Summary and Evaluation of the Quality of Stormwater in Denver, Colorado, Water Years 1998–2001

By Clifford R. Bossong, Michael R. Stevens, John T. Doerfer, and Ben R. Glass

Prepared in cooperation with the
Urban Drainage and Flood Control District

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Conversion Factors, Vertical Datum, and Abbreviations

Multiply	By	To obtain
	Length	
foot (ft)	0.3048	meter (m)
	Area	
acre-foot (acre-ft)	0.001233	cubic hectometer (hm^3)
square mile (mi^2)	259	hectare (ha)
square mile (mi^2)	2.590	square kilometer (km^2)
	Volume	
acre-foot (acre-ft)	1,233	cubic meter (m^3)
acre-foot (acre-ft)	0.001233	cubic hectometer (hm^3)
	Flow	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
cubic foot per second per square mile [(ft^3/s)/mi^2]	0.01093	cubic meter per second per square kilometer [(m^3/s)/km^2]

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

$$°F=(1.8×°C)+32$$

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 either in milligrams per liter (mg/L) or micrograms per liter (µg/L).

Horizontal coordinate information is referenced to the North American Datum of 1927 (NAD 27).

Additional Abbreviations

L	liter
µS/cm	microsiemens per centimeter at 25 degrees Celsius
mg/L	milligrams per liter
µg/L	micrograms per liter
acre-ft/mi^2	acre-feet per square mile
µm	micrometer

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Clifford R. Bossong, Michael R. Stevens, John T. Doerfer,[1] and Ben R. Glass

Abstract

Stormwater in the Denver area was sampled by the U.S. Geological Survey, in cooperation with the Urban Drainage and Flood Control District, in a network of five stations, three on the South Platte River and two on tributary streams, beginning in October 1997 and continuing through September 2001. Composite samples of stormwater were analyzed at the Metro Wastewater Reclamation District Laboratory for physical properties such as specific conductance, calcium carbonate hardness, and residue after evaporation at 105 degrees Celsius; and for constituents such as organic carbon and nutrients, including ammonia, nitrite plus nitrate, ammonia plus organic nitrogen, phosphorus, and orthophosphate; and for metals, including total and dissolved phases of copper, lead, manganese, and zinc. Bacteriological samples for *Escherichia coli* and fecal coliform collected during some storms also were analyzed at the Metro Wastewater Reclamation Laboratory. Discrete samples collected during selected storms were analyzed at the U.S. Geological Survey National Water-Quality Laboratory for a suite of water-quality properties and constituents similar to composite samples that did not include determinations for total phases of metals.

Streamflow characteristics associated with 255 composite stormwater samples indicate that, for individual stations and storms, mean streamflow for portions of hydrographs representing rising, falling, or entire event streamflow conditions were generally within 35 percent of overall station means, and differences in mean streamflow for different portions of the storm hydrographs were not large. Results from chemical analyses of the composite samples indicate spatial patterns related to contributing drainage area in the South Platte River, but no well-defined relation with the amount of urban land cover identified using national land-cover data available from the U.S. Geological Survey National Land Cover data.

Results from 52 discrete samples collected during three storms indicate that correlation coefficients between time-weighted and volume-weighted concentrations were always at least 0.88, indicating a strong correlation between the two weighting methods for the stations involved in this study. In addition, the central tendency for relative percent differences between the various weighting methods typically has a value of about 1, indicating good agreement for the various weighting methods for data collected as part of this study.

Comparison of stormwater results from composite samples to historical results representing base flow indicates that concentrations for some water-quality properties and constituents such as specific conductance, hardness, ammonia, nitrite plus nitrate, ammonia plus organic nitrogen, phosphorus, and orthophosphate were elevated in base flow, whereas concentrations for some constituents such as dissolved copper, lead, and zinc were elevated in stormwater runoff. Comparison of stormwater results to numeric standards developed by the Colorado Department of Public Health and Environment on the basis of use classifications indicates that concentrations of some metals such as dissolved copper, manganese, and zinc did not meet standards in 10 to 25 percent of composite samples at some stations, and that bacteriological indicators such as *Escherichia coli* and fecal coliform did not meet standards in all bacteriological samples.

