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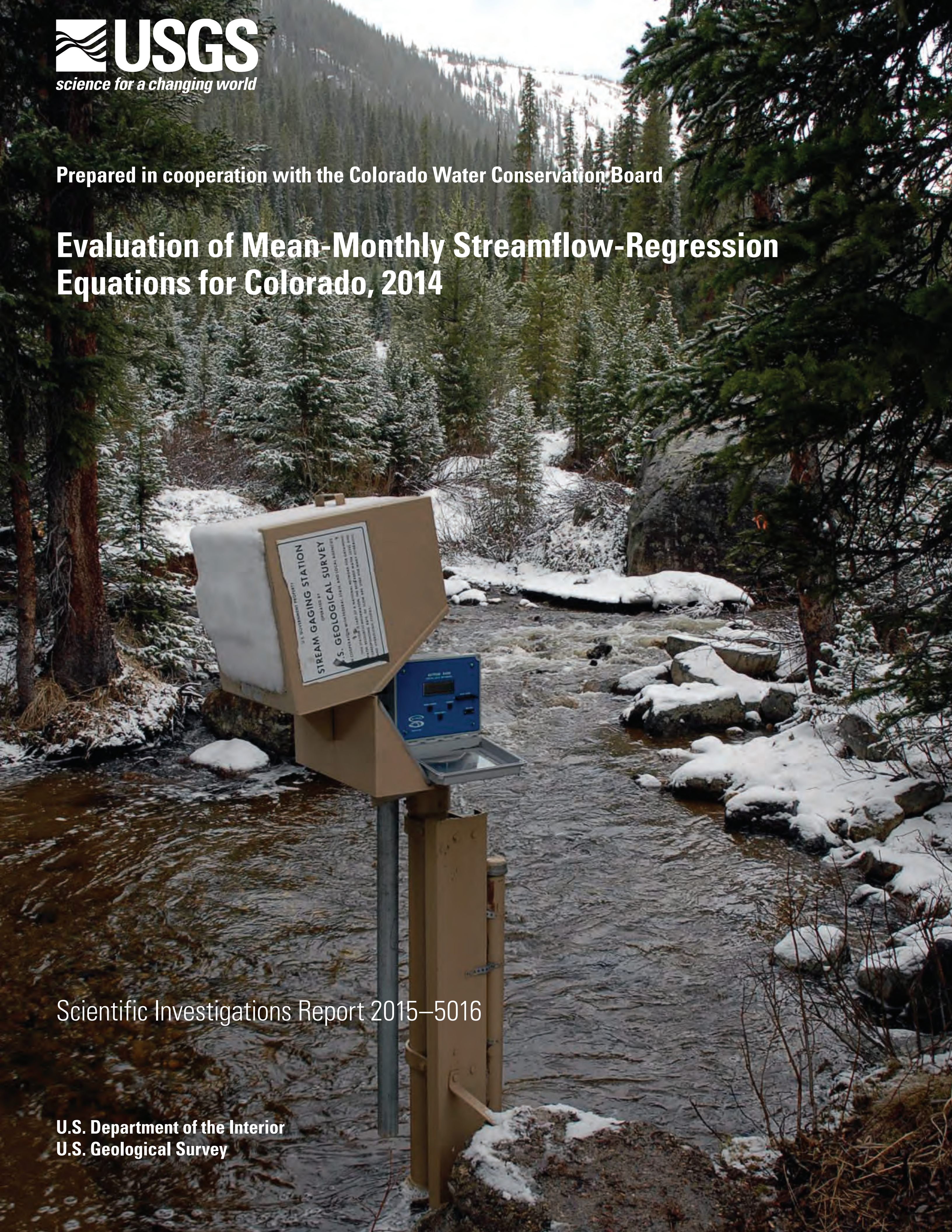
Evaluation of Mean-Monthly Streamflow-Regression Equations for Colorado, 2014



Scientific Investigations Report 2015–5016

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

Cover. Photograph showing Missouri Creek near Gold Park, Colorado by Jeff Foster, U.S. Geological Survey.

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By Michael S. Kohn, Michael R. Stevens, Andrew R. Bock, and Stephen J. Char

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U.S. Department of the Interior
SALLY JEWELL, Secretary

U.S. Geological Survey
Suzette M. Kimball, Acting Director

U.S. Geological Survey, Reston, Virginia: 2015

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Conversion Factors

[Inch/Pound 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)
	Volume	
cubic foot (ft^3)	28.32	cubic decimeter (dm^3)
cubic foot (ft^3)	0.02832	cubic meter (m^3)
	Flow rate	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)

Datums

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

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

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

Supplemental Information

Water year in this report is defined as the period from October 1st of one year through September 30th of the following year and is named for the year of the ending date.

Abbreviations

adjR^2	adjusted-coefficient of determination
CDWR	Colorado Division of Water Resources
NWIS	National Water Information System
SEP	standard error of prediction
USGS	U.S. Geological Survey

Acknowledgments

Jeff Baessler and Brandy Logan of the Colorado Water Conservation Board provided helpful guidance and thoughtful feedback throughout the study. Chris Brown and Doug Stenzel of the Colorado Division of Water Resources were instrumental in coordinating the compilation of Colorado Division of Water Resources streamgage data to be used in this study. The following Colorado Division of Water Resources lead hydrographers helped determine which Colorado Division of Water Resources streamgages were representative of natural streamflow conditions and could be used in this study: Russell Stroud (Region 1), Joseph Talbott (Region 2), Scott Veneman (Region 3), Jerry Thrush (Region 4), Craig Bruner (Region 5), Dan Meyer (Region 6), and Brian Boughton (Region 7).

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Evaluation of Mean-Monthly Streamflow-Regression Equations for Colorado

By Michael S. Kohn, Michael R. Stevens, Andrew R. Bock, and Stephen J. Char

Abstract

The U.S. Geological Survey, in cooperation with the Colorado Water Conservation Board, evaluated the predictive uncertainty of mean-monthly streamflow-regression equations representative of natural streamflow conditions in Colorado. This study evaluates the predictive uncertainty of mean-monthly streamflow-regression equations developed in a 2009 U.S. Geological Survey study using streamflow data collected over the entire period of record at each streamgage through calendar year 2013. The study area for this report is limited to the Mountain, Northwest, Rio Grande, and Southwest hydrologic regions of Colorado.

Data collected from the beginning of the period of record through calendar year 2013 were used to evaluate the mean-monthly streamflow equations using the same basin characteristics as in the 2009 study. U.S. Geological Survey and Colorado Division of Water Resources streamgages with at least 10 years of streamflow record and identified as representative of natural streamflow conditions were selected for this study. During the streamgage selection process, a total of 432 streamgages, composed of 278 from the 2009 study and 154 new streamgages, were identified.

The updated standard error of prediction and adjusted coefficient of determination values that correspond to the mean-monthly streamflow equations developed in the 2009 study are in close agreement with the results of this study. The old streamgages performed slightly better than the new streamgages, with approximately 88 and 85 percent of the data within the prediction intervals, respectively. This result was expected because the streamgages used to develop the regression equations should yield a better performance than the new streamgages.

For all hydrologic regions, approximately 87 percent of the data are within the 95-percent prediction intervals. The explanation for why fewer than 95 percent of the data are within the prediction intervals is that the data do not conform perfectly to the regression assumptions required to accurately estimate performance metrics. The equations for the Rio Grande hydrologic region had the best fit with the parametric prediction-interval assumptions, with approximately 91.8 percent of the data within the prediction interval (average 12 months). The Mountain, Northwest, and Southwest hydrologic regions had 87.8, 84.9, and 83.5 percent of the data contained within the prediction interval, respectively.

Monthly adjusted coefficient of determination values were computed and have the same general pattern for all four hydrologic regions. The largest values usually occur in March or April, and the lowest values usually occur in August or September. Only the Rio Grande hydrologic region deviates from this seasonal pattern, exhibiting a decrease in adjusted coefficient of determination values in August and September, with the lowest values occurring in the winter months (December, January, and February). Generally, the adjusted coefficient of determination values for this report are just slightly less (0.76 compared to 0.79) than the values computed in the 2009 study. The similarity of values, even when tested with data not used to originally develop the mean-monthly streamflow-regression equations, provides confidence that the predictive uncertainty of mean-monthly regression equations in the 2009 study are accurate. The fact that the results for the two datasets are very similar provides assurance that when these equations are applied to locations not used to develop the equations, the standard error of prediction and adjusted-coefficient of determination error metrics should be similar to those established in the 2009 study for locations with natural streamflow.

The median absolute differences between the observed and computed mean-monthly streamflow for Mountain, Northwest, and Southwest hydrologic regions are fairly uniform throughout the year, with the exception of late summer and early fall (July, August, and September), when each hydrologic region exhibits a substantial increase in median absolute percent difference. The greatest difference occurs in the Northwest hydrologic region, and the smallest difference occurs in the Mountain hydrologic region. The Rio Grande hydrologic region shows seasonal variation in median absolute percent difference with March, April, August, and September having a median absolute difference near or below 40 percent, and the remaining months of the year having a median absolute difference near or above 50 percent. In the Mountain, Northwest, and Southwest hydrologic regions, the mean-monthly streamflow equations perform the best during spring (March, April, and May). However, in the Rio Grande hydrologic region, the mean-monthly streamflow equations perform the best during late summer and early fall (August and September).

Introduction

Streamflow-regression equations are statistical relations between streamflow statistics computed from available streamgage records (including mean-monthly streamflow) and relevant basin and climatic characteristics. Streamflow-regression equations generally are developed for geographic regions where basin and climatic conditions are relatively consistent. The equations are accompanied by estimates of predictive uncertainty and provide useful and economic tools for calculating streamflow statistics at ungaged locations. Streamflow-regression equations are commonly used to estimate streamflow statistics at ungaged sites across the Nation (Capesius and Stephens, 2009). Reliable estimates of streamflow statistics are critical for water-resource management, stream-related structural design, stream-hazard identification, and water-quality management.

The U.S. Geological Survey (USGS) developed a Web-based computer program called StreamStats (Ries and others, 2004). The software facilitates the computation of streamflow statistics using regional regression equations or other procedures that have been published previously. StreamStats allows the user to compute streamflow statistics for both gaged and ungaged sites by selecting a specific stream location on a map interface. If the location of interest lacks a streamgage, the algorithms in StreamStats delineate the basin for the location, compute basin and climatic characteristics, and provide estimates of the streamflow statistics using the available regression equations.

The USGS, in cooperation with the Colorado Water Conservation Board, evaluated the predictive uncertainty of mean-monthly streamflow-regression equations representative of natural streamflow conditions in Colorado. Streamflow-regression equations were previously developed to estimate natural streamflow statistics at ungaged sites in Colorado by Capesius and Stephens (2009), which is hereinafter referred to as the “2009 study.” The present study evaluates the predictive uncertainty of mean-monthly streamflow-regression equations developed in the 2009 study using streamflow data collected over the entire period of record at each streamgage through calendar year 2013. Mean-monthly streamflow data from the regression equations were compared to mean-monthly streamflow data from streamgage records to evaluate the predictive uncertainty.

Purpose and Scope

The purpose of this report is to evaluate the streamflow-regression equations presented in the 2009 study by comparing the predictive uncertainty using streamflow data through calendar year 2013 for computation of mean-monthly streamflow for Colorado basins with hydrology that is influenced predominantly by natural runoff processes (fig. 1).

The 2009 study updated mean-monthly streamflow equations developed by Kircher and others (1985) in four (Mountain, Northwest, Rio Grande, and Southwest) of the five Colorado hydrologic regions. The 2009 study determined that data in the Plains hydrologic region were inadequate for regression-equation development for any streamflow statistics other than peak streamflow, so no mean-monthly streamflow equations exist for this hydrologic region. The study area for this report is therefore limited to the Mountain, Northwest, Rio Grande, and Southwest hydrologic regions of Colorado. The appropriate area for the use of the equations is limited to Colorado, despite the extension of the study area to include streamgages within a 50-mile boundary or buffer surrounding Colorado for the purpose of equation development (Capesius and Stephens, 2009).

The regression equations for mean-monthly streamflow estimation in Colorado were developed in the 2009 study by Capesius and Stephens using streamflow data collected from the beginning of the period of record at each streamgage through water year 2007 (October 1, 2006, through September 30, 2007). Data collected from the beginning of the period of record through calendar year 2013 were used to evaluate the mean-monthly streamflow equations using the same basin characteristics as in the 2009 study.

Regression equations computed in the 2009 study are used to estimate natural streamflow statistics for ungaged sites. “To clarify, the equations are based on analysis of streamflow data representing streamflow conditions relatively unaffected by anthropogenic influences such as regulation and diversion or return flows such as from a municipality, or mining operation, or urban development in a basin” (Capesius and Stephens, 2009, p. 3). “Kircher and others (1985) defined natural streamflow as streamflow from drainage basins relatively unaffected by urban development or water-management activities such as substantial reservoir storage, streamflow diversions, or return flows of previously diverted streamflow. Further, those authors defined natural streamflow as streamflow having less than about 10 percent of the mean-annual streamflow volume at the streamgage affected by anthropogenic activity” (Capesius and Stephens, 2009, p. 3). This report includes only streamgages that have been determined to meet the Kircher and others (1985) criteria.

Previous Studies and Background Information

Many studies have computed regression equations for estimating flood-frequency streamflow statistics in Colorado—Patterson (1964, 1965), Patterson and Somers (1966), and Matthai (1968), Headman and others (1972), McCain and Jarrett (1976), Kircher and others (1985), Livingston and Minges (1987), Vaill (1999), and the 2009 study—but fewer studies have developed regression equations for mean-monthly streamflow, such as Kircher and others (1985) and the 2009 study. The hydrologic regions used in this report were delineated by McCain and Jarrett (1976) and were incorporated as the regional framework in Kircher and others (1985). Kircher and others (1985) developed regression equations for

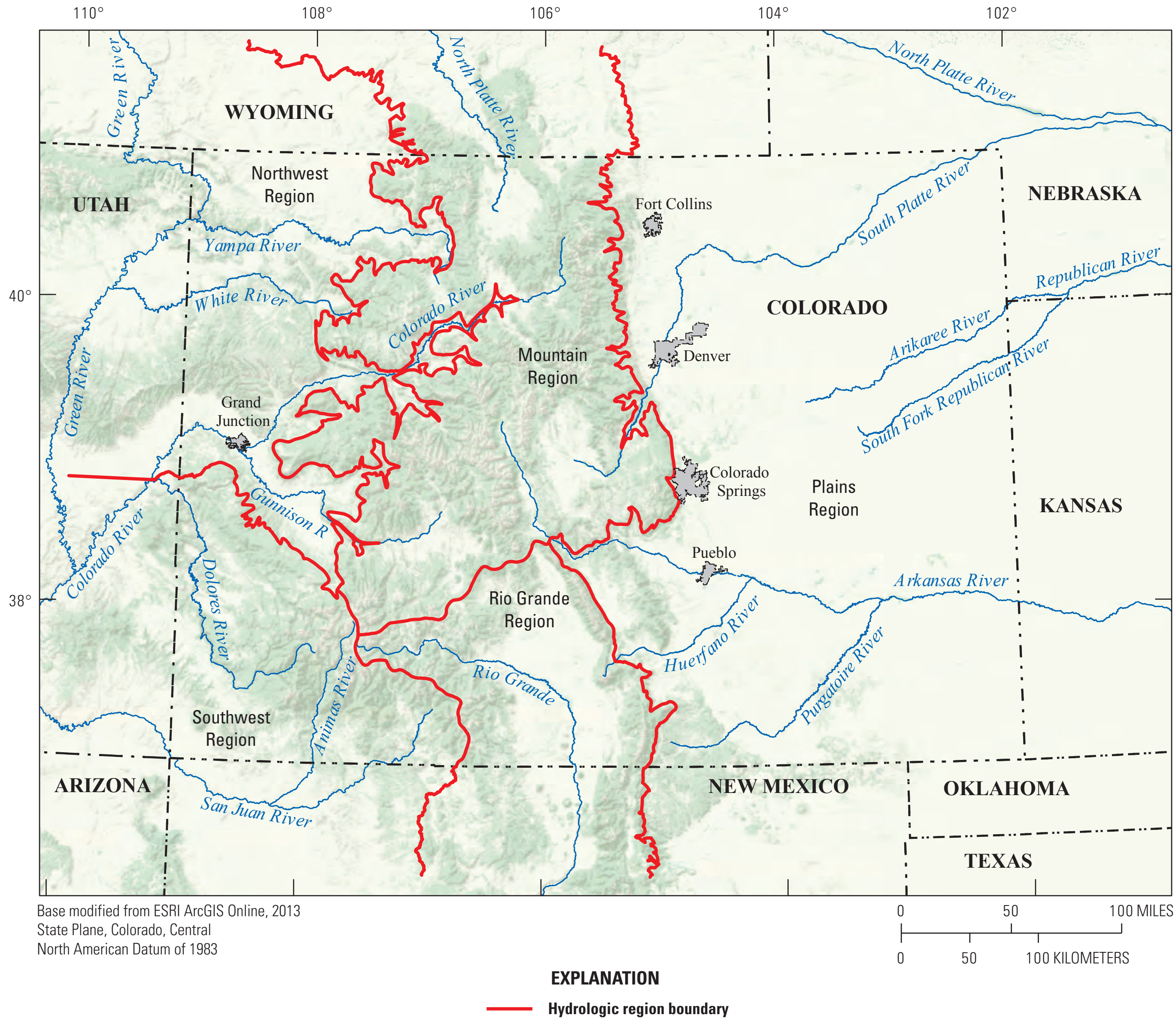

Figure 1. Boundaries of the hydrologic regions in Colorado that extend 50 miles into the adjacent States included in the study area.

mean-monthly streamflow in western Colorado for data collected through 1983. The 2009 study published Statewide peak and non-peak (with the exception of the Plains hydrologic region) statistics (including mean-monthly streamflow) using USGS streamflow data from the beginning of the period of record at each streamgage through water years 2006 and 2007, respectively. In the 2009 study, error associated with the mean-monthly streamflow-regression equations was characterized using the standard error of prediction (SEP, in percent) and the adjusted-coefficient of determination (adjR^2, dimensionless).

Description of the Study Area

Colorado has a diverse landscape and climate and includes the headwaters of the major river basins of the Colorado, Rio Grande, Platte, and Arkansas Rivers. The physiographic differences in Colorado can be described by three major physiographic provinces, which trend north to south across the State (Fenneman, 1931). The Great Plains Province, in the eastern 40 percent of the State, consists mostly of grasslands with scattered hills, bluffs, shallow river valleys, and some cultivated areas. The Southern Rocky Mountains Province, west of the Great Plains, includes most of central Colorado from north to south and is characterized by mountain ranges and intermountain valleys. The Colorado Plateaus Province is in western Colorado between the Utah border to the west and the Southern Rocky Mountains to the east. The landscape is distinguished by mesas, plateaus, and eroded canyon terrain that includes much of the western quarter of Colorado from north to south. More detailed descriptions of the major physiographic provinces can be found in Fenneman (1931) and the 2009 study.

For this report "…a hydrologic region is qualitatively defined as a region of similar hydrology and climatology. The five hydrologic regions of Colorado were defined on the basis of the physiographic and climatic characteristics that were used to develop best-fit regression equations. The Mountain hydrologic region is identified as that region of central Colorado above about 7,500 feet in elevation located between the Colorado-Wyoming border and the Rio Grande basin. The Mountain hydrologic region encompasses the headwaters of most major river basins in Colorado where the annual peak streamflow generally is produced by snowmelt runoff. The Northwest hydrologic region is defined as the northwestern part of Colorado below 7,500 feet and encompassing substantial areas of the Yampa, White, and Gunnison River basins. The Rio Grande hydrologic region ranges in elevation from about 5,000 feet near the Colorado-New Mexico border to more than 14,000 feet in the northern parts and encompasses the Rio Grande basin. The Southwest hydrologic region is defined as the region located south of the Gunnison River basin and west of the Rio Grande basin and encompasses the Dolores, Animas, and San Juan River basins. The Plains hydrologic region is east of the Rocky Mountains and below 7,500 feet in the South Platte River basin and below 9,000 feet in the Arkansas River basin" (Capesius and Stephens, 2009, p. 4). Because hydrology is not affected by the political borders between States, the hydrologic region boundaries were extended 50 miles into all States surrounding Colorado (fig. 1) (Capesius and Stephens, 2009). As a result, the study area includes parts of Arizona, New Mexico, Utah, and Wyoming along with the four western hydrologic regions in Colorado.

Methods

This section describes the methods used in data acquisition, processing, and computations necessary to determine mean-monthly streamflows and evaluation statistics.

Mean-Monthly Streamflow from Streamgage Record

The mean-monthly streamflow-regression equations were evaluated by analyzing the predictive uncertainties of the equations presented in the 2009 study. Mean-monthly streamflow data from the beginning of the period of record at each streamgage through calendar year 2013 from USGS and Colorado Division of Water Resources (CDWR) streamgages were compared to mean-monthly streamflow determined from the regression equations at all suitable streamgages in the study area. During the streamgage selection process, a total of 432 streamgages, composed of 278 from the 2009 study and 154 new streamgages, were identified, and the mean-monthly streamflow was determined from the streamgage records. At the streamgage locations, basin and climate characteristics were used to compute mean-monthly streamflow with regression equations (fig. 2, tables 1 and 2, appendix 1). Observed (streamgage data) and predicted (regression equation values) data were compared by scatter plots, computation of median absolute percent difference in streamflow, graphical analysis of monthly bias by examination of boxplots of residual streamflow, adjR^2 statistics, and SEP statistics.

Streamgages selected for the analysis were chosen on the basis of location, inclusion in the 2009 study, and available data. For the four hydrologic regions, all streamgages used in the 2009 study were selected. The USGS National Water Information System (NWIS) mapper (USGS, 2013a) was used to compile the USGS streamgages within 50 miles of the Colorado border. Only USGS and CDWR streamgages with at least 10 years of streamflow records and identified as representative of natural streamflow conditions were selected. In determining which streamgages were representative of natural streamflow conditions, codes from the NWIS peak streamflow database were followed along with professional judgment. In each of the CDWR regions, the lead CDWR hydrographer for that respective region was contacted and engaged to help determine which streamgages were representative of natural streamflow conditions as defined in a 1985 study by Kircher and others. A number of the selected streamgages have been operated at different periods of time by both the USGS and the CDWR. In these special cases, if 10 years of data had been collected between the two agencies, the streamgage was used. A total of 300 daily-mean values for a month are approximately equal to 10 years of record. Hereinafter in this report, streamgages used in the 2009 study will be referred to as "old streamgages" and streamgages not used in the 2009 study will be referred to as "new streamgages."

Mean-monthly streamflow was computed following the same procedure used in the 2009 study and as described herein. Daily-mean streamflow data were retrieved from the USGS NWIS database (USGS, 2013b) with an automated script developed in Python 2.7 (Python Software Foundation, 2013). Data were retrieved for each of the 432 streamgages operated by the USGS from the beginning of the period of record through the 2013 calendar year. Daily-mean streamflow data for each of the 47 streamgages operated by the CDWR were retrieved from the beginning of the period of record through the 2013 calendar year from the CDWR Web page (Colorado Division of Water Resources, 2013). The CDWR streamflow data included 19 streamgages operated solely by the CDWR and 28 streamgages that have been operated

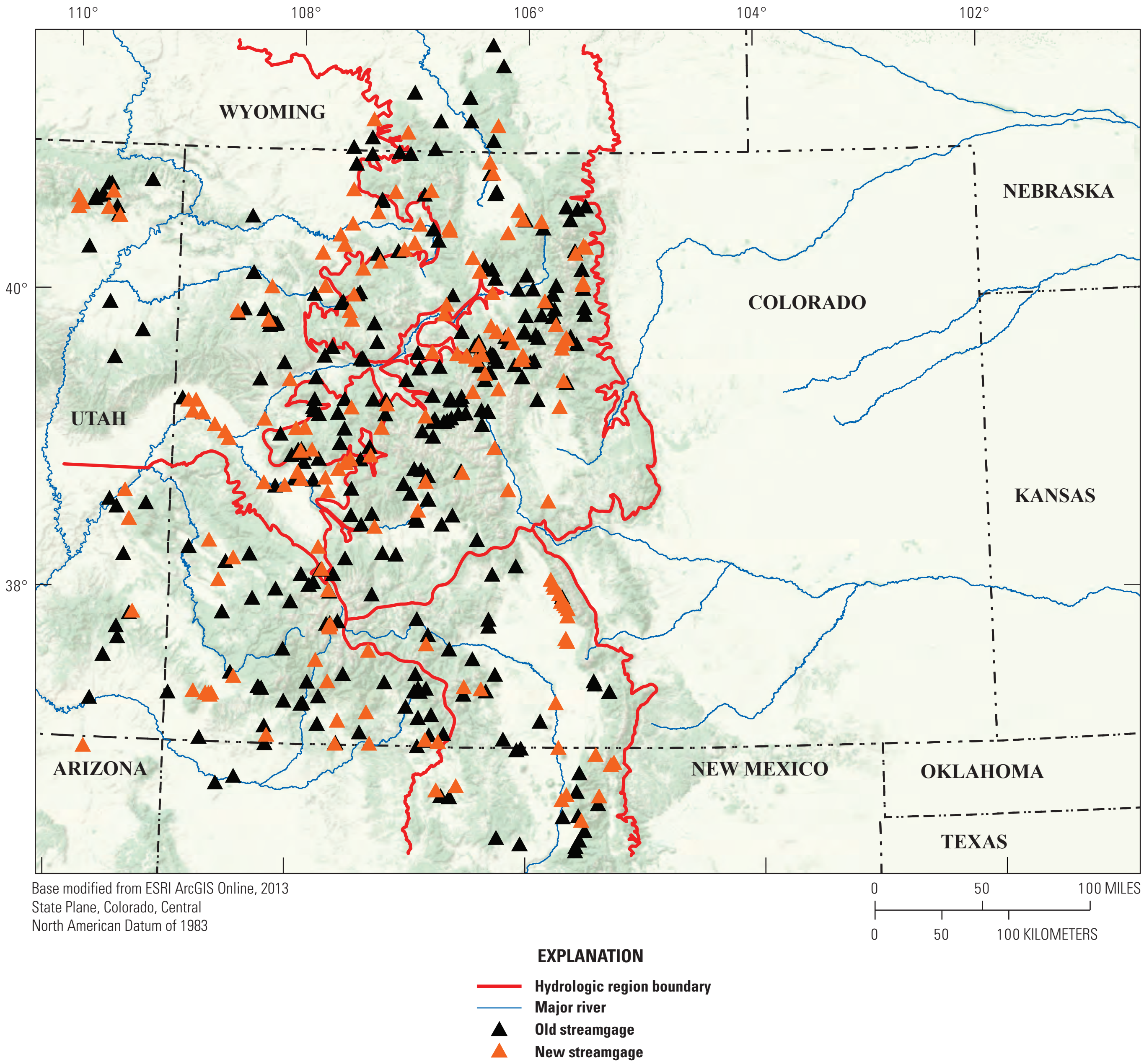

Figure 2. Location of the streamgages used to evaluate the mean-monthly streamflow-regression equations; old streamgages were used in the 2009 study, and new streamgages were not used in the 2009 study.

by both the USGS and CDWR. CDWR daily-mean streamflow data for the nonoverlapping period of record for the 28 streamgages that have been operated jointly by the CDWR and USGS (fig. 2 and table 1) were appended to the USGS NWIS daily-mean streamflow data.

