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Scientific Investigations Report 2016–5145

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

Cover. *Front*, Staff gage at USGS 07105945, Rock Creek above Fort Carson Reservation, Colorado, and *back*, Purgatoire River at USGS 07126485, Purgatoire River at Rock Crossing near Timpas, Colorado.

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Conversion Factors

U.S. customary units to International System of Units

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

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

$$°F = (1.8 \times °C) + 32.$$

Datum

Vertical coordinate information is referenced to the National Geodetic Vertical Datum of 1929 (NGVD 29) or 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

Specific conductance is given in microsiemens per centimeter at 25 degrees Celsius (µS/cm at 25 °C).

Concentrations of chemical constituents in water are given in either milligrams per liter (mg/L) or micrograms per liter (µg/L).

Suspended-sediment discharge is given in tons per day.

Relative percentages of ions are given in milliequivalents per liter (meq/L).

A water year (WY) is the period from October 1 through September 30 of the following year and is designated by the year in which it ends; for example, WY 2013 began October 1, 2012, and ended September 30, 2013.

Abbreviations

CSG	crest-stage gage
CV	coefficient of variation
IQR	interquartile range
LRL	laboratory reporting level
LT–MDL	long-term method detection level
NWQL	National Water-Quality Laboratory
USGS	U.S. Geological Survey

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Abstract

To evaluate the influence of military training activities on streamflow and water quality, the U.S. Geological Survey, in cooperation with the U.S. Department of the Army, began a hydrologic data collection network on the U.S. Army Garrison Fort Carson in 1978 and on the Piñon Canyon Maneuver Site in 1983. This report is a summary and characterization of the precipitation, streamflow, and water-quality data collected at 43 sites between October 1, 2012, and September 30, 2014 (water years 2013 and 2014).

Variations in the frequency of daily precipitation, seasonal distribution, and seasonal and annual precipitation at 5 stations at the U.S. Army Garrison Fort Carson and 18 stations at or near the Piñon Canyon Maneuver Site were evaluated. Isohyetal diagrams indicated a general pattern of increase in total annual precipitation from east to west at the U.S. Army Garrison Fort Carson and the Piñon Canyon Maneuver Site. Between about 54 and 79 percent of daily precipitation was 0.1 inch or less in magnitude. Precipitation events were larger and more frequent between July and September.

Daily streamflow data from 16 sites were used to evaluate temporal and spatial variations in streamflow for the water years 2013 and 2014. At all sites, median daily mean streamflow for the 2-year period ranged from 0.0 to 9.60 cubic feet per second. Daily mean streamflow hydrographs are included in this report. Five sites on the Piñon Canyon Maneuver Site were monitored for peak stage using crest-stage gages.

At the Piñon Canyon Maneuver Site, five sites had a stage recorder and precipitation gage, providing a paired streamflow-precipitation dataset. There was a statistically significant correlation between precipitation and streamflow based on Spearman's rho correlation (rho values ranged from 0.17 to 0.35).

Suspended-sediment samples were collected in April through October for water years 2013–14 at one site at the U.S. Army Garrison Fort Carson and five sites at the Piñon Canyon Maneuver Site. Suspended-sediment-transport curves were used to illustrate the relation between streamflow and suspended-sediment concentration. All these sediment-transport curves showed a streamflow dependent suspended-sediment concentration relation except for the U.S. Geological Survey station Bent Canyon Creek at mouth near Timpas, CO.

Water-quality data were collected and reported from seven sites on the U.S. Army Garrison Fort Carson and the Piñon Canyon Maneuver Site during water years 2013–14. Sample results exceeding an established water-quality standard were identified. Selected water-quality properties and constituents were stratified to compare spatial variation among selected characteristics using boxplots.

Trilinear diagrams were used to classify water type based on ionic concentrations of water-quality samples collected during the study period.

At the U.S. Army Garrison Fort Carson and the Piñon Canyon Maneuver Site, 27 samples were classified as very hard or brackish. Seven samples had a lower hardness character relative to the other samples. Four of those nine samples were collected at two U.S. Geological Survey stations (Turkey Creek near Fountain, CO, and Little Fountain Creek above Highway 115 at Fort Carson, CO), which have different geologic makeup. Three samples collected at the Piñon Canyon Maneuver Site had a markedly lower hardness likely because of dilution from an increase in streamflow.

Introduction

Before human alteration, the North American Great Plains included more than 500 million acres of undisturbed land. Currently (2016), less than about 50,000 acres of undisturbed prairie habitat remains (Klopatek and others, 1979; Sieg and others, 1999). By the mid-1800s, humans had altered stream habitats, natural flow regimes, and aquatic biota in streams and tributaries near the transition from plains to mountains along the Front Range of Colorado (Fausch and Bestgen, 1997). Historical accounts from the 1840s of the physical habitat attributes from transition zone and plains streams of eastern Colorado indicate that several changes had happened with minimal documentation. Primary among the physical habitat modifications to plains streams in Colorado during this time was channel widening, which was exacerbated by drought in the 1930s, increased sinuosity and pool frequency, and riparian encroachment by woody vegetation (Fausch and Bestgen, 1997). The grassland ecosystem of southeastern Colorado can be disturbed and degraded by drought, overgrazing, row-crop farming, and intense animal traffic (Lewontin, 1969; Angelini and Silliman, 2012). Changes to the ecosystem can alter surface-water and groundwater hydrology, resulting in increased runoff rates and peak flows (Knighton, 1998) and decreased infiltration rates and pollutant-filtering efficiency (Riordan and others, 1978). Increased flood frequency and peak streamflow during precipitation can cause severe erosion of a stream channel, riparian areas, and adjacent upland landforms. Flooding, erosion, and streambank instability deteriorate the natural and intrinsic values of streams and can damage adjacent properties. Changes in stream hydrology, water chemistry, and physical habitat associated with changes in land-cover characteristics often result in altered aquatic communities and biological processes (Paul and Meyer, 2001).

The U.S. Army manages about 12 million acres of land and uses installations on that land for training and mission readiness (Shaw and Diersing, 1989). Military training is an intensive type of land use, and one of the most intensive uses involves tracked-vehicle training. These tracked vehicles, such as tanks and armored personnel carriers, destroy herbaceous and woody vegetation and compact the soil. Training with tracked vehicles causes soil compaction that can increase erosion by wind and surface-water runoff (Shaw and Diersing, 1989). Perennial warm-season grasses are the dominant climax community vegetation on two military installations in southeast Colorado, the U.S. Army Garrison Fort Carson and the Piñon Canyon Maneuver Site. These warm-season grasslands are characteristic of high elevation desert grasslands or shortgrass steppes and correspond to the Level III ecoregion—Southwestern Tablelands (Omernik, 1987). Cool-season grasses will invade this climax community and become established when the land is disturbed. Once established, these cool-season grasses can thrive when spring precipitation is average or above average; however, during periods of drought, these cool-season grasses generally do not establish and the potential for wind and water erosion increases. Maintaining the perennial warm-season grassland climax community would require no tracked-vehicle training, which is contrary to the mission of the U.S. Army and military readiness (Shaw and Diersing, 1989).

The Integrated Training Area Management Conservation Program, which is part of the U.S. Army's Sustainable Range Program, combines military training with the monitoring and evaluation of land condition (U.S. Department of the Army, 2005). This integrative training approach is intended to limit disturbance of land cover while providing areas that are appropriate for sustainable military training. In conjunction with the Integrated Training Area Management, the Army also has a Limited Use Area program to enhance land rehabilitation of military training areas (Brian Goss, oral commun., October 2015); furthermore, the U.S. Environmental Protection Agency, under Section 319 of the Water Quality Act of 1987, requires the Department of Defense and the Army to "assess the nature and extent of nonpoint sources of pollution." To address these information requirements, the U.S. Geological Survey (USGS), in cooperation with the U.S. Department of the Army, began a hydrologic data collection network on the U.S. Army Garrison Fort Carson in 1978 and the Piñon Canyon Maneuver Site in 1983 to evaluate the influence of military training activities on streamflow and water quality. This report is a summary and characterization of the hydrologic data collected from October 1, 2012, through September 30, 2014.

Purpose and Scope

This report evaluates and summarizes the characteristics and relation of precipitation, streamflow, and water-quality characteristics at sites on or near the U.S. Army Garrison Fort Carson and the Piñon Canyon Maneuver Site (figs. 1*A*, 1*B*; table 1) from October 1, 2012, through September 30, 2014. The study period for this report is defined as water years (WYs) 2013 and 2014. A water year is the 12-month period October 1 through September 30 designated by the calendar year in which it ends. Precipitation, streamflow, and water-chemistry data within this report can be obtained through the USGS National Water Information System at http://dx.doi.org/10.5066/F7P55KJN (search by USGS station number, table 1). Results from this study were derived from only 2 years of data that also contained data gaps; therefore, results of this study were interpreted with caution.

Description of Study Areas

The following section describes the landscape, geology, and climate of the U.S. Army Garrison Fort Carson and the Piñon Canyon Maneuver Site. These descriptions contain citations with more detailed information on the study areas.

U.S. Army Garrison Fort Carson

Located along the transition zone between the Great Plains and the Rocky Mountains, U.S. Army Garrison Fort Carson (fig. 1*A*) covers about 215 square miles (mi^2; 138,000 acres) in El Paso, Pueblo, and Fremont Counties, south of and adjacent to the city of Colorado Springs, Colorado (Brown, 2014). The land is characterized by dissected plains and terraces in the northern and eastern parts, and deep canyons, hills, and hogbacks to the west. Elevations at U.S. Army Garrison Fort Carson range from 5,400 to 6,900 feet (ft). The higher elevations are in the western region near State Highway 115 and the lower elevations are in the south and east. The climate is semiarid and corresponds to the Level III ecoregions—Southern Rockies and Southwestern Tablelands (Omernik, 1987). The U.S. Army Garrison Fort Carson is a part of the Arkansas River Basin, and streams

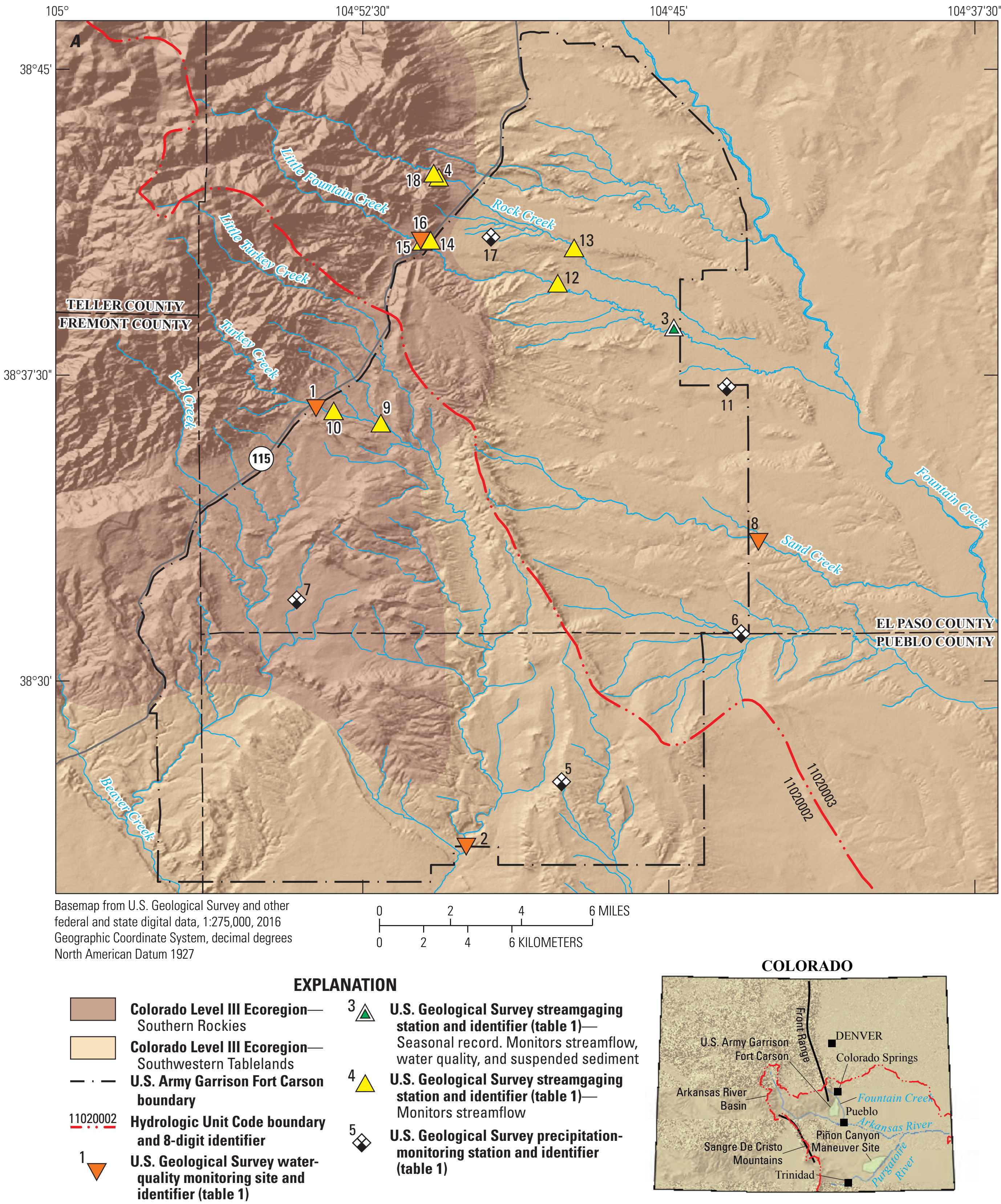


Figure 1. Map showing locations of U.S. Geological Survey precipitation, streamflow, and water-quality sampling sites, Colorado, water years 2013–14. *A*, U.S. Army Garrison Fort Carson. *B*, Piñon Canyon Maneuver Site.

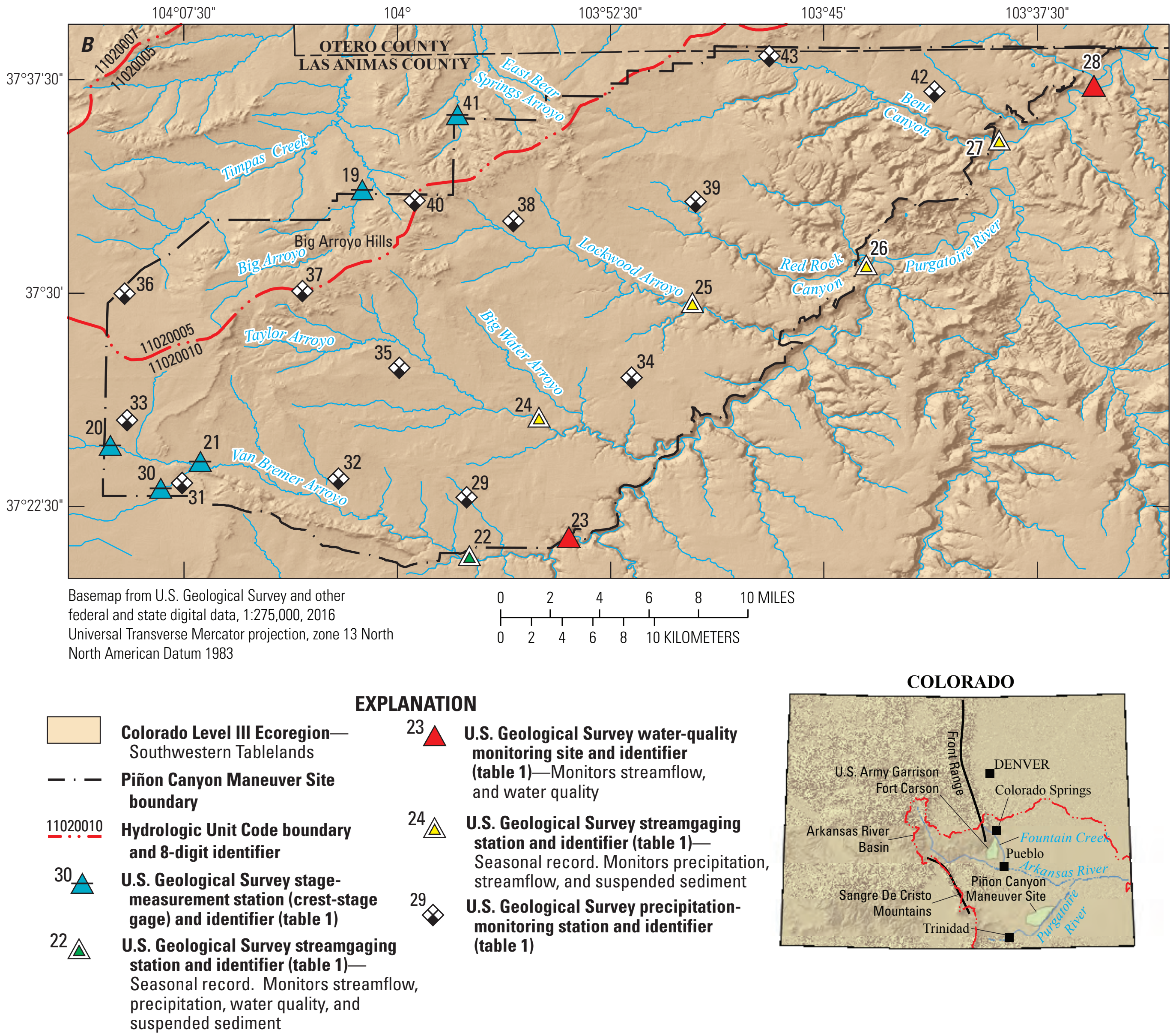


Figure 1. Map showing locations of U.S. Geological Survey precipitation, streamflow, and water-quality sampling sites, Colorado, water years 2013–14. *A*, U.S. Army Garrison Fort Carson. *B*, Piñon Canyon Maneuver Site.—Continued

generally flow from northwest to southeast (Diersing and Severinghaus, 1984). The northern and eastern parts of the Garrison are drained by a number of tributaries to Fountain Creek, including Little Fountain, Sand, and Rock Creeks, whereas the southern part is drained to the Arkansas River by Turkey and Little Turkey Creeks; and the southwestern area is drained by Red Creek, a tributary of Beaver Creek (fig. 1*A*). Fountain, Turkey, and Beaver Creeks are tributaries to the Arkansas River (Leonard, 1984).

The geology of U.S. Army Garrison Fort Carson varies; the northern and western areas being characterized by shale and sedimentary rock, respectively (Tweto, 1979). Moving west to east across the U.S. Army Garrison Fort Carson, most of the rest of the Garrison is made up of shale and unconsolidated alluvium where streams are located (fig. 2*A*).

Piñon Canyon Maneuver Site

The Piñon Canyon Maneuver Site is in southeastern Colorado (fig. 1*B*) and is about 25 miles northeast of Trinidad, Colorado. In 1982, the U.S. Army purchased 381 mi^2 (244,000 acres) to create the Piñon Canyon Maneuver Site. The Maneuver Site was established to supplement military training sites at U.S. Army Garrison Fort Carson. In 1989, about 1.25 mi^2 (800 acres) were sold back to the original owner because the land was determined to be unsuitable for mechanized military training (von Guerard and others, 1993; Stevens and others, 2008). Also, in 1991, the Army transferred about 7,200 acres of “uneconomic remnants” that were unsuited to military training, reducing the area of the Piñon Canyon Maneuver Site to about 236,000 acres (Brian Goss, U.S. Army Garrison Fort

Carson, oral commun., December, 2015). Primarily composed of rangeland and canyons, the Piñon Canyon Maneuver Site is in a semiarid environment, is entirely within the Arkansas River Basin, and corresponds to the Level III ecoregion—the Southwestern Tablelands (Omernik, 1987). The uplands and hills are forested with piñon pine and juniper trees. Rolling short-grass prairie lies intermixed between the uplands and canyons. Historically, livestock grazing was the predominant land use but was eliminated in 1983 after the land was acquired by the Army (Stevens and others, 2008). Currently (2016), the Piñon Canyon Maneuver Site offers hunting opportunities, and the adjoining Comanche National Grasslands to the north offers hunting and other outdoor recreation opportunities, such as biking, birding, bouldering, and hiking. Also, the Santa Fe Trail and a dinosaur track site on the Purgatoire River are popular cultural, historical, and archeological destinations. McLain and Britt (2007) provided a thorough historical and cultural account of the Piñon Canyon Maneuver Site. Rock outcroppings and cliffs are exposed along the 400- to 500-ft-deep Purgatoire Canyon, and vegetation grows along the bottom of incised reaches of the primary tributaries near the confluences with the Purgatoire River (Stevens and others, 2008). The elevation of the land surface at the Piñon Canyon Maneuver Site ranges from about 4,305 ft at the northeast edge of the Maneuver Site where the Purgatoire River flows out of the study area to about 5,905 ft in the Big Arroyo Hills at the northwest boundary of the Maneuver Site.

About 96 percent of the Piñon Canyon Maneuver Site drains eastward to the Purgatoire River; the remaining 4 percent drains northeast into Timpas Creek (Stevens and others, 2008). The streams that drain the Piñon Canyon Maneuver Site are predominantly intermittent or ephemeral (fig. 1*B*; table 1) and occupy shallow valleys that intersect the rolling plains of the Maneuver Site (von Guerard and others, 1993). Near the confluence with the Purgatoire River, the tributary stream channels become entrenched in the sandstone of the canyon rim and form side canyons to the Purgatoire Canyon (von Guerard and others, 1993). Near the upper ends of the side canyons, the channels of some of the tributary streams intersect the water table, and the streams become perennial or intermittent downstream from that point (von Guerard and others, 1993; J.F. Bruce, oral commun., 2013).

The geologic formations at the Piñon Canyon Maneuver Site consist mainly of sedimentary rocks (including limestone and sandstone) and shale (fig. 2*B*) (von Guerard and others, 1993). This sedimentary geology has produced fined-grained soils to silty loams that are readily erodible. Von Guerard and others (1987) thoroughly describe the geology and soils of the Piñon Canyon Maneuver Site. The climate at the Piñon Canyon Maneuver Site is semiarid with about 12 inches of precipitation per year (Stevens and others, 2008); furthermore, about 80 percent of the precipitation at the Piñon Canyon Maneuver Site occurs as rainfall from March through October from convective thunderstorms (Stevens and others, 2008).

Study Methods

In total, 43 sites on the U.S. Army Garrison Fort Carson and the Piñon Canyon Maneuver Site (fig. 1) were used in this evaluation of precipitation, streamflow, and water-quality data from October 2012 through September 2014 (table 1).

Precipitation was recorded seasonally at 5 sites from April through October and at 18 sites continuously from October through September (table 1). There were 5 precipitation monitoring stations on U.S. Army Garrison Fort Carson and 18 on the Piñon Canyon Maneuver Site. Streamflow was computed continuously at nine sites from April through October (eight on the U.S. Army Garrison Fort Carson and one on the Piñon Canyon Maneuver Site) and seasonally at seven sites from October through September (one on the Garrison and six on the Maneuver Site). Water-quality samples (chemistry) were collected from one to four times annually during the WY at eight sites during the study period, five at the U.S. Army Garrison Fort Carson and three at the Piñon Canyon Maneuver Site. All data types collected at each site are listed in table 1 and can be accessed at http://dx.doi.org/10.5066/F7P55KJN (search by USGS station number, table 1).

Data Collection

The following section briefly describes how precipitation, streamflow, and water-quality data were collected. These methods were based on standard USGS protocols. Quality-assurance and quality-control measures are also described.

Precipitation

All precipitation-monitoring stations (table 1; fig. 1) were equipped with tipping-bucket gages having 8-, 10- or 12-inch (in.) precipitation collectors. The collector funnels precipitation to a tipping-bucket mechanism, consisting of two buckets that collect precipitation in 0.01-in. volumes. When full, the bucket tips, emptying the contents and initiating the filling of the adjacent tipping bucket. The tipping of the bucket initiates a signal sent to a data collection platform. The number of tips recorded within a 5-minute interval are summed and logged within the data collection platform. These gages were routinely visited and maintained by USGS hydrographers. During each warm-weather site visit, calibration checks were made that covered the historical range of precipitation intensities and single-tip volume checks. Because the tipping-bucket gages at some stations (those not colocated with streamgaging stations) did not have heaters incorporated into the precipitation collectors, and the inherent inability of the tipping-bucket gages to accurately measure snowfall, the winter (November through March) precipitation data were considered less accurate than data for the remainder of the year.

Table 1. Description of sites and types of data collected at U.S. Army Garrison Fort Carson, Colorado, and the Piñon Canyon Maneuver Site, Colorado, water years 2013–14.

[ID, identifier; USGS, U.S. Geological Survey; ft, foot; mi^2, square mile; CDPHE, Colorado Department of Health and Environment, CO, Colorado; °, degree; ', minute; ", second; --, not applicable; X, applicable; S, seasonal; C, continuous; MPRC, Multipurpose Range Complex; PCMS, Piñon Canyon Maneuver Site; CIG, Colorado Interstate Gas]

Site ID (fig. 1)	USGS station number	Station name	Latitude	Longitude	Elevation (ft)	Contributing drainage area (mi^2)	Strahler stream order[c]
		U.S. Army Garrison Fort Carson					
1	07099215	Turkey Creek near Fountain, CO	38°36'42"	104°53'39"	6,420[a]	13.0	2
2	07099235	Turkey Creek near Stone City, CO	38°25'56"	104°49'58"	5,350[a]	72.5	3
3	07105940	Little Fountain Creek near Fountain, CO	38°38'33"	104°44'54"	5,566[b]	26.9	3
4	07105945	Rock Creek above Fort Carson, CO	38°42'27"	104°50'46"	6,390[a]	6.8	2
5	382731104473701	MPRC meteorologic station at Fort Carson, CO	38°27'31"	104°47'37"	5,800[a]	--	--
6	383109104431301	Young Hollow meteorologic station at Fort Carson, CO	38°31'09"	104°43'13"	5,350[a]	--	--
7	383159104540701	Sullivan Park meteorologic station at Fort Carson, CO	38°31'59"	104°54'07"	6,010[a]	--	--
8	383325104424801	Sand Creek below Fort Carson near Wigwam, CO	38°33'25"	104°42'48"	5,463[b]	Not determined	2
9	383619104520401	Lytle Ditch at Fort Carson, CO	38°36'19"	104°52'04"	6,270[a]	Indeterminate	--
10	383637104531301	Strobel Ditch from Turkey Creek at Fort Carson, CO	38°36'37"	104°53'13"	6,370[a]	Indeterminate	--
11	383713104433401	Range 111 meteorologic station at Fort Carson, CO	38°37'13"	104°43'34"	5,600[a]	--	--
12	383944104474201	Merriams Little Fountain Ditch at Fort Carson, CO	38°39'45"	104°47'44"	5,770[a]	Indeterminate	--
13	384037104472001	Merriams Rock Creek Ditch at Fort Carson, CO	38°40'37"	104°47'20"	5,830[a]	Indeterminate	--
14	384047104510301	Ripley Ditch from Little Fountain Creek at Fort Carson, CO	38°40'47"	104°51'03"	6,340[a]	Indeterminate	--
15	384048104504901	Womack Ditch from Little Fountain Creek near Fort Carson, CO	38°40'48"	104°50'51"	6,370[a]	Indeterminate	--
16	384048104510401	Little Fountain Creek above Highway 115 at Fort Carson, CO	38°40'48"	104°51'05"	6,338[b]	Not determined	2
17	384053104492001	Rod and Gun meteorologic station at Fort Carson, CO	38°40'53"	104°49'20"	6,120[a]	--	--
18	384220104503701	Gale Ditch from Rock Creek near Fort Carson, CO	38°42'21"	104°50'39"	6,380[a]	Indeterminate	--
		Piñon Canyon Maneuver Site					
19	07120620	Big Arroyo near Thatcher, CO	37°33'17"	104°01'16"	5,288[a]	15.4	2
20	07126130	Van Bremer Arroyo near Thatcher, CO	37°24'36"	104°10'06"	5,396[a]	67.9	3
21	07126140	Van Bremer Arroyo near Tyrone, CO	37°23'58"	104°06'55"	5,310[a]	119.0	3
22	07126200	Van Bremer Arroyo near Model, CO	37°20'44"	103°57'27"	4,960[a]	162.0	3
23	07126300	Purgatoire River near Thatcher, CO	37°21'23"	103°53'59"	4,790[a]	1,902.2	5
24	07126325	Taylor Arroyo below Rock Crossing near Thatcher, CO	37°25'27"	103°55'11"	4,982[a]	48.4	3
25	07126390	Lockwood Canyon Creek near Thatcher, CO	37°29'34"	103°49'39"	4,785[a]	48.8	3
26	07126415	Red Rock Canyon Creek at mouth near Thatcher, CO	37°30'55"	103°43'30"	4,510[a]	48.7	2
27	07126480	Bent Canyon Creek at mouth near Timpas, CO	37°35'21"	103°38'52"	4,402[a]	56.1	2
28	07126485	Purgatoire River at Rock Crossing near Timpas, CO	37°37'06"	103°35'35"	4,350[a]	2,746.2	5
29	372249103573302	Gutierrez Windmill meteorologic station near Model, CO	37°22'49"	103°57'33"	5,130[a]	--	--
30	372308104081801	Unnamed Tributary above Van Bremer Arroyo at PCMS, CO	37°23'08"	104°08'18"	5,364[b]	16.8	1
31	372319104073301	Brown Sheep Camp meteorologic station near Tyrone, CO	37°23'19"	104°07'33"	5,390[a]	--	--
32	372329104020501	Route Two Windmill meteorologic station near Tyrone, CO	37°23'29"	104°02'05"	5,255[a]	--	--
33	372532104093001	Cantonment Windmill meteorologic station near Tyrone, CO	37°25'32"	104°09'30"	5,460[a]	--	--
34	372701103514501	Mincic meteorologic station near Houghton, CO	37°27'01"	103°51'45"	5,078[a]	--	--
35	372721103595601	CIG Pipeline South meteorologic station near Simpson, CO	37°27'21"	103°59'56"	5,220[a]	--	--
36	372959104092201	Cantonment meteorologic station near cemetery at Simpson, CO	37°29'59"	104°09'35"	5,630[a]	--	--
37	373004104032001	Burson Well meteorologic station near Thatcher, CO	37°30'04"	104°03'20"	5,630[a]	--	--
38	373232103555201	Bear Springs Hills meteorologic station near Houghton, CO	37°32'32"	103°55'55"	5,200[a]	--	--
39	373315103493101	Upper Red Rock Canyon meteorologic station near Houghton, CO	37°33'12"	103°49'30"	4,860[a]	--	--
40	373316103592401	Big Arroyo Hills meteorologic station near Houghton, CO	37°33'16"	103°59'24"	5,500[a]	--	--
41	373556103575201	West Bear Springs Arroyo at boundary at PCMS, CO	37°35'56"	103°57'52"	5,108[b]	4.7	1
42	373706103410701	Rourke meteorologic station near Higbee, CO	37°37'06"	103°41'07"	4,700[a]	--	--
43	373823103465601	Upper Bent Canyon meteorologic station near Delhi, CO	37°38'20"	103°46'55"	4,860[a]	--	--

Table 1. Description of sites and types of data collected at U.S. Army Garrison Fort Carson, Colorado, and the Piñon Canyon Maneuver Site, Colorado, water years 2013–14.—Continued

[ID, identifier; USGS, U.S. Geological Survey; ft, foot; mi², square mile; CDPHE, Colorado Department of Health and Environment, CO, Colorado; °, degree; ‘, minute; “, second; --, not applicable; X, applicable; S, seasonal; C, continuous; MPRC, Multipurpose Range Complex; PCMS, Piñon Canyon Maneuver Site; CIG, Colorado Interstate Gas]

Site ID (fig. 1)	8-digit Hydrologic Unit Code	Level III ecoregion[d]	CDPHE basin, stream segment[e]	Precipitation	Streamflow	Peak stage	Chemistry	Suspended-sediment concentration
U.S. Army Garrison Fort Carson								
1	11020002	Southern Rockies	Upper Arkansas Basin, 14d	--	--	--	X	--
2	11020002	Southwest Tablelands	Upper Arkansas Basin, 14d	--	--	--	X	--
3	11020003	Southwest Tablelands	Fountain Creek Basin, 4	--	S	--	X	X
4	11020003	Southern Rockies	--	--	C	--	--	--
5	11020002	Southwest Tablelands	--	C	--	--	--	--
6	11020003	Southwest Tablelands	--	C	--	--	--	--
7	11020002	Southern Rockies	--	C	--	--	--	--
8	11020003	Southwest Tablelands	Fountain Creek Basin, 4	--	--	--	X	--
9	11020002	Southern Rockies	--	--	C	--	--	--
10	11020002	Southern Rockies	--	--	C	--	--	--
11	11020003	Southwest Tablelands	--	C	--	--	--	--
12	11020003	Southwest Tablelands	--	--	C	--	--	--
13	11020003	Southwest Tablelands	--	--	C	--	--	--
14	11020003	Southern Rockies	--	--	C	--	--	--
15	11020003	Southern Rockies	--	--	C	--	--	--
16	11020003	Southern Rockies	Fountain Creek Basin, 4	--	--	--	X	--
17	11020003	Southwest Tablelands	--	C	--	--	--	--
18	11020003	Southern Rockies	--	--	C	--	--	--
Piñon Canyon Maneuver Site								
19	11020005	Southwest Tablelands	--	--	--	X	--	--
20	11020010	Southwest Tablelands	--	--	--	X	--	--
21	11020010	Southwest Tablelands	--	--	--	X	--	--
22	11020010	Southwest Tablelands	Lower Arkansas Basin, 9a	S	S	--	X	X
23	11020010	Southwest Tablelands	Lower Arkansas Basin, 7	--	C	--	X	--
24	11020010	Southwest Tablelands	--	S	S	--	--	X
25	11020010	Southwest Tablelands	--	S	S	--	--	X
26	11020010	Southwest Tablelands	--	S	S	--	--	X
27	11020010	Southwest Tablelands	--	S	S	--	--	X
28	11020010	Southwest Tablelands	Lower Arkansas Basin, 7	--	S	--	X	--
29	11020010	Southwest Tablelands	--	C	--	--	--	--
30	11020010	Southwest Tablelands	--	--	--	X	--	--
31	11020010	Southwest Tablelands	--	C	--	--	--	--
32	11020010	Southwest Tablelands	--	C	--	--	--	--
33	11020010	Southwest Tablelands	--	C	--	--	--	--
34	11020010	Southwest Tablelands	--	C	--	--	--	--
35	11020010	Southwest Tablelands	--	C	--	--	--	--
36	11020005	Southwest Tablelands	--	C	--	--	--	--
37	11020010	Southwest Tablelands	--	C	--	--	--	--
38	11020010	Southwest Tablelands	--	C	--	--	--	--
39	11020010	Southwest Tablelands	--	C	--	--	--	--
40	11020010	Southwest Tablelands	--	C	--	--	--	--
41	11020005	Southwest Tablelands	--	--	--	X	--	--
42	11020010	Southwest Tablelands	--	C	--	--	--	--
43	11020010	Southwest Tablelands	--	C	--	--	--	--

[a]National Geodetic Vertical Datum of 1929.

