Prepared in cooperation with Colorado Springs City Engineering

Characterization of Water Quality and Suspended Sediment during Cold-Season Flows, Warm-Season Flows, and Stormflows in the Fountain and Monument Creek Watersheds, Colorado, 2007–2015

Scientific Investigations Report 2017–5084

U.S. Department of the Interior
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Cover. Monument Creek near Pikeview Reservoir at Colorado Springs, Colo. (Photograph by Holly Fransua, U.S. Geological Survey).

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Conversion Factors

U.S. customary units to International System of Units

Multiply	By	To obtain
	Length	
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
acre	4,047	square meter (m^2)
square foot (ft^2)	0.09290	square meter (m^2)
square mile (mi^2)	259.0	hectare (ha)
square mile (mi^2)	2.590	square kilometer (km^2)
	Volume	
ounce (oz)	29.5735	milliliter (mL)
gallon (gal)	3.785	liter (L)
gallon (gal)	0.003785	cubic meter (m^3)
cubic foot (ft^3)	0.02832	cubic meter (m^3)
acre-foot (acre-ft)	1,233	cubic meter (m^3)
	Flow rate	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
	Mass	
pound, avoirdupois (lb)	0.4536	kilogram (kg)
ton, short (2,000 lb)	0.9072	metric ton (t)
ton, long (2,240 lb)	1.016	metric ton (t)

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

$$°F = (1.8 \times °C) + 32.$$

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

$$°C = (°F - 32) / 1.8.$$

Datum

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

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

Altitude, 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).

Abbreviation and Acronyms Used in This Report

CDPHE	Colorado Department of Public Health and Environment
col/100 mL	colonies per 100 milliliters
EPA	U.S. Environmental Protection Agency
E. coli	*Escherichia coli*
ft	feet
ft^3	cubic feet per second
GCLAS	Graphical Constituent Loading Analysis System
IQR	Interquartile Range
lb/d	pounds per day
LRL	laboratory reporting level
LT-MDL	long-term method detection level
mg/L	milligrams per liter
µg/L	micrograms per liter
µS/cm	microsiemens per centimeter at 25 degrees Celsius
mm	millimeter
mL	milliliter
mi^2	square mile
NWQL	National Water Quality Laboratory
NWIS	National Water Information System
tons/d	tons per day
tons/d/mi^2	tons per day per square mile
USGS	U.S. Geological Survey

Characterization of Water Quality and Suspended Sediment during Cold-Season Flows, Warm-Season Flows, and Stormflows in the Fountain and Monument Creek Watersheds, Colorado, 2007–2015

By Lisa D. Miller and Robert W. Stogner, Sr.

Abstract

From 2007 through 2015, the U.S. Geological Survey, in cooperation with Colorado Springs City Engineering, conducted a study in the Fountain and Monument Creek watersheds, Colorado, to characterize surface-water quality and suspended-sediment conditions for three different streamflow regimes, with an emphasis on characterizing water quality during storm runoff. Data collected during this study were used to evaluate the effects of stormflows and wastewater-treatment effluent discharge on Fountain and Monument Creeks in the Colorado Springs, Colorado, area. Water-quality samples were collected at 2 sites on Upper Fountain Creek, 2 sites on Monument Creek, 3 sites on Lower Fountain Creek, and 13 tributary sites during 3 flow regimes: cold-season flow (November–April), warm-season flow (May–October), and stormflow from 2007 through 2015. During 2015, additional samples were collected and analyzed for *Escherichia coli* (*E. coli*) during dry weather conditions at 41 sites, located in *E. coli* impaired stream reaches, to help identify source areas and scope of the impairment.

Concentrations of *E. coli*, total arsenic, and dissolved copper, selenium, and zinc in surface-water samples were compared to Colorado in-stream standards. Stormflow concentrations of *E. coli* frequently exceeded the recreational use standard of 126 colonies per 100 milliliters at main-stem and tributary sites by more than an order of magnitude. Even though median *E. coli* concentrations in warm-season flow samples were lower than median concentrations in stormflow samples, the water-quality standard for *E. coli* was still exceeded at most main-stem sites and many tributary sites during warm-season flows. Six samples (three warm-season flow and three stormflow samples) collected from Upper Fountain Creek, upstream from the confluence of Monument Creek, and two stormflow samples collected from Lower Fountain Creek, downstream from the confluence with Monument Creek, exceeded the acute water-quality standard for total arsenic of 50 micrograms per liter. All concentrations of dissolved copper, selenium, and zinc measured in samples were below the water-quality standard.

Concentrations of dissolved nitrate plus nitrite generally increased from upstream to downstream during all flow periods. The largest downstream increase in dissolved nitrate plus nitrite concentration was measured between sites 07103970 and 07104905 on Monument Creek. All but one tributary that drain into Monument Creek between the two sites had higher median nitrate plus nitrite concentrations than the nearest upstream site on Monument Creek, site 07103970 (MoCr_Woodmen). Increases in the concentration of dissolved nitrate plus nitrite were also evident below wastewater treatment plants located on Fountain Creek.

Most stormflow concentrations of dissolved trace elements were smaller than concentrations from cold-season flow or warm-season samples. However, median concentrations of total arsenic, lead, manganese, nickel, and zinc generally were much larger during periods of stormflow than during cold-season flow or warm-season flow. Median concentrations of total arsenic, total copper, total lead, dissolved and total manganese, total nickel, dissolved and total selenium, and dissolved and total zinc concentrations increased from 1.5 to 28.5 times from site 07103700 (FoCr_Manitou) to 07103707 (FoCr_8th) during cold-season and warm-season flows, indicating a large source of trace elements between these two sites. Both of these sites are located on Fountain Creek, upstream from the confluence with Monument Creek.

Median suspended-sediment concentrations and median suspended-sediment loads increased in the downstream direction during all streamflow regimes between Monument Creek sites 07103970 (MoCr_Woodmen) and 07104905 (MoCr_Bijou); however, statistically significant increases (p-value less than 0.05) were only present during warm-season flow and stormflow. Significant increases in median suspended-sediment concentrations were measured during cold-season flow and warm-season flow between Upper Fountain Creek site 07103707 (FoCr_8th) and Lower Fountain Creek site 07105500 (FoCr_Nevada) because of inflows from Monument Creek with higher suspended-sediment concentrations. Median suspended-sediment concentrations between sites 07104905 (MoCr_Bijou) and 07105500 (FoCr_Nevada) increased significantly during

warm-season flow but showed no significant differences during cold-season flow and stormflow. Significant decreases in median suspended-sediment concentrations were measured between sites 07105500 (FoCr_Nevada) and 07105530 (FoCr_Janitell) during all flow regimes.

Suspended-sediment concentrations, discharges, and yields associated with stormflow were significantly larger than those associated with warm-season flow. Although large spatial variations in suspended-sediment yields occurred during warm-season flows, the suspended-sediment yields associated with stormflow were as much as 1,000 times larger than the suspended-sediment yields that occurred during warm-season flow.

Introduction

Fountain Creek is a tributary of the Arkansas River, draining a 926-square mile (mi^2) area that includes portions of El Paso, Teller, and Pueblo Counties in Colorado. Monument Creek is a major tributary to Fountain Creek, draining 235 mi^2. The population of the metropolitan area in and around Colorado Springs within the Fountain Creek watershed increased rapidly between 1940 and 2015 (Colorado Department of Local Affairs, 2017a, b, c). Considerable changes in land use and water use have occurred during this time. Land use has changed from rangeland and forest use to urban and municipal use in many areas. Groundwater and surface-water withdrawals within the Fountain Creek watershed have also increased, and water is imported from outside of the watershed to meet the needs of the growing population. As the population has increased, the volume of treated municipal wastewater return flows discharged to Fountain and Monument Creeks has increased, and the number of onsite wastewater treatment systems has increased. In 2017, El Paso County Public Health estimated that there are about 30,000 onsite wastewater treatment systems operating in El Paso County (El Paso County Public Health, 2017). Water-quality information is needed to evaluate stream health related to changes in land use and water use and to meet regulatory requirements for storm water discharge within the Fountain Creek watershed.

From 2007 through 2015, the U.S. Geological Survey, in cooperation with Colorado Springs City Engineering, conducted a study within the Fountain and Monument Creek watersheds (fig. 1; table 1) to characterize surface-water-quality and suspended-sediment conditions in the watershed for three different streamflow regimes, with an emphasis on characterizing water quality during storm runoff. The scope of the study also included evaluating spatial differences in water quality and suspended sediment, and to the extent possible, evaluating the effects of wastewater-treatment plant operations on water quality and suspended sediment.

Purpose and Scope

The purpose of this report is to characterize water quality and suspended sediment during three streamflow regimes, cold-season flows, warm-season flows, and stormflows within the Fountain and Monument Creek watersheds using data collected from 2007 through 2015. To characterize water-quality and suspended-sediment conditions in this report: (1) values of onsite measurements of specific conductance, pH, and dissolved oxygen and concentrations of *Escherichia coli (E. coli)*, dissolved nitrate plus nitrite, total phosphorus, ammonia, selected trace elements, and suspended sediment were compared spatially and in relation to streamflow conditions, (2) concentrations of selected constituents were compared to Colorado in-stream water-quality standards, and (3) water-quality loads were estimated and compared for selected constituents during warm-season flow and stormflow.

Description of Study Area

The study area drains about 500 mi^2 and encompasses most of the urbanized area within the Fountain and Monument Creek watersheds. Elevations in the study area range from 14,109 feet (ft) at the summit of Pikes Peak to 5,460 ft at the southern end of the study area. There are two major physiographic regions in the study area—the Front Range of the Southern Rocky Mountains and the Colorado Piedmont (Hansen and Crosby, 1982). The Front Range, which comprises about the western one-third of the study area, is underlain by granite. Soils in this area are well drained and lie on steep slopes (Larsen, 1981; von Guerard, 1989a). The Colorado Piedmont, which comprises the remaining eastern two-thirds of the area, abuts the base of the Rampart Range. Underlying the northern part of the Colorado Piedmont in the study area is the Denver Basin, a structural basin containing principal aquifers composed of sandstone, shale, and alluvial and wind lain deposits. Soils in this area generally are sandy and well drained with gentler slopes than in the Front Range (Larsen, 1981; von Guerard, 1989a). Underlying the southern part of the Colorado Piedmont in the study area is an outcrop of the Pierre Shale. The Pierre Shale is the confining unit separating the aquifers of the Denver Basin from the Niobrara Formation, part of the Dakota-Cheyenne Aquifer (Colorado Geological Survey, 2003). The soils and geology on the Colorado Piedmont are readily erodible, especially relative to the granitic rocks on the west side of the study area. More details of the soils and geology of the study area are contained in Larsen (1981), von Guerard (1989a), and Colorado Geological Survey (2003).

The population of El Paso County, which includes Colorado Springs, increased from about 75,000 people in 1950 to about 310,000 in 1980, and to about 515,000 in 2000 (table 2). The 2015 population was estimated to be about 675,000. The rate of growth was about 8,000 people per year between 1950 and 1990. Between 1990 and 2000, the rate of growth increased to about 11,000 people per year. In recent

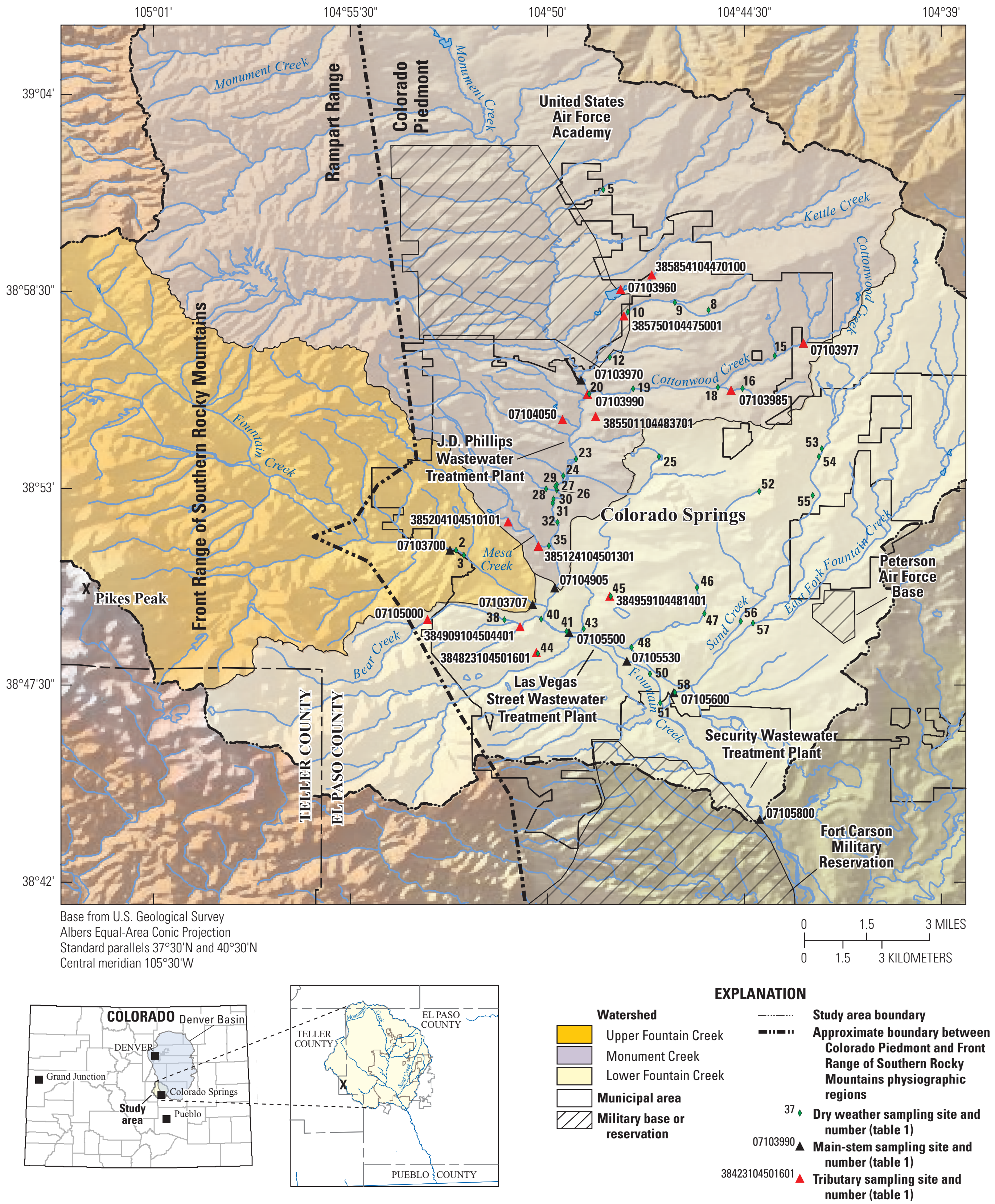

Figure 1. Location of study area and sampling sites for the Fountain and Monument Creek watersheds, Colorado.

Table 1. Selected surface-water sites in the Fountain and Monument Creek watersheds, Colorado, and water-quality constituents, suspended-sediment and biological parameters measured or analyzed 2007 through 2015.

[WQ, water quality; *E. coli*, *Escherichia coli*; --, no value; USGS, U.S. Geological Survey]

USGS site number	Abbreviated name	USGS site name	Site type	Dry weather site number	Network	Period of data collection	Water-quality constituents			Sediment
							Bacteria, *E. coli*	Nutrients	Trace elements	
Upper Fountain Creek										
07103700	FoCr_Manitou	Fountain Creek near Colorado Springs, Colo.	Main stem		WQ	2007–2015	X	X	X	X
385116104523301		Fountain Creek at South 32nd Street near Colorado Springs (culvert)	Tributary	2	*E. coli*	2015	X			
385108104522001		Camp Creek at South 31st Street near Colorado Springs	Tributary	3	*E. coli*	2015	X			
07103707	FoCr_8th	Fountain Creek below 8th Street, at Colorado Springs, Colo.	Main stem		WQ	2007–2015	X	X	X	X
Monument Creek										
390121104482601		Monument Creek tributary near Diamond Rim Drive near Colorado Springs	Tributary	5	*E. coli*	2015	X			
385854104470100	upper_Ke	Kettle Creek above Old Ranch Road near Colorado Springs, Colo.	Tributary		WQ	2007–2008	X	X		
07103960	lower_Ke	Kettle Creek above U.S. Air Force Academy, Colo.	Tributary		WQ	2007–2015	X	X	X	X
385759104453001		Pine Creek drain at North Union Boulevard North Park at Colorado Springs	Tributary	8	*E. coli*	2015	X			
385812104462601		Pine Creek drain at Pine Creek Golf Club at Colorado Springs	Tributary	9	*E. coli*	2015	X			
385756104474501		Pine Creek drain Briargate Parkway at Colorado Springs (culvert)	Tributary	10	*E. coli*	2015	X			
385750104475001		Pine Creek above Highway 83 at Colorado Springs, Colo.	Tributary		WQ	2007–2008	X	X		
385640104481501		South Pine Creek (culvert 2 aqueduct) at Goddard Street at Colorado Springs	Tributary	12	*E. coli*	2015	X			
07103970	MoCr_Woodmen	Monument Creek above Woodmen Road at Colorado Springs, Colo.	Main stem		WQ	2007–2015	X	X	X	X[1]
07103977		Cottonwood Creek at Cowpoke Road at Colorado Springs, Colo.	Tributary		WQ	2007–2008	X	X		
385642104433901		Cottonwood Creek tributary at Potomac Drive at Colorado Springs	Tributary	15	*E. coli*	2015	X			
385548104443301		Cottonwood Creek drain at Austin Bluffs Parkway, Colorado Springs	Tributary	16	*E. coli*	2015	X			
07103985		Cottonwood Creek tributary above Rangewood Drive at Colorado Springs, Colo.	Tributary		WQ	2007–2008	X	X		
385549104451401		Cottonwood Creek drain Rangewood Drive at Colorado Springs	Tributary	18	*E. coli*	2015	X			
385547104473601		Cottonwood Creek drain at North Academy Boulevard near York Road	Tributary	19	*E. coli*	2015	X			
07103990	lower_CoCr	Cottonwood Creek at mouth at Pikeview	Tributary	20	*E. coli*/WQ	2007–2015	X	X	X	X[1]
385501104483701		Monument Creek tributary 1 near Pulpit Rock at Colorado Springs, Colo.	Tributary		WQ	2007		X		
07104050	N. RoCr	North Rockrimmon Creek above Delmonico Drive at Colorado Springs, Colo.	Tributary		WQ	2007–2008	X	X		
385349104491201		Monument Creek drain Pikeview Reservoir at Colorado Springs (culvert)	Tributary	23	*E. coli*	2015	X			
385321104493301		Douglas Creek at the mouth at Colorado Springs, Colo.	Tributary	24	*E. coli*	2007–2015	X			
385353104465301		Templeton Gap floodway at North Union Boulevard at Colorado Springs	Tributary	25	*E. coli*	2015	--[2]	--	--	--
385307104494401		Monument Creek drain 1 Mark Dabling Boulevard at Colorado Springs	Tributary	26	*E. coli*	2015	X			
385303104494601		Monument Creek drain 2 Mark Dabling Boulevard at Colorado Springs	Tributary	27	*E. coli*	2015	X			
385259104500201		Douglas Creek drain at Sinton Road at Colorado Springs (culvert)	Tributary	28	*E. coli*	2015	X			
385257104494401		Douglas Creek south at mouth at Colorado Springs, Colo.	Tributary	29	*E. coli*	2015	X			
385242104495001		Monument Creek drain 3 Mark Dabling Boulevard at Colorado Springs	Tributary	30	*E. coli*	2015	X			
385235104495101		Monument Creek drain 4 Mark Dabling Boulevard at Colorado Springs	Tributary	31	*E. coli*	2015	X			
385203104494301		Monument Creek aqueduct at Tremont Street at Colorado Springs	Tributary	32	*E. coli*	2015	X			
385204104510101		Monument Creek tributary 2 below Fillmore Street at Colorado Springs	Tributary		WQ	2007–2008	X	X		
385124104501301		Monument Creek tributary 2 at Sondermann Park at Colorado Springs	Tributary		WQ	2007–2015	X	X	X	X
385124104495701		Mesa Creek at mouth at Recreation Way at Colorado Springs	Tributary	35	*E. coli*	2015	X			
07104905	MoCr_Bijou	Monument Creek at Bijou Street at Colorado Springs, Colo.	Main stem		WQ	2007–2015	X	X	X	X[1]

Table 1. Selected surface-water sites in the Fountain and Monument Creek watersheds, Colorado, and water-quality constituents, suspended-sediment and biological parameters measured or analyzed 2007 through 2015.—Continued

[WQ, water quality; *E. coli*, *Escherichia coli*; --, no value; USGS, U.S. Geological Survey]

USGS site number	Abbreviated name	USGS site name	Site type	Dry weather site number	Network	Period of data collection	Water-quality constituents: Bacteria, *E. coli*	Water-quality constituents: Nutrients	Water-quality constituents: Trace elements	Sediment
		Lower Fountain Creek								
07105000	FoCr_Nevada	Bear Creek near Colorado Springs, Colo.	Tributary		WQ	2007–2008	X	X		
384920104511201		Bear Creek drain near Creek Crossing Street at Colorado Springs	Tributary	38	*E. coli*	2015	X			
384909104504401		Bear Creek above 8th Street at Colorado Springs, Colo.	Tributary		WQ	2007–2014	X	X	X	X
384921104501001		Bear Creek at Interstate 25 at Colorado Springs	Tributary	40	*E. coli*	2015	X			
384900104492801		Fountain Creek drain at South Tejon Street at Colorado Springs (culvert)	Tributary	41	*E. coli*	2015	X			
07105500		Fountain Creek at Colorado Springs, Colo.	Main stem		WQ	2007–2015	X	X	X	X[1]
384905104485901		Shooks Run at Las Vegas Street at Colorado Springs	Tributary	43	*E. coli*	2007–2015	X			
384823104501601		Cheyenne Run tributary at Colorado Springs (culvert)	Tributary	44	*E. coli*	2015	X			
384959104481401		Shooks Run tributary at Colorado Springs (culvert to ditch)	Tributary	45	*E. coli*	2015	X			
385014104454901		Spring Creek drain at Auburn Drive at Colorado Springs (culvert)	Tributary	46	*E. coli*	2015	X			
384930104453701		Spring Creek drain Majorie Lee Drive near Arpt Road at Colorado Springs	Tributary	47	*E. coli*	2015	X			
384833104473900		Spring Creek downstream Las Vegas Street	Tributary	48	*E. coli*	2007–2015	X			
07105530	FoCr_Janitell	Fountain Creek below Janitell Road below Colorado Springs, Colo.	Main stem		WQ	2007–2015	X	X	X	X[1,3]
384749104470801		Fountain Creek drain near Circle Drive at Colorado Springs (culvert)	Tributary	50	*E. coli*	2015	X			
384701104465101		Unnamed ditch to Fountain Creek below I-25 at pond Colorado Springs	Tributary	51	*E. coli*	2015	X			
385255104440501		Valencia Creek near Oro Blanco Drive at Colorado Springs (culvert)	Tributary	52	*E. coli*	2015	X			
385406104422001		Sand Creek drain near Barnes Road at Colorado Springs (culvert)	Tributary	53	*E. coli*	2015	X			
385353104422501		Sand Creek drain at Barnes Road at Colorado Springs (culvert)	Tributary	54	*E. coli*	2015	X			
385248104423501		Sand Creek drain at Spring Ranch Golf Club at Colorado Springs	Tributary	55	*E. coli*	2015	X			
384917104443601		Sand Creek drain near Crestline Drive at Colorado Springs (culvert)	Tributary	56	*E. coli*	2015	--[2]	--	--	--
384914104441501		Sand Creek drain at Nolte Drive west at Colorado Springs (culvert)	Tributary	57	*E. coli*	2015	--[2]	--	--	--
07105600		Sand Creek above mouth at Colorado Springs	Tributary	58	*E. coli*/WQ	2007–2015	X	X	X	X[1]
07105800	FoCr_Security	Fountain Creek at Security, Colo.	Main stem		WQ	2007–2015	X	X	X	X[1]

[1]Daily suspended-sediment record.

[2]No flow during sampling period.

[3]Period of record for daily suspended sediment, 2013–2015.

Table 2. Population totals for El Paso County and Colorado Springs, Colorado, 1870–2015.

[E, estimated; --, no value]

Year	El Paso County	Year	Colorado Springs
1870	[1]987	1870	--
1880	[1]7,949	1880	[1]4,226
1890	[1]21,239	1890	[1]11,140
1900	[1]31,602	1900	[1]21,085
1910	[1]43,321	1910	[1]29,078
1920	[1]44,027	1920	[1]30,105
1930	[1]49,570	1930	[1]33,237
1940	[1]54,025	1940	[1]36,789
1950	[1]74,523	1950	[1]45,472
1960	[1]143,742	1960	[1]70,194
1970	[1]235,972	1970	[1]135,517
1980	[1]309,424	1980	[1]215,105
1990	[1]397,014	1990	[1]281,140
2000	[1]516,929	2000	[1]360,890
2010	[1]622,263	2010	[1]417,335
2015	[2]677,022E	2015	[3]451,585E

[1]Colorado Department of Local Affairs, 2017a, Historical census data—Counties and municipalities: Colorado Department of Local Affairs web page accessed March 30, 2017, at https://demography.dola.colorado.gov/population/data/historical_census/.

[2]Colorado Department of Local Affairs, 2017b, Population totals for Colorado and sub-state regions: Colorado Department of Local Affairs web page accessed March 30, 2017, at https://demography.dola.colorado.gov/population/population-totals-colorado-substate/.

[3]Colorado Department of Local Affairs, 2017c, Population totals for Colorado municipalities: Colorado Department of Local Affairs web page accessed March 30, 2017, at https://demography.dola.colorado.gov/population/population-totals-municipalities/.

years (2001–2015), the rate of growth remained about the same, 10,700 people per year (Colorado Department of Local Affairs, 2017a,b,c).

Annual precipitation in the Fountain and Monument Creek watersheds generally decreases as elevation decreases and decreases with distance from the headwaters of the watershed. The mean annual precipitation varies considerably from year to year (fig. 2). At the Colorado Springs Weather Service Office at Peterson Air Force Base (fig. 1), annual precipitation for 1949 through 2015 ranged from 7.8 to 27.6 inches (fig. 2*A*). Between 2007 and 2015, the annual precipitation ranged from 9.4 inches in 2010 to 25.2 inches in 2015 (fig. 2*B*). Much of the annual precipitation in the study area occurs from May through August (U.S. Climate Data, 2017).