The statistical software package R (R Core Team, 2013) was used to calculate mean-monthly streamflow at each streamgage from the daily-mean value dataset for each of the 12 months. In addition, the total number of days for each month with no data collected at a streamgage, such as at gages that were operated seasonally, was summarized. The summaries of the number of days with no data did not include days when the streamgage was operating normally, but the streamflow was below the reportable limit of the streamgage computation. From these summaries of the number of days with no data, the number of daily-mean values used to compute the mean-monthly streamflow at each streamgage for each of the 12 months was tabulated. Any streamgage with fewer than 280 daily-mean values for February or fewer than 300 daily-mean values for all other months for the computation of mean-monthly streamflow was omitted from analysis for February and all other months, similar to the criteria in the 2009 study. Some streamgages used in the analysis are operated seasonally and computations could not be made for all 12 months.

Table 1. Streamgages used in analysis sorted by (1) hydrologic region, (2) whether the streamgage was used in the 2009 study, and (3) the agency that collected the data.

[USGS, U.S. Geological Survey; CDWR, Colorado Division of Water Resources; new streamgage, a streamgage not used by Capesius and Stephens (2009); old streamgage, a streamgage used by Capesius and Stephens (2009)]

	All sites	Mountain region	Northwest region	Rio Grande region	Southwest region
Both new and old streamgages					
USGS data only	385	162	113	31	79
CDWR data only	19	6	1	10	2
Both USGS and CDWR data	28	11	1	14	2
Total streamgages	432	179	115	55	83
New streamgages only					
USGS data only	131	44	53	8	26
CDWR data only	19	6	1	10	2
Both USGS and CDWR data	4	3	0	1	0
Total streamgages	154	53	54	19	28
Old streamgages only					
USGS data only	254	118	60	23	53
CDWR data only	0	0	0	0	0
Both USGS and CDWR data	24	8	1	13	2
Total streamgages	278	126	61	36	55

Table 2. Comparison of basin and climate characteristics of the 278 old streamgages and the 154 new streamgages that were used for analysis in this report.

[mi^2, square miles; in, inches; ft, feet]

	Drainage area (mi^2)	Mean-annual precipitation (in)	Mean-basin elevation (ft)	Number of daily-mean values in a month
Mean				
Old streamgages	181	28.9	9,710	1,230
New streamgages	185	28.0	9,450	786
Median				
Old streamgages	51.7	28.9	9,860	899
New streamgages	71.9	27.6	9,670	565

Mean-Monthly Streamflow from Basin Characteristics and Regression Equations

Environmental Systems Research Institute, Inc. (Esri), ArcMap 10.1 was used to determine the basin and climate characteristics, which were used in the regression equations to determine the mean-monthly streamflow at each streamgage (Esri, 2014). For the computation of mean-monthly streamflow in the Mountain, Northwest, and Southwest hydrologic regions, the drainage area (in square miles), and the mean-annual precipitation (in inches), were determined for the basin of each streamgage. In the Rio Grande hydrologic region, the mean elevation of the basin (in feet) also was determined for the computations.

First, the location coordinates of every streamgage were converted into GIS data points. To perform the basin delineation, the locations of some points were moved slightly to lie directly on the digital stream network used in the 2009 study. For streamgages used in the 2009 study, the drainage area was determined using the National Elevation Dataset (Gesch and others, 2009), which is the same elevation raster dataset used in the 2009 study. Then, using the elevation and precipitation raster data that were used in the 2009 study (Parameter-elevation Regressions on Independent Slopes Model Total Precipitation, 1971–2000; Daly and others, 1994), the mean elevation of the basin, in feet, and the mean-annual precipitation, in inches, were determined for each streamgage.

For streamgages not used in the 2009 study but within the area covered by Colorado StreamStats, basin data were determined by submitting the point data to the USGS StreamStats Web site (USGS, 2013c). Results were returned in a vector GIS dataset. Because various methodologies are supported within the National StreamStats program, the results of the basin characterization were checked to ensure the results were reasonable by comparing the results from the different methodologies and confirming the different methodologies provided similar solutions.

For streamgages in adjacent States outside the Colorado StreamStats domain, for which there were no StreamStats data because those States do not currently have StreamStats, basins were generated using elevation and flow-direction raster data from the Elevation Derivatives for National Applications (EDNA) program (USGS, 2013d). Points representing streamgage locations were assigned to raster cells of maximum-flow accumulation (Esri, 2014) before the basins were generated. EDNA data are coarser in spatial resolution than StreamStats data, but this did not affect computation of the specific basin characteristics. The basins were converted from a raster format into a vector format and submitted to the Geo Data Portal of the USGS Center for Integrated Data Analysis to determine the basin characteristics needed to use the mean-monthly streamflow-regression equations (Blodgett, 2013). The mean elevation of the basin, in feet, was determined from the Geo Data Portal using the National Elevation Dataset Digital Elevation Model Web Coverage Service (Gesch and others, 2009). The mean-annual precipitation, in inches, was determined from the Geo Data Portal using Parameter-elevation Regressions on Independent Slopes Model monthly Climate Data for the Continental United States (Daly and others, 1994).

The mean-monthly streamflow for all 12 months of the year was computed by using the regression equations from the 2009 study (appendix 2) and the following basin characteristics: drainage area, mean-annual precipitation of the basin, and mean elevation of the basin.

Quality Assurance

The streamgaged basins that were initially complied to evaluate the mean-monthly streamflow-regression equations were analyzed to confirm that their basin characteristics were within the constraints outlined in the 2009 study. This eliminated 11 new streamgages from the study resulting in 154 new streamgages for the analysis. The regression equations in the 2009 study were developed for streamgages with drainage areas between 1 and 5,250 square miles, mean-annual precipitation between 8 and 51 inches, and mean basin elevations between 4,808 and 11,955 feet for the Mountain, Northwest, Rio Grande, and Southwest hydrologic regions. A comparison of the drainage area, precipitation, and elevation for the 278 old streamgages and the 154 new streamgages is shown in figures 3–5. The comparison of drainage area, precipitation, and elevation for old and new gages provided assurance that only streamgages that fit the ranges of basin characteristics listed above would be used for this analysis.

Evaluation of Mean-Monthly Streamflow-Regression Equations

Evaluation of mean-monthly streamflow-regression equations was accomplished through the use of scatter plots of observed and predicted data, computation of median absolute percent difference in streamflow between observed and predicted streamflow, graphical analysis of monthly bias by examination of boxplots of residual streamflow, adjR^2 statistics, and SEP statistics (Helsel and Hirsch, 2002).

Graphical Comparison of Observed and Predicted Mean-Monthly Streamflow

The observed (streamgage record) mean-monthly streamflows are plotted with the predicted (regression computed) mean-monthly streamflows for each of the four hydrologic regions for both the old streamgages and the new streamgages for all 12 months. These plots facilitated identification of variance and bias for evaluation of the regression equations.

Generally, the mean-monthly streamflow-regression equations in the Mountain and the Rio Grande hydrologic regions had the least amount of variance over the range of streamflows as shown graphically by more narrow clustering of data points along the line of agreement in figures 6

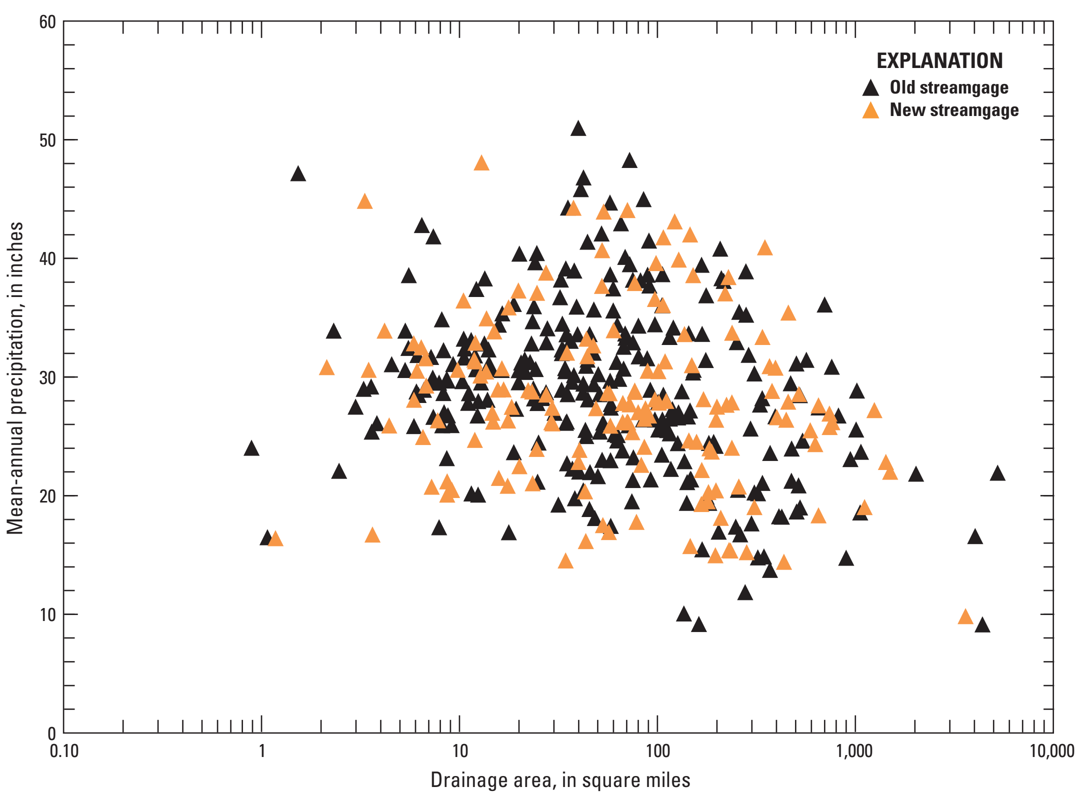

Figure 3. Drainage area and mean-annual precipitation for the 278 old streamgages and the 154 new streamgages that were used for analysis in this report.

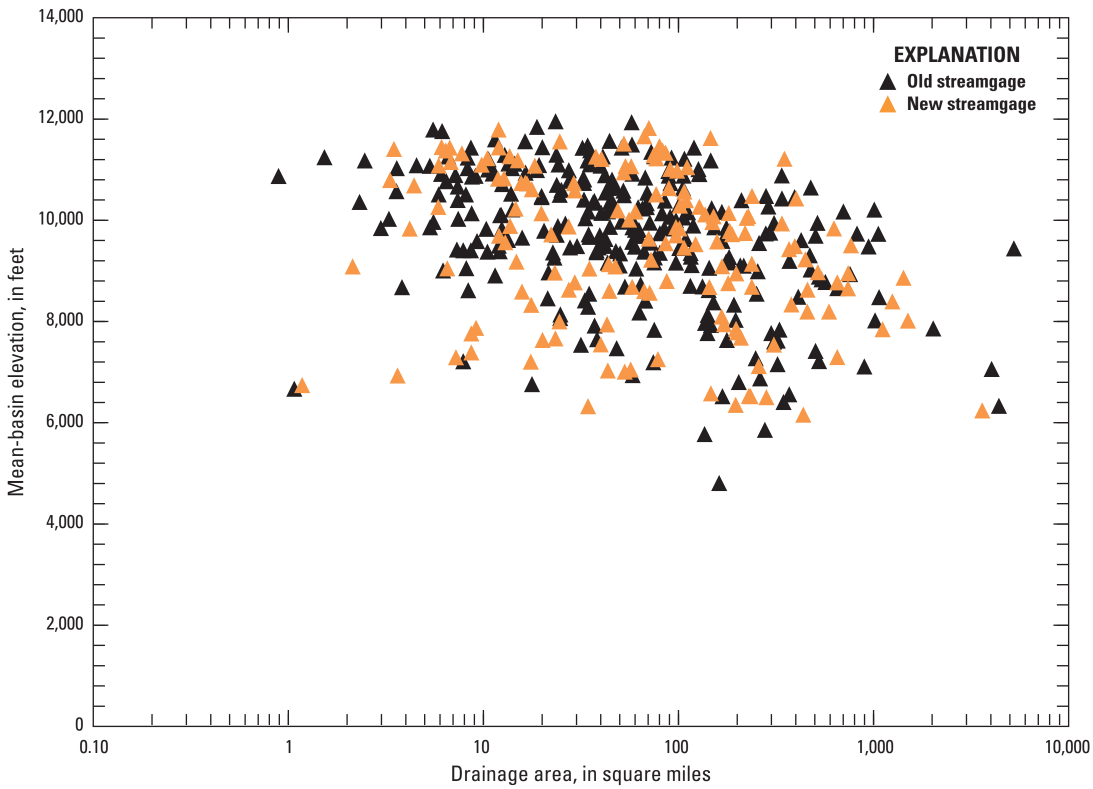

Figure 4. Drainage area and mean-basin elevation for the 278 old streamgages and the 154 new streamgages that were used for analysis in this report.

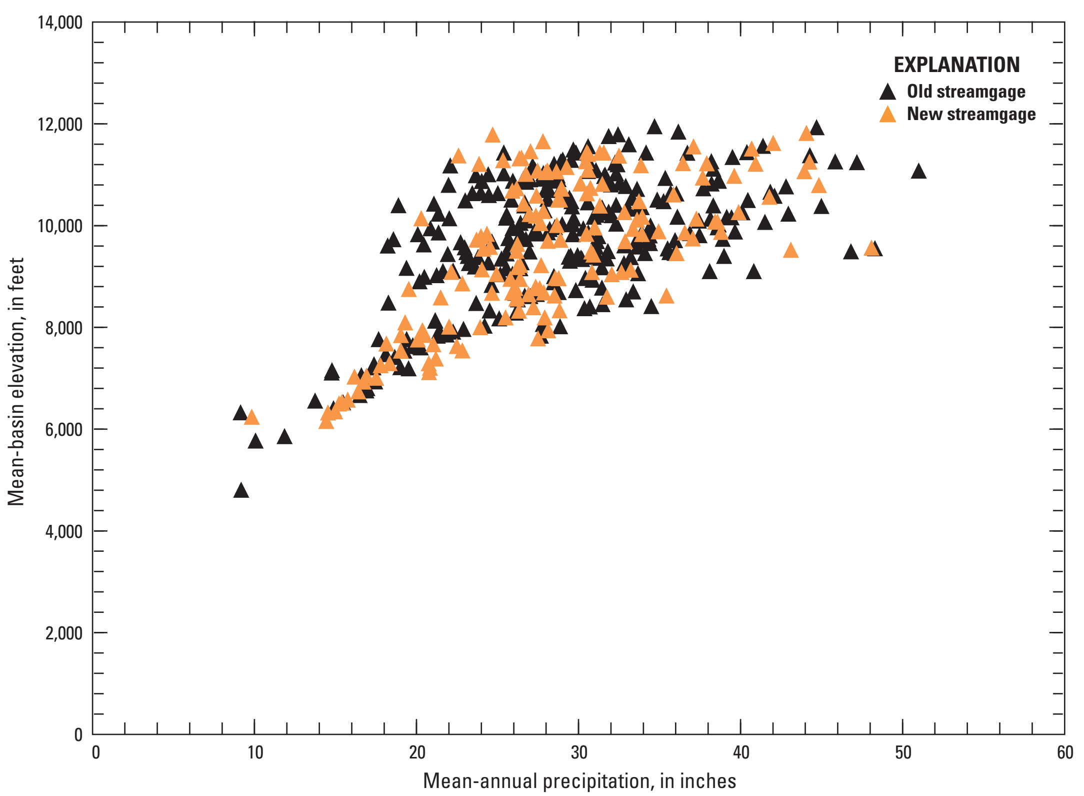

Figure 5. Mean-annual precipitation and mean-basin elevation for the 278 old streamgages and the 154 new streamgages that were used for analysis in this report.

and 8, respectively. The regression equations for the Mountain hydrologic region have the best agreement between observed and predicted values (although still somewhat biased toward underprediction at the high end) when the predicted streamflows are greater than 100 cubic feet per second (ft^3/s), evidenced by data that more closely fit the line of agreement when compared to the streamflows less than 100 ft^3/s (fig. 6). At predicted streamflows of less than 3 ft^3/s in the Mountain hydrologic region, the regression equations tend to overpredict mean-monthly streamflow (fig. 6).

The Northwest hydrologic region follows the same pattern as the Mountain hydrologic region showing predicted streamflows greater than 200 ft^3/s with a closer fit (although still biased toward underprediction at the high end) with the line of agreement, and at streamflows less than 10 ft^3/s in the Northwest hydrologic region, the regression equation bias tends to overpredict mean-monthly streamflow (fig. 7).

Unlike the other three hydrologic regions, the Rio Grande has relatively consistent variance from the line of agreement throughout the range of streamflows. However, similar to the other three hydrologic regions, predicted streamflows at the high end are biased low. At streamflows less than 3 ft^3/s, the regression equations in the Rio Grande hydrologic region show high bias and tend to overpredict mean-monthly streamflow. The bias seems mainly to be a result of extremely low streamflow values from the new streamgages added for this report (fig. 8).

The Southwest hydrologic region exhibits the lowest variance and least bias at predicted streamflows greater than 100 ft^3/s and the greatest variance at predicted streamflows less than 20 ft^3/s of any of the four hydrologic regions. At predicted streamflows less than 20 ft^3/s, the regression equations are imprecise and tend to overpredict mean-monthly streamflow (fig. 9).

Absolute Percent Difference

The absolute percent difference between the predicted (regression equations) and observed (streamgage record) mean-monthly streamflow, expressed as a percent, was determined as

$$d_r = \frac{\left| Q_{predicted} - Q_{observed} \right|}{Q_{observed}} * 100 \quad (1)$$

where

d_r is absolute difference, in percent,

$Q_{predicted}$ is mean-monthly streamflow from the regression equation, in cubic feet per second, and

$Q_{observed}$ is mean-monthly streamflow from the streamgage record, in cubic feet per second.

The absolute percent difference between the observed and predicted streamflows for each of the 48 mean-monthly streamflow-regression equations is listed in table 3 and shown on maps in appendix 3 (figs. 3–1 through 3–12). This statistic provides a metric for assessing performance of the regression equation based on all currently (2013) available streamgage data.

The median absolute differences between the observed and predicted streamflows computed for Mountain, Northwest, and Southwest hydrologic regions have fairly uniform values throughout the year (table 3), with the exception of late summer and early fall (July, August, and September), when each hydrologic region exhibits a substantial increase in median absolute percent difference. The greatest difference occurs in the Northwest hydrologic region, and the smallest difference occurs in the Mountain hydrologic region (table 3). The Rio Grande hydrologic region shows seasonal variation in median absolute percent difference with March, April, August, and September having a median absolute difference near or below 40 percent and the remaining months of the year having a median absolute difference near or above 50 percent. In the Mountain, Northwest, and Southwest hydrologic regions, the mean-monthly streamflow equations perform the best during spring (March, April, and May). However, in the Rio Grande hydrologic region, the mean-monthly streamflow equations perform the best during late summer and early fall (August and September).

The 30 mean-monthly streamflow equations identified as having "no bias" in the 2009 study (appendix 2), seem to have less bias than the remaining 18 mean-monthly streamflow equations when comparing the median absolute percent differences. The 30 equations identified as "no bias" have a median absolute difference of 40 percent, on average; whereas, the 18 equations identified in the 2009 study as having a bias have a median absolute difference of 54 percent, on average.

Graphical Analysis of Monthly Bias

The residual streamflow (in cubic feet per second) is the difference between the observed (from streamgage record) and predicted (from regression equations) mean-monthly streamflow. Residual streamflows were determined for each of the 48 mean-monthly streamflow-regression equations and are shown on boxplots, by hydrologic region, in figures 10–13, using all available data. These figures exhibit a tendency for over- or underprediction bias for the 48 equations when compared to the observed data by illustrating measures of central tendency (median), interquartile range (central tendency and symmetry of the middle 50 percent of the data), and range of extremes of the data (5th and 95th percentiles).

In the Mountain hydrologic region, boxplots of residuals indicate slight overprediction bias in the months of May, June, and July based on median differences (fig. 10). The residual plots for the September through March equations seem to indicate some positive bias in the upper quartile (50th to 75th percentile range). The April plot indicates some negative bias (underprediction in the lower quartile (25th to 50th percentile range).

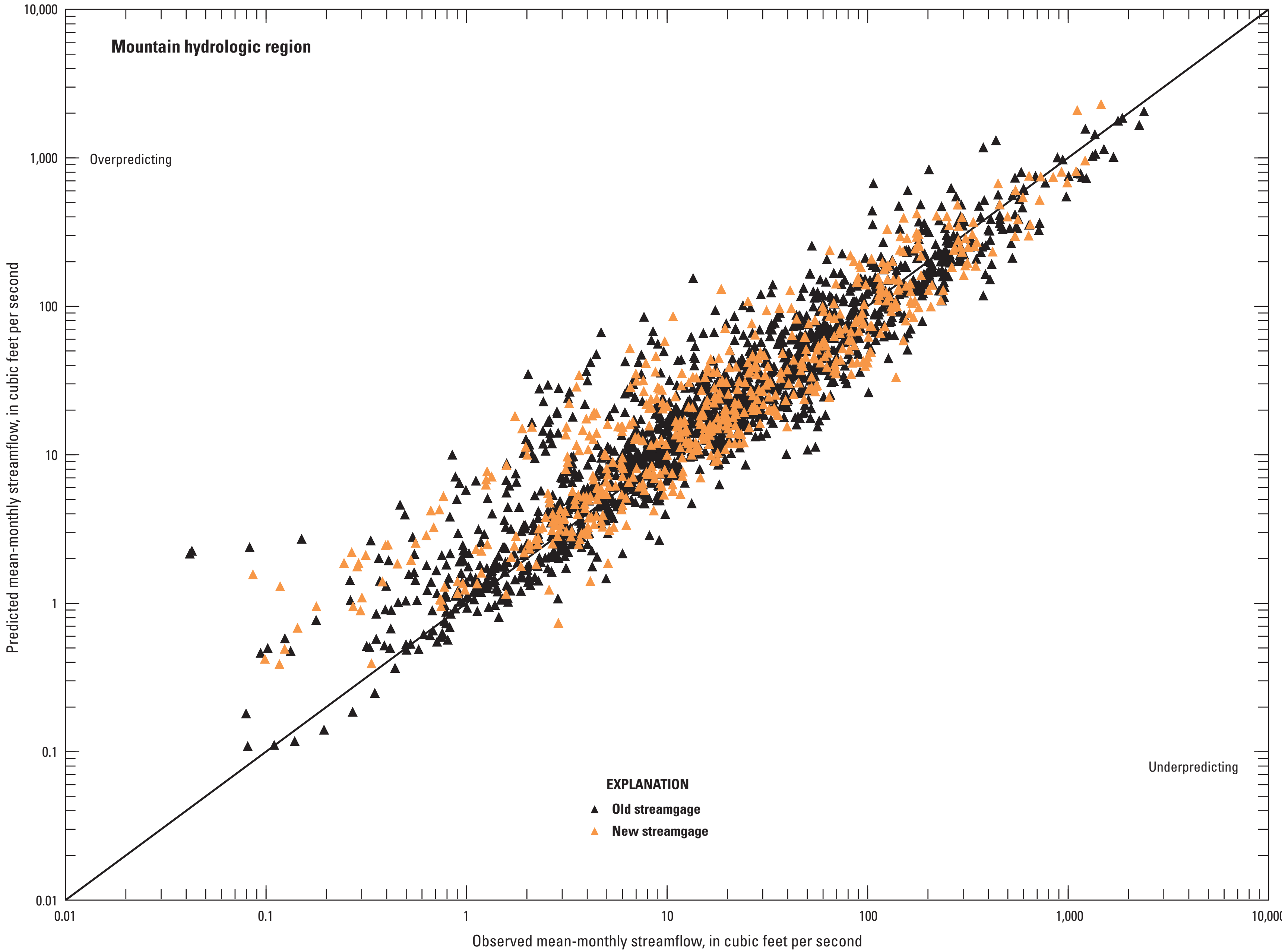

Figure 6. Comparison of observed and predicted mean-monthly streamflow in the Mountain hydrologic region for all 12 months.

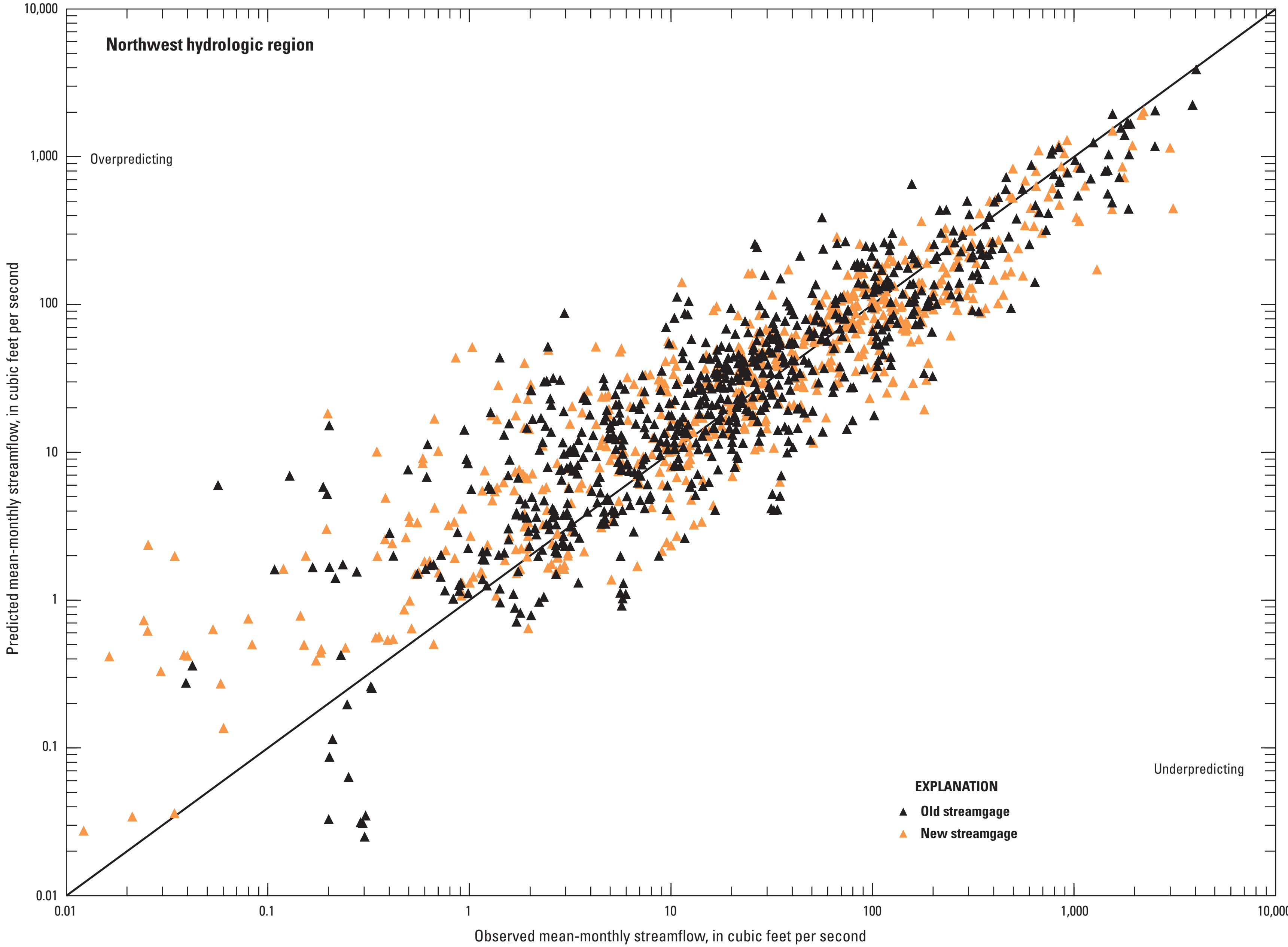

Figure 7. Comparison of observed and predicted mean-monthly streamflow in the Northwest hydrologic region for all 12 months.