[b]North American Vertical Datum of 1988.

[c]Strahler stream order (Strahler, 1957).

[d]Level III Ecoregion (Omernick, 1987).

[e]CDPHE basin, stream segment (Colorado Department of Public Health and Environment, Water Quality Control Commission, 2013, 2015).

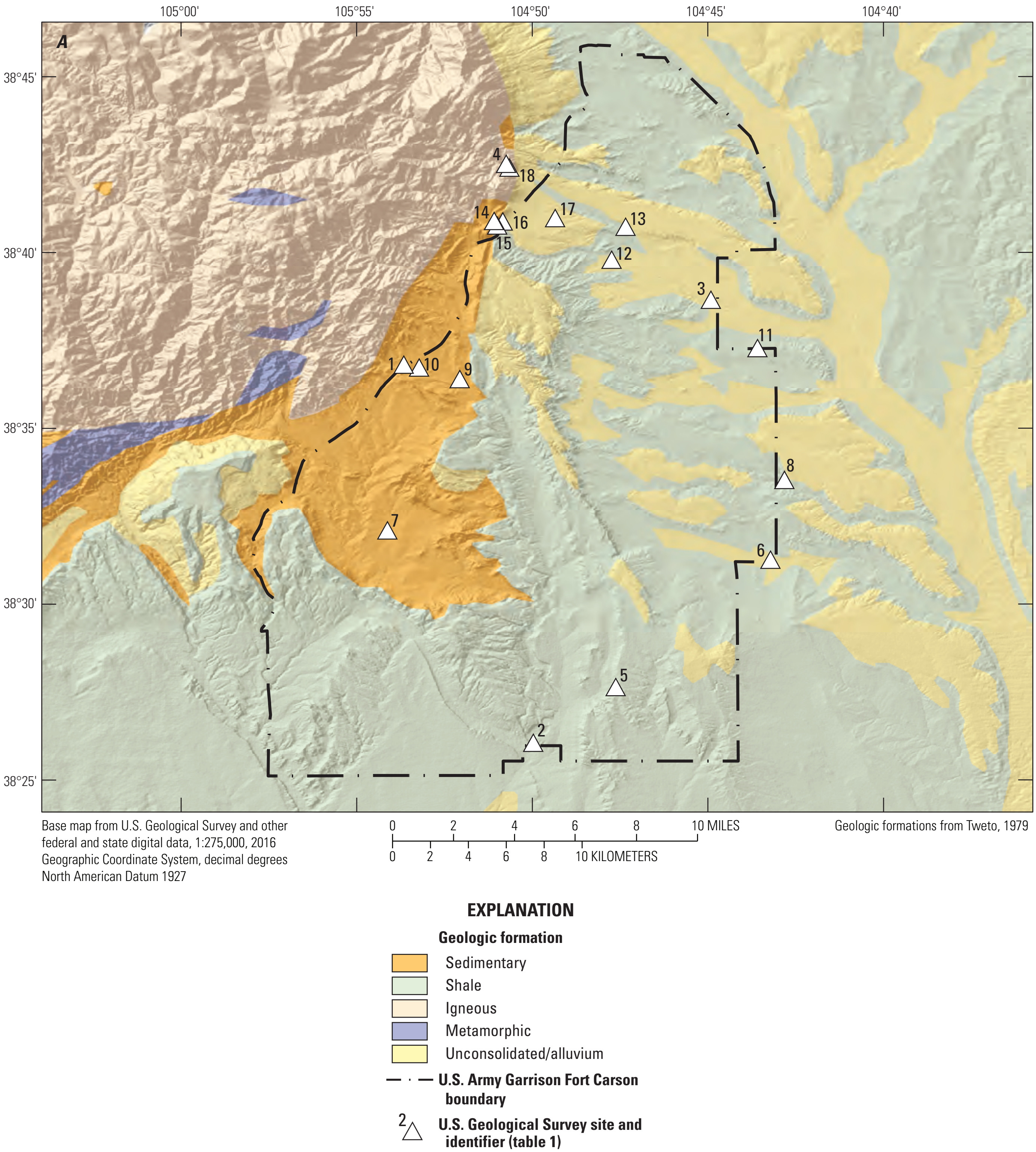


Figure 2. Map showing geologic formations and U.S. Geological Survey sites, Colorado. *A*, U.S. Army Garrison Fort Carson. *B*, Piñon Canyon Maneuver Site.

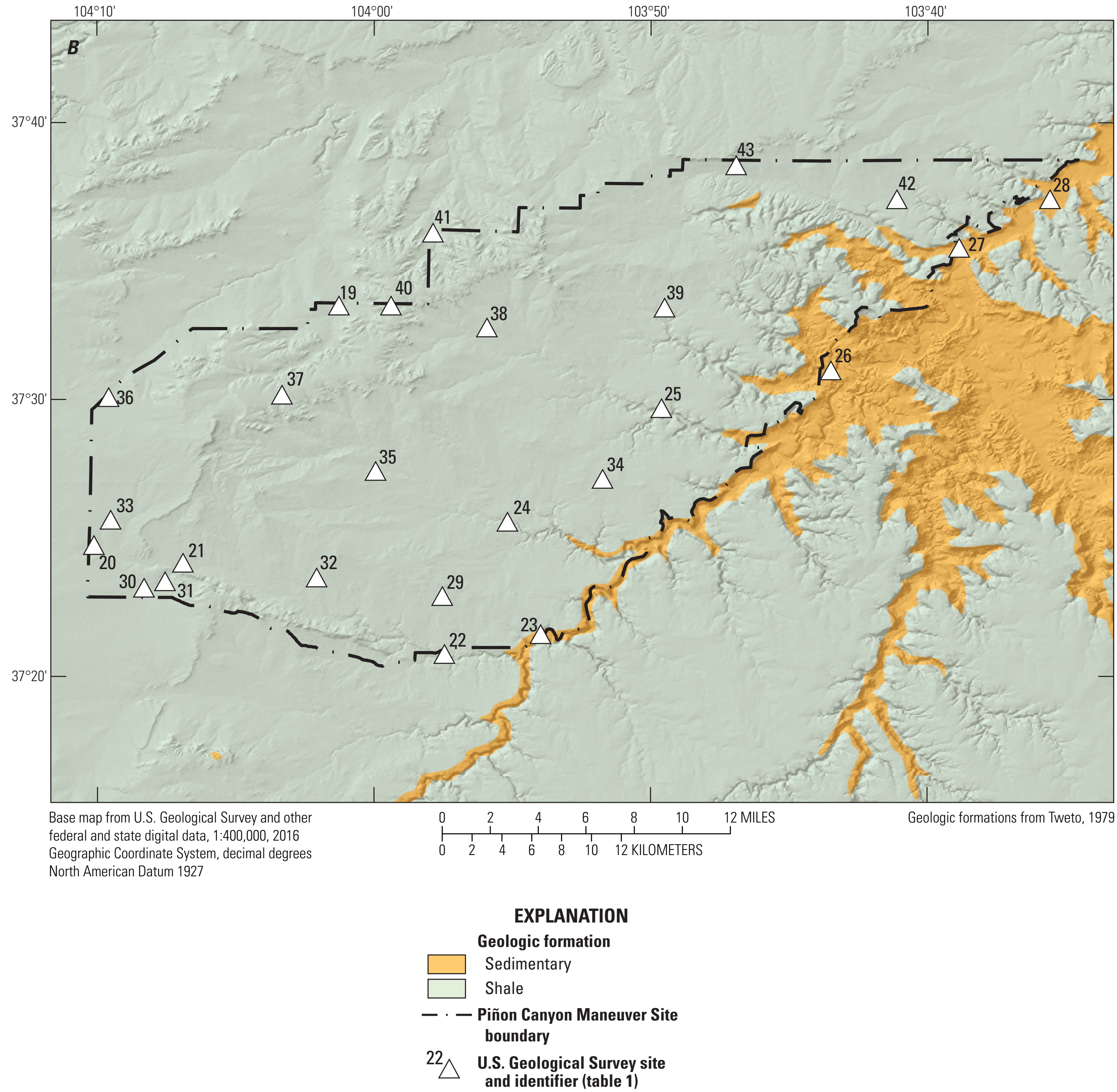


Figure 2. Map showing geologic formations and U.S. Geological Survey sites, Colorado. *A*, U.S. Army Garrison Fort Carson. *B*, Piñon Canyon Maneuver Site.—Continued

Streamflow

Streamflow at streamgaging stations was computed after developing a rating, or the relation of stage (the water-surface level in the stream relative to an established vertical datum) to streamflow for a particular location (Carter and Davidian, 1968; Kennedy, 1983; Turnipseed and Sauer, 2010). At a typical USGS streamflow site, stream stage is digitally recorded and transmitted at periodic intervals. Streamflow is measured across a wide range of stream stage. A streamflow rating is then developed. Based on the defined relation between stage and streamflow, recorded stream stage is converted to instantaneous streamflow. In the event that a gaging station malfunctions or stream stage goes above the maximum stage (or below the minimum stage) defined by the streamflow rating, instantaneous streamflow values are estimated by USGS hydrographers. These estimates are done using historical observations, data recorded at nearby streamgaging stations, and precipitation records. Streamflow data were collected continuously or seasonally at 16 USGS streamgaging stations from October 2012 through September 2014 (table 1). Instantaneous streamflow (in cubic feet per second [ft^3/s]) was measured, and daily mean streamflow was computed in accordance with standard USGS procedures described by Rantz and others (1982a, b). Measurements of instantaneous streamflow were made throughout the study period near the USGS streamgages at cross sections that had the most even distribution of streamflow. These measurements of streamflow were used to develop site-specific stage-discharge relations (rating curves) that were used to compute continuous streamflow data from the stage record associated with the 16 USGS streamgaging stations. Daily mean streamflow was acquired from USGS streamgage records (U.S. Geological Survey, 2013, 2014).

A crest-stage gage (CSG) is a peak-stage recorder often consisting of a vented steel pipe (Rantz and others, 1982a; Sauer and Turnipseed, 2010) that is installed at a stage-measurement station. When the stage rises, the water causes a small amount of cork dust contained within the steel pipe to float, which is deposited on a staff also contained inside the steel pipe. The cork-line must be measured relative to an established and maintained vertical datum by a hydrographer. Direct measurements are often challenging at CSGs because of the ephemeral nature of most sites; therefore, discharge measurements are often made using indirect discharge methods (Benson and Dalrymple, 1967). These measurements of streamflow by direct or indirect methods were used to develop site-specific stage-discharge relations (rating curves) that were used to compute peak streamflow (Rantz and others, 1982b; Kennedy, 1984).

Water Quality and Suspended-Sediment Concentration

Water-quality data were collected periodically at five sites on U.S. Army Garrison Fort Carson and three sites on the Piñon Canyon Maneuver Site (table 1; fig. 1), accounting for a total of 31 samples analyzed for water-chemistry data. In general, these samples were collected on a quarterly basis. If conditions warranted, routine water-chemistry samples were collected using standard equipment with width- and depth-integrating techniques (U.S. Geological Survey, variously dated). At the time of sampling, field measurements were made for dissolved oxygen, pH, specific conductance, and water temperature. All samples were collected, processed, and preserved in the field according to standard methods described in the National Field Manual by the U.S. Geological Survey (variously dated). These samples were analyzed at the USGS National Water Quality Laboratory (NWQL, Lakewood, Colo.) as described by Fishman (1993).

Escherichia coli and fecal coliform bacteria samples were collected in the field and then processed, incubated, and counted in the USGS Colorado Water Science Center Pueblo office laboratory as described by the U.S. Geological Survey (variously dated).

Suspended-sediment samples were collected as described by Edwards and Glysson (1988) at six stations and analyzed at the USGS Iowa Water Science Center Sediment Laboratory using methods described by Guy (1969). Discrete point samples were collected using automatic samplers installed at the selected streamgaging stations that were programed to collect sediment samples during rises and recessions in stream stage at or above a defined base stage and a defined rate of change in stage. Suspended-sediment concentrations obtained from samples collected at a single point within the cross section were adjusted based on relations developed from depth-integrated samples collected periodically using the equal-width-increment method (Koltun and others, 1994). All suspended-sediment samples were evaluated by the station hydrographer to determine if they were suitable for analysis by the USGS Iowa Water Science Center Sediment Laboratory. This procedure identifies underfilled or overfilled samples that could introduce concentration bias into the computation of the sediment record.

Analytical Methods

All samples were analyzed for physical properties, major ions, nutrients, trace elements, bacteria, and a radiochemical (table 2). Concentrations were reported in terms of laboratory reporting levels (LRLs), which the NWQL defines as equal to twice the yearly determined long-term method detection level (LT–MDL). The LT–MDL is a detection level derived by determining the standard deviation of 20 or more spike-sample measurements collected during an extended time. In September 2001, the USGS analytical laboratory began to calculate the LT–MDL using nonparametric statistics as described in Childress and others (1999). Yearly changes to the LT–MDL and, subsequently, the LRL were made if the values were different from the previous year. As a result, the LRLs in table 2 are presented as a range for some constituents.

Table 2. Analysis methods for water-quality properties and constituents.

[USGS, U.S. Geological Survey; ft^3/s, cubic foot per second; mg/L, milligram per liter; µS/cm at 25 °C, microsiemens per centimeter at 25 degrees Celsius; °C, degree Celsius; $CaCO_3$, calcium carbonate; SiO_2, silicon dioxide; N, nitrogen; MPN/100 mL, most probable number of colonies per 100 milliliters; --, not applicable; mg/L, microgram per liter]

Water-quality property or constituent	Parameter group	USGS parameter code	Units	Analytical methodology	Laboratory reporting level
Streamflow	Physical	00061	ft^3/s	Stage-discharge rating curve	0.01
Dissolved oxygen	Inorganics, major, nonmetals	00300	mg/L	Luminescence	0.1
pH, field	Physical	00400	standard pH units	Mulitprobe	0.1
Specific conductance	Physical	00095	µS/cm at 25 °C	Mulitprobe	1
Water temperature	Physical	00010	°C	Mulitprobe	0.1
Dissolved solids	Physical	70300	mg/L	Evaporation	20
Hardness as calcium carbonate	Physical	00900	mg/L $CaCO_3$	Calculated	1
Dissolved calcium	Inorganics, major, metals	00915	mg/L	Inductively coupled plasma	0.022
Dissolved magnesium	Inorganics, major, metals	00925	mg/L	Inductively coupled plasma	0.011
Dissolved potassium	Inorganics, major, metals	00935	mg/L	Inductively coupled plasma	0.03
Dissolved sodium	Inorganics, major, metals	00930	mg/L	Inductively coupled plasma	0.06
Dissolved chloride	Inorganics, major, nonmetals	00940	mg/L	Ion chromatography	0.02 to 0.06
Dissolved fluoride	Inorganics, major, nonmetals	00950	mg/L	Ion chromatography	0.01
Dissolved silica as SiO_2	Inorganics, major, nonmetals	00955	mg/L	Inductively coupled plasma	0.018
Dissolved sulfate	Inorganics, major, nonmetals	00945	mg/L	Ion chromatography	0.02 to 0.09
Dissolved ammonia	Nutrient	00608	mg/L	Colorimetry	0.01
Total ammonia	Nutrient	00610	mg/L	Colorimetry	0.02
Dissolved nitrite plus nitrate	Nutrient	00631	mg/L	Colorimetry	0.04
Dissolved orthophosphorus	Nutrient	00671	mg/L	Colorimetry	0.004
Dissolved phosphorus	Nutrient	00666	mg/L	Colorimetry	0.02
Total phosphorus	Nutrient	00665	mg/L	Colorimetry	0.004
Total nitrogen [nitrate + nitrite + ammonia + organic-N]	Nutrient	62855	mg/L	Colorimetry	0.05
Escherichia coli	Biological	50468	MPN/100 mL	Water, colilert	--
Total coliforms	Biological	50569	MPN/100 mL	Water, colilert	--
Dissolved aluminum	Inorganics, minor, metals	01106	µg/L	Inductively coupled plasma-mass spectrometry	2.2
Dissolved barium	Inorganics, minor, metals	01005	µg/L	Inductively coupled plasma-mass spectrometry	0.1 to 0.25
Dissloved beryllium	Inorganics, minor, metals	01010	µg/L	Inductively coupled plasma-mass spectrometry	0.006 to 0.02
Dissolved cadmium	Inorganics, minor, metals	01025	µg/L	Inductively coupled plasma-mass spectrometry	0.016 to 0.03
Dissolved chromium	Inorganics, minor, metals	01030	µg/L	Inductively coupled plasma-mass spectrometry	0.07 to 0.3
Dissolved cobalt	Inorganics, minor, metals	01035	µg/L	Inductively coupled plasma-mass spectrometry	0.023 to 0.05
Dissolved copper	Inorganics, minor, metals	01040	µg/L	Inductively coupled plasma-mass spectrometry	0.8
Dissolved Iron	Inorganics, minor, metals	01046	µg/L	Inductively coupled plasma-mass spectrometry	4
Dissolved lead	Inorganics, minor, metals	01049	µg/L	Inductively coupled plasma-mass spectrometry	0.025 to 0.04
Dissolved manganese	Inorganics, minor, metals	01056	µg/L	Inductively coupled plasma-mass spectrometry	0.15 to 0.4
Dissolved molybdenum	Inorganics, minor, metals	01060	µg/L	Inductively coupled plasma-mass spectrometry	0.014 to 0.5
Dissolved nickel	Inorganics, minor, metals	01065	µg/L	Inductively coupled plasma-mass spectrometry	0.09 to 0.2
Dissolved silver	Inorganics, minor, metals	01075	µg/L	Inductively coupled plasma-mass spectrometry	0.005 to 0.02
Dissolved zinc	Inorganics, minor, metals	01090	µg/L	Inductively coupled plasma-mass spectrometry	1.4 to 2
Dissolved antimony	Inorganics, minor, nonmetals	01095	µg/L	Inductively coupled plasma-mass spectrometry	0.027
Dissolved arsenic	Inorganics, minor, nonmetals	01000	µg/L	Inductively coupled plasma-mass spectrometry	0.04 to 0.1
Dissolved selenium	Inorganics, minor, nonmetals	01145	µg/L	Inductively coupled plasma-mass spectrometry	0.03 to 0.05
Dissolved uranium (natural)	Radiochemical	22703	µg/L	Inductively coupled plasma-mass spectrometry	0.004 to 0.014
Suspended sediment concentration	Physical	80154	mg/L	Filtration	1

Quality Assurance of Water-Quality Data

Quality-assurance samples were collected and analyzed to identify, quantify, and document bias and variability in the collection and processing of water-quality data (table 3). Sample processing was done primarily in a mobile USGS laboratory at the sampling site. Field blanks were collected to measure the effects of potential contamination by sampling and processing equipment and environmental conditions in the mobile laboratory. Quality-assurance samples were submitted to the NWQL for analysis. Three field blank samples analyzed for inorganic constituents were prepared with inorganic-grade blank water from the NWQL, where the water was quality assured for suitability in the testing of equipment and sampling. Results from three field blanks indicated one detection of dissolved cobalt and two detections of dissolved chloride near the LRL (table 3); however, blank detection concentrations were minimal, and contamination was not indicated in the associated environmental samples (U.S. Geological Survey, 2015).

All data have been published and are stored in the USGS National Water Information System (http://dx.doi.org/10.5066/F7P55KJN). In addition to field blank samples, two replicate samples were collected from sites at the Piñon Canyon Maneuver Site during the course of this study to assess the variability among samples resulting from collection, processing, and laboratory procedures completed at different sampling times (U.S. Geological Survey, variously dated). The results of the replicate samples are provided in table 3. The relative percent difference was calculated as the absolute difference between the replicate and original sample concentrations divided by the average of the two values, multiplied by 100. When constituent concentrations are low, small absolute differences between the original and replicate sample result in larger relative percent differences. Overall, the magnitude of the relative percent difference was within 10 percent for most constituents, and the mean combined relative percent difference of all constituent results was 4.61 percent. The results from these samples used in this report had acceptable ranges of relative percent

Table 3. Results of water analyses for quality-control samples collected at the Pinon Canyon Maneuver Site, Colorado, water years 2013–14.

[Orange shading indicates water-quality result values that exceeded the laboratory reporting level; ID, identifier; µS/cm at 25 °C, microsiemens per centimeter at 25 degrees Celsius; °C, degree Celsius; mg/L, milligram per liter; $CaCO_3$, calcium carbonate; OAQ, quality-control sample, artificial; --, no data; <, less than; E, estimated; WSQ, quality-control sample, surface water; SiO_2, silicon dioxide; N, nitrogen; P, phosphorus; µg/L, microgram per liter]

Site ID (table 1)	Date	Medium	Type of sample	pH (standard units)	Specific conductance (µS/cm at 25 °C)	Water temperature (°C)	Dissolved solids (mg/L)	Hardness (mg/L as $CaCO_3$)	Calcium, dissolved (mg/L)	Magnesium, dissolved (mg/L)	Potassium, dissolved (mg/L)
22	3/19/2014	OAQ	Field blank	--	--	--	<20	<0.10	<0.022	<0.011	<0.03
23	5/20/2013	OAQ	Field blank	E7.0	<10	--	<20	<0.10	<0.022	<0.011	<0.03
23	8/20/2014	WSQ	Replicate	8.4	2,080	23.4	1,810	923	192	108	7.83
28	3/27/2013	WSQ	Replicate	8.3	3,060	--	2,920	1,560	316	187	6.14
28	8/21/2014	OAQ	Field blank	--	--	--	<20	<0.10	<0.022	<0.011	<0.03

Site ID (table 1)	Date	Sodium, dissolved (mg/L)	Chloride, dissolved (mg/L)	Fluoride, dissolved (mg/L)	Silica, dissolved (mg/L as SiO_2)	Sulfate, dissolved (mg/L)	Ammonia, dissolved (mg/L as N)	Total ammonia (mg/L as N)	Dissolved nitrate plus nitrite (mg/L as N)	Orthophosphate, dissolved (mg/L as P)	Phosphorus, dissolved (mg/L as P)
22	3/19/2014	<0.06	0.05	<0.01	<0.018	<0.02	<0.01	<0.02	<0.040	<0.004	<0.02
23	5/20/2013	<0.06	<0.06	<0.01	<0.018	<0.09	<0.01	<0.02	<0.040	<0.004	<0.02
23	8/20/2014	167	35.5	0.44	7.11	1,010	<0.01	0.04	0.113	<0.004	<0.02
28	3/27/2013	242	52.1	0.36	3.17	1,710	0.01	0.06	<0.040	<0.004	<0.02
28	8/21/2014	<0.06	0.04	<0.01	<0.018	<0.02	<0.01	<0.02	<0.040	<0.004	<0.02

Site ID (table 1)	Date	Total phosphorus (mg/L as P)	Total nitrogen [nitrate + nitrite + ammonia + organic-N] (mg/L as N)	Aluminum, dissolved (µg/L)	Barium, dissolved (µg/L)	Beryllium, dissolved (µg/L)	Cadmium, dissolved (µg/L)	Chromium, dissolved (µg/L)	Cobalt, dissolved (µg/L)	Copper, dissolved (µg/L)	Iron, dissolved (µg/L)
22	3/19/2014	<0.004	<0.05	<2.2	<0.25	<0.020	<0.030	<0.30	0.119	<0.80	<4.0
23	5/20/2013	<0.004	<0.05	<2.2	<0.10	<0.006	<0.016	<0.07	<0.023	<0.80	<4.0
23	8/20/2014	0.058	0.65	2.8	95.1	<0.020	<0.030	<0.30	0.495	1.1	<8.0
28	3/27/2013	0.033	0.34	9.5	29.2	<0.018	<0.048	<0.21	0.756	<2.4	25.3
28	8/21/2014	<0.004	<0.05	<2.2	<0.25	<0.020	<0.030	<0.30	<0.050	<0.80	<4.0

Site ID (table 1)	Date	Lead, dissolved (µg/L)	Manganese, dissolved (µg/L)	Molybdenum, dissolved (µg/L)	Nickel, dissolved (µg/L)	Silver, dissolved (µg/L)	Zinc, dissolved (µg/L)	Antimony, dissolved (µg/L)	Arsenic, dissolved (µg/L)	Selenium, dissolved (µg/L)	Uranium [natural], dissolved (µg/L)
22	3/19/2014	<0.040	<0.40	<0.050	<0.20	<0.020	<2.0	<0.027	<0.10	<0.05	<0.014
23	5/20/2013	<0.025	<0.15	<0.014	<0.09	<0.005	<1.4	<0.027	<0.04	<0.03	<0.004
23	8/20/2014	<0.040	7.5	5.74	3.4	<0.020	<2.0	0.2	0.88	3.8	7.7
28	3/27/2013	<0.075	66.7	9.27	2.7	<0.015	<4.2	0.248	0.88	3.2	18.1
28	8/21/2014	<0.040	<0.40	<0.050	<0.20	<0.020	<2.0	<0.027	<0.10	<0.05	<0.014

differences, and all environmental data were retained and published in the USGS National Water Information System (http://dx.doi.org/10.5066/F7P55KJN).

Data Analysis

A variety of analyses and plotting techniques were used to characterize data types and evaluate the relation between selected parameters. Data were analyzed using descriptive statistics, such as summary statistics, and correlation analysis (Pearson's r and Spearman's rho [ρ]) (Helsel and Hirsch, 1992) was used to evaluate the strength and form of the associations among variable types. Spearman's ρ, which is based on ranks of values, was used because this measure can account for nonlinear relations. In addition, a p-value<0.05 (95-percent confidence that the statistical test is valid) was used to reject the null hypothesis for all tests. Boxplots were used to display constituent variability and provide a graphical method for making spatial comparisons between data collected from the U.S. Army Garrison Fort Carson, Piñon Canyon Maneuver Site, and among stream segments.

Characterization and Relation among Precipitation, Streamflow, and Water-Quality Data

The following sections characterize and describe the relation among the different types of hydrologic data collected at the U.S. Army Garrison Fort Carson and the Piñon Canyon Maneuver Site.

Precipitation

Analysis of spatial and temporal distribution of precipitation at the U.S. Army Garrison Fort Carson and the Piñon Canyon Maneuver Site (fig. 1) is constrained by the sparse distribution and unequal recording periods (table 4) of precipitation monitoring stations in the respective basins. Variations in the frequency of daily precipitation, seasonal distribution, and seasonal and annual precipitation at 5 stations at the Garrison and 18 stations at or near the Maneuver Site were evaluated (table 1) for 2013. Because of budget constraints, 3 of the precipitation monitoring stations at the Garrison and 10 at the Maneuver Site were discontinued after WY 2013. Seasonal and annual precipitation data were evaluated for WYs 2013 and 2014.