An evaluation of stormwater results by year on the basis of annual means indicates that, in general, there are few monotonic trends in concentrations, indicating generally uniform or stationary conditions, for most water-quality properties and constituents at individual stations. At some sampling stations, however, annual means for water-quality properties and constituents such as specific conductance, hardness, orthophosphate, and ammonia indicated a consistent increase in concentration, or upward monotonic trend, through the data-collection period. In addition, total organic carbon, ammonia plus organic nitrogen, and total phosphorus all indicated a consistent decrease, or downward monotonic trend, through the data-collection period, at some stations.

Two-sided 95-percent confidence tolerance intervals, generally with 99-percent coverage, were computed to be used as a basis for comparisons with future samples. Linear regressions and correlation coefficients also were computed to help evaluate intradistributional changes on the basis of future samples. Together, relatively weak correlation coefficients between water-quality properties and constituents with mean streamflow, and the lack of spatially consistent regressions, indicate a heterogeneous and mixed system.

[1]Urban Drainage and Flood Control District.

Introduction

The quality of stormwater runoff is of interest to many management and regulatory agencies as well as academia, scientists, recreational stream users, and the general public. The basic character of stormwater runoff is of general interest to all, whereas more detailed information concerning spatial and temporal variations may be of interest to management and regulatory agencies. In response to these interests, the U.S. Geological Survey (USGS), in cooperation with the Urban Drainage and Flood Control District (UDFCD), systematically collects stormwater samples during wet weather from a monitoring network of five stations in and around metropolitan Denver, Colorado. The monitoring network consists of three stations on the South Platte River, the principal stream draining the area, and two tributary stations (fig. 1). These streams are included in segments 14, 15, and 16A of the South Platte River as designated by the Water-Quality Control Division of the Colorado Department of Public Health and Environment (CDPHE). Segments 14, 15, and 16A are defined by CDPHE and have use classifications and associated numeric standards for some water-quality properties and constituents, such as pH, *Escherichia coli*, fecal coliform, nitrite plus nitrate, dissolved copper, lead, manganese, and zinc, and total manganese, that were included in this study (Colorado Department of Public Health and Environment, 2001, 2002).

Purpose and Scope

The purpose of this report is to present summaries and an evaluation of chemical analyses of different types of stormwater samples that characterize the quality of stormwater in and around metropolitan Denver for a contemporary period beginning in water year 1998 (October 1, 1997) and continuing through water year 2001 (September 30, 2001). Specifically, the summaries and evaluation include:

- Characterizations of streamflow associated with each composite sample,
- Univariate statistics describing stormwater quality,
- A comparison of time-weighted results to discharge and volume-weighted results,
- Comparisons of contemporary stormwater quality and historical results from base-flow samples,
- Comparisons of contemporary stormwater quality and numeric standards for various use classifications established by the CDPHE, and
- Descriptive statistics for annual means, tolerance intervals, and regression relations among water-quality properties and constituents.

Although descriptions of relations between water-quality properties and constituents are included, this report does not provide detailed descriptions of the physical basis for any identified relations. The summaries presented in this report, however, do provide a basis on which future comparisons to similar data can be made.

Description of Stations

The five stations in the monitoring network include three stations on the main stem of the South Platte River (fig. 1). These stations are located below Union Avenue, at Denver, and at Henderson and will be referred to in this report as “Union,” “Denver,” and “Henderson.” The stations on the South Platte River receive streamflow from several tributaries; consequently, the South Platte River is sometimes referred to as a “receiving stream.” The two additional stations, Sand Creek at mouth and Tollgate Creek above 6th Avenue, represent tributaries and are referred to in this report as “Sand Creek” and “Tollgate.” Sand Creek is tributary to the South Platte River and Tollgate is tributary to Sand Creek. Collectively, these five stations define a system that drains the majority of the area in and around metropolitan Denver.