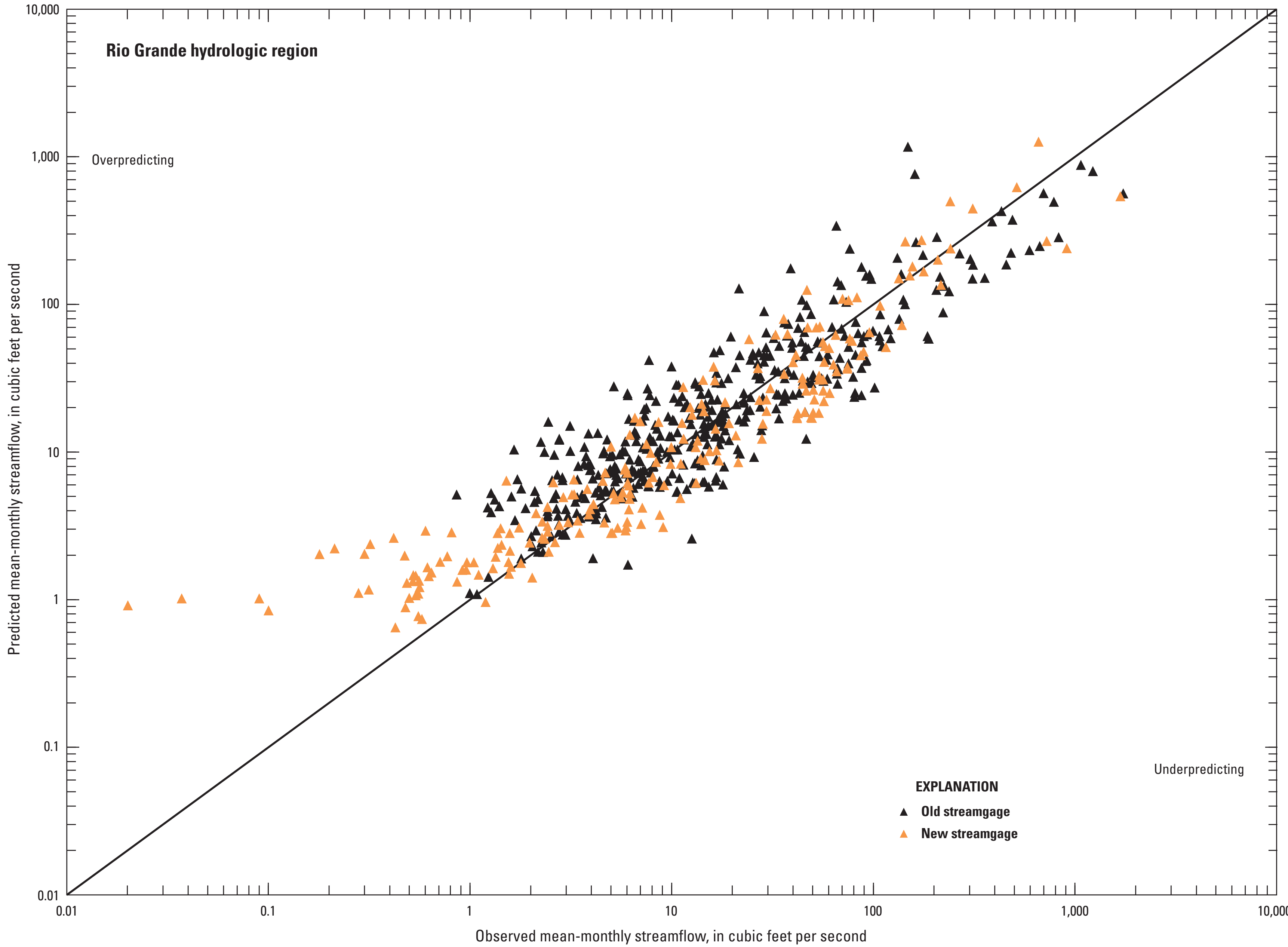

Figure 8. Comparison of observed and predicted mean-monthly streamflow in the Rio Grande hydrologic region for all 12 months.

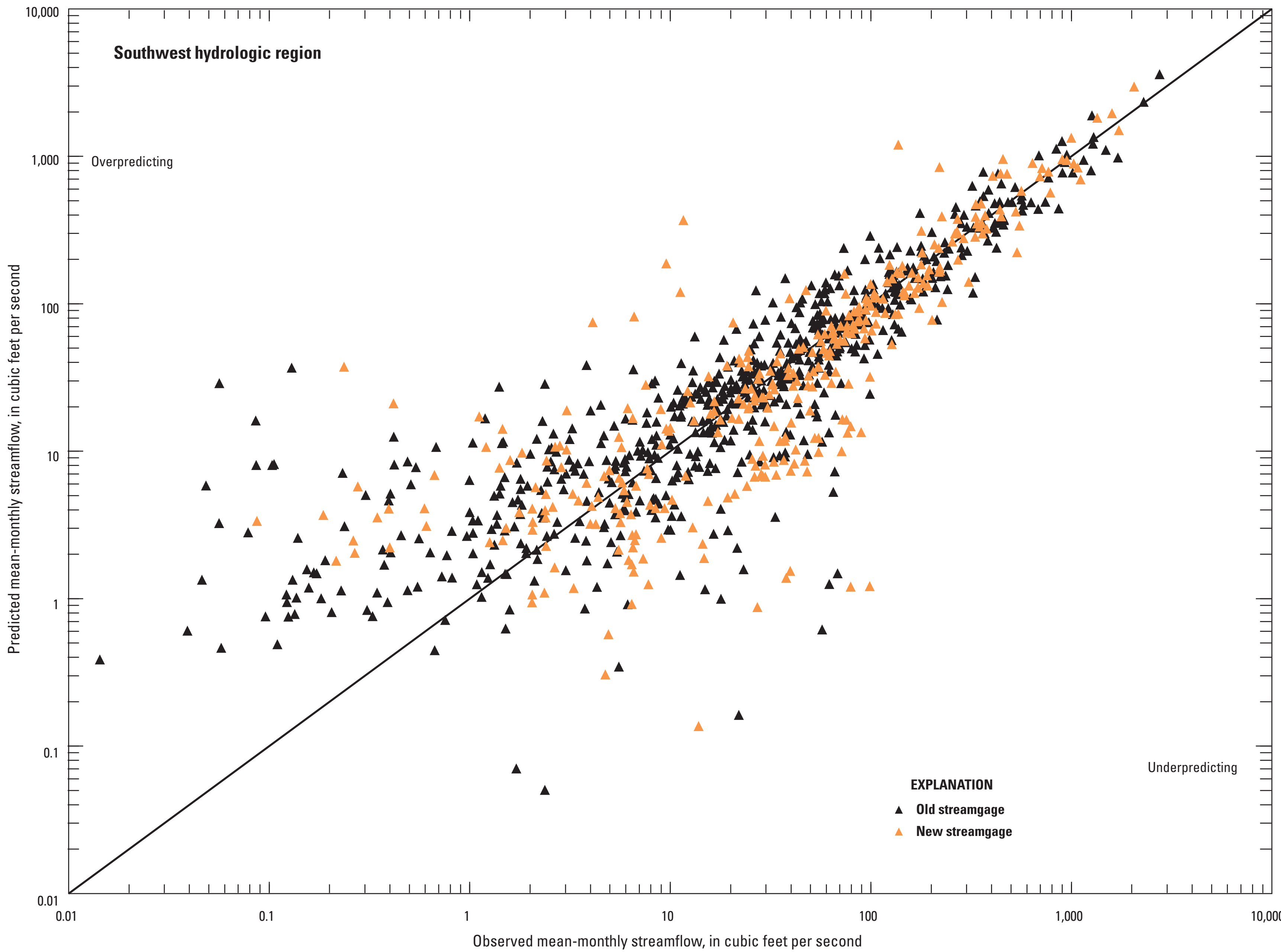

Figure 9. Comparison of observed and predicted mean-monthly streamflow in the Southwest hydrologic region for all 12 months.

Table 3. The median absolute percent difference between the observed and predicted mean-monthly streamflow for each of the 48 mean-monthly streamflow-regression equations.

[Jan., January; Feb., February; Mar., March; Apr., April; Aug., August; Sep., September; Oct., October; Nov., November; Dec., December]

Hydrologic region	Median absolute difference, in percent											
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Mountain hydrologic region	35	35	28	28	28	30	42	40	40	30	31	31
Northwest hydrologic region	44	51	35	45	39	44	72	110	109	62	47	45
Rio Grande hydrologic region	49	49	43	41	53	52	48	34	37	45	49	46
Southwest hydrologic region	48	44	34	34	27	45	52	52	62	35	43	44

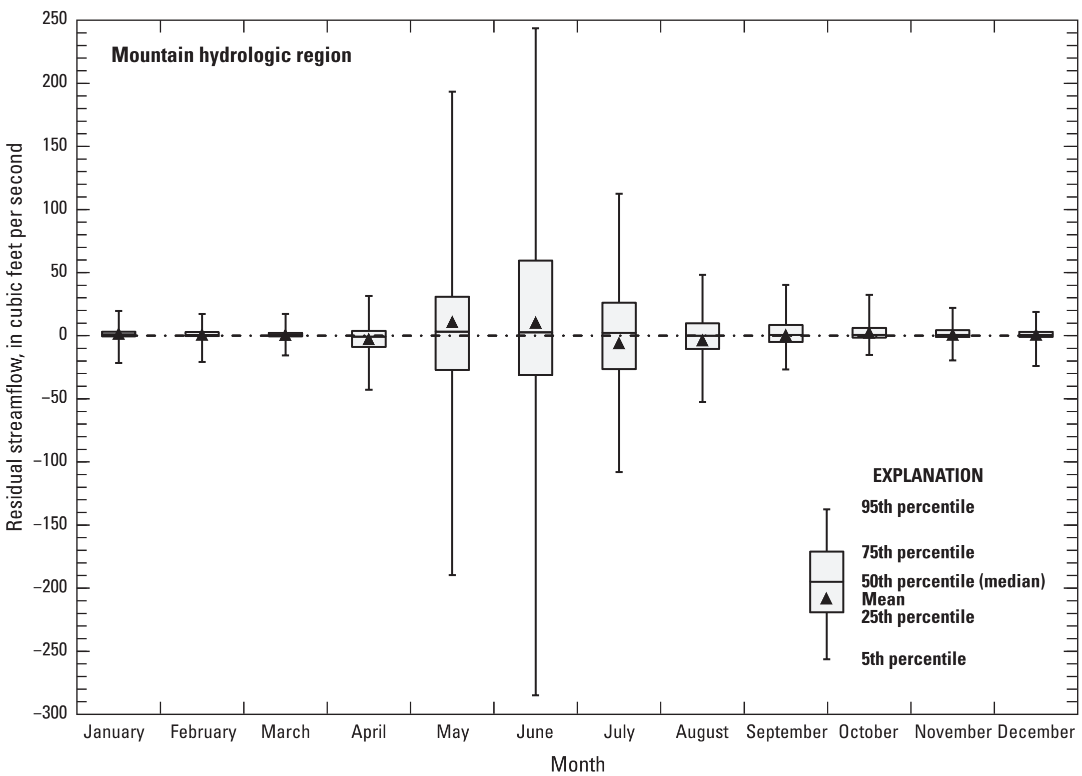

Figure 10. Residual streamflow for each month for the Mountain hydrologic region.

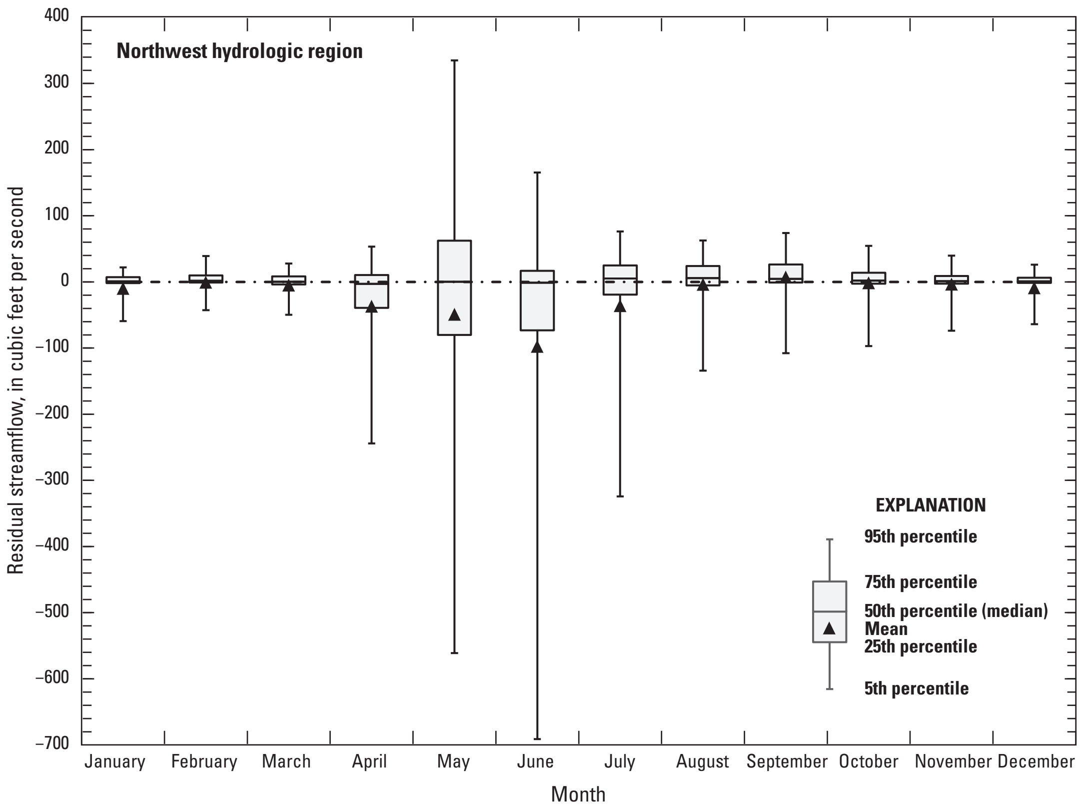

Figure 11. Residual streamflow for each month for the Northwest hydrologic region.

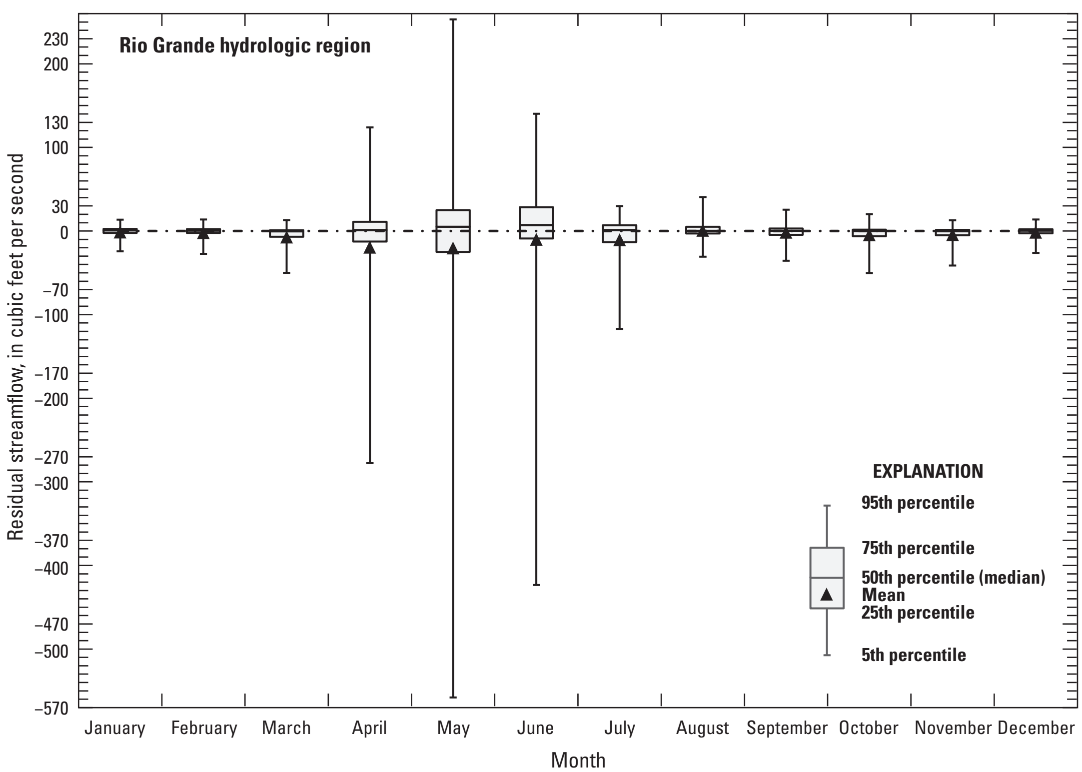

Figure 12. Residual streamflow for each month for the Rio Grande hydrologic region.

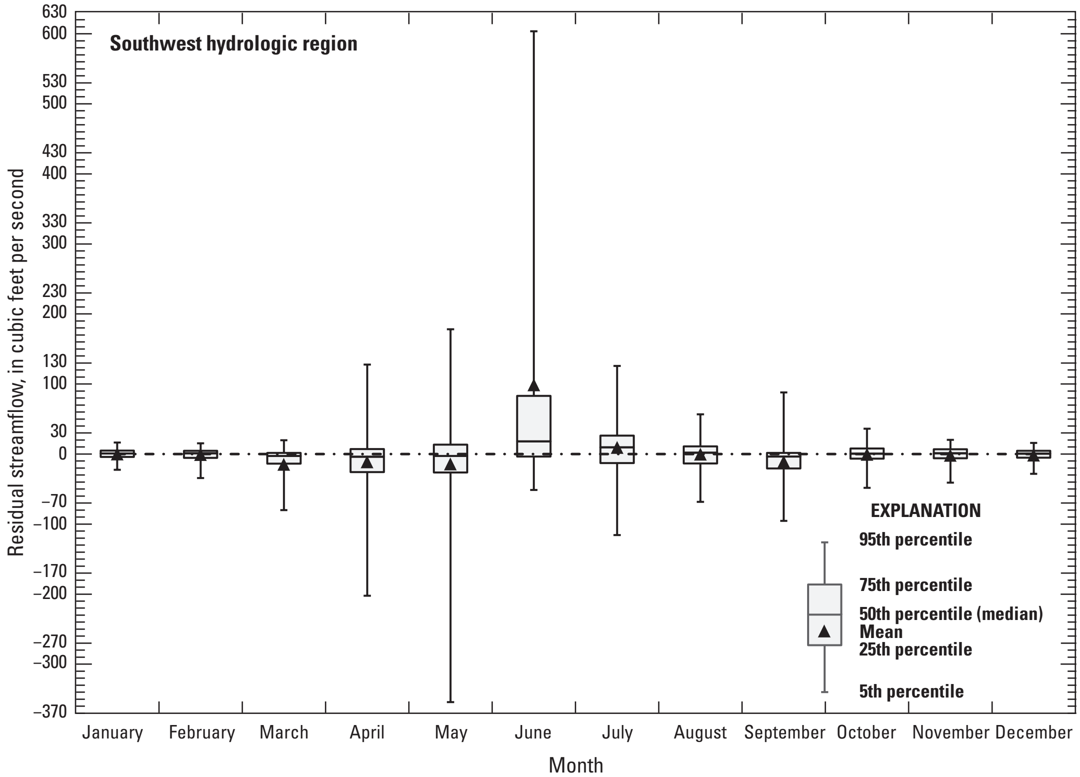

Figure 13. Residual streamflow for each month for the Southwest hydrologic region.

In the Northwest hydrologic region, the residual plots (fig. 11) for April and June indicate the equation underpredicts the lower quartile. Equations for July, August, and September overpredict mean-monthly streamflow; whereas, the October through March residual plots indicate some positive bias in the upper quartile (50th to 75th percentile range).

In the Rio Grande hydrologic region, residual plots (fig. 12) seem to indicate small bias of the predicted values, with the exception of May and June, which tend to overpredict mean-monthly streamflow. Small under- and overpredictions (interquartile range bias) are evident in the July through April months.

In the Southwest hydrologic region, the residual plots for March, April, May, and September seem to indicate some underprediction of streamflows; whereas, the equations for June and July tend to overpredict streamflow. Residuals for the remaining months seem to indicate little substantial bias.

Adjusted Coefficient of Determination

The adjusted coefficient of determination is indicative of goodness-of-fit (accuracy) for the data in the regression equation (higher values usually indicate better fit) (Eng and others, 2009). The adjusted coefficient of determination ($adjR^2$) compensates for the number of independent variables used in the regression. The $adjR^2$ values for the mean-monthly streamflow for each of the 48 mean-monthly streamflow-regression equations are shown in table 4 (dataset current through the 2013 calendar year); $adjR^2$ values were computed for each equation using all available streamgage data. The $adjR^2$ values were determined as follows (Eng and others, 2009):

$$adjR^2 = 1 - \frac{SS_r / (n-k-1)}{SS_T / (n-1)} \quad (2)$$

where

SS_r is residual sum of squares,
n is total number of samples,
k is number of independent variables, and
SS_T is total sum of squares.

The residual sum of squares is determined using a logarithmic transformation (base 10) (Eng and others, 2009):

$$SS_r = \frac{1}{n} \Sigma e_i^2 = \frac{1}{n} \Sigma \left[\left| log(Q_{predicted}) - log(Q_{observed}) \right| \right]^2 \quad (3)$$

where

e_i is the residual errors,

The total sum of squares is determined using a logarithmic transformation (base 10) (Eng and others, 2009):

$$SS_T = \Sigma S = \Sigma \left[log(Q_{predicted}) - log(\bar{Q}) \right]^2 \quad (4)$$

where

S are squares that are equal to the sum of the amount of variability in the observations, and

$\bar{Q}$ is average of the mean-monthly streamflow from the regression equation, in cubic feet per second.

The monthly adjR^2 values were computed and have the same general pattern for all four hydrologic regions (table 4). The largest values usually occur in March or April, and the lowest values usually occur in August or September. Only the Rio Grande hydrologic region deviates from this seasonal pattern, exhibiting a decrease in adjR^2 values in August and September, with the lowest values occurring in the winter months (December, January, and February). Generally, the adjR^2 values for this report are just slightly less (0.76 compared to 0.79) than the values computed in the 2009 study. The similarity of values, even when tested with data not used to originally develop the mean-monthly streamflow-regression equations, provides confidence that the predictive uncertainty of mean-monthly regression equations in the 2009 study are accurate.

Standard Error of Prediction

The SEP, in percent, in the 2009 study was used as a measure of the precision of values predicted from the regression equation. Standard error of prediction as a percentage for each hydrologic region and each month at all streamgages from the 2009 study is shown in table 5. The average of the 12 monthly SEPs for the Mountain hydrologic region was smallest at 53 percent, followed in increasing order by Rio Grande (64 percent), Northwest (83 percent), and Southwest (91 percent). Generally, many of the largest mean SEPs among all hydrologic regions tended to be associated with the April through October open-water season, but there is variation among the hydrologic regions. In the Mountain hydrologic region, the largest SEPs were in July and August (76 and 80 percent, respectively). In the Northwest hydrologic region, the largest SEPs were in August, September, and October (90, 104, and 94 percent, respectively). In the Rio Grande hydrologic region, the largest SEPs were in May and June (84 percent for both months), and in the Southwest hydrologic region,

Table 4. The adjusted coefficient of determination for the 48 mean-monthly streamflow-regression equations.

[Jan., January; Feb., February; Mar., March; Apr., April; Aug., August; Sep., September; Oct., October; Nov., November; Dec., December]

Hydrologic region	Adjusted coefficient of determination (adjR^2)											
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Mountain hydrologic region	0.81	0.82	0.81	0.89	0.86	0.80	0.68	0.67	0.72	0.82	0.84	0.83
Northwest hydrologic region	0.69	0.83	0.86	0.76	0.78	0.84	0.77	0.65	0.67	0.75	0.74	0.78
Rio Grande hydrologic region	0.72	0.76	0.85	0.86	0.82	0.83	0.80	0.76	0.76	0.81	0.81	0.74
Southwest hydrologic region	0.64	0.70	0.76	0.78	0.77	0.77	0.66	0.61	0.44	0.70	0.70	0.69

Table 5. Mean standard error of prediction for mean-monthly streamflow from the 2009 study.

[Ann., annual; Jan., January; Feb., February; Mar., March; Apr., April; Aug., August; Sep., September; Oct., October; Nov., November; Dec., December]

	Ann.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Mountain hydrologic region	33	50	51	49	44	46	46	76	80	59	45	46	47
Northwest hydrologic region	55	85	77	68	84	71	80	75	90	104	94	83	79
Rio Grande hydrologic region	73	64	56	49	79	84	84	74	53	57	55	53	63
Southwest hydrologic region	60	77	58	47	50	62	121	180	119	120	106	80	75

the largest SEPs were in June, July, August, September, and October (121, 180, 119, 120, and 106 percent, respectively). Generally, SEPs tended to be smallest during November through March (table 5).