Precipitation Characteristics

Climate within the basins that contribute streamflow to the U.S. Army Garrison Fort Carson and the Piñon Canyon Maneuver Site (fig. 1) can be broadly characterized as semiarid temperate continental; however, it can vary from alpine arctic to semiarid, depending on the elevation (Hansen and others, 1978). Spatial distribution of precipitation on the U.S. Army Garrison Fort Carson and the Piñon Canyon Maneuver Site during WY 2013 was evaluated using isohyetal maps (fig. 3). The isohyetal maps indicate a general pattern of increase in total annual precipitation from east to west at the U.S. Army Garrison Fort Carson similar to the elevation gradient (fig. 3*A*). This pattern can be explained by the orographic effect of increasing precipitation with elevation as an air mass moving horizontally is forced to travel upslope in response to increasing land-surface elevation (Hansen and others, 1978). Several sites at the Piñon Canyon Maneuver Site were operated as seasonal stations and were discontinued from October through March; therefore, an analysis of the annual distribution of precipitation was not possible. The spatial distribution of precipitation at the Piñon Canyon Maneuver Site from April 1 through September 30, 2013, is represented in figure 3*B*. Despite censoring winter precipitation data from the Piñon Canyon Maneuver Site dataset, spatial precipitation patterns associated with changes in elevation are still evident. Many summertime storms are intense, local convectional storms driven by the inflow of subtropical moisture from the Pacific and Atlantic Oceans (Doesken and others, 1984) associated with seasonal monsoon-like airflow. In addition to the orographic effect of increasing precipitation with an increase in elevation, the intense, localized nature of summertime storms may, in part, explain the clumped distribution of spatial patterns of precipitation for WY 2013 as shown in figure 3.

The frequency of precipitation events of varying magnitudes was evaluated (tables 4 and 5) (Stogner, 2000). Among all precipitation monitoring stations at the U.S. Army Garrison Fort Carson and the Piñon Canyon Maneuver Site, between about 54 and 79 percent of daily precipitation was 0.1 in. or less in magnitude. Between about 74 and 89 percent of daily precipitation was less than or equal to 0.25 in. Between about 93 and 99 percent of daily precipitation was less than or equal to 1.0 and 3.0 in., respectively. Relatively large magnitude precipitation events greater than 1.0 and 3.0 in. were infrequent (less than 8 and 2 percent of the events, respectively). Interestingly, the record 24-hour precipitation amount for Colorado, 11.85 in., was measured at site 17 on September 12, 2013 (National Weather Service, 2015).

Temporal variations in precipitation at the U.S. Army Garrison Fort Carson and the Piñon Canyon Maneuver Site were evaluated (table 6). Data were stratified into quasiseasonal periods: winter, November through February; spring, March through June; and summer, July through October. In general, the number and intensity of storms producing precipitation increased from winter to spring and spring to summer, likely because of the onset of monsoon-like airflow bringing subtropical moisture from the Pacific and Atlantic Oceans (Paulson and others, 1991).

Streamflow

Daily streamflow data from 16 sites (fig. 1*A*, 1*B*; table 1) were used to evaluate temporal and spatial variations in streamflow for the U.S. Army Garrison Fort Carson and the Piñon Canyon Maneuver Site for WYs 2013–14 (fig. 4). In table 1, the operation of streamgaging stations are defined as seasonal or continuous recording gages. Data for these sites were evaluated

Table 4. Number of observations in days and cumulative percentage of daily values equal to or less than the defined magnitude of daily precipitation at U.S. Army Garrison at Fort Carson, Colorado, water years 2013–14.

[ID, identifier]

Observation	Number of observations, in days Site ID (table 1) 5	6	7	11	17
	Period of record				
Dry	315	298	375	309	382
Precipitation	84	95	168	83	161
Gage inactive	331	334	187	338	187
	Water year 2013				
Dry	288	280	263	289	263
Precipitation	77	85	102	76	102
Gage inactive	0	0	0	0	0
	Water year 2014				
Dry	27	21	112	20	119
Precipitation	7	10	66	7	59
Gage inactive	331	334	187	338	187
Magnitude, in inches of precipitation	**Percentage of daily precipitation values less than or equal to indicated magnitude for the period of record**				
0.10	78.6	67.4	61.3	62.7	59.0
0.25	89.3	86.3	76.2	85.5	76.4
0.50	97.6	92.6	86.9	90.4	82.6
0.75	98.8	94.7	89.9	95.2	88.8
1.00	98.8	95.8	94.0	96.4	93.8
2.00	100	98.9	98.2	97.6	98.1
3.00	100	98.9	98.8	98.8	99.4
5.00	100	100	99.4	100	99.4
10.0	100	100	100	100	99.4
12.0	100	100	100	100	100

for WYs 2013 and 2014 and for the 2-year period of record. Descriptive statistics, graphical methods, and Spearman's correlation analyses were used to summarize and analyze these data.

Streamflow Characteristics

Most of the gaged streams at the U.S. Army Garrison Fort Carson and the Piñon Canyon Maneuver Site are ephemeral or intermittent. Little Fountain Creek and Rock Creek on the U.S. Army Garrison Fort Carson and the Purgatoire River on the Piñon Canyon Maneuver Site have periods of substantial flow, but these streams often go dry (http://dx.doi.org/10.5066/F7P55KJN, search by USGS station number, table 1). These dry periods might happen because of diversions or during severe drought as reported by the National Oceanic and Atmospheric Administration at http://www.ncdc.noaa.gov/temp-and-precip/drought/historical-palmers/. Only site 22 (fig. 1*B*) at the Piñon Canyon Maneuver Site did not have at least 1 day with a daily mean streamflow of 0 ft^3/s in WY 2013 or 2014 (fig. 4*J*; table 7). At the U.S. Army Garrison Fort Carson, site 10 diverts water from Turkey Creek; sites 12, 14, and 15 divert water from Little Fountain Creek; and sites 13 and 18 divert water from Rock Creek (see USGS station names in table 1) when their respective water rights are in priority. The daily mean streamflow at 13 of the 16 sites was below 3.0 ft^3/s. Site 3 at the U.S. Army Garrison Fort Carson and sites 23 and 28 at the Piñon Canyon Maneuver Site were the exceptions. Many sites at the U.S. Army Garrison Fort Carson and the Piñon Canyon Maneuver Site had zero flow at the 25th percentile (table 7). During WYs 2013 and 2014, sites on the U.S. Army Garrison Fort Carson with zero flow at the 90th percentile had, on average, 702 days of zero flow during the 2-year period, whereas those at the Piñon Canyon Maneuver Site with zero flow at the 90th percentile had an average of 401 days of zero flow (table 7). The diversion pipe from Rock Creek to site 18 at the U.S. Army Garrison Fort Carson was destroyed during the flood in September of 2013 and remained broken through the end of WY 2014; therefore, no flow happened during WY 2014 at this site (fig. 4*I*). When comparing the number of days greater than or equal to the daily mean streamflow to the number of days below the daily mean streamflow at all sites on the U.S. Army Garrison Fort Carson and the Piñon Canyon Maneuver Site, sites 9 and 13 were the only two that did not have a difference greater than 60 days (table 7). This might suggest that large precipitation-producing storms did not have a substantial effect on the 2-year daily mean streamflow at these sites. This also demonstrates the unstable nature of streamflow among sites in these study areas.

As expected, the maximum instantaneous streamflows were largest at the sites with the largest contributing drainage areas, and the sites with the smallest drainage area had the largest drainage-area normalized instantaneous streamflow (table 7); furthermore, Pearson's correlation analysis indicated that the direct relation between maximum instantaneous streamflow and drainage area was statistically significant (p-value = 0.002, correlation coefficient = 0.881).

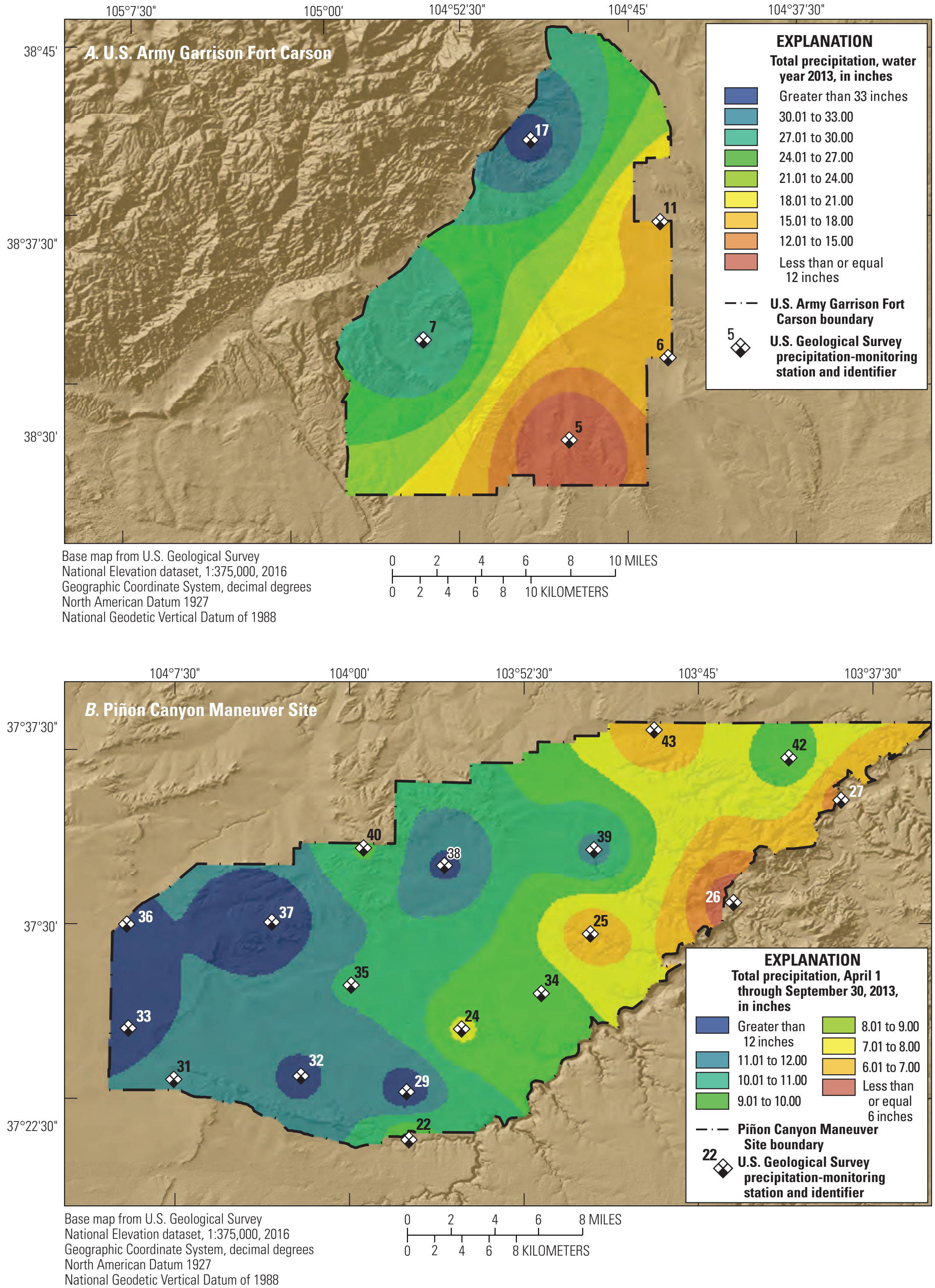


Figure 3. Maps showing isohyetal regions of total precipitation, Colorado. *A*, the U.S. Army Garrison Fort Carson for water year 2013. *B*, the Piñon Canyon Maneuver Site for April 1–September 30, 2013.

Table 5. Number of observations in days and cumulative percentage of daily values equal to or less than the defined magnitude of daily precipitation at the Piñon Canyon Maneuver Site, Colorado, water years 2013–14.

[ID, identifier]

Observation	Number of observations, in days — Site ID (table 1)																	
	22	24	25	26	27	29	31	32	33	34	35	36	37	38	39	40	42	43
	Period of record																	
Dry	328	330	328	326	326	316	460	322	332	325	421	317	328	410	416	327	310	408
Precipitation	100	98	100	102	102	85	109	78	68	75	121	85	72	129	124	75	91	131
Gage inactive	302	302	302	302	302	329	161	330	330	330	188	328	330	191	190	328	329	191
	Water year 2013																	
Dry	167	172	173	169	172	288	303	294	301	296	296	286	298	291	290	295	281	284
Precipitation	47	42	41	45	42	77	62	71	64	69	69	79	67	74	75	70	84	81
Gage inactive	151	151	151	151	151	0	0	0	0	0	0	0	0	0	0	0	0	0
	Water year 2014																	
Dry	161	158	155	157	154	28	157	28	31	29	125	31	31	119	126	32	30	124
Precipitation	53	56	59	57	60	8	47	7	4	6	52	6	5	55	49	5	7	50
Gage inactive	151	151	151	151	151	329	161	330	330	330	188	328	329	191	190	328	328	191
Magnitude, in inches of precipitation	**Percentage of daily precipitation values less than or equal to indicated magnitude for the period of record**																	
0.10	54.2	63.3	61.0	63.7	56.9	76.3	63.3	73.1	61.8	73.3	64.5	65.9	66.7	58.9	58.9	69.3	79.1	60.3
0.25	78.9	79.6	79.0	85.3	84.3	87.1	78.0	84.6	77.9	84.0	80.2	83.5	80.6	79.1	74.2	85.3	87.9	80.2
0.50	93.0	90.8	89.0	93.1	94.1	92.5	87.2	91.0	88.2	93.3	89.3	92.9	93.1	89.9	85.5	96.0	96.7	92.4
0.75	96.5	93.9	96.0	98.0	97.1	95.7	94.5	94.9	94.1	94.7	94.2	95.3	93.1	93.0	91.1	96.0	96.7	96.2
1.00	97.2	98.0	98.0	99.0	97.1	95.7	97.2	97.4	95.6	96.0	95.9	97.6	95.8	96.1	92.7	96.0	97.8	97.7
2.00	99.3	100	100	100	100	100	100	97.4	98.5	100	98.3	100	98.6	99.2	98.4	100	98.9	100
3.00	100	100	100	100	100	100	100	100	100	100	100	100	98.6	100	99.2	100	100	100
4.00	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

In table 7, the maximum daily mean streamflow at the U.S. Army Garrison Fort Carson ranged from 1.4 (site 9; fig. 4*C*) to 478 ft^3/s (site 3; fig. 4*A*). Of the nine U.S. Army Garrison Fort Carson sites, daily mean maximums were 3.0 ft^3/s or less at sites 9, 10, 14, 15, and 18 (figs. 4*C*, 4*D*, 4*G*, 4*H*, 4*I*). Sites 3, 4, 12, and 13 had higher and more variable maximum flows ranging from 13 to 478 ft^3/s (figs. 4*A*, 4*B*, 4*E*, 4*F*). At the Piñon Canyon Maneuver Site only sites 25–27 had maximum daily mean streamflow below 200 ft^3/s (figs. 4*M*, 4*N*, 4*O*); and sites 23 and 28 reached peaks greater than 3,000 ft^3/s (table 7; figs. 4*K*, 4*P*).

Because of the large range between the minimum and low percentile streamflows, and the maximum streamflow in table 7, the median of the daily mean streamflows was more indicative of normal conditions at these sites than the mean because the middle value (median) was not affected by outliers. At all sites, median daily mean streamflow for the 2-year period ranged from 0.0 to 9.60 ft^3/s (table 7). At the U.S. Army Garrison Fort Carson, sites 10, 12, 14, and 18 all had a median streamflow of 0.0 ft^3/s. The median daily mean streamflow was less than 1.0 ft^3/s at all other U.S. Army Garrison Fort Carson sites. At the Piñon Canyon Maneuver Site, sites 24–27 had median streamflows of 0.0 ft^3/s, and site 22 was near zero at 0.09 ft^3/s. Sites 23 and 28 had median streamflows of 6.90 and 9.60 ft^3/s, respectively.

Coefficients of variation (CV) were calculated by dividing the standard deviation at each site by the mean at each respective site. The CV is a dimensionless metric that expresses the variability of a sample relative to the mean (Zar, 1974). This allows for magnitude-independent comparison of variations among daily mean streamflow. In this study, CV values greater than 3.0 indicate greater variability of daily mean streamflow and suggest a strong surface-water response to environmental factors, such as intense precipitation.

The CV values at the U.S. Army Garrison Fort Carson ranged from 0.99 (site 9) to 18.87 (site 12). Sites 9 and 15 do not vary considerably with a CV of 0.99 and 1.0, respectively. The average CV for U.S. Army Garrison Fort Carson streamgages is 6.0 for the 2-year period. At the Piñon Canyon Maneuver Site, the CV ranged from 4.29 (site 28) to 9.87 (site 24), with an average CV of 7.02 (table 7).

Crest-Stage Gages

Five sites at the Piñon Canyon Maneuver Site were monitored for peak stage only: sites 19–21, 30, and 41 (fig. 1*B*; table 1). These streams were monitored using a CSG. Peak stage was converted to instantaneous streamflow using a stage-discharge rating developed for each site (Benson and Dalrymple, 1967; Rantz and others, 1982b; Kennedy, 1984; Saur and Turnipseed, 2010). If multiple peak storm stages were recorded, only the highest peak stage for each WY was published for these sites (table 8).

In WY 2013 a peak stage was recorded at all CSG sites. The highest computed streamflow was 2,010 ft^3/s at site 41 on September 15, 2013, and the lowest computed streamflow was 22.1 ft^3/s at site 30 on August 7, 2013. The remaining three sites recorded peak stage, and the computed flows ranged from 223 to 240 ft^3/s. In 2014, only sites 19 and 41 recorded peak stage (270 and 261 ft^3/s, respectively). The peak stage at both sites was recorded on July 28, 2014 (table 8). No CSG marks were recorded at the three other sites, and visits by hydrographers indicated no flow in 2014.

Table 6. Temporal distribution of days in which recorded precipitation was less than or equal to 0.1 inch, or greater than 0.1 inch, excluding days with no precipitation, U.S. Army Garrison Fort Carson, Colorado, and the Piñon Canyon Maneuver Site, Colorado, water years 2013–14.

[ID, identifier; ≤, less than or equal to; >, greater than; --, no data]

Site ID (table 1)	Daily magnitude, in inches of precipitation	November to February		March to June		July to October	
		Number of days during period	Percentage of days	Number of days during period	Percentage of days	Number of days during period	Percentage of days
U.S. Army Garrison Fort Carson							
5	≤0.1	20	23.8	16	19.0	30	35.7
	>0.1	0	0.0	7	8.3	11	13.1
6	≤0.1	17	17.9	19	20.0	28	29.5
	>0.1	1	1.1	7	7.4	23	24.2
7	≤0.1	21	12.5	38	22.6	44	26.2
	>0.1	3	1.8	15	8.9	47	28.0
11	≤0.1	11	13.3	15	18.1	26	31.3
	>0.1	1	1.2	8	9.6	22	26.5
17	≤0.1	19	11.8	38	23.6	38	23.6
	>0.1	0	0.0	20	12.4	46	28.6
Piñon Canyon Maneuver Site							
22	≤0.1	--	--	27	27.0	34	34.0
	>0.1	--	--	11	11.0	28	28.0
24	≤0.1	--	--	24	24.5	38	38.8
	>0.1	--	--	10	10.2	26	26.5
25	≤0.1	--	--	24	24.0	37	37.0
	>0.1	--	--	13	13.0	26	26.0
26	≤0.1	--	--	27	26.5	38	37.3
	>0.1	--	--	10	9.8	27	26.5
27	≤0.1	--	--	21	20.6	37	36.3
	>0.1	--	--	12	11.8	32	31.4
29	≤0.1	17	20.0	23	27.1	24	28.2
	>0.1	1	1.2	3	3.5	17	20.0
31	≤0.1	7	6.4	26	23.9	36	33.0
	>0.1	0	0.0	9	8.3	31	28.4
32	≤0.1	13	16.7	27	34.6	17	21.8
	>0.1	0	0.0	1	1.3	20	25.6
33	≤0.1	13	19.1	20	29.4	9	13.2
	>0.1	0	0.0	4	5.9	22	32.4
34	≤0.1	13	17.3	24	32.0	18	24.0
	>0.1	2	2.7	3	4.0	15	20.0
35	≤0.1	8	6.6	29	24.0	41	33.9
	>0.1	3	2.5	8	6.6	32	26.4
36	≤0.1	16	18.8	23	27.1	17	20.0
	>0.1	1	1.2	8	9.4	20	23.5
37	≤0.1	14	19.4	23	31.9	11	15.3
	>0.1	1	1.4	2	2.8	21	29.2
38	≤0.1	16	12.4	26	20.2	34	26.4
	>0.1	1	0.8	13	10.1	39	30.2
39	≤0.1	14	11.3	24	19.4	35	28.2
	>0.1	0	0.0	13	10.5	38	30.6
40	≤0.1	16	21.3	21	28.0	15	20.0
	>0.1	0	0.0	4	5.3	19	25.3
42	≤0.1	18	19.8	29	31.9	25	27.5
	>0.1	1	1.1	5	5.5	13	14.3
43	≤0.1	17	13.0	24	18.3	38	29.0
	>0.1	2	1.5	18	13.7	32	24.4

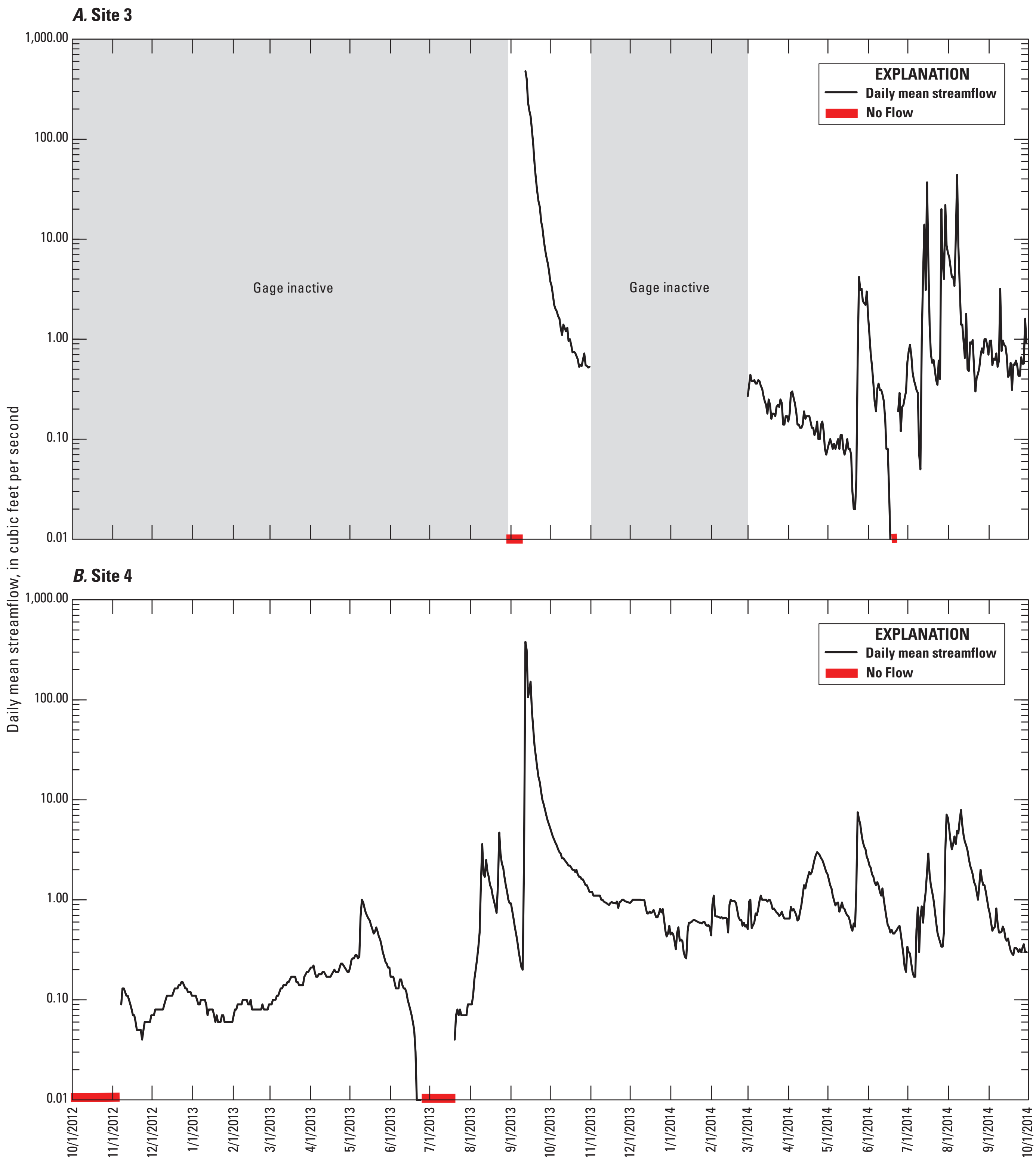
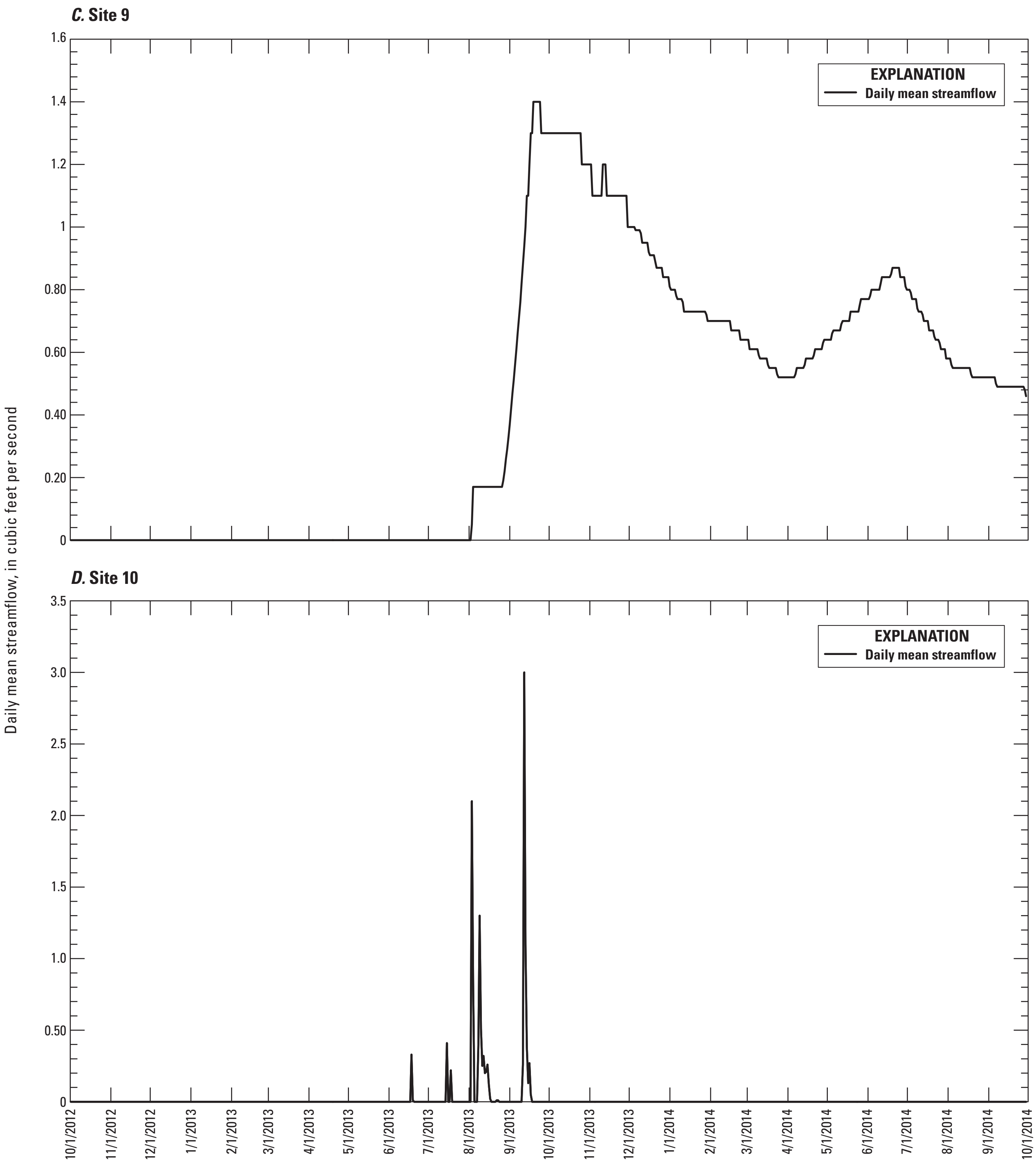


Figure 4. Hydrographs showing daily mean streamflow at the U.S. Army Garrison Fort Carson and the Piñon Canyon Maneuver Site, Colorado, water years 2013–14. See table 1 for site information. *A*, site 3. *B*, site 4. *C*, site 9. *D*, site 10. *E*, site 12. F, site 13. *G*, site 14. *H*, site 15. *I*, site 18. *J*, site 22. *K*, site 23. *L*, site 24. *M*, site 25. *N*, site 26. *O*, site 27. *P*, site 28.