Methods of Investigation

Water-quality samples were collected at 2 sites on Upper Fountain Creek, 2 sites on Monument Creek, 3 sites on Lower Fountain Creek, and 13 tributary sites under various streamflow conditions between 2007 and 2015 (table 1; fig. 1). Tributaries sampled included Kettle Creek, Cottonwood Creek, Mesa Creek, Bear Creek, and Sand Creek. Water-quality samples were classified into two groups: routine and storm. Routine samples were further classified as warm season or cold season as described below. At main-stem sites, routine water-quality samples were collected in February, May, July, and October at scheduled times with little regard for hydrologic conditions. Storm samples specifically targeted conditions during stormflow. Stormflow is defined as flow that is twice the base flow as calculated during winter months (cold season) on main-stem sites and three times the base flow as calculated during winter months on tributary sites. Stormflow samples were collected annually between April 1 and September 30 at main-stem sites. At tributary sites, routine water-quality samples were collected in June and October during warm-season flow and one storm sample was collected between April 1 and September 30. The sampling routine for Sand Creek was different from the other tributary sites. Two routine water-quality samples were collected in March and July, and two storm samples were collected between April 1 and September 30.

Measurements of specific conductance, pH, dissolved oxygen, *Escherichia coli* (*E. coli*), ammonia, nitrate plus nitrite, phosphorus, suspended sediment, and selected trace elements were made to characterize water quality in the Fountain and Monument Creek watersheds near Colorado Springs, Colorado. Samples for analysis of dissolved constituents were filtered using a 0.45-micron filter and are hereafter referred to as dissolved; unfiltered samples are referred to as total samples. The trace elements analyzed include dissolved and total arsenic, dissolved boron, dissolved and total copper, total lead, dissolved and total manganese, total nickel, dissolved and total selenium, and dissolved and total zinc.

Suspended-sediment samples were collected from April 1 through September 30 in conjunction with routine and stormwater-quality samples to evaluate variations in suspended-sediment concentrations, discharge, and yield. In addition, suspended-sediment samples were collected daily by automatic samplers at Monument Creek above Woodmen (site 07103970, MoCr_Woodmen), Cottonwood Creek at mouth at Pikeview (site 07103990, lower_CoCr), Monument Creek at Bijou Street (site 07104905, MoCr_Bijou), Fountain Creek at Colorado Springs (site 07105500, FoCr_Nevada), Sand Creek above mouth (site 07105600, SaCr), and Fountain Creek at Security (site 07105800, FoCr_Security) to evaluate daily variations in suspended-sediment concentrations, discharge, and yield. Automatic samplers were operated annually from April 1 through September 30. Routine and daily samples data were used to evaluate annual and spatial variations in suspended-sediment concentrations, discharge, and yield that occurred during cold-season flow, warm-season flow, and stormflow.

In addition to the above described sampling regime, during 2015, samples were collected quarterly and analyzed for *E. coli* at 41 sites (table 1) to aid in identifying and documenting dry weather discharges within stream segments listed as impaired for *E. coli* by the Colorado Department of Public Health and Environment (CDPHE) Water Quality Control

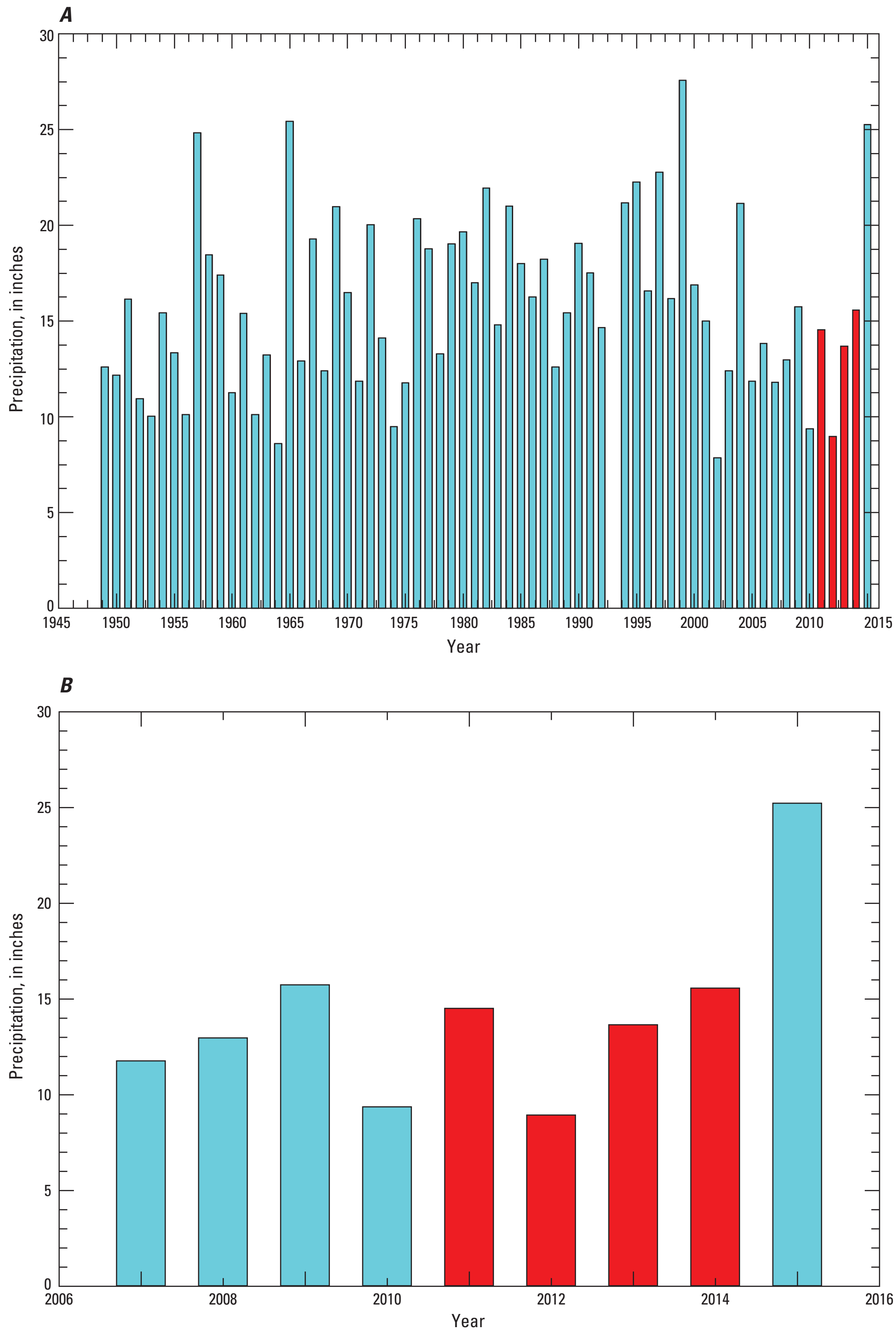

Figure 2. Annual precipitation at the Colorado Springs Weather Service Office Colorado; *A*, 1949 through 2015 and *B*, 2007 through 2015. (Data from Colorado Springs Weather Service Office, site identification number 51778, accessed 9/6/2016 at http://ccc.atmos.colostate.edu/dly form.html. Red colored bars indicate estimated data from U.S. Geological Survey precipitation monitoring site 385010104422901, accessed 4/26/2017 at https://waterdata.usgs.gov/nwis/inventory/?site_no=385010104422901&agency_cd=USGS&amp.)

Commission (Colorado Department of Public Health and Environment, 2016c). These dry weather samples were collected when streamflow discharge was greater than 5 gallons per minute (gal/min) at the sampling location, there had been at least 48 hours since the last precipitation event, and there was no evidence of snowmelt.

Streamflow Regimes

Water quality commonly varies with different streamflow regimes in the Fountain Creek watershed (Mau and others, 2007). Figure 3 shows an example of the seasonal (temporal) variations in streamflow that occur in the study area. Based on the observed seasonal variations in streamflow and results from previous studies, water-quality data were grouped into three streamflow regimes (cold-season flow, warm-season flow, and stormflow) for analysis (fig. 3). Cold-season flow was defined as the period November 1 through April 30, when streamflows were generally low and predominantly sustained by groundwater discharge, wastewater effluent, and other regulated discharges and not affected by stormflow. Warm-season flow was defined as the period May 1 through October 31, when streamflows were elevated above cold-season conditions because of snowmelt runoff. Stormflows were defined as daily mean streamflow larger than two times the computed daily cold-season flow for all main-stem sites. For the tributary sites, stormflow was defined as streamflow greater than three times the computed daily cold-season flow.

As in previous summaries of data collected for this study area (Edelmann and others, 2002; Mau and others, 2007), the number of stormflow events from May through October for each year were estimated from 2007 through 2015 by using a technique to separate the base-flow component from the daily mean streamflow (Wahl and Wahl, 1995). This computer program implements a deterministic procedure to estimate the base-flow component of the daily hydrograph by combining a local minimums approach with a recession slope test. Based on inspection of streamflow hydrographs, a decision was made that daily mean streamflow larger than two times the computed daily cold-season flow was a conservative indicator of stormflow for all main-stem sites. For the tributary sites, a daily mean streamflow larger than three times the computed daily cold-season flow was a conservative indicator of stormflow. Based on these techniques, between 2007 and 2015, the number of stormflow events per year generally ranged from 45 to 85, with an average of 68.

For sample sites located at U.S. Geological Survey (USGS) streamflow-gaging stations, instantaneous streamflow values were obtained from gage readings. At ungaged sites, instantaneous streamflow measurements were made when water-quality samples were collected (Rantz and others, 1982). Streamflow data used in this report are available from the USGS National Water Information System (NWIS) at http://dx.doi.org/10.5066/F7P55KJN (search by USGS site number given in table 1).

Water-Quality Data

Water-quality samples were collected and processed using standard USGS techniques and procedures (U.S. Geological Survey, 1977; Horowitz and others, 1994; Wilde and others, 1998). Sample processing was done primarily in a mobile USGS laboratory at the sampling site. Sampling equipment was cleaned using part-per-billion protocols (Wilde, 2004). Specific conductance, pH, and dissolved oxygen measurements were made using protocols described by Wilde and others (1998). Water-quality constituents were analyzed at the USGS National Water Quality Laboratory (NWQL) in Denver, Colorado (Fishman and Friedman, 1989). Water-quality data used in this report are available from the USGS NWIS at http://dx.doi.org/10.5066/F7P55KJN (search by USGS site number given in table 1).

The “E” remark code is used to signify that a measured concentration or field value is estimated. For samples analyzed at the NWQL, analytes detected at concentrations less than the laboratory reporting level (LRL) and as low as the long term method detection level (LT-MDL) are reported with an “E” remark code, whereas non-detections are reported as less than LRL (Childress and others, 1999).

Instantaneous nutrient, trace element, and suspended-sediment loads were computed at selected sites in the study area by multiplying concentration data by streamflow and a unit conversion factor. In contrast to concentration data, instantaneous loads provide an estimate of the mass of a constituent transported past a given site at a given time and were expressed in pounds per day (lb/d). The instantaneous loads discussed in the report were based on a small dataset and may not represent the range in loads that occurred in the watershed during the study.

Quality-Control Data

Quality-control samples were routinely collected and analyzed to identify, quantify, and document bias and variability in the collection and processing of data (Wilde and others, 1998). Quality-control samples collected included field and equipment blanks and replicates. Field and equipment blanks were collected and analyzed to test for sample contamination. Replicate samples were collected to estimate variability in the environmental data. All quality-control samples were submitted to the NWQL for analysis.

Dissolved ammonia, dissolved nitrate plus nitrite, total phosphorus, total arsenic, dissolved and total copper, dissolved and total zinc, and dissolved selenium were detected in one or more field blanks (table 3). Concentrations of these constituents in the field blanks were low and usually less than or equal to the laboratory reporting levels. Concentrations measured in field blanks were small fractions of concentrations measured in the majority of environmental samples.

For each analyte, the relative percent difference was calculated as the absolute difference between a replicate and

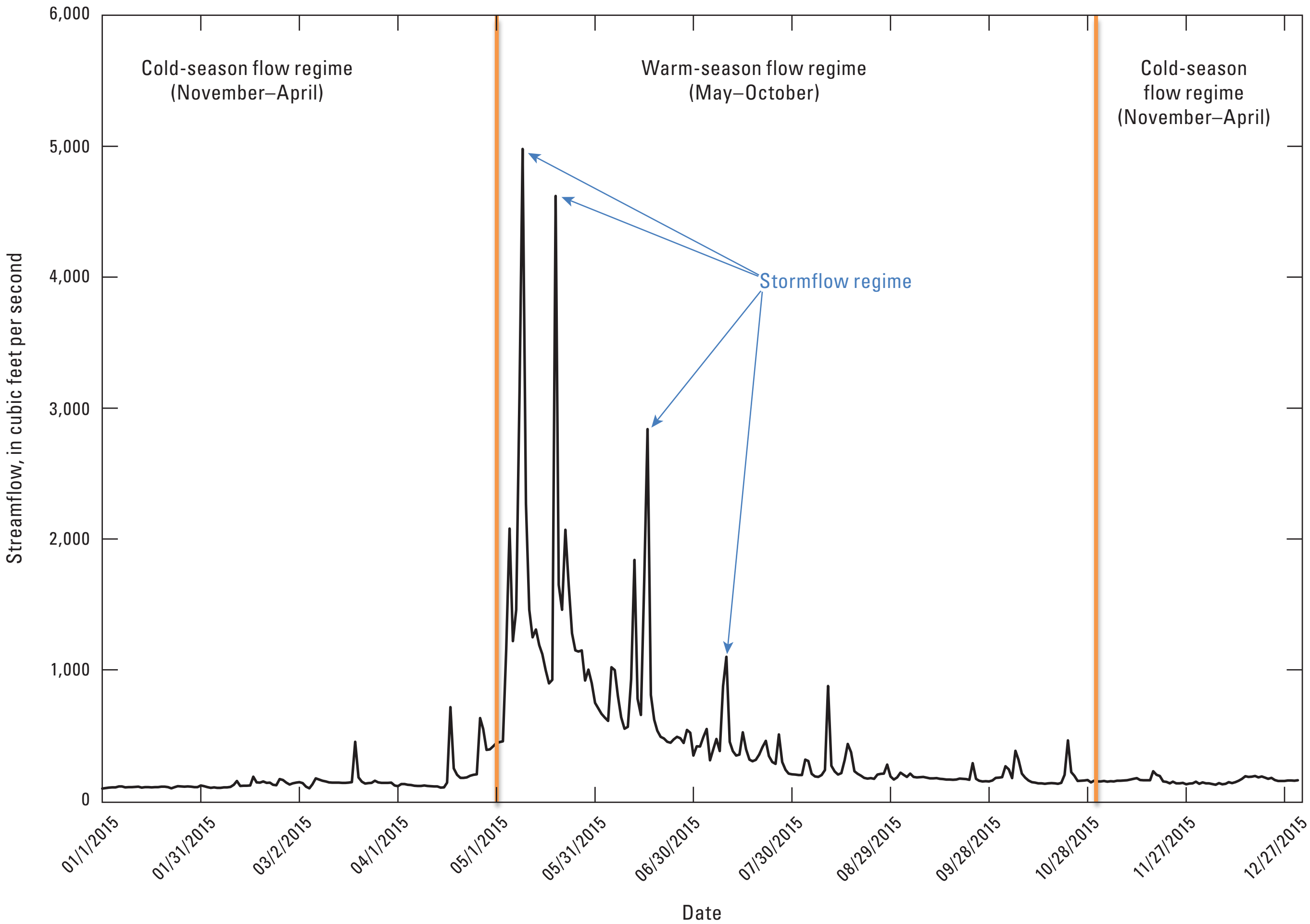

Figure 3. Annual hydrograph for site 07105800, Fountain Creek at Security, depicting flow regimes.

its paired environmental sample concentration, divided by the average of the two values, and multiplied by 100. The mean relative percent difference among replicate samples ranged from about 2 percent for nutrient concentrations to about 3 percent for trace element concentrations. Consequently, the small relative percent differences (less than 5 percent) indicate that there was little variability introduced into the results by the collection, processing, and analysis of water-quality samples in this study.

Suspended-Sediment Data

Suspended-sediment samples generally were collected daily from April through September each year from 2007 through 2015 at six sites and at one site, 07105530 (FoCr_Janitell), from 2013 through 2015 (table 1). Discrete point samples were collected using automatic samplers installed at selected streamflow-gaging stations and were programmed to collect samples daily and during rises in stream stage. Suspended-sediment samples were also manually collected when routine water-quality samples were collected as described by Edwards and Glysson (1988). All suspended-sediment samples were analyzed at the USGS Iowa Water Science Center Sediment Laboratory, Iowa City, Iowa Guy (1969). Suspended-sediment concentrations obtained from samples collected by automatic samplers were adjusted on the basis of a relation developed from depth-integrated samples collected periodically using the equal-width-increment method (Edwards and Glysson, 1988). The Graphical Constituent Loading Analysis System (GCLAS) program (Koltun and others, 2006) was used to analyze daily suspended-sediment concentration and streamflow to estimate the daily mean suspended-sediment concentration and discharge. Suspended-sediment data are available from the USGS NWIS at http://dx.doi.org/10.5066/F7P55KJN (search by USGS site number given in table 1).

Suspended-sediment discharge is the mass of suspended sediment transported over time and, in this report, is expressed in tons per day (tons/d). Sediment discharge in a stream is the result of erosion and sediment transport throughout the watershed. Some tributaries may discharge large volumes of sediment to a stream and others may discharge small

Table 3. Field blank values, Fountain Creek watershed, Colorado, 2007–2015.

[USGS, U.S. Geological Survey, --, no value; N, nitrogen; P, phosphorus; mg/L, milligrams per liter; µg/L, micrograms per liter; E, estimated value; <, less than the value shown; gray shading, value detected]

USGS site number	Abbreviated site name	Date (yyyy mmdd)	Time (24-hour)	Ammonia, dissolved (mg/L as N)	Nitrate plus nitrite, dissolved (mg/L as N)	Phos-phorus, total (mg/L as P)	Arsenic, total (µg/L)	Boron, dissolved (µg/L)	Copper, dissolved (µg/L)	Copper, total (µg/L)	Lead, total (µg/L)	Manga-nese, total (µg/L)	Nickel, total (µg/L)	Zinc, dissolved (µg/L)	Zinc, total (µg/L)	Selenium, dissolved (µg/L)	Selenium, total (µg/L)
07103700	FoCr_Manitou	20100224	1044	<0.02	<0.04	<0.04	<0.18	<3	<1.0	1.9	<0.06	<0.8	<0.36	<2.8	<2.0	<0.04	<0.100
		20110622	1214	--	--	--	--	--	--	--	--	--	--	--	--	<0.03	--
		20120424	1159	--	--	--	--	--	--	--	--	--	--	--	--	<0.03	--
		20121217	1159	--	--	--	--	--	--	--	--	--	--	--	--	<0.03	--
		20130128	1144	--	--	<0.004	--	--	--	--	--	--	--	--	--	<0.03	--
		20140710	1044	<0.01	<0.040	<0.004	<0.28	<5	<0.80	<0.80	<0.04	<0.4	<0.20	<2.0	<2.0	<0.05	<0.100
		20150205	1029	<0.01	<0.040	<0.004	<0.20	<5	<0.80	<0.80	<0.04	<0.4	<0.20	<2.0	<2.0	<0.05	<0.100
		20150811	1029	--	--	--	--	--	--	--	--	--	--	--	--	<0.05	--
07103707	FoCr_8th	20080514	1001	<0.02	<0.04	<0.008	<0.60	<6	<1.0	<1.2	<0.06	<0.40	<0.12	<1.8	<2.0	<0.04	<0.080
		20091008	1059	<0.02	<0.04	<0.04	--	<3	<1.0	--	--	--	--	<2.8	--	<0.04	--
		20120228	1414	<0.01	<0.040	<0.02	<0.28	<3	<0.80	<0.70	<0.04	<0.4	<0.19	<1.4	<3.0	<0.03	<0.050
		20131022	1344	--	--	<0.004	<0.28	--	<0.80	<0.80	--	--	<0.20	<2.0	--	<0.05	--
		20150902	1229	--	--	<0.004	--	--	--	--	--	--	--	--	--	--	--
385854104470100	upper_Ke	20070620	1121	<0.02	0.07	0.07	--	--	--	--	--	--	--	--	--	--	--
07103960	lower_Ke	20081006	1504	<0.02	<0.04	<0.04	--	--	--	--	--	--	--	--	--	--	--
07103970	MoCr_Woodmen	20080429	1044	<0.02	<0.04	<0.04	--	<6	<1.0	--	--	--	--	<1.8	--	<0.04	--
		20140203	1314	<0.01	<0.040	<0.004	<0.28	<5	<0.80	<0.80	<0.04	<0.4	<0.20	<2.0	<2.0	<0.05	<0.100
		20141003	1059	<0.01	<0.040	<0.004	<0.20	<5	<0.80	<0.80	<0.04	<0.4	<0.20	<2.0	<2.0	<0.05	<0.100
07103990	lower_CoCr	20070619	1059	E0.02	<0.06	<0.04	--	--	--	--	--	--	--	--	--	--	--
07104050	N. RoCr	20071009	1529	<0.02	<0.04	<0.04	--	--	--	--	--	--	--	--	--	--	--
07104905	MoCr_Bijou	20100727	1244	<0.02	<0.04	<0.04	E0.09	<3	<1.0	<1.4	<0.06	<0.8	<0.36	<2.8	<2.0	<0.04	<0.100
		20110725	1359	0.01	<0.02	<0.02	<0.09	<3	<0.50	<0.70	<0.04	<0.4	<0.12	<1.4	<2.4	<0.03	<0.050
		20120628	1259	--	--	--	--	--	--	--	--	--	--	--	--	<0.03	--
		20130506	1244	--	--	<0.004	<0.28	--	<0.80	<0.70	--	<0.4	<0.19	<1.4	<3.0	<0.03	<0.050
		20140304	1044	--	--	<0.004	--	--	--	--	--	--	--	--	--	<0.05	--
		20141104	1229	--	--	<0.004	--	--	--	--	--	--	--	--	--	<0.05	--
		20151104	1114	--	--	<0.004	--	--	--	--	--	--	--	--	--	<0.05	--
07105500	FoCr_Nevada	20070214	1459	E0.010	<0.06	<0.04	--	<8	<0.40	--	--	--	--	0.90	--	<0.08	--
		20070718	1229	<0.02	<0.06	E0.02	--	<8	<0.40	--	--	--	--	E0.56	--	<0.08	--
		20090223	1014	E0.01	<0.04	<0.04	<0.20	<4	<1.0	<4.0	<0.10	<0.4	<0.20	<2.0	<2.0	<0.06	<0.120
		20110929	1344	--	--	--	--	--	--	--	--	--	--	--	--	<0.03	--
		20120830	1114	--	--	--	--	--	--	--	--	--	--	--	--	<0.03	--
		20130320	1014	--	--	<0.004	--	--	--	--	--	--	--	--	--	<0.03	--
		20140904	1314	--	--	<0.004	--	--	--	--	--	--	--	--	--	<0.05	--
07105530	FoCr_Janitell	20090514	1059	E0.02	<0.04	<0.04	<0.20	<4	<1.0	<4.0	<0.10	<0.4	<0.20	<2.0	5.5	<0.06	<0.120
		20110526	1329	0.01	<0.02	<0.02	<0.09	<3	<0.50	<0.70	<0.04	<0.4	<0.12	<1.4	<2.4	<0.03	<0.050
		20120124	0959	--	--	--	--	--	--	--	--	--	--	--	--	<0.03	--
		20121127	1314	--	--	--	--	--	--	--	--	--	--	--	--	<0.03	--
		20130606	1059	--	--	<0.004	--	--	--	--	--	--	--	--	--	<0.03	--
		20140513	1129	<0.01	<0.040	<0.004	<0.28	<5	<0.80	<0.80	<0.04	<0.4	<0.20	<2.0	<2.0	<0.05	<0.100
		20150107	1459	--	--	<0.004	--	--	--	--	--	--	--	--	--	<0.05	--
		20150707	1314	<0.01	<0.040	<0.004	<0.20	<5	<0.80	<0.80	<0.04	<0.4	<0.20	<2.0	<2.0	<0.05	<0.100

Table 3. Field blank values, Fountain Creek watershed, Colorado, 2007–2015.—Continued

[USGS, U.S. Geological Survey, --, no value; N, nitrogen; P, phosphorus; mg/L, milligrams per liter; µg/L, micrograms per liter; E, estimated value; <, less than the value shown; gray shading, value detected]

USGS site number	Abbreviated site name	Date (yyyy mmdd)	Time (24-hour)	Ammonia, dissolved (mg/L as N)	Nitrate plus nitrite, dissolved (mg/L as N)	Phosphorus, total (mg/L as P)	Arsenic, total (µg/L)	Boron, dissolved (µg/L)	Copper, dissolved (µg/L)	Copper, total (µg/L)	Lead, total (µg/L)	Manganese, total (µg/L)	Nickel, total (µg/L)	Zinc, dissolved (µg/L)	Zinc, total (µg/L)	Selenium, dissolved (µg/L)	Selenium, total (µg/L)
07105800	FoCr_Security	20070529	1359	<0.02	<0.06	<0.04	--	<8	E0.35	--	--	--	--	0.50	--	<0.08	--
		20100624	1114	E0.01	<0.04	<0.04	E0.13	<3	<1.0	<1.4	<0.06	<0.8	<0.36	<2.8	<2.0	E0.02	<0.100
		20110427	0959	--	--	--	--	--	--	--	--	--	--	--	--	<0.03	--
		20120726	1414	<0.01	<0.040	<0.02	<0.28	<3	<0.80	1.7	<0.04	<0.4	<0.19	<1.4	<3.0	<0.03	<0.050
		20130227	0959	--	--	<0.004	<0.28	--	<0.80	<0.70	--	--	<0.19	<1.4	--	<0.03	<0.050
		20130709	1444	<0.01	<0.040	<0.004	<0.28	<3	<0.80	<0.70	<0.04	<0.4	<0.19	<1.4	<3.0	<0.03	<0.050
		20150303	1144	--	--	<0.004	--	--	--	--	--	--	--	--	--	<0.05	--

volumes. Additionally, in-channel processes erode banks, mobilize (scour) bed sediments, and deposit (fill) bed sediments. Eroded sediments can be transported by two modes: rolling, bouncing, and sliding along the bed as "bedload," or transported in the water column by turbulence as "suspended load" (Edwards and Glysson, 1988). Total sediment load is the sum of bedload and suspended load. von Guerard (1989b) indicated that in Monument and Fountain Creek, bedload represented about 6 to 30 percent of the total sediment load during stormflow. Daily suspended-sediment yield was computed by dividing the daily suspended-sediment discharge by the drainage area and does not account for bedload, and in this report, is expressed in tons per day per square mile (ton/d/mi^2). von Guerard (1989a) indicated that the areas producing the largest suspended-sediment yields tended to be in streams on the readily erodible Colorado Piedmont.