In this study, the data were split into subsets based on hydrologic region, period of record, and old and new streamgages (table 6). To evaluate the performance of the 48 mean-monthly streamflow equations, the upper and lower prediction intervals (calculated for the 95-percent confidence level) were used to determine the number of data points from observed streamgage data inside those limits. The SEP was converted from percent to logarithmic (base 10) units by (Tasker, 1978):

$$\text{SEP}_{log10\ units} = \sqrt{\frac{\ln\left[\left(SEP_{percent} / 100\right)^2 + 1\right]}{Ln\left(10\right)^2}} \tag{5}$$

where

$SEP_{percent}$ is standard error of prediction, in percent.

Then, the upper and lower prediction intervals (PI) were determined as follows:

$$PI_{upper,lower\left(in\ log10\ units\right)} = log\left(Q_{predicted}\right) \pm 2\text{SEP}_{log10\ units} \tag{6}$$

Each streamgage for every month was categorized as outside or within the 95-percent prediction intervals, established by the SEP values in the 2009 study. For all hydrologic regions, approximately 87 percent of the data are within the 95-percent prediction intervals (average of the 12 months in table 6). The explanation for why fewer than 95 percent of the data are within the prediction intervals is that the data do not conform perfectly to the regression assumptions required to accurately estimate performance metrics. For example, if the regression residuals are not normally distributed and homoscedastic, then the predictions intervals are inexact. In addition, the regression equations were developed using weighted least squares giving greater weight to streamgages with longer periods of record. As a result, the regression line is pulled slightly toward the longer record stations. In contrast, the prediction intervals are evaluated without regard to record length, and this difference may somewhat confound the analysis.

The equations for the Rio Grande hydrologic region had the best fit with the parametric (Helsel and Hirsch, 2002) prediction-interval assumptions, with approximately 91.8 percent of the data within the prediction interval (mean for 12 months, table 6). The Mountain, Northwest, and Southwest hydrologic regions had 87.8, 84.9, and 83.5 percent contained within the prediction interval, respectively (mean for 12 months, table 6). The performance of the equations did not change when analyzing different the periods of record of the streamgage. Streamflow data from 1971 through 2000 were used to analyze the equations because the precipitation data from Daly and others (1994) that were used to generate the regression equations in the 2009 study only included data from 1971 through 2000. When compared to the dataset for the entire period of record, the results from the 1971 through 2000 dataset (average of the mean in all four hydrologic regions) were equivalent with both datasets having 87 percent of the data within the prediction interval. The old streamgages performed slightly better than the new streamgages, with approximately 88 and 85 percent of the data within the prediction intervals, respectively. This result was expected as the streamgages used to develop the regression equations should yield a better performance than the new streamgages. The fact that the results for the two datasets are very similar provides assurance that when these equations are applied to locations not used to develop the equations, the SEP and $adjR^2$ error metrics should be similar to those established in the 2009 study for locations with natural streamflow. The 30 mean-monthly streamflow equations identified as having no bias in the 2009 study (appendix 2) did not have substantially lower SEPs than the remaining 18 mean-monthly streamflow equations. The 30 equations identified in the 2009 study as having no bias were determined to have 86 percent of their data within the prediction intervals, and the 18 equations identified in the 2009 study as having a bias were determined to have 83 percent of their data within the prediction intervals. In April 2014, a miscalculation of the SEP in Capesius and Stephens (2009) was uncovered. As a result, in April 2014, the SEP was updated. The updated SEP and $adjR^2$ values that correspond to the mean-monthly streamflow equations developed in a study by Capesius and Stephens in 2009 are in close agreement with the results of this study. Based on the results presented in this report, the updated standard error of prediction and adjusted coefficient of determination values for the mean-monthly streamflow equations developed in the 2009 study are consistent with the findings of this study.

Table 6. Percentages of data from streamgages that are within the 95-percent prediction interval, based on the standard error of prediction from the 2009 study.

[Jan., January; Feb., February; Mar., March; Apr., April; Aug., August; Sep., September; Oct., October; Nov., November; Dec., December; POR, period of record]

	Percentage of data within prediction interval												
	Jan.	**Feb.**	**Mar.**	**Apr.**	**May**	**June**	**July**	**Aug.**	**Sep.**	**Oct.**	**Nov.**	**Dec.**	**Mean**
Mountain hydrologic region, all streamgages, all POR	86.1	87.3	94.1	89.7	92.0	86.4	88.3	87.2	85.5	84.7	88.2	84.3	87.8
Mountain hydrologic region, old streamgages, all POR	88.6	89.4	95.1	91.3	92.1	87.3	88.9	88.1	85.7	86.5	90.3	87.8	89.3
Mountain hydrologic region, new streamgages, all POR	79.1	81.4	91.3	85.7	92.0	84.3	86.8	84.9	84.9	80.0	82.6	74.4	84.1
Northwest hydrologic region, all streamgages, all POR	88.8	89.9	88.2	88.4	89.5	89.5	72.2	72.2	75.7	88.3	88.1	89.8	84.9
Northwest hydrologic region, old streamgages, all POR	85.0	86.7	86.7	88.1	86.9	88.5	83.6	82.0	78.7	90.0	86.7	86.7	85.8
Northwest hydrologic region, new streamgages, all POR	93.6	93.9	90.0	88.7	92.5	90.6	59.3	61.1	72.2	86.3	89.8	93.8	83.9
Rio Grande hydrologic region, all streamgages, all POR	83.7	87.8	89.8	98.1	96.3	96.4	96.4	94.5	90.9	94.3	87.8	83.7	91.8
Rio Grande hydrologic region, old streamgages, all POR	84.4	90.6	93.8	97.1	94.4	94.4	94.4	91.7	86.1	91.4	90.6	84.4	91.2
Rio Grande hydrologic region, new streamgages, all POR	82.4	82.4	82.4	100	100	100	100	100	100	100	82.4	82.4	93.0
Southwest hydrologic region, all streamgages, all POR	81.5	76.5	79.0	78.0	94.0	90.4	90.4	85.5	73.5	86.4	85.0	81.3	83.5
Southwest hydrologic region, old streamgages, all POR	83.3	79.6	81.5	75.9	94.5	92.7	89.1	87.3	81.8	86.8	86.8	83.0	85.2
Southwest hydrologic region, new streamgages, all POR	77.8	70.4	74.1	82.1	92.9	85.7	92.9	82.1	57.1	85.7	81.5	77.8	80.1
All hydrologic regions, all streamgages, all POR	85.6	85.9	89.0	88.1	92.3	89.3	85.4	83.8	81.3	87.2	87.5	85.1	86.7
Mountain hydrologic region, all streamgages, 1971–2000	87.1	88.2	91.5	87.2	88.3	91.6	92.6	88.4	86.3	84.1	89.5	88.2	88.6
Northwest hydrologic region, all streamgages, 1971–2000	88.3	88.7	87.1	87.3	89.1	89.1	73.8	72.3	73.8	85.5	90.0	88.3	84.3
Rio Grande hydrologic region, all streamgages, 1971–2000	86.7	96.7	90.3	96.9	94.1	94.1	94.1	91.2	88.2	89.7	89.7	89.3	91.8
Southwest hydrologic region, all streamgages, 1971–2000	84.4	75.6	68.9	84.4	95.6	93.3	95.6	80.0	64.4	81.8	84.1	79.5	82.3

Summary

The U.S. Geological Survey, in cooperation with the Colorado Water Conservation Board, evaluated the predictive uncertainty of mean-monthly streamflow-regression equations representative of natural streamflow conditions in Colorado. The purpose of this report is to evaluate the streamflow-regression equations presented in a 2009 U.S. Geological Survey study by comparing the predictive uncertainty using streamflow data through calendar year 2013 for computation of mean-monthly streamflow for Colorado basins with hydrology that is influenced predominantly by natural runoff processes. The study area for this report is limited to the Mountain, Northwest, Rio Grande, and Southwest hydrologic regions of Colorado.

Data collected from the beginning of the period of record through calendar year 2013 were used to evaluate the mean-monthly streamflow equations using the same basin characteristics as in the 2009 study. U.S. Geological Survey and Colorado Division of Water Resources streamgages with at least 10 years of streamflow record and identified as representative of natural streamflow conditions were selected. During the streamgage selection process, a total of 432 streamgages, composed of 278 from the 2009 study and 154 new streamgages, were identified.

Generally, the mean-monthly streamflow-regression equations in the Mountain and the Rio Grande hydrologic regions had the least amount of variance over the range of streamflows as shown graphically by more narrow clustering of data points. The regression equations for the Mountain hydrologic region have the best agreement between observed and predicted values (although still somewhat biased toward underprediction at the high end) when the predicted streamflows are greater than 100 cubic feet per second (ft^3/s), evidenced by data that more closely fit the line of agreement when compared to the streamflows less than 100 ft^3/s. At predicted streamflows of less than 3 ft^3/s in the Mountain hydrologic region, the regression equations tend to overpredict mean-monthly streamflow.

The Northwest hydrologic region follows the same pattern as the Mountain hydrologic region showing predicted streamflows greater than 200 ft^3/s with a better fit (although still biased toward underprediction at the high end) with the line of agreement, and at streamflows less than 10 ft^3/s in the Northwest hydrologic region, the regression equation bias tends to overpredict mean-monthly streamflow.

Unlike the other three hydrologic regions, the Rio Grande has relatively consistent variance from the line of agreement throughout the range of streamflows. However, similar to the other three hydrologic regions, predicted streamflows at the high end are biased low. At streamflows less than 3 ft^3/s, the regression equations in the Rio Grande hydrologic region show high bias and tend to overpredict mean-monthly streamflow. The bias seems mainly to be a result of extremely low streamflow values from the new streamgages added for this report.

The Southwest hydrologic region exhibits the lowest variance and least bias at predicted streamflows greater than 100 ft^3/s and the greatest variance at predicted streamflows less than 20 ft^3/s of any of the four hydrologic regions. At predicted streamflows less than 20 ft^3/s, the regression equations are imprecise and tend to overpredict mean-monthly streamflow.

The median absolute differences between the observed and predicted streamflow computed for Mountain, Northwest, and Southwest hydrologic regions have fairly uniform values throughout the year, with the exception of late summer and early fall (July, August, and September) when each hydrologic region exhibits a substantial increase in median absolute percent difference. The greatest difference occurs in the Northwest hydrologic region, and the smallest difference occurs in the Mountain hydrologic region. The Rio Grande hydrologic region shows seasonal variation in median absolute percent difference with March, April, August, and September having a median absolute difference near or below 40 percent and the remaining months of the year having a median absolute difference near or above 50 percent. In the Mountain, Northwest, and Southwest hydrologic regions, the mean-monthly streamflow equations perform the best during spring (March, April, and May). However, in the Rio Grande hydrologic region, the mean-monthly streamflow equations perform the best during late summer and early fall (August and September).

In the Mountain hydrologic region, boxplots of residuals indicate slight overprediction bias in the months of May, June, and July based on median differences. The residual plots for the September through March equations seem to indicate some positive bias in the upper quartile (50th to 75th percentile range). The April plot indicates some negative bias (underprediction) in the lower quartile (25th to 50th percentile range).

In the Northwest hydrologic region, the residual plots for April and June indicate the equation underpredicts the lower quartile. Equations for July, August, and September overpredict mean-monthly streamflow; whereas, the October through March residual plots indicate some positive bias in the upper quartile (50th to 75th percentile range).

In the Rio Grande hydrologic region, residual plots seem to indicate small bias of the predicted values, with the exception of May and June, which tend to overpredict mean-monthly streamflow. Small under- and overpredictions (interquartile range bias) are evident in the July through April months.

In the Southwest hydrologic region, the residual plots for March, April, May, and September seem to indicate some underprediction of streamflows; whereas, the equations for June and July tend to overpredict streamflow. Residuals for the remaining months seem to indicate little substantial bias.

The adjusted coefficient of determination ($adjR^2$) is indicative of goodness-of-fit (accuracy) for the data in the regression equation (higher values usually indicate better fit). The monthly $adjR^2$ values were computed and have the same general pattern for all four hydrologic regions. The largest values usually occur in March or April, and the lowest values usually occur in August or September. Only the Rio Grande

hydrologic region deviates from this seasonal pattern, exhibiting a decrease in adjR^2 values in August and September, with the lowest values occurring in the winter months (December, January, and February). Generally, the adjR^2 values for this report are just slightly less (0.76 compared to 0.79) than the values computed in the 2009 study. The similarity of values, even when tested with data not used to originally develop the mean-monthly streamflow-regression equations, provides confidence that the predictive uncertainty of mean-monthly regression equations in the 2009 study are accurate.

Each streamgage for every month was categorized as outside or within the 95-percent prediction intervals established by the SEP values in the 2009 study. For all hydrologic regions, approximately 87 percent of the data are within the prediction intervals. The explanation for why fewer than 95 percent of the data are within the prediction intervals is that the data do not conform perfectly to the regression assumptions required to accurately estimate performance metrics. For example, if the regression residuals are not normally distributed and homoscedastic, then the predictions intervals are inexact. In addition, the regression equations were developed using weighted least squares giving greater weight to streamgages with longer periods of record. As a result, the regression line is pulled slightly toward the longer record stations. In contrast, the prediction intervals are evaluated without regard to record length, and this difference may somewhat confound the analysis.

The Rio Grande hydrologic region had the best fit with the parametric prediction-interval assumptions, with approximately 91.8 percent of the data within the prediction. The Mountain, Northwest, and Southwest hydrologic regions had 87.8, 84.9, and 83.5 percent of the data contained within the prediction interval, respectively. The performance of the equations did not change when analyzing different periods of record of the streamgage. Streamflow data from 1971 through 2000 were used to analyze the equations because the precipitation data used to generate the regression equations in the 2009 study only included data from 1971 through 2000. When compared to the dataset for the entire period of record, the results from the 1971 through 2000 dataset (average of the mean in all four hydrologic regions) were equivalent with both datasets having 87 percent of the data within the prediction interval. The old streamgages performed slightly better than the new streamgages, with approximately 88 and 85 percent of the data within the prediction intervals, respectively. This result was expected because the streamgages used to develop the regression equations should yield a better performance than the new streamgages. The fact that the results for the two datasets are very similar provides assurance that when these equations are applied to locations not used to develop the equations, the SEP and adjR^2 error metrics should be similar to those established in the 2009 study for locations with natural streamflow. Based on the results presented in this report, the updated standard error of prediction and adjusted coefficient of determination values of the mean-monthly streamflow equations developed in the 2009 study are consistent with the findings of this study.

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Appendixes 1–3

Appendix 1. Streamgage Summary

Table 1–1. Summary of the streamgages used in the analysis.

[USGS, U.S. Geological Survey; CDWR, Colorado Division of Water Resources; A, drainage area; mi^2, square miles; P, mean-annual precipitation; in, inches; E, mean basin elevation; ft, feet; Colo., Colorado; Wyo., Wyoming; N. Mex., New Mexico; Ariz., Arizona]

USGS streamgage number	Streamgage name	Latitude (decimal degrees)	Longitude (decimal degrees)	Hydrologic region	USGS data	CDWR data	A (mi^2)	P (in)	E (ft)
06614800	Michigan River near Cameron Pass, Colo.	40.496094	–105.865012	Mountain	X	--	1.53	47.2	11,246
06615500	Michigan River near Lindland, Colo.	40.553592	–106.041685	Mountain	X	--	60.2	33.9	10,174
06616000	North Fork Michigan River near Gould, Colo.	40.549426	–106.021129	Mountain	X	--	20.5	31.2	9,792
06617100	Michigan River at Walden, Colo.	40.741088	–106.279470	Mountain	X	X	182	24.4	9,274
06617500	Illinois Creek near Rand, Colo.	40.462478	–106.176972	Mountain	--	X	70.5	26.2	9,638
06618500	Illinois Creek at Walden, Colo.	40.726366	–106.290582	Mountain	X	--	255	20.5	8,993
06619000	Michigan River near Cowdrey, Colo.	40.861641	–106.337249	Mountain	X	--	476	21.3	9,026
06619500	Canadian River at Cowdrey, Colo.	40.863030	–106.311415	Mountain	X	--	180	19.5	8,756
06620000	North Platte River near Northgate, Colo.	40.936639	–106.339194	Mountain	X	--	1,430	22.8	8,865
06620400	Douglas Creek above Keystone, Wyo.	41.183306	–106.270018	Mountain	X	--	22.3	28.9	9,721
06621000	Douglas Creek near Foxpark, Wyo.	41.081084	–106.307522	Mountain	X	--	117	22.3	9,115
06622500	French Creek near French, Wyo.	41.213889	–106.511944	Mountain	X	--	59.9	35.6	9,479
06622700	North Brush Creek near Saratoga, Wyo.	41.370245	–106.520582	Mountain	X	--	38.1	39.0	9,403
06623800	Encampment River above Hog Park Creek, near Encampment, Wyo.	41.023579	–106.824766	Mountain	X	--	72.5	48.3	9,557
06624500	Encampment River at Encampment, Wyo.	41.210521	–106.778928	Mountain	X	--	208	40.8	9,106
06627500	Jack Creek at Matheson Ranch, near Saratoga, Wyo.	41.401111	–107.016389	Northwest	X	--	33.2	34.5	8,417
06631000	Medicine Bow River near Medicine Bow, Wyo.	41.724722	–106.318611	Northwest	X	--	193	24.5	8,331
06632400	Rock Creek Above King Canyon Canal, near Arlington, Wyo.	41.585245	–106.222791	Mountain	X	--	62.8	34.4	9,807
06696980	Tarryall Creek at Upper Station near Como, Colo.	39.339433	–105.911681	Mountain	X	--	23.7	29.0	11,297
06698500	Tarryall Creek near Jefferson, Colo.	39.294989	–105.718620	Mountain	X	--	181	20.3	10,143
06705500	Geneva Creek at Grant, Colo.	39.472210	–105.682228	Mountain	X	--	74.7	25.4	11,283
06706000	North Fork South Platte River below Geneva Creek, at Grant, Colo.	39.457210	–105.658616	Mountain	X	--	127	24.4	11,009
06714800	Leavenworth Creek at Mouth near Georgetown, Colo.	39.687210	–105.700282	Mountain	X	--	12.0	24.7	11,792
06715000	Clear Creek above West Fork Clear Creek near Empire, Colo.	39.751932	–105.661947	Mountain	X	--	86.1	26.5	11,334
06716100	West Fork Clear Creek above Mouth near Empire, Colo.	39.758876	–105.660003	Mountain	X	--	57.4	28.6	11,066
06716500	Clear Creek near Lawson, Colo.	39.765821	–105.626112	Mountain	X	--	147	27.2	11,180
06717400	Chicago Creek below Devils Canyon near Idaho Springs, Colo.	39.716377	–105.571388	Mountain	X	--	43.7	25.0	10,641
06721500	North Saint Vrain Creek near Allens Park, Colo.	40.218874	–105.528333	Mountain	X	--	32.5	38.2	10,828
06722500	South Saint Vrain Creek near Ward, Colo.	40.090819	–105.514443	Mountain	X	X	13.4	38.3	11,120
06725500	Middle Boulder Creek at Nederland, Colo.	39.961654	–105.504442	Mountain	X	X	36.5	33.1	10,346
06729000	South Boulder Creek near Rollinsville, Colo.	39.914709	–105.501942	Mountain	X	--	43.6	30.9	10,175

Table 1–1. Summary of the streamgages used in the analysis.—Continued

[USGS, U.S. Geological Survey; CDWR, Colorado Division of Water Resources; A, drainage area; mi^2, square miles; P, mean-annual precipitation; in, inches; E, mean basin elevation; ft, feet; Colo., Colorado; Wyo., Wyoming; N. Mex., New Mexico; Ariz., Arizona]

USGS streamgage number	Streamgage name	Latitude (decimal degrees)	Longitude (decimal degrees)	Hydrologic region	USGS data	CDWR data	A (mi^2)	P (in)	E (ft)
06732000	Glacier Creek near Estes Park, Colo.	40.345262	–105.585557	Mountain	X	--	24.6	40.5	10,502
06733000	Big Thompson River at Estes Park, Colo.	40.378317	–105.513887	Mountain	X	X	137	33.6	10,116
06734500	Fish Creek near Estes Park, Colo.	40.368595	–105.493886	Mountain	X	X	15.8	21.5	8,590
06746095	Joe Wright Creek above Joe Wright Reservoir, Colo.	40.539982	–105.882790	Mountain	X	--	3.33	44.8	10,796
06748200	Fall Creek near Rustic, Colo.	40.551649	–105.626946	Mountain	X	--	3.60	25.4	11,028
06748510	Little Beaver Creek near Idylwilde, Colo.	40.638593	–105.661668	Mountain	X	--	0.89	24.0	10,876
06748530	Little Beaver Creek near Rustic, Colo.	40.623037	–105.564998	Mountain	X	--	12.4	20.1	9,831
06748600	South Fork Cache La Poudre River near Rustic, Colo.	40.646926	–105.493605	Mountain	X	--	92.6	21.4	9,866
07079500	East Fork Arkansas River near Leadville, Colo.	39.259711	–106.340581	Mountain	X	--	51.2	25.4	11,434
07081000	Tennessee Creek near Leadville, Colo.	39.264156	–106.340859	Mountain	X	--	45.7	22.0	10,800
07082000	Lake Fork above Sugar Loaf Reservoir, Colo.	39.269711	–106.395027	Mountain	X	--	24.3	30.7	11,100
07083000	Halfmoon Creek near Malta, Colo.	39.172213	–106.389193	Mountain	X	--	23.5	34.7	11,955
07086500	Clear Creek above Clear Creek Reservoir, Colo.	39.018049	–106.277800	Mountain	X	X	67.0	27.8	11,658
07091015	Chalk Creek at Nathrop, Colo.	38.733607	–106.160017	Mountain	--	X	83.0	22.6	11,379
08216500	Willow Creek at Creede, Colo.	37.856110	–106.927546	Rio Grande	X	--	34.3	30.5	11,476
08218000	Goose Creek near Wagonwheel Gap, Colo.	37.687889	–106.844722	Rio Grande	X	--	53.6	43.9	11,070
08218500	Goose Creek at Wagonwheel Gap, Colo.	37.751947	–106.830044	Rio Grande	X	X	91.1	37.7	10,732
08219500	South Fork Rio Grande River at South Fork, Colo.	37.656949	–106.649208	Rio Grande	X	X	211	38.3	10,397
08220500	Pinos Creek near Del Norte, Colo.	37.591671	–106.450038	Rio Grande	X	X	69.2	33.3	10,546
08223500	Rock Creek near Monte Vista, Colo.	37.490282	–106.259477	Rio Grande	X	--	32.9	32.3	10,408
08224500	Kerber Creek above Little Kerber Creek near Villa Grove, Colo.	38.220277	–106.089741	Rio Grande	X	X	45.4	18.9	10,400
08226700	Cotton Creek near Mineral Hot Springs, Colo.	38.131941	–105.788620	Rio Grande	--	X	13.7	30.5	11,265
08227000	Saguache Creek near Saguache, Colo.	38.163333	–106.290583	Rio Grande	X	X	517	20.9	9,949
08227500	North Crestone Creek near Crestone, Colo.	38.013610	–105.692788	Rio Grande	X	X	12.9	29.5	11,291
08229500	Cottonwood Creek near Crestone, Colo.	37.933300	–105.645560	Rio Grande	--	X	6.74	31.6	11,434
08230500	Carnero Creek near La Garita, Colo.	37.859723	–106.319477	Rio Grande	X	X	106	26.4	10,055
08231000	La Garita Creek near La Garita, Colo.	37.813335	–106.318644	Rio Grande	X	X	62.2	31.3	10,257
08235250	Alamosa River above Wightman Fork near Jasper, Colo.	37.402505	–106.521982	Rio Grande	X	X	37.8	44.3	11,256
08236000	Alamosa River above Terrace Reservoir, Colo.	37.374728	–106.334756	Rio Grande	X	X	106	38.7	10,883
08240500	Trinchera Creek above Turners Ranch, near Fort Garland, Colo.	37.374733	–105.295010	Rio Grande	X	X	52.6	23.0	10,495
08241500	Sangre De Cristo Creek near Fort Garland, Colo.	37.425009	–105.415011	Rio Grande	X	X	183	19.4	9,169

Table 1–1. Summary of the streamgages used in the analysis.—Continued

[USGS, U.S. Geological Survey; CDWR, Colorado Division of Water Resources; A, drainage area; mi², square miles; P, mean-annual precipitation; in, inches; E, mean basin elevation; ft, feet; Colo., Colorado; Wyo., Wyoming; N. Mex., New Mexico; Ariz., Arizona]