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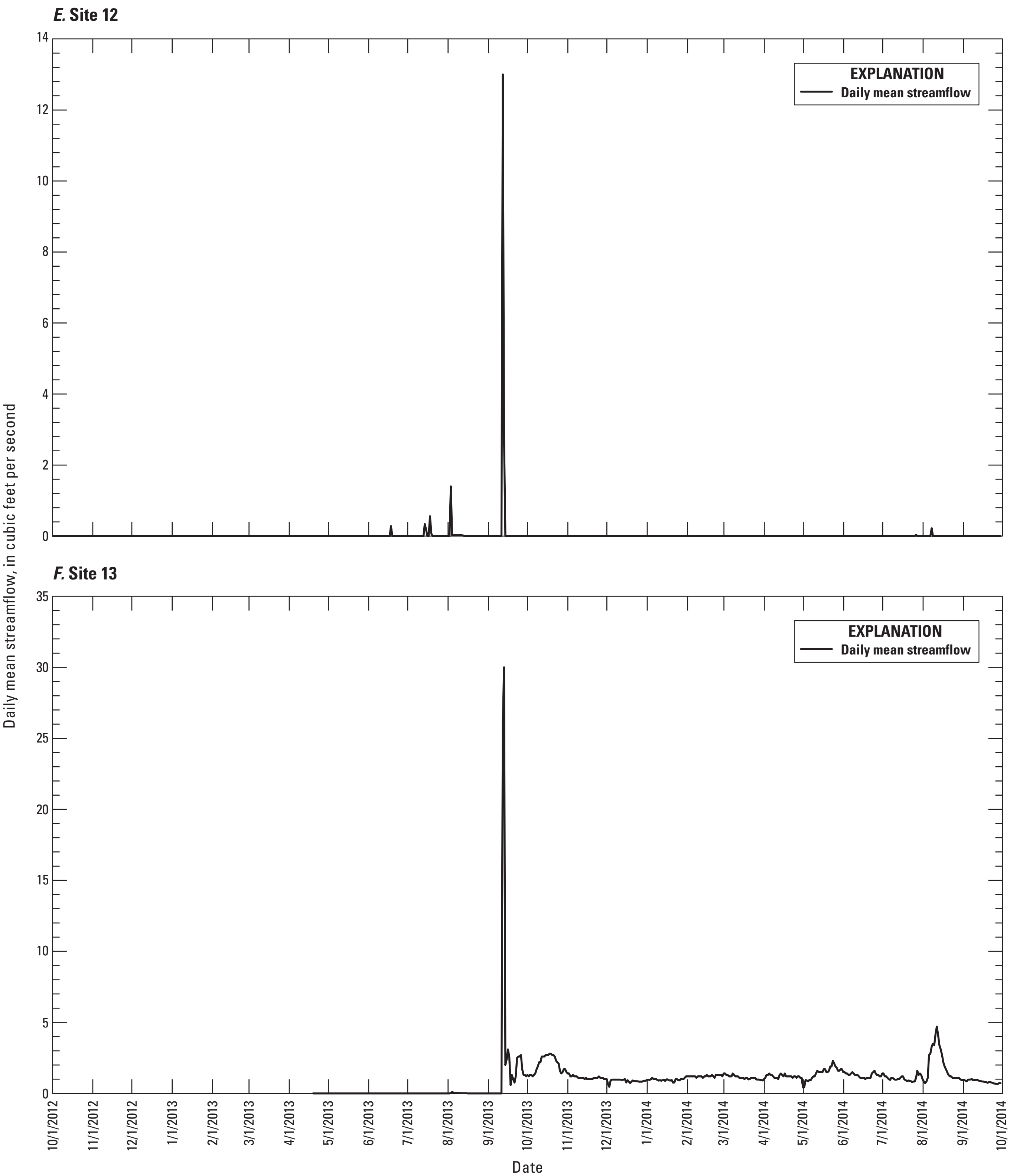

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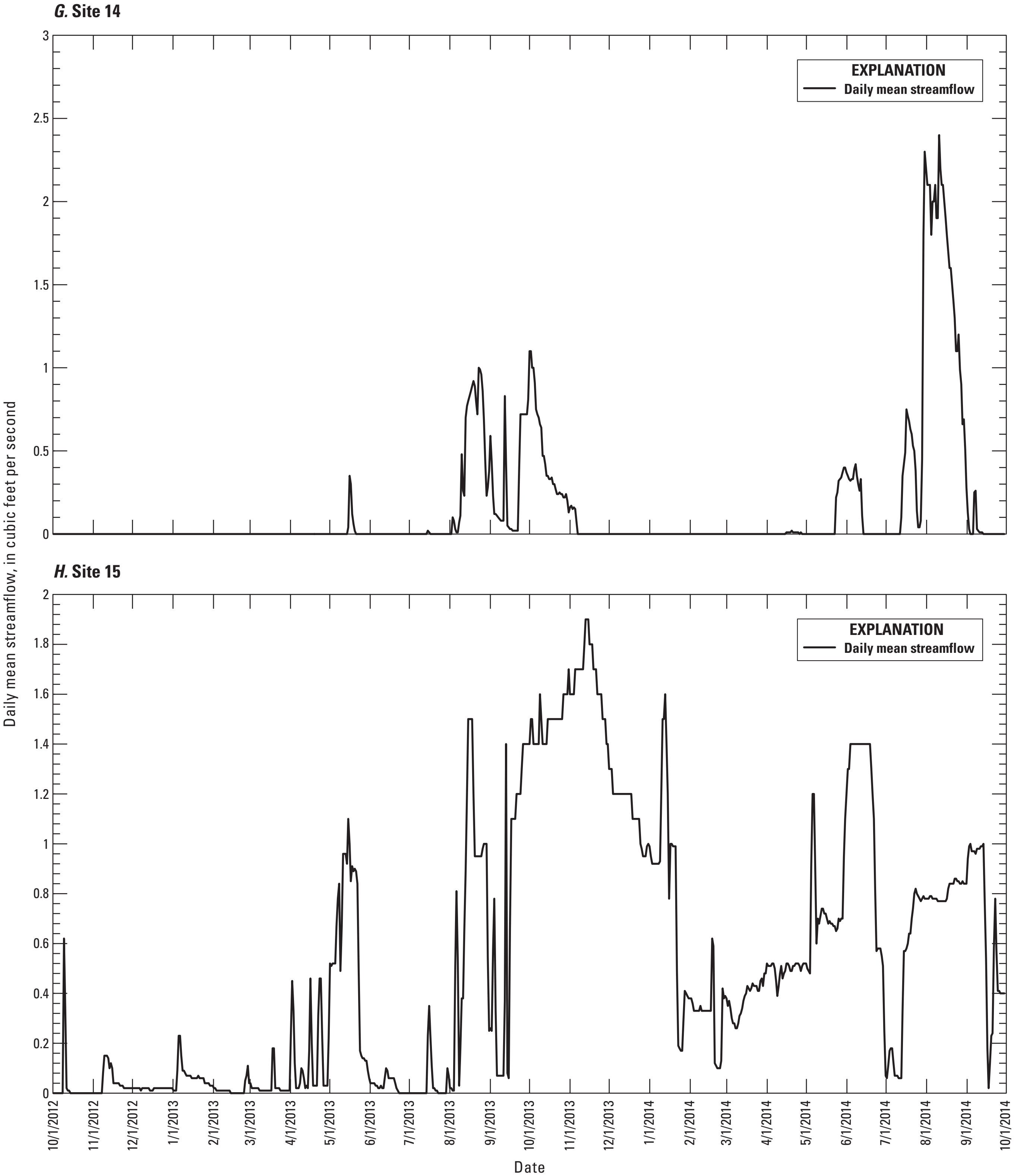

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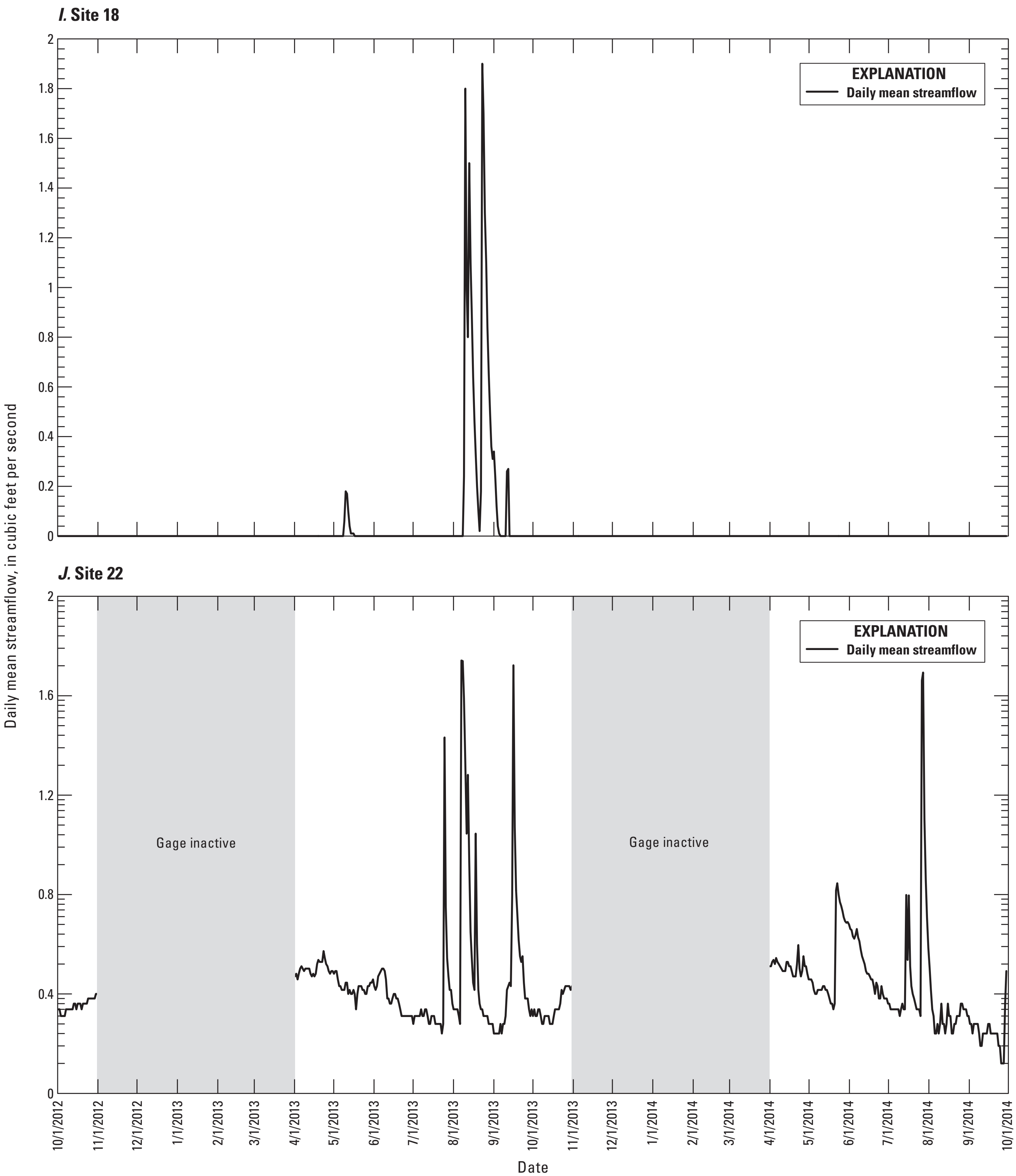

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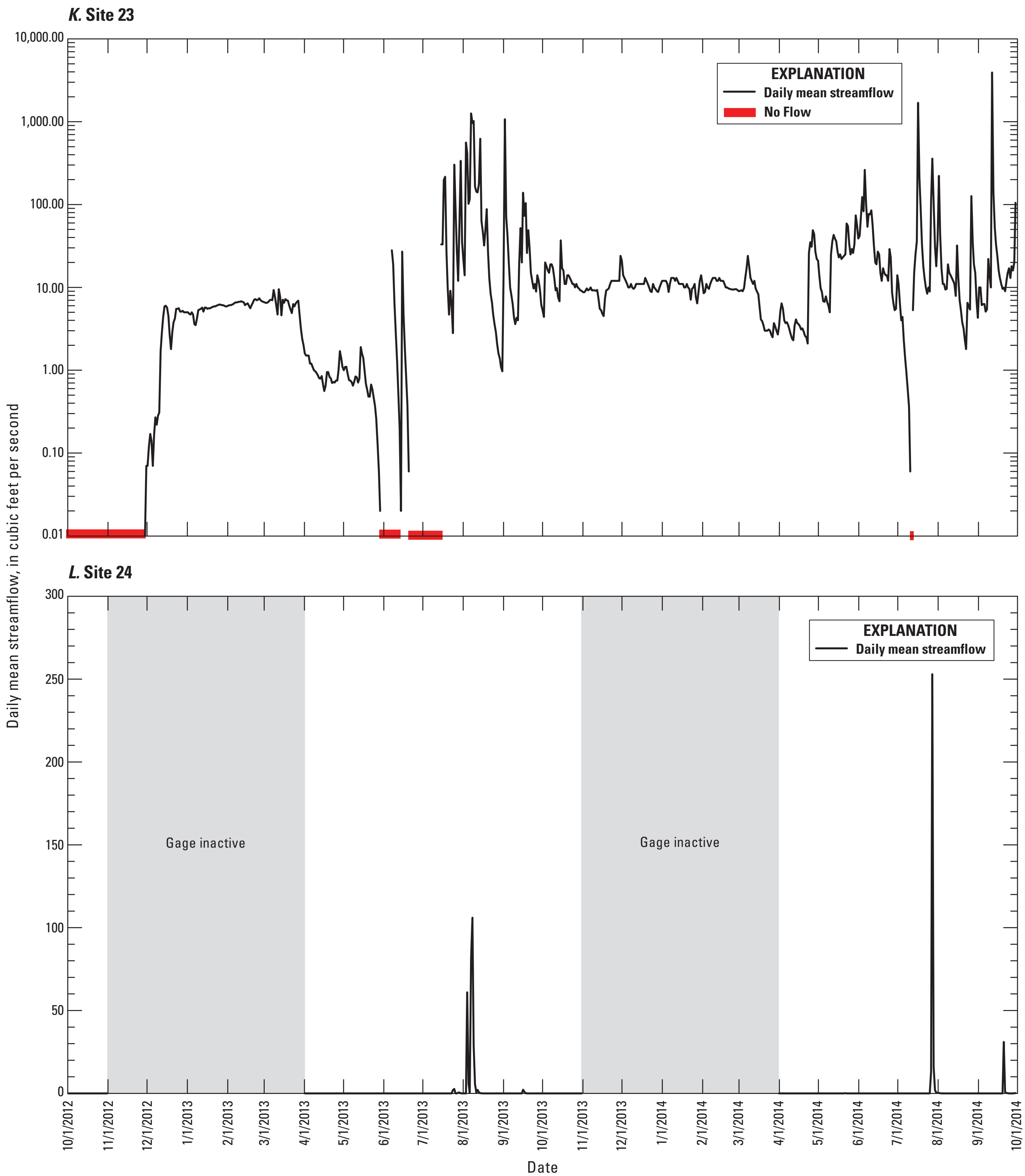

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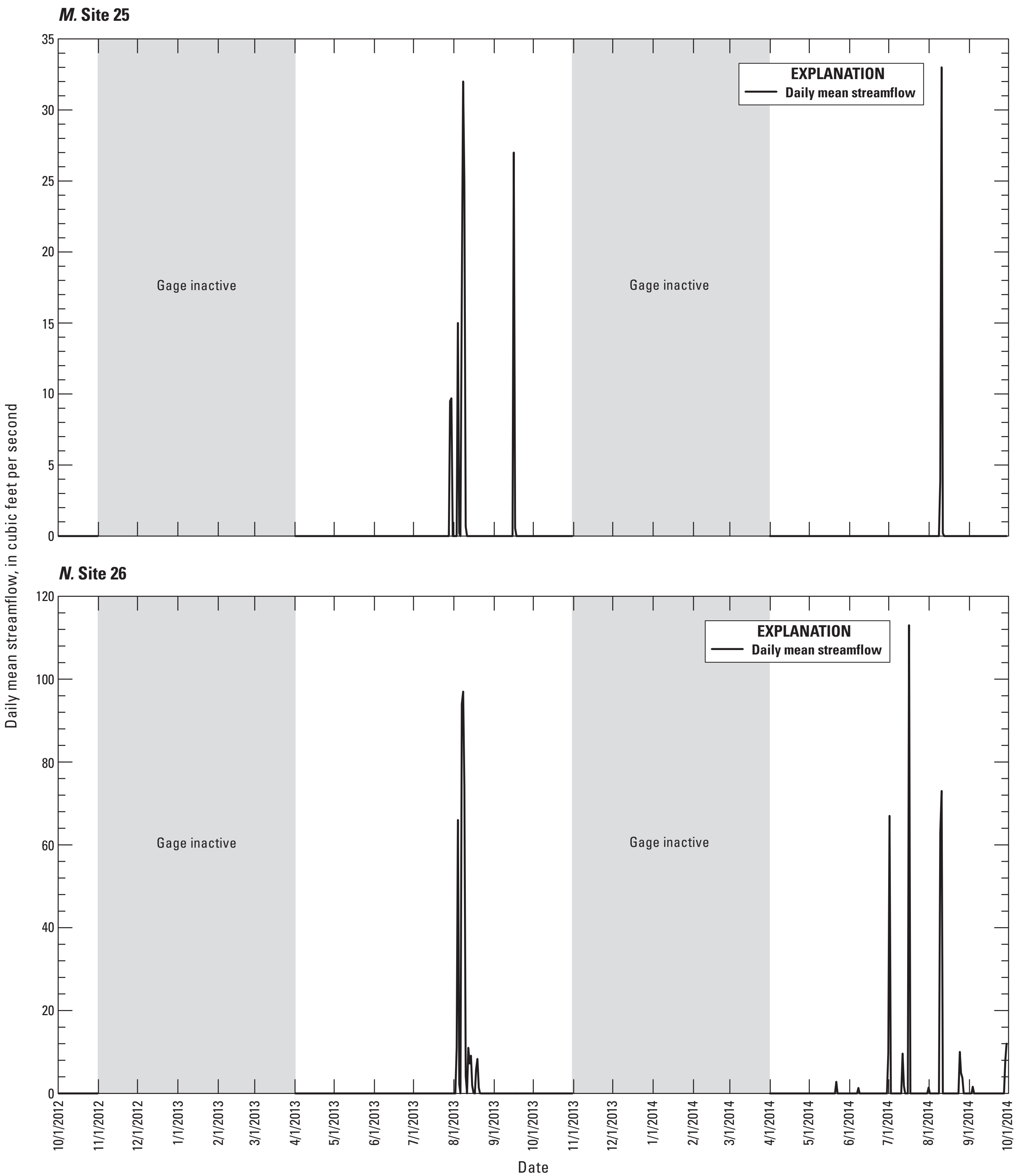

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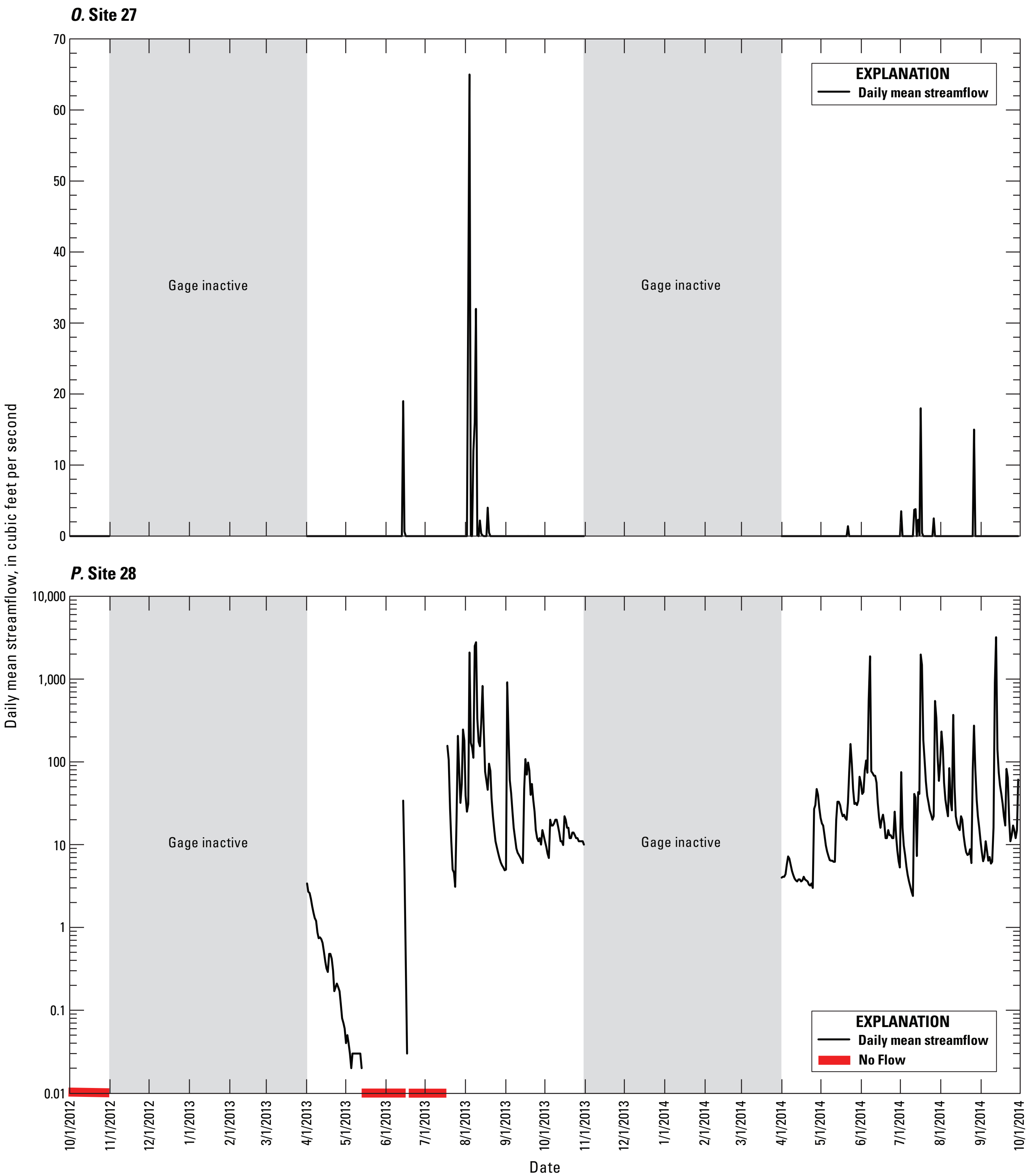

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Table 7. Descriptive statistics for streamflow data from U.S. Geological Survey surface-water sites at U.S. Army Garrison Fort Carson, Colorado, and the Piñon Canyon Maneuver Site, Colorado, water years 2013–14.

[ID, Identifier; NA, not applicable; E, estimated]

Statistic	Site ID (table 1), U.S. Army Garrison Fort Carson									Site ID (table 1), Piñon Canyon Maneuver						
	3[a]	4	9	10	12	13	14	15	18[b]	22	23	24	25	26	27	28
Daily mean stream discharge																
Minimum, in cubic feet per second	0	0	0	0	0	0	0	0	0	0.02	0	0	0	0	0	0
10th percentile, in cubic feet per second	0.08	0.05	0	0	0	0	0	0.01	0	0.05	0	0	0	0	0	0
25th percentile, in cubic feet per second	0.16	0.11	0	0	0	0	0	0.03	0	0.06	1.93	0	0	0	0	0.07
Median, in cubic feet per second	0.45	0.48	0.52	0	0	0.77	0	0.40	0	0.09	6.90	0	0	0	0	9.60
75th percentile, in cubic feet per second	1.00	1.00	0.73	0	0	1.20	0.01	0.92	0	0.17	12.8	0	0	0	0	30.3
90th percentile, in cubic feet per second	6.30	2.31	1.10	0	0	1.50	0.50	1.40	0	0.33	33.0	0	0	0	0	83.3
Maximum, in cubic feet per second	478	380	1.40	3.00	13.0	30.0	2.40	1.90	1.90	226	3,920	253	33.0	113	65.0	3,200
Mean, in cubic feet per second	8.24	2.65	0.43	0.02	0.03	0.75	0.15	0.53	0.03	2.84	31.1	1.45	0.41	1.81	0.55	71.8
Days greater than or equal to mean, in days	23	63	393	22	18	369	138	293	33	13	80	15	25	17	57	11
Days below mean, in days	253	667	337	708	712	361	592	437	697	415	650	413	403	411	371	417
Days of zero flow, in days	17	62	306	705	710	333	534	73	692	0	91	391	415	394	403	92
Standard deviation	43.7	20.3	0.43	0.16	0.50	1.63	0.40	0.53	0.17	21.6	182	14.3	3.10	11.3	4.23	308
Coefficient of variation	5.30	7.67	0.99	9.06	18.87	2.16	2.64	1.00	6.25	7.61	5.85	9.87	7.64	6.22	7.65	4.29
Instantaneous stream discharge																
Maximum instantaneous, in cubic feet per second	2,810	805	NA	NA	NA	NA	NA	NA	NA	2,420	17,000 E	2,220	406	1,340	2,100	11,000
Maximum normalized to drainage area, in cubic feet per second per square mile	105	118	NA	NA	NA	NA	NA	NA	NA	14.9	8.94 E	45.9	8.32	27.5	37.4	4.01

[a]Active for last 31 days of water year 2013 and all of water year 2014.

[b]Feeder pipe broken all of water year 2014, unable to flow.

Table 8. Peak stage and calculated peak streamflow at crest-stage gage sites at the Piñon Canyon Maneuver Site, Colorado, water years 2013–2014.

[ID, identifier; ft, foot; ft^3/s, cubic foot per second; --, no flow]

Site ID (table 1)	Water year 2013			Water year 2014		
	Date	Peak stage (ft)	Computed peak streamflow (ft^3/s)	Date	Peak stage (ft)	Computed peak streamflow (ft^3/s)
19	9/15/2013	3.97	223	7/28/2014	4.08	270
20	8/7/2013	8.15	236	--	--	--
21	8/7/2013	9.89	240	--	--	--
30	8/7/2013	5.35	22.1	--	--	--
41	9/15/2013	10.48	2,010	7/28/2014	6.93	261

Relation Between Precipitation and Streamflow

At the Piñon Canyon Maneuver Site, sites 22 and 24–27 had a stage recorder and precipitation gage, providing a paired streamflow-precipitation dataset. Daily value hydrographs plotted with daily precipitation hyetographs (fig. 5) and a nonparametric correlation test (table 9) were used to determine if relations exist between streamflow and precipitation at these five gages.

By comparing daily mean streamflow hydrographs with daily precipitation hyetographs for sites with paired streamflow-precipitation data, stream response to precipitation can be analyzed, assuming that the precipitation recorded at the gage is representative of precipitation in the drainage area upstream from the gage. At all five sites, many of the larger precipitation events showed a corresponding rise in streamflow; however, sometimes rises in streamflow had no corresponding precipitation, or a small precipitation event relative to the magnitude of the hydrograph spike (for example, fig. 5*J*, August 27, 2014). This might be due to sites being at or near the downstream point of each basin, variable precipitation distribution, and precipitation occurring in upstream, ungaged areas of the basin. In other cases, large amounts of precipitation did not cause a rise in streamflow (fig. 5*D*, May 22, 2014), which might suggest some other factor caused a lack of stream response to precipitation, such as rapid infiltration, seasonal soil-moisture deficits, variable precipitation distribution, or effective runoff detention in erosion ponds within the basins. Site 22 shows a more correlated and responsive rainfall-runoff pattern than other streams (fig. 5*A*, 5*B*). A more constant base flow at site 22 may mitigate potential streamflow losses to channel alluvium in this stream compared to the more intermittent or ephemeral streams in the study areas.

Correlation analysis (Spearman's ρ) was used to evaluate the strength and form of the relation between daily mean streamflow and daily total precipitation using Minitab (Minitab, Inc., 2004). Spearman's ρ values indicate the strength and form of the relation between streamflow and precipitation, and *p*-values indicate the statistical significance of the test. For all tests completed, *p*-values were less than 0.001. Spearman's ρ values ranged from 0.17 (sites 22 and 25) to 0.35 (site 27) (table 9). Although all tests indicated a significant positive relation between streamflow and precipitation, the strength of the relations were low based on the maximum ρ value. The ephemeral nature of these streams, variable precipitation distribution, and the inconsistent conversion of precipitation to streamflow likely contributed to the low Spearman's ρ values for these analyses.

Relation Between Streamflow and Suspended-Sediment Concentration

Suspended-sediment samples were collected from April through October in 2013 and 2014 at six sites on the U.S. Army Garrison Fort Carson (one) and the Piñon Canyon Maneuver Site (five) (table 1). Suspended-sediment concentration and streamflow were subdivided using the Graphical Constituent Loading Analysis System program to compute the daily mean suspended-sediment concentration (in milligrams per liter) and suspended-sediment discharge (in tons per day) (Koltun and others, 1994). Data for all suspended-sediment sites are published in the annual Water-Resources Data Report (U.S. Geological Survey, 2013, 2014). Suspended-sediment discharge in a stream is the result of erosion and sediment-transport rates that happen throughout a basin. Certain tributaries discharge large quantities of suspended sediment to a stream and others discharge small quantities. Additionally, in-channel processes erode streambanks, mobilize (scour) streambed sediments, and deposit (fill) streambed sediments.