The South Platte River heads in central Colorado and has a contributing drainage area of 3,589 mi^2 at the Denver station. Reservoirs and diversions along the South Platte River regulate streamflow. Chatfield Reservoir contains the vast majority of storm runoff generated upstream from Chatfield Dam and essentially truncates the contributing drainage area for the stations used in this study. Consequently, most stormwater runoff in the South Platte River in the Denver area is derived from a local contributing drainage area that does not extend upstream from Chatfield Dam. Streamflow regulation also occurs along Sand Creek and Tollgate but does not affect local contributing drainage areas.

Land-cover characteristics used in this report (table 1) represent percentages of the local contributing drainage areas for four aggregated categories developed on the basis of USGS National Land Cover data from 1992 (U.S. Geological Survey, 2003). In the aggregated classification, areas related to crops are classified as “agricultural”; areas identified as commercial, industrial, or transportation and areas related to mining are classified as “urban”; areas identified as residential or recreational are classified as “residential”; and all remaining area is classified as “undeveloped.” The local contributing drainage areas are less than 10 percent urban and consist mostly of undeveloped land (43.08 to 75.97 percent) and residential areas (19.41 to 50.43 percent). Only the agricultural land-cover classification shows a tendency to increase with local contributing drainage area (0.70 to 3.16 percent in the South Platte and 4.97 to 8.72 percent in Sand Creek).