USGS streamgage number	Streamgage name	Latitude (decimal degrees)	Longitude (decimal degrees)	Hydrologic region	USGS data	CDWR data	A (mi²)	P (in)	E (ft)
08242500	Ute Creek near Fort Garland, Colo.	37.447222	–105.425833	Rio Grande	X	X	40.3	22.0	10,146
08245500	Conejos River at Platoro, Colo.	37.353895	–106.525037	Rio Grande	X	--	41.0	45.8	11,261
08246500	Conejos River near Mogote, Colo.	37.053900	–106.187527	Rio Grande	X	--	281	35.3	10,481
08247500	San Antonio River at Ortiz, Colo.	36.993069	–106.038633	Rio Grande	X	--	116	25.2	9,353
08248000	Los Pinos River near Ortiz, Colo.	36.982236	–106.073633	Rio Grande	X	--	153	30.6	9,863
08248500	San Antonio River at Mouth, near Manassa, Colo.	37.176956	–105.878076	Rio Grande	X	X	372	23.6	9,197
08249000	Conejos River near Lasauses, Colo.	37.300288	–105.746963	Rio Grande	X	--	766	26.2	9,506
08252500	Costilla Creek above Costilla Dam, N. Mex.	36.898361	–105.254667	Rio Grande	X	--	25.2	24.5	10,602
08253000	Casias Creek near Costilla, N. Mex.	36.896856	–105.260458	Rio Grande	X	--	18.8	23.7	10,991
08253500	Santistevan Creek near Costilla, N. Mex.	36.884167	–105.281111	Rio Grande	X	--	2.47	22.1	11,183
08255000	Ute Creek near Amalia, N. Mex.	36.952802	–105.410285	Rio Grande	X	--	11.2	28.6	10,924
08263000	Latir Creek near Cerro, N. Mex.	36.829192	–105.547785	Rio Grande	X	--	10.6	31.6	11,001
08264000	Red River near Red River, N. Mex.	36.622252	–105.389451	Rio Grande	X	--	19.3	27.3	11,091
08264500	Red River below Zwergle Damsite near Red River, N. Mex.	36.673641	–105.381116	Rio Grande	X	--	29.1	26.2	10,734
08265000	Red River near Questa, N. Mex.	36.703311	–105.568431	Rio Grande	X	--	112	25.5	10,157
08266820	Red River below Fish Hatchery, near Questa, N. Mex.	36.682839	–105.654122	Rio Grande	X	--	183	24.0	9,789
08267000	Red River at Mouth, near Questa, N. Mex.	36.648078	–105.693342	Rio Grande	X	--	189	23.7	9,726
08267500	Rio Hondo near Valdez, N. Mex.	36.541797	–105.556522	Rio Grande	X	--	37.1	29.6	10,379
08268500	Arroyo Hondo at Arroyo Hondo, N. Mex.	36.532245	–105.685567	Rio Grande	X	--	66.7	23.8	9,381
08269000	Rio Pueblo De Taos near Taos, N. Mex.	36.439444	–105.503611	Rio Grande	X	--	58.0	23.0	9,575
08271000	Rio Lucero near Arroyo Seco, N. Mex.	36.508289	–105.530964	Rio Grande	X	--	16.7	29.0	10,725
08275000	Rio Fernando De Taos near Taos, N. Mex.	36.375583	–105.549178	Rio Grande	X	--	60.8	25.2	9,044
08275500	Rio Grande Del Rancho near Talpa, N. Mex.	36.303103	–105.581003	Rio Grande	X	--	80.4	31.7	9,356
08275600	Rio Chiquito near Talpa, N. Mex.	36.331971	–105.578901	Rio Grande	X	--	37.9	30.2	9,369
08283500	Rio Chama at Park View, N. Mex.	36.737514	–106.578369	Rio Grande	X	--	396	30.8	9,489
08284100	Rio Chama near La Puente, N. Mex.	36.662658	–106.633367	Rio Grande	X	--	472	29.5	9,309
08284300	Horse Lake Creek above Heron Reservoir near Los Ojos, N. Mex.	36.706681	–106.745594	Rio Grande	X	--	43.1	20.4	7,942
08284500	Willow Creek near Park View, N. Mex.	36.668070	–106.704760	Rio Grande	X	--	141	19.4	7,770
08288000	El Rito near El Rito, N. Mex.	36.391684	–106.239470	Rio Grande	X	--	50.1	21.6	9,107
08289000	Rio Ojo Caliente at La Madera, N. Mex.	36.349742	–106.044186	Rio Grande	X	--	412	18.3	8,488
09016500	Arapaho Creek at Monarch Lake Outlet, Colo.	40.112486	–105.749730	Mountain	X	--	47.8	35.7	10,642

Table 1–1. Summary of the streamgages used in the analysis.—Continued

[USGS, U.S. Geological Survey; CDWR, Colorado Division of Water Resources; A, drainage area; mi², square miles; P, mean-annual precipitation; in, inches; E, mean basin elevation; ft, feet; Colo., Colorado; Wyo., Wyoming; N. Mex., New Mexico; Ariz., Arizona]

USGS streamgage number	Streamgage name	Latitude (decimal degrees)	Longitude (decimal degrees)	Hydrologic region	USGS data	CDWR data	A (mi²)	P (in)	E (ft)
09020000	Willow Creek near Granby, Colo.	40.180541	–106.009185	Mountain	X	--	109	25.8	9,630
09022000	Fraser River at Upper Station, near Winter Park, Colo.	39.845820	–105.751951	Mountain	X	--	10.5	36.5	11,226
09024000	Fraser River at Winter Park, Colo.	39.899987	–105.776674	Mountain	X	--	27.6	32.9	10,780
09026500	Saint Louis Creek near Fraser, Colo.	39.909987	–105.878345	Mountain	X	--	32.8	28.9	10,737
09032000	Ranch Creek near Fraser, Colo.	39.949987	–105.765563	Mountain	X	--	19.9	30.6	10,456
09032500	Ranch Creek near Tabernash, Colo.	39.997487	–105.823621	Mountain	X	--	51.1	28.5	9,971
09033000	Meadow Creek near Tabernash, Colo.	40.050820	–105.777508	Mountain	X	--	8.15	34.9	10,509
09033300	Fraser River below Crooked Creek at Tabernash, Colo.	40.006892	–105.848272	Mountain	X	--	224	27.7	10,049
09034000	Fraser River at Granby, Colo.	40.085264	–105.955294	Mountain	X	--	296	25.7	9,755
09034500	Colorado River at Hot Sulphur Springs, Colo.	40.083319	–106.088077	Mountain	X	--	824	26.8	9,736
09034900	Bobtail Creek near Jones Pass, Colo.	39.760264	–105.906401	Mountain	X	--	5.53	32.5	11,793
09035500	Williams Fork below Steelman Creek, Colo.	39.778875	–105.928347	Mountain	X	--	16.4	30.6	11,560
09035700	Williams Fork above Darling Creek, near Leal, Colo.	39.797194	–106.025639	Mountain	X	--	35.2	28.6	11,107
09035800	Darling Creek near Leal, Colo.	39.800542	–106.026407	Mountain	X	--	8.30	28.7	11,029
09035900	South Fork of Williams Fork near Leal, Colo.	39.795820	–106.030573	Mountain	X	--	27.4	28.7	10,988
09036500	Keyser Creek near Leal, Colo.	39.907486	–106.017240	Mountain	X	--	13.9	28.1	10,526
09039000	Troublesome Creek near Pearmont, Colo.	40.217484	–106.313085	Mountain	X	--	44.6	28.1	9,868
09040000	East Fork Troublesome Creek near Troublesome, Colo.	40.157485	–106.283362	Mountain	X	--	75.7	23.2	9,266
09040500	Troublesome Creek near Troublesome, Colo.	40.059152	–106.305584	Northwest	X	--	168	22.2	9,090
09041000	Muddy Creek near Kremmling, Colo.	40.293595	–106.483647	Mountain	X	--	87.3	27.4	8,798
09041090	Muddy Creek above Antelope Creek near Kremmling, Colo.	40.202484	–106.422534	Mountain	X	--	144	24.7	8,680
09041100	Antelope Creek near Kremmling, Colo.	40.240540	–106.373643	Mountain	X	--	11.5	20.2	8,907
09046530	French Gulch at Breckenridge, Colo.	39.493042	–106.044741	Mountain	X	--	11.1	27.8	11,033
09047000	Blue River at Dillon, Colo.	39.613875	–106.051963	Mountain	X	--	128	27.0	10,912
09047500	Snake River near Montezuma, Colo.	39.605361	–105.943131	Mountain	X	--	57.8	29.7	11,495
09047700	Keystone Gulch near Dillon, Colo.	39.594431	–105.972516	Mountain	X	--	9.13	25.9	10,879
09048000	Snake River at Dillon, Colo.	39.612487	–106.042241	Mountain	X	--	90.8	26.8	11,015
09050100	Tenmile Creek below North Tenmile Creek, at Frisco, Colo.	39.575264	–106.110577	Mountain	X	--	92.2	28.9	11,237
09050500	Tenmile Creek at Dillon, Colo.	39.612487	–106.054741	Mountain	X	--	111	28.0	11,049
09051050	Straight Creek below Laskey Gulch near Dillon, Colo.	39.639709	–106.040296	Mountain	X	--	18.4	27.5	11,079
09052000	Rock Creek near Dillon, Colo.	39.723042	–106.128633	Mountain	X	--	15.6	28.9	10,738

Table 1–1. Summary of the streamgages used in the analysis.—Continued

[USGS, U.S. Geological Survey; CDWR, Colorado Division of Water Resources; A, drainage area; mi², square miles; P, mean-annual precipitation; in, inches; E, mean basin elevation; ft, feet; Colo., Colorado; Wyo., Wyoming; N. Mex., New Mexico; Ariz., Arizona]

USGS streamgage number	Streamgage name	Latitude (decimal degrees)	Longitude (decimal degrees)	Hydrologic region	USGS data	CDWR data	A (mi²)	P (in)	E (ft)
09052400	Boulder Creek at Upper Station, near Dillon, Colo.	39.728041	–106.173357	Mountain	X	--	8.32	32.3	11,240
09052800	Slate Creek at Upper Station, near Dillon, Colo.	39.763041	–106.192524	Mountain	X	--	14.0	32.3	11,028
09053000	Slate Creek near Dillon, Colo.	39.781652	–106.167801	Mountain	X	--	16.4	30.7	10,742
09054000	Black Creek below Black Lake, near Dillon, Colo.	39.799152	–106.268360	Mountain	X	--	15.0	33.9	11,186
09055300	Cataract Creek near Kremmling, Colo.	39.835263	–106.316417	Mountain	X	--	11.9	31.5	10,820
09058500	Piney River below Piney Lake, near Minturn, Colo.	39.708042	–106.426697	Mountain	X	--	12.8	30.1	10,827
09058610	Dickson Creek near Vail, Colo.	39.704111	–106.457250	Mountain	X	--	3.28	29.0	10,027
09058700	Freeman Creek near Minturn, Colo.	39.698319	–106.445586	Mountain	X	--	2.99	27.5	9,846
09058800	East Meadow Creek near Minturn, Colo.	39.731653	–106.426697	Mountain	X	--	3.58	29.2	10,573
09059500	Piney River near State Bridge, Colo.	39.795722	–106.574347	Northwest	X	--	84.7	26.4	9,837
09060500	Rock Creek near Toponas, Colo.	40.041098	–106.655872	Mountain	X	--	47.8	29.4	9,390
09060550	Rock Creek at Crater, Colo.	39.978321	–106.710039	Northwest	X	--	72.5	27.7	9,221
09060770	Rock Creek at McCoy, Colo.	39.912209	–106.725594	Northwest	X	--	198	26.4	8,952
09061600	East Fork Eagle River near Climax, Colo.	39.410265	–106.249747	Mountain	X	--	7.77	26.4	11,321
09063200	Wearyman Creek near Red Cliff, Colo.	39.522208	–106.323638	Mountain	X	--	8.75	26.8	10,861
09063400	Turkey Creek near Red Cliff, Colo.	39.522764	–106.336139	Mountain	X	--	23.8	28.2	10,700
09063500	Turkey Creek at Red Cliff, Colo.	39.513875	–106.367250	Mountain	X	--	29.5	27.4	10,588
09063900	Missouri Creek near Gold Park, Colo.	39.390265	–106.470029	Mountain	X	--	6.42	32.5	11,377
09064500	Homestake Creek near Red Cliff, Colo.	39.473320	–106.367806	Mountain	X	--	58.2	27.7	10,920
09065100	Cross Creek near Minturn, Colo.	39.568292	–106.412431	Mountain	X	--	34.2	30.8	11,183
09065500	Gore Creek at Upper Station, near Minturn, Colo.	39.625819	–106.278082	Mountain	X	--	14.5	30.7	11,117
09066000	Black Gore Creek near Minturn, Colo.	39.596375	–106.265026	Mountain	X	--	12.5	28.0	10,714
09066100	Bighorn Creek near Minturn, Colo.	39.639986	–106.293361	Mountain	X	--	4.55	31.1	11,088
09066150	Pitkin Creek near Minturn, Colo.	39.643597	–106.302527	Mountain	X	--	5.32	30.6	11,074
09066200	Booth Creek near Minturn, Colo.	39.648319	–106.323083	Mountain	X	--	6.08	28.8	10,915
09066300	Middle Creek near Minturn, Colo.	39.645819	–106.382251	Mountain	X	--	5.90	25.9	10,509
09066310	Gore Creek, Lower Station, at Vail, Colo.	39.641097	–106.394196	Mountain	X	--	77.0	28.9	10,514
09066325	Gore Creek above Red Sandstone Creek at Vail, Colo.	39.641097	–106.394752	Mountain	X	--	77.1	28.7	10,511
09066400	Red Sandstone Creek near Minturn, Colo.	39.682764	–106.401418	Mountain	X	--	7.39	26.6	10,398
09066500	Gore Creek near Minturn, Colo.	39.614708	–106.440030	Mountain	X	--	101	27.9	10,304
09066510	Gore Creek at Mouth near Minturn, Colo.	39.609430	–106.447808	Mountain	X	--	102	27.8	10,289

Table 1–1. Summary of the streamgages used in the analysis.—Continued

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USGS streamgage number	Streamgage name	Latitude (decimal degrees)	Longitude (decimal degrees)	Hydrologic region	USGS data	CDWR data	A (mi²)	P (in)	E (ft)
09067000	Beaver Creek at Avon, Colo.	39.629708	–106.522810	Northwest	X	--	14.7	27.0	10,229
09067005	Eagle River at Avon, Colo.	39.631653	–106.522532	Mountain	X	--	395	26.7	10,455
09067020	Eagle River below Wastewater Treatment Plant at Avon, Colo.	39.634861	–106.531944	Northwest	X	--	402	26.6	10,431
09067200	Lake Creek near Edwards, Colo.	39.647486	–106.609200	Northwest	X	--	49.0	27.4	10,196
09067500	Eagle River at Eagle, Colo.	39.656652	–106.825317	Northwest	X	--	629	24.4	9,838
09068000	Brush Creek near Eagle, Colo.	39.557207	–106.763093	Mountain	X	--	71.5	25.9	9,952
09069500	Gypsum Creek near Gypsum, Colo.	39.545540	–106.934766	Mountain	X	--	62.6	24.7	9,689
09070000	Eagle River below Gypsum, Colo.	39.649430	–106.953655	Mountain	X	--	945	23.1	9,481
09071300	Grizzly Creek near Glenwood Springs, Colo.	39.716649	–107.310333	Mountain	X	--	6.47	42.8	10,770
09073500	Roaring Fork River at Aspen, Colo.	39.189432	–106.814483	Mountain	X	--	107	28.5	11,215
09073700	Hunter Creek above Midway Creek, near Aspen, Colo.	39.213877	–106.655867	Mountain	X	--	6.15	31.9	11,761
09073800	Midway Creek near Aspen, Colo.	39.196377	–106.690035	Mountain	X	--	8.65	29.8	11,437
09073900	No Name Creek near Aspen, Colo.	39.188877	–106.718369	Mountain	X	--	6.62	28.9	11,262
09074000	Hunter Creek near Aspen, Colo.	39.205820	–106.797538	Mountain	X	--	42.1	28.7	10,889
09074800	Castle Creek above Aspen, Colo.	39.087489	–106.812261	Mountain	X	--	32.2	36.7	11,430
09075700	Maroon Creek above Aspen, Colo.	39.123599	–106.905320	Mountain	X	--	35.3	44.3	11,383
09076520	Owl Creek near Aspen, Colo.	39.223597	–106.879763	Mountain	X	--	6.54	24.9	9,049
09077200	Fryingpan River near Ivanhoe Lake, Colo.	39.245544	–106.531419	Mountain	X	X	18.9	36.2	11,845
09077800	South Fork Fryingpan River at Upper Station, near Norrie, Colo.	39.241654	–106.593087	Mountain	X	X	11.5	33.1	11,597
09078000	Fryingpan River at Norrie, Colo.	39.330820	–106.658090	Mountain	X	--	88.9	31.6	10,974
09078100	North Fork Fryingpan River above Cunningham Creek, near Norrie, Colo.	39.358876	–106.568365	Mountain	X	--	10.7	32.4	11,204
09078200	Cunningham Creek near Norrie, Colo.	39.334154	–106.575310	Mountain	X	--	7.20	31.7	10,892
09078500	North Fork Fryingpan River near Norrie, Colo.	39.342764	–106.665868	Mountain	X	X	42.3	29.4	10,546
09080300	Rocky Fork Creek near Meredith, Colo.	39.361652	–106.820595	Mountain	X	X	12.4	26.8	10,103
09081550	Crystal River at Placita, Colo.	39.142764	–107.257828	Northwest	X	--	107	41.8	10,566
09081600	Crystal River above Avalanche Creek, near Redstone, Colo.	39.232639	–107.227500	Northwest	X	--	167	39.5	10,164
09082500	Crystal River near Redstone, Colo.	39.298595	–107.214217	Northwest	X	--	229	38.4	10,080
09082800	North Thompson Creek near Carbondale, Colo.	39.329705	–107.333386	Mountain	X	--	27.9	34.1	9,462
09083000	Thompson Creek near Carbondale, Colo.	39.330539	–107.224496	Northwest	X	--	75.4	32.9	9,167
09084000	Cattle Creek near Carbondale, Colo.	39.466650	–107.052270	Mountain	X	--	30.3	27.0	9,490
09085200	Canyon Creek above New Castle, Colo.	39.605259	–107.448388	Northwest	X	--	23.8	36.0	9,712

Table 1–1. Summary of the streamgages used in the analysis.—Continued

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USGS streamgage number	Streamgage name	Latitude (decimal degrees)	Longitude (decimal degrees)	Hydrologic region	USGS data	CDWR data	A (mi²)	P (in)	E (ft)
09085300	East Canyon Creek near New Castle, Colo.	39.609148	–107.434777	Northwest	X	--	15.8	34.4	9,658
09085400	Possum Creek near New Castle, Colo.	39.597759	–107.423943	Northwest	X	--	6.22	28.5	9,007
09089000	West Divide Creek below Willow Creek, near Raven, Colo.	39.275537	–107.520055	Mountain	X	--	35.0	32.1	9,044
09089500	West Divide Creek near Raven, Colo.	39.331092	–107.580056	Mountain	X	--	64.2	29.8	8,731
09091500	East Rifle Creek near Rifle, Colo.	39.677758	–107.698396	Northwest	X	--	34.9	26.3	8,549
09092000	Rifle Creek near Rifle, Colo.	39.619980	–107.763398	Northwest	X	--	137	22.9	7,971
09092500	Beaver Creek near Rifle, Colo.	39.471924	–107.832566	Northwest	X	--	7.90	29.5	9,408
09093000	Parachute Creek near Parachute, Colo.	39.566922	–108.110912	Northwest	X	--	141	21.1	8,133
09093500	Parachute Creek at Parachute, Colo.	39.453034	–108.059798	Northwest	X	--	198	20.4	7,854
09095000	Roan Creek near De Beque, Colo.	39.453311	–108.317031	Northwest	X	--	323	20.2	7,624
09096000	Plateau Creek at Upper Station, near Collbran, Colo.	39.223591	–107.802007	Mountain	X	--	22.8	31.3	9,365
09096500	Plateau Creek near Collbran, Colo.	39.250535	–107.840620	Mountain	X	--	80.4	34.3	9,743
09096800	Buzzard Creek below Owens Creek, near Heiberger, Colo.	39.236092	–107.633946	Mountain	X	--	50.3	30.2	9,344
09097500	Buzzard Creek near Collbran, Colo.	39.272202	–107.850621	Mountain	X	--	143	26.7	8,621
09097600	Brush Creek near Collbran, Colo.	39.324979	–107.842287	Mountain	X	--	9.30	31.1	9,587
09099500	Big Creek at Upper Station, near Collbran, Colo.	39.131924	–107.918678	Mountain	X	--	19.9	37.3	10,137
09100500	Cottonwood Creek at Upper Station, near Molina, Colo.	39.127757	–107.996459	Mountain	X	--	13.7	34.9	9,887
09104500	Mesa Creek near Mesa, Colo.	39.086369	–108.126743	Northwest	X	--	5.33	33.9	9,860
09105000	Plateau Creek near Cameo, Colo.	39.183611	–108.268333	Northwest	X	--	592	25.5	8,196
09107000	Taylor River at Taylor Park, Colo.	38.860271	–106.566697	Mountain	X	--	128	26.6	10,924
09107500	Texas Creek at Taylor Park, Colo.	38.846944	–106.554639	Mountain	X	--	40.5	23.9	11,211
09110000	Taylor River at Almont, Colo.	38.664437	–106.845317	Mountain	X	--	477	24.0	10,646
09110500	East River near Crested Butte, Colo.	38.864437	–106.909764	Mountain	X	--	89.3	38.6	10,881
09111500	Slate River near Crested Butte, Colo.	38.869715	–106.969489	Mountain	X	--	68.9	33.7	10,334
09112000	Cement Creek near Crested Butte, Colo.	38.824437	–106.852817	Mountain	X	--	32.9	32.0	10,807
09112200	East River below Cement Creek near Crested Butte, Colo.	38.784160	–106.870874	Mountain	X	--	239	33.7	10,480
09112500	East River at Almont, Colo.	38.664437	–106.848095	Mountain	X	--	289	31.9	10,271
09113300	Ohio Creek at Baldwin, Colo.	38.765550	–107.058381	Mountain	X	--	47.7	32.1	10,204
09113500	Ohio Creek near Baldwin, Colo.	38.702216	–106.998379	Mountain	X	--	119	27.3	9,894
09113980	Ohio Creek above Mouth near Gunnison, Colo.	38.587770	–106.931432	Mountain	X	--	158	24.5	9,580
09114500	Gunnison River near Gunnison, Colo.	38.541936	–106.949766	Mountain	X	--	1,010	25.6	10,210

Table 1–1. Summary of the streamgages used in the analysis.—Continued

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USGS streamgage number	Streamgage name	Latitude (decimal degrees)	Longitude (decimal degrees)	Hydrologic region	USGS data	CDWR data	A (mi²)	P (in)	E (ft)
09115500	Tomichi Creek at Sargents, Colo.	38.395028	–106.422625	Mountain	X	--	148	21.4	10,236
09117000	Tomichi Creek at Parlin, Colo.	38.497214	–106.726147	Mountain	X	--	426	18.2	9,606
09118000	Quartz Creek near Ohio City, Colo.	38.559715	–106.636422	Mountain	X	--	105	23.5	10,637
09119000	Tomichi Creek at Gunnison, Colo.	38.521111	–106.940958	Mountain	X	--	1,060	18.6	9,733
09122000	Cebolla Creek at Powderhorn, Colo.	38.291383	–107.114496	Mountain	X	--	340	21.1	10,431
09122500	Soap Creek near Sapinero, Colo.	38.560833	–107.325000	Mountain	X	--	58.2	27.4	9,862
09123000	Soap Creek at Sapinero, Colo.	38.474992	–107.298944	Mountain	X	--	86.1	24.1	9,546
09123500	Lake Fork at Lake City, Colo.	38.018889	–107.314444	Mountain	X	--	120	34.2	11,434
09124500	Lake Fork at Gateview, Colo.	38.298883	–107.230056	Mountain	X	--	339	28.2	10,884
09125000	Curecanti Creek near Sapinero, Colo.	38.487767	–107.415057	Mountain	X	--	35.0	22.7	9,673
09126000	Cimarron River near Cimarron, Colo.	38.258194	–107.546111	Mountain	X	--	67.7	32.6	10,842
09127500	Crystal Creek near Maher, Colo.	38.551933	–107.506169	Mountain	X	--	42.3	20.5	9,631
09128500	Smith Fork near Crawford, Colo.	38.727768	–107.506723	Northwest	X	--	43.4	25.5	9,164
09129600	Smith Fork near Lazear, Colo.	38.707444	–107.710139	Northwest	X	--	167	19.3	8,097
09130500	East Muddy Creek near Bardine, Colo.	39.013322	–107.358385	Northwest	X	--	133	28.8	8,694
09130600	West Muddy Creek near Ragged Mountain, Colo.	39.130817	–107.575334	Mountain	X	--	7.33	29.9	9,419
09131490	Muddy Creek above Paonia Reservoir, Colo.	38.954150	–107.347831	Northwest	--	X	238	27.9	8,686
09132500	North Fork Gunnison River near Somerset, Colo.	38.925823	–107.434221	Northwest	X	--	526	28.5	8,886
09132900	West Hubbard Creek near Paonia, Colo.	39.032207	–107.613668	Mountain	X	--	2.32	33.9	10,363
09132960	Hubbard Creek at Highway 133 at Mouth near Bowie, Colo.	38.925544	–107.518389	Northwest	X	--	58.0	25.9	8,685
09132995	Terror Creek at Mouth near Bowie, Colo.	38.903876	–107.562001	Northwest	X	--	29.5	26.1	8,774
09133000	North Fork Gunnison River near Paonia, Colo.	38.899154	–107.563668	Northwest	X	--	653	27.6	8,771
09134100	North Fork Gunnison River below Paonia, Colo.	38.857500	–107.621944	Northwest	X	--	742	26.9	8,654
09134500	Leroux Creek near Cedaredge, Colo.	38.926371	–107.793672	Northwest	X	--	34.7	33.6	9,723
09135900	Leroux Creek at Hotchkiss, Colo.	38.798040	–107.732003	Northwest	X	--	66.8	26.2	8,601
09136200	Gunnison River near Lazear, Colo.	38.783040	–107.837840	Northwest	X	--	5,247	21.9	9,444
09137050	Currant Creek near Read, Colo.	38.784706	–107.938954	Northwest	X	--	56.9	16.9	7,050
09137800	Dirty George Creek near Grand Mesa, Colo.	38.944704	–108.028125	Northwest	X	--	12.0	31.8	9,499
09139200	Ward Creek near Grand Mesa, Colo.	38.983592	–107.972012	Mountain	X	--	12.2	37.4	10,100
09140200	Kiser Creek near Grand Mesa, Colo.	38.986647	–107.943677	Mountain	X	--	5.55	38.6	9,968
09140700	Cottonwood Creek near Grand Mesa, Colo.	38.977361	–107.950306	Mountain	X	--	2.14	30.8	9,088
09141200	Youngs Creek near Grand Mesa, Colo.	38.958037	–107.918676	Northwest	X	--	10.5	33.2	9,380