Suspended-sediment concentration data from one site at the U.S. Army Garrison Fort Carson and five sites at the Piñon Canyon Maneuver Site are presented here. Sediment-transport curves (fig. 6) show the relation between streamflow (in cubic feet per second) and suspended-sediment concentration (in milligrams per liter). The number of samples collected depends on the number of precipitation events, the length of the storm hydrograph, site-specific stream-stage thresholds, and access to the site under variable road and weather conditions. In WY 2013, the number of samples collected at each site ranged from 19 to 46, and in WY 2014, the range of samples was 10 to 99 (fig. 6). Suspended-sediment-transport curves can be used to estimate the concentration of suspended sediment at a given location and streamflow. Regressions drawn from these data (appendix 1) using Microsoft Excel (Microsoft, 2010) are represented as a power function and plot linearly on a logarithmic scale. The mean coefficient of determination (R^2) of the relation between streamflow

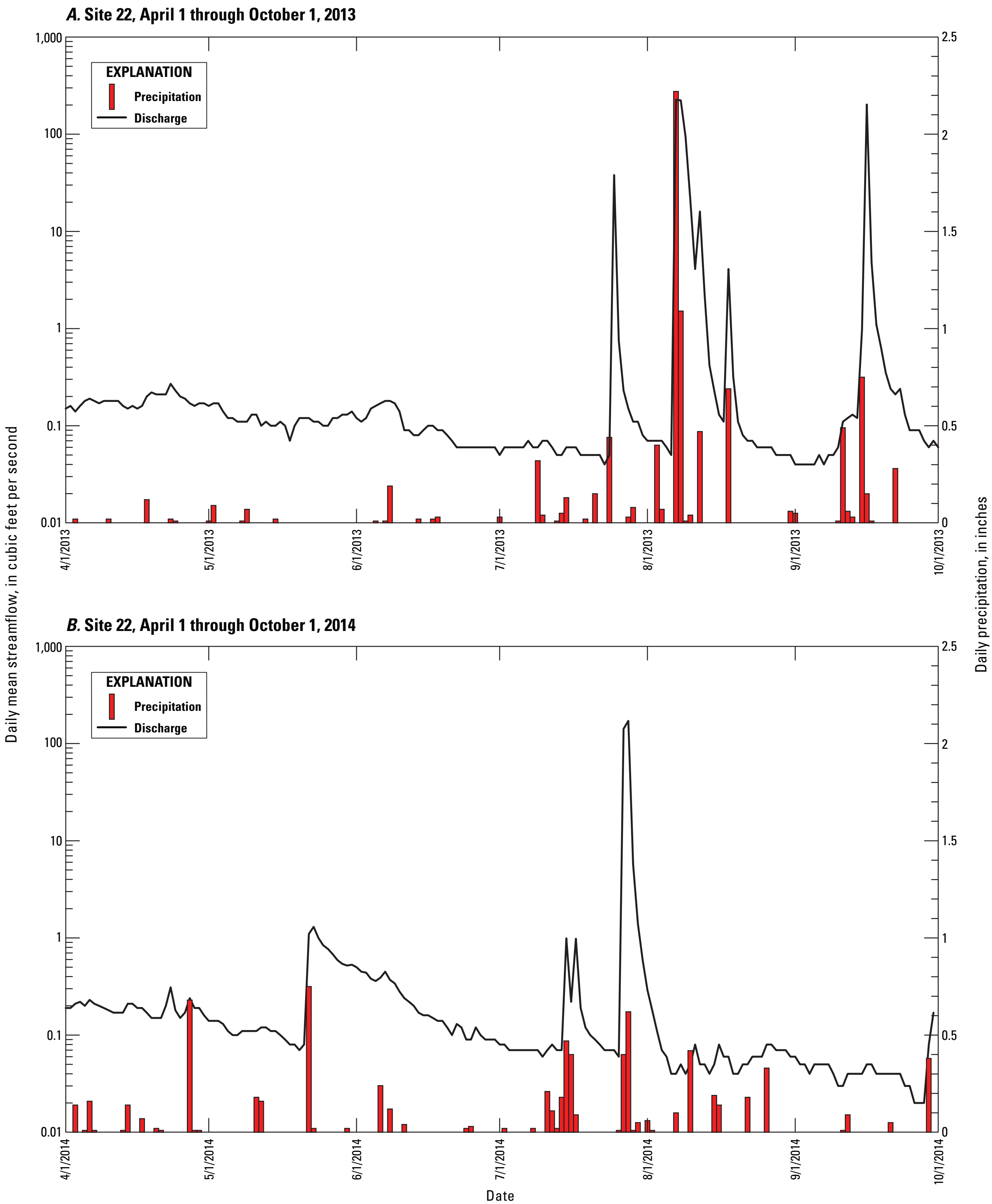
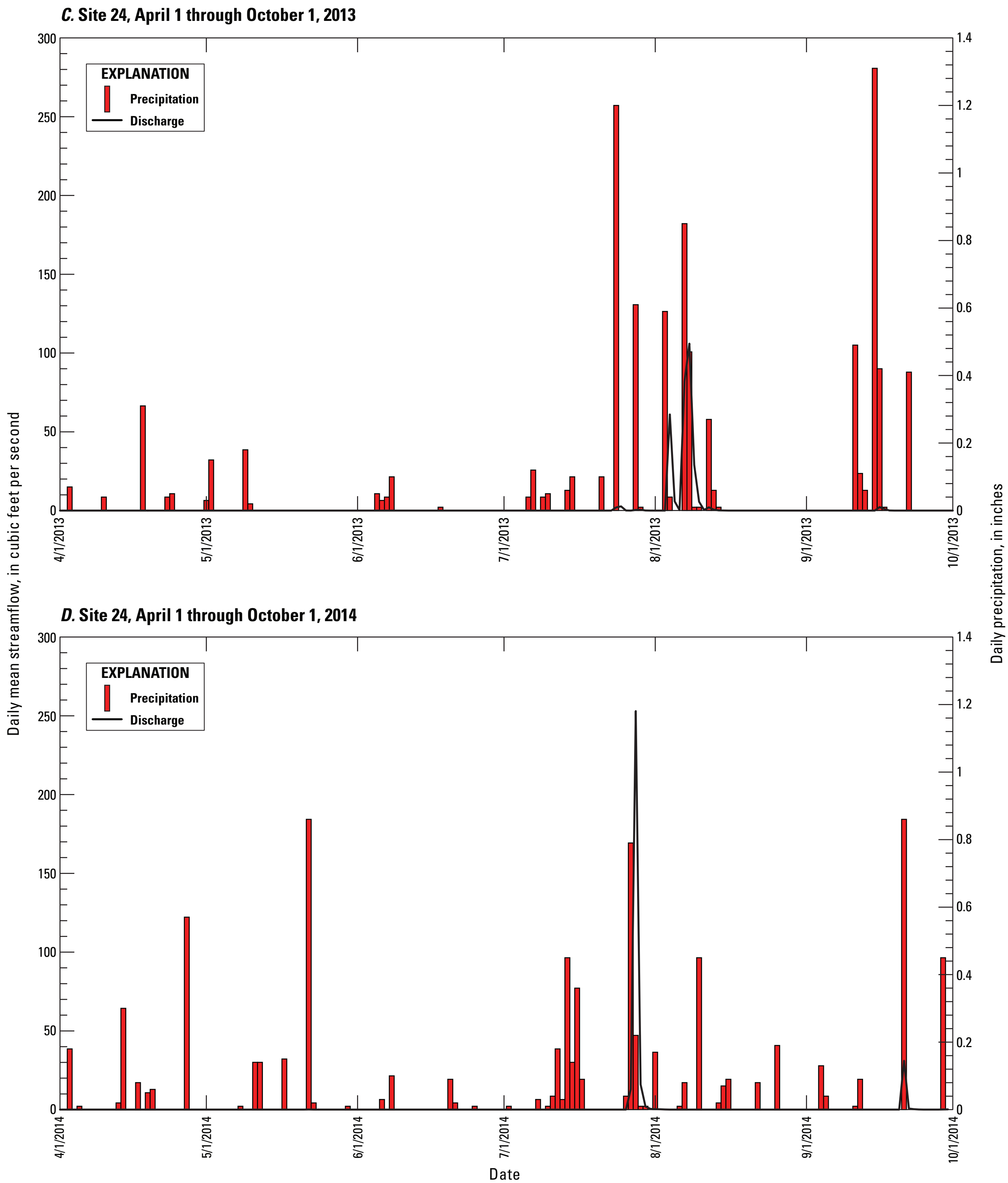


Figure 5. Hydrographs showing daily mean streamflow plotted with daily precipitation hyetographs for the Piñon Canyon Maneuver Site, Colorado, April 1 through October 1 of water year 2013 or 2014. See table 1 for site information. *A*, site 22, 2013. *B*, site 22, 2014. *C*, site 24, 2013. *D*, site 24, 2014. *E*, site 25, 2013. *F*, site 25, 2014. *G*, site 26, 2013. *H*, site 26, 2014. *I*, site 27, 2013. *J*, site 27, 2014.



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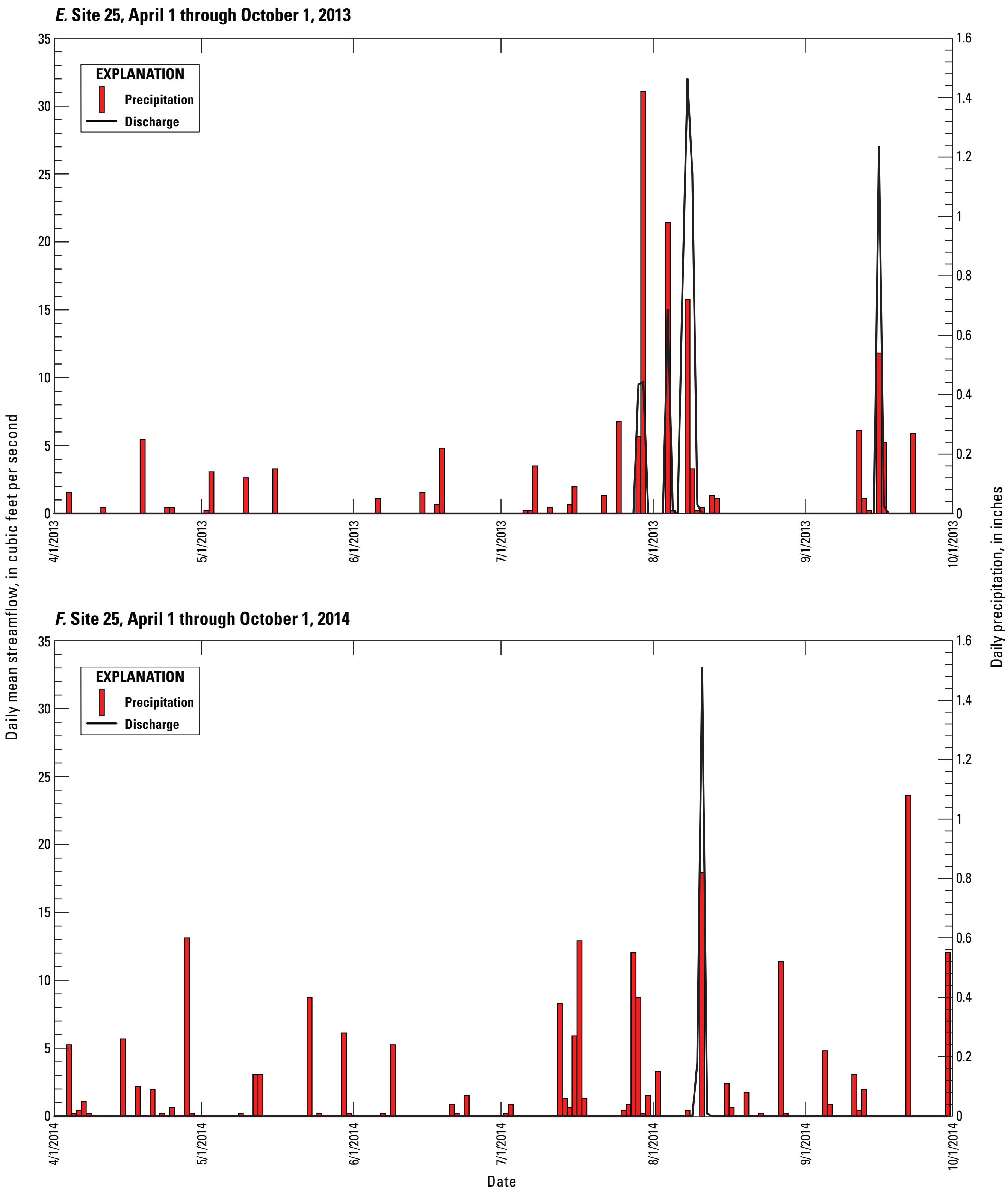

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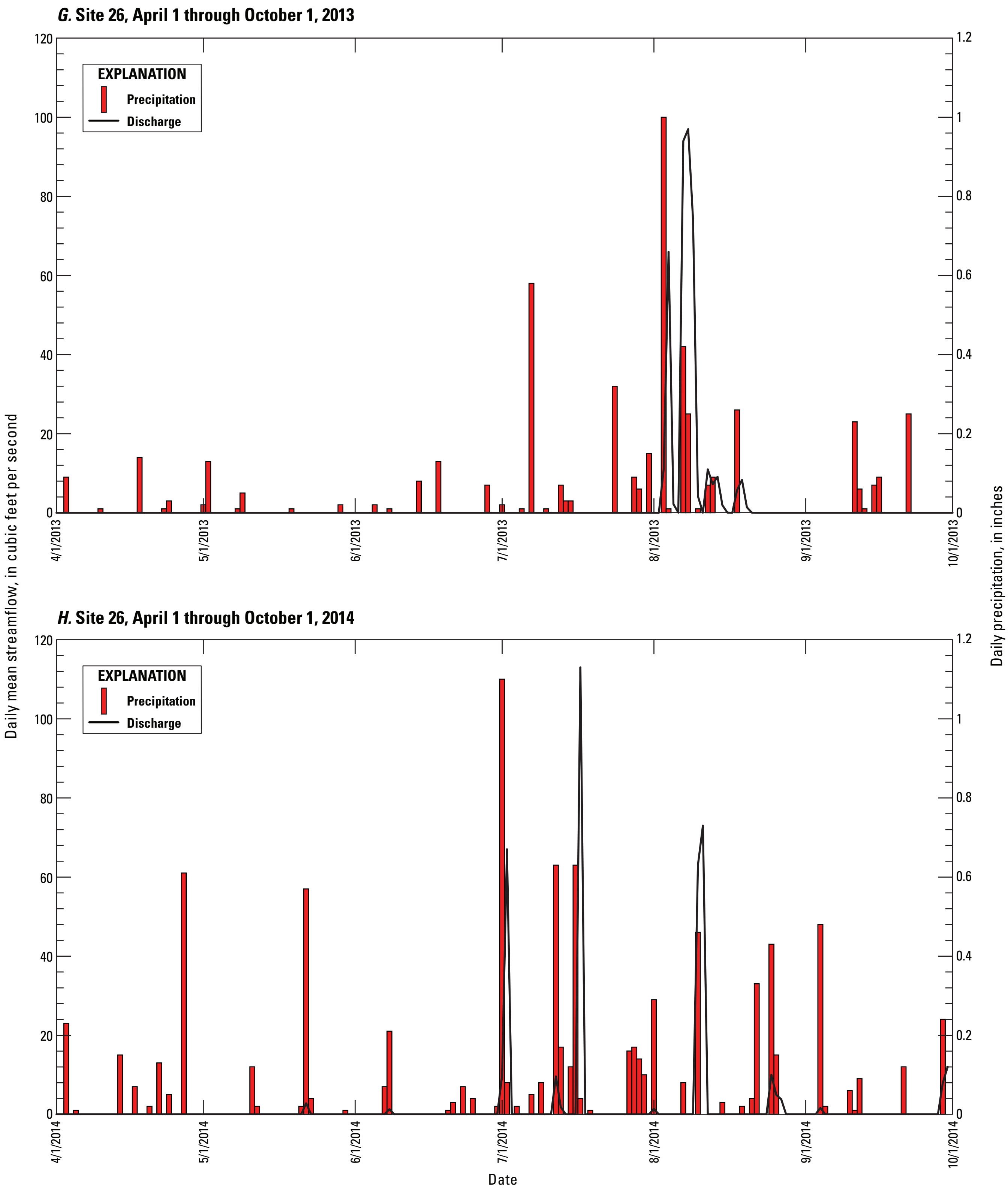

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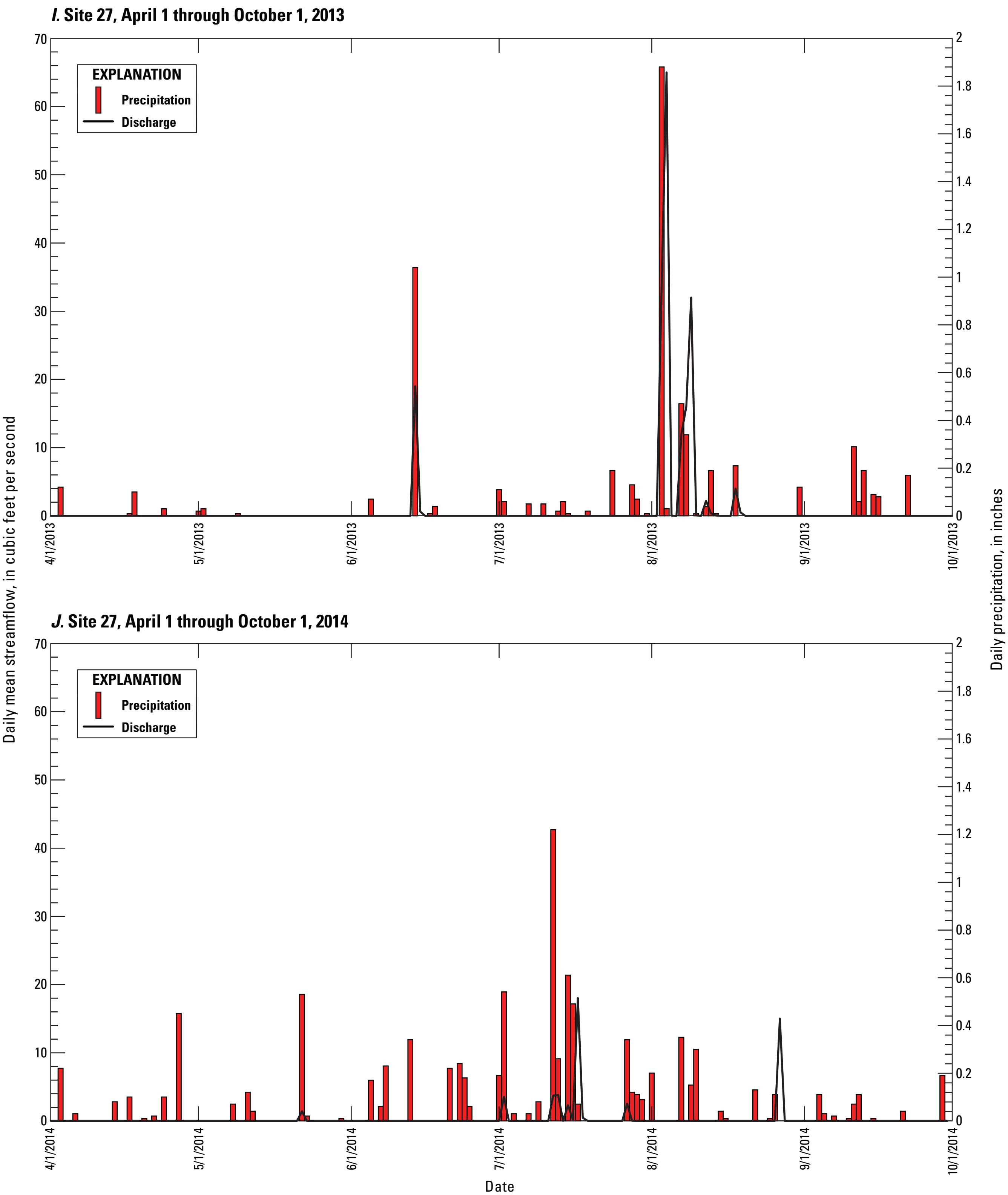

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Table 9. Results from Spearman's rho correlation analysis for sites at the Piñon Canyon Maneuver Site, Colorado, with paired daily streamflow and precipitation data, water years 2013–2014.

[ID, identifier; <, less than]

Correlation analysis	Site ID (table 1) 22	24	25	26	27
rho	0.17	0.27	0.17	0.31	0.35
p-value	0.0004	<0.0001	0.0004	<0.0001	<0.0001

and suspended-sediment concentration computed for the six sites in WY 2013 was 0.50. At site 27, the R^2 value was 0.01 (fig. 6*F*), and the R^2 value at the remaining five sites ranged from 0.46 (sites 24 and 26; figs. 6*C*, 6*E*) to 0.86 (site 3; fig. 6*A*). In WY 2014 the mean R^2 value was 0.62. Excluding site 27 (R^2=0.01), the R^2 values ranged from 0.58 (site 26; fig. 6*E*) to 0.97 (site 25; fig. 6*D*). At site 27, the R^2 values were less than 0.01 for each WY (fig. 6*F*) and 0.07 for the combined 2-year period, indicating these sediment-transport curves show no streamflow dependent suspended-sediment concentration relation (fig. 6*F*). Further investigation is needed to determine why there is no relation between suspended-sediment concentration and streamflow at site 27.

Water-Quality

This section of the report summarizes and characterizes the physical, biological, and chemical data collected on the U.S. Army Garrison Fort Carson and the Piñon Canyon Maneuver Site during WYs 2013 and 2014. These data were compared to established water-quality criteria and used to determine water type.

Water-Quality Sample Results

The Colorado Department of Health and Environment Water Quality Control Commission in Regulation Numbers 31 and 32, Classification and Numeric Standards for the Arkansas River Basin (Colorado Department of Public Health and Environment, Water Quality Control Commission, 2013, 2015), established stream classifications and water-quality standards for the surface waters of Colorado (Regulation Number 31) and the Arkansas River Basin (Regulation Number 32). These numeric water-quality standards apply to all flowing and standing waters within the Arkansas River Basin and apply to physical, biological, and chemical characteristics, and the allowable standards were set based on the designated beneficial uses of the water. Within this classification scheme, streams with Cold Water and Warm Water biota are considered separately. All sites in this report are classified as Aquatic Life Warm Water Class 1 or 2, except for sites 1 and 2, which are Aquatic Life Cold Water Class 2. These two sites are in stream segment 14d in the Upper Arkansas River Basin as defined in Regulation 32.

Some constituent concentrations were reported below the LRL and are considered censored (shown in numeric form as less than values). Helsel and Hirsch (1992) described several methods to estimate summary statistics when data include censored values. The approach used in this report was to compare censored water-quality data to instream water-quality standards using the LRL as the estimated concentration. This methodology produced a conservative (worst case) estimate of the constituent concentration. Boxplots were also plotted using the LRL as the estimated concentration, again providing the worst-case estimate of the constituent concentration (fig. 7).

The water-quality properties and constituents in this report include physical properties, biological, major ions, nutrients, trace elements (inorganics, minor ions, and metals), and a radiochemical. This section of the report summarizes and compares water-quality data collected during WYs 2013 and 2014 from a network of sites on the U.S. Army Garrison Fort Carson and the Piñon Canyon Maneuver Site (figs. 1*A*, 1*B*; table 1). The measured properties and constituents are presented in table 10. These water-quality standards were determined by the State of Colorado as described above, and are statewide, basinwide, or standards specific to defined stream segments in the Upper, Middle, and Lower Arkansas River Basin, as well as the Fountain Creek Basin (Colorado Department of Public Health and Environment, Water Quality Control Commission, 2013, 2015). The sites in this report are distributed in the following stream basins and stream segments (table 1): In the Upper Arkansas River Basin, sites 1 and 2 are in stream segment 14d; in the Fountain Creek Basin, sites 3, 8, and 16 are in stream segment 4; and in the Lower Arkansas River Basin, site 22 is in stream segment 9a, and sites 23 and 28 are in stream segment 7. Selected water-quality properties and constituents were stratified by military installation or stream segment to compare spatial or geographic variation among selected characteristics using boxplots. Where applicable, boxplots in figure 7 contain dashed horizontal lines indicating water-quality thresholds.

As defined by Regulations 31 and 32, thresholds for all of the selected characteristics except total phosphorus were consistent throughout the Arkansas River Basin; thus, the water-quality characteristics (except total phosphorus) were compared at a coarser geographic level based on military installation (the U.S. Army Garrison Fort Carson compared to the Piñon Canyon Maneuver Site). Regulation 32, however, defines thresholds for total phosphorus by stream segment; therefore, distributions of total phosphorus were compared by stream segment. The high value in figure 7*I* for total phosphorus at site 1 in stream segment 14d was collected during a storm; furthermore, two of the selected characteristics, specific conductance (fig. 7*C*) and dissolved solids (fig. 7*F*), did not have regulated thresholds but did demonstrate a separation of the waters between the military installations.

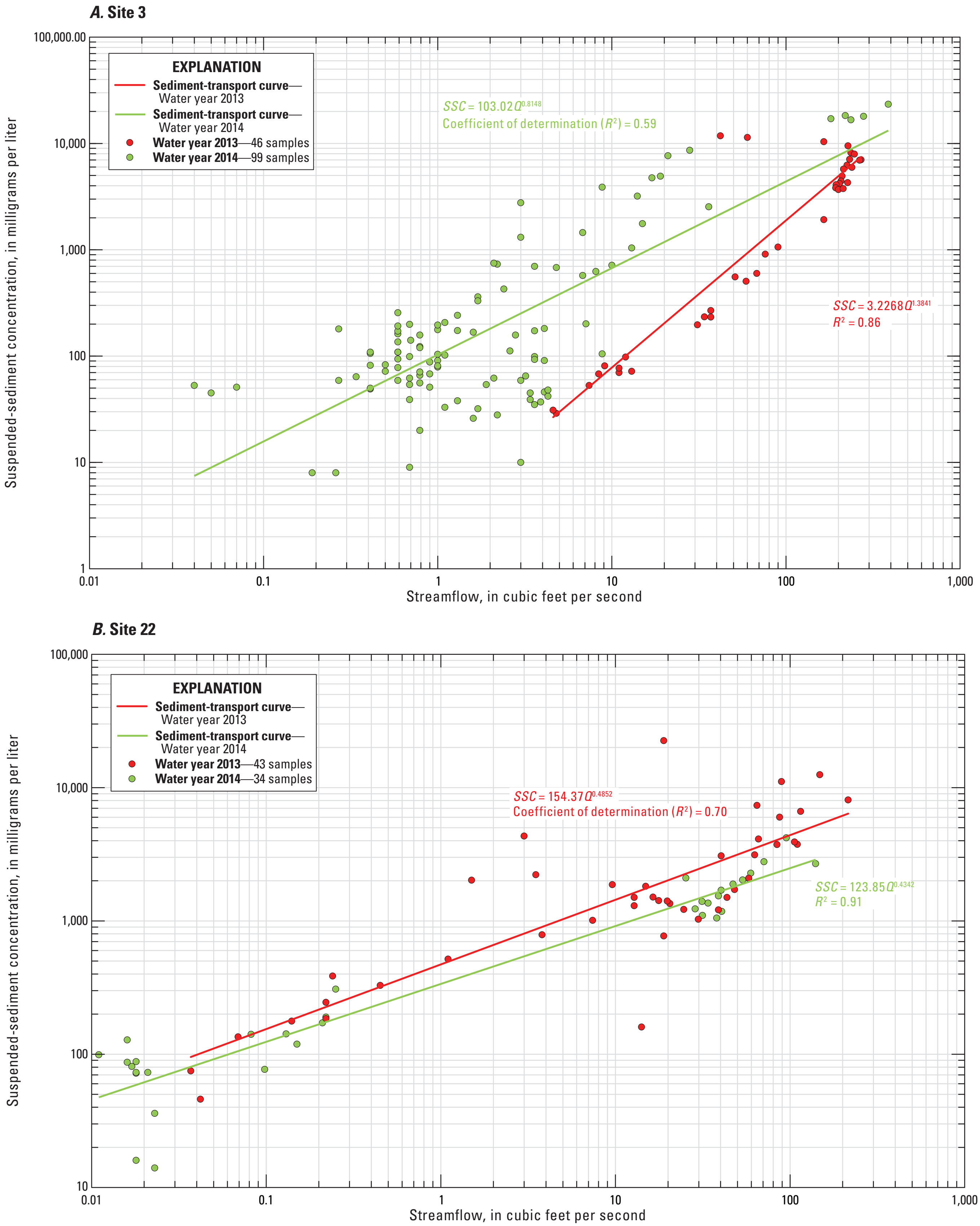
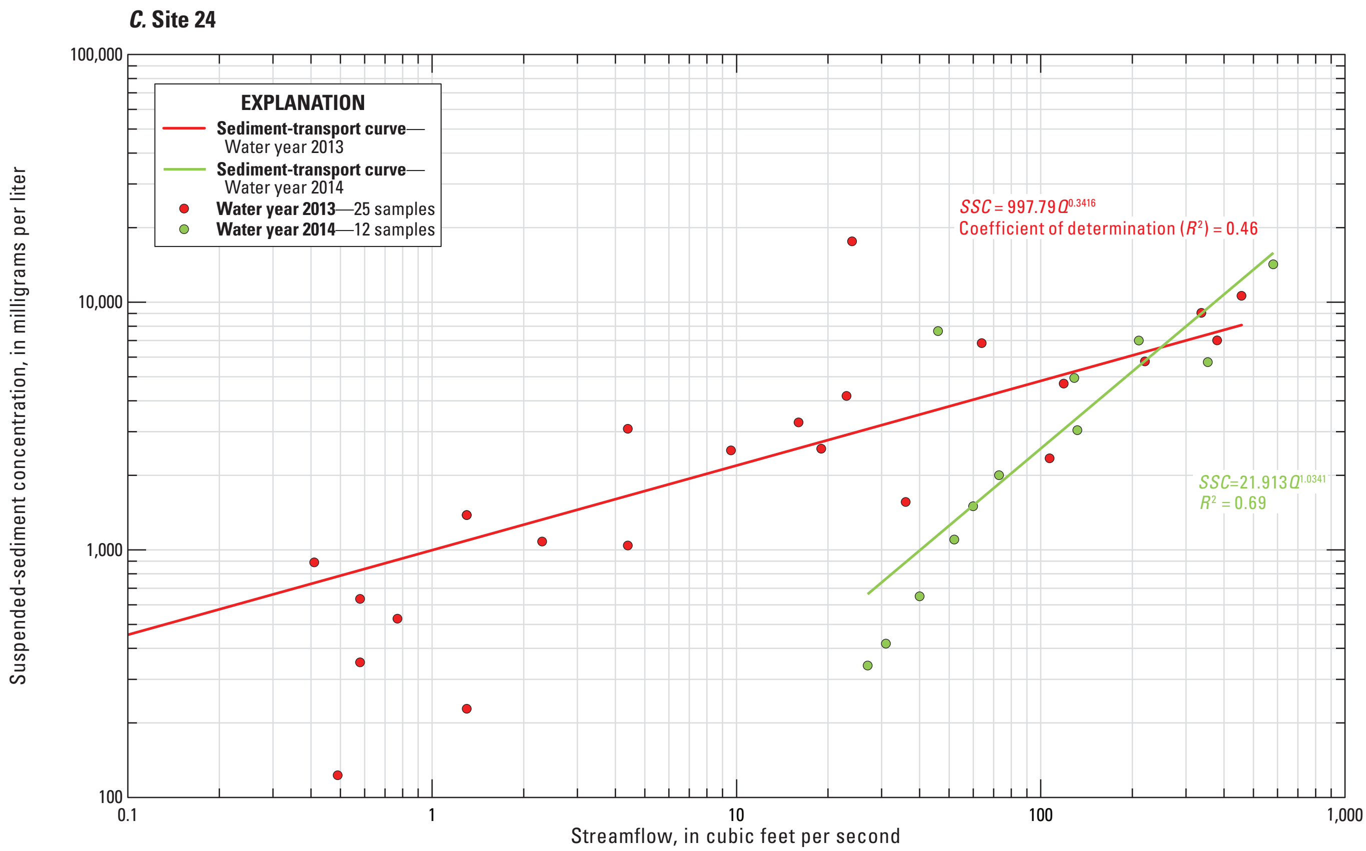
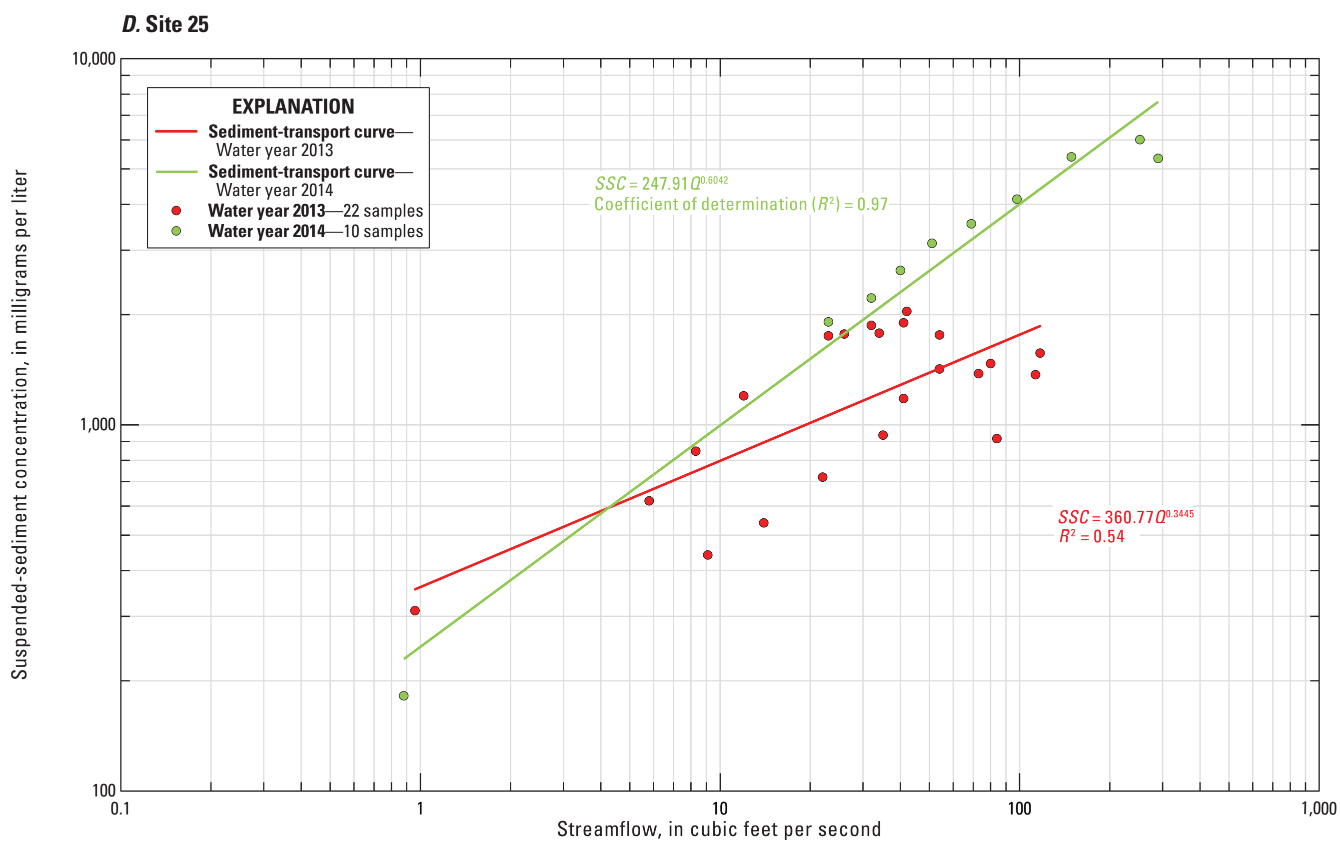


Figure 6. Sediment-transport curves relating suspended-sediment concentration (*SSC*) to instantaneous streamflow (*Q*) at the U.S. Army Garrison Fort Carson and the Piñon Canyon Maneuver Site, Colorado, water years 2013–14. See table 1 for site information. *A*, site 3. *B*, site 22. *C*, site 24. *D*, site 25. *E*, site 26. *F*, site 27.





