomings of the streamgage network in the Southwest hydrologic region include small underrepresentation of basins with drainage areas less than about 30 mi^2, mean elevation from about 5,000 to 6,800 ft, and (or) mean annual precipitation from 12 to 17 inches. Intuitively, the streamgage network in the Southwest hydrologic region might benefit from establishing several (possibly about four) CSGs on basins with the specified characteristics.

About 17 percent of the streamgages in the Southwest hydrologic region are considered to have mixed-population characteristics (table 1). Identification and treatment of mixed-population datasets are specifically noted in Bulletin 17C (England and others, 2019) as a topic needing further study. Potential future advances in understanding and treatment of mixed-population datasets in frequency analysis might contribute to improvements in frequency analyses in the Southwest hydrologic region. Among the candidate explanatory variables included in the regional regression analyses, there are no variables that represent spatial variability in precipitation intensity (such as indices of the 100-year 24-hour precipitation; for example, U.S. Weather Bureau, 1961). Inclusion of variables that represent spatial variability in precipitation intensity might help address some mixed-population issues and improve potential future regional regression analyses in the Southwest hydrologic region.

Summary

The U.S. Geological Survey (USGS), in cooperation with the Montana Department of Transportation (MDT), has operated a crest-stage gage (CSG) network in Montana to collect peak-flow data since 1955. The CSG network is vital to collecting peak-flow data on small drainage basins that typically are not addressed by continuous streamflow operations. Discussions between the USGS and MDT identified a need for evaluating the CSG network to allow for better decision making in the management of the network. The purpose of this report is to (1) generally describe peak-flow variability in Montana, (2) assess peak-flow informational needs relevant to MDT activities, and (3) consider the characteristics of the active CSG network in relation to addressing the informational needs. The evaluation of the CSG network is intended to assist in prioritization for discontinuation of CSGs and other activities involving changes to the CSG network.

Montana is a large State (147,000 square miles [mi^2]) with large spatial variability in geologic, topographic, ecologic, and climatic characteristics; the large variability in these characteristics translates to large spatial variability in hydrologic regimes. Major drivers of peak-flow events in Montana include snowmelt, rainfall, and snowmelt with rainfall. Across Montana, large variability in climatic and topographic characteristics affects the spatial dominance among the major drivers and results in large variability in the flood regimes of streamgages. In conjunction with large variability in hydrologic regimes, the socioeconomic characteristics of Montana present substantial challenges for operating a large statewide streamgage network that consistently captures the hydrologic variability.

Peak-flow variability was investigated by analysis of selected peak-flow characteristics of 659 unregulated streamgages in or near Montana. A generalized peak-flow variability index (*PFVI*) was developed to provide large-scale representation of peak-flow variability in Montana. For unregulated Montana streamgages, *PFVI* generally monotonically decreases with increasing drainage area, although there is somewhat large (but generally consistent) variability about the locally weighted scatterplot smooth (LOWESS) line. Presumably, highly variable small-scale hydroclimatic processes are integrated with increasing drainage area such that variability in many hydrologic characteristics is reduced. *PFVI* also decreases with increasing mean basin elevation and mean annual precipitation. Presumably, higher elevation and wetter hydroclimatic settings in Montana contribute to reduced variability in hydrologic characteristics. Intuitively, *PFVI* might be expected to generally decrease with increasing years of record because the standard deviation might typically be expected to decrease with increasing sample size. However, relations between *PFVI* and years of record are more complex and variable than drainage area, elevation, and precipitation. *PFVI* variably increases from 10 to about 40 years of record, and then generally monotonically decreases from about 40 to about 105 years of record. Relations among *PFVI* and the years of record might be confounded by effects of drainage area because streamgages with long periods of record (greater than about 60 years) generally have large drainage areas (greater than about 100 mi^2).

The relations between *PFVI* and drainage area, mean basin elevation, mean annual precipitation, and years of record substantially differ among the eight hydrologic regions in Montana. As such, the *PFVI* relations were further investigated within each hydrologic region.

A major use of peak-flow information by the MDT is for design of road and highway infrastructure, including bridges, culverts, and roadside drainage ditches. As such, basin characteristics (including drainage area, mean basin elevation, and mean annual precipitation) of the Montana streamgage network (735 regulated and unregulated streamgages) were statistically investigated in relation to basin characteristics of 12,639 road and stream intersections in Montana. Both regulated and unregulated streamgages were investigated because the road and stream intersections are on both regulated and unregulated streams. Exploratory analyses indicated that the various relations substantially differ among the hydrologic regions. As such, the relations between the Montana streamgage network and the road and stream intersections were further investigated within each hydrologic region.