Statistical Analyses

Water-quality and suspended-sediment data presented in this report were summarized using boxplots. Boxplots graphically display the constituent variability and provide an easy visual method for comparing spatial, temporal, and flow-related data. Boxplots are useful because the variability between datasets, extreme values, and selected summary statistics are easily observed. Boxplots contain the following information: The horizontal line within the box represents the median value (50 percent of the data are larger than this value and 50 percent of the data are less than this value). The lower horizontal line of the box is the 25th percentile or lower quartile (25 percent of the data are less than this value). The upper horizontal line of the box is the 75th percentile or upper quartile (75 percent of the data are less than this value). The interquartile range (IQR) contains the values between the 25th and 75th percentiles and is the difference between the 25th and 75th percentiles. The bottom of the vertical line on the boxplot is the smallest value within 1.5 times the IQR of the box. The top of the vertical line on the boxplot is the largest value within 1.5 times the IQR of the box. Outlier values are larger than 1.5 times the IQR from the box.

Concentrations of some constituents in some samples were qualified with a less than, estimated, or greater than remark code next to the reported value. These values were used to generate boxplots and summary tables, and the remark code was shown with the value. For example, minimum values of dissolved ammonia were frequently reported as less than the laboratory reporting level of 0.01 or 0.02; the less than code was shown with the minimum value in the table. Minimum, maximum, and median values were computed for water-quality constituents using R (R Core Team, 2016). These summary statistics were used to compare differences in water-quality constituent concentrations between flow regimes at a given site and to evaluate spatial differences in water-quality constituent concentrations throughout the study area.

The nonparametric Mann-Whitney test (Helsel and Hirsch, 1992) was used to determine whether there were spatial and temporal differences for suspended-sediment concentrations, discharge, and suspended-sediment yields. The Mann-Whitney test is a nonparametric test used to compare two populations (datasets). Specifically, it is used to test the null hypothesis that two datasets have identical distribution functions against the alternative hypothesis that the two distribution functions differ only with respect to location (median), if at all. For the purpose of this study, the null hypothesis is the statistical hypothesis that there is no difference in constituent concentrations between datasets. The p-value is the probability of wrongly rejecting the null hypothesis if it is in fact true. The confidence interval is a measure of the degree of certainty with which the decision to reject the null hypothesis is made. For the current study, a confidence interval of 0.95 or 95 percent was used. The null hypothesis, that the populations are different, was rejected when the p-value was 0.05 or less.

Water Quality and Suspended Sediment in the Fountain and Monument Creek Watersheds

The following sections of the report characterize water quality and sediment in the Fountain and Monument Creek watersheds using data collected from 2007 through 2015. To characterize water quality and sediment conditions: (1) values of onsite measurements of specific conductance, pH, and dissolved oxygen and concentrations of *E. coli*, dissolved nitrate plus nitrite, total phosphorus, ammonia, selected trace elements, and suspended sediment were compared spatially and in relation to streamflow conditions, (2) concentrations of selected constituents were compared to Colorado in-stream water-quality standards, and (3) water-quality loads were estimated and compared for selected constituents during warm-season flow and stormflow conditions.

Specific conductance, pH, and dissolved oxygen were measured onsite when water-quality samples were collected. Additional measurements of specific conductance, pH, and dissolved oxygen done as part of routine sampling for other projects from 2007 through 2015 were also included in this analysis.

Samples were collected and analyzed for dissolved ammonia, nitrate plus nitrite as nitrogen, (referred to as nitrate plus nitrite in this report), and total phosphorus at multiple main-stem and tributary sites. The standard for nitrate plus nitrite that was compared to sample concentrations in this report is 10 milligrams per liter (mg/L) (Colorado Department of Public Health and Environment, 2016a).

Samples were collected and analyzed for *E. coli* bacteria at multiple main-stem and tributary sites throughout the study area. These bacteria are "indicator bacteria," which are used to identify a potential for pathogenicity in water samples (U.S. Environmental Protection Agency, 2004). All stream segments in the Fountain Creek Watershed are classified as

"Recreation E" use. The standard for *E. coli* bacteria that was referenced in this report was based on the recreational use standard of 126 colonies per 100 milliliters for streams classified as "Recreation E" (col/100 mL) (Colorado Department of Public Health and Environment, 2016a).

Trace elements are inorganic chemicals that usually occur in small amounts in nature. Samples collected at main-stem sites were analyzed for the following trace elements: dissolved and total arsenic, dissolved boron, dissolved and total copper, total lead, dissolved and total manganese, total nickel, dissolved and total selenium, and dissolved and total zinc. Samples collected at tributary site Sand Creek above mouth (07105600, SaCr) were analyzed for total arsenic, total copper, total lead, total manganese, total nickel, dissolved and total selenium, and total zinc. Total and dissolved selenium samples were collected at four additional tributary sites including Kettle Creek (07103960), Cottonwood Creek (07103990, lower_CoCr), Mesa Creek (385124104501301, lower_MeCr), and Bear Creek (384909104504401, lower_BeCr).

In-stream water-quality standards have been established for stream segments in the Fountain and Monument Creek watersheds. Standards are based on stream classifications and designated use of the stream segment as determined by the Colorado Department of Public Health and Environment (CDPHE) Water Quality Control Commission with public participation (Colorado Department of Public Health and Environment, 2016a). Standards for many constituents are fixed values; standards for other constituents, specifically for some trace elements, are calculated values that use mean hardness in determining the standard for each site. The mean hardness used in this report was calculated at each main-stem site using the lower 95-percentile confidence interval for cold-season water-quality samples collected between November and March (Colorado Department of Public Health and Environment, 2016b). The acute standards for dissolved copper and dissolved zinc varied by site and were based on mean cold-season hardness. The acute standard for dissolved copper ranged from 9.68 to 25.6 micrograms per liter (mg/L), and the acute standard for dissolved zinc ranged from 116 to 296 mg/L. The Colorado Department of Public Health and Environment (2016a) defined an acute standard as the level not to be exceeded by a concentration in a single sample or by an average calculated from all samples collected during a 1-day period. The acute standard used in this report for total arsenic was 50 mg/L and for dissolved selenium was 18.4 mg/L. In-stream water-quality standards for nitrate plus nitrite, *E. coli*, and selected trace elements were compared to concentrations of these constituents in stream samples to characterize water quality in the study area.

Upper Fountain Creek Watershed

Water-quality samples were collected during cold-season flows and warm-season flows at sites 07103700 (FoCr_Manitou) and 07103707 (FoCr_8th) along Upper Fountain Creek. Stormflow samples were only collected at site 07103700 (FoCr_Manitou). As a result, changes in water-quality constituent concentrations along Upper Fountain Creek could not be evaluated during stormflows. Between 2007 and 2015, the median cold-season flow, based on streamflow measurements when samples were collected, decreased from 10.0 cubic feet per second (ft^3/s) at 07103700 (FoCr_Manitou) to 9.1 ft^3/s at 07103707 (FoCr_8th), and the median warm-season flow increased from 9.9 ft^3/s to 14.0 ft^3/s, respectively (table 4). In 2015, additional samples for *E. coli* bacteria were collected quarterly during dry weather conditions (described in the Methods of Investigation section of this report) at site 385116104523301 on Fountain Creek and site 385108104522001 on Camp Creek.

Runoff from a recent wildfire and a historic gold mill tailings pile are potential sources for elevated nutrients and trace elements in surface water in Upper Fountain Creek. From June 23, 2012, to July 10, 2012, the Waldo Canyon fire burned 18,247 acres within and near the Upper Fountain Creek watershed (City of Colorado Springs, 2013). Post-fire runoff may contain high levels of nutrients, from burned vegetation and fire retardants, and high levels of suspended sediment because reduced infiltration into fire-affected soils increases overland flow (Moody and Martin, 2001; Smith and others, 2011; State of New Mexico Environment Department, 2017). Gold Hill Mesa is a tailings pile for a former gold refinery located just upstream from the confluence with Monument Creek and upstream from site 07103707 (FoCr_8th). In 2004, the Gold Hill Mesa area received authorization to build 1,400 houses and 700,000 square feet of office and retail space on the tailings (Philips, 2017). Ground broke on the project in March 2005 and building is presently (2017) ongoing. Development on the tailings pile has the potential to increase suspended-sediment concentrations in runoff, and thus, increase trace element loads to the stream, particularly during stormflows. The following sections of the report discuss water-quality constituent values and loads in the Upper Fountain Creek watershed.

Specific Conductance, pH, and Dissolved Oxygen

Between sites 07103700 (FoCr_Manitou) and 07103707 (FoCr_8th), specific-conductance values increased, whereas, dissolved oxygen and pH values remained relatively constant. Values of specific conductance measured in the Upper Fountain Creek watershed ranged from 112 to 2,410 µS/cm (table 4). Specific-conductance values generally decreased as streamflow increased at both sites (figs. 4 and 5). The median cold-season flow specific-conductance value increased in the downstream direction from 356 µS/cm at site 07103700 (FoCr_Manitou) to 522 µS/cm at site 07103707 (FoCr_8th). Dissolved oxygen concentrations ranged from 6.10 to 11.9 mg/L. Median dissolved oxygen concentrations were higher during cold-season flows than during warm-season flows at both sites (table 4). Median pH values ranged from 8.1 to 8.3 (table 4).

Table 4. Minimum, median, and maximum values for selected field parameters and discharge at sites in the Fountain Creek watershed, Colorado, 2007 through 2015.

[USGS, U.S. Geological Survey; Main, main-stem site; Trib, tributary site; µS/cm, microsiemens per centimeter; mg/L, milligrams per liter; N, number of samples; $CaCO_3$, calcium carbonate; --, no value]

USGS site number	Site type	Cold-season flow				Warm-season flow				Stormflow			
		N	Minimum	Median	Maximum	N	Minimum	Median	Maximum	N	Minimum	Median	Maximum
Specific conductance (µs/cm)													
07103700	Main	101	180	356	735	97	164	349	769	37	112	245	525
07103707	Main	33	374	522	1,110	64	155	428	2,410	--	--	--	--
385854104470100	Trib	--	--	--	--	5	335	393	434	1	236	236	236
07103960	Trib	2	589	637	684	18	125	475.5	625	1	215	215	215
385750104475001	Trib	--	--	--	--	6	161	540	583	--	--	--	--
07103970	Main	79	226	529	1,960	76	209	484	845	26	96	185	447
07103977	Trib	--	--	--	--	4	447	468	498	2	270	325	380
07103985	Trib	--	--	--	--	6	437	942	1,000	--	--	--	--
07103990	Trib	10	737	817	2,470	43	589	736	1,250	10	141	329	747
07104050	Trib	--	--	--	--	4	1,750	2,065	2,210	2	248	409	570
385501104483701	Trib	--	--	--	--	2	758	777	796	--	--	--	--
385204104510101	Trib	--	--	--	--	4	533	575	685	1	330	330	330
385124104501301	Trib	3	895	1,030	1,130	18	342	770	1,470	3	520	551	663
07104905	Main	70	350	711	1,300	74	316	623	820	52	135	365	785
07105000	Trib	--	--	--	--	6	75	83	101	--	--	--	--
384909104504401	Trib	2	435	634	832	19	124	399	884	--	--	--	--
07105500	Main	132	278	698	1,260	171	230	613	1,210	47	151	378	700
07105530	Main	46	590	735	1,060	49	347	667	804	23	130	278	651
07105600	Trib	13	781	1,270	1,530	40	646	1,115	1,280	34	122	459	966
07105800	Main	126	325	800	1,280	117	365	752	1,270	28	200	430	665
pH (standard units)													
07103700	Main	36	7.8	8.3	8.5	38	7.6	8.3	8.7	24	7.4	8.1	8.4
07103707	Main	33	7.7	8.2	8.5	62	7.6	8.1	8.8	--	--	--	--
385854104470100	Trib	--	--	--	--	5	7.9	8.1	8.8	1	7.5	7.5	7.5
07103960	Trib	2	7.5	7.9	8.3	18	7.7	8	8.2	1	7.8	7.8	7.8
385750104475001	Trib	--	--	--	--	6	7.6	8.2	8.4	--	--	--	--
07103970	Main	12	8.0	8.2	8.5	23	8.1	8.3	8.9	20	7.5	8.0	8.4
07103977	Trib	--	--	--	--	4	7.6	8.1	8.2	2	7.3	7.7	8.1
07103985	Trib	--	--	--	--	6	7.8	8.3	8.6	--	--	--	--
07103990	Trib	10	8.2	8.4	8.5	42	7.8	8.4	8.8	9	7.6	8.2	8.5
07104050	Trib	--	--	--	--	4	8.1	8.2	8.5	2	7.8	7.9	8.0
385501104483701	Trib	--	--	--	--	2	8.3	8.4	8.4	--	--	--	--
385204104510101	Trib	--	--	--	--	4	8.3	8.4	8.4	1	8.0	8.0	8.0
385124104501301	Trib	3	8.2	8.2	8.2	18	8.0	8.3	8.5	3	8.2	8.3	8.3
07104905	Main	34	8.2	8.5	9.0	39	8.1	8.4	9.0	17	7.7	8.1	8.4
07105000	Trib	--	--	--	--	6	7.4	7.7	8.0	--	--	--	--
384909104504401	Trib	2	8.1	8.2	8.3	19	7.8	8.0	8.8	--	--	--	--
07105500	Main	38	8.0	8.4	9.0	44	7.7	8.2	8.8	19	7.5	8.1	8.5
07105530	Main	34	7.8	8.1	8.5	37	7.8	8.1	8.4	23	6.7	7.9	8.7
07105600	Trib	2	8.2	8.3	8.3	13	8.0	8.2	8.4	7	7.7	7.8	8.7
07105800	Main	35	8.1	8.4	8.8	42	8.0	8.4	8.8	13	7.6	7.9	8.1

Table 4. Minimum, median, and maximum values for selected field parameters and discharge at sites in the Fountain Creek watershed, Colorado, 2007 through 2015.—Continued

[USGS, U.S. Geological Survey; Main, main-stem site; Trib, tributary site; µS/cm, microsiemens per centimeter; mg/L, milligrams per liter; N, number of samples; $CaCO_3$, calcium carbonate; --, no value]

USGS site number	Site type	Cold-season flow				Warm-season flow				Stormflow			
		N	Minimum	Median	Maximum	N	Minimum	Median	Maximum	N	Minimum	Median	Maximum
Dissolved oxygen (mg/L)													
07103700	Main	36	8.20	10.6	11.9	35	7.30	8.60	11.1	23	7.10	8.40	10.2
07103707	Main	25	7.80	10.3	11.8	45	6.10	8.00	10.0	--	--	--	--
385854104470100	Trib	--	--	--	--	5	7.00	8.20	9.30	--	--	--	--
07103960	Trib	2	10.6	10.9	11.1	17	6.10	7.90	10.1	--	--	--	--
385750104475001	Trib	--	--	--	--	5	6.90	8.10	9.80	--	--	--	--
07103970	Main	12	8.20	10.5	11.6	23	6.40	8.30	9.80	20	6.90	8.40	9.60
07103977	Trib	--	--	--	--	4	5.80	7.60	8.10	1	8.60	8.60	8.60
07103985	Trib	--	--	--	--	6	6.50	9.00	11.1	--	--	--	--
07103990	Trib	10	7.50	8.80	11.9	39	6.20	7.70	9.90	9	7.00	7.90	8.60
07104050	Trib	--	--	--	--	4	6.30	7.60	8.60	2	8.10	8.30	8.40
385501104483701	Trib	--	--	--	--	2	7.40	8.00	8.60	--	--	--	--
385204104510101	Trib	--	--	--	--	4	7.20	8.00	8.10	1	8.30	8.30	8.30
385124104501301	Trib	3	10.3	11.2	11.3	18	6.50	8.00	9.60	3	6.90	7.50	8.20
07104905	Main	34	8.40	10.3	11.5	39	6.30	8.10	10.0	16	6.30	7.70	9.60
07105000	Trib	--	--	--	--	6	8.20	8.70	10.3	--	--	--	--
384909104504401	Trib	2	10.2	10.8	11.3	18	7.30	8.30	9.80	--	--	--	--
07105500	Main	36	7.60	10.1	11.8	37	6.40	7.80	10.5	16	5.80	8.20	9.30
07105530	Main	34	7.90	9.60	10.8	37	6.20	7.90	9.60	23	6.80	8.00	10.4
07105600	Trib	2	10.3	10.5	10.6	12	5.30	7.60	9.20	6	7.20	8.00	9.60
07105800	Main	35	7.30	9.60	11.2	42	6.10	7.50	10.0	12	6.00	8.30	9.10
Biological oxygen demand (mg/L)													
07103700	Main	1	3.40	3.40	3.40	--	--	--	--	1	13.0	13.0	13.0
07103707	Main	1	2.00	2.00	2.00	2	1.60	2.95	4.30	--	--	--	--
385854104470100	Trib	--	--	--	--	--	--	--	--	--	--	--	--
07103960	Trib	--	--	--	--	--	--	--	--	--	--	--	--
385750104475001	Trib	--	--	--	--	--	--	--	--	--	--	--	--
07103970	Main	2	2.00	6.40	10.8	--	--	--	--	1	10.4	10.4	10.4
07103977	Trib	--	--	--	--	--	--	--	--	--	--	--	--
07103985	Trib	--	--	--	--	--	--	--	--	--	--	--	--
07103990	Trib	--	--	--	--	--	--	--	--	--	--	--	--
07104050	Trib	--	--	--	--	--	--	--	--	--	--	--	--
385501104483701	Trib	--	--	--	--	--	--	--	--	--	--	--	--
385204104510101	Trib	--	--	--	--	--	--	--	--	--	--	--	--
385124104501301	Trib	--	--	--	--	--	--	--	--	--	--	--	--
07104905	Main	2	2.00	3.40	4.80	--	--	--	--	1	11.0	11.0	11.0
07105000	Trib	--	--	--	--	--	--	--	--	--	--	--	--
384909104504401	Trib	--	--	--	--	--	--	--	--	--	--	--	--
07105500	Main	1	4.30	4.30	4.30	--	--	--	--	1	3.40	3.40	3.40
07105530	Main	3	6.10	6.10	8.30	2	5.30	5.80	6.30	--	--	--	--
07105600	Trib	--	--	--	--	--	--	--	--	--	--	--	--
07105800	Main	3	7.50	9.60	10.0	2	2.40	3.70	5.00	1	7.40	7.40	7.40

Table 4. Minimum, median, and maximum values for selected field parameters and discharge at sites in the Fountain Creek watershed, Colorado, 2007 through 2015.—Continued

[USGS, U.S. Geological Survey; Main, main-stem site; Trib, tributary site; µS/cm, microsiemens per centimeter; mg/L, milligrams per liter; N, number of samples; $CaCO_3$, calcium carbonate; --, no value]

USGS site number	Site type	Cold-season flow				Warm-season flow				Stormflow			
		N	Minimum	Median	Maximum	N	Minimum	Median	Maximum	N	Minimum	Median	Maximum
Hardness (mg/L as $CaCO_3$)													
07103700	Main	11	70.6	123	211	23	57.2	123	216	21	35.6	69.2	215
07103707	Main	10	140	186	331	36	52.9	144	911	--	--	--	--
385854104470100	Trib	--	--	--	--	--	--	--	--	--	--	--	--
07103960	Trib	--	--	--	--	--	--	--	--	--	--	--	--
385750104475001	Trib	--	--	--	--	--	--	--	--	--	--	--	--
07103970	Main	11	108	155	203	23	94.1	150	214	21	23.8	43.1	127
07103977	Trib	--	--	--	--	--	--	--	--	--	--	--	--
07103985	Trib	--	--	--	--	--	--	--	--	--	--	--	--
07103990	Trib	--	--	--	--	--	--	--	--	--	--	--	--
07104050	Trib	--	--	--	--	--	--	--	--	--	--	--	--
385501104483701	Trib	--	--	--	--	--	--	--	--	--	--	--	--
385204104510101	Trib	--	--	--	--	--	--	--	--	--	--	--	--
385124104501301	Trib	--	--	--	--	--	--	--	--	--	--	--	--
07104905	Main	10	139	192	247	24	113	193	280	15	46.9	72.8	158
07105000	Trib	--	--	--	--	--	--	--	--	--	--	--	--
384909104504401	Trib	--	--	--	--	--	--	--	--	--	--	--	--
07105500	Main	13	182	209	288	30	99.0	191	268	18	48.7	97.3	223
07105530	Main	10	162	180	202	24	131	176	232	20	38.2	80	158
07105600	Trib	--	--	--	--	--	--	--	--	--	--	--	--
07105800	Main	10	197	226	235	25	125	209	294	13	62	127	176
Alkalinity (mg/L as $CaCO_3$)													
07103700	Main	1	130	130	130	8	45.9	108	147	1	698	698	698
07103707	Main	1	168	168	168	9	49.5	106	643	--	--	--	--
385854104470100	Trib	--	--	--	--	--	--	--	--	--	--	--	--
07103960	Trib	--	--	--	--	--	--	--	--	--	--	--	--
385750104475001	Trib	--	--	--	--	--	--	--	--	--	--	--	--
07103970	Main	1	106	106	106	7	73.0	106	127	1	39.8	39.8	39.8
07103977	Trib	--	--	--	--	--	--	--	--	--	--	--	--
07103985	Trib	--	--	--	--	--	--	--	--	--	--	--	--
07103990	Trib	--	--	--	--	--	--	--	--	--	--	--	--
07104050	Trib	--	--	--	--	--	--	--	--	--	--	--	--
385501104483701	Trib	--	--	--	--	--	--	--	--	--	--	--	--
385204104510101	Trib	--	--	--	--	--	--	--	--	--	--	--	--
385124104501301	Trib	--	--	--	--	--	--	--	--	--	--	--	--
07104905	Main	1	122	122	122	8	52.6	114	133	--	--	--	--
07105000	Trib	--	--	--	--	--	--	--	--	--	--	--	--
384909104504401	Trib	--	--	--	--	--	--	--	--	--	--	--	--
07105500	Main	1	143	143	143	8	52.8	113	139	--	--	--	--
07105530	Main	1	104	104	104	7	65.3	101	114	1	100	100	100
07105600	Trib	--	--	--	--	--	--	--	--	--	--	--	--
07105800	Main	1	132	132	132	7	60.5	116	139	1	109	109	109

Table 4. Minimum, median, and maximum values for selected field parameters and discharge at sites in the Fountain Creek watershed, Colorado, 2007 through 2015.—Continued

[USGS, U.S. Geological Survey; Main, main-stem site; Trib, tributary site; µS/cm, microsiemens per centimeter; mg/L, milligrams per liter; N, number of samples; $CaCO_3$, calcium carbonate; --, no value]

USGS site number	Site type	Cold-season flow				Warm-season flow				Stormflow			
		N	Minimum	Median	Maximum	N	Minimum	Median	Maximum	N	Minimum	Median	Maximum
Instantaneous discharge (cubic feet per second)													
07103700	Main	101	3.10	10.0	40.0	96	2.70	9.90	263	37	8.10	25.0	624
07103707	Main	33	2.00	9.10	19.0	62	0.140	14.0	480	--	--	--	--
385854104470100	Trib	--	--	--	--	5	0.610	1.70	13.0	1	2.50	2.50	2.50
07103960	Trib	2	0.260	0.465	0.670	18	0.100	0.880	340	1	6.00	6.00	6.00
385750104475001	Trib	--	--	--	--	6	1.10	1.60	20.0	--	--	--	--
07103970	Main	112	7.30	16.0	148	117	4.40	15.0	161	104	9.60	280	1770
07103977	Trib	--	--	--	--	4	0.010	0.130	0.400	2	1.50	2.65	3.80
07103985	Trib	--	--	--	--	6	0.900	1.60	6.20	--	--	--	--
07103990	Trib	33	2.40	4.10	7.90	81	1.80	4.80	18.0	44	10.0	198	1190
07104050	Trib	--	--	--	--	4	0.010	0.040	0.060	2	2.60	13.8	25.0
385501104483701	Trib	--	--	--	--	2	0.010	0.015	0.020	--	--	--	--
385204104510101	Trib	--	--	--	--	4	0.300	0.740	1.40	1	2.80	2.80	2.80
385124104501301	Trib	2	0.580	0.790	1.00	18	0.300	0.750	2.60	3	1.20	2.50	3.60
07104905	Main	74	14.0	32.5	99.0	77	9.60	36.0	525	95	26.0	476	2500
07105000	Trib	--	--	--	--	6	0.960	1.80	8.30	--	--	--	--
384909104504401	Trib	2	0.700	0.950	1.20	19	0.040	1.30	26.0	--	--	--	--
07105500	Main	134	15.0	45.0	237.0	122	14.0	46.5	907	102	41.0	585	4910
07105530	Main	59	36.0	84.0	415	75	39.0	110	1420	49	104	1070	7800
07105600	Trib	13	0.400	1.90	18.0	41	0.100	1.90	11.0	53	5.50	207	3040
07105800	Main	140	41.0	81.0	411	148	39.0	87.0	1580.0	107	119	1620	8140

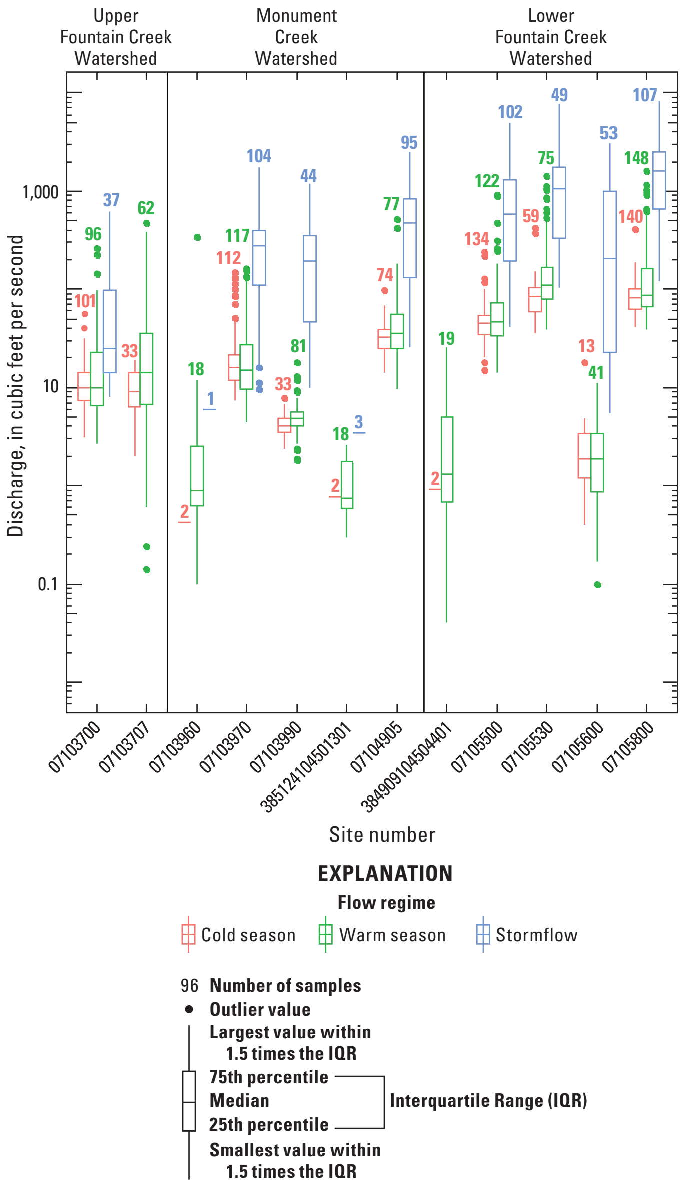

Figure 4. Variations in sampled streamflow at *A*, main-stem sites and *B*, tributary sites for cold-season flow, warm-season flow, and stormflow in Fountain and Monument Creek watersheds, Colorado, 2007 through 2015.