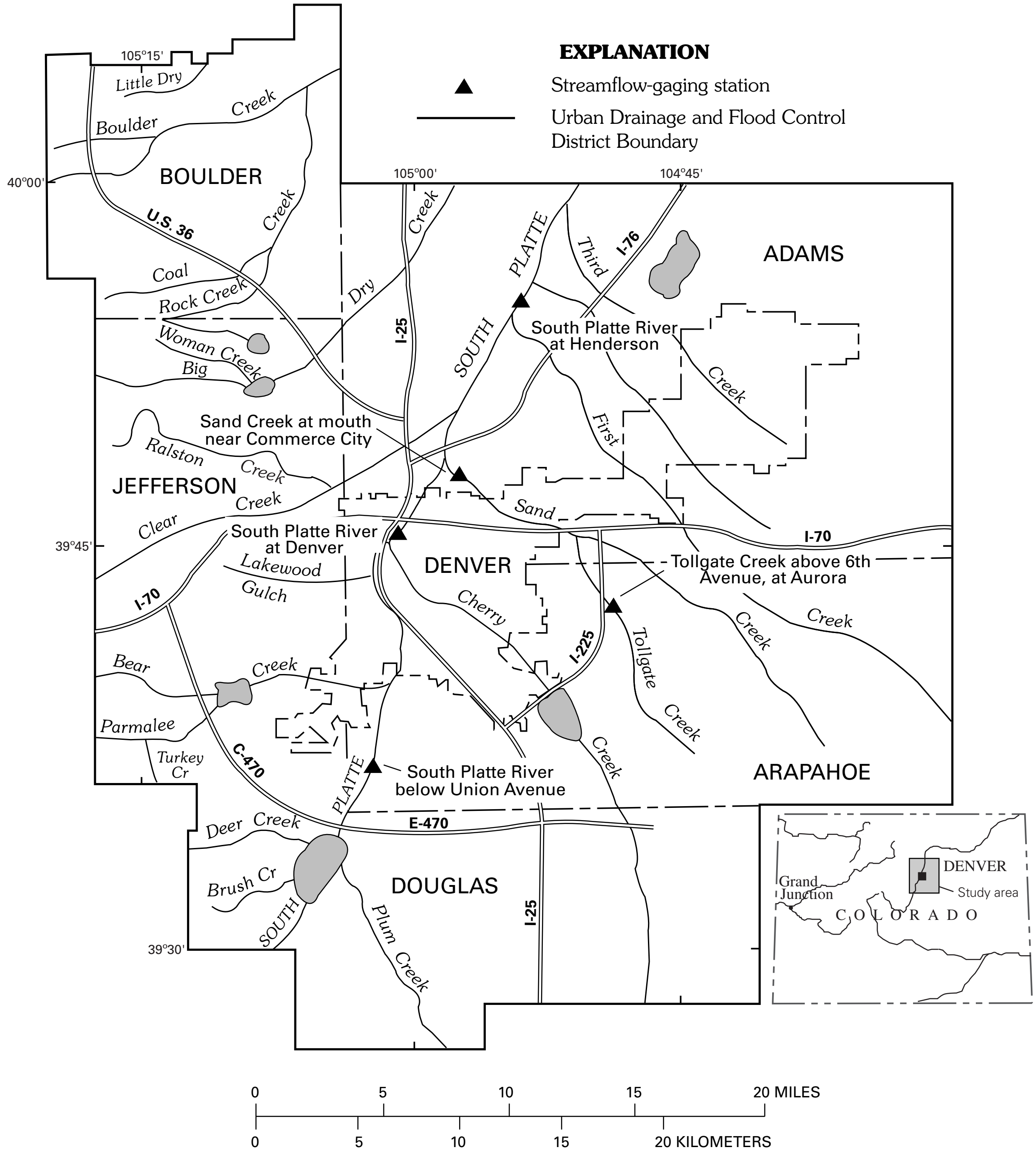

Figure 1. Location of stations.

Previous Investigations

Several investigations of stormwater quality have been conducted in the Denver area. Beginning in 1979 and through 1983, annual data reports were issued summarizing stormwater-monitoring activities by USGS for various stations in the Denver metropolitan area (Ellis, 1978; Ellis and Alley, 1979; Hall and Duncan, 1980, 1981; Gibbs, 1981; Gibbs and Doerfer, 1982; Gibbs and others, 1983). Although these activities included some sampling in the South Platte River, most of the activities focused on tributaries to the South Platte River. Blakely and others (1983) reported on washoff characteristics from two experimental plots, and Ellis and others (1984), Ellis and Mustard (1985), and Mustard and others (1985) provided additional information on storm runoff on the basis of the USGS stormwater-monitoring activities. In addition, the Denver Regional Council of Governments (1983) summarized their stormwater-monitoring activities in the Denver metropolitan area.

Table 1. Station characteristics.

[Station number and name from the USGS National Water Inventory System. Latitude and Longitude, geographic coordinates in degrees minutes seconds. Operation indicates agency responsible for streamflow records: USGS, U.S. Geological Survey; CODWR, Colorado Division of Water Resources; UDFCD, Urban Drainage and Flood Control District. RF location, location of precipitation gage associated with station, the source for all precipitation records is UDFCD. CDA, contributing drainage area in square miles; LCDA, local contributing drainage area in square miles adjusted for regulation (excludes CDA upstream from Chatfield Dam for South Platte River stations). Land cover indicates percentage of LCDA on basis of National Land Cover data from 1992 for undeveloped areas (Und), agricultural areas (Ag), residential areas (Res), and urban areas (Urb). Comments provide important historical operational events. ft^3/s, cubic feet per second; [$(ft^3/s)/mi^2$], cubic feet per second per square mile; acre-ft/mi^2, acre-feet per square mile]

Station number	Station name	Local identifier	Station location		Operating agency	RF location	
			Latitude	Longitude		Latitude	Longitude
06710247	South Platte River below Union Avenue	SPRU	39°37'57"	105°00'52"	USGS	39°37'57"	105°00'52"
06714000	South Platte River at Denver	SPRD	39°45'35"	105°00'10"	CODWR	39°44'32"	104°59'58"
394329104490101	Tollgate Creek above 6th Avenue	TGC6	39°43'29"	104°49'01"	UDFCD	39°43'30"	104°49'06"
394839104570300	Sand Creek at mouth	SCRM	39°48'36"	104°57'00"	USGS	39°48'39"	104°57'03"
06720500	South Platte River at Henderson	SPRH	39°55'19"	104°52'04"	CODWR	39°55'19"	104°52'00"

Station number	CDA	LCDA	Land cover				Comments
			Und	Ag	Res	Urb	
06710247	3,043	76	43.08	0.70	50.43	5.79	Gage operated as described in Rantz and others (1982). Various other precipitation records used previous to water year 2000.
06714000	3,861	841	75.97	1.23	19.41	3.39	Gage operated as described in Rantz and others (1982). Various other precipitation records used previous to water year 2001.
394329104490101	35	35	41.56	4.97	47.98	5.49	Gage operated as part of flood warning network. Various other precipitation records used previous to water year 2001.
394839104570300	184	184	62.58	8.72	22.41	6.29	Gage operated as described in Rantz and others (1982). Various other precipitation records used previous to water year 2001.
06720500	4,768	1,741	75.30	3.16	17.79	3.75	Gage operated as described in Rantz and others (1982.) Various other precipitation records used previous to water year 2001.