Table 1–1. Summary of the streamgages used in the analysis.—Continued

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USGS streamgage number	Streamgage name	Latitude (decimal degrees)	Longitude (decimal degrees)	Hydrologic region	USGS data	CDWR data	A (mi^2)	P (in)	E (ft)
09143000	Surface Creek near Cedaredge, Colo.	38.984703	–107.854508	Mountain	X	--	27.4	38.8	9,875
09143500	Surface Creek at Cedaredge, Colo.	38.901649	–107.921176	Northwest	X	--	39.1	35.9	9,463
09144000	Surface Creek at Eckert, Colo.	38.833594	–107.971733	Northwest	X	--	43.9	33.2	9,133
09144200	Tongue Creek at Cory, Colo.	38.787761	–107.995344	Northwest	X	--	197	24.2	8,034
09146000	Uncompahgre River below Ouray, Colo.	38.031105	–107.675060	Southwest	X	--	75.2	38.2	11,266
09146020	Uncompahgre River near Ouray, Colo.	38.043327	–107.683115	Southwest	X	--	77.0	37.9	11,223
09146200	Uncompahgre River near Ridgway, Colo.	38.183879	–107.745892	Northwest	X	--	149	31.0	9,964
09146400	West Fork Dallas Creek near Ridgway, Colo.	38.073603	–107.851174	Southwest	X	--	14.1	31.1	10,214
09146500	East Fork Dallas Creek near Ridgway, Colo.	38.093325	–107.813673	Southwest	X	--	16.5	35.4	10,938
09146600	Pleasant Valley Creek near Noel, Colo.	38.145546	–107.919787	Southwest	X	--	8.19	25.9	9,053
09147000	Dallas Creek near Ridgway, Colo.	38.177768	–107.758393	Southwest	X	--	97.2	26.4	9,162
09147100	Cow Creek near Ridgway, Colo.	38.149436	–107.644782	Mountain	X	--	45.6	33.6	10,721
09147500	Uncompahgre River at Colona, Colo.	38.331377	–107.779504	Northwest	X	--	449	26.4	9,228
09149500	Uncompahgre River at Delta, Colo.	38.741944	–108.080417	Northwest	X	--	1,115	19.0	7,848
09150500	Roubideau Creek at Mouth, near Delta, Colo.	38.734984	–108.161740	Northwest	X	--	249	17.4	7,274
09151500	Escalante Creek near Delta, Colo.	38.756651	–108.260078	Northwest	X	--	209	18.1	7,682
09153400	West Salt Creek near Mack, Colo.	39.308590	–108.983720	Northwest	X	--	168	15.5	6,525
09163310	East Salt Creek near Mack, Colo.	39.297201	–108.866771	Northwest	X	--	197	15.0	6,351
09163490	Salt Creek near Mack, Colo.	39.221647	–108.892883	Northwest	X	--	437	14.4	6,161
09165000	Dolores River below Rico, Colo.	37.638884	–108.060352	Southwest	X	--	106	36.1	10,631
09166500	Dolores River at Dolores, Colo.	37.472493	–108.497591	Southwest	X	--	505	31.1	9,696
09166950	Lost Canyon Creek near Dolores, Colo.	37.446105	–108.469256	Southwest	X	--	71.3	26.2	8,567
09168100	Disappointment Creek near Dove Creek, Colo.	37.876658	–108.583150	Southwest	X	--	147	21.4	7,931
09169500	Dolores River at Bedrock, Colo.	38.310268	–108.885381	Southwest	X	--	2,029	21.9	7,861
09172000	Fall Creek near Fall Creek, Colo.	37.958326	–108.005901	Southwest	X	--	33.4	32.3	10,040
09172500	San Miguel River near Placerville, Colo.	38.042500	–108.133333	Southwest	X	--	310	30.3	9,944
09174500	Cottonwood Creek near Nucla, Colo.	38.273601	–108.362862	Southwest	X	--	38.3	19.8	7,649
09174600	San Miguel River at Brooks Bridge near Nucla, Colo.	38.244157	–108.502034	Southwest	X	--	743	25.8	8,955
09175000	West Naturita Creek near Norwood, Colo.	37.975825	–108.327861	Southwest	X	--	53.3	26.2	8,687
09175500	San Miguel River at Naturita, Colo.	38.217768	–108.566481	Southwest	X	--	1,070	23.7	8,480
09175900	Dry Creek near Naturita, Colo.	38.092214	–108.622039	Southwest	X	--	78.5	17.8	7,253

Table 1–1. Summary of the streamgages used in the analysis.—Continued

[USGS, U.S. Geological Survey; CDWR, Colorado Division of Water Resources; A, drainage area; mi², square miles; P, mean-annual precipitation; in, inches; E, mean basin elevation; ft, feet; Colo., Colorado; Wyo., Wyoming; N. Mex., New Mexico; Ariz., Arizona]

USGS streamgage number	Streamgage name	Latitude (decimal degrees)	Longitude (decimal degrees)	Hydrologic region	USGS data	CDWR data	A (mi²)	P (in)	E (ft)
09177000	San Miguel River at Uravan, Colo.	38.357212	–108.712875	Southwest	X	--	1,502	22.0	8,016
09182000	Castle Creek above Diversions, near Moab, Utah	38.592764	–109.265671	Southwest	X	--	8.64	23.2	9,405
09182400	Castle Creek below Castle Valley near Moab, Utah	38.673871	–109.450117	Southwest	X	--	53.1	17.5	7,010
09183000	Courthouse Wash near Moab, Utah	38.612759	–109.579840	Southwest	X	--	162	9.2	4,808
09183500	Mill Creek at Sheley Tunnel, near Moab, Utah	38.483040	–109.404004	Southwest	X	--	27.5	28.5	8,627
09184000	Mill Creek near Moab, Utah	38.562205	–109.514006	Southwest	X	--	74.4	19.5	7,194
09185500	Hatch Wash near La Sal, Utah	38.243320	–109.440114	Southwest	X	--	371	13.7	6,562
09235600	Pot Creek above Diversions, near Vernal, Utah	40.768015	–109.319022	Northwest	X	--	24.8	21.2	8,139
09238500	Walton Creek near Steamboat Springs, Colo.	40.408035	–106.786992	Northwest	X	X	42.3	46.8	9,493
09239500	Yampa River at Steamboat Springs, Colo.	40.482986	–106.832431	Northwest	X	--	567	31.4	8,782
09240900	Elk River above Clark, Colo.	40.743306	–106.855325	Mountain	X	--	123	43.1	9,526
09241000	Elk River at Clark, Colo.	40.717473	–106.915883	Mountain	X	--	216	38.1	9,104
09242500	Elk River near Milner, Colo.	40.514698	–106.953941	Northwest	X	--	460	35.4	8,627
09243700	Middle Creek near Oak Creek, Colo.	40.385533	–106.993107	Northwest	X	--	23.5	21.1	7,665
09243800	Foidel Creek near Oak Creek, Colo.	40.345811	–107.085053	Northwest	X	--	8.67	21.2	7,387
09243900	Foidel Creek at Mouth near Oak Creek, Colo.	40.390255	–106.994774	Northwest	X	--	17.5	20.8	7,206
09244100	Fish Creek near Milner, Colo.	40.334145	–107.139221	Northwest	X	--	34.5	26.1	8,291
09244500	Elkhead Creek near Clark, Colo.	40.732194	–107.169501	Mountain	X	--	44.3	31.8	8,604
09245000	Elkhead Creek near Elkhead, Colo.	40.669694	–107.285059	Northwest	X	--	67.7	30.7	8,412
09245500	North Fork Elkhead Creek near Elkhead, Colo.	40.680527	–107.287281	Northwest	X	--	21.4	31.5	8,458
09246200	Elkhead Creek above Long Gulch, near Hayden, Colo.	40.591639	–107.320893	Northwest	X	--	171	28.1	7,944
09246920	Fortification Creek near Fortification, Colo.	40.743858	–107.540900	Northwest	X	--	40.0	22.8	7,548
09247000	Fortification Creek at Craig, Colo.	40.514138	–107.541454	Northwest	X	--	258	20.8	7,120
09248600	East Fork of Williams Fork above Willow Creek, Colo.	40.261090	–107.295057	Northwest	X	--	107	36.1	9,461
09249000	East Fork of Williams Fork near Pagoda, Colo.	40.312477	–107.320058	Northwest	X	--	144	33.7	9,063
09249200	South Fork of Williams Fork near Pagoda, Colo.	40.212199	–107.442838	Northwest	X	--	47.5	32.7	9,087
09249500	Williams Fork at Hamilton, Colo.	40.369973	–107.609233	Northwest	X	--	380	28.8	8,335
09249750	Williams Fork at Mouth, near Hamilton, Colo.	40.437194	–107.647846	Northwest	X	--	458	27.9	8,196
09250507	Wilson Creek above Taylor Creek near Axial, Colo.	40.314695	–107.800072	Northwest	X	--	20.1	22.5	7,634
09250510	Taylor Creek at Mouth near Axial, Colo.	40.313306	–107.799794	Northwest	X	--	7.24	20.8	7,293
09251500	Middle Fork Little Snake River near Battle Creek, Colo.	40.990522	–107.044219	Northwest	X	--	115	33.4	8,706

Table 1–1. Summary of the streamgages used in the analysis.—Continued

[USGS, U.S. Geological Survey; CDWR, Colorado Division of Water Resources; A, drainage area; mi^2, square miles; P, mean-annual precipitation; in, inches; E, mean basin elevation; ft, feet; Colo., Colorado; Wyo., Wyoming; N. Mex., New Mexico; Ariz., Arizona]

USGS streamgage number	Streamgage name	Latitude (decimal degrees)	Longitude (decimal degrees)	Hydrologic region	USGS data	CDWR data	A (mi^2)	P (in)	E (ft)
09253000	Little Snake River near Slater, Colo.	40.999410	–107.143388	Northwest	X	--	252	32.9	8,550
09253400	Battle Creek near Encampment, Wyo.	41.132222	–107.069167	Mountain	X	--	13.0	48.1	9,567
09255000	Slater Fork near Slater, Colo.	40.982466	–107.382839	Northwest	X	--	151	30.4	8,377
09255500	Savery Creek at Upper Station, near Savery, Wyo.	41.218018	–107.372283	Northwest	X	--	200	27.5	7,786
09256000	Savery Creek near Savery, Wyo.	41.097778	–107.381944	Northwest	X	--	330	27.7	7,838
09257000	Little Snake River near Dixon, Wyo.	41.028298	–107.549233	Northwest	X	--	1,020	28.9	8,022
09258000	Willow Creek near Dixon, Wyo.	40.915522	–107.521732	Northwest	X	--	24.8	27.8	8,066
09260000	Little Snake River near Lily, Colo.	40.549017	–108.424322	Northwest	X	--	4,040	16.6	7,060
09264000	Ashley Creek below Trout Creek near Vernal, Utah	40.733290	–109.678479	Northwest	X	--	26.3	28.2	9,933
09264500	South Fork Ashley Creek near Vernal, Utah	40.733290	–109.703480	Northwest	X	--	19.9	29.6	10,478
09265300	Ashley Creek above Red Pine Creek near Vernal, Utah	40.679679	–109.660978	Northwest	X	--	55.9	28.7	10,013
09266500	Ashley Creek near Vernal, Utah	40.577458	–109.622086	Northwest	X	--	101	25.6	9,452
09268000	Dry Fork above Sinks, near Dry Fork, Utah	40.626345	–109.820149	Northwest	X	--	44.5	31.5	10,355
09268500	North Fork of Dry Fork near Dry Fork, Utah	40.642733	–109.810982	Northwest	X	--	8.72	29.7	10,140
09268900	Brownie Canyon above Sinks, near Dry Fork, Utah	40.659401	–109.750981	Northwest	X	--	7.44	29.6	10,030
09269000	East Fork of Dry Fork near Dry Fork, Utah	40.649956	–109.761814	Northwest	X	--	10.4	29.6	9,829
09270000	Dry Fork below Springs near Dry Fork, Utah	40.569402	–109.697644	Northwest	X	--	97.3	28.1	9,702
09270500	Dry Fork at Mouth near Dry Fork, Utah	40.526348	–109.605696	Northwest	X	--	116	26.5	9,280
09271000	Ashley Creek, Sign of the Maine, near Vernal, Utah	40.517181	–109.596529	Northwest	X	--	238	24.0	9,141
09298000	Farm Creek near Whiterocks, Utah	40.567454	–109.961541	Northwest	X	--	14.8	26.2	9,184
09298500	Whiterocks River above Paradise Creek near Whiterocks, Utah	40.636064	–109.967375	Northwest	X	--	89.4	30.5	10,636
09299500	Whiterocks River near Whiterocks, Utah	40.593565	–109.932374	Northwest	X	--	110	31.3	10,395
09300500	Uintah River at Fort Duchesne, Utah	40.301904	–109.853201	Northwest	X	--	542	24.6	8,833
09302450	Lost Creek near Buford, Colo.	40.050256	–107.468948	Mountain	X	--	21.6	30.4	8,970
09302500	Marvine Creek near Buford, Colo.	40.038312	–107.488115	Mountain	X	--	59.9	37.5	9,813
09302800	North Fork White River near Buford, Colo.	40.035534	–107.520894	Northwest	X	--	220	37.1	9,749
09303000	North Fork White River at Buford, Colo.	39.987477	–107.614508	Northwest	X	--	259	35.5	9,550
09303300	South Fork White River at Budges Resort, Colo.	39.843315	–107.334778	Mountain	X	--	52.2	42.1	10,584
09303320	Wagonwheel Creek at Budges Resort, Colo.	39.842760	–107.336722	Mountain	X	--	7.40	41.8	10,667
09303400	South Fork White River near Budges Resort, Colo.	39.864146	–107.533948	Mountain	X	--	128	39.9	10,266
09303500	South Fork White River near Buford, Colo.	39.921646	–107.551727	Mountain	X	--	152	38.6	10,077

Table 1–1. Summary of the streamgages used in the analysis.—Continued

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USGS streamgage number	Streamgage name	Latitude (decimal degrees)	Longitude (decimal degrees)	Hydrologic region	USGS data	CDWR data	A (mi²)	P (in)	E (ft)
09304000	South Fork White River at Buford, Colo.	39.974422	–107.625341	Northwest	X	--	176	36.9	9,852
09304300	Coal Creek near Meeker, Colo.	40.091363	–107.770069	Northwest	X	--	24.6	23.9	8,003
09304500	White River near Meeker, Colo.	40.033585	–107.862295	Northwest	X	--	760	30.9	8,938
09306007	Piceance Creek below Rio Blanco, Colo.	39.826085	–108.183138	Northwest	X	--	177	19.9	7,634
09306036	Sorghum Gulch at Mouth, near Rio Blanco, Colo.	39.824973	–108.199250	Northwest	X	--	3.64	16.7	6,933
09306039	Cottonwood Gulch near Rio Blanco, Colo.	39.826640	–108.207584	Northwest	X	--	1.18	16.4	6,743
09306042	Piceance Creek tributary near Rio Blanco, Colo.	39.833584	–108.220640	Northwest	X	--	1.07	16.5	6,671
09306052	Scandard Gulch at Mouth, near Rio Blanco, Colo.	39.814140	–108.243696	Northwest	X	--	7.90	17.3	7,213
09306058	Willow Creek near Rio Blanco, Colo.	39.837195	–108.244252	Northwest	X	--	48.3	18.1	7,473
09306061	Piceance Creek above Hunter Creek, near Rio Blanco, Colo.	39.850528	–108.258975	Northwest	X	--	309	19.0	7,542
09306200	Piceance Creek below Ryan Gulch, near Rio Blanco, Colo.	39.921083	–108.297588	Northwest	X	--	506	18.7	7,418
09306222	Piceance Creek at White River, Colo.	40.078026	–108.236475	Northwest	X	--	652	18.3	7,297
09306235	Corral Gulch below Water Gulch, near Rangely, Colo.	39.906085	–108.532874	Northwest	X	--	8.68	20.1	7,763
09306240	Box Elder Gulch near Rangely, Colo.	39.888307	–108.528429	Northwest	X	--	9.19	20.5	7,875
09306242	Corral Gulch near Rangely, Colo.	39.920250	–108.472872	Northwest	X	--	31.7	19.3	7,541
09306255	Yellow Creek near White River, Colo.	40.168581	–108.401205	Northwest	X	--	263	16.7	6,877
09306800	Bitter Creek near Bonanza, Utah	39.753301	–109.354842	Northwest	X	--	322	14.8	7,157
09307500	Willow Creek above Diversions near Ouray, Utah	39.566354	–109.587353	Northwest	X	--	299	17.7	7,771
09339900	East Fork San Juan River above Sand Creek, near Pagosa Springs, Colo.	37.389730	–106.841151	Southwest	X	--	65.5	43.0	10,234
09340000	East Fork San Juan River near Pagosa Springs, Colo.	37.368896	–106.892540	Southwest	X	--	90.8	41.5	10,071
09340500	West Fork San Juan River above Borns Lake, near Pagosa Springs, Colo.	37.485562	–106.930321	Southwest	X	--	39.9	51.0	11,079
09341500	West Fork San Juan River near Pagosa Springs, Colo.	37.392472	–106.906889	Southwest	X	--	85.4	45.0	10,387
09342000	Turkey Creek near Pagosa Springs, Colo.	37.369451	–106.940318	Southwest	X	--	24.1	39.7	9,883
09342500	San Juan River at Pagosa Springs, Colo.	37.265528	–107.011000	Southwest	X	--	281	38.9	9,738
09343000	Rio Blanco near Pagosa Springs, Colo.	37.212786	–106.794480	Southwest	X	--	57.8	38.7	10,023
09343500	Rio Blanco near Pagosa Springs, Colo.	37.193618	–106.905315	Southwest	X	--	23.1	32.8	9,261
09344000	Navajo River at Banded Peak Ranch, near Chromo, Colo.	37.085288	–106.689480	Southwest	X	X	68.9	40.1	10,261
09344300	Navajo River above Chromo, Colo.	37.031956	–106.732814	Southwest	X	--	97.3	36.6	9,863
09345200	Little Navajo River below Lake Oso Dibersion Dam, near Chromo, Colo.	37.077306	–106.811222	Southwest	X	--	13.4	32.8	9,612
09345500	Little Navajo River at Chromo, Colo.	37.045566	–106.843092	Southwest	X	--	23.3	28.8	8,965
09346000	Navajo River at Edith, Colo.	37.002788	–106.907537	Southwest	X	--	176	31.4	9,182

Table 1–1. Summary of the streamgages used in the analysis.—Continued

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USGS streamgage number	Streamgage name	Latitude (decimal degrees)	Longitude (decimal degrees)	Hydrologic region	USGS data	CDWR data	A (mi²)	P (in)	E (ft)
09346400	San Juan River near Carracas, Colo.	37.013617	–107.312267	Southwest	X	--	1,250	27.2	8,395
09347500	Piedra River at Bridge Ranger Station, near Pagosa Springs, Colo.	37.428614	–107.193381	Southwest	X	--	82.4	38.1	10,137
09349500	Piedra River near Piedra, Colo.	37.222226	–107.342826	Southwest	X	--	369	30.9	9,429
09349800	Piedra River near Arboles, Colo.	37.088338	–107.397826	Southwest	X	--	653	27.4	8,657
09352500	Los Pinos River below Snowslide Canyon, near Weminuche Pass, Colo.	37.638889	–107.333943	Southwest	X	--	24.7	37.1	11,558
09352900	Vallecito Creek near Bayfield, Colo.	37.477501	–107.543669	Southwest	X	--	72.6	39.5	11,350
09353800	Los Pinos River near Ignacio, Colo.	37.166111	–107.582500	Southwest	X	--	340	33.4	9,937
09354500	Los Pinos River at La Boca, Colo.	37.009448	–107.599500	Southwest	X	--	520	28.6	8,973
09355000	Spring Creek at La Boca, Colo.	37.015278	–107.595333	Southwest	X	--	58.3	17.5	6,940
09357500	Animas River at Howardsville, Colo.	37.833052	–107.599505	Southwest	X	X	57.6	44.7	11,936
09358000	Animas River at Silverton, Colo.	37.811108	–107.659228	Southwest	X	--	70.6	44.1	11,821
09358550	Cement Creek at Silverton, Colo.	37.819719	–107.663672	Southwest	X	--	20.1	40.4	11,443
09359000	MineraL Creek near Silverton, Colo.	37.814750	–107.695889	Southwest	X	--	44.4	41.4	11,570
09359010	Mineral Creek at Silverton, Colo.	37.802774	–107.672839	Southwest	X	--	52.7	40.7	11,514
09359020	Animas River below Silverton, Colo.	37.790275	–107.667561	Southwest	X	--	146	42.0	11,626
09359500	Animas River at Tall Timber Resort above Tacoma, Colo.	37.570277	–107.780620	Southwest	X	--	350	40.9	11,216
09361000	Hermosa Creek near Hermosa, Colo.	37.421945	–107.845067	Southwest	X	--	168	33.6	9,590
09361500	Animas River at Durango, Colo.	37.279169	–107.880345	Southwest	X	--	701	36.1	10,173
09362000	Lightner Creek near Durango, Colo.	37.270558	–107.893678	Southwest	X	--	63.0	25.1	8,177
09362750	Florida River above Lemon Reservoir near Durango, Colo.	37.426670	–107.674445	Southwest	--	X	52.6	37.7	10,946
09363000	Florida River near Durango, Colo.	37.325280	–107.748952	Southwest	X	--	97.2	34.4	10,002
09363100	Salt Creek near Oxford, Colo.	37.139725	–107.753396	Southwest	X	--	17.8	16.9	6,761
09365500	La Plata River at Hesperus, Colo.	37.289722	–108.040628	Southwest	X	--	34.5	39.2	10,170
09366000	Cherry Creek near Red Mesa, Colo.	37.118888	–108.198689	Southwest	X	--	75.3	21.3	7,836
09366500	La Plata River at Colorado-New Mexico State line	36.999722	–108.188688	Southwest	X	--	309	20.3	7,605
09367561	Shumway Arroyo near Waterflow, N. Mex.	36.773334	–108.441193	Southwest	X	--	136	10.1	5,774
09367950	Chaco River near Waterflow, N. Mex.	36.724445	–108.591474	Southwest	X	--	4,400	9.1	6,332
09368500	West Mancos River near Mancos, Colo.	37.381663	–108.258137	Southwest	X	--	39.5	33.6	9,702
09369000	East Mancos River near Mancos, Colo.	37.370274	–108.231469	Southwest	X	--	12.0	32.9	9,693
09369500	Middle Mancos River near Mancos, Colo.	37.373885	–108.230636	Southwest	X	--	12.1	30.7	9,387
09371000	Mancos River near Towaoc, Colo.	37.027494	–108.741484	Southwest	X	--	527	19.0	7,216

Table 1–1. Summary of the streamgages used in the analysis.—Continued

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USGS streamgage number	Streamgage name	Latitude (decimal degrees)	Longitude (decimal degrees)	Hydrologic region	USGS data	CDWR data	A (mi²)	P (in)	E (ft)
09371420	McElmo Creek above Alkali Canyon, near Cortez, Colo.	37.327216	–108.649262	Southwest	X	--	147	15.8	6,580
09371492	Mud Creek at State Highway 32, near Cortez, Colo.	37.312772	–108.661207	Southwest	X	--	34.5	14.5	6,328
09371500	McElmo Creek near Cortez, Colo.	37.322771	–108.673152	Southwest	X	--	230	15.4	6,530
09371520	McElmo Creek above Trail Canyon near Cortez, Colo.	37.326660	–108.700653	Southwest	X	--	234	15.4	6,523
09371700	McElmo Creek below Cortez, Colo.	37.340548	–108.805935	Southwest	X	--	283	15.2	6,503
09372000	McElmo Creek near Colorado-Utah State line	37.324160	–109.015666	Southwest	X	--	346	14.9	6,408
09378170	South Creek above Reservoir near Monticello, Utah	37.846661	–109.369563	Southwest	X	--	8.37	27.0	8,615
09378200	Montezuma Creek at Golf Course at Monticello, Utah	37.860550	–109.342339	Southwest	X	--	17.6	26.3	8,328
09378630	Recapture Creek near Blanding, Utah	37.755550	–109.476511	Southwest	X	--	3.83	26.1	8,677
09378650	Recapture Creek below Johnson Creek near Blanding, Utah	37.680830	–109.462621	Southwest	X	--	37.2	22.3	7,918
09378700	Cottonwood Wash near Blanding, Utah	37.560554	–109.578735	Southwest	X	--	204	17.0	6,805
09379000	Comb Wash near Bluff, Utah	37.266112	–109.675678	Southwest	X	--	278	11.9	5,861
09379200	Chinle Creek near Mexican Water, Ariz.	36.943891	–109.710668	Southwest	X	--	3,611	9.8	6,243
394308105413800	Clear Creek above Georgetown Lake near Georgetown, Colo.	39.718876	–105.694448	Mountain	X	--	80.1	27.0	11,463
DWR603	Beaver Creek above Beaver Creek Reservoir, Colo.	40.116649	–105.522223	Mountain	--	X	5.88	32.8	10,265
DWR609	Middle Saint Vrain Creek at Peaceful Valley, Colo.	40.131925	–105.517223	Mountain	--	X	17.7	35.9	10,614
DWR616	Wind River near Estes Park, Colo.	40.326923	–105.581956	Mountain	--	X	4.19	33.9	9,834
DWR620	Michigan River near Meadow Creek Reservoir, Colo.	40.616645	–106.083916	Mountain	--	X	101	30.5	9,839
DWR628	Alamosa River below Ranger Creek near Jasper, Colo.	37.389690	–106.378615	Rio Grande	--	X	98.6	39.6	10,979
DWR630	Deadman Creek near Crestone, Colo.	37.884725	–105.646386	Rio Grande	--	X	9.82	30.6	11,097
DWR633	Rito Alto Creek near Crestone, Colo.	38.077970	–105.759045	Rio Grande	--	X	12.0	31.3	11,437
DWR634	San Isabel Creek near Crestone, Colo.	38.034435	–105.718064	Rio Grande	--	X	6.81	29.3	11,153
DWR636	South Crestone Creek near Crestone, Colo.	37.983204	–105.702123	Rio Grande	--	X	4.42	25.9	10,688
DWR637	Spanish Creek near Crestone, Colo.	37.952777	–105.661665	Rio Grande	--	X	3.48	30.6	11,410
DWR638	Wild Cherry Creek near Crestone, Colo.	38.100252	–105.768309	Rio Grande	--	X	5.90	28.1	11,084
DWR639	Willow Creek near Crestone, Colo.	37.967528	–105.676461	Rio Grande	--	X	6.11	30.5	11,447
DWR641	Long Hollow at the Mouth near Red Mesa, Colo.	37.056380	–108.177853	Southwest	--	X	43.5	16.2	7,033

Appendix 2. Table of Mean-Monthly Streamflow-Regression Equations from Figures 3–6 of Capesius and Stephens (2009)

[A, drainage area in square miles; P, mean-annual precipitation in inches; √, denotes equations for which no bias was identified; SEP, standard error of prediction in percent; adjR^2, adjusted coefficient of determination]

Mean-Monthly Streamflow for Mountain Hydrologic Region

Weighted least-squares (WLS) regression, 129 stations

Approximate range of predictor variables

A: 1–1,060 square miles and P: 18–47 inches

$Q_{oct} = 10^{-3.29} A^{0.97} P^{1.98}$	√	$SEP = 45$,	adj$R^2 = 89$,
$Q_{nov} = 10^{-3.14} A^{0.98} P^{1.78}$	√	$SEP = 46$,	adj$R^2 = 90$,
$Q_{dec} = 10^{-2.90} A^{1.00} P^{1.52}$	√	$SEP = 47$,	adj$R^2 = 89$,
$Q_{jan} = 10^{-2.99} A^{1.02} P^{1.53}$	√	$SEP = 50$,	adj$R^2 = 88$,
$Q_{feb} = 10^{-2.92} A^{1.02} P^{1.46}$	√	$SEP = 51$,	adj$R^2 = 88$,
$Q_{mar} = 10^{-2.87} A^{1.06} P^{1.42}$	√	$SEP = 49$,	adj$R^2 = 89$,
$Q_{apr} = 10^{-2.95} A^{1.14} P^{1.64}$	√	$SEP = 44$,	adj$R^2 = 92$,
$Q_{may} = 10^{-1.60} A^{0.94} P^{1.44}$	√	$SEP = 46$,	adj$R^2 = 87$,
$Q_{jun} = 10^{-1.29} A^{0.82} P^{1.52}$		$SEP = 46$,	adj$R^2 = 87$,
$Q_{jul} = 10^{-2.80} A^{0.84} P^{2.23}$		$SEP = 76$,	adj$R^2 = 72$,
$Q_{aug} = 10^{-2.73} A^{0.85} P^{1.91}$		$SEP = 80$,	adj$R^2 = 75$, and
$Q_{sep} = 10^{-2.93} A^{0.92} P^{1.84}$		$SEP = 59$,	adj$R^2 = 86$.