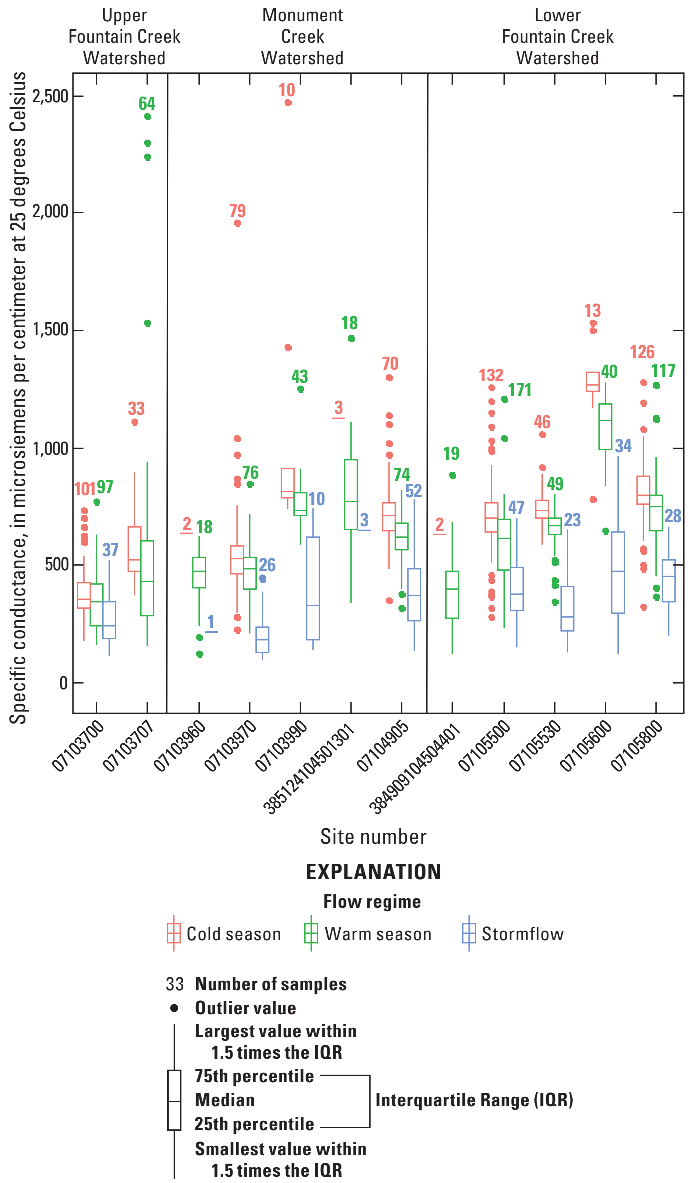

Figure 5. Variations in specific conductance at *A*, main-stem sites and *B*, tributary sites for cold-season flow, warm-season flow, and stormflow in Fountain and Monument Creek watersheds, Colorado, 2007 through 2015.

Bacteria

E. coli concentrations were lower in cold-season flow samples than in warm-season flow and stormflow samples and concentrations increased in the downstream direction, particularly during warm-season flows (fig. 6). Median cold-season flow *E. coli* concentrations ranged from 63 col/100 mL at site 07103700 (FoCr_Manitou) to 80 col/100 mL at site 07103707 (FoCr_8th); and median warm-season flow concentrations ranged from 410 col/100 mL at site 07103700 (FoCr_Manitou) to 1,350 at site 07103707 (FoCr_8th) (table 5; fig. 6). Median warm-season flow concentrations at the two main-stem sites exceeded the recreational use standard of 126 col/100 mL for *E. coli*. The median *E. coli* stormflow concentration of 1,800 col/100 mL at site 07103700 (FoCr_Manitou) was more than 14 times higher than the recreational use standard (table 5). Concentrations of *E. coli* measured in samples from dry weather sites in the Upper Fountain Creek watershed ranged from 8 to 310 col/100 mL (table 6). The highest concentrations were measured during the lowest flows. Two of the four samples collected at site 385116104523301 (Fountain Creek at South 32nd Street) had concentrations that exceeded the standard. Concentrations of *E. coli* measured in samples at site 385108104522001 (Camp Creek at South 31st Street)

Table 5. Minimum, median, and maximum *Escherichia coli* and suspended-sediment concentrations in cold-season flow, warm-season flow, and stormflow samples at selected sites in the Fountain Creek watershed, 2007–2015.

[Main, main-stem site; Trib, tributary site; mL, milliliter; N, number of samples; E, estimated value; <, less than the value shown; >, greater than the value shown]

USGS site number	Site type	Cold-season flow				Warm-season flow				Storm flow			
		N	Minimum	Median	Maximum	N	Minimum	Median	Maximum	N	Minimum	Median	Maximum
Escherichia coli (most probable number per 100 mL of water)													
07103700	Main	77	4	63	>2,400	84	9	410	3,500	34	13	1,800	52,000
07103707	Main	23	12	80	>2,400	58	60	1,350	61,000	--	--	--	--
385854104470100	Trib	--	--	--	--	2	37	48	59	1	7,300	7,300	7,300
07103960	Trib	--	--	--	--	9	32	370	E39,000	1	3,900	3,900	3,900
385750104475001	Trib	--	--	--	--	3	93	610	6,600	--	--	--	--
07103970	Main	56	2	41	>2,400	63	1	100	2,000	19	160	9,200	37,000
07103977	Trib	--	--	--	--	2	20	1,660	3,300	1	2,100	2,100	2,100
07103985	Trib	--	--	--	--	3	20	66	8,200	--	--	--	--
07103990	Trib	9	2	5	56	37	20	160	2,400	8	0	3,850	33,000
07104050	Trib	--	--	--	--	2	920	1,110	1,300	1	6,400	6,400	6,400
385204104510101	Trib	--	--	--	--	2	7	174	340	1	2,000	2,000	2,000
385124104501301	Trib	--	--	--	--	7	34	360	1,100	2	7,300	9,150	11,000
07104905	Main	43	18	61	690	46	30	390	2,600	15	93	4,600	49,000
07105000	Trib	--	--	--	--	3	11	12	2,000	--	--	--	--
384909104504401	Trib	--	--	--	--	10	28	225	13,000	--	--	--	--
07105500	Main	80	7	58	2,000	77	22	440	2,900	20	22	4,750	77,000
07105530	Main	43	26	100	330	45	47	330	2,600	21	300	11,000	58,000
07105600	Trib	1	4	4	4	6	61	520	1,100	6	140	5,850	14,000
07105800	Main	81	5	43	>2,400	82	2	160	6,500	13	100	8,800	92,000
Suspended sediment (mg/L)													
07103700	Main	11	2	9	36	23	2	17	1,020	20	6	3,925	155,000
07103707	Main	7	2	26	161	25	1	24	51,300	--	--	--	--
385854104470100	Trib	--	--	--	--	--	--	--	--	--	--	--	--
07103960	Trib	--	--	--	--	12	0.5	66	10,600	1	3,970	3,970	3,970
385750104475001	Trib	--	--	--	--	--	--	--	--	--	--	--	--
07103970	Main	69	6	145	20,300	577	4	1,480	24,800	95	38	1,310	10,300
07103977	Trib	--	--	--	--	--	--	--	--	--	--	--	--
07103985	Trib	--	--	--	--	--	--	--	--	--	--	--	--
07103990	Trib	41	28	394	7,460	148	14	2,375	20,100	41	97	8,050	26,400
07104050	Trib					--	--	--	--	--	--	--	--
385204104510101	Trib					--	--	--	--	--	--	--	--
385124104501301	Trib	--	--	--	--	9	6	57	118	3	384	549	968
07104905	Main	71	7	614	6,260	145	7	2,960	7,360	92	18	2,580	9,760
07105000	Trib					--	--	--	--	--	--	--	--
384909104504401	Trib	--	--	--	--	14	3	32	2,970	--	--	--	--
07105500	Main	67	9	240	13,100	189	3	4,170	56,900	86	38	2,860	21,300
07105530	Main	22	9	29	286	427	7	2,490	24,500	42	77	2,145	8,810
07105600	Trib	10	34	202	1,820	50	0.5	182	14,100	52	60	3,075	12,200
07105800	Main	54	14	95	5,030	516	11	3,195	36,300	104	137	3,000	13,000

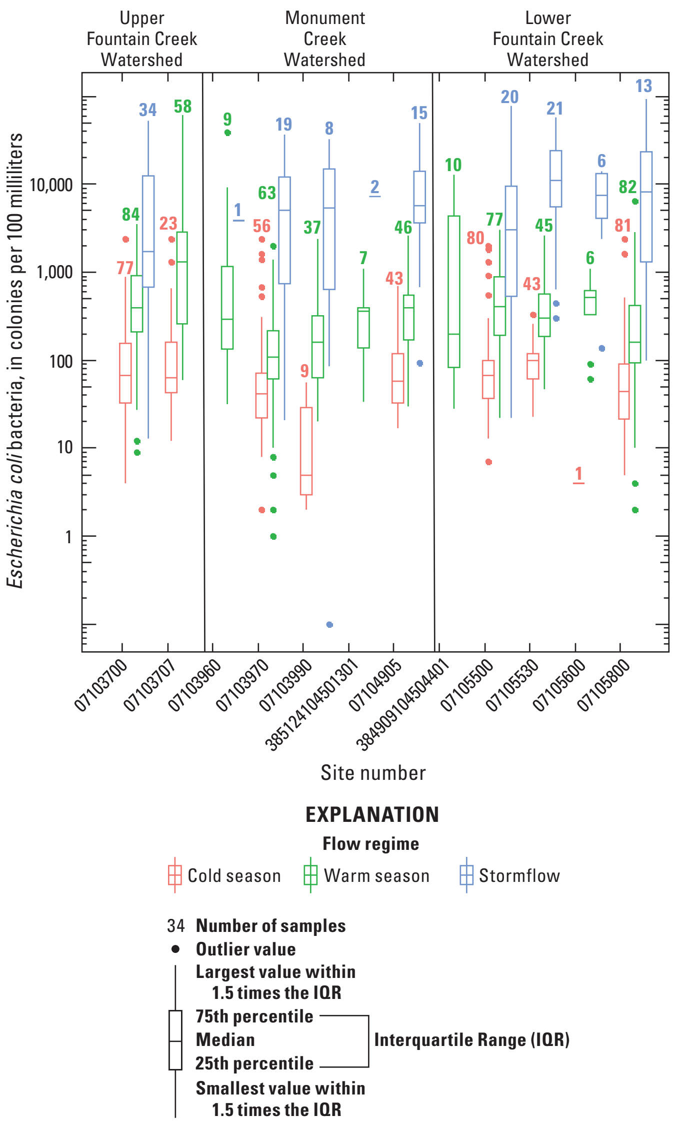

Figure 6. Variations in *Escherichia coli* (*E. coli*) for cold-season flow, warm-season flow, and stormflow at sites in Fountain and Monument Creek watersheds, Colorado, 2007 through 2015.

were well below the water-quality standard of 126 col/100 mL (table 6). The elevated concentrations of *E. coli* within the Upper Fountain Creek watershed during warm-season flows and stormflows may be because of runoff from urban and suburban areas, areas with domestic livestock, and possibly, input from onsite wastewater treatment systems.

Nutrients

Dissolved-ammonia concentrations ranged from less than 0.01 to 1.67 mg/L, nitrate plus nitrite concentrations ranged from 0.127 to 13.2 mg/L, and total phosphorus concentrations ranged from less than 0.02 to 71.3 mg/L in samples from main-stem sites along Upper Fountain Creek (07103700 and 07103707; table 7). Median dissolved-ammonia concentrations in cold-season flows and warm-season flows at sites 07103700 (FoCr_Manitou) and 07103707 (FoCr_8th) were low, 0.02 mg/L or less. Median nitrate plus nitrite concentrations were less than 1 mg/L for all flow regimes (fig. 7). Ninety-five percent of samples had concentrations of total phosphorus less than 5 mg/L. Median concentrations of total phosphorus ranged from 0.02 mg/L during cold-season flow to 1.96 mg/L during stormflows. Runoff from the Waldo Canyon fire burn area appeared to increase nutrient concentrations in some warm-season flow and stormflow samples in Upper Fountain Creek after June 2012. The maximum concentrations of dissolved ammonia (1.67 mg/L), nitrate plus nitrite (13.2 mg/L), and total phosphorus (71.3 mg/L) were measured in a single stormflow sample collected July 1, 2013. Concentrations of nitrate plus nitrite greater than 1.5 mg/L and total phosphorus concentrations greater than 5 mg/L were only measured in Upper Fountain Creek samples collected after the Waldo Canyon fire. One concentration of nitrate plus nitrite, 13.2 mg/L, measured in a stormflow sample collected at 07103700 (FoCr_Manitou) exceeded the in-stream water-quality standard of 10 mg/L.

Nutrient Loads

Instantaneous nutrient loads in stormflow were considerably larger than cold-season flow and warm-season flow loads (fig. 8). In Upper Fountain Creek at site 07103700 (FoCr_Manitou) during 2007–2015, median dissolved ammonia loads ranged from about 0.6 lb/d during warm-season flow to about 44 lb/d during stormflow. Median total phosphorus loads at the same location ranged from less than 2.0 lb/d during cold-season flow to 1,560 lb/d during stormflow, and median nitrate plus nitrite loads ranged from 33 lb/d during warm-season flow to 288 lb/d during stormflow. Median stormflow loads of dissolved ammonia and total phosphorus were substantially lower in Upper Fountain Creek at site 07103700 (FoCr_Manitou) during 1998–2006 than during 2007–2015. During 1998–2006, the median dissolved ammonia load during stormflow was 16 lb/d (less than half the 2007–2015 median of 44 lb/d), and the median total phosphorus load was 275 lb/d (about five times less than the 2007–2015 median of 1,560 lb/d) during stormflow (Mau and others, 2007). The increase in median stormflow loads during 2007–2015 may be because concentrations of nutrients increased in streamflow after the Waldo Canyon fire in 2012 and, as a result, nutrient loads increased. In addition, stormflow loads may have increased because of active development in the Gold Hill Mesa area. Land development typically alters ground cover, which can change runoff characteristics.

Trace Elements

Concentrations of trace elements varied by site and by flow regime. Increases (from 1.5 to 28.5 times higher) in median total arsenic, total copper, total lead, dissolved and total manganese, total nickel, dissolved and total selenium, and dissolved and total zinc concentrations occurred during

Table 6. Instantaneous flow and *Escherichia coli* concentrations at dry weather sites during 2015.

[Dry weather site number, number shown on figure 1; USGS, U.S. Geological Survey; gal/min, gallons per minute; col, colonies; mL, milliliter; N, number of samples; --, no data; E, estimated value; <, less than the value shown; >, greater than the value shown]

Dry weather site number	USGS site number	USGS site name	Instantaneous flow (gal/min)				*E. coli* (col/100 mL)			
			N	Min	Max	Avg	N	Min	Max	Avg
Upper Fountain Creek										
2	385116104523301	Fountain Creek at South 32nd Street near Colorado Springs (culvert)	4	0	27	13.5	4	8	310	154
3	385108104522001	Camp Creek at South 31st Street near Colorado Springs	4	76	7,630	2,065	4	8	52	22
Monument Creek										
5	390121104482601	Monument Creek tributary near Diamond Rim Drive near Colorado Springs	4	36	323	189	4	<1	460	129
8	385759104453001	Pine Creek drain at North Union Boulevard North Park at Colorado Springs	4	9.0	583	274	4	<1	160	98
9	385812104462601	Pine Creek drain at Pine Creek Golf Club at Colorado Springs	4	126	673	431	4	29	210	89
10	385756104474501	Pine Creek drain Briargate Parkway at Colorado Springs (culvert)	4	9.0	27	18.0	4	170	1,400	820
12	385640104481501	South Pine Creek (culvert 2 aqueduct) at Goddard Street at Colorado Springs	4	9.0	22	18.0	4	390	>2,400	1,898
15	385642104433901	Cottonwood Creek tributary at Potomac Drive at Colorado Springs	4	13	31	27	4	1	260	95
16	385548104443301	Cottonwood Creek drain at Austin Bluffs Parkway, Colorado Springs	4	13	36	22	4	22	84	47
18	385549104451401	Cottonwood Creek drain Rangewood Drive at Colorado Springs	4	9.0	350	135	4	80	>2,400	1,260
19	385547104473601	Cottonwood Creek drain at North Academy Boulevard near York Road	4	18	45	36	4	<1	12	4
20	07103990	Cottonwood Creek at mouth at Pikeview	4	1,212	5,835	3,052	4	3	1,000	312
23	385349104491201	Monument Creek drain Pikeview Reservoir at Colorado Springs (culvert)	4	22	130	71	4	2	10	7
24	385321104493301	Douglas Creek at the mouth at Colorado Springs, Colo.	4	256	2,513	1,005	4	4	190	64
25	385353104465301	Templeton Gap floodway at North Union Boulevard at Colorado Springs	--	--	--	--	--	--	--	--
26	385307104494401	Monument Creek drain 1 Mark Dabling Boulevard at Colorado Springs	4	13	49	27	4	<1	21	8
27	385303104494601	Monument Creek drain 2 Mark Dabling Boulevard at Colorado Springs	4	18	58	45	4	<1	230	62
28	385259104500201	Douglas Creek drain at Sinton Road at Colorado Springs (culvert)	4	9.0	175	76	4	<1	10	4
29	385257104494401	Douglas Creek South at mouth at Colorado Springs, Colo.	4	278	987	718	4	16	230	107
30	385242104495001	Monument Creek drain 3 Mark Dabling Boulevard at Colorado Springs	4	13	36	27	4	<1	1	1
31	385235104495101	Monument Creek drain 4 Mark Dabling Boulevard at Colorado Springs	4	40	58	49	4	68	200	150
32	385203104494301	Monument Creek aqueduct at Tremont Street at Colorado Springs	4	31	45	40	4	12	1,300	397
35	385124104495701	Mesa Creek at mouth at Recreation Way at Colorado Springs	4	171	449	314	4	91	510	205
Lower Fountain Creek										
38	384920104511201	Bear Creek drain near Creek Crossing Street at Colorado Springs	1	9.0	9.0	9.0	1	1,100	1,100	1,100
40	384921104501001	Bear Creek at Interstate 25 at Colorado Springs	4	1,257	3,860	2,020	4	12	330	96
41	384900104492801	Fountain Creek drain at South Tejon Street at Colorado Springs (culvert)	4	72	229	139	4	49	>2,400	835
43	384905104485901	Shooks Run at Las Vegas Street at Colorado Springs	4	166	628	395	6	55	380	221
44	384823104501601	Cheyenne Run tributary at Colorado Springs (culvert)	4	4.5	72	27	4	550	8,200	3,612
45	384959104481401	Shooks Run tributary at Colorado Springs (culvert to ditch)	4	4.5	13.5	9.0	4	130	2,800	1,405
46	385014104454901	Spring Creek drain at Auburn Drive at Colorado Springs (culvert)	2	E0.13	E40	E20	2	<1	<10	--
47	384930104453701	Spring Creek drain Majorie Lee Drive near Airport Road at Colorado Springs	4	27	117	76	4	110	>2,400	725
48	384833104473900	Spring Creek downstream Las Vegas Street	4	4,488	6,284	5,476	4	68	560	247
50	384749104470801	Fountain Creek drain near Circle Drive at Colorado Springs (culvert)	4	9.0	18	13.5	4	1	19	10
51	384701104465101	Unnamed ditch to Fountain Creek below I-25 at Pond Colorado Springs	4	9.0	144	72	4	2	110	34
52	385255104440501	Valencia Creek near Oro Blanco Drive at Colorado Springs (culvert)	4	4.5	135	49	4	<1	150	68
53	385406104422001	Sand Creek drain near Barnes Road at Colorado Springs (culvert)	4	4.5	31	13.5	4	5	1,700	464
54	385353104422501	Sand Creek drain at Barnes Road at Colorado Springs (culvert)	4	4.5	22	13.5	4	3	>2,400	1,038
55	385248104423501	Sand Creek drain at Spring Ranch Golf Club at Colorado Springs	4	9.0	27	18.0	4	17	610	223
56	384917104443601	Sand Creek drain near Crestline Drive at Colorado Springs (culvert)	--	--	--	--	--	--	--	--
57	384914104441501	Sand Creek drain at Nolte Drive West at Colorado Springs (culvert)	--	--	--	--	--	--	--	--
58	07105600	Sand Creek above mouth at Colorado Springs	4	180	9,425	3,815	4	4	350	139

Table 7. Minimum, median, and maximum concentrations for ammonia, nitrate plus nitrite, and phosphorus at sites in the Fountain Creek watershed, Colorado, 2007–2015.