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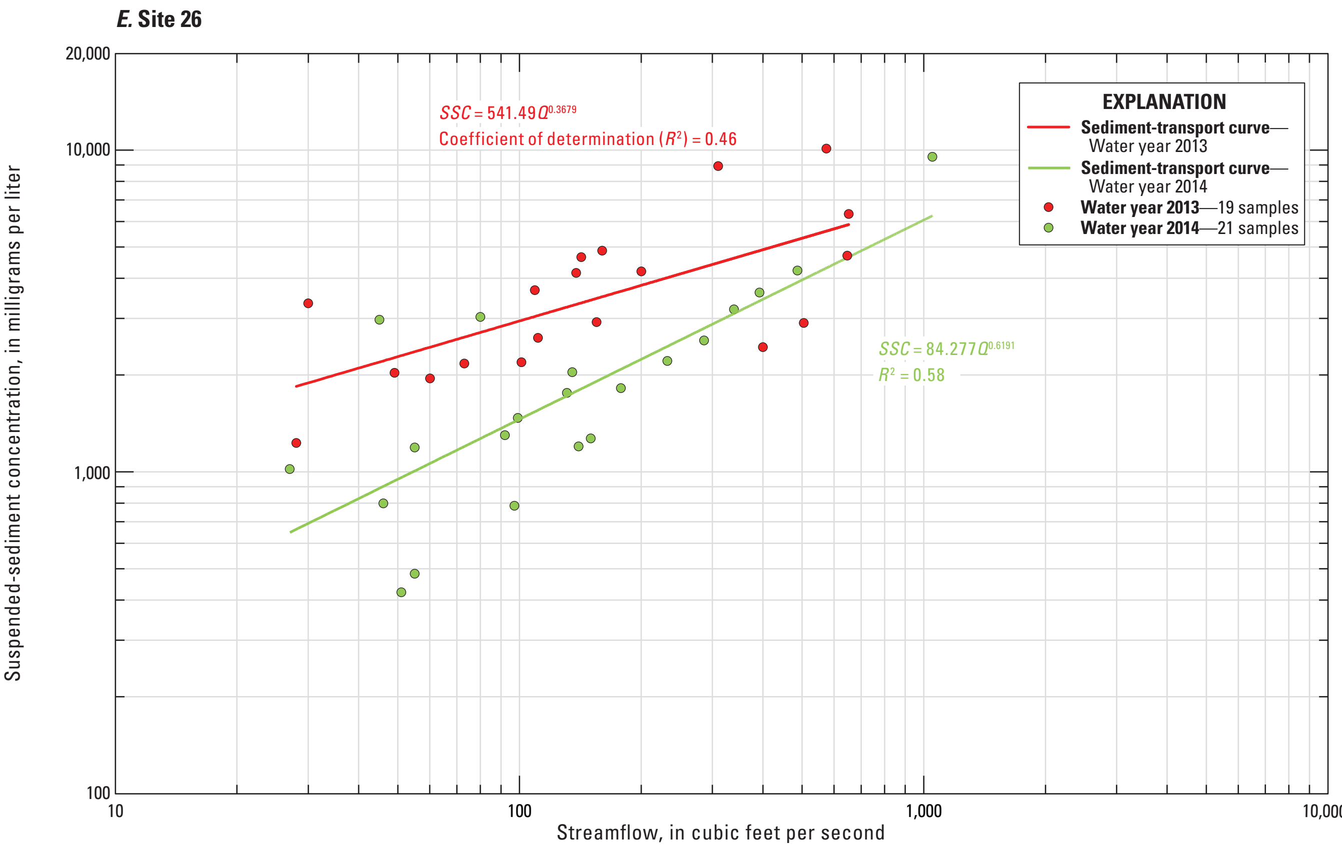

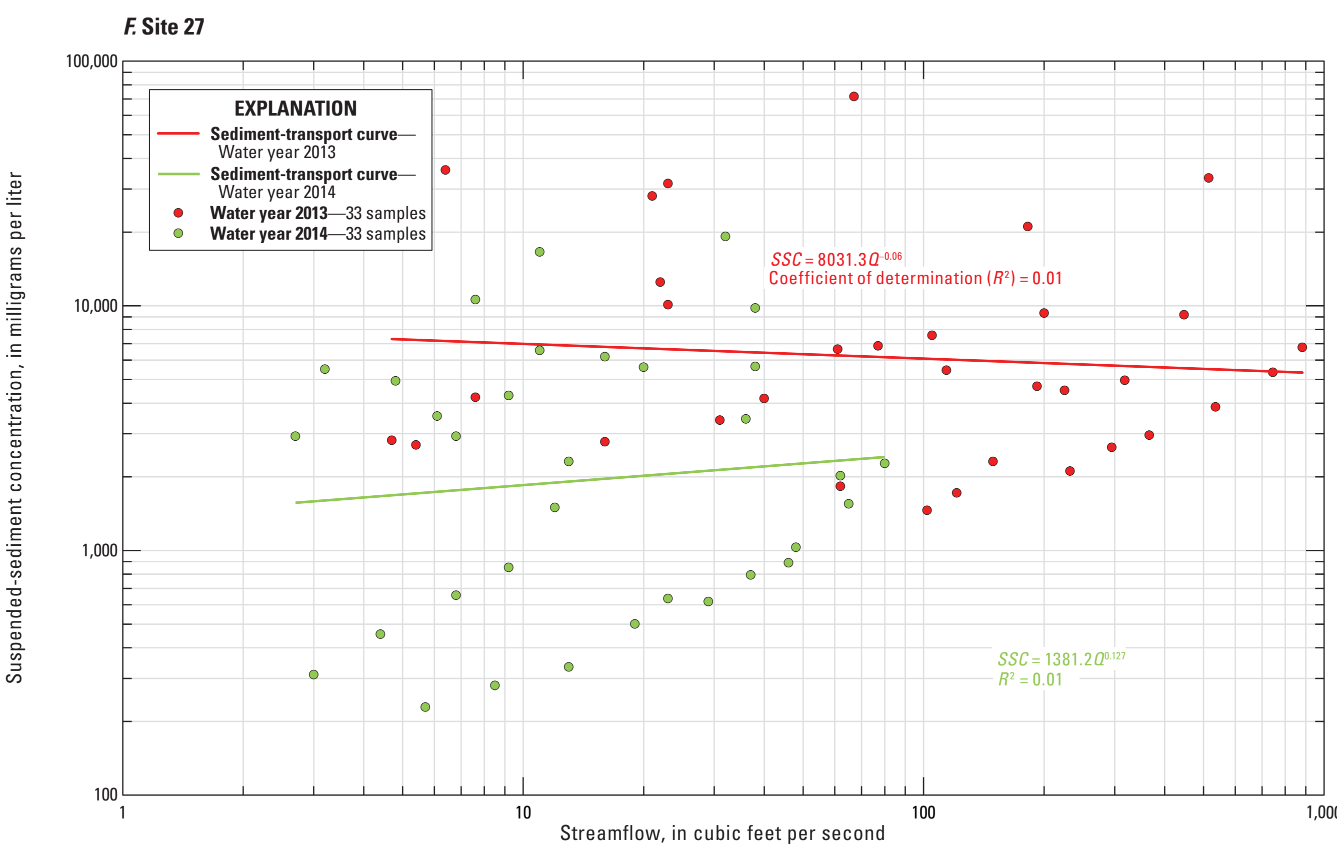

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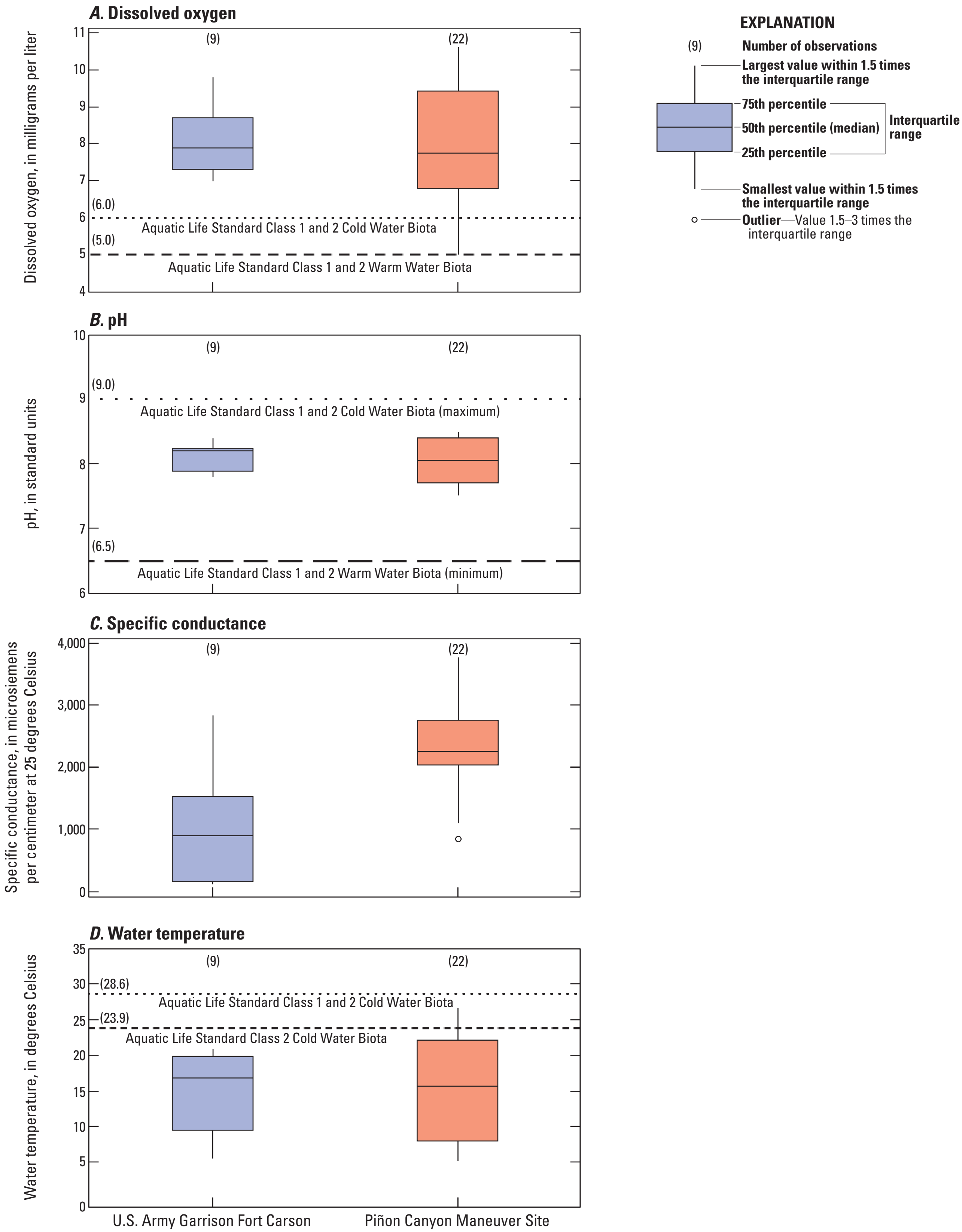
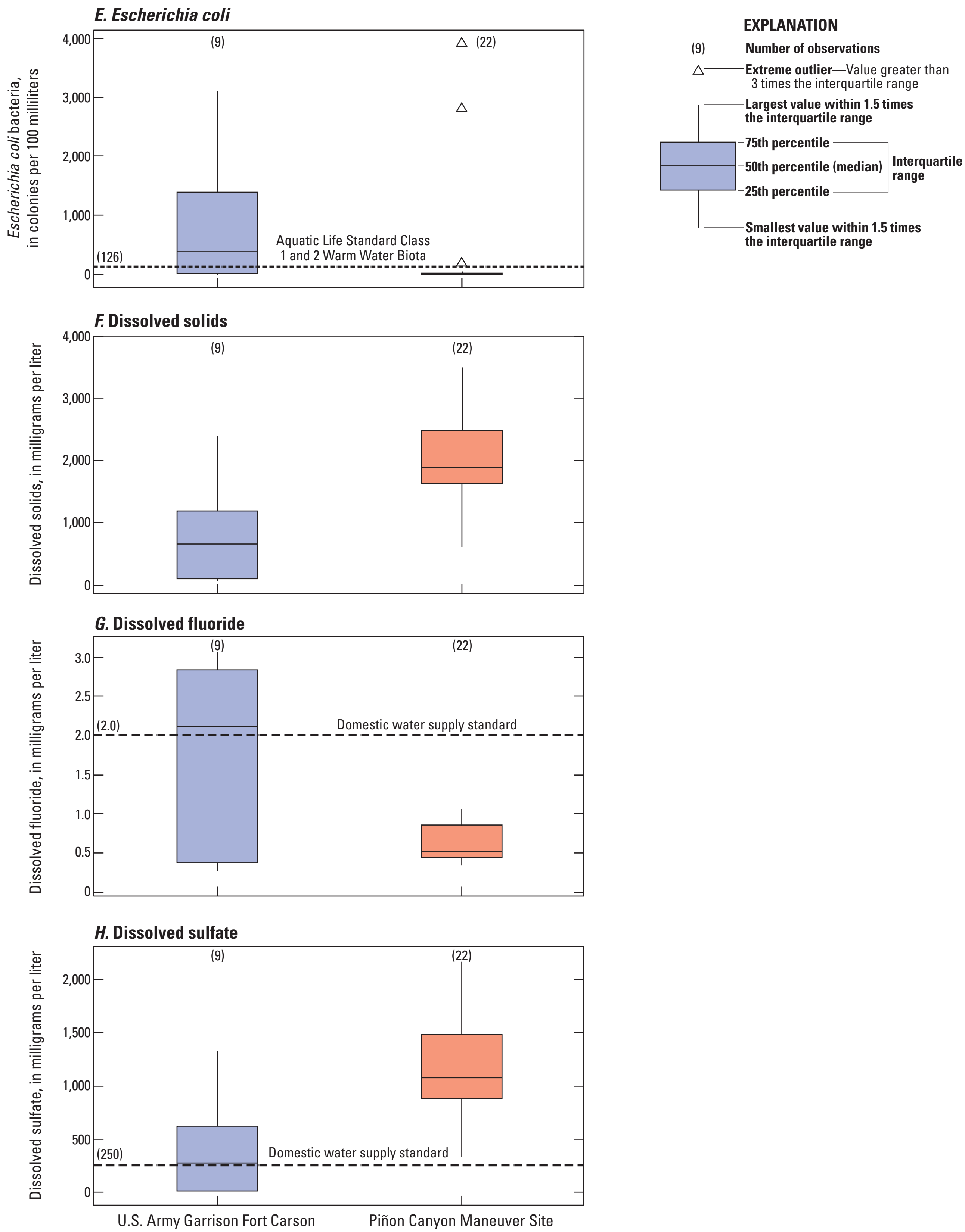


Figure 7. Boxplots showing distributions of constituents at the U.S. Army Garrison Fort Carson and the Piñon Canyon Maneuver Site, Colorado, water years 2013–14. Horizontal lines indicate water-quality standards and are associated with the numeric value. *A*, dissolved oxygen. *B*, pH. *C*, specific conductance. *D*, water temperature. E, *Escherichia coli*, *F*, dissolved solids. *G*, dissolved fluoride. *H*, dissolved sulfate. *I*, total phosphorus. *J*, dissolved selenium. *K*, dissolved uranium.



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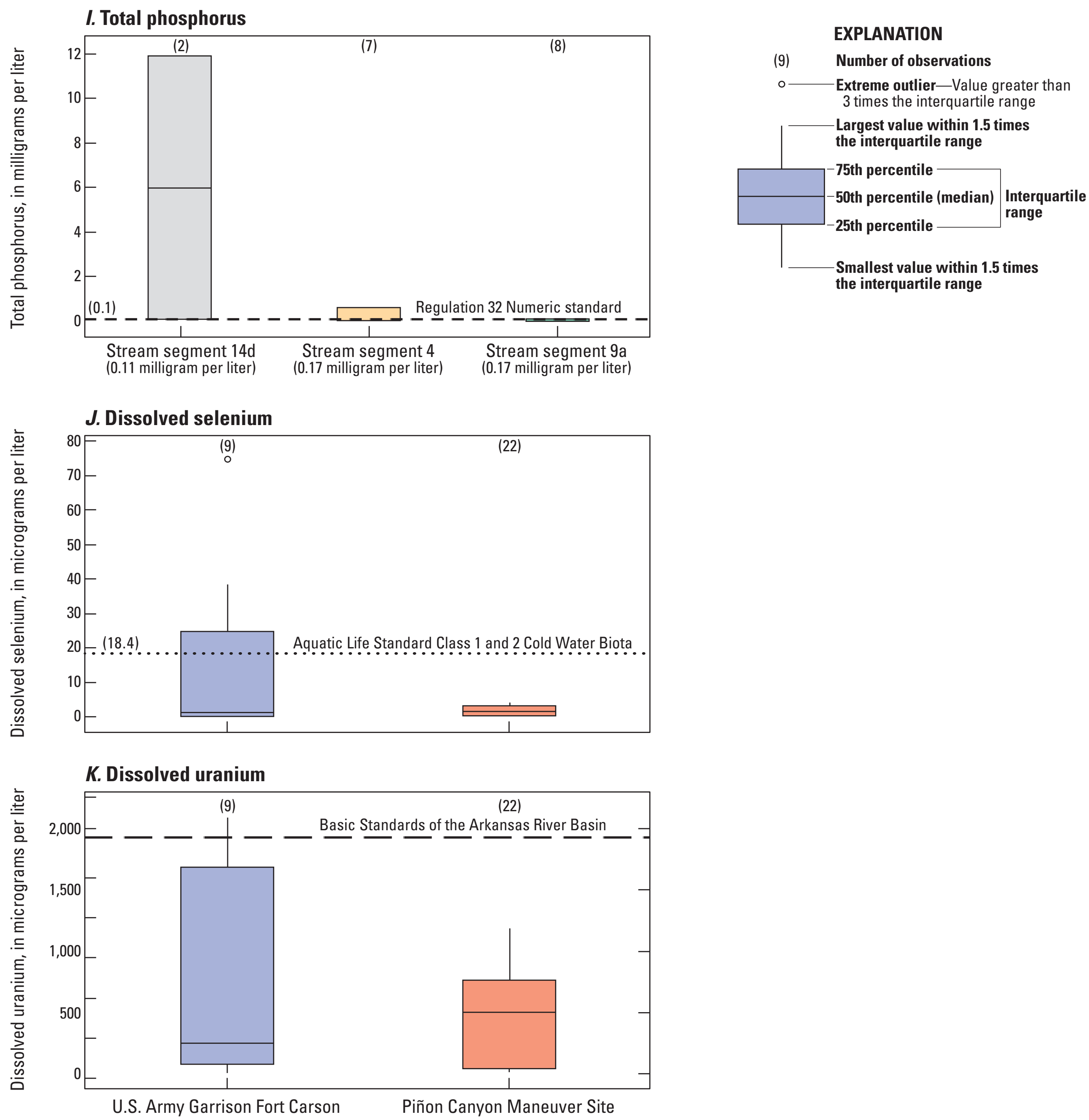

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Table 10. Water-quality data for 31 samples collected at U.S. Army Garrison Fort Carson, Colorado, and the Pinon Canyon Maneuner Site, Colorado, water years 2013–14.

[Yellow shading indicates water-quality result values that exceed a numeric water-quality standard or threshold; ID, identifier; ft^3/s, cubic foot per second; mg/L, milligram per liter; µS/cm at 25 °C, microsiemens per centimeter at 25 degrees Celsius; °C, degree Celsius; $CaCO_3$, calcium carbonate; E, estimated; SiO_2, silicon dioxide; N, nitrogen; <, less than; P, phosphorus; MPN/100 mL, most probable number per 100 milliliters; µg/L, microgram per liter; CDPHE, Colorado Department of Public Health and Environment]

Site ID (table 1)	Date	Hydrologic event	Discharge (ft^3/s)	Dissolved oxygen (mg/L)	pH (standard units)	Specific conductance (µS/cm at 25 °C)	Water temperature (°C)	Dissolved solids (mg/L)	Hardness (mg/L as $CaCO_3$)
U.S. Army Garrison Fort Carson									
1	08/03/13	Storm sample	36	7.6	8.4	157	16.8	111	57.2
2	10/31/13	Routine sample	0.29	7.9	7.9	1,480	11	1,190	784
3	10/31/13	Routine sample	0.77	9.2	8.1	2,830	8	2,390	1,150
3	08/18/14	Routine sample	1.3	8.2	8.2	1,570	19.8	1,200	659
8	08/03/13	Storm sample	E360	7.9	8.2	1,030	16.9	819	467
8	07/29/14	Storm sample	0.25	5.2	8.2	899	20.9	661	346
16	08/03/13	Storm sample	E7.1	7	8.3	145	20.1	92	51.3
16	10/31/13	Routine sample	0.24	9.8	7.9	150	5.5	97	61.3
16	07/30/14	Storm sample	E13	7.9	7.8	114	15.7	73	43.7
Piñon Canyon Maneuver Site									
22	11/26/12	Routine sample	0.22	5.9	7.7	2,040	6.8	1,690	850
22	03/26/13	Routine sample	0.14	9.3	7.8	2,140	9.7	1,870	891
22	05/20/13	Routine sample	0.11	9	7.7	2,140	19	1,690	846
22	08/14/13	Routine sample	0.42	6.8	7.5	1,090	22	796	426
22	11/06/13	Routine sample	0.08	6.2	7.8	1,930	8.1	1,450	785
22	03/19/14	Routine sample	0.16	7.7	7.9	2,300	10.8	1,900	918
22	05/19/14	Routine sample	0.09	5.9	7.7	2,200	17.4	1,820	880
22	08/20/14	Routine sample	0.04	5[a]	7.5	1,700	22.9	1,330	693
23	12/05/12	Routine sample	0.07	10.6	8.5	2,800	5.5	2,470	1,140
23	03/26/13	Routine sample	7	10.4	8.3	2,740	5.2	2,530	1,370
23	05/20/13	Routine sample	0.45	7.9	7.9	3,760	20.9	3,500	1,710
23	08/15/13	Routine sample	62	7.5	7.6	835	20.9	612	344
23	11/05/13	Routine sample	9.1	9.9	8.4	2,680	7.3	2,230	1,200
23	03/19/14	Routine sample	4	10.3	8.4	2,390	6	2,010	1,050
23	05/21/14	Routine sample	21	7.8	8.2	2,090	18.8	1,730	873
23	08/20/14	Routine sample	3.6	7.5	8.4	2,080	23.4	1,790	926
28	03/27/13	Routine sample	4.5	9.4	8.3	3,060	13.9	2,910	1,570
28	08/16/13	Routine sample	71	6.7	7.8	1,100	23.6	859	465
28	11/04/13	Routine sample	9.6	9.5	8.4	2,320	11.3	1,950	1,020
28	03/18/14	Routine sample	11	9.4	8.3	3,260	9	3,010	1,580
28	05/20/14	Routine sample	21	7.7	8.4	3,130	22.3	2,890	1,390
28	08/21/14	Routine sample	8.1	7.2	8.3	2,440	26.6	2,160	1,130

Table 10. Water-quality data for 31 samples collected at U.S. Army Garrison Fort Carson, Colorado, and the Pinon Canyon Maneuner Site, Colorado, water years 2013–14.—Continued

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Site ID (table 1)	Calcium, dissolved (mg/L)	Magnesium, dissolved (mg/L)	Potassium, dissolved (mg/L)	Sodium, dissolved (mg/L)	Chloride, dissolved (mg/L)	Fluoride, dissolved (mg/L)	Silica, dissolved (mg/L as SiO_2)	Sulfate, dissolved (mg/L)	Ammonia, dissolved (mg/L as N)
U.S. Army Garrison Fort Carson									
1	14.6	5.01	5.52	7.59	3.26	0.44	9.38	13.7	0.1
2	219	57.7	8.2	53.6	17.4	0.82	10.4	565	0.07
3	272	115	4.78	302	25.2	2.11	8.82	1,330	0.03
3	173	55.1	3.42	134	18.1	2.77[b]	11.5	678[b]	0.02
8	155	19.5	9.05	48.7	11.2	0.26	4.19	494[b]	0.13
8	84.9	32.5	9	69	21	0.3	10.3	277[b]	0.03
16	15.8	2.88	2.32	8.34	3.23	2.83[b]	9.36	10.2	0.02
16	18.6	3.59	1.64	5.59	2.56	2.84[b]	12.9	9.66	<0.01
16	13.2	2.6	1.86	5.09	1.53	3.07[b]	12.6	8.36	0.01
Piñon Canyon Maneuver Site									
22	180	97	11.8	191	36	0.91	8	900[b]	0.02
22	185	104	14.2	198	44.4	0.9	7.71	1,250[b]	0.02
22	176	98.9	12.4	205	35.6	0.86	8.44	956[b]	<0.01
22	113	34.8	11	69	18.5	0.42	11.6	422[b]	0.04
22	180	81.3	11.3	171	35.4	0.72	7.53	829[b]	0.06
22	199	102	12.4	208	42.8	0.84	7.08	1,020[b]	0.04
22	188	99.3	12.8	205	39.1	1.06	6.61	992[b]	0.03
22	160	71.2	11	139	29.1	0.77	9.08	666[b]	0.02
23	220	143	14.3	291	62.8	0.93	5.18	1,430[b]	<0.01
23	254	180	5.68	222	66.3	0.46	2.17	2,140[b]	0.01
23	318	223	8.7	337	81.4	0.63	3.6	2,170[b]	0.1
23	94.3	26.3	6.41	42.4	8.3	0.33	8.95	330[b]	0.01
23	229	152	4.52	217	61.3	0.45	2.48	1,360[b]	0.03
23	193	137	4.84	191	54	0.54	2.17	1,120[b]	<0.01
23	159	115	3.96	175	49.4	0.51	3.04	959[b]	<0.01
23	193	108	8.07	166	33.9	0.43	7.14	961[b]	<0.01
28	320	188	6.23	246	52.1	0.35	3.24	1,720[b]	0.02
28	124	37.3	7.66	60.5	11.1	0.35	9.99	471[b]	0.03
28	216	116	5.19	196	45.9	0.49	5.22	1,150[b]	0.02
28	298	203	5.48	263	68.3	0.49	1.56	1,790[b]	0.06
28	232	197	6.22	259	65.6	0.5	4.35	1,640[b]	0.07
28	250	123	8.05	189	37.7	0.41	8.69	1,120[b]	<0.01

Table 10. Water-quality data for 31 samples collected at U.S. Army Garrison Fort Carson, Colorado, and the Pinon Canyon Maneuner Site, Colorado, water years 2013–14.—Continued

[Yellow shading indicates water-quality result values that exceed a numeric water-quality standard or threshold; ID, identifier; ft^3/s, cubic foot per second; mg/L, milligram per liter; µS/cm at 25 °C, microsiemens per centimeter at 25 degrees Celsius; °C, degree Celsius; $CaCO_3$, calcium carbonate; E, estimated; SiO_2, silicon dioxide; N, nitrogen; <, less than; P, phosphorus; MPN/100 mL, most probable number per 100 milliliters; µg/L, microgram per liter; CDPHE, Colorado Department of Public Health and Environment]