Methods of Study

The methods used to collect and process streamflow data, to collect and process stormwater samples, and to perform chemical analyses are described in this section. The section also describes the quality-control and quality-assurance (QA/QC) measures used in the study.

Streamflow Data Collection

Streamflow records are maintained at each station by various operating agencies (table 1). Union and Sand Creek are operated by USGS in accordance with methods described by Rantz and others (1982). The streamflow data are maintained in the USGS National Water Information System (NWIS). Both daily data, which represent average conditions for a 24-hour period, and subdaily data, which represent instantaneous values, are available from NWIS. In addition, the records were published annually in USGS annual data reports for water years 1998–2001 (U.S. Geological Survey, 1999–2002). The published records received additional processing to obtain a variety of summary streamflow statistics, some of which are included in table 1.

Denver and Henderson are operated by the Colorado Division of Water Resources (CODWR). The CODWR records are reviewed and published by the USGS (U.S. Geological Survey, 1999–2002). Daily streamflow values are maintained in NWIS; the three most recent days of subdaily data are maintained on a publicly available CODWR Web-based system (URL *http://www.dwr.state.co.us/Hydrology/flow_search.asp*), and all subdaily data are available on a UDFCD Web-based system (*http://alert.udfcd.org/datadisp.html*).

Tollgate is operated by UDFCD using systematic but undocumented methods that involve theoretical stage and streamflow relations developed on the basis of channel geometry. The Tollgate data are used as part of an Automated Local Evaluation in Real Time (ALERT) system operated by UDFCD to assess field conditions in a real-time mode in order to facilitate flood forecasting. Consequently, the UDFCD data are focused on real-time information, and sometimes data are available only for periods of storm runoff. Although the UDFCD records are archived, they do not receive further processing or extensive review and consist only of subdaily data.

Some changes were made at the Sand Creek gaging station in 2000. Prior to March 1, 2000, streamflow data for Sand Creek were collected 400 ft downstream from the current (2001) gage location; however, the stormwater sampling point has been located at the current gage location throughout this study. Streamflow measurements from the former location may include additional flows from irrigation and other ditches that entered Sand Creek downstream from the current sampling point, whereas streamflow measurements at the current location characterize flow in all conveyances individually and provide a record of Sand Creek streamflow at the current sampling point. Consequently, streamflow measurements

Table 1. Station characteristics.—Continued

[Station number and name from the USGS National Water Inventory System. Latitude and Longitude, geographic coordinates in degrees minutes seconds. Operation indicates agency responsible for streamflow records: USGS, U.S. Geological Survey; CODWR, Colorado Division of Water Resources; UDFCD, Urban Drainage and Flood Control District. RF location, location of precipitation gage associated with station, the source for all precipitation records is UDFCD. CDA, contributing drainage area in square miles; LCDA, local contributing drainage area in square miles adjusted for regulation (excludes CDA upstream from Chatfield Dam for South Platte River stations). Land cover indicates percentage of LCDA on basis of National Land Cover data from 1992 for undeveloped areas (Und), agricultural areas (Ag), residential areas (Res), and urban areas (Urb). Comments provide important historical operational events. ft³/s, cubic feet per second; [(ft³/s)/mi²], cubic feet per second per square mile; acre-ft/mi², acre-feet per square mile]