[USGS, U.S. Geological Survey; Main, main-stem site; Trib, tributary site; mg/L, milligrams per liter; N, number of samples; E, estimated value; <, less than the value shown; --, no value]

USGS site number	Site type	Cold-season flow				Warm-season flow				Stormflow			
		N	Minimum	Median	Maximum	N	Minimum	Median	Maximum	N	Minimum	Median	Maximum
						Ammonia in unfiltered water (mg/L as nitrogen)							
07103700	Main	30	<0.02	<0.02	0.08	26	<0.02	<0.02	0.04	8	<0.02	0.23	1.64
07103707	Main	2	0.02	0.055	0.09	7	0.02	0.02	0.46	--	--	--	--
385854104470100	Trib	--	--	--	--	--	--	--	--	--	--	--	--
07103960	Trib	--	--	--	--	--	--	--	--	--	--	--	--
385750104475001	Trib	--	--	--	--	--	--	--	--	--	--	--	--
07103970	Main	1	0.03	0.03	0.03	3	<0.02	<0.02	0.03	5	0.19	0.41	0.79
07103977	Trib	--	--	--	--	--	--	--	--	--	--	--	--
07103985	Trib	--	--	--	--	--	--	--	--	--	--	--	--
07103990	Trib	--	--	--	--	--	--	--	--	--	--	--	--
07104050	Trib	--	--	--	--	--	--	--	--	--	--	--	--
385501104483701	Trib	--	--	--	--	--	--	--	--	--	--	--	--
385204104510101	Trib	--	--	--	--	--	--	--	--	--	--	--	--
385124104501301	Trib	--	--	--	--	--	--	--	--	--	--	--	--
07104905	Main	29	<0.02	0.08	0.72	29	<0.02	0.06	0.20	3	0.28	0.57	1.52
07105000	Trib	--	--	--	--	--	--	--	--	--	--	--	--
384909104504401	Trib	--	--	--	--	--	--	--	--	--	--	--	--
07105500	Main	30	<0.02	0.04	1.08	28	<0.02	0.03	0.51	4	0.04	0.22	0.54
07105530	Main	29	<0.02	0.05	0.80	27	<0.02	0.05	0.28	8	<0.02	0.25	0.87
07105600	Trib	--	--	--	--	--	--	--	--	--	--	--	--
07105800	Main	30	0.10	0.38	1.24	29	<0.02	0.23	0.51	1	0.17	0.17	0.17
						Ammonia in filtered water (mg/L as nitrogen)							
07103700	Main	11	<0.01	<0.01	<0.02	23	<0.01	<0.01	0.02	21	<0.01	0.04	1.67
07103707	Main	13	0.02	0.02	0.05	38	<0.01	0.02	0.61	--	--	--	--
385854104470100	Trib	--	--	--	--	5	<0.02	<0.02	<0.02	1	0.02	0.02	0.02
07103960	Trib	--	--	--	--	12	<0.01	0.02	1.17	1	0.12	0.12	0.12
385750104475001	Trib	--	--	--	--	6	E0.01	E0.01	0.08	--	--	--	--
07103970	Main	11	<0.01	0.02	0.60	23	<0.01	<0.01	0.03	21	<0.01	0.13	0.62
07103977	Trib	--	--	--	--	4	E0.01	0.02	0.05	2	E0.01	E0.02	E0.02
07103985	Trib	--	--	--	--	6	E0.01	0.02	1.01	--	--	--	--
07103990	Trib	--	--	--	--	8	<0.01	E0.01	<0.02	6	0.05	0.08	0.30
07104050	Trib	--	--	--	--	4	<0.02	<0.02	<0.02	2	0.06	0.25	0.44
385501104483701	Trib	--	--	--	--	2	0.02	0.02	0.02	--	--	--	--
385204104510101	Trib	--	--	--	--	4	E0.01	0.02	0.02	1	0.02	0.02	0.02
385124104501301	Trib	--	--	--	--	9	<0.01	0.02	0.02	3	0.01	0.02	0.07
07104905	Main	7	0.02	0.12	0.23	15	<0.01	0.03	0.69	15	0.02	0.12	0.47
07105000	Trib	--	--	--	--	6	<0.02	<0.02	E0.02	--	--	--	--
384909104504401	Trib	--	--	--	--	13	<0.01	<0.02	0.16	--	--	--	--
07105500	Main	9	0.02	0.07	0.25	14	<0.01	0.02	0.46	15	<0.02	0.11	0.43
07105530	Main	10	0.02	0.10	0.30	24	E0.01	0.04	0.59	20	E0.01	0.22	0.58
07105600	Trib	--	--	--	--	4	<0.01	0.02	2.65	3	0.08	0.36	0.70
07105800	Main	7	0.22	0.36	0.98	17	0.02	0.17	0.40	12	E0.01	0.15	0.39

Table 7. Minimum, median, and maximum concentrations for ammonia, nitrate plus nitrite, and phosphorus at sites in the Fountain Creek watershed, Colorado, 2007–2015. —Continued

[USGS, U.S. Geological Survey; Main, main-stem site; Trib, tributary site; mg/L, milligrams per liter; N, number of samples; E, estimated value; <, less than the value shown; --, no value]

USGS site number	Site type	Cold-season flow				Warm-season flow				Stormflow			
		N	Minimum	Median	Maximum	N	Minimum	Median	Maximum	N	Minimum	Median	Maximum
Nitrate plus nitrite in filtered water (mg/L as nitrogen)													
07103700	Main	11	0.420	0.880	1.10	23	0.310	0.612	1.68	21	0.360	0.660	13.2
07103707	Main	13	0.690	0.810	1.05	38	0.127	0.625	2.79	--	--	--	--
385854104470100	Trib	--	--	--	--	5	0.070	0.23	0.57	1	0.200	0.200	0.200
07103960	Trib	--	--	--	--	12	<0.04	0.27	0.86	1	0.390	0.390	0.390
385750104475001	Trib	--	--	--	--	6	0.430	1.58	2.31	--	--	--	--
07103970	Main	11	0.863	1.32	1.92	23	0.203	0.61	1.84	21	0.295	0.451	0.870
07103977	Trib	--	--	--	--	4	<0.06	<0.06	<0.06	2	0.10	0.20	0.30
07103985	Trib	--	--	--	--	6	2.01	5.65	7.29	--	--	--	--
07103990	Trib	--	--	--	--	8	2.54	3.89	5.41	6	0.440	0.698	1.65
07104050	Trib	--	--	--	--	4	4.38	8.37	14.4	2	0.790	1.71	2.62
385501104483701	Trib	--	--	--	--	2	0.54	1.34	2.14	--	--	--	--
385204104510101	Trib	--	--	--	--	4	1.39	2.03	2.52	1	0.67	0.67	0.67
385124104501301	Trib	--	--	--	--	9	1.11	1.47	1.86	3	0.57	0.72	0.80
07104905	Main	7	1.75	2.80	4.33	15	0.89	3.68	5.52	15	0.51	1.13	2.98
07105000	Trib	--	--	--	--	6	<0.04	0.05	0.19	--	--	--	--
384909104504401	Trib	--	--	--	--	13	<0.04	0.42	1.01	--	--	--	--
07105500	Main	10	1.46	2.23	3.32	21	1.33	2.35	4.41	18	0.56	0.86	2.94
07105530	Main	10	2.76	3.39	5.98	24	1.26	3.37	5.78	20	0.48	1.09	2.92
07105600	Trib	--	--	--	--	4	0.149	0.87	4.36	3	0.45	0.610	1.05
07105800	Main	7	3.18	3.56	4.41	17	1.55	3.66	4.98	12	0.854	1.31	3.32
Phosphorus in unfiltered water (mg/L as phosphorus)													
07103700	Main	13	<0.02	0.02	0.04	23	0.011	0.030	0.563	21	0.02	1.96	71.3
07103707	Main	31	<0.02	0.023	0.228	56	0.008	0.052	65.5	--	--	--	--
385854104470100	Trib	--	--	--	--	5	E0.02	0.070	0.260	1	1.09	1.09	1.09
07103960	Trib	2	<0.02	0.027	0.037	18	0.010	0.049	4.76	1	0.69	0.69	0.69
385750104475001	Trib	--	--	--	--	6	0.04	0.07	0.74	--	--	--	--
07103970	Main	11	0.430	0.484	0.850	23	0.180	0.404	0.64	21	0.21	0.870	2.83
07103977	Trib	--	--	--	--	4	E0.04	0.075	0.15	2	0.34	0.545	0.750
07103985	Trib	--	--	--	--	6	E0.04	0.050	2.08	--	--	--	--
07103990	Trib	4	<0.02	0.041	0.173	16	0.006	0.030	0.20	6	0.42	3.44	8.45
07104050	Trib	--	--	--	--	4	E0.02	0.025	0.05	2	0.29	0.545	0.800
385501104483701	Trib	--	--	--	--	2	<0.04	<0.04	E0.04	--	--	--	--
385204104510101	Trib	--	--	--	--	4	<0.04	<0.04	<0.04	1	0.11	0.11	0.11
385124104501301	Trib	3	<0.02	0.007	0.021	18	0.007	0.036	0.937	3	0.31	0.46	0.73
07104905	Main	24	0.241	0.469	1.48	33	0.240	0.450	1.43	16	0.23	1.77	7.62
07105000	Trib	--	--	--	--	6	<0.04	<0.04	0.16	--	--	--	--
384909104504401	Trib	2	0.009	0.010	0.010	19	<0.02	<0.04	3.48	--	--	--	--
07105500	Main	27	0.130	0.300	1.330	32	0.130	0.299	1.18	15	0.150	1.89	13.3
07105530	Main	25	0.221	0.612	2.44	33	0.189	0.363	1.720	20	0.460	2.11	7.70
07105600	Trib	3	0.032	0.135	0.142	12	0.026	0.085	2.54	4	0.991	2.53	6.46
07105800	Main	25	0.306	0.730	1.70	34	0.356	0.722	2.18	13	0.730	2.37	5.73

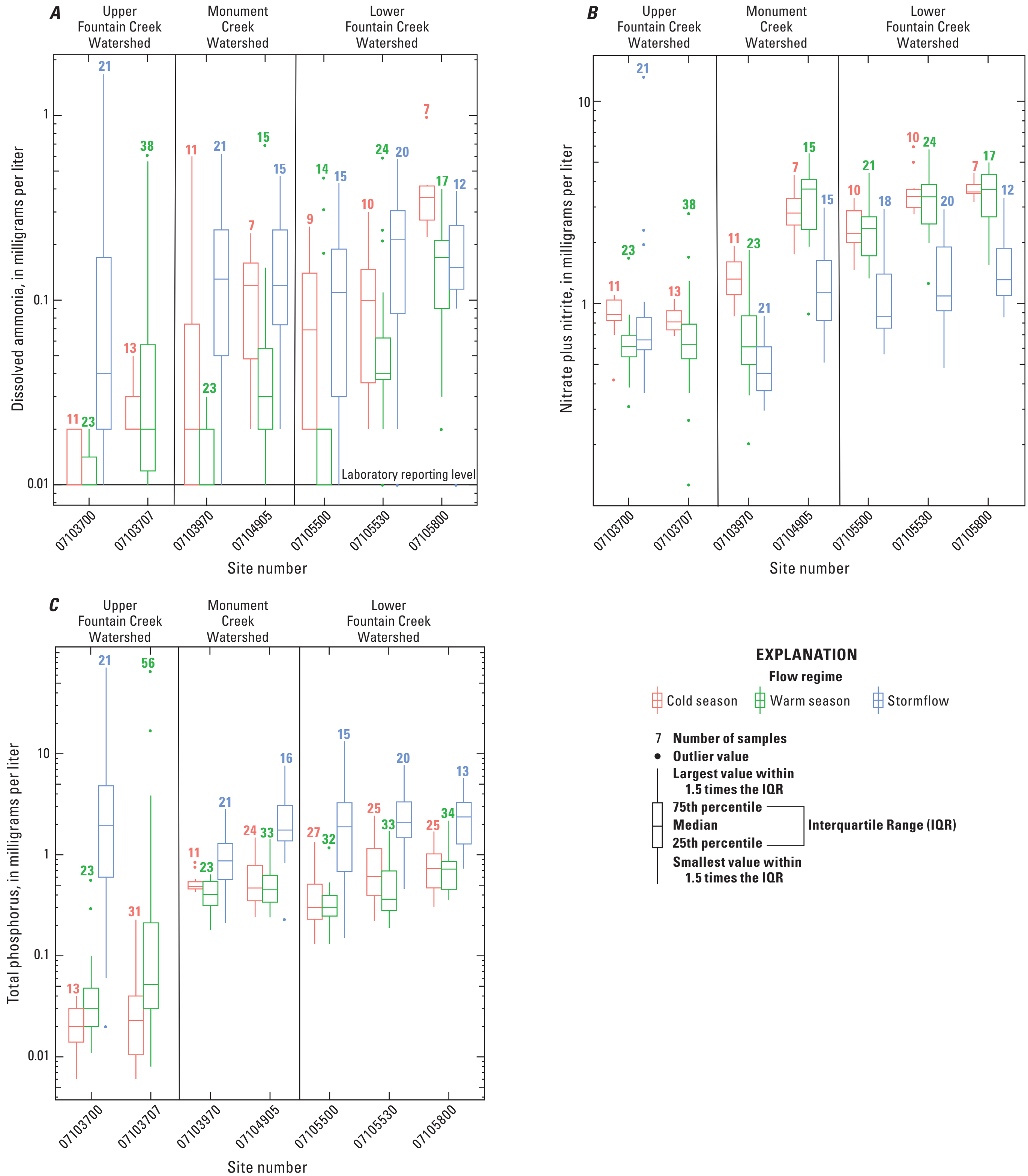

Figure 7. Variations in *A*, dissolved ammonia, *B*, nitrate plus nitrite, and *C*, total phosphorus concentrations at sites for cold-season flow, warm-season flow, and stormflow in the Fountain and Monument Creek watersheds, Colorado, 2007 through 2015.

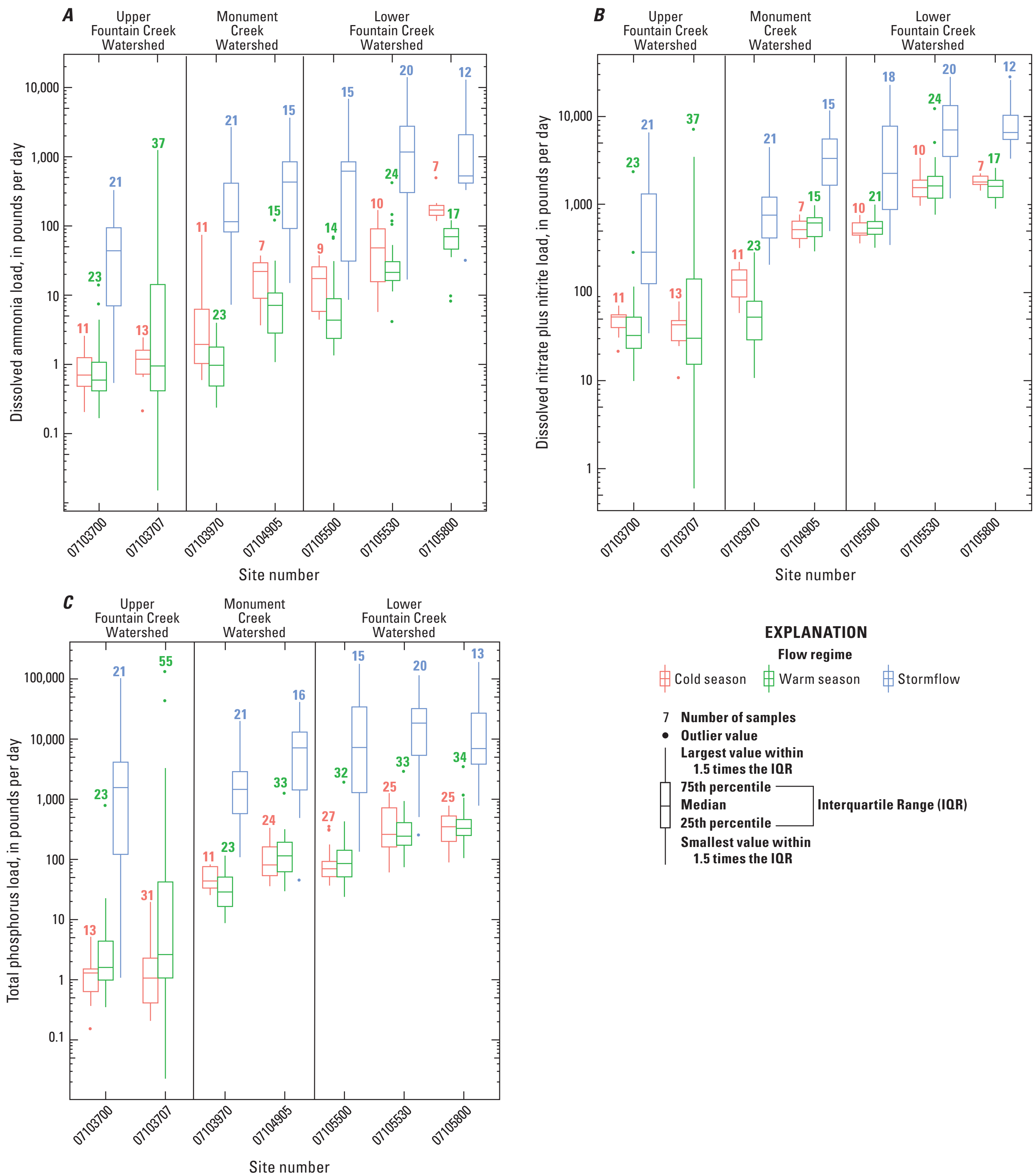

Figure 8. Variations in *A*, dissolved ammonia, *B*, dissolved nitrate plus nitrite, and *C*, total phosphorus loads at sites for cold-season flow, warm-season flow, and stormflow in the Fountain and Monument Creek watersheds, Colorado, 2007 through 2015.

cold-season and warm-season flows in Upper Fountain Creek between sites 07103700 (FoCr_Manitou) and 07103707 (FoCr_8th) (figs. 9 and 10, table 8). Of these trace elements, manganese, selenium, and zinc concentrations increased the most between the two sites and the largest increases occurred during cold-season flow when streamflow is predominantly from groundwater sources (table 8). These large increases in trace element concentrations, particularly during cold-season flows, between sites 07103700 and 07103707 are likely because of input from the Gold Hill Mesa area. It is possible that large increases in concentrations of some or all of these trace elements also occurred during stormflows between these two sites, but stormflow samples were not collected at the downstream site 07103707 (FoCr_8th).

The water-quality standard for total arsenic of 50 µg/L was exceeded in three samples collected during warm-season flows at site 07103707 (FoCr_8th), and in three samples collected during stormflows at site 07103700 (FoCr_Manitou), but not in cold-season flows. As with maximum nutrient concentrations, the maximum concentrations of dissolved and total arsenic, dissolved boron, total lead, total manganese, total nickel, dissolved and total selenium, and total zinc concentrations were measured in a single stormflow sample collected on July 1, 2013, after the Waldo Canyon fire.

Trace-Element Loads

Trace-element loads during cold-season flow and warm-season flow generally were small in Upper Fountain Creek at sites 07103700 (FoCr_Manitou) and 07103707 (FoCr_8th) (figs. 11 and 12). Median cold-season flow and warm-season flow loads of dissolved boron, copper, and selenium were less than 5 lb/d compared to stormflow loads that ranged from 4 to 24 times larger. The differences in loads are largely because of the proportional streamflow increase during periods of stormflow. Median cold-season and warm-season loads of total arsenic, copper, lead, nickel, and selenium were less than 1 lb/d at sites 07103700 (FoCr_Manitou) and 07103707 (FoCr_8th), whereas, stormflow loads for these constituents were 300 to more than 3,000 times larger than cold-season and warm-season loads. Median stormflow loads at site 07103700 (FoCr_Manitou) for total manganese and total zinc were 1,842 and 187 lb/d, respectively, and were 720 to 880 times larger during stormflow than during cold-season flow and warm-season flow.

Suspended Sediment

Suspended-sediment concentrations ranged from 2 to 155,000 mg/L in samples collected at site 07103700 (FoCr_Manitou) and from 1 to 51,300 mg/L at site 07103707 (FoCr_8th). Median suspended-sediment concentrations increased in the downstream direction from 9 to 26 mg/L in cold-season flows and from 17 to 24 mg/L in warm-season flows between the main-stem sites, however, these increases were not statistically significant (tables 5 and 9). The highest suspended-sediment concentrations were measured in stormflow samples collected after the Waldo Canyon fire, with the maximum concentration of 155,000 mg/L being measured in the first stormflow sample collected at site 07103700 (FoCr_Manitou) after the Waldo Canyon fire on July 1, 2013. As previously discussed, the maximum concentrations of dissolved ammonia, nitrate plus nitrite, total phosphorus, dissolved and total arsenic, dissolved boron, total lead, total manganese, total nickel, dissolved and total selenium, and total zinc were also measured in this same sample.

Suspended-Sediment Discharge and Yield

During warm-season flow and cold-season flow, median suspended-sediment discharge and median suspended-sediment yield increased in the downstream direction between the main-stem sites on Upper Fountain Creek; however, these increases were not statistically significant (tables 10 and 11). At site 07103700 (FoCr_Manitou), median suspended-sediment discharge ranged from 0.26 tons per day (tons/d) during cold-season flow to 1,130 tons/d during stormflow (table 10). The median suspended-sediment yield at site 07103700 (FoCr_Manitou) was more than 3,600 times larger during stormflow than during warm-season flow. At downstream site 07103707 (FoCr_8th), the median suspended-sediment discharge during cold-season flow was 0.76 tons/d (table 10) and the median suspended-sediment yield was 0.006 tons/d/mi^2 (table 11). No stormflow samples were collected at this site; therefore, downstream changes during stormflow could not be evaluated.

Monument Creek Watershed

Water-quality samples were collected during cold-season flows, warm-season flows, and stormflows at main-stem sites 07103970 (MoCr_Woodmen) and 07104905 (MoCr_Bijou) and during warm-season flows and stormflows at seven tributary sites from 2007 through 2015. In 2015, additional samples for *E. coli* bacteria were collected quarterly during dry weather conditions (described in the Methods of Investigation section of this report) at 21 sites in the Monument Creek watershed (table 1). Based on the median instantaneous discharge values at each site (table 4), Monument Creek gained about 16.5 ft^3/s of streamflow during cold-season flows and 21.0 ft^3/s during warm-season flows between sites 07103970 (MoCr_Woodmen) and 07104905 (MoCr_Bijou). Much of this increase in streamflow can be attributed to the many tributaries that drain into Monument Creek between the two sites. At the measured tributary sites, median warm-season flows ranged from less than 1.0 to 4.8 ft^3/s while median stormflows ranged from 2.5 to 198 ft^3/s (table 4, fig. 4). In addition, the J.D. Phillips Water Resource Recovery Facility discharges treated water to the stream between the two sites. The following sections of the report discuss water-quality constituent values and loads in the Monument Creek watershed.

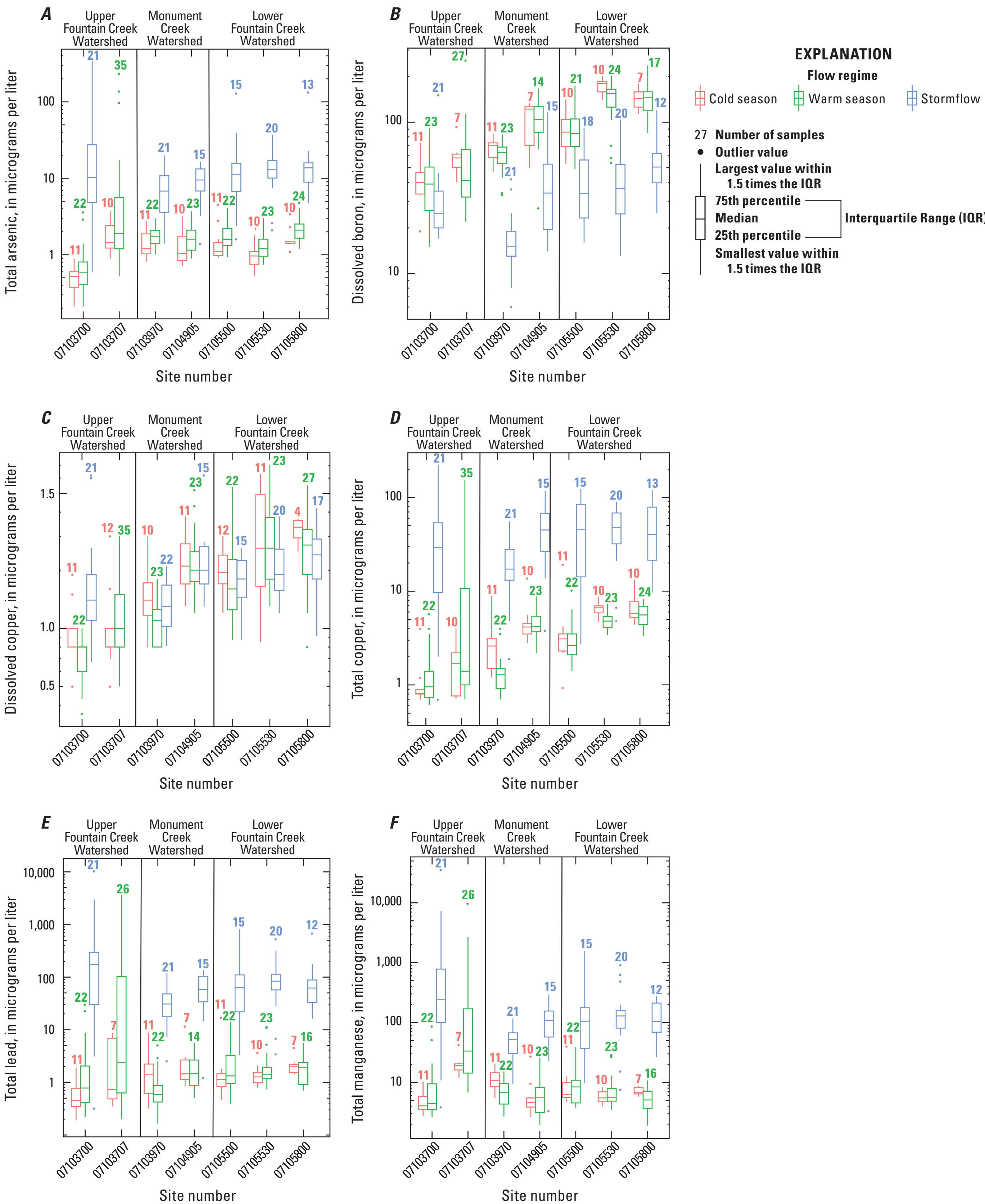

Figure 9. Variations in *A*, total arsenic, *B*, dissolved boron, *C*, dissolved copper, *D*, total copper, *E*, total lead, and *F*, total manganese concentrations at sites for cold-season flow, warm-season flow, and stormflow in the Fountain and Monument Creek watersheds, Colorado, 2007 through 2015.

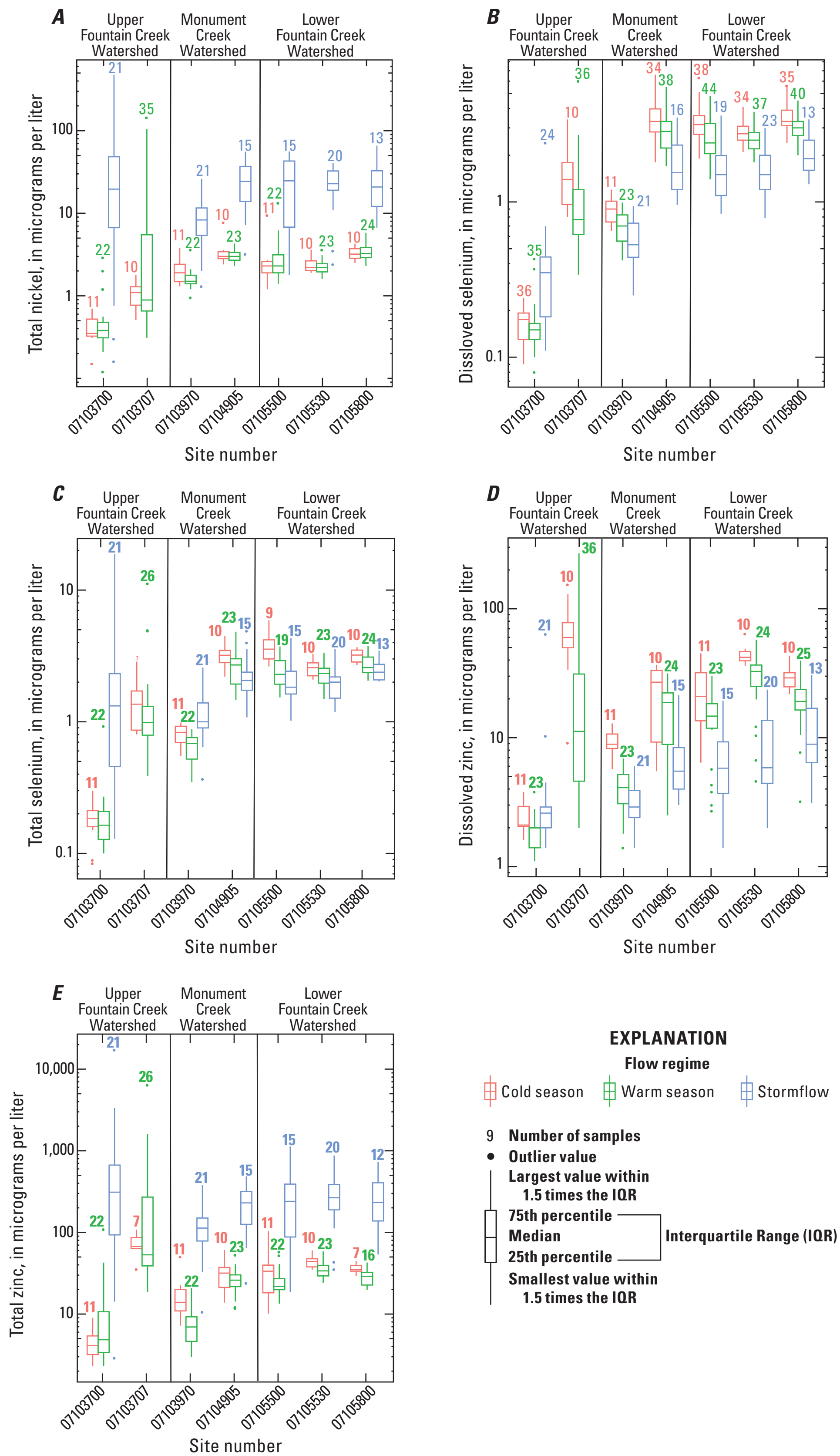

Figure 10. Variations in *A*, total nickel, *B*, dissolved selenium, *C*, total selenium, *D*, dissolved zinc, and *E*, total zinc concentrations at sites for cold-season flow, warm-season flow, and stormflow in the Fountain and Monument Creek watersheds, Colorado, 2007 through 2015.