An important objective of the CSG network is to provide data for developing regional regression equations (RREs) for estimating frequencies at ungaged sites in Montana. In providing regional information, the CSG network is vital to collecting peak-flow data on small drainage basins that typically are not addressed by continuous streamflow operations. Various characteristics of the RREs substantially differ among the eight hydrologic regions in Montana. As such, the RRE characteristics were further investigated within each hydrologic region.

The West hydrologic region has an area of 21,371 mi^2, which ranks fourth largest among the eight hydrologic regions. The 2,380 road and stream intersections in the West hydrologic region represent a density of 0.111 road and stream intersection per mi^2, which ranks second among the hydrologic regions. The median *PFVI* value for unregulated streamgages in the West hydrologic region (7.63) ranks as the seventh largest among the eight hydrologic regions. The 1-percent AEP RRE for the West hydrologic region has a mean standard error of prediction (SEP) of 56.0 percent, which ranks sixth largest among the eight hydrologic regions. The 41 active unregulated streamgages (with no CSGs) represent a density of 0.01723 streamgage per road and stream intersection (ranking fifth among hydrologic regions). These various characteristics might indicate that the streamgage network in the West hydrologic region has a smaller need for improvements than most of the other hydrologic regions.

Investigation of relations between the Montana streamgage network and the road and stream intersections indicated possible shortcomings of the streamgage network in the West hydrologic region, including no active CSGs, and possible underrepresentation of basins with drainage area less than about 5 mi^2, mean elevation less than about 4,000 ft, and (or) mean annual precipitation less than about 25 inches. The lack of active CSGs might contribute to poor understanding of effects of future climatic variability on small drainage basins in the West hydrologic region. Intuitively, the streamgage network in the West hydrologic region might benefit from establishing a CSG on a basin with the specified characteristics.

The Northwest hydrologic region has an area of 7,938 mi^2, which ranks eighth largest among the eight hydrologic regions. The 356 road and stream intersections in the Northwest hydrologic region represent a density of 0.045 road and stream intersection per mi^2, which ranks eighth among the hydrologic regions. The median *PFVI* value for streamgages in the Northwest hydrologic region (6.04) ranks as the eighth largest among the eight hydrologic regions. The 1-percent AEP RRE for the Northwest hydrologic region has an SEP of 13.6 percent, which ranks eighth largest among the eight hydrologic regions. The RREs for the Northwest hydrologic region were developed using weighted least squares regression to better handle complexities introduced by the large proportion of mixed-population peak-flow datasets; the use of weighted least squares regression might contribute to the low SEP. The 12 active unregulated streamgages (including 1 CSG) represent an areal density of 0.00151 streamgage per mi^2 (ranking fifth largest among hydrologic regions) and a density of 0.03371 streamgage per road and stream intersection (ranking first among hydrologic regions). These various characteristics might indicate that the streamgage network in the Northwest hydrologic region has a smaller need for improvements than most of the other hydrologic regions.

Investigation of relations between the Montana streamgage network and the road and stream intersections indicated possible shortcomings of the streamgage network in the Northwest hydrologic region include possible underrepresentation of basins with drainage area less than about 125 mi^2, mean elevation less than about 5,400 ft, and (or) mean annual precipitation less than about 37 inches. Intuitively, the streamgage network in the Northwest hydrologic region might benefit from establishing a CSG on a basin with the specified characteristics.

The Northwest Foothills hydrologic region has an area of 10,624 mi^2, which ranks seventh largest among the eight hydrologic regions. The 1,043 road and stream intersections in the Northwest Foothills hydrologic region represent a density of 0.098 road and stream intersection per mi^2, which ranks third among the hydrologic regions. The median *PFVI* value for unregulated streamgages in the Northwest Foothills hydrologic region (27.17) ranks as the fourth largest among the eight hydrologic regions. The 1-percent AEP RRE for the Northwest Foothills hydrologic region has an SEP of 65.8 percent, which ranks fifth largest among the eight hydrologic regions. The 15 active unregulated streamgages (including 6 CSGs) represent an areal density of 0.00141 streamgage per mi^2 (ranking sixth largest among hydrologic regions) and a density of 0.01438 streamgage per road and stream intersection (ranking seventh among hydrologic regions). These various characteristics might indicate that the streamgage network in the Northwest Foothills hydrologic region has a somewhat larger need for improvements than some of the other hydrologic regions.

Investigation of relations between the Montana streamgage network and the road and stream intersections indicated possible shortcomings of the streamgage network in the Northwest Foothills hydrologic region include possible underrepresentation of basins with drainage area from about 30 to 225 mi^2, mean elevation from about 4,000 to 4,600 ft, and (or) mean annual precipitation from about 14 to 18 inches. Intuitively, the streamgage network in the Northwest Foothills hydrologic region might benefit from establishing several (possibly about four) CSGs on basins with the specified characteristics.