Summary streamflow statistics				
Station number	06710247	06714000	394839104570300	06720500
Period of record, in water years	1996–2001	1976–2001	1992–2001	1976–2001
Annual mean, in ft³/s	184	377	58.4	569
Annual mean, in ft³/mi²	2.42	0.45	0.31	0.33
Highest annual mean, in ft³/s	293	961	99.9	1379
Highest annual mean, in ft³/mi²	3.9	1.14	0.52	0.79
Date	1999	1983	1997	1983
Lowest annual mean, in ft³/s	93.8	138	35.5	252
Lowest annual mean, in ft³/mi²	1.23	0.16	0.19	0.14
Date	2001	1978	1993	1981
Highest daily mean, in ft³/s	1,940	4,020	1,100	6,500
Highest daily mean, in ft³/mi²	25.5	4.78	5.76	3.73
Date	June 18, 1999	May 27, 1987	July 29, 1997	June 9, 1995
Lowest daily mean, in ft³/s	3.3	43	4.0	27
Lowest daily mean, in ft³/mi²	0.04	0.05	0.02	0.02
Date	April 24, 1996	April 8, 1978	July 4, 1996	April 7, 1977
Annual 7-day minimum, in ft³/s	8.7	50	7.2	69
Annual 7-day minimum, in ft³/mi²	0.11	0.06	0.04	0.04
Date	March 5, 1996	April 2, 1978	June 28 1996	March 13, 1982
Maximum peak flow, in ft³/s	2,150	12,600	5,750	12,300
Maximum peak flow, in ft³/mi²	28.3	15.0	30.1	7.06
Date	May 28, 1999	July 25, 1998	July 29, 1997	June 27, 1983
Annual runoff, in acre-feet	133,300	273,200	42,310	412,300
Annual runoff, in acre-ft/mi²	1,754	325	222	237
10 percent exceeds, in acre-feet	434	765	125	1,070
10 percent exceeds, in acre-ft/mi²	5.71	0.91	0.65	0.61
50 percent exceeds, in acre-feet	76	192	33	348
50 percent exceeds, in acre-ft/mi²	1.00	0.23	0.17	0.20
90 percent exceeds, in acre-feet	18	89	14	182
90 percent exceeds, in acre-ft/mi²	0.24	0.11	0.07	0.10

before March 1, 2001, may be larger compared to streamflow at the sampling point. The available streamflow measurements, which begin in March of 2001, indicate that irrigation and other ditches return flow to Sand Creek intermittently and actively discharge water only during about 50 percent of the period covered by available records. When active, the median flow added to Sand Creek is about 45 ft³/s on the basis of subdaily data contained in NWIS, and flows of more than 100 ft³/s account for only about 5 percent of available record records.

Historical streamflow data are available for all stations except Tollgate and can be used to prepare streamflow summaries. Some summary streamflow information is included in table 1. The data used to prepare the summary information are for differing periods of record due to the history of operation for individual stations; however, the summary information can be used to make general observations about streamflow patterns. Dates for annual streamflow minima and maxima occur at about the same time of year for all streams, indicating that seasonal patterns are similar at all stations, or are stationary. The 90-percent exceedances (table 1) indicate that streamflow is sustained throughout the year at the four stations listed in table 1. The sustaining flow is referred to as “base flow” in this report and is a combination of groundwater discharge to streams, discharge from wastewater-treatment plants, and releases from reservoirs.

Most of the stormwater samples collected as part of this study were composite samples. The composite samples, which are described in detail in the “Sample Collection and

Analysis" section, integrate aliquots of streamflow collected over a period of time and are associated with a streamflow volume and mean streamflow for the data-collection period. The streamflow volume and mean streamflow were computed using subdaily data. In most cases, the subdaily time increment was between 5 and 15 minutes; however, time increments varied according to conditions and the agency responsible for streamflow records. Methods based on subdivision techniques described in Rantz and others (1982, chapter 15) were implemented to calculate streamflow volume and mean streamflow associated with composite samples.

Sample Collection and Analysis

Two principal types of investigative samples, referred to as "composite" and "discrete" samples, were collected as part of this study. All composite and discrete samples were collected using automatic pumping samplers that withdraw water from a fixed point in the channel cross section; four of the samplers are refrigerated, and ice is used in the fifth sampler to chill samples. In addition, bacteriological samples were sometimes manually collected during storms. The composite, bacteriological, and discrete samples are collectively referred to as "stormwater samples."