Mean-Monthly Streamflow for Northwest Hydrologic Region

Weighted least-squares (WLS) regression, 56 stations

Approximate range of predictor variables

A: 1–5,250 square miles and *P*: 8–49 inches

$Q_{oct} = 10^{-4.32} A^{1.01} P^{2.54}$		$SEP = 94$,	$\text{adj}R^2 = 78$,
$Q_{nov} = 10^{-4.68} A^{1.08} P^{2.62}$		$SEP = 83$,	$\text{adj}R^2 = 83$,
$Q_{dec} = 10^{-4.53} A^{1.07} P^{2.46}$		$SEP = 79$,	$\text{adj}R^2 = 82$,
$Q_{jan} = 10^{-4.73} A^{1.05} P^{2.62}$		$SEP = 85$,	$\text{adj}R^2 = 81$,
$Q_{feb} = 10^{-4.63} A^{1.14} P^{2.46}$		$SEP = 77$,	$\text{adj}R^2 = 85$,
$Q_{mar} = 10^{-4.39} A^{1.14} P^{2.36}$		$SEP = 68$,	$\text{adj}R^2 = 90$,
$Q_{apr} = 10^{-4.77} A^{1.06} P^{3.02}$	√	$SEP = 84$,	$\text{adj}R^2 = 85$,
$Q_{may} = 10^{-4.54} A^{0.96} P^{3.40}$	√	$SEP = 71$,	$\text{adj}R^2 = 84$,
$Q_{jun} = 10^{-6.90} A^{1.00} P^{4.87}$	√	$SEP = 80$,	$\text{adj}R^2 = 82$,
$Q_{jul} = 10^{-4.37} A^{0.83} P^{3.09}$		$SEP = 75$,	$\text{adj}R^2 = 68$,
$Q_{aug} = 10^{-3.03} A^{0.84} P^{1.98}$		$SEP = 90$,	$\text{adj}R^2 = 67$, and
$Q_{sep} = 10^{-2.62} A^{0.92} P^{1.55}$		$SEP = 104$,	$\text{adj}R^2 = 70$.

Mean-Monthly Streamflow for Rio Grande Hydrologic Region

Weighted least-squares (WLS) regression, 32 stations

Approximate range of predictor variables

A: 2–517 square miles and E: 7,790–11,500 feet

$Q_{oct} = 10^{-32.88} A^{0.95} E^{8.04}$	√	$SEP = 55$,	$\text{adj}R^2 = 72$,
$Q_{nov} = 10^{-24.79} A^{0.90} E^{6.02}$	√	$SEP = 53$,	$\text{adj}R^2 = 73$,
$Q_{dec} = 10^{-17.71} A^{0.86} E^{4.26}$	√	$SEP = 63$,	$\text{adj}R^2 = 68$,
$Q_{jan} = 10^{-13.34} A^{0.83} E^{3.18}$	√	$SEP = 64$,	$\text{adj}R^2 = 66$,
$Q_{feb} = 10^{-11.68} A^{0.87} E^{2.75}$	√	$SEP = 56$,	$\text{adj}R^2 = 74$,
$Q_{mar} = 10^{-9.32} A^{0.97} E^{2.14}$	√	$SEP = 49$,	$\text{adj}R^2 = 82$,
$Q_{apr} = 10^{-5.09} A^{1.10} E^{1.16}$	√	$SEP = 79$,	$\text{adj}R^2 = 75$,
$Q_{may} = 10^{-37.25} A^{1.26} E^{9.23}$	√	$SEP = 84$,	$\text{adj}R^2 = 71$,
$Q_{jun} = 10^{-61.30} A^{1.23} E^{15.22}$	√	$SEP = 84$,	$\text{adj}R^2 = 74$,
$Q_{jul} = 10^{-53.30} A^{1.07} E^{13.17}$	√	$SEP = 74$,	$\text{adj}R^2 = 72$,
$Q_{aug} = 10^{-43.00} A_{1.03} E^{10.59}$	√	$SEP = 53$,	$\text{adj}R^2 = 80$, and
$Q_{sep} = 10^{-41.49} A^{0.99} E^{10.19}$	√	$SEP = 57$,	$\text{adj}R^2 = 75$.

Mean-Monthly Streamflow for Southwest Hydrologic Region

Weighted least-squares (WLS) regression, 57 stations

Approximate range of predictor variables

A: 1–4,390 square miles and P: 10–51 inches

$Q_{oct} = 10^{-4.80} A^{1.00} P^{2.89}$	√	$SEP = 106$,	$\text{adj}R^2 = 77$,
$Q_{nov} = 10^{-4.59} A^{0.91} P^{2.78}$	√	$SEP = 80$,	$\text{adj}R^2 = 76$,
$Q_{dec} = 10^{-4.22} A^{0.91} P^{2.45}$	√	$SEP = 75$,	$\text{adj}R^2 = 75$,
$Q_{jan} = 10^{-4.28} A^{0.96} P^{2.39}$	√	$SEP = 77$,	$\text{adj}R^2 = 77$,
$Q_{feb} = 10^{-3.97} A^{0.98} P^{2.18}$	√	$SEP = 58$,	$\text{adj}R^2 = 83$,
$Q_{mar} = 10^{-3.79} A^{1.00} P^{2.12}$	√	$SEP = 47$,	$\text{adj}R^2 = 82$,
$Q_{apr} = 10^{-4.98} A^{1.12} P^{3.11}$		$SEP = 50$,	$\text{adj}R^2 = 95$,
$Q_{may} = 10^{-5.16} A^{1.01} P^{3.63}$	√	$SEP = 62$,	$\text{adj}R^2 = 88$,
$Q_{jun} = 10^{-6.13} A^{1.05} P^{4.30}$		$SEP = 121$,	$\text{adj}R^2 = 85$,
$Q_{jul} = 10^{-5.19} A^{0.91} P^{3.58}$		$SEP = 180$,	$\text{adj}R^2 = 63$,
$Q_{aug} = 10^{-4.60} A^{0.94} P^{2.95}$		$SEP = 119$,	$\text{adj}R^2 = 64$, and
$Q_{sep} = 10^{-8.72} A^{0.98} P^{5.46}$		$SEP = 120$,	$\text{adj}R^2 = 79$.

Appendix 3. Figures Showing Absolute Percentage Difference Between Observed and Predicted Mean-Monthly Streamflow at all Streamgages

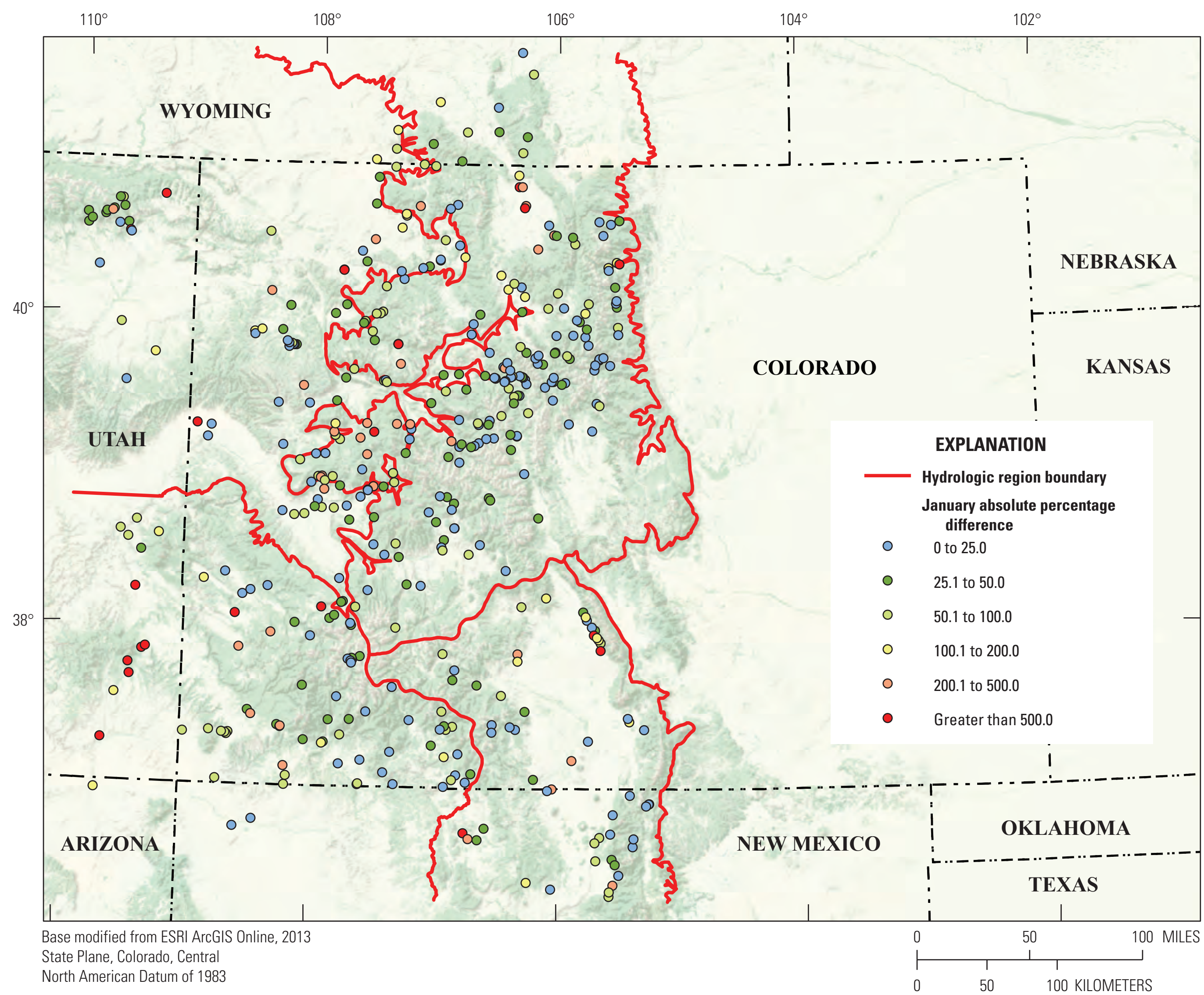

Figure 3–1. Absolute percentage difference between observed and predicted mean-monthly streamflow at all streamgages used in the analysis for the month of January.

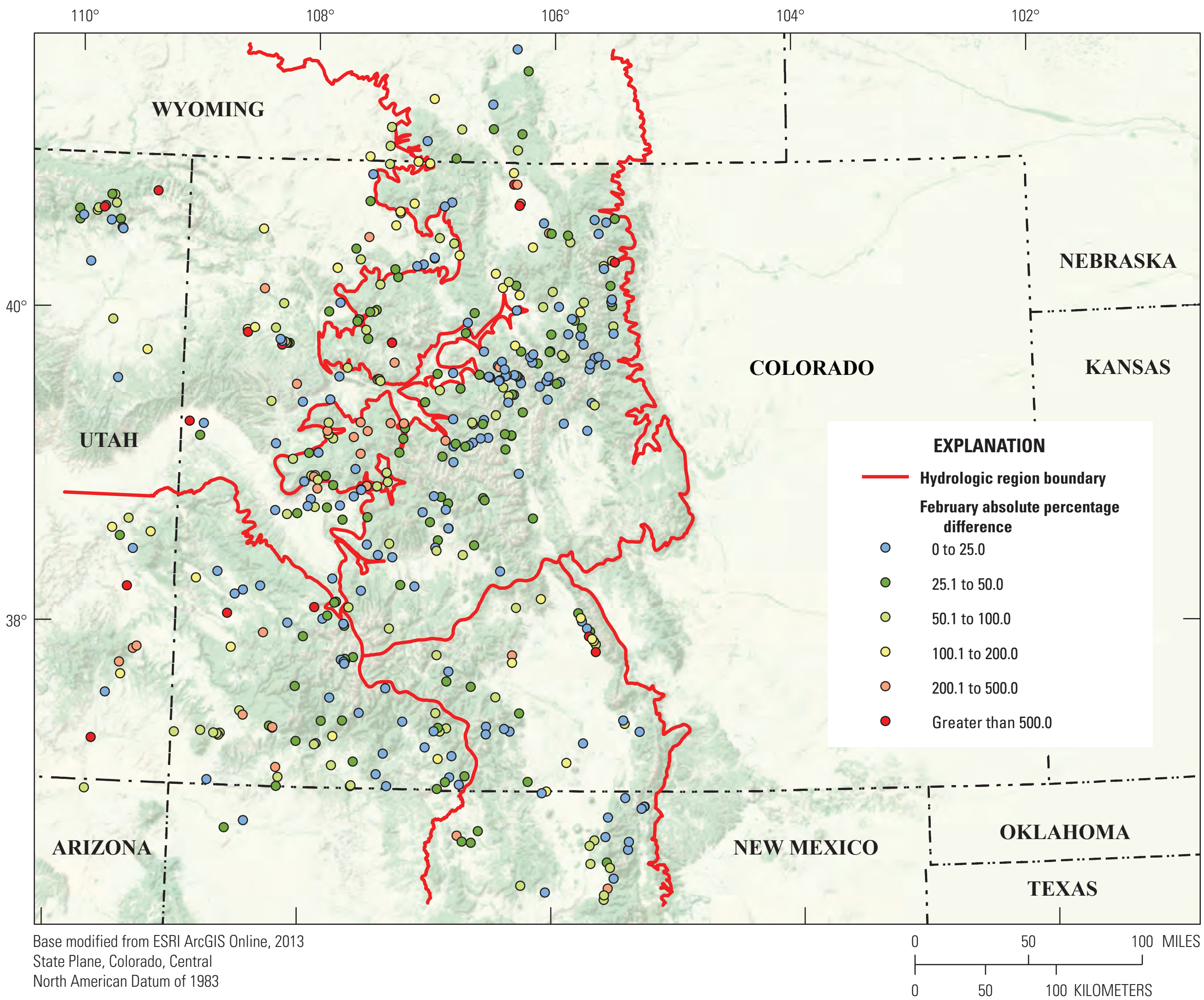

Figure 3–2. Absolute percentage difference between observed and predicted mean-monthly streamflow at all streamgages used in the analysis for the month of February.

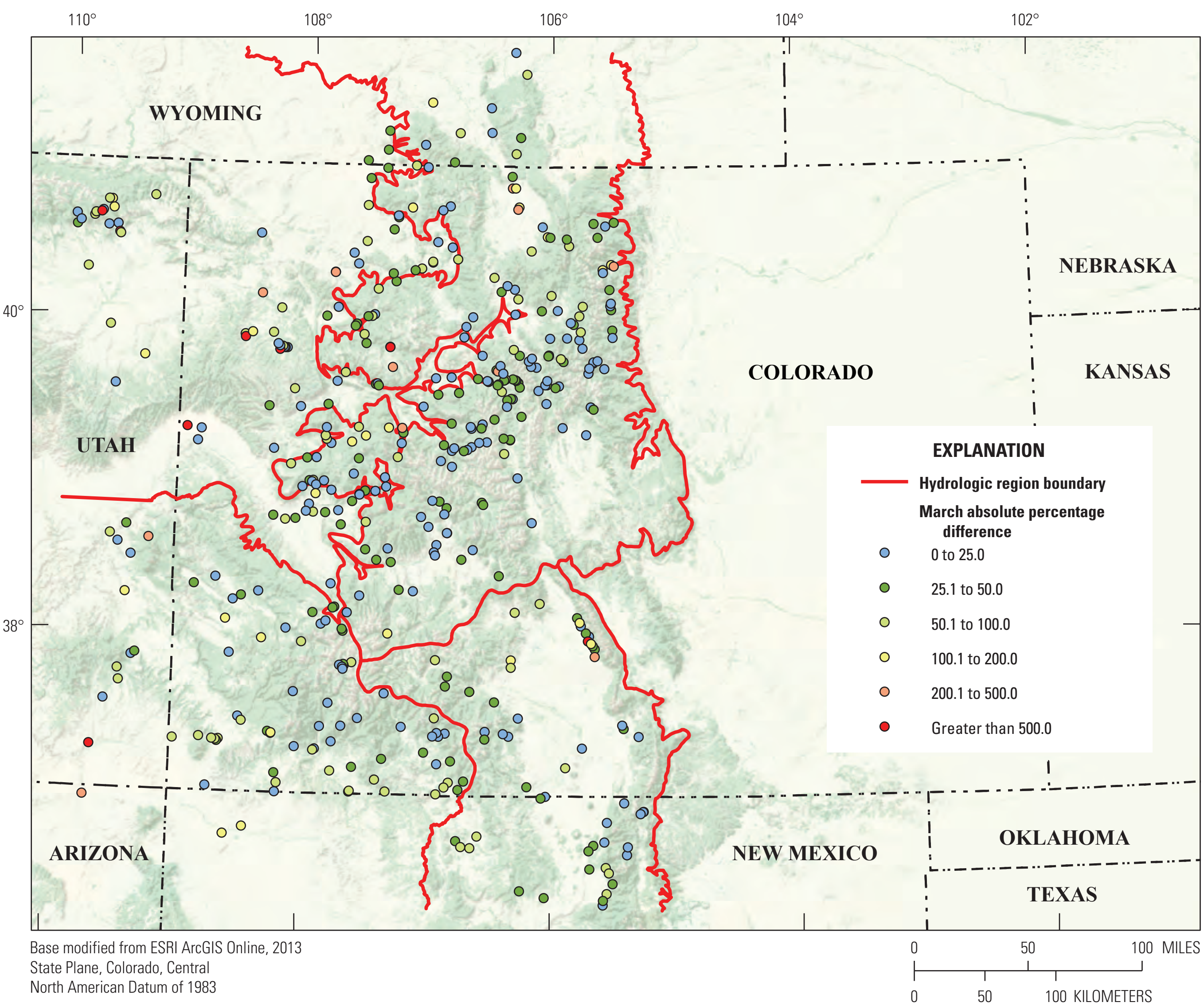

Figure 3–3. Absolute percentage difference between observed and predicted mean-monthly streamflow at all streamgages used in the analysis for the month of March.

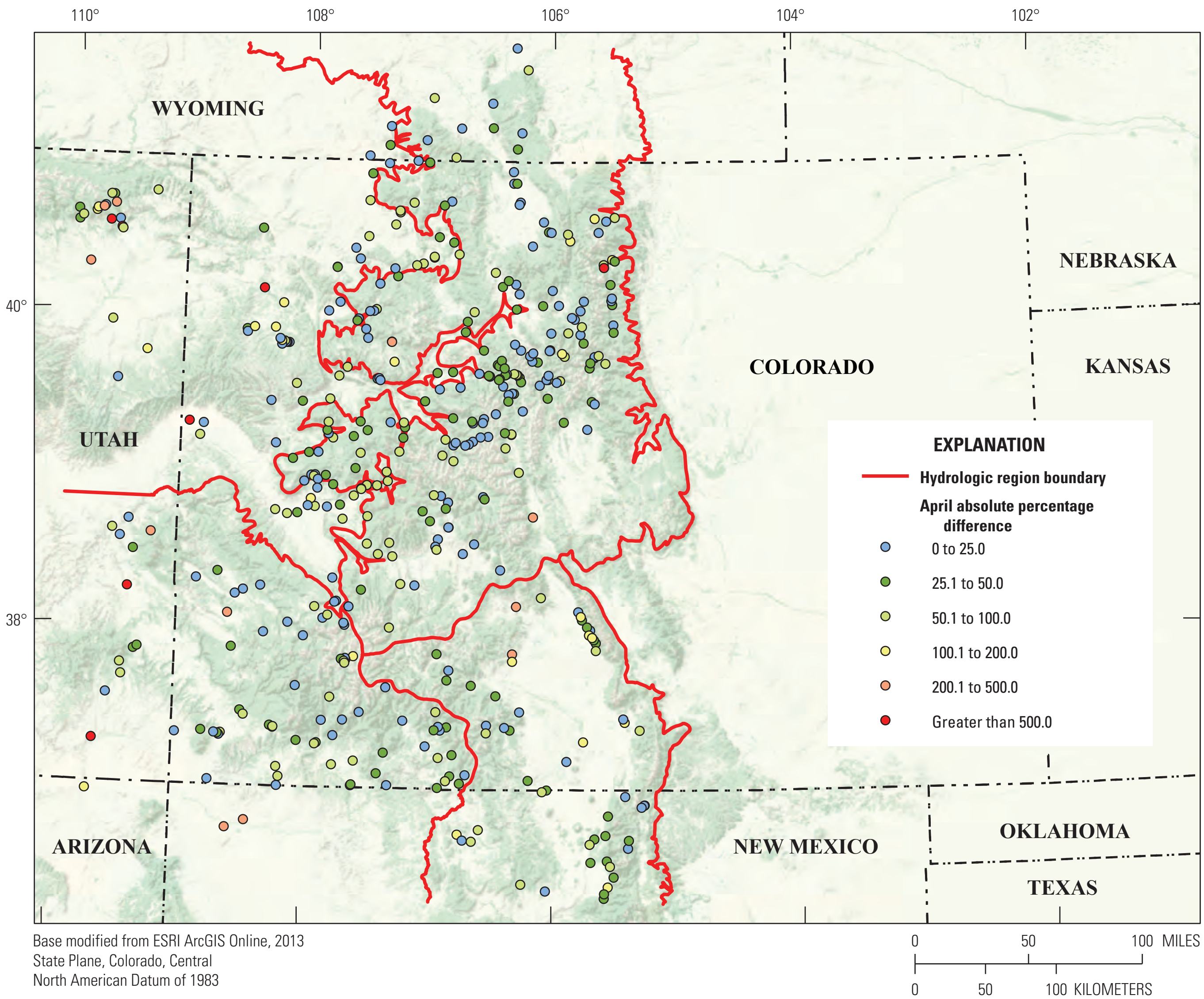

Figure 3–4. Absolute percentage difference between observed and predicted mean-monthly streamflow at all streamgages used in the analysis for the month of April.

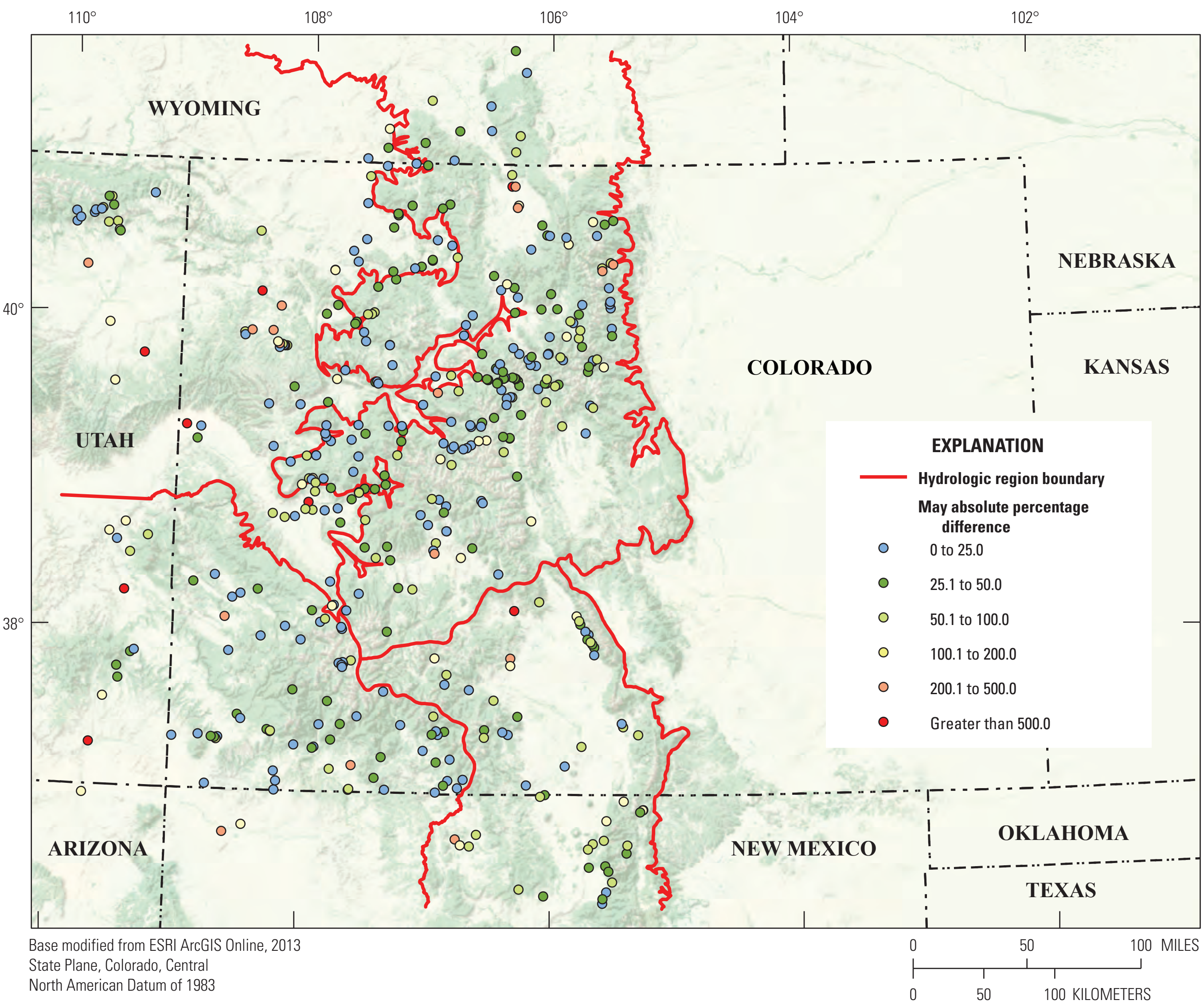

Figure 3–5. Absolute percentage difference between observed and predicted mean-monthly streamflow at all streamgages used in the analysis for the month of May.