The Northeast Plains hydrologic region has an area of 22,059 mi^2, which ranks third largest among the eight hydrologic regions. The 1,470 road and stream intersections in the Northeast Plains hydrologic region represent a density of 0.067 road and stream intersection per mi^2, which ranks sixth among the hydrologic regions. The median *PFVI* value for unregulated streamgages in the Northeast Plains hydrologic region (32.05) ranks as the third largest among the eight hydrologic regions. The 1-percent AEP RRE for the Northeast Plains hydrologic region has an SEP of 54.5 percent, which ranks seventh largest among the eight hydrologic regions. The 26 active unregulated streamgages (including 14 CSGs) represent an areal density of 0.00118 streamgage per mi^2 (ranking eighth largest among hydrologic regions) and a density of 0.01769 streamgage per road and stream intersection (ranking fourth among hydrologic regions). These various characteristics might indicate that the streamgage network in the Northeast Plains hydrologic region has a smaller need for improvements than some of the other hydrologic regions.

Investigation of relations between the Montana streamgage network and the road and stream intersections indicated possible shortcomings of the streamgage network in the Northeast Plains hydrologic region are minor and do not include clear underrepresentation of important basin characteristics. Intuitively, the Northeast Plains hydrologic region would not substantially benefit from revisions to the streamgaging network.

The East-Central Plains hydrologic region has an area of 28,451 mi^2, which ranks first largest among the eight hydrologic regions. The 1,586 road and stream intersections in the East-Central Plains hydrologic region represent a density of 0.056 road and stream intersection per mi^2, which ranks seventh among the hydrologic regions. The median *PFVI* value for unregulated streamgages in the East-Central Plains hydrologic region (36.00) ranks as the first largest among the eight hydrologic regions. The 1-percent AEP RRE for the East-Central Plains hydrologic region has an SEP of 73.5 percent, which ranks second largest among the eight hydrologic regions. The 36 active unregulated streamgages (including 27 CSGs) represent an areal density of 0.00127 streamgage per mi^2 (ranking seventh largest among hydrologic regions) and a density of 0.02270 streamgage per road and stream intersection (ranking second among hydrologic regions). These various characteristics might indicate that the streamgage network in the East-Central Plains hydrologic region has a larger need for improvements than most of the other hydrologic regions.

Small basins are more strongly represented in the East-Central Plains hydrologic region than most other hydrologic regions. It is noteworthy that about 58 percent of the streamgages (both regulated and unregulated) in the East-Central Plains hydrologic region are on basins with drainage areas less than about 17 mi^2, whereas the other 42 percent of the streamgages are distributed over a large range in drainage areas from about 17 to several thousand square miles. In the East-Central Plains hydrologic region, the relatively large median *PFVI* value and high SEP for the 1-percent AEP RRE might be affected by strong representation of small basins. Intuitively, many (possibly about one-half) of the 27 active CSGs might be discontinued to free resources for redistributing CSGs to underrepresented hydroclimatic settings. Investigation of relations between the Montana streamgage network and the road and stream intersections indicated possible shortcomings of the streamgage network in the East-Central Plains hydrologic region include underrepresentation of basins with contributing drainage area (*CONTDA*) from about 17 to 220 mi^2, mean elevation from about 3,600 to 4,000 ft, and (or) mean annual precipitation from about 15 to 16 inches. Intuitively, the streamgage network in the East-Central Plains hydrologic region might benefit from establishing several (possibly about four) CSGs on basins with the specified characteristics.

The Southeast Plains hydrologic region has an area of 18,520 mi^2, which ranks fifth largest among the eight hydrologic regions. The 1,371 road and stream intersections in the Southeast Plains hydrologic region represent a density of 0.074 road and stream intersection per mi^2, which ranks fifth among the hydrologic regions. The median *PFVI* value for unregulated streamgages in the Southeast Plains hydrologic region (35.21) ranks as the second largest among the eight hydrologic regions. The 1-percent AEP RRE for the Southeast Plains hydrologic region has an SEP of 71.1 percent, which ranks third largest among the eight hydrologic regions. The 30 active unregulated streamgages (including 22 CSGs) represent an areal density of 0.00162 streamgage per mi^2 (ranking third largest among hydrologic regions) and a density of 0.02188 streamgage per road and stream intersection (ranking third among hydrologic regions). These various characteristics might indicate that the streamgage network in the Southeast Plains hydrologic region has a larger need for improvements than most of the other hydrologic regions.