Table 8. Minimum, median, and maximum concentrations for selected trace elements at sites in the Fountain Creek watershed, Colorado, 2007–2015.

[USGS, U.S. Geological Survey; Main, main-stem site; Trib, tributary site; µg/L, micrograms per liter; N, number of samples; E, estimated value; <, less than the value shown; --, no value]

USGS site number	Site type	Cold-season flow				Warm-season flow				Stormflow			
		N	Minimum	Median	Maximum	N	Minimum	Median	Maximum	N	Minimum	Median	Maximum
Arsenic in unfiltered water (µg/L)													
07103700	Main	11	0.210	0.520	0.890	22	0.210	0.595	3.60	21	0.590	10.3	338
07103707	Main	10	0.890	1.45	3.80	35	0.520	1.90	223	--	--	--	--
07103960	Trib	--	--	--	--	--	--	--	--	--	--	--	--
07103970	Main	11	0.810	1.20	2.80	22	1.00	1.75	3.00	21	1.40	6.80	20.0
07103990	Trib	--	--	--	--	--	--	--	--	--	--	--	--
385124104501301	Trib	--	--	--	--	--	--	--	--	--	--	--	--
07104905	Main	10	0.720	1.06	3.20	23	0.890	1.60	3.70	15	1.40	9.50	16.4
384909104504401	Trib	--	--	--	--	--	--	--	--	--	--	--	--
07105500	Main	11	0.920	1.10	4.50	22	0.930	1.60	4.10	15	1.60	11.3	129
07105530	Main	10	0.530	0.965	1.80	23	0.740	1.20	3.00	20	2.10	13.0	36.9
07105600	Trib	--	--	--	--	3	2.80	4.00	4.40	4	7.60	9.15	14.6
07105800	Main	10	1.10	1.40	3.40	24	1.20	2.10	4.80	13	4.70	13.7	133
Arsenic in filtered water (µg/L)													
07103700	Main	--	--	--	--	--	--	--	--	3	0.730	2.70	10.3
07103707	Main	3	0.560	0.610	1.10	12	0.290	0.810	6.40	--	--	--	--
07103960	Trib	--	--	--	--	--	--	--	--	--	--	--	--
07103970	Main	--	--	--	--	--	--	--	--	4	0.550	0.630	1.00
07103990	Trib	--	--	--	--	--	--	--	--	--	--	--	--
385124104501301	Trib	--	--	--	--	--	--	--	--	--	--	--	--
07104905	Main	3	0.470	0.600	0.670	9	0.600	0.830	1.70	1	0.610	0.610	0.610
384909104504401	Trib	--	--	--	--	--	--	--	--	--	--	--	--
07105500	Main	3	0.630	0.660	0.850	9	0.520	0.960	1.70	1	2.50	2.50	2.50
07105530	Main	3	0.390	0.540	0.580	8	0.520	0.650	1.50	3	0.840	1.40	1.70
07105600	Trib	--	--	--	--	--	--	--	--	--	--	--	--
07105800	Main	3	0.730	0.920	0.930	8	0.630	0.840	2.00	1	0.940	0.940	0.940
Boron in filtered water (µg/L)													
07103700	Main	11	19	40	73	23	15	39	91	21	17	25	151
07103707	Main	7	40	58	93	27	22	41	256	--	--	--	--
07103960	Trib	--	--	--	--	--	--	--	--	--	--	--	--
07103970	Main	11	47	70	84	23	33	63	83	21	6	15	42
07103990	Trib	--	--	--	--	--	--	--	--	--	--	--	--
07104050	Trib	--	--	--	--	--	--	--	--	--	--	--	--
385124104501301	Trib	--	--	--	--	--	--	--	--	--	--	--	--
07104905	Main	7	50	122	133	14	27	104	167	15	14	34	116
384909104504401	Trib	--	--	--	--	--	--	--	--	--	--	--	--
07105500	Main	10	53	86	142	21	49	84	174	18	16	34	92
07105530	Main	10	140	180	202	24	54	155	202	20	13	37	104
07105600	Trib	--	--	--	--	--	--	--	--	--	--	--	--
07105800	Main	7	113	143	181	17	85	145	237	12	25	51	120

Table 8. Minimum, median, and maximum concentrations for selected trace elements at sites in the Fountain Creek watershed, Colorado, 2007–2015.—Continued

[USGS, U.S. Geological Survey; Main, main-stem site; Trib, tributary site; µg/L, micrograms per liter; N, number of samples; E, estimated value; <, less than the value shown; --, no value]

USGS site number	Site type	Cold-season flow				Warm-season flow				Stormflow			
		N	Minimum	Median	Maximum	N	Minimum	Median	Maximum	N	Minimum	Median	Maximum
Copper in unfiltered water (µg/L)													
07103700	Main	11	0.700	0.810	4.00	22	0.610	0.955	5.70	21	0.700	29.1	221
07103707	Main	10	0.700	1.70	4.00	35	0.700	1.40	152	--	--	--	--
07103960	Trib	--	--	--	--	--	--	--	--	--	--	--	--
07103970	Main	11	1.20	2.60	8.90	22	0.700	1.30	4.00	21	1.90	17.2	55.6
07103990	Trib	--	--	--	--	--	--	--	--	--	--	--	--
385124104501301	Trib	--	--	--	--	--	--	--	--	--	--	--	--
07104905	Main	10	2.80	4.15	13.7	23	2.20	4.20	8.80	15	3.80	45.0	118
384909104504401	Trib	--	--	--	--	--	--	--	--	--	--	--	--
07105500	Main	11	0.930	3.10	19.2	22	1.40	2.65	10.2	15	2.70	45.3	123
07105530	Main	10	4.70	6.65	8.70	23	3.40	4.80	7.30	20	4.80	48.0	89.5
07105600	Trib	--	--	--	--	3	2.90	7.50	13.1	4	40.4	58.9	65.7
07105800	Main	10	4.40	5.80	13.3	24	3.30	5.60	8.30	13	9.70	40.3	120
Copper in filtered water (µg/L)													
07103700	Main	11	0.500	1.00	1.90	23	0.360	0.800	1.00	21	0.670	1.40	6.20
07103707	Main	10	0.500	0.900	3.00	36	0.500	0.900	3.000	--	--	--	--
07103960	Trib	--	--	--	--	--	--	--	--	--	--	--	--
07103970	Main	11	0.900	1.40	3.00	23	0.800	0.900	1.80	21	0.800	1.30	2.10
07103990	Trib	--	--	--	--	--	--	--	--	--	--	--	--
385124104501301	Trib	--	--	--	--	--	--	--	--	--	--	--	--
07104905	Main	10	1.50	2.40	3.50	24	1.20	2.10	5.20	15	1.30	1.90	6.20
384909104504401	Trib	--	--	--	--	--	--	--	--	--	--	--	--
07105500	Main	11	1.20	2.00	3.00	23	0.870	1.60	5.40	15	0.870	1.80	3.00
07105530	Main	10	2.20	3.70	6.30	24	0.850	2.60	7.00	20	1.20	1.60	4.00
07105600	Trib	--	--	--	--	--	--	--	--	--	--	--	--
07105800	Main	10	2.20	3.00	3.70	25	0.800	2.70	5.50	13	0.910	1.70	4.20
Lead in unfiltered water (µg/L)													
07103700	Main	11	0.190	0.450	1.91	22	0.220	0.780	30.2	21	0.320	173	10300
07103707	Main	7	0.350	0.730	8.74	26	0.200	2.39	3660	--	--	--	--
07103960	Trib	--	--	--	--	--	--	--	--	--	--	--	--
07103970	Main	11	0.320	1.43	8.65	22	0.160	0.590	5.07	21	2.54	30.9	118
07103990	Trib	--	--	--	--	--	--	--	--	--	--	--	--
385124104501301	Trib	--	--	--	--	--	--	--	--	--	--	--	--
07104905	Main	7	0.840	1.45	11.6	14	0.510	1.47	5.57	15	1.21	58.4	135
384909104504401	Trib	--	--	--	--	--	--	--	--	--	--	--	--
07105500	Main	11	0.460	1.14	16.9	22	0.39	1.33	14.2	15	3.32	62.8	806
07105530	Main	10	0.790	1.28	3.66	23	0.74	1.43	11.4	20	3.44	83.7	527
07105600	Trib	--	--	--	--	3	1.21	4.07	7.05	4	34.2	62.3	130
07105800	Main	7	1.38	1.98	4.54	16	0.70	1.94	5.59	12	16.1	62.0	680

Table 8. Minimum, median, and maximum concentrations for selected trace elements at sites in the Fountain Creek watershed, Colorado, 2007–2015.—Continued

[USGS, U.S. Geological Survey; Main, main-stem site; Trib, tributary site; µg/L, micrograms per liter; N, number of samples; E, estimated value; <, less than the value shown; --, no value]

USGS site number	Site type	Cold-season flow				Warm-season flow				Stormflow			
		N	Minimum	Median	Maximum	N	Minimum	Median	Maximum	N	Minimum	Median	Maximum
Manganese in unfiltered water (µg/L)													
07103700	Main	11	27.4	40.5	103	22	26.3	44.4	863	21	38.5	2,440	357,000
07103707	Main	7	118	192	422	26	67.9	334	97200	--	--	--	--
07103960	Trib	--	--	--	--	--	--	--	--	--	--	--	--
07103970	Main	11	54.3	108	206	22	26.8	67.1	152	21	93.2	523	1,170
07103990	Trib	--	--	--	--	--	--	--	--	--	--	--	--
385124104501301	Trib	--	--	--	--	--	--	--	--	--	--	--	--
07104905	Main	10	26.1	46.3	272	23	19.2	56.5	261	15	33.2	1,080	2,940
384909104504401	Trib	--	--	--	--	--	--	--	--	--	--	--	--
07105500	Main	11	47.2	63.1	399	22	37.1	84.3	390	15	96.5	1,050	15,600
07105530	Main	10	39.8	55.0	83.0	23	34.3	55.0	286	20	75.8	1,290	9,100
07105600	Trib	--	--	--	--	3	106	161	313	4	629	1,083	2,790
07105800	Main	7	56.8	67.0	99.3	16	18.9	51.1	108	12	263	1,059	2,750
Manganese in filtered water (µg/L)													
07103700	Main	11	15.7	26.8	62.3	23	8.56	21.3	82.1	21	2.92	13.4	1,020
07103707	Main	10	104	176	806	36	8.58	104	944	--	--	--	--
07103960	Trib	--	--	--	--	--	--	--	--	--	--	--	--
07103970	Main	11	28.3	54.6	124	23	5.70	29.1	98.1	21	11.9	29.8	43.4
07103990	Trib	--	--	--	--	--	--	--	--	--	--	--	--
385124104501301	Trib	--	--	--	--	--	--	--	--	--	--	--	--
07104905	Main	10	2.10	14.7	38.1	24	2.01	8.47	120	15	0.610	6.75	67.0
384909104504401	Trib	--	--	--	--	--	--	--	--	--	--	--	--
07105500	Main	11	17.6	40.5	97.3	23	5.50	24.2	95.0	15	0.710	11.9	83.8
07105530	Main	10	30.4	42.9	75.9	24	6.01	30.5	157	20	4.69	16.9	297
07105600	Trib	--	--	--	--	--	--	--	--	--	--	--	--
07105800	Main	10	5.92	30.0	63.4	25	2.80	5.94	50.8	13	2.42	10.2	66.5
Nickel in unfiltered water (µg/L)													
07103700	Main	11	0.15	0.4	0.7	22	<0.12	0.380	2.90	21	<0.16	19.6	476
07103707	Main	10	0.5	1.1	1.8	35	0.3	0.9	144	--	--	--	--
07103960	Trib	--	--	--	--	--	--	--	--	--	--	--	--
07103970	Main	11	1.3	1.9	3.8	22	1.0	1.5	3.60	21	1.3	8.3	26.1
07103990	Trib	--	--	--	--	--	--	--	--	--	--	--	--
385124104501301	Trib	--	--	--	--	--	--	--	--	--	--	--	--
07104905	Main	10	2.4	3.0	7.0	23	2.3	3.0	4.30	15	3.2	24.3	55.8
384909104504401	Trib	--	--	--	--	--	--	--	--	--	--	--	--
07105500	Main	11	1.20	2.30	9.44	22	1.4	2.3	13.3	15	1.8	24.7	56.1
07105530	Main	10	1.90	2.20	3.62	23	1.6	2.2	3.60	20	2.4	22.9	40.7
07105600	Trib	--	--	--	--	3	4.4	4.6	7.20	4	19.2	24.6	39.5
07105800	Main	10	2.50	3.20	4.29	24	2.30	3.25	5.80	13	6.7	20.8	65.9

Table 8. Minimum, median, and maximum concentrations for selected trace elements at sites in the Fountain Creek watershed, Colorado, 2007–2015.—Continued

[USGS, U.S. Geological Survey; Main, main-stem site; Trib, tributary site; µg/L, micrograms per liter; N, number of samples; E, estimated value; <, less than the value shown; --, no value]

USGS site number	Site type	Cold-season flow				Warm-season flow				Stormflow			
		N	Minimum	Median	Maximum	N	Minimum	Median	Maximum	N	Minimum	Median	Maximum
Selenium in unfiltered water (µg/L)													
07103700	Main	11	0.084	0.185	0.300	22	E 0.100	0.164	0.925	21	0.129	1.32	18.8
07103707	Main	7	0.802	1.36	2.86	26	0.388	0.988	11.2	--	--	--	--
07103960	Trib	--	--	--	--	7	0.903	1.14	3.47	--	--	--	--
07103970	Main	11	0.550	0.830	0.987	22	0.348	0.685	0.880	21	0.367	1.00	2.58
07103990	Trib	--	--	--	--	4	2.67	3.81	4.32	4	1.77	2.62	3.44
385124104501301	Trib	--	--	--	--	5	0.539	0.588	0.747	1	0.667	0.667	0.667
07104905	Main	10	2.20	3.20	4.47	23	1.46	2.70	4.83	15	1.08	2.06	4.89
384909104504401	Trib	--	--	--	--	7	0.618	1.09	4.39	--	--	--	--
07105500	Main	9	2.63	3.56	5.90	19	1.53	2.29	3.73	15	1.02	1.83	4.32
07105530	Main	10	2.09	2.58	3.28	23	1.49	2.33	3.34	20	1.18	2.00	3.56
07105600	Trib	--	--	--	--	7	4.00	5.44	13.3	7	1.27	2.47	3.66
07105800	Main	10	2.69	3.21	3.68	24	2.05	2.58	3.75	13	2.02	2.38	3.47
Selenium in filtered water (µg/L)													
07103700	Main	36	0.09	0.18	0.24	35	0.08	0.15	0.43	24	0.11	0.35	2.40
07103707	Main	10	0.80	1.40	3.40	36	0.34	0.77	6.00	--	--	--	--
07103960	Trib	--	--	--	--	7	0.72	1.20	1.80	--	--	--	--
07103970	Main	11	0.65	0.90	1.20	23	0.42	0.70	0.99	21	0.25	0.53	0.94
07103990	Trib	2	3.40	3.55	3.70	10	2.30	3.75	4.50	4	0.86	1.45	1.90
385124104501301	Trib	--	--	--	--	5	0.59	0.65	0.78	1	0.78	0.78	0.78
07104905	Main	34	1.80	3.30	6.60	38	1.70	2.85	5.50	16	0.96	1.55	3.50
384909104504401	Trib	--	--	--	--	7	0.34	1.20	5.10	--	--	--	--
07105500	Main	38	1.90	3.15	6.30	44	1.40	2.40	4.80	19	0.84	1.50	3.60
07105530	Main	34	2.10	2.75	4.10	37	1.80	2.50	3.80	23	0.79	1.50	3.00
07105600	Trib	2	14.1	14.9	15.7	10	4.30	11.8	17.4	3	0.67	1.20	1.80
07105800	Main	35	2.40	3.30	5.60	40	2.00	3.00	4.50	13	1.30	1.90	3.40
Zinc in unfiltered water (µg/L)													
07103700	Main	11	2.30	4.10	9.00	22	2.30	4.85	109	21	2.90	311	17,200
07103707	Main	7	35.4	67.4	108	26	18.6	53.2	6390	--	--	--	--
07103960	Trib	--	--	--	--	--	--	--	--	--	--	--	--
07103970	Main	11	7.20	13.9	50.3	22	3.00	6.95	20.8	21	10.6	113	379
07103990	Trib	--	--	--	--	--	--	--	--	--	--	--	--
385124104501301	Trib	--	--	--	--	--	--	--	--	--	--	--	--
07104905	Main	10	13.8	31.8	61.0	23	11.8	26.0	52.9	15	23.9	230	486
384909104504401	Trib	--	--	--	--	--	--	--	--	--	--	--	--
07105500	Main	11	10.1	33.5	104	22	13.4	21.8	57.8	15	18.7	240	1,130
07105530	Main	10	35.0	44.1	60.3	23	24.1	33.8	58.7	20	35.3	268	875
07105600	Trib	--	--	--	--	3	6.50	16.7	22.8	4	164	242	260
07105800	Main	7	29.3	35.0	44.6	16	19.8	29.0	42.8	12	53.7	233	728

Table 8. Minimum, median, and maximum concentrations for selected trace elements at sites in the Fountain Creek watershed, Colorado, 2007–2015.—Continued

[USGS, U.S. Geological Survey; Main, main-stem site; Trib, tributary site; µg/L, micrograms per liter; N, number of samples; E, estimated value; <, less than the value shown; --, no value]

USGS site number	Site type	Cold-season flow				Warm-season flow				Stormflow			
		N	Minimum	Median	Maximum	N	Minimum	Median	Maximum	N	Minimum	Median	Maximum
Zinc in filtered water (µg/L)													
07103700	Main	11	E1.6	2.1	3.80	23	1.10	<2.0	3.80	21	<1.4	2.6	63.5
07103707	Main	10	9.10	59.8	154	36	<2.0	11.6	269	--	--	--	--
07103960	Trib	--	--	--	--	--	--	--	--	--	--	--	--
07103970	Main	11	5.70	8.90	12.9	23	<1.4	4.10	6.90	21	<1.4	2.9	6.00
07103990	Trib	--	--	--	--	--	--	--	--	--	--	--	--
385124104501301	Trib	--	--	--	--	--	--	--	--	--	--	--	--
07104905	Main	10	5.50	27.0	36.8	24	2.5	18.8	31.5	15	3.0	5.5	21.3
384909104504401	Trib	--	--	--	--	--	--	--	--	--	--	--	--
07105500	Main	11	6.40	20.9	45.1	23	2.7	14.7	30.2	15	1.4	5.8	19.4
07105530	Main	10	36.2	42.1	63.9	24	4.6	32.7	57.3	20	E2.0	5.85	23.6
07105600	Trib	--	--	--	--	--	--	--	--	--	--	--	--
07105800	Main	10	21.8	29.1	43.3	25	3.2	19.1	39.6	13	3.1	8.90	30.5

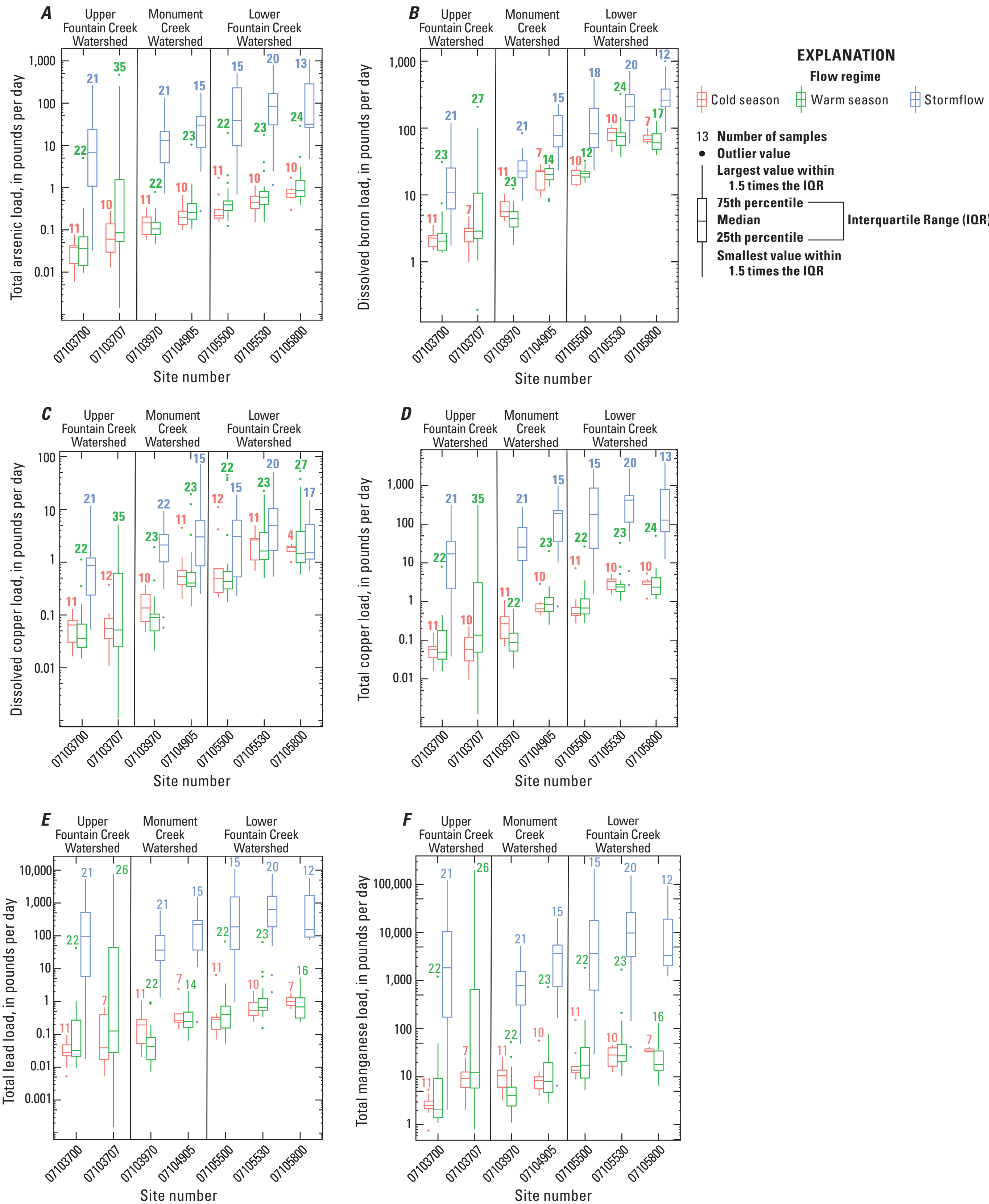

Figure 11. Variations in *A*, total arsenic, *B*, dissolved boron, *C*, dissolved copper, *D*, total copper, *E*, total lead, and *F*, total manganese loads at sites for cold-season flow, warm-season flow, and stormflow in the Fountain and Monument Creek watersheds, Colorado, 2007 through 2015.

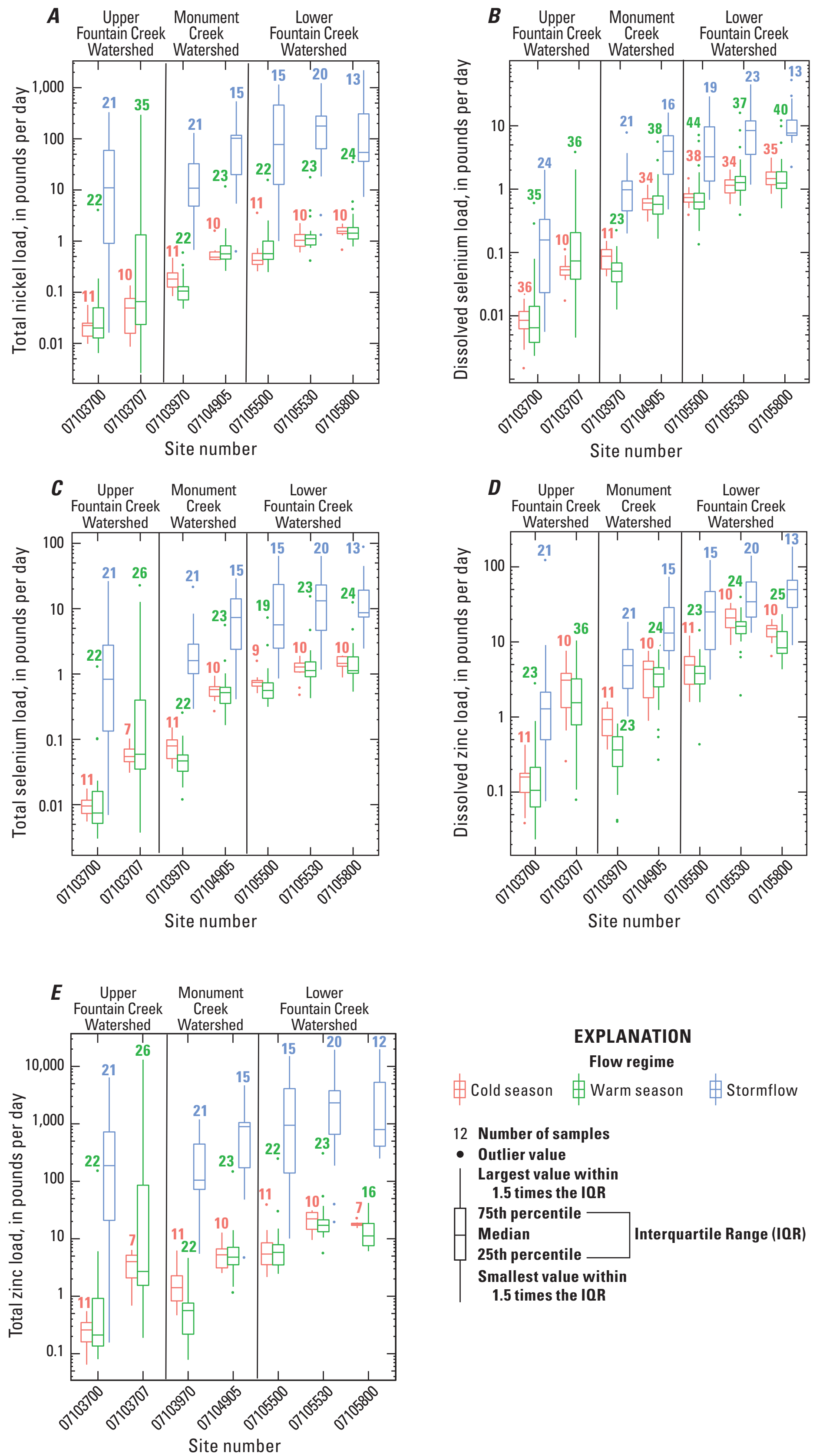

Figure 12. Variations in *A*, total nickel, *B*, dissolved selenium, *C*, total selenium, *D*, dissolved zinc, and *E*, total zinc loads at sites for cold-season flow, warm-season flow, and stormflow in the Fountain and Monument Creek watersheds, Colorado, 2007 through 2015.