Site ID (table 1)	Total ammonia (mg/L as N)	Dissolved nitrate plus nitrite (mg/L as N)	Ortho phosphate, dissolved (mg/L as P)	Phosphorus, dissolved (mg/L as P)	Total phosphorus (mg/L as P)	Total nitrogen [nitrate + nitrite + ammonia + organic-N] (mg/L as N)	*Escherichia coli* (MPN/100 mL)	Total fecal coliforms (MPN/100 mL)
U.S. Army Garrison Fort Carson								
1	E0.17	3.06	0.139	0.15	11.9[c]	5.93	3100[d]	24,000
2	0.1	2.27	0.008	<0.02	0.029	2.82	1	410
3	0.05	0.314	<0.004	<0.02	0.009	0.59	29	1,400
3	0.04	0.153	<0.004	<0.02	0.042	0.38	370[d]	24,000
8	E0.45	1.68	0.057	0.62	14.6[c]	10	1,600[d]	>24,000
8	0.09	0.259	0.022	0.09	0.605[c]	1.76	1,200[d]	>24,000
16	0.12	0.213	0.015	0.03	0.126	0.65	8,80[d]	7,300
16	<0.02	<0.04	<0.004	<0.02	0.009	0.09	1	88
16	<0.02	0.077	<0.004	<0.02	0.046	0.3	120	>2,400
Piñon Canyon Maneuver Site								
22	0.03	<0.04	<0.004	<0.02	<0.004	<0.05	1	210
22	0.04	<0.04	<0.004	<0.02	0.011	0.17	<1	280
22	0.03	<0.04	<0.004	<0.02	0.005	0.09	E8	E2,000
22	E0.06	0.059	0.01	0.02	0.116	0.65	130[d]	2,400
22	0.07	<0.04	<0.004	<0.02	0.015	0.21	1	490
22	0.07	<0.04	<0.004	<0.02	0.011	0.19	<1	260
22	0.04	<0.04	<0.004	<0.02	0.015	0.18	3	400
22	0.04	<0.04	<0.004	<0.02	0.019	0.24	5	>2400
23	0.03	<0.04	<0.004	<0.02	0.033	0.31	<1	E770
23	0.04	<0.04	<0.004	<0.02	0.017	0.29	<1	54
23	0.03	<0.04	<0.004	<0.02	0.032	0.41	E1	>2400
23	E0.08	0.68	0.025	0.03	9.66	6.34	2,800[d]	>24000
23	0.02	0.127	<0.004	<0.02	0.026	0.42	2	310
23	<0.02	<0.04	<0.004	<0.02	0.025	0.32	<1	160
23	0.03	<0.04	<0.004	<0.02	0.075	0.36	11	980
23	0.04	0.123	<0.004	<0.02	0.059	0.66	4	>2400
28	0.05	<0.04	<0.004	<0.02	0.031	0.32	<1	50
28	E0.14	0.83	0.03	0.04	11.7	7.66	3,900[d]	24,000
28	0.03	<0.04	<0.004	<0.02	0.085	0.4	36	870
28	<0.02	<0.04	<0.004	<0.02	0.09	0.44	<1	310
28	0.04	<0.04	<0.004	<0.02	0.059	0.46	36	1,400
28	0.05	<0.04	<0.004	<0.02	0.067	0.57	2	>2,400

Table 10. Water-quality data for 31 samples collected at U.S. Army Garrison Fort Carson, Colorado, and the Pinon Canyon Maneuner Site, Colorado, water years 2013–14.—Continued

[Yellow shading indicates water-quality result values that exceed a numeric water-quality standard or threshold; ID, identifier; ft^3/s, cubic foot per second; mg/L, milligram per liter; µS/cm at 25 °C, microsiemens per centimeter at 25 degrees Celsius; °C, degree Celsius; $CaCO_3$, calcium carbonate; E, estimated; SiO_2, silicon dioxide; N, nitrogen; <, less than; P, phosphorus; MPN/100 mL, most probable number per 100 milliliters; µg/L, microgram per liter; CDPHE, Colorado Department of Public Health and Environment]

Site ID (table 1)	Aluminum, dissolved (µg/L)	Barium, dissolved (µg/L)	Beryllium, dissolved (µg/L)	Cadmium, dissolved (µg/L)	Chromium, dissolved (µg/L)	Cobalt, dissolved (µg/L)	Copper, dissolved (µg/L)	Iron, dissolved (µg/L)	Lead, dissolved (µg/L)
U.S. Army Garrison Fort Carson									
1	190	52.7	0.033	0.044	0.29	0.424	5.3	181	0.188
2	<2.2	70.5	<0.02	0.043	<0.3	0.437	<0.8	11.8	<0.04
3	<4.4	106	<0.04	0.133	<0.6	2.73	1.6	<8	<0.08
3	3.5	57.1	<0.02	0.065	<0.3	0.673	<0.8	<60	<0.04
8	40.7	70.9	<0.006	0.107	0.08	0.936	3.1	16.1	<0.025
8	1,100	111	0.072	0.126	0.79	1.26	2.4	228	0.854
16	48.6	34.8	0.044	<0.016	<0.07	0.442	<0.8	76	0.052
16	15.9	33.3	0.111	<0.03	<0.3	0.173	<0.8	363	<0.04
16	97.2	23.2	0.103	<0.03	<0.3	0.113	<0.8	109	0.088
Piñon Canyon Maneuver Site									
22	<2.2	22.9	0.019	<0.016	<0.07	0.707	<0.8	41.3	<0.025
22	<6.6	23	<0.018	<0.048	<0.21	0.543	<2.4	18.5	<0.075
22	<2.2	22.8	0.017	0.02	<0.07	0.521	<0.8	42	<0.025
22	18.1	127	0.012	0.023	<0.07	1.32	0.86	83	<0.025
22	<2.2	66.2	0.025	<0.03	<0.3	1	<0.8	216	<0.04
22	<4.4	34.9	<0.04	<0.06	<0.6	1.12	<1.6	142	<0.08
22	<2.2	33.2	<0.02	<0.03	<0.3	1.34	<0.8	37.3	<0.04
22	<2.2	53.5	<0.02	<0.03	<0.3	0.901	<0.8	30.3	<0.04
23	<6.6	28.8	<0.018	<0.048	<0.21	0.708	<2.4	<8	<0.075
23	<4.4	24.8	0.506	<0.03	<0.14	0.638	<1.6	15.3	<0.05
23	<6.6	33.1	0.087	0.173	0.21	0.878	18.1	10.8	0.136
23	23.9	107	0.008	0.03	0.1	0.723	1.4	18.7	<0.025
23	<4.4	60.8	<0.04	<0.06	<0.6	0.733	<1.6	<8	<0.08
23	<4.4	30.2	<0.04	<0.06	<0.6	0.71	<1.6	12.2	<0.08
23	2.3	56.4	<0.02	<0.03	<0.3	0.882	<0.8	8.7	<0.04
23	3	94.9	<0.02	<0.03	<0.3	0.529	1.1	<8	<0.04
28	7	28.8	<.012	<0.03	<0.14	0.919	<1.6	25.5	<0.05
28	25.4	155	<0.006	0.03	0.1	0.69	1.6	15.8	<0.025
28	<4.4	65.6	<0.04	<0.06	<0.6	0.53	<1.6	<8	<0.08
28	<4.4	32.6	<0.04	<0.06	<0.6	1.11	<1.6	14.3	<0.08
28	<4.4	59.6	<0.04	<0.06	<0.6	0.624	<1.6	12.3	1.09
28	2.5	175	<0.02	0.034	<0.3	0.882	<0.8	<8	<0.04

Table 10. Water-quality data for 31 samples collected at U.S. Army Garrison Fort Carson, Colorado, and the Pinon Canyon Maneuner Site, Colorado, water years 2013–14.—Continued

[Yellow shading indicates water-quality result values that exceed a numeric water-quality standard or threshold; ID, identifier; ft^3/s, cubic foot per second; mg/L, milligram per liter; µS/cm at 25 °C, microsiemens per centimeter at 25 degrees Celsius; °C, degree Celsius; $CaCO_3$, calcium carbonate; E, estimated; SiO_2, silicon dioxide; N, nitrogen; <, less than; P, phosphorus; MPN/100 mL, most probable number per 100 milliliters; µg/L, microgram per liter; CDPHE, Colorado Department of Public Health and Environment]

Site ID (table 1)	Manganese, dissolved (µg/L)	Molybdenum, dissolved (µg/L)	Nickel, dissolved (µg/L)	Silver, dissolved (µg/L)	Zinc, dissolved (µg/L)	Antimony, dissolved (µg/L)	Arsenic, dissolved (µg/L)	Selenium, dissolved (µg/L)	Uranium [natural], dissolved (µg/L)	CDPHE Aquatic Life Classification (Regulation 31)
U.S. Army Garrison Fort Carson										
1	6.58	14.8	0.95	<0.005	<1.4	0.14	0.76	1.2	20.4	Cold Class 2 (Tier II)
2	330	14.2	2.3	<0.02	<2	0.171	0.81	11.3	32	Cold Class 2 (Tier II)
3	777	23.8	12.7	<0.04	<4	0.477	1.1	38.6[e]	32.4[e]	Warm Class 2 (Tier II)
3	120	10.3	4.1	<0.02	<2	0.255	0.68	11.2	8.95	Warm Class 2 (Tier II)
8	2.86	18.6	2.9	<0.005	<1.4	0.449	1	74.5[e]	1.95	Warm Class 2 (Tier II)
8	55.8	2.84	3.5	<0.02	4.1	0.326	1.7	1.1	4.27	Warm Class 2 (Tier II)
16	6.66	2.03	0.4	<0.005	<1.4	0.058	0.16	0.2	3.42	Warm Class 2 (Tier II)
16	334	1.62	0.25	<0.02	<2	0.03	0.19	0.17	1.39	Warm Class 2 (Tier II)
16	28.6	1.67	0.99	<0.02	<2	0.076	0.14	0.12	0.609	Warm Class 2 (Tier II)
Piñon Canyon Maneuver Site										
22	57.5	3.54	2.2	<0.005	<1.4	0.057	0.57	0.12	1.24	Warm Class 1 (Tier II)
22	48.5	3.54	2.3	<0.015	<4.2	0.098	0.72	0.24	1.42	Warm Class 1 (Tier II)
22	70.1	3.41	2.1	0.007	<1.4	0.072	0.86	0.19	0.945	Warm Class 1 (Tier II)
22	267	5.81	3.4	<0.005	<1.4	0.245	1.8	3.2	1.04	Warm Class 1 (Tier II)
22	133	3.64	3.2	<0.02	<2	0.055	0.99	0.17	0.896	Warm Class 1 (Tier II)
22	155	2.92	3.3	<0.04	<4	0.054	0.82	0.15	1.02	Warm Class 1 (Tier II)
22	134	3.22	3.9	<0.02	<2	0.067	0.89	0.18	0.904	Warm Class 1 (Tier II)
22	124	3.8	3.3	<0.02	<2	0.073	0.91	0.18	0.71	Warm Class 1 (Tier II)
23	24.6	5.81	2.8	<0.015	<4.2	0.226	0.69	2.7	8.42	Warm Class 1 (Tier II)
23	41.7	3.91	2.5	<0.01	<2.8	0.167	0.65	3.1	16.6	Warm Class 1 (Tier II)
23	154	7.83	5.9	0.027	24.7	0.386	1.5	2.4	18.5	Warm Class 1 (Tier II)
23	1.46	6.41	2.2	<0.005	<1.4	0.337	0.98	2.7	1.96	Warm Class 1 (Tier II)
23	35.4	2.67	3.5	<0.04	<4	0.114	0.46	1.6	11.5	Warm Class 1 (Tier II)
23	71.6	2.88	3.1	<0.04	<4	0.101	0.42	1.7	10.6	Warm Class 1 (Tier II)
23	21.2	3.03	3.5	<0.02	<2	0.193	0.59	1.8	10.1	Warm Class 1 (Tier II)
23	7.63	5.68	3.3	<0.02	<2	0.216	0.86	3.7	7.65	Warm Class 1 (Tier II)
28	65.4	9.22	2.8	<0.01	<2.8	0.231	0.89	3.7	17.8	Warm Class 1 (Tier II)
28	1.16	9.24	2.5	<0.005	<1.4	0.37	1.2	4.1	3.14	Warm Class 1 (Tier II)
28	60	6.03	3.1	<0.04	<4	0.161	0.8	1.4	9.16	Warm Class 1 (Tier II)
28	131	5.22	3.9	<0.04	<4	0.138	0.67	1.5	14.8	Warm Class 1 (Tier II)
28	32.4	5.3	4.9	<0.04	<4	0.288	0.89	2.8	13.5	Warm Class 1 (Tier II)
28	94.9	9.9	4.1	<0.02	<2	0.418	1.5	3.2	8.78	Warm Class 1 (Tier II)

[a]Regulation 31 (Colorado Department of Public Health and Environment, Water Quality Control Commission, 2013) Aquatic Life Standard Class 1 and 2 Warm Water Biota.

[b]Regulation 31 (Colorado Department of Public Health and Environment, Water Quality Control Commission, 2013) Recreational Class E Standard.

[c]Regulation 32 (Colorado Department of Public Health and Environment, Water Quality Control Commission, 2015) Numeric Standard.

[d]Regulation 31 (Colorado Department of Public Health and Environment, Water Quality Control Commission, 2013) Domestic Water Supply Standard.

[e]Regulation 32 (Colorado Department of Public Health and Environment, Water Quality Control Commission, 2015) Basic Standard for all waters of the Arkansas River Basin.

Major Ions and Water Hardness

Possible water types based on ionic composition are depicted in a trilinear diagram (fig. 8). Trilinear diagrams of the major cations and anions analytically determined from the water-quality samples collected during the study period are shown in figure 9. Trilinear diagrams, also known as Piper diagrams (Hem, 1992), show the relative percentages of ions in milliequivalents per liter (meq/L). Trilinear diagrams are useful for classification of water because they show relative percentages of ion concentration, rather than the actual ion concentrations of each species observed in a sample. Classifications are broken down into three parts: cation type, anion type, and total major ionic classification (fig. 8). Cation and anion types are determined by the dominant species in each category. Cation types include calcium type, magnesium type, sodium or potassium type, and no dominant species. Anion types include bicarbonate type; sulfate type; and chloride, fluoride, or nitrite plus nitrate type; and no dominant species (Piper, 1944). The diamond in the middle of the trilinear diagram represents the total major ionic composition. Samples that plot near the top of the diamond are high in calcium and magnesium cations, and chloride and sulfate anions, and are classified as having permanent (or carbonate) hardness. Water samples plotted near the bottom of the diamond show higher concentrations of alkali carbonates, sodium plus potassium cations, and carbonate and bicarbonate anions. Samples that plot on the right-hand corner of the diamond are considered saline and are richer in sodium, potassium, chloride, and sulfate ions. Finally, water samples that plot on the left-hand corner of the diamond are classified as primarily containing ions that give water temporary (or noncarbonate) hardness; these include calcium, magnesium, and bicarbonate ions (Hounslow, 1995).

To obtain the carbonate plus bicarbonate concentrations of these samples, cation and anion concentrations of available constituents were converted to milliequivalents per liter and then the anions subtracted from the cations. The difference between the two is attributed to alkalinity, or carbonate plus bicarbonate concentration. The collection of field alkalinities would have provided more accurate alkalinity values and improved confidence in characterization of water types. Two of these samples, one at site 22 and one at site 23 (both on March 26, 2013), yielded an ionic imbalance and, therefore, were not plotted in the trilinear diagrams; however, the results of these samples were not censored. At the U.S. Army Garrison Fort Carson, five of the nine samples plot in the calcium type region, and four in the no dominant species region of the cation triangle. In the anion triangle, five samples plot in the sulfate type region and four in the bicarbonate type region. In the total major ionic composition diamond, two U.S. Army Garrison Fort Carson samples are classified as permanent hardness, three samples are mixed/indeterminate, and four samples plot in the region of temporary hardness (fig. 9). Notably, the four samples that plot in the bicarbonate type anion region and the temporary hardness region of the total major ionic composition diamond are samples taken from sites 1 and 16. Site 1 is on the far west side of the U.S. Army Garrison Fort Carson, where Turkey Creek enters the Garrison, and site 16 is west of the Garrison before Little Fountain Creek reaches the base. These sites are downstream from regions where the geology is made up of predominantly igneous and metamorphic rock and transitions into an area where the geology is characterized by sedimentary rock (fig. 2*A*). These samples are interesting because samples at these two sites represent water that has not yet interacted with the alluvium and calcium carbonate rich shale that make up the geology of most of the U.S. Army Garrison Fort Carson. All the other samples at the U.S. Army Garrison Fort Carson group together, in the sulfate type anion region and in or around the permanent hardness region of the total major ionic composition diamond. The difference between the samples taken at sites 1 and 16 and the rest of the U.S. Army Garrison Fort Carson samples is further discussed in the following discussion on water hardness in this section.

At the Piñon Canyon Maneuver Site, all but two samples plot on the cation triangle as no dominant species, indicating that there is a rather uniform mixture of cations present in these samples. The remaining two are in the calcium type region, and these plot very close to the no dominant species region. All Piñon Canyon Maneuver Site samples plot in the sulfate type region of the anion triangle. All but seven samples taken from the Piñon Canyon Maneuver Site plot in the region of permanent hardness. The other seven samples were collected at site 22, and these samples plot near the permanent hardness region but remain in the mixed/indeterminate area of the diagram.

Ionic composition of water determines another very important factor—hardness. Water hardness is defined as the amount of dissolved calcium and magnesium in the water. Hard water is high in dissolved minerals, both calcium and magnesium. Hardness is generally associated with the soap-consuming capacity of water (the amount of soap it takes to create a lather), and the scaly residue left by some types of water (Hem, 1992). Hardness of water is commonly reported in milligrams per liter as calcium carbonate, and the concentration of hardness determines the classification. A water hardness classification is provided in figure 10 (Lindeburg, 2008). This classification includes soft, moderately hard, hard, very hard, and saline or brackish. In total, 27 samples collected at the U.S. Army Garrison Fort Carson and Piñon Canyon Maneuver Site classify as very hard or brackish (fig. 10). Nine samples had a lower hardness character relative to the other samples. The four samples (one from site 1 and three from site 16) at the U.S. Army Garrison Fort Carson that plot in the temporary (noncarbonate) hardness region in figure 9 also have the lowest hardness concentration (fig. 10) and were collected at locations with different geologic makeup (fig. 2*A*).

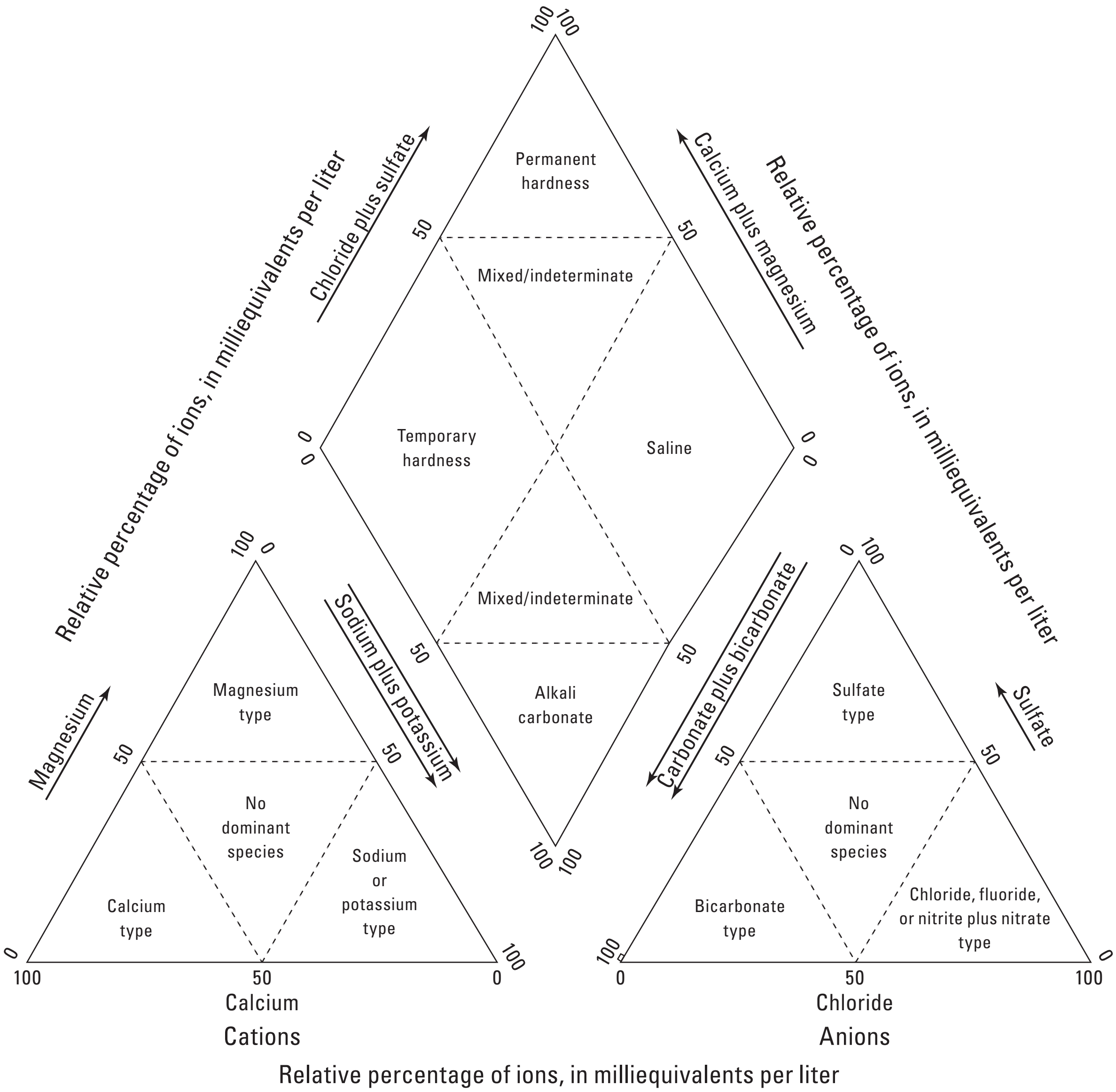

Figure 8. Trilinear diagram showing water types based on ionic composition (Hounslow, 1995).

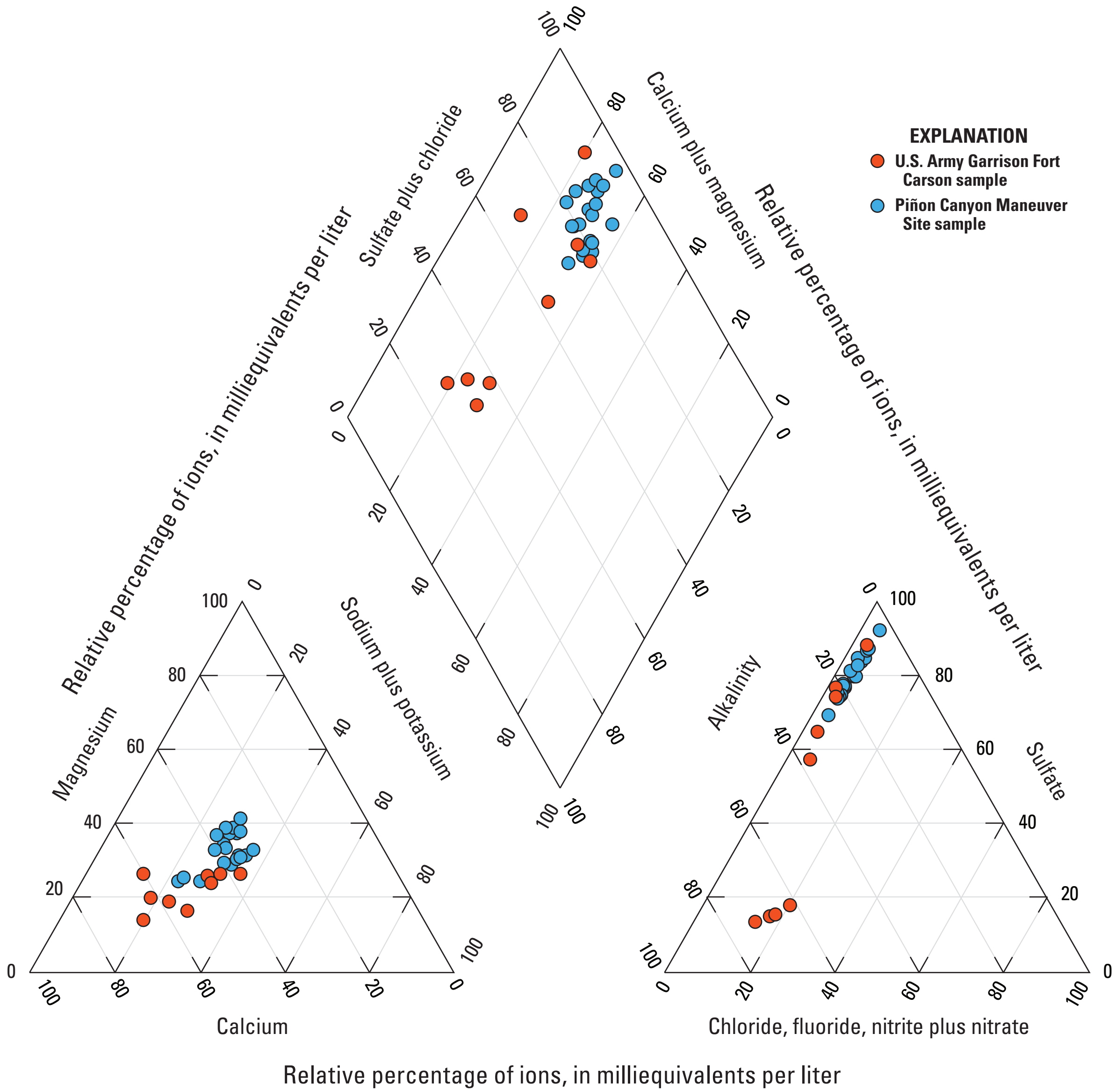

Figure 9. Trilinear diagram showing major ionic composition and classification for all samples collected at the U.S. Army Garrison Fort Carson and the Piñon Canyon Maneuver Site, Colorado, water years 2013–14.

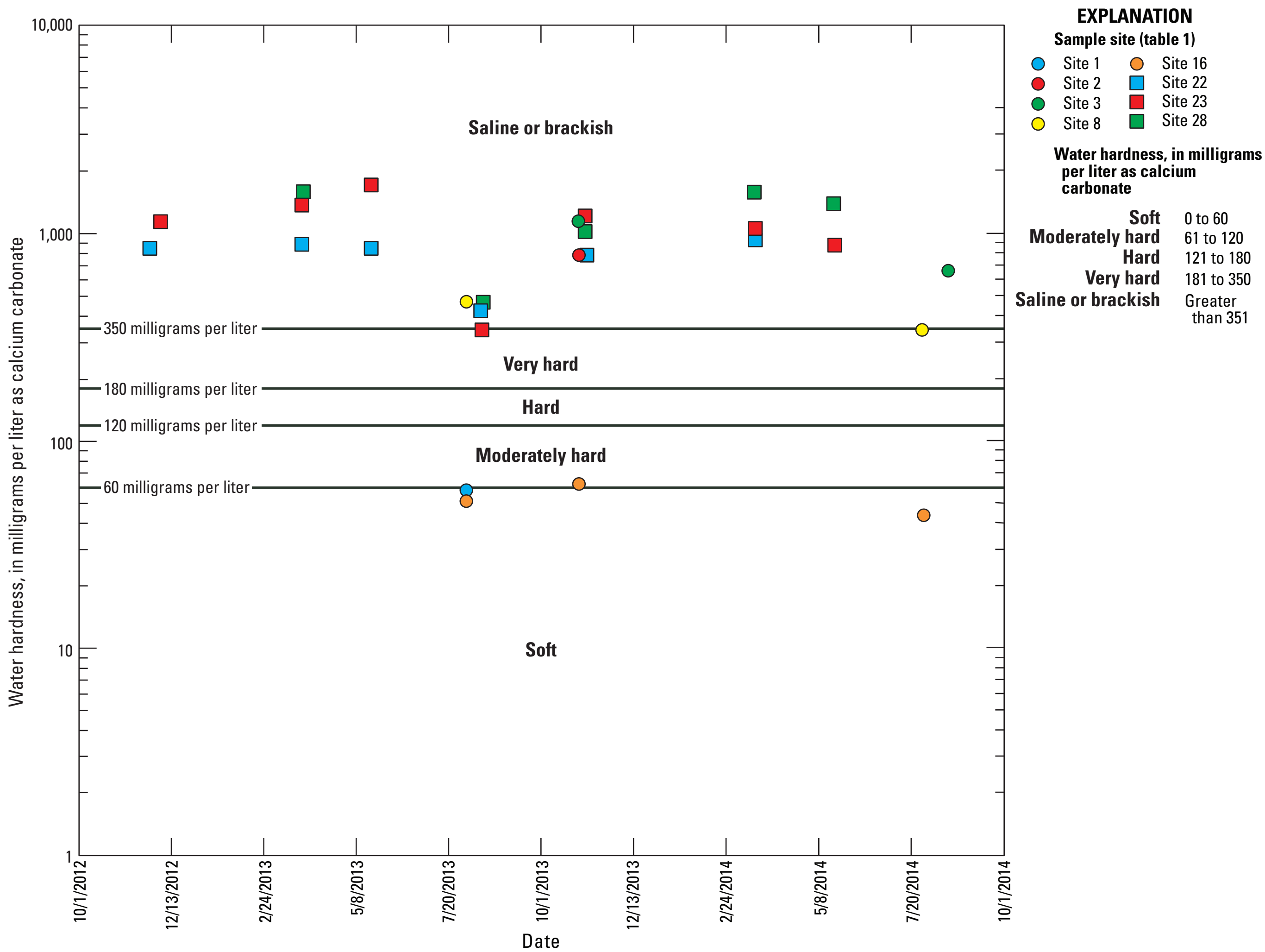

Figure 10. Plot showing calculated water hardness and each sample's classification (Lindeburg, 2008) as soft, moderately hard, hard, very hard, or saline or brackish at the U.S. Army Garrison Fort Carson and Piñon Canyon Maneuver Site, Colorado, water years 2013–14.

An interesting occurrence at the Piñon Canyon Maneuver Site is shown in figure 10. Three samples collected between August 14, 2013, and August 16, 2013, one at each Piñon Canyon Maneuver site (sites 22, 23, and 28), plot well below the rest of the samples at these sites. Although they are still in the very hard or brackish regions, when comparing the August 2013 samples to the remaining samples collected during the 2-year period, they are 49, 71, and 65 percent lower than the average hardness concentration of the other samples at sites 22, 23, and 28, respectively. This is likely due to the samples being collected after a rise in streamflow, which may have caused a dilution effect during this period (fig. 11).

Implications of Study Findings and Further Study Needs

There are several areas where additional data collection and an expanded study area would help land managers better understand the relation among precipitation, streamflow, and water-quality at the U.S. Army Garrison Fort Carson and the Piñon Canyon Maneuver Site.

The nature of activities at the U.S. Army Garrison Fort Carson and the Piñon Canyon Maneuver Site may limit the geographic distribution and operation of additional precipitation stations; however, because of the regional precipitation characteristics of the U.S. Army Garrison Fort Carson and the Piñon Canyon Maneuver Site related to variations in topography and seasonal cyclonic storms, additional monitoring stations could aid in understanding the variations in the distribution, duration, and magnitude of precipitation at these military installations. In addition to increasing the number of onsite monitoring stations, the addition of offsite precipitation stations would enhance data interpretation and presentation. Also, inconsistencies in field operations (that is, unequal data collection periods) need to be addressed because large data gaps at one or more sites made interpretations of temporal and spatial precipitation characteristics difficult to impossible; therefore, a precipitation monitoring network, which is spatially and temporally stable and extends beyond the U.S. Army Garrison Fort Carson and the Piñon Canyon Maneuver Site boundaries, is necessary to adequately convey precipitation characteristics across the Garrison and Maneuver Site facilities. This is particularly true in basins with relatively large contributing areas. Currently (2016), any attempts to analyze the relation between precipitation and streamflow at sites with paired precipitation and streamflow data are based on the assumption that precipitation falls evenly throughout a basin because these monitoring stations are at the pour points of the basins. Additional precipitation monitoring stations would allow the use of storm totals or hydrograph routing techniques to assess the amount of precipitation that has been converted to streamflow and can assist in quantifying upstream erosion and sediment transport. Erosion because of increased flood frequency and peak streamflow during precipitation can cause changes in stream hydrology, which, in turn, can alter aquatic communities and biological processes. The monitoring of stream channel geometry and the surveying of invertebrate and fish populations on the U.S. Army Garrison Fort Carson and the Piñon Canyon Maneuver Site would aid in monitoring the effects of stream morphology on the hydrology and ecology of the study regions with time.