Small basins are more strongly represented in the Southeast Plains hydrologic region than most other hydrologic regions. It is noteworthy that about 63 percent of the streamgages (both regulated and unregulated) in the Southeast Plains hydrologic region are on basins with drainage areas less than about 20 mi^2; whereas, the other 37 percent of the streamgages are distributed over a large range in drainage areas from about 20 to several thousand square miles. In the Southeast Plains hydrologic region, the relatively large median *PFVI* value and high SEP for the 1-percent AEP RRE might be affected by strong representation of small basins. Intuitively, many (possibly about one-half) of the 22 active CSGs might be discontinued to free resources for redistributing CSGs to underrepresented hydroclimatic settings. Investigation of relations between the Montana streamgage network and the road and stream intersections indicated possible shortcomings of the streamgage network in the Southeast Plains hydrologic region include underrepresentation of basins with *CONTDA* from about 20 to 370 mi^2, mean elevation from about 3,600 to 4,200 ft, and (or) mean annual precipitation from about 15 to 16 inches. Intuitively, the streamgage network in the Southeast Plains hydrologic region might benefit from establishing several (possibly about four) CSGs on basins with the specified characteristics.

The Upper Yellowstone-Central Mountain hydrologic region has an area of 23,003 mi^2, which ranks second largest among the eight hydrologic regions. The 2,166 road and stream intersections in the Upper Yellowstone-Central Mountain hydrologic region represent a density of 0.094 road and stream intersection per mi^2, which ranks fourth among the hydrologic regions. The median *PFVI* value for unregulated streamgages in the Upper Yellowstone-Central Mountain hydrologic region (14.48) ranks as the fifth largest among the eight hydrologic regions. The 1-percent AEP RRE for the Upper Yellowstone-Central Mountain hydrologic region has an SEP of 69.0 percent, which ranks fourth largest among the eight hydrologic regions. The 35 active unregulated streamgages (including 10 CSGs) represent an areal density of 0.00152 streamgage per mi^2 (ranking fourth largest among hydrologic regions) and a density of 0.01616 streamgage per road and stream intersection (ranking sixth among hydrologic regions). These various characteristics might indicate that the streamgage network in the Upper Yellowstone-Central Mountain hydrologic region has a somewhat smaller need for improvements than some of the other hydrologic regions.

Investigation of relations between the Montana streamgage network and the road and stream intersections indicated possible shortcomings of the streamgage network in the Upper Yellowstone-Central Mountain hydrologic region include small underrepresentation of basins with drainage areas from 10 to 32 mi^2, mean basin elevation less than about 5,100 ft, and (or) mean annual precipitation from 18 to 22 inches. Intuitively, the streamgage network in the Upper Yellowstone-Central Mountain hydrologic region might benefit from establishing a CSG on a basin with the specified characteristics.

The Southwest hydrologic region has an area of 14,891 mi^2, which ranks sixth largest among the eight hydrologic regions. The 2,267 road and stream intersections in the Southwest hydrologic region represent a density of 0.152 road and stream intersection per mi^2, which ranks first among the hydrologic regions. The median *PFVI* value for unregulated streamgages in the Southwest hydrologic region (9.30) ranks as the sixth largest among the eight hydrologic regions. The 1-percent AEP RRE for the Southwest hydrologic region has an SEP of 73.8 percent, which ranks first largest among the eight hydrologic regions. The 29 active unregulated streamgages (including 8 CSGs) represent an areal density of 0.00195 streamgage per mi^2 (ranking first largest among hydrologic regions) and a density of 0.01279 streamgage per road and stream intersection (ranking eighth among hydrologic regions). These various characteristics might indicate that the streamgage network in the Southwest hydrologic region has a somewhat larger need for improvements than some of the other hydrologic regions.

Investigation of relations between the Montana streamgage network and the road and stream intersections indicated possible shortcomings of the streamgage network in the Southwest hydrologic region include small underrepresentation of basins with drainage areas in the range less than about 30 mi^2, mean elevation from about 5,000 to 6,800 ft, and (or) mean annual precipitation from 12 to 17 inches. Intuitively, the streamgage network in the Southwest hydrologic region might benefit from establishing several (possibly about four) CSGs on basins with the specified characteristics.

Four hydrologic regions have substantial percentages of streamgages considered to have mixed-population characteristics: the West (about 12.5 percent), Northwest (about 56 percent), Northwest Foothills (about 22 percent), and Southwest (about 17 percent). Often, mixed-population datasets result from unusually large peak-flow events caused by extremely intense rainfall events in May and June that happen near the peak of snowmelt runoff.

Potential future advances in understanding and treatment of mixed-population datasets in frequency analysis might contribute to improvements in frequency analyses in the four hydrologic regions with substantial mixed-population characteristics. Among the candidate explanatory variables included in the regional regression analyses, there are no variables that represent spatial variability in precipitation intensity. Inclusion of variables that represent spatial variability in precipitation intensity might help address some mixed-population issues and improve potential future regional regression analyses in the four hydrologic regions.

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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

Sando—**Peak-Flow Variability, Peak-Flow Informational Needs, and Consideration of Regional Regression Analyses in Montana**—Scientific Investigations Report 2021–5063

ISSN 2328-0328 (online)
https://doi.org/10.3133/sir20215063