Table 9. Median suspended-sediment concentrations during cold-season flow, warm-season flow, and stormflow in the Fountain and Monument Creek watersheds, Colorado, and *p*-values of Mann-Whitney test of significance of spatial variations in suspended-sediment concentrations.

U.S. Geological Survey site number	Median suspended-sediment concentrations, in milligrams per liter	Median rank	Wilcoxon-Mann-Whitney test *p*-values of significance of spatial variations between sites								
			07103700	07103707	07103970	07103990	07104905	07105500	07105530	07105600	07105800
Cold-season flow											
07103700	9	1									
07103707	26	2	0.4145								
07103970	145	5									
07103990	394	8			0.0076					0.1041	
07104905	614	9			0.0613	0.1149					
07105500	240	7		0.0012			0.587				
07105530	29	3						0.0000			
07105600	202	6									0.1545
07105800	95	4							0.0000		
Warm-season flow											
07103700	17	1									
07103707	24	2	0.3266								
07103970	1,480	4									
07103990	2,375	5			0.0048					0.0176	
07104905	2,960	7			0.0018	0.6323					
07105500	4,170	9		0.0000			0.0004				
07105530	2,490	6						0.0013			
07105600	182	3									0.0000
07105800	3,195	8							0.0030		
Stormflow											
07103700	3,925	7									
07103970	1,310	1									
07103990	8,050	8			0.0000					0.0008	
07104905	2,580	3			0.0011	0.0000					
07105500	2,860	4					0.4839				
07105530	2,145	2						0.0214			
07105600	3,075	6									0.9132
07105800	3,000	5							0.0053		

Specific Conductance, pH, and Dissolved Oxygen

Median specific-conductance values increased during all flow regimes between main-stem sites 07103970 (MoCr_Woodmen) and 07104905 (MoCr_Bijou) likely because of tributary inflow with higher specific-conductance values. The largest increase occurred during stormflows where median specific-conductance values in Monument Creek increased from 185 to 365 µS/cm (fig. 5). Specific-conductance values measured at Monument Creek tributary sites varied substantially. During warm-season flow conditions, median specific-conductance values ranged from 468 µS/cm at site 07103977 on upper Cottonwood Creek to 2,065 µS/cm at site 07104050 on North Rockrimmon Creek (table 4). The median specific-conductance value (during warm-season flows) at site 07104050 (RkCr) was generally 2 to 5 times higher than the median values at most other Monument Creek tributary sites and about 4 times larger than the median value in Monument Creek at site 07103970 (MoCr_Woodmen).

Median dissolved oxygen concentrations decreased slightly and pH values increased slightly in Monument Creek between sites 07103970 (MoCr_Woodmen) and 07104905 (MoCr_Bijou). Dissolved oxygen concentrations ranged from 6.3 to 11.6 mg/L at the main-stem sites and from 5.8 to 11.9 mg/L at tributary sites. Median pH values at main-stem sites along Monument Creek ranged from 8.0 to 8.5 and at tributary sites ranged from 7.7 to 8.4 (table 4).

Bacteria

E. coli concentrations were lowest in cold-season flows and highest in stormflows. Median *E. coli* concentrations increased from 41 to 61 col/100 mL during cold-season flow and from 100 to 390 col/100 mL during warm-season flow (table 5) in the downstream direction between sites 07103970 (MoCr_Woodmen) and 07104905 (MoCr_Bijou). During stormflow, however, median *E. coli* concentrations decreased from 9,200 to 4,600 col/100 mL between the two sites (table 5, fig. 6).

The median *E. coli* concentration in stormflow samples exceeded the recreational use standard of 126 col/100 mL by more than 73 times at site 07103970 (MoCr_Woodmen) and by more than 36 times at site 07104905 (MoCr_Bijou). *E. coli*

Table 10. Median suspended-sediment discharge during cold-season flow, warm-season flow, and stormflow in the Fountain and Monument Creek watersheds, Colorado, and *p*-values of Mann-Whitney test of significance of spatial variations in suspended-sediment discharges.

U.S. Geological Survey site number	Median suspended-sediment discharge, in tons per day	Median rank	Wilcoxon-Mann-Whitney test *p*-values of significance of spatial variations between sites								
			07103700	07103707	07103970	07103990	07104905	07105500	07105530	07105600	07105800
			Cold-season flow								
07103700	0.26	1									
07103707	0.76	2	0.751								
07103970	2.8	5									
07103990	1.4	4			0.0466					0.6808	
07104905	5.4	6			0.176	0.0001					
07105500	8.1	8		0.0003			0.0696				
07105530	6.3	7						0.3971			
07105600	1.08	3									0.0002
07105800	16.5	9							0.0065		
			Warm-season flow								
07103700	0.35	1									
07103707	0.44	2	0.4892								
07103970	1.3	5									
07103990	0.58	4			0.241					0.0521	
07104905	7.2	7			0.0003	0.0000					
07105500	4.3	6		0.3992			0.3701				
07105530	13.	8						0.0002			
07105600	0.48	3									0.0000
07105800	21.5	9							0.6753		
			Stormflow								
07103700	1,130	2									
07103970	1,090	1									
07103990	4,770	6			0.0008					0.3756	
07104905	3,740	4			0.0004	0.7533					
07105500	6,730	7					0.0161				
07105530	4,285	5						0.9171			
07105600	1,820	3									0.0000
07105800	14,300	8							0.01667		

concentrations also exceeded the 126 col/100 mL standard at many tributary sites during periods of warm-season flow and stormflow. Median concentrations at three sites on tributaries to Monument Creek were particularly elevated during warm-season and stormflow conditions: site 385750104475001 (PiCr) on Pine Creek, site 07103977 (upper_CoCr) on Cottonwood Creek, and site 07104050 (RkCr) on North Rockrimmon Creek. Median warm-season concentrations were 610, 1,660, and 1,100 col/100 mL, respectively. The Pine Creek and Cottonwood Creek sites are located in rural areas where cattle and horses are present, and manure may be a possible source of the elevated *E. coli* concentrations. Site 07104050 (RkCr) on North Rockrimmon Creek is urbanized and, based on the few data sampled at this site, it is unclear what may be causing the high *E. coli* concentrations.

At dry weather sample sites in the Monument Creek watershed, *E. coli* concentrations ranged from less than 1 to greater than 2,400 col/100 mL. The highest concentrations were measured at sites 385640104481501 on South Pine Creek and 385549104451401 on Cottonwood Creek (table 6). Eight of 21 sites had average sample concentrations of *E. coli* that exceeded the recreational use standard of 126 col/100 mL (table 6).

Nutrients

Dissolved-ammonia concentrations ranged from less than 0.01 mg/L to 0.69 mg/L, nitrate plus nitrite concentrations ranged from 0.203 mg/L to 5.52 mg/L, and total phosphorus concentrations ranged from 0.18 mg/L to 7.62 mg/L in samples from main-stem sites on Monument Creek (table 7). Concentrations of all three nutrients increased or stayed about the same between the two sites for all three flow conditions (fig. 7). The largest downstream increase in median nitrate plus nitrite concentrations between main-stem sites was measured along Monument Creek. During warm-season flow, the median nitrate plus nitrite concentration increased by more than 6 times, from 0.61 to 3.68 mg/L between sites 07103970 (MoCr_Woodmen) and 07104905 (MoCr_Bijou). The median nitrate plus nitrite concentration doubled between the two sites during cold-season flow and stormflow. All but one tributary that drains into Monument Creek between the two sites had higher median nitrate plus nitrite concentrations than the nearest upstream site on Monument Creek, site 07103970 (MoCr_Woodmen) during warm-season flow and stormflow (table 7). During warm-season flows, the median concentration

Table 11. Median suspended-sediment yield during cold-season, warm-season flow, and stormflow in the Fountain and Monument Creek watersheds, Colorado, and *p*-values of Mann-Whitney test of significance of spatial variations in suspended-sediment yields.

U.S. Geological Survey site number	Median suspended-sediment yield, in tons per day per square mile	Median rank	Wilcoxon-Mann-Whitney test *p*-values of significance of spatial variations between sites								
			07103700	07103707	07103970	07103990	07104905	07105500	07105530	07105600	07105800
Cold-season flow											
07103700	0.003	1									
07103707	0.006	2	1.0								
07103970	0.016	3									
07103990	0.075	9			0.0005					0.0243	
07104905	0.024	7			0.5348						
07105500	0.021	5		0.0077		0.0000					
07105530	0.016	3					0.8746	0.3194			
07105600	0.021	5									0.6007
07105800	0.033	8							0.0322		
Warm-season flow											
07103700	0.003	1									
07103707	0.004	2	0.6204								
07103970	0.007	3									
07103990	0.031	6			0.0000					0.0002	
07104905	0.032	7			0.0021	0.1036					
07105500	0.011	5		.8827			0.0239				
07105530	0.032	7						0.0003			
07105600	0.009	4									0.0000
07105800	0.043	8							0.916		
Stormflow											
07103700	11.0	3									
07103970	6.06	1									
07103990	255	8			0.0000					0.0077	
07104905	16.4	4			0.0042	0.0000					
07105500	17.5	5					0.7411				
07105530	10.4	2						0.7704			
07105600	34.6	7									0.5767
07105800	28.7	6							0.0615		

of nitrate plus nitrite was 3.89 mg/L in Cottonwood Creek at site 07103990 (lower_CoCr) and 8.37 mg/L in North Rockrimmon Creek at site 07104050 (RkCr), more than 6 and 13 times larger, respectively, than the median concentration at site 07103970 (MoCr_Woodmen) on Monument Creek (table 7). The J.D. Phillips Water Resource Recovery Facility, that became operational in 2007, discharges water into the stream between the two sites but it is not known how much this discharge contributes to the increase in nutrient concentrations. The in-stream water-quality standard for nitrate plus nitrite is 10 mg/L (Colorado Department of Public Health and Environment, 2016b). More than 95 percent of samples collected at main-stem sites had concentrations of nitrate plus nitrite less than 5 mg/L. Only one sample at 07104050 (RkCr) during warm-season flow had a concentration of nitrate plus nitrite that exceeded the in-stream water-quality standard of 10 mg/L. Median total phosphorous concentration more than doubled between sites 07103970 (MoCr_Woodmen) and 07104905 (MoCr_Bijou) during stormflow conditions, whereas, during cold-season flows the median concentration of total phosphorus decreased by 3 percent between the sites (table 7, fig. 7).

Nutrient Loads

Nutrient loads varied by flow regime and location. In Monument Creek at site 07103970 (MoCr_Woodmen), median total phosphorus loads increased from less than 30 lb/d during warm-season flow to more than 1,460 lb/d during stormflow (fig. 8). Between sites 07103970 (MoCr_Woodmen) and 07104905 (MoCr_Bijou), median nitrate plus nitrite loads in Monument Creek during warm-season flow increased from 52 to 618 lb/d and during stormflow increased from 750 to 3,340 lb/d. This large increase in nitrate plus nitrite load between the two sites may possibly be attributed to inflow from tributaries and the J.D. Phillips Water Resource Recovery Facility; however, during 2007 through 2015, very few stormflow samples were collected from Monument Creek tributary sites (table 7). Only Cottonwood Creek site 07103990 (lower_CoCr) had enough data to estimate nutrients loads. Based on stormflow data collected at this site during the study, 41 percent of the median nitrate plus nitrite stormflow load at downstream site 07104905 (MoCr_Bijou) originated from Cottonwood Creek.

Trace Elements

In Monument Creek, increases in median dissolved boron, dissolved and total copper, total nickel, dissolved and total selenium, and dissolved and total zinc concentrations were measured between sites 07103970 (MoCr_Woodmen) and 07104905 (MoCr_Bijou) during all flow conditions (table 8, figs. 9 and 10). An increase in the median total lead concentration was only measured during warm-season flow and stormflow between the sites (table 8, figs. 9). Median total arsenic and total manganese concentrations decreased during cold-season flow and warm-season flow but increased during stormflow, whereas, median dissolved manganese concentrations decreased during all flow regimes. During cold-season flow, median dissolved manganese concentrations decreased from 54.6 to 14.7 mg/L, whereas median concentrations of dissolved zinc increased from 8.90 to 27.0 mg/L between the main-stem sites.

Concentrations of dissolved and total selenium varied spatially and by flow regime. Between sites 07103970 (MoCr_Woodmen) and 07104905 (MoCr_Bijou), the median concentration of dissolved selenium during cold-season flow increased from 0.90 mg/L to 3.30 mg/L, and the median concentration of total selenium increased from 0.83 mg/L to 3.20 mg/L. Concentrations of dissolved and total selenium were also measured at three tributaries to Monument Creek. These tributaries included Kettle Creek (07103960) which flows from the northeast to the southwest spilling into Monument Creek upstream from site 07103970 (MoCr_Woodmen), Cottonwood Creek (07103990) which flows from east to west spilling into Monument Creek downstream from site 07103970 (MoCr_Woodmen), and Mesa Creek (385124104501301, lower_MeCr) which flows from west to east and spills into Monument Creek upstream from site 07104905 (MoCr_Bijou). In Monument Creek tributaries, median dissolved selenium concentrations during warm-season flow ranged from 0.65 mg/L at site 385124104501301 (lower_MeCr) to 3.75 mg/L at site 07103990 (lower_CoCr). Median total selenium concentrations during warm-season flow ranged from 0.59 mg/L at site 385124104501301 (lower_MeCr) to 3.81 mg/L at 07103990 (lower_CoCr). Median concentrations of dissolved and total selenium were most often highest at site 07103990 (lower_CoCr) during all flow periods.

Trace-Element Loads

Instantaneous loads were calculated for Monument Creek sites 07103970 (MoCr_Woodmen) and 07104905 (MoCr_Bijou). Cold-season flow and warm-season flow loads for most dissolved constituents were less than 1 lb/d, but 2 to 8 times larger during stormflow (figs. 11 and 12). Median dissolved boron loads at site 07103970 (MoCr_Woodmen) ranged from 4.4 to 5.6 lb/d during cold-season flow and warm-season flow and were about 4 times larger during stormflow. Loads of total trace elements also increased between cold-season flow, warm-season flow, and stormflow, and at site 07104905 (MoCr_Bijou), depending on the constituent, were 7 to 890 times larger during storm periods. At this site, the median storm load of total lead was 221 lb/d compared to 0.25 lb/d or less during cold-season flow and warm-season flow.

Loads of most dissolved and total trace elements increased between sites 07103970 (MoCr_Woodmen) and 07104905 (MoCr_Bijou) during cold-season flow, warm-season flow, and stormflow (figs. 11 and 12). The load increase generally was between 2 and 4 times larger at the downstream site than the upstream site during cold-season flow and warm-season flow but was larger during stormflow, for example, when loads at site 07104905 (MoCr_Bijou) increased by 1.3 to 11.4 times over loads at site 07103970 (MoCr_Woodmen). Only one tributary, 07103960 (lower_Ke), upstream from site 07103970 (MoCr_Woodmen) was sampled for analysis of trace elements and only for dissolved and total selenium during warm-season flow. Dissolved and total selenium loads at 07103960 (lower_Ke) represented about 10 percent of the load at 07103970 (MoCr_Woodmen).

Suspended Sediment

Suspended-sediment concentrations ranged from 4 to 24,800 mg/L at site 07103970 (MoCr_Woodmen) and from 7 to 9,760 mg/L at site 07104905 (MoCr_Bijou) (table 5). Median suspended-sediment concentrations increased in the downstream direction during cold-season flow, warm-season flow, and stormflow between sites 07103970 (MoCr_Woodmen) and 07104905 (MoCr_Bijou); however, statistically significant increases (p-value less than 0.05) were only present during warm-season flow and stormflow (table 9). Increases in suspended-sediment concentrations in Monument Creek between sites 07103970 (MoCr_Woodmen) and 07104905 (MoCr_Bijou) are likely the result of contributions of suspended sediment from intervening tributaries such as the Cottonwood Creek, site 07103990 (lower_CoCr) (table 5). Median suspended-sediment concentrations at site 07103990 (lower_CoCr) were significantly higher than median suspended-sediment concentrations at site 07103970 (MoCr_Woodmen) during all flow regimes (table 9).

Suspended-Sediment Discharge and Yield

Suspended-sediment discharges varied by site and with flow regime. At site 07103970 (MoCr_Woodmen), median suspended-sediment discharges ranged from 1.3 tons/d during warm-season flow to 1,090 tons/d during stormflow, and at site 07104905 (MoCr_Bijou), median suspended-sediment discharges ranged from 5.4 tons/d during cold-season flow to 3,740 tons/d during stormflow (table 10). During warm-season flow and stormflow, median suspended-sediment discharge was significantly higher at site 07104905 (MoCr_Bijou) than at site 07103970 (MoCr_Woodmen);

whereas, differences in median suspended-sediment discharge were not significant in cold-season flow (table 10). The median suspended-sediment discharge at Cottonwood Creek site 07103990 (lower_CoCr) was about half of the median suspended-sediment discharge at Monument Creek site 07103970 (MoCr_Woodmen) during cold-season flow but, during stormflow, was almost four times greater.

Suspended-sediment yields increased in the downstream direction in Monument Creek and were substantially higher during stormflow than during cold-season and warm-season flows. At upstream site 07103970 (MoCr_Woodmen), the median suspended-sediment yield was 0.016 tons/d/mi^2 during cold-season flow and 6.06 tons/d/mi^2 during stormflow (table 11). The median suspended-sediment yield downstream at site 07104905 (MoCr_Bijou) was 0.024 ton/d/mi^2 during cold-season flow and 16.4 tons/d/mi^2 during stormflow (table 11). The median suspended-sediment yield at site 07103970 (MoCr_Woodmen) was more than 860 times larger during stormflow than during warm-season flow.

Variations in suspended-sediment yields were observed between sites 07103970 (MoCr_Woodmen) and 07103990 (lower_CoCr) and between sites 07103990 (lower_CoCr) and 07104905 (MoCr_Bijou) in the Monument Creek watershed during cold-season flow and during stormflow (table 11). Median suspended-sediment yields between sites 07103970 (MoCr_Woodmen) and 07104905 (MoCr_Bijou) showed no significant differences during cold-season flow; however, during warm-season flow and stormflow, median suspended-sediment yields were significantly higher at the downstream site 07104905 (MoCr_Bijou) (table 11). The median suspended-sediment yield at site 07103990 (lower_CoCr) was significantly higher than median suspended-sediment yield at site 07104905 (MoCr_Bijou) during stormflow (table 11). The median suspended-sediment yield at site 07103990 (lower_CoCr) during stormflow (255 tons/d/mi^2) was about an order of magnitude higher than all other sites (table 11). During warm-season flow, site 07103990 (lower_CoCr), a site with the smallest drainage area (18.7 mi^2) and second smallest streamflow, had suspended-sediment discharges comparable or larger than sites with drainage areas 3 to 10 times larger.

Lower Fountain Creek Watershed

Water-quality samples were collected during cold-season flows, warm-season flows, and stormflows at main-stem sites 07105500 (FoCr_Nevada), 07105530 (FoCr_Janitell), and 07105800 (FoCr_Security) and during warm-season flows and stormflows at site 07105600 (SaCr) on Sand Creek from 2007 through 2015. In 2015, additional samples for *E. coli* bacteria were collected quarterly during dry weather conditions (described in the Methods of Investigation section of this report) at 18 sites in the Lower Fountain Creek watershed (table 1; fig. 1).

Streamflow generally increases in Lower Fountain Creek in the downstream direction because of inflow from tributaries, discharge from wastewater treatment plants, urban runoff, and irrigation return flow, and these increases vary by flow regime. Based on median instantaneous discharge values at each site (table 4), the median increase in streamflow between sites 07104905 (MoCr_Bijou) and 07105500 (FoCr_Nevada) during warm-season flows was 10 ft^3/s and during cold-season flows, it was 13 ft^3/s. Between sites 07105500 (FoCr_Nevada) and 07105530 (FoCr_Janitell), the median increase in streamflow during warm-season flows was 63 ft^3/s and during cold season flows, it was 39 ft^3/s because of discharge from the Las Vegas Street Wastewater Treatment Plant (fig. 1). Sand Creek enters Fountain Creek downstream from site 07105530 (FoCr_Janitell), and although median warm-season inflows to Fountain Creek were small (1.9 ft^3/s), median stormflow inflows were about 207 ft^3/s, and ranged from 5.5 to more than 3,000 ft^3/s. Discharge from Security Wastewater Treatment Plant enters Fountain Creek upstream from site 07105800 (FoCr_Security). Between sites 07105530 (FoCr_Janitell) and 07105800 (FoCr_Security) the median decrease in streamflow during warm-season flows was 23 ft^3/s and during cold season flows, it was 3 ft^3/s (table 4).

Specific Conductance, pH, and Dissolved Oxygen

Median specific-conductance values increased in Lower Fountain Creek between sites 07105500 (FoCr_Nevada) and 07105800 (FoCr_Security) during cold-season flow and warm-season flow at all main-stem sites but, during stormflow, the median specific-conductance value at 07105530 (FoCr_Janitell) was lower than all the other sites (table 4). Tributary site 07105600 (SaCr) had elevated specific-conductance values compared to the main-stem sites. The median specific-conductance value during warm-season flow was 1,115 µS/cm at site 07105600 (SaCr) compared to 667 µS/cm at upstream site 07105530 (FoCr_Janitell) and 752 µS/cm at downstream site 07105800 (FoCr_Security) on Fountain Creek (figs. 1 and 5; table 4). Although specific-conductance values are relatively high in Sand Creek above the mouth compared to specific-conductance values in Fountain Creek, the median discharge measured at this location was only 1.9 ft^3/s during warm-season flow compared to about 110 ft^3/s at Fountain Creek site 07105530 (FoCr_Janitell) upstream from the confluence with Sand Creek. Between Fountain Creek sites 07105530 and 07105800, the median specific-conductance value increased by about 12 percent during warm-season flows and increased by about 55 percent during stormflows, probably in part because of inflow from Sand Creek (fig.1; table 4).

Values of pH ranged from 6.7 to 9.0 and were generally lower during stormflows than during cold-season flows and warm-season flows (table 4). All measurements were within the Colorado in-stream water-quality standard range for pH of 6.5 to 9.0 (Colorado Department of Public Health and Environment, 2016b).

Dissolved-oxygen concentrations ranged from 5.3 to 11.8 mg/L in samples (table 4). Median dissolved-oxygen concentrations were higher during cold-season flow conditions. Dissolved-oxygen concentrations generally were greater than 6 mg/L and concentrations were similar for warm-season flow and stormflow at most sites (table 4). At all main-stem and tributary sites in Fountain Creek, percent saturation of dissolved oxygen generally was larger than 90 percent during all flow conditions, which indicated well-oxygenated streams.

Bacteria

E. coli concentrations at each site generally differed by a factor of 10 or more during all flow conditions (fig. 6). The lowest concentrations of *E. coli* were measured during cold-season flow and the highest during stormflow. Median *E. coli* concentrations at main-stem sites during cold-season flow were less than or equal to 100 col/100 mL, whereas median *E. coli* concentrations during warm-season flow and stormflow were much larger, ranging between 160 and 440 col/100 mL during warm-season flow and 4,750 and 11,000 col/100 mL during stormflow (table 5). During warm-season flow, median *E. coli* concentrations decreased in the downstream direction at main-stem sites (table 5). Median *E. coli* concentrations exceeded the recreational use standard of 126 col/100 mL during warm-season flows and stormflows at all Lower Fountain Creek main-stem sites and at Salt Creek site 07105600 (SaCr). During stormflow, median *E. coli* concentrations were from 37 to 155 times higher than the recreational use standard. Concentrations of *E. coli* measured at dry weather sites ranged from less than 1 col/100 mL to 8,200 col/100 mL (table 6). The highest concentrations were measured in samples from Shooks Run tributary at site 45 (fig. 1; table 1) where concentrations ranged from 130 col/100 mL to 2,800 col/100 mL, and Cheyenne Run tributary at site 44 (fig. 1, table 1) where concentrations ranged from 550 col/100 mL to 8,200 col/100 mL (table 6).

Nutrients

At main-stem sites, dissolved-ammonia concentrations measured in samples ranged from less than 0.01 mg/L to 0.98 mg/L (table 7). At Sand Creek site 07105600 (SaCr), dissolved-ammonia concentrations measured in samples ranged from less than 0.01 to 2.65 mg/L (table 7). Median dissolved-ammonia concentrations were higher in stormflow samples than in warm- and cold-season flow samples at most sites (fig. 7). Between Fountain Creek sites 07105500 (FoCr_Nevada) and 07105530 (FoCr_Janitell), the median warm-season dissolved-ammonia concentration increased from 0.02 to 0.04 mg/L. However, the largest downstream increase in median dissolved-ammonia concentrations occurred between Fountain Creek sites 07105530 (FoCr_Janitell) and 07105800 (FoCr_Security) where the median concentration increased from 0.04 mg/L to 0.17 mg/L during warm-season flows. Possible sources of ammonia may be discharge from the Security Wastewater Treatment Plant and inflow from Sand Creek between the two sites.