The inability to reliably predict the relation between precipitation and streamflow at the Piñon Canyon Maneuver Site might be associated with the erosion control ponds. A paired-basin or upstream-downstream study design to evaluate the effects of erosion control ponds on the hydrologic processes within the Piñon Canyon Maneuver Site might allow land managers to plan the size and distribution of these erosion control ponds. A brief survey of the existing network indicates that sites 24 (48.4 mi^2), 25 (48.8 mi^2), and 26 (48.7 mi^2) would be appropriate candidates for this effort because of similar characteristics, including drainage area, proximity, geology, soils, and land cover (Clausen and Spooner, 1993). The covariate of interest is the number, size, and spatial distribution of the erosion control ponds within these basins.

A real-time web-based tool displaying isohyetal maps (fig. 3) at variable time scales (similar to existing USGS real-time streamflow or precipitation data) could be a useful tool for land managers at the U.S. Army Garrison Fort Carson and Piñon Canyon Maneuver Site. Using a geographic information system to show historical and up-to-date maps of recorded precipitation, land managers would then be able to determine if training maneuvers would result in an unacceptable impact on soil and vegetative resources in training areas, and be able to identify areas where environmental conditions are suitable for military training.

Von Guerard and others (1993) completed a study to determine the effects of military training on streamflow, water quality, and sediment yields on the Piñon Canyon Maneuver Site from 1983 to 1987. An extension of this study could assist land managers at the U.S. Army Garrison Fort Carson and the Piñon Canyon Maneuver Site in making land-management decisions. A retrospective analysis would evaluate the effectiveness of land-management practices intended to ameliorate the environmental influences of military training on the U.S. Army Garrison Fort Carson and Piñon Canyon Maneuver Site.

Periodic evaluation of the data-collection program would help determine if the data being collected are providing the necessary information to assess the quality of the water resources on the U.S. Army Garrison Fort Carson and the Piñon Canyon Maneuver Site through time. Revision of the current water-quality constituent list to include field alkalinities for all samples collected would aid in completing the analysis of the ionic makeup of the surface water, and would assist in classifying water type and potentially aid in identifying point sources of constituent loading or ionic exchange. It is evident that there is a difference in ionic composition of water as it travels west to east across the U.S. Army Garrison Fort Carson; however, it is not known if this change is abrupt or a gradual gradient. A synoptic investigation could help define the gradient profile.

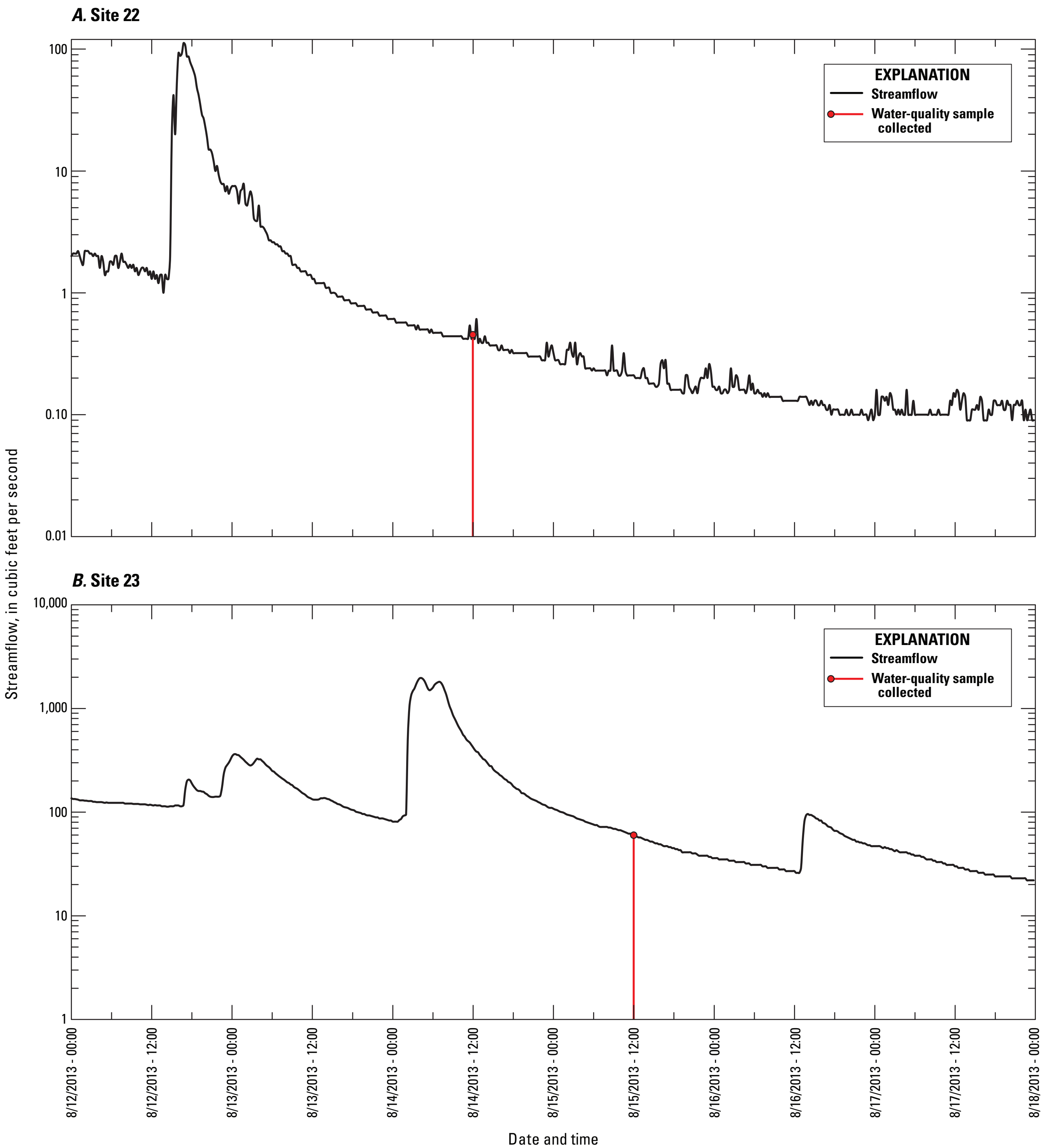

Figure 11. Unit-value streamflow hydrographs with water-quality sample date and time, the Piñon Canyon Maneuver Site, Colorado, August 12–17, 2013. See table 1 for site information. *A*, site 22. *B*, site 23. *C*, site 28.

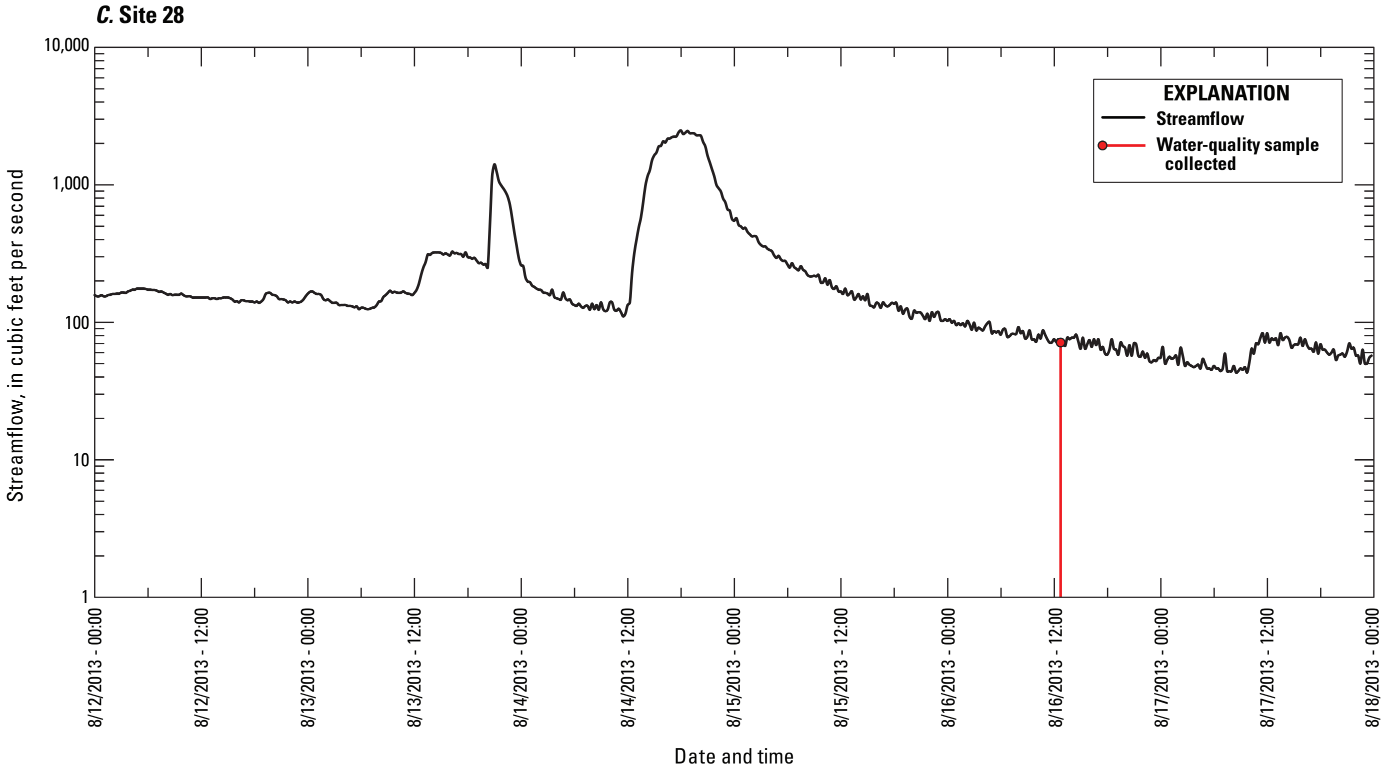

Figure 11. Unit-value streamflow hydrographs with water-quality sample date and time, the Piñon Canyon Maneuver Site, Colorado, August 12–17, 2013. See table 1 for site information. *A*, site 22. *B*, site 23. *C*, site 28.—Continued

Summary

To evaluate the influence of military training activities on streamflow and water quality, the U.S. Geological Survey (USGS), in cooperation with the U.S. Department of the Army, began a hydrologic data collection network on the U.S. Army Garrison Fort Carson in 1978 and on the Piñon Canyon Maneuver Site in 1983. This report is a summary and characterization of the hydrologic data collected at 43 sites between October 1, 2012, and September 30, 2014 (water years 2013 and 2014). A variety of analyses and plotting techniques were used to characterize data types and evaluate the relation between selected parameters. Data were analyzed using descriptive statistics, such as summary statistics, and correlation analyses were used to evaluate the strength and form of the associations among variable types.

Variations in the frequency of daily precipitation, seasonal distribution, and seasonal and annual precipitation at 5 stations at the U.S. Army Garrison Fort Carson and 18 stations at or near the Piñon Canyon Maneuver Site were evaluated. Seasonal and annual precipitation data were evaluated for 2013 and 2014. Isohyetal maps indicated a general pattern of increase in total annual precipitation from east to west at the U.S. Army Garrison Fort Carson and Piñon Canyon Maneuver Site. Between about 54 and 79 percent of daily precipitation is 0.1 inch or less in magnitude. Precipitation events are larger and more frequent between July and September.

Daily streamflow data from 16 sites were used to evaluate temporal and spatial variations in streamflow for water years 2013 and 2014. The daily mean streamflow was below 3.0 cubic feet per second at all sites, except sites 23 (Purgatoire River near Thatcher, CO) and 28 (Purgatoire River at Rock Crossing near Timpas, CO). At all sites, median daily mean streamflow for the 2-year period ranged from 0.0 to 9.60 cubic feet per second. Daily mean streamflow hydrographs were included in this report. Five sites on the Piñon Canyon Maneuver Site are monitored for peak stage using crest-stage gages. The peak stage for each water year is converted to streamflow using a stage-discharge rating.

Five Piñon Canyon Maneuver Site sites—sites 22 (Van Bremer Arroyo near Model, CO) and 24–27 (Taylor Arroyo below Rock Crossing near Thatcher, CO ; Lockwood Canyon Creek near Thatcher, CO; Red Rock Canyon Creek at mouth near Thatcher, CO; Bent Canyon Creek at mouth near Timpas, CO) —have a stage recorder and precipitation gage, providing a paired streamflow-precipitation dataset. At all five sites, many of the larger precipitation events had a corresponding rise in streamflow; however, occasionally rises in streamflow had no corresponding rainfall event, or a small event relative to the magnitude of the hydrograph spike. In other cases, large amounts of precipitation did not cause a rise in streamflow. This observation is possibly because of variable precipitation distribution and these gages are at or near the far downstream point in each basin. There was a statistically significant relation between precipitation and streamflow based on Spearman's correlation (rho values ranged from 0.17 to 0.35).

Suspended-sediment samples were collected from April through October for water years 2013–14 at six sites on the U.S. Army Garrison Fort Carson and the Piñon Canyon Maneuver Site. Suspended-sediment-transport curves were used to demonstrate the relation between streamflow and suspended-sediment concentration. All these sediment-transport curves had a streamflow dependent suspended-sediment concentration relation except for site 27 (Bent Canyon Creek at mouth near Timpas, CO).

Water-quality data were collected and reported from seven sites on the U.S. Army Garrison Fort Carson and the Piñon Canyon Maneuver Site during the study period. Numeric water-quality standards established by the Water Quality Control Commission published in Regulation 31 and 32, Classification and Numeric Standards for the Arkansas River Basin, apply to all flowing and standing waters within the Arkansas River Basin. These standards were used to compare the measured properties and constituents of the water-quality samples collected during the study period. Sample results exceeding an established water-quality standard were identified. Selected water-quality properties and constituents were stratified to compare spatial variation among selected parameters using boxplots.

Trilinear diagrams were used to classify water type based on ionic concentrations of water-quality samples collected during the study period. One sample from site 1 (Turkey Creek near Fountain, CO) and three samples from site 16 (Little Fountain Creek above Highway 115 at Fort Carson, CO) plotted notably different than the remaining samples. These sites are downstream from regions where the geology is made up of predominantly igneous and metamorphic rock and transitions into an area where the geology is characterized by sedimentary rock. These samples are interesting because samples at these two sites represent water that has not yet interacted with the shale and alluvium that make up the geology of most of the U.S. Army Garrison Fort Carson.

In total, 27 samples collected at the U.S. Army Garrison Fort Carson and the Piñon Canyon Maneuver Site classify as very hard or brackish. Seven samples had a lower hardness character relative to the rest of the samples. Four of these samples were collected at sites 1 (Turkey Creek near Fountain, CO) and 16 (Little Fountain Creek above Highway 115 at Fort Carson, CO), which were collected at locations with different geologic makeup, and three samples collected at the Piñon Canyon Maneuver Site had a markedly lower hardness likely because of dilution from an increase in streamflow.

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Appendix 1. Suspended-sediment concentration and streamflow data used for linear regression model (fig. 6).

[USGS, U.S. Geological Survey; CO, Colorado; ft^3/s, cubic foot per second; mg/L, milligram per liter; data are available in the U.S. Geological Survey National Water Information System at http://dx.doi.org/10.5066/F7P55KJN]

USGS 07105940—Little Fountain Creek near Fountain, CO (Site 3)

Date	Streamflow, (ft^3/s)	Suspended-sediment concentration (mg/L)	Date	Streamflow, (ft^3/s)	Suspended-sediment concentration (mg/L)	Date	Streamflow, (ft^3/s)	Suspended-sediment concentration (mg/L)
9/12/2013	42	11,800	10/31/2013	8.8	105	12/19/2013	7.1	201
9/13/2013	60	11,400	11/1/2013	3.6	173	12/20/2013	13	1,040
9/14/2013	165	10,400	11/2/2013	3.6	99	12/21/2013	6.8	1,450
9/15/2013	227	9,500	11/3/2013	1.7	32	12/22/2013	4.8	681
9/16/2013	236	8,190	11/4/2013	3	59	12/23/2013	219	18,300
9/17/2013	232	7,090	11/5/2013	4.3	42	12/24/2013	387	23,400
9/18/2013	224	6,250	11/6/2013	3.4	45	12/25/2013	279	18,000
9/19/2013	214	5,740	11/7/2013	3	10	12/26/2013	181	17,100
9/20/2013	210	4,930	11/8/2013	2.2	28	12/27/2013	14	3,200
9/21/2013	207	4,430	11/9/2013	2.1	62	12/28/2013	8.1	626
9/22/2013	203	4,190	11/10/2013	1.9	54	12/29/2013	2.6	112
9/23/2013	194	4,090	11/11/2013	3.6	93	12/30/2013	1.6	168
9/24/2013	193	3,820	11/12/2013	0.79	158	12/31/2013	1.7	361
9/25/2013	200	3,680	11/13/2013	0.59	162	1/1/2014	1.7	331
9/26/2013	226	4,280	11/14/2013	0.79	123	1/2/2014	1.3	242
9/27/2013	239	5,950	11/15/2013	0.9	88	1/3/2014	0.79	120
9/28/2013	247	7,950	11/16/2013	0.34	64	1/4/2014	0.59	94
9/29/2013	270	7,030	11/17/2013	0.19	8	1/5/2014	0.69	62
9/30/2013	265	6,960	11/18/2013	0.04	53	1/6/2014	0.27	180
10/1/2013	213	3,760	11/19/2013	0.05	45	1/7/2014	1.3	38
10/2/2013	165	1,920	11/20/2013	0.07	51	1/8/2014	0.9	68
10/3/2013	90	1,060	11/21/2013	4.1	182	1/9/2014	1	79
10/4/2013	76	910	11/22/2013	1.1	102	1/10/2014	1	91
10/5/2013	68	600	11/23/2013	8.8	3,880	1/11/2014	0.5	72
10/6/2013	59	506	11/24/2013	2.2	733	1/12/2014	0.41	106
10/7/2013	51	556	11/25/2013	1.1	207	1/13/2014	0.41	109
10/8/2013	37	233	11/26/2013	28	8,630	1/14/2014	0.41	82
10/9/2013	37	268	11/27/2013	1	177	1/15/2014	0.41	49
10/10/2013	34	234	11/28/2013	236	16,700	1/16/2014	0.79	20
10/11/2013	31	197	11/29/2013	21	7,670	1/17/2014	0.79	66
10/12/2013	13	72	11/30/2013	3	1,310	1/18/2014	0.69	39
10/13/2013	12	98	12/1/2013	2.4	428	1/19/2014	0.9	51
10/14/2013	11	70	12/2/2013	1	196	1/20/2014	0.59	78
10/15/2013	11	77	12/3/2013	0.59	172	1/21/2014	0.79	71
10/16/2013	9.1	81	12/4/2013	0.69	199	1/22/2014	0.41	50
10/17/2013	8.4	68	12/5/2013	0.59	192	1/23/2014	0.69	54
10/18/2013	7.4	53	12/6/2013	19	4,920	1/24/2014	0.59	59
10/19/2013	4.8	29	12/7/2013	2.1	749	1/25/2014	0.5	83
10/20/2013	4.6	31	12/8/2013	1.3	174	1/26/2014	3	2,770
10/21/2013	3.9	37	12/9/2013	1	104	1/27/2014	0.59	256
10/22/2013	4.1	46	12/10/2013	17	4,750	1/28/2014	1	81
10/23/2013	3.6	35	12/11/2013	3.6	698	1/29/2014	0.79	56
10/24/2013	3.2	65	12/12/2013	36	2,540	1/30/2014	0.27	59
10/25/2013	3.4	39	12/13/2013	15	1,760	1/31/2014	0.59	109
10/26/2013	1.6	26	12/14/2013	6.8	573	2/1/2014	0.59	109
10/27/2013	0.69	9	12/15/2013	4.3	48	2/2/2014	0.69	99
10/28/2013	0.41	3	12/16/2013	4.1	91	2/3/2014	0.59	136
10/29/2013	0.34	4	12/17/2013	1.1	33	2/4/2014	2.8	158
10/30/2013	0.26	8	12/18/2013	10	716	2/5/2014	0.7	141

Appendix 1. Suspended-sediment concentration and streamflow data used for linear regression model (fig. 6).—Continued

[USGS, U.S. Geological Survey; CO, Colorado; ft^3/s, cubic foot per second; mg/L, milligram per liter; data are available in the U.S. Geological Survey National Water Information System at http://dx.doi.org/10.5066/F7P55KJN]

USGS 07126200—Van Bremer Arroyo near Model, CO (Site 22)					
Date	Streamflow, (ft^3/s)	Suspended-sediment concentration (mg/L)	Date	Streamflow, (ft^3/s)	Suspended-sediment concentration (mg/L)
7/25/2013	141	160	4/16/2014	0.18	72
7/25/2013	189	771	4/17/2014	0.18	73
7/25/2013	128	1,300	4/18/2014	0.16	87
7/25/2013	74	1,010	4/19/2014	0.16	128
7/25/2013	38	788	7/15/2014	2.5	308
7/25/2013	11	517	7/15/2014	2.2	190
7/25/2013	4.5	328	7/15/2014	1.3	142
7/25/2013	2.2	245	7/15/2014	0.82	141
7/26/2013	1.4	177	7/17/2014	2.1	172
7/26/2013	0.37	75	7/17/2014	1.5	119
8/7/2013	189	22,500	7/17/2014	0.98	77
8/7/2013	893	11,100	7/19/2014	0.11	99
8/7/2013	646	7,360	7/27/2014	253	2,100
8/7/2013	871	6,000	7/27/2014	580	2,080
8/7/2013	1,150	6,640	7/27/2014	1,400	2,690
8/7/2013	2,150	8,090	7/27/2014	951	4,200
8/7/2013	1,480	12,500	7/27/2014	709	2,780
8/7/2013	659	4,120	7/27/2014	595	2,280
8/7/2013	403	3,080	7/27/2014	535	2,030
8/14/2013	0.42	46	7/28/2014	471	1,890
8/18/2013	30	4,330	7/28/2014	403	1,700
8/18/2013	15	2,020	7/28/2014	389	1,540
8/18/2013	2.4	386	7/28/2014	339	1,360
8/18/2013	2.2	185	7/28/2014	313	1,400
8/19/2013	0.69	135	7/28/2014	286	1,230
9/15/2013	35	2,220	7/28/2014	406	1,180
9/16/2013	96	1,870	7/28/2014	380	1,050
9/16/2013	149	1,820	7/28/2014	315	1,100
9/16/2013	627	3,130			
9/16/2013	1,100	3,750			
9/16/2013	1,060	3,910			
9/16/2013	841	3,740			
9/16/2013	580	2,090			
9/16/2013	481	1,720			
9/16/2013	435	1,500			
9/16/2013	389	1,210			
9/16/2013	298	1,030			
9/16/2013	246	1,220			
9/16/2013	205	1,350			
9/16/2013	198	1,410			
9/16/2013	177	1,420			
9/16/2013	164	1,510			
9/16/2013	128	1,500			
3/5/2014	0.18	16			
3/5/2014	0.18	88			
3/6/2014	0.17	81			
4/15/2014	0.23	14			
4/15/2014	0.23	36			
4/15/2014	0.21	73			

Appendix 1. Suspended-sediment concentration and streamflow data used for linear regression model (fig. 6).—Continued

[USGS, U.S. Geological Survey; CO, Colorado; ft³/s, cubic foot per second; mg/L, milligram per liter; data are available in the U.S. Geological Survey National Water Information System at http://dx.doi.org/10.5066/F7P55KJN]

USGS 07126325—Taylor Arroyo below Rock Crossing near Thatcher, CO (Site 24)			USGS 07126390—Lockwood Canyon near Thatcher, CO (Site 25)		
Date	Streamflow, (ft^3/s)	Suspended-sediment concentration (mg/L)	Date	Streamflow, (ft^3/s)	Suspended-sediment concentration (mg/L)
7/24/2013	4.4	1,040	7/29/2013	23	1,750
7/24/2013	36	1,560	7/29/2013	34	1,780
7/25/2013	9.6	2,520	7/29/2013	117	1,570
7/25/2013	1.3	1,380	7/29/2013	113	1,370
7/25/2013	0.41	890	7/29/2013	80	1,470
7/28/2013	0.58	351	7/30/2013	54	1,420
7/29/2013	1.3	228	7/30/2013	41	1,180
7/29/2013	0.49	123	7/30/2013	35	937
8/4/2013	107	2,340	7/30/2013	22	720
8/4/2013	119	4,690	7/30/2013	14	540
8/4/2013	220	5,760	7/30/2013	9.1	441
8/4/2013	380	7,010	8/4/2013	84	917
8/4/2013	337	9,050	8/4/2013	73	1,380
8/4/2013	64	6,830	8/4/2013	54	1,760
8/4/2013	24	17,600	8/4/2013	41	1,900
8/4/2013	23	4,180	8/4/2013	32	1,870
8/4/2013	19	2,560	8/4/2013	26	1,770
8/5/2013	16	3,270	8/4/2013	12	1,200
8/5/2013	4.4	3,080	8/4/2013	8.3	847
8/5/2013	1.3	1,380	8/4/2013	5.8	620
8/6/2013	0.58	633	8/5/2013	0.96	311
8/7/2013	457	10,600	8/7/2013	42	2,040
9/16/2013	0.09	7,120	8/11/2014	290	5,340
9/17/2013	2.3	1,080	8/11/2014	252	6,010
9/17/2013	0.77	527	8/11/2014	149	5,390
7/27/2014	46	7,640	8/11/2014	98	4,130
7/27/2014	210	7,000	8/11/2014	69	3,540
7/27/2014	129	4,940	8/11/2014	51	3,130
7/28/2014	354	5,720	8/11/2014	40	2,640
7/28/2014	581	14,200	8/11/2014	32	2,220
7/28/2014	132	3,040	8/11/2014	23	1,910
7/28/2014	73	2,000	8/12/2014	0.88	182
7/28/2014	60	1,500			
7/28/2014	52	1,100			
7/28/2014	40	649			
7/28/2014	31	418			
7/29/2014	27	341			

Appendix 1. Suspended-sediment concentration and streamflow data used for linear regression model (fig. 6).—Continued

[USGS, U.S. Geological Survey; CO, Colorado; ft^3/s, cubic foot per second; mg/L, milligram per liter; data are available in the U.S. Geological Survey National Water Information System at http://dx.doi.org/10.5066/F7P55KJN]

USGS 07126415—Red Rock Canyon Creek at mouth near Thatcher, CO (Site 26)			USGS 07126480—Bent Canyon Creek at mouth near Timpas, CO (Site 27)					
Date	Streamflow, (ft^3/s)	Suspended-sediment concentration (mg/L)	Date	Streamflow, (ft^3/s)	Suspended-sediment concentration (mg/L)	Date	Streamflow, (ft^3/s)	Suspended-sediment concentration (mg/L)
8/3/2013	109	3,670	7/14/2013	67	71,700	7/2/2014	2.7	2,930
8/3/2013	160	4,870	7/14/2013	515	33,300	7/12/2014	62	2,020
8/3/2013	30	3,340	7/14/2013	182	21,100	7/12/2014	38	9,790
8/4/2013	101	2,190	7/14/2013	105	7,570	7/12/2014	20	5,610
8/4/2013	574	10,100	7/14/2013	77	6,860	7/12/2014	9.2	4,300
8/4/2013	310	8,920	7/14/2013	61	6,650	7/12/2014	6.8	2,930
8/4/2013	138	4,150	7/14/2013	40	4,180	7/13/2014	13	2,310
8/4/2013	49	2,030	7/14/2013	31	3,410	7/13/2014	9.2	853
8/4/2013	28	1,230	7/14/2013	16	2,780	7/13/2014	12	1,500
8/4/2013	142	4,650	7/14/2013	5.4	2,700	7/13/2014	6.8	656
8/4/2013	200	4,200	8/3/2013	22	12,500	7/13/2014	4.4	455
8/4/2013	155	2,920	8/3/2013	23	31,600	7/13/2014	3	311
8/4/2013	111	2,610	8/3/2013	23	10,100	7/15/2014	6.1	3,540
8/4/2013	73	2,170	8/3/2013	7.6	4,230	7/15/2014	38	5,650
8/4/2013	60	1,950	8/3/2013	4.7	2,820	7/15/2014	16	6,190
8/7/2013	652	6,330	8/3/2013	6.4	35,900	8/27/2014	80	2,270
8/7/2013	647	4,700	8/3/2013	21	28,100	8/27/2014	65	1,550
8/7/2013	505	2,900	8/3/2013	200	9,340	8/27/2014	48	1,030
8/7/2013	400	2,440	8/3/2013	447	9,190	8/27/2014	46	891
8/10/2014	1,050	9,530	8/3/2013	883	6,760	8/27/2014	37	794
8/11/2014	487	4,220	8/4/2013	745	5,350	8/27/2014	29	618
8/11/2014	392	3,610	8/4/2013	536	3,860	8/27/2014	23	636
8/11/2014	339	3,200	8/4/2013	366	2,960	8/27/2014	19	501
8/11/2014	286	2,560	8/4/2013	295	2,640	8/27/2014	13	334
8/11/2014	232	2,210	8/4/2013	232	2,110	8/27/2014	8.5	281
8/11/2014	178	1,820	8/4/2013	149	2,310	8/27/2014	5.7	229
8/11/2014	131	1,760	8/4/2013	121	1,720			
8/11/2014	99	1,470	8/4/2013	102	1,460			
8/11/2014	92	1,300	8/4/2013	62	1,830			
8/11/2014	55	1,190	8/4/2013	318	4,960			
8/11/2014	27	1,020	8/4/2013	225	4,510			
8/25/2014	135	2,040	8/4/2013	192	4,690			
8/25/2014	80	3,030	8/4/2013	114	5,450			
8/25/2014	45	2,970	5/22/2014	11	16,600			
8/27/2014	46	798	5/22/2014	7.6	10,600			
9/29/2014	150	1,270	5/22/2014	3.2	5,510			
9/29/2014	140	1,200	7/2/2014	36	3,450			
9/30/2014	97	785	7/2/2014	32	19,200			
9/30/2014	55	482	7/2/2014	11	6,570			
9/30/2014	51	422	7/2/2014	4.8	4,930			

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