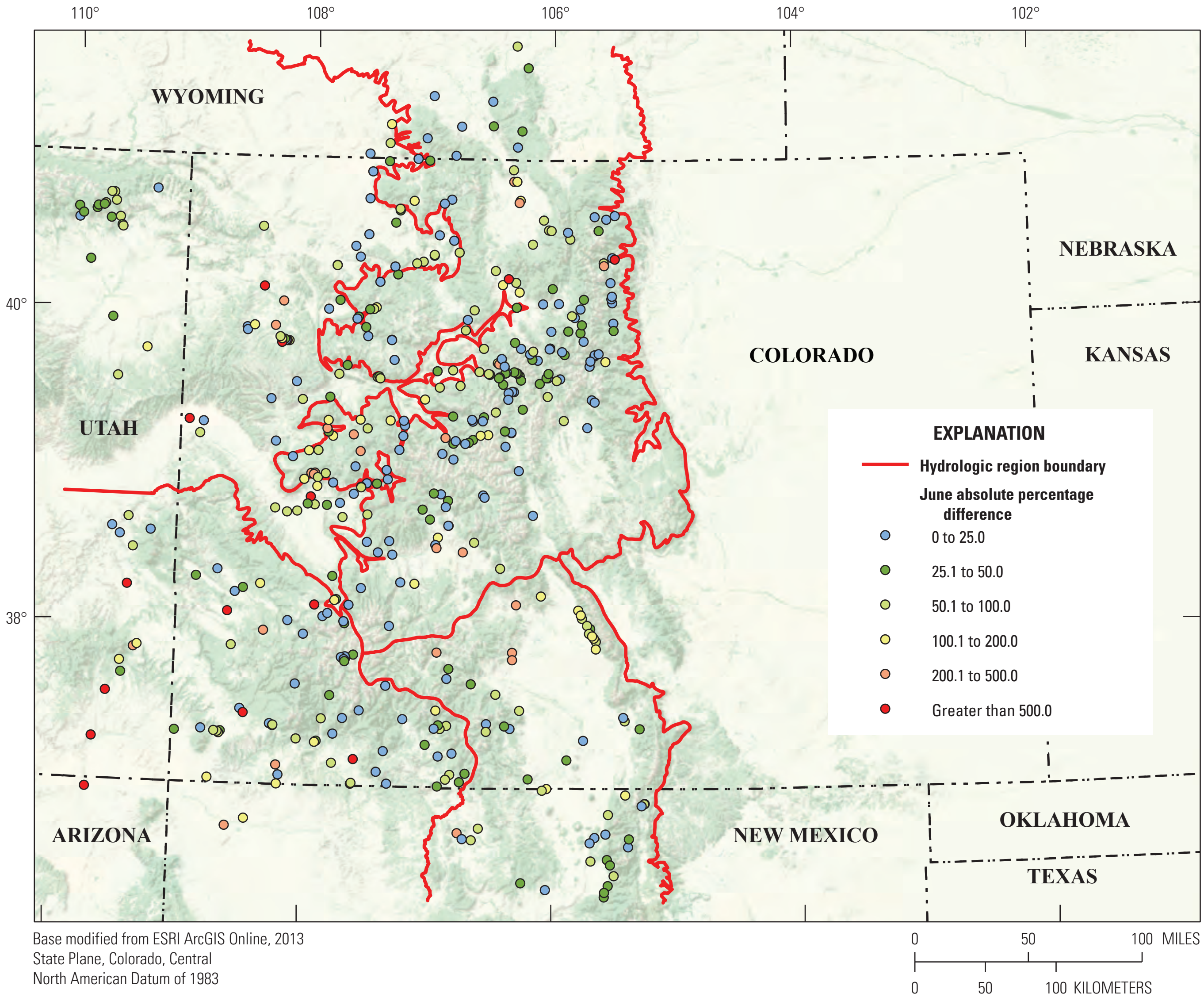

Figure 3–6. Absolute percentage difference between observed and predicted mean-monthly streamflow at all streamgages used in the analysis for the month of June.

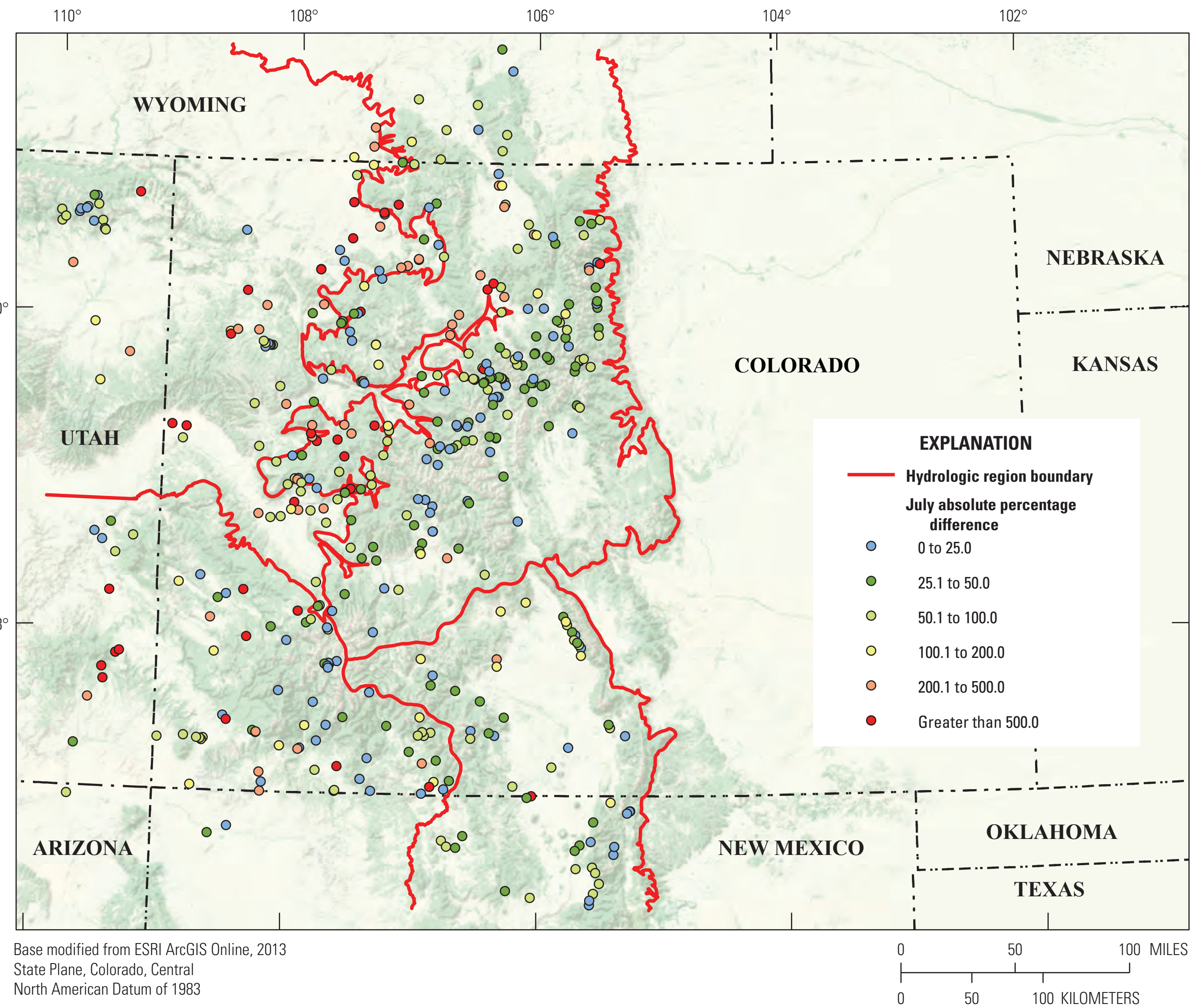

Figure 3–7. Absolute percentage difference between observed and predicted mean-monthly streamflow at all streamgages used in the analysis for the month of July.

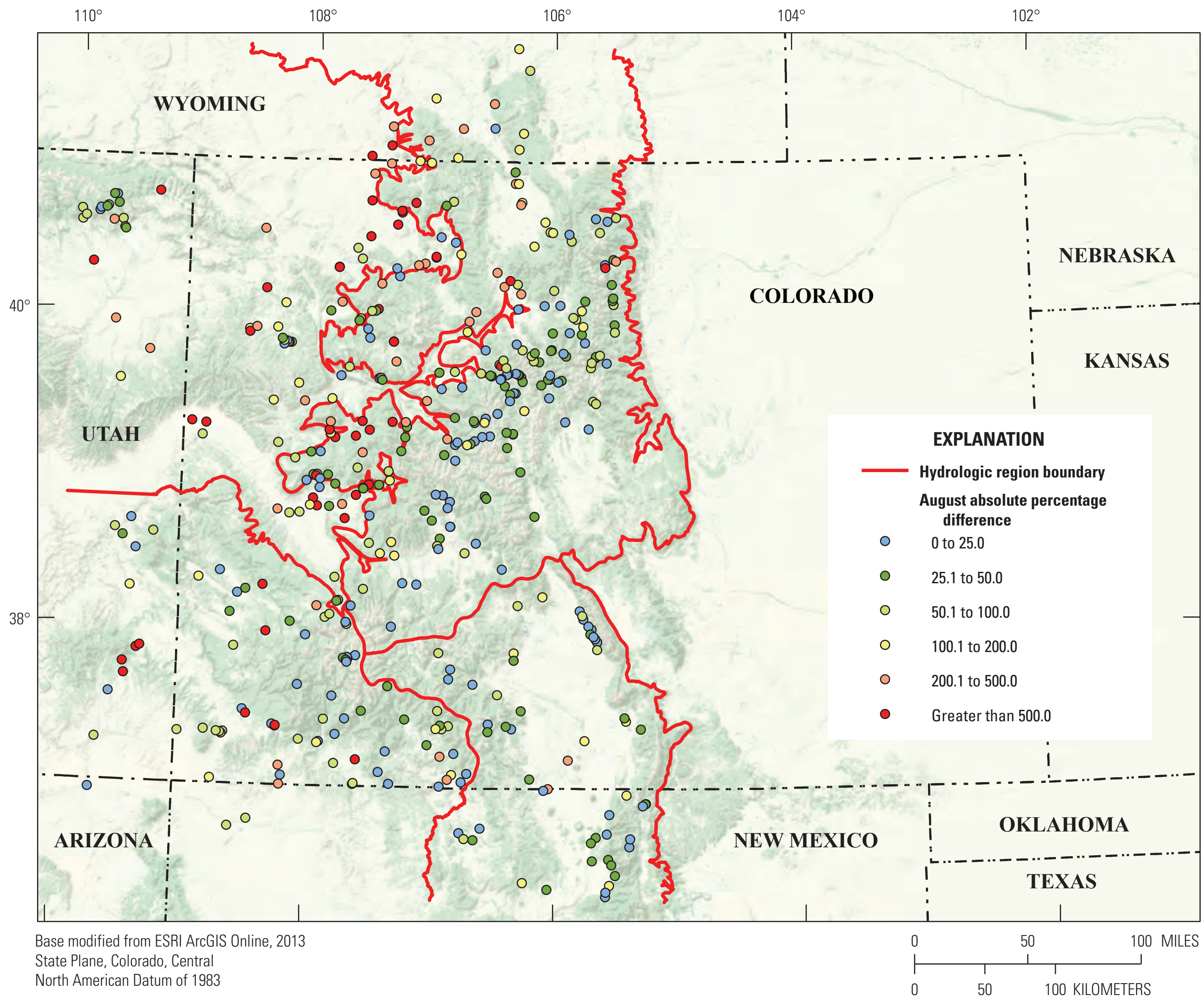

Figure 3–8. Absolute percentage difference between observed and predicted mean-monthly streamflow at all streamgages used in the analysis for the month of August.

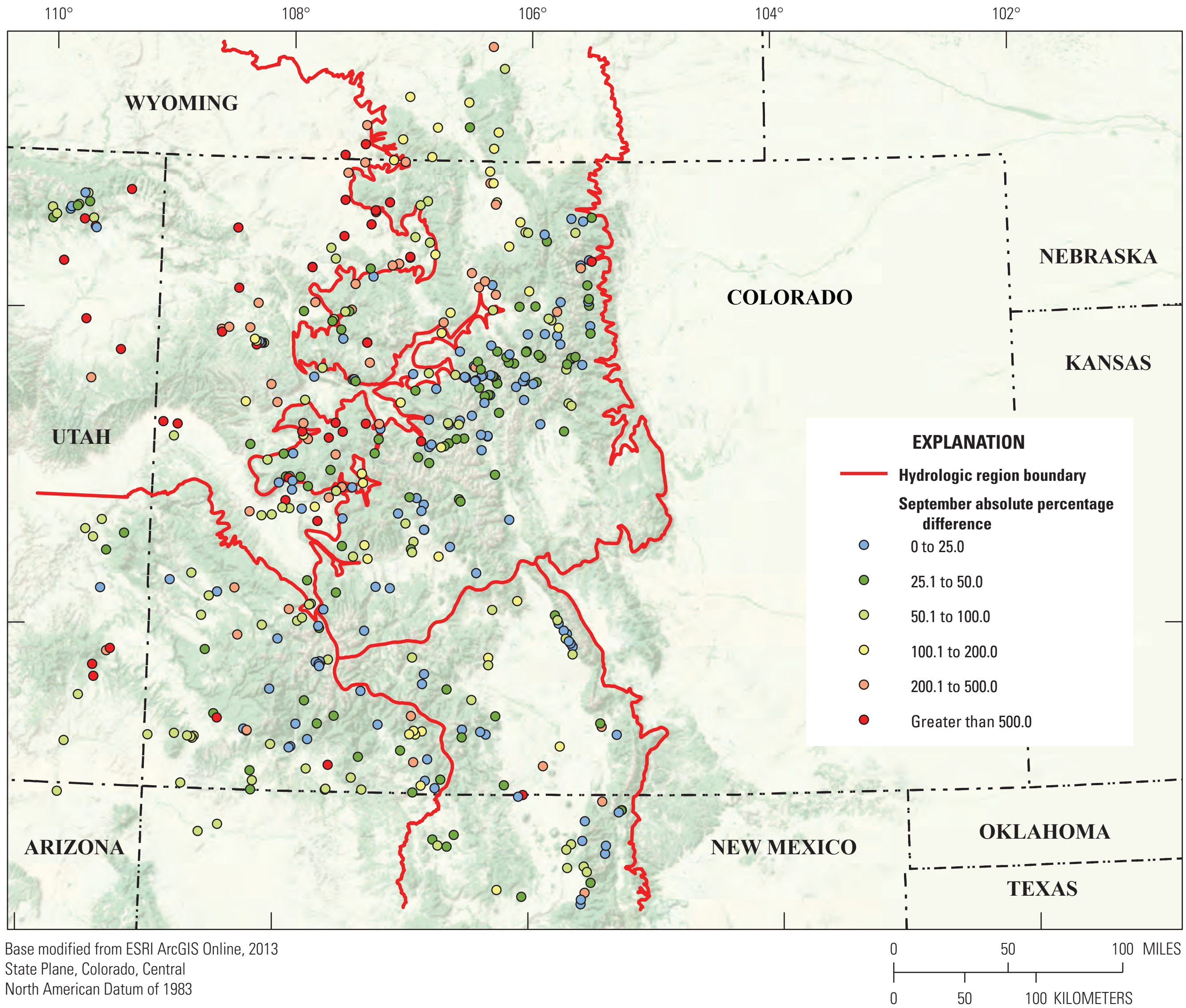

Figure 3–9. Absolute percentage difference between observed and predicted mean-monthly streamflow at all streamgages used in the analysis for the month of September.

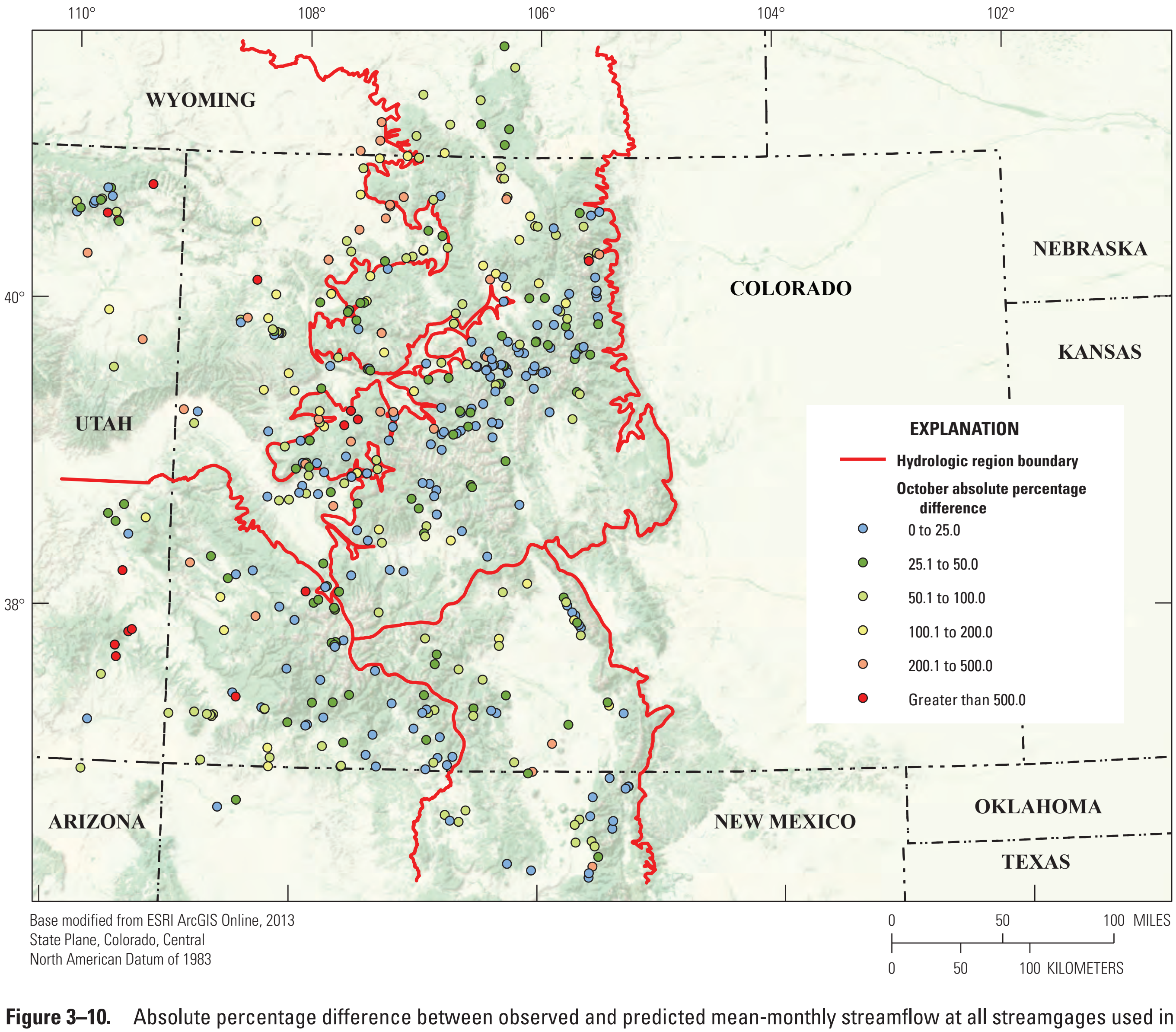

Figure 3–10. Absolute percentage difference between observed and predicted mean-monthly streamflow at all streamgages used in the analysis for the month of October.

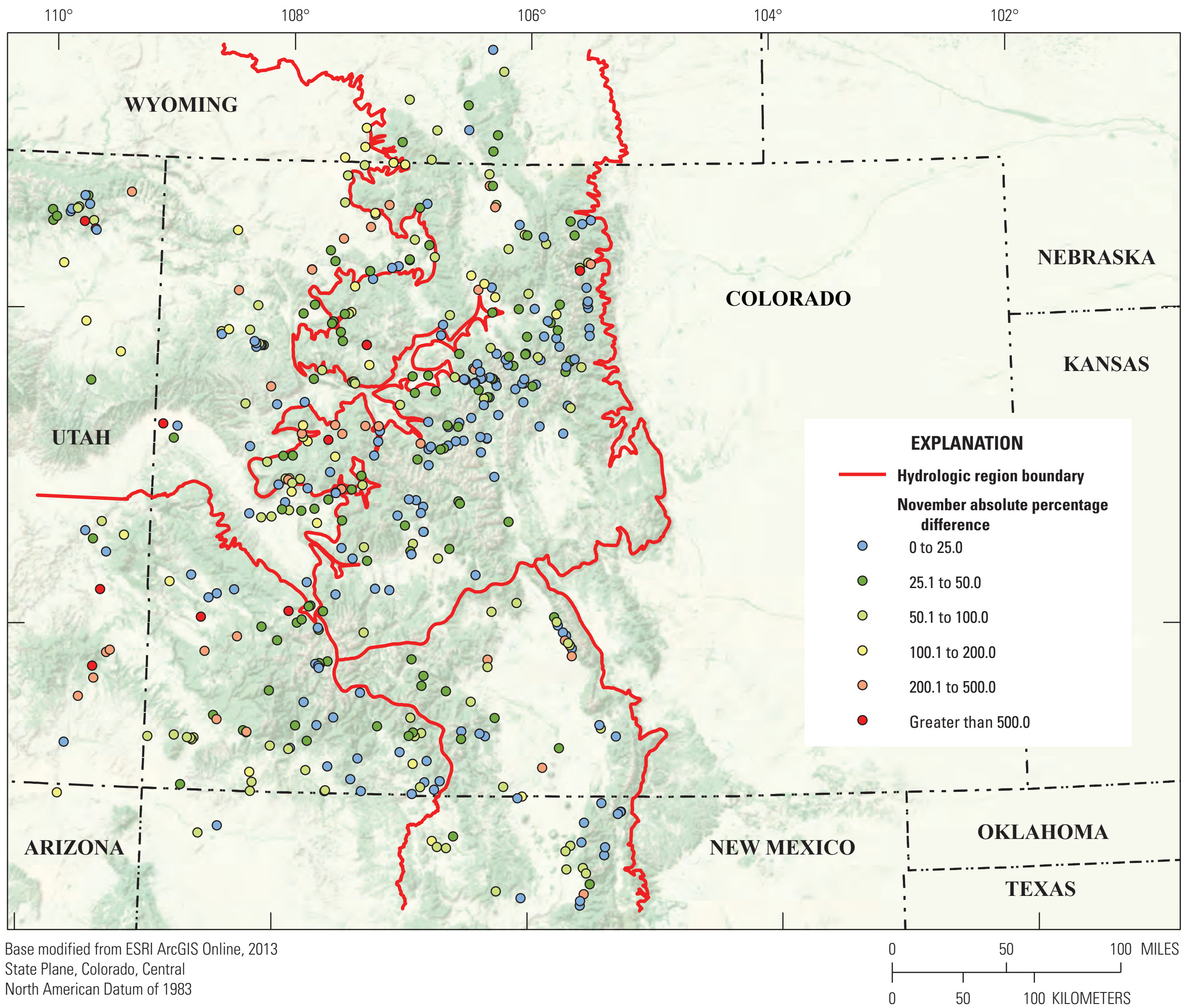

Figure 3–11. Absolute percentage difference between observed and predicted mean-monthly streamflow at all streamgages used in the analysis for the month of November.

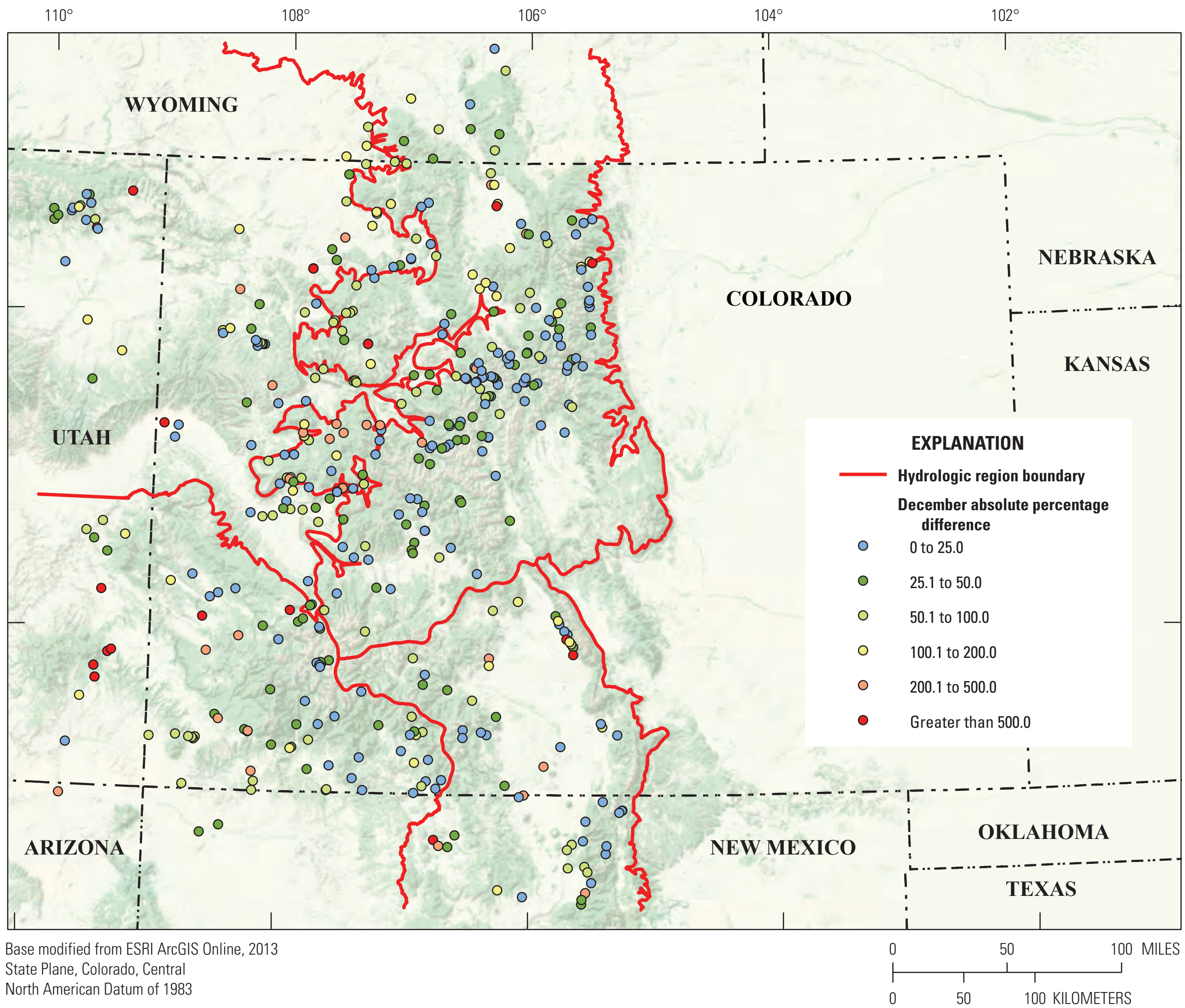

Figure 3–12. Absolute percentage difference between observed and predicted mean-monthly streamflow at all streamgages used in the analysis for the month of December.

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