Median nitrate plus nitrite concentrations during warm-season flow increased from 2.35 mg/L at site 07105500 (FoCr_Nevada) to 3.66 mg/L at site 07105800 (FoCr_Security). The largest downstream increase in median nitrate plus nitrite concentrations occurred between main-stem sites 07105500 (FoCr_Nevada) and 07105530 (FoCr_Janitell) on Lower Fountain Creek (fig. 7; table 7). Between the two sites, the median nitrate plus nitrite concentration increased from 2.23 to 3.39 mg/L during cold-season flow, from 2.35 to 3.37 mg/L during warm-season flow, and from 0.86 to 1.09 mg/L percent during stormflow. The relatively large increase in median nitrate plus nitrite concentrations between site 07105500 and 07105530 coincides with the operations of the Las Vegas Street Wastewater Treatment Plant that is located between the two sites. Median nitrate plus nitrite concentrations in Sand Creek at site 07105600 (SaCr) were lower than median concentrations in Fountain Creek (table 7).

In the Lower Fountain Creek watershed, total phosphorus concentrations measured in samples ranged from 0.026 mg/L to 13.3 mg/L. Total phosphorus concentrations were higher in samples collected during stormflows than in samples collected during cold-season flow and warm-season flow (fig. 7). Median total phosphorus concentrations were from 2 to 65 times higher in stormflow samples than in warm-season flow samples at main-stem sites. During warm-season flows, median total phosphorus concentrations increased from 0.299 mg/L at site 07105500 (FoCr_Nevada) to 0.722 mg/L at site 07105800 (FoCr_Security) in Lower Fountain Creek (fig. 7).

Nutrient Loads

Increases in nutrient loading were particularly noticeable downstream from the Las Vegas Street Wastewater Treatment Plant, at site 07105530 (FoCr_Janitell). Nutrient loads increased, on average, more than 200 percent during stormflow between sites 07105500 (FoCr_Nevada) and 07105530 (FoCr_Janitell) because streamflow and nutrient concentrations were higher at 07105530 (FoCr_Janitell) than 07105500 (FoCr_Nevada) (fig. 8). The median instantaneous streamflow during stormflow increased by 83 percent between the two sites; the median dissolved ammonia, nitrate plus nitrite, and total phosphorus concentrations increased by 95, 27, and 12 percent, respectively, during stormflow between 07105500 (FoCr_Nevada) and 07105530 (FoCr_Janitell). Median streamflow during stormflow at Sand Creek site 07105600 (SaCr) was about 207 ft^3/s and ranged from 5.5 to 3,040 ft^3/s (table 4).

Trace Elements

Trace element concentrations varied by location and flow regime in Lower Fountain Creek. During cold-season flow, median concentrations of dissolved and total arsenic, total manganese, total nickel, and dissolved and total selenium decreased between sites 07105500 (FoCr_Nevada) and 07105530 (FoCr_Janitell). Whereas, median concentrations of dissolved boron, dissolved and total copper, total lead, dissolved manganese, and dissolved and total zinc increased between the two sites during cold-season flow. During warm-season flow, median concentrations of dissolved boron, total copper, and dissolved zinc increased by more than 80 percent between the two sites, whereas median concentrations of dissolved and total arsenic, and total manganese decreased by 25 percent or more.

Changes in median concentrations of trace elements in Fountain Creek between sites 07105500 (FoCr_Nevada) and 07105530 (FoCr_Janitell), particularly during cold-season and warm-season flows, are likely affected by wastewater effluent chemistry and volume. For example, during cold-season flow, the median suspended-sediment concentration at site 07105530 (FoCr_Janitell) was almost an order of magnitude lower than the median suspended-sediment concentration in Fountain Creek upstream at site 07105500 (FoCr_Nevada) (table 5). Concentrations of certain total (unfiltered) trace elements, transported in the particulate matter, may have been lower at site 07105530 (FoCr_Janitell) because the wastewater discharge diluted the in-stream concentrations.

During warm-season flow, median concentrations of dissolved and total arsenic, dissolved and total copper, total lead, total nickel, and dissolved and total selenium increased in Fountain Creek between sites 07105530 (FoCr_Janitell) and 07105800 (FoCr_Security). Sand Creek flows into Fountain Creek between sites 07105530 (FoCr_Janitell) and 07105800 (FoCr_Security) and likely contributes to the increase in certain trace element concentrations in Fountain Creek between these sites. At Sand Creek site 07105600 (SaCr), median warm-season flow concentrations of total arsenic, total copper, total lead, total manganese, total nickel, and dissolved and total selenium were greater than concentrations at main-stem sites upstream and downstream from the Sand Creek confluence. During warm-season flow, the median dissolved selenium concentration at Sand Creek site (07105600) was 11.8 mg/L, about 4 times higher than the median concentrations at the surrounding Fountain Creek sites 07105530 and 07105800.

Water-quality standards for trace elements were only exceeded in two samples in the Lower Fountain Creek watershed. The water-quality standard for total arsenic of 50 mg/L was exceeded in one stormflow sample at site 07105500 (FoCr_Nevada) and one stormflow sample at site 07105800 (FoCr_Security), both collected on July 7, 2010. The highest median dissolved selenium concentration (14.9 mg/L) in the Lower Fountain Creek watershed were measured at Sand Creek site 07105600 (SaCr) during cold-season flow (table 8). All dissolved selenium concentrations measured in samples in the Lower Fountain Creek watershed were below the water-quality standard of 18.4 mg/L. Concentrations of dissolved copper and dissolved zinc were below the computed standards.

Trace-Element Loads

Loads for most dissolved and total trace elements at Fountain Creek sites downstream from the confluence with Monument Creek (figs. 9–12) increased between sites 07105500 (FoCr_Nevada) and 07105530 (FoCr_Janitell) and then decreased between site 07105530 and 07105800 (FoCr_Security). The increase corresponded to the increase in streamflow measured between sites 07105500 (FoCr_Nevada) and 07105530 (FoCr_Janitell), and the decrease corresponded to the decrease in flow between 07105530 and 07105800 (FoCr_Security). The median cold-season flow and warm-season flow at site 07105530 (FoCr_Janitell) was about 2 times larger than at site 07105500 (FoCr_Nevada), and the differences in streamflow between the two sites can be attributed to the Las Vegas Street Wastewater Treatment Plant. The difference, however, in selected trace-element loads was larger than the differences in streamflow between the two sites. During warm-season conditions, the median loads of dissolved boron, total copper, and total zinc were about 3 times larger at site 07105530 (FoCr_Janitell) than at site 07105500 (FoCr_Nevada). Median dissolved zinc loads during warm-season flow increased from 3.8 to 16.2 lb/d between the two sites, a 326-percent increase that cannot be attributed solely to the increased streamflow. During warm-season flow, median dissolved zinc concentrations increased from 14.7 to 32.7 mg/L between the sites. Zinc commonly is found in urban runoff, is directly correlated with street traffic volumes (University of Wisconsin-Extension, 1997), and may be contributing to the increase. At site 07105800 (FoCr_Security), the most downstream site for purposes of this report, trace-element loads generally were similar or slightly smaller than at site 07105530 (FoCr_Janitell) during cold-season flow and warm-season flow. Median storm loads were 3.5 to 890 times larger than cold-season flow and warm-season flow loads; total lead and total manganese increased by factors of 225 and 185, respectively, compared to warm-season flow.

Suspended Sediment

In Lower Fountain Creek, median suspended-sediment concentrations decreased between sites 07105500 (FoCr_Nevada) and 07105530 (FoCr_Janitell) and increased between sites 07105530 (FoCr_Janitell) and 07105800 (FoCr_Security) during all flow regimes (fig.1; table 5). The highest median suspended-sediment concentrations were measured in stormflow. During stormflow, the median suspended-sediment concentration was 2,860 mg/L at site 07105500 (FoCr_Nevada), 2,145 mg/L at site 07105530 (FoCr_Janitell), and 3,000 mg/L at site 07105800 (FoCr_Security) (table 9). Significant (*p*-value less than 0.05) increases in median suspended-sediment concentrations were measured during cold-season flow and warm-season flow between Upper Fountain Creek site 07103707 (FoCr_8th) and Lower Fountain Creek site 07105500 (FoCr_Nevada) because of inflows from Monument Creek with higher suspended-sediment concentrations (table 5). Median suspended-sediment concentrations between sites 07104905 (MoCr_Bijou) and 07105500 (FoCr_Nevada) increased significantly during warm-season flow but showed no significant differences during cold-season flow and stormflow (table 9). Significant decreases in median suspended-sediment concentrations were measured between sites 07105500 (FoCr_Nevada) and 07105530 (FoCr_Janitell) during all flow regimes.

Suspended-Sediment Discharge and Yield

Median suspended-sediment discharge ranged from 4.3 to 6,730 tons/d at site 07105500 (FoCr_Nevada), from 6.3 to 4,285 tons/d at site 07105530 (FoCr_Janitell), and from 16.5 to 14,300 tons/d at site 07105800 (FoCr_Security) (table 10). During stormflows, significant increases in median suspended-sediment discharges occurred between 07104905 (MoCr_Bijou) and 07105500 (FoCr_Nevada) and between 07105530 (FoCr_Janitell) and 07105800 (FoCr_Security). Significant increases in median suspended-sediment discharges and median suspended-sediment yield occurred between 07103707 (FoCr_8thSt) and 07105500 (FoCr_Nevada) and between 07105530 (FoCr_Janitell) and 07105800 (FoCr_Security) during cold-season flow and between 07105500 (FoCr_Nevada) and 07105530 (FoCr_Janitell) during warm-season flow. Median suspended-sediment yields at main-stem sites in Lower Fountain Creek were between 325 and 1,590 times larger during stormflow than during warm-season flow.

Summary

From 2007 through 2015, the U.S. Geological Survey, in cooperation with Colorado Springs City Engineering, conducted a study within the Fountain and Monument Creek watersheds, Colorado, to characterize surface-water quality and suspended sediment for three different streamflow regimes, with an emphasis on characterizing water quality during storm runoff. Data collected during this study were used to evaluate the effects of stormflows and wastewater-treatment effluent discharge on Fountain and Monument Creeks in the Colorado Springs, Colorado, area. Water-quality samples were collected at 2 sites on Upper Fountain Creek, 2 sites on Monument Creek, 3 sites on Lower Fountain Creek, and 13 tributary sites during cold-season flow (November–April), warm-season flow (May–October), and stormflow. During 2015, additional surface-water samples were collected and analyzed for *Escherichia coli* (*E. coli*) during dry weather conditions at 41 sites, located in *E. coli* impaired stream reaches, to help identify source areas and scope of the impairment. Concentrations of *E. coli*, total arsenic, and dissolved copper, selenium, and zinc in surface-water samples were compared to Colorado acute in-stream standards.

Along Upper Fountain Creek, water quality varied by location and streamflow regime. Post-fire runoff from the recent (June 23, 2012, to July 10, 2012) Waldo Canyon Fire burn area affected surface-water quality and suspended sediment in Fountain Creek, particularly during stormflow conditions. Runoff from urban and suburban areas and Gold Hill Mesa, a tailings pile for a former gold refinery located just upstream from site 07103707 (FoCr_8th), affected surface-water quality during all flow regimes. Between main-stem sites 07103700 (FoCr_Manitou) and 07103707 (FoCr_8th), specific-conductance values increased in the downstream direction, whereas, dissolved oxygen and pH values remained relatively constant. For example, the median cold-season flow specific-conductance value increased in the downstream direction from 356 μS/cm at site 07103700 (FoCr_Manitou) to 522 μS/cm at site 07103707 (FoCr_8th). Concentrations of *E. coli* also increased in the downstream direction and were substantially higher in warm-season flow and stormflow samples than in cold-season flow samples at the main-stem sites. During cold-season flow, median *E. coli* concentrations ranged from 63 colonies per 100 milliliters (col/100 mL) at site 07103700 (FoCr_Manitou) to 80 col/100 mL at site 07103707 (FoCr_8th), whereas, during warm-season flow, median *E. coli* concentrations at the two sites ranged from 410 to 1,350 col/100 mL, respectively. These median warm-season *E. coli* concentrations exceeded the recreational use standard of 126 col/100 mL. The median *E. coli* stormflow concentration of 1,800 col/100 mL at site 07103700 (FoCr_Manitou) was more than 14 times higher than the water-quality standard. Concentrations of *E. coli* measured in two of the four dry weather samples collected at site 385116104523301 (Fountain Creek at South 32nd Street) exceeded the recreational use standard. At site 385108104522001 (Camp Creek at South 31st Street), *E. coli* concentrations measured in dry weather samples were well below the water-quality standard. The elevated concentrations of *E. coli* within the Upper Fountain Creek watershed during warm-season flows and stormflows may be because of runoff from urban and suburban areas and areas with domestic livestock, and possibly, input from onsite wastewater treatment systems.

Dissolved-ammonia concentrations ranged from less than 0.01 to 1.67 milligrams (mg/L), nitrate plus nitrite concentrations ranged from 0.127 to 13.2 mg/L, and total phosphorus concentrations ranged from less than 0.02 to 71.3 mg/L in samples from main-stem sites on Upper Fountain Creek. Runoff from the Waldo Canyon fire burn area appeared to increase nutrient concentrations in some warm-season flow and stormflow samples in Upper Fountain Creek after June 2012. The maximum concentrations of dissolved ammonia (1.67 mg/L), nitrate plus nitrite (13.2 mg/L), and total phosphorus (71.3 mg/L) were measured in a single stormflow sample collected July 1, 2013. Instantaneous nutrient loads in stormflow were considerably larger than cold-season flow and warm-season flow loads. At site 07103700 (FoCr_Manitou), median dissolved-ammonia loads ranged from about 0.6 pounds per day (lb/d) during warm-season flow to about 44 lb/d during stormflow, median total phosphorus loads ranged from less than 2.0 lb/d during warm-season flow to 1,560 lb/d during stormflow, and median nitrate plus nitrite loads ranged from 33 lb/d during warm-season flow to 288 lb/d during stormflow.

Increases in median total arsenic, total copper, total lead, dissolved and total manganese, total nickel, dissolved and total selenium, and dissolved and total zinc concentrations were measured during cold-season and warm-season flows in Upper Fountain Creek between sites 07103700 (FoCr_Manitou) and 07103707 (FoCr_8th). Dissolved and total manganese, dissolved and total selenium, and dissolved and total zinc concentrations increased the most between the two sites and the largest increases occurred during cold-season flow when streamflow was low and predominantly from groundwater sources. During cold-season flows, in particular, the likely source of these metals is input from the Gold Hill Mesa area between the two sites.

The water-quality standard for total arsenic of 50 µg/L was exceeded in three samples collected during warm-season flows at site 07103707 (FoCr_8th), and in three samples collected during stormflows at site 07103700 (FoCr_Manitou), but not during cold-season flows. Concentrations of dissolved copper, selenium, and zinc measured in samples were below the water-quality standard. As with maximum nutrient concentrations, the maximum concentrations of dissolved and total arsenic, dissolved boron, total lead, total manganese, total nickel, dissolved and total selenium, and total zinc concentrations were measured in a single stormflow sample collected on July 1, 2013, after the Waldo Canyon fire. Median cold-season flow and warm-season flow loads of dissolved arsenic, boron, copper, and selenium were less than 5 lb/d compared to stormflow loads that ranged from 4 to 24 times larger.

Suspended-sediment concentrations in Upper Fountain Creek ranged from 2 to 155,000 mg/L in samples collected at site 07103700 (FoCr_Manitou) and from 1 to 51,300 mg/L at site 07103707 (FoCr_8th). The highest suspended-sediment concentrations were measured in stormflow samples collected after the Waldo Canyon fire, with the maximum concentration of 155,000 mg/L being measured at site 07103700 (FoCr_Manitou) in the first stormflow sample collected after the Waldo Canyon fire on July 1, 2013. The maximum concentrations of dissolved ammonia, nitrate plus nitrite, total phosphorus, dissolved and total arsenic, dissolved boron, total lead, total manganese, total nickel, dissolved and total selenium, and total zinc were also measured in this same sample.

In the Monument Creek watershed, water quality varied by location and streamflow regime. Based on the median instantaneous discharge values at each site, Monument Creek gained about 16.5 cubic feet per second (ft^3/s) of streamflow during cold-season flows and 21.0 ft^3/s during warm-season flows between sites 07103970 (MoCr_Woodmen) and 07104905 (MoCr_Bijou). Much of this increase in streamflow can be attributed to the many tributaries that drain into Monument Creek between the two sites and inflow from the J.D. Phillips Water Resource Recovery Facility. Median specific-conductance values increased during all flow regimes between main-stem sites 07103970 (MoCr_Woodmen) and 07104905 (MoCr_Bijou) likely because of tributary inflow with higher specific-conductance values. During warm-season flow conditions, the median specific-conductance values at tributary sites 07103990 on Cottonwood Creek and 07104050 on North Rockrimmon Creek were about 1.5 to 4 times larger, respectively, than the median value in Monument Creek at the nearest upstream main-stem site 07103970 (MoCr_Woodmen).

Between Monument Creek sites 07103970 (MoCr_Woodmen) and 07104905 (MoCr_Bijou), median *E. coli* concentrations increased from 41 to 61 col/100 mL during cold-season flow and increased from 100 to 390 col/100 mL during warm-season flow. During stormflow, however, median *E. coli* concentrations decreased in the downstream direction from 9,200 to 4,600 col/100 mL between the two sites. The median *E. coli* concentration in stormflow samples exceeded the recreational use standard of 126 col/100 mL by more than 73 times at site 07103970 (MoCr_Woodmen) and by more than 36 times at site 07104905 (MoCr_Bijou). *E. coli* concentrations also exceeded the 126 col/100 mL standard at tributary sites during periods of stormflow. It is unclear what may be causing the high *E. coli* concentrations.

Nitrate plus nitrite concentrations and loads increased in Monument Creek in the downstream direction. The largest downstream increase in median nitrate plus nitrite concentrations between main-stem sites was measured along Monument Creek. During warm-season flow, the median nitrate plus nitrite concentration increased by more than 6 times, from 0.61 to 3.68 mg/L between sites 07103970 (MoCr_Woodmen) and 07104905 (MoCr_Bijou). The median nitrate plus nitrite concentration doubled between the two sites during cold-season flow and stormflow. All but one tributary that drain into Monument Creek between the two sites had higher median nitrate plus nitrite concentrations than the nearest upstream site on Monument Creek, site 07103970 (MoCr_Woodmen). During warm-season flows, the median concentration of nitrate plus nitrite was 3.89 mg/L in Cottonwood Creek at site 07103990 (lower_CoCr) and 8.37 mg/L in North Rockrimmon Creek at site 07104050 (RkCr), more than 6 and 13 times larger, respectively, than the median concentration at site 07103970 (MoCr_Woodmen) on Monument Creek. Only one sample collected at 07104050 (RkCr) during warm-season flow had a concentration of nitrate plus nitrite that exceeded the instream water-quality standard of 10 mg/L. Between sites 07103970 (MoCr_Woodmen) and 07104905 (MoCr_Bijou), median nitrate plus nitrite loads during warm-season flow increased from 52 lb/d to 618 lb/d and during stormflow increased from 750 lb/d to 3,340 lb/d.

Increases in median dissolved boron, dissolved and total copper, total nickel, dissolved and total selenium, and dissolved and total zinc concentrations were measured between main-stem sites 07103970 (MoCr_Woodmen) and 07104905 (MoCr_Bijou) during all flow conditions. Median dissolved manganese concentrations decreased between the two sites during all flow regimes, whereas, median total manganese and median total arsenic concentrations decreased during cold-season flow and warm-season flow but increased during stormflow.

Median suspended-sediment concentrations and median suspended-sediment loads increased in the downstream direction during all streamflow regimes between main-stem sites 07103970 (MoCr_Woodmen) and 07104905 (MoCr_Bijou); however, statistically significant increases (*p*-value less than 0.05) were only present during warm-season flow and stormflow. These downstream increases in suspended-sediment concentrations and loads in Monument Creek are likely the result of contributions of suspended sediment from intervening tributaries such as the Cottonwood Creek. Median suspended-sediment concentrations at site 07103990 (lower_CoCr) were significantly higher than median suspended-sediment concentrations at site 07103970 (MoCr_Woodmen) during all flow regimes.

In the Lower Fountain Creek watershed, water quality varied by location and streamflow regime. Streamflow generally increases in Lower Fountain Creek in the downstream direction because of inflow from tributaries, discharge from wastewater treatment plants, urban runoff, and irrigation return flow, and these increases vary by flow regime. Median specific-conductance values increased in Lower Fountain Creek between sites 07105500 (FoCr_Nevada) and 07105800 (FoCr_Security) during cold-season flow and warm-season flow at all main-stem sites but, during stormflow, the median specific-conductance value at 07105530 (FoCr_Janitell) was lower than all the other sites. Tributary site 07105600 (SaCr) had elevated specific-conductance values, particularly during cold-season and warm-season flows, compared to the main-stem sites.

Concentrations of *E. coli* varied by streamflow regime and site location. Median *E. coli* concentrations were less than or equal to 100 col/100 mL during cold-season flow, whereas, during stormflow, median concentrations at sites ranged from 4,750 to 11,000 col/100 mL. During warm-season flow, the highest median *E. coli* concentration in Lower Fountain Creek was measured at site 07105500 (FoCr_Nevada), and median *E. coli* concentrations decreased in the downstream direction at main-stem sites. Based on median *E. coli* concentrations, the recreational use standard of 126 col/100 mL was exceeded during warm-season flows and stormflows at all Lower Fountain Creek main-stem sites and at Salt Creek site 07105600 (SaCr). Concentrations of *E. coli* measured at dry weather sites ranged from less than 1 col/100 mL to 8,200 col/100 mL. The highest concentrations were measured in samples from Shooks Run tributary and Cheyenne Run tributary.

Dissolved-ammonia, dissolved-nitrate plus nitrite, and total phosphorus concentrations varied with flow regime and location in the Lower Fountain Creek watershed. At main-stem sites, dissolved-ammonia concentrations measured in samples ranged from 0.01 mg/L to 0.98 mg/L. Median dissolved-ammonia concentrations were higher in stormflow samples than in warm-season flow and cold-season flow samples at most sites. Median concentrations of dissolved nitrate plus nitrite were higher in cold-season flow and warm-season flow samples than in stormflow samples and increased in the downstream direction. For example, between sites 07105500 (FoCr_Nevada) and 07105530 (FoCr_Janitell), the median nitrate plus nitrite concentration increased from 2.23 to 3.39 mg/L during cold-season flow, from 2.35 to 3.37 mg/L during warm-season flow, and from 0.86 to 1.09 mg/L during stormflow. Total phosphorus concentrations in samples ranged from 0.026 mg/L to 13.3 mg/L. Median total phosphorus concentrations were from 2 to 65 times higher in stormflow samples than in warm-season flow samples at main-stem sites.

Nutrient loads increased, on average, more than 200 percent during stormflows between sites 07105500 (FoCr_Nevada) and 07105530 (FoCr_Janitell) because streamflow and nutrient concentrations were higher at 07105530 (FoCr_Janitell) than 07105500 (FoCr_Nevada). The median instantaneous streamflow during stormflow increased by 82 percent between the two sites; the median dissolved ammonia, nitrate plus nitrite, and total phosphorus concentrations increased by 95, 27, and 12 percent, respectively, during stormflow between 07105500 (FoCr_Nevada) and 07105530 (FoCr_Janitell).

Trace element concentrations varied by location and flow regime in Lower Fountain Creek. During cold-season flow, median concentrations of dissolved and total arsenic, total manganese, total nickel, and dissolved and total selenium decreased between sites 07105500 (FoCr_Nevada) and 07105530 (FoCr_Janitell), whereas median concentrations of dissolved boron, dissolved and total copper, total lead, dissolved manganese, and dissolved and total zinc increased between the two sites. Changes in trace element concentrations in Fountain Creek between sites 07105500 (FoCr_Nevada) and 07105530 (FoCr_Janitell), particularly during cold-season and warm-season flows, are likely affected by wastewater effluent chemistry and volume. Sand Creek flows into Fountain Creek between main-stem sites 07105530 (FoCr_Janitell) and 07105800 (FoCr_Security) and likely effects trace element concentrations in Fountain Creek during certain flow conditions. At Sand Creek site 07105600 (SaCr), median warm-season flow concentrations of total arsenic, total copper, total lead, total manganese, total nickel, and dissolved and total selenium were greater than concentrations at main-stem sites upstream and downstream from the Sand Creek confluence.

In Lower Fountain Creek, median suspended-sediment concentrations decreased between sites 07105500 (FoCr_Nevada) and 07105530 (FoCr_Janitell) and increased between sites 07105530 (FoCr_Janitell) and 07105800 (FoCr_Security) during all flow regimes. Significant increases in median suspended-sediment concentrations were measured during cold-season flow and warm-season flow between Upper Fountain Creek site 07103707 (FoCr_8th) and Lower Fountain Creek site 07105500 (FoCr_Nevada) because of inflows from Monument Creek with higher suspended-sediment concentrations. Median suspended-sediment concentrations between sites 07104905 (MoCr_Bijou) and 07105500 (FoCr_Nevada) increased significantly during warm-season flow but showed no significant differences during cold-season flow and stormflow. Significant decreases in median suspended-sediment concentrations were measured between sites 07105500 (FoCr_Nevada) and 07105530 (FoCr_Janitell) during all flow regimes.

Median suspended-sediment discharge ranged from 4.3 to 6,730 tons/d at site 07105500 (FoCr_Nevada), from 6.3 to 4,285 tons/d at site 07105530 (FoCr_Janitell), and from 16.5 to 14,300 tons/d at site 07105800 (FoCr_Security). During stormflows, significant increases in median suspended-sediment discharges occurred between 07104905 (MoCr_Bijou) and 07105500 (FoCr_Nevada) and between 07105530 (FoCr_Janitell) and 07105800 (FoCr_Security). Significant increases in median suspended-sediment discharges and median suspended-sediment yield occurred between 07103707 (FoCr_8thSt) and 07105500 (FoCr_Nevada) and between 07105530 (FoCr_Janitell) and 07105800 (FoCr_Security) during cold-season flow and between 07105500 (FoCr_Nevada) and 07105530 (FoCr_Janitell) during warm-season flow.

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