Analyses of the stormwater samples were provided by two laboratories in Denver, Colorado: the Metro Wastewater Reclamation District Laboratory (MWRD) and the USGS National Water-Quality Laboratory (NWQL). Most chemical analyses were performed at the MWRD. The results of all chemical analyses obtained as part of this study reside in the NWIS database and can be accessed using the USGS Web interface to water data at URL *http://waterdata.usgs.gov/co/nwis/qw/*. Table 2 describes the chemical analyses and analytical methods used for the principal types of samples collected as part of this study; references for analytical methods used at the NWQL are listed at URL *http://nwql.usgs.gov/Public/ref_list.html*. Results referred to as "dissolved" are from water that has been passed through a filter that removes all particles greater than 0.45 micrometer in their smallest diameter; results referred to as "total" are from unfiltered water that has undergone an in-bottle digestion procedure (Hoffman and others, 1996). Results referred to as "whole water" are from water that has not been filtered or digested.

Composite Samples

Composite samples were collected and submitted to MWRD for chemical analyses (table 2) to characterize stormwater quality. A total of 255 composite samples were collected using refrigerated, or iced, automatic pumping samplers that were activated when stormwater runoff began. Once activated, the samplers obtained aliquots, or sample portions, by withdrawing fixed volumes of water from the stream every 60 minutes. The samplers were outfitted with eight 2-L bottles and were programmed to add three aliquots to each bottle. In theory, the samplers could operate unattended for 24 hours; however, in practice, each station was visited by project staff at least every 12 to 24 hours during storm events. As the stations were visited, the contents of four sequential bottles were composited into a single time-weighted composite sample. Each sample was composited according to churn-splitter procedures described in the USGS National Field Manual (U.S. Geological Survey, 1997–2005, chapter A5), which documents USGS protocols for collection of water-quality data. Once composited, the samples represented conditions for a period of time (typically 12 hours). If individual sample bottles were found to contain different volumes of water, it was assumed that individual aliquot volumes varied, and the sample volumes were adjusted, if possible, or the samples were discarded. The composited samples were delivered to the MWRD for further processing and analysis. The samples were analyzed for physical properties such as specific conductance, calcium carbonate hardness, and residue on evaporation at 105 degrees Celsius; for constituents such as organic carbon and nutrients, including ammonia, nitrite plus nitrate, ammonia plus organic nitrogen, phosphorus, and orthophosphate; and for metals, including total and dissolved phases of copper, lead, manganese, and zinc (table 2).

The composite samples integrate concentrations over time and are appropriate for evaluating water-quality criteria developed for aquatic wildlife. The aquatic wildlife criteria defined by CDPHE (Colorado Department of Public Health and Environment, 2001, 2002), generally the most stringent criteria in place, describe acute standards that specify a concentration for a period of time, usually 24 hours. The acute criteria, like the composite samples, describe concentration over a period of time rather than instantaneous concentration.

The samplers can be activated to collect samples automatically in a number of different ways; however, due to streamflow regulation and relatively complex weather patterns, decisions to activate samplers in this study were made by project staff on the basis of local weather and streamflow conditions. Local weather and streamflow conditions were nearly continuously monitored through a variety of sources including near real-time data available from the World Wide Web. The ALERT system operated by UDFCD provides very near real-time data from an extensive network of precipitation gages. In addition, the ALERT system provides information from many UDFCD gaging stations and also integrates streamflow data from USGS and CODWR gaging stations into very near real-time Web-based reports. The very near real-time data available from the ALERT system typically are within a few minutes of real time.

Bacteriological Samples

A total of 34 bacteriological samples were collected during selected storms. The samples were collected manually as grab samples by filling bottles at streambeds and then transporting them directly to MWRD for immediate analysis. The bacteriological samples were analyzed for *Escherichia coli* and fecal coliform (table 2).

Table 2. Water-quality properties and constituents for composite, bacteriological, and discrete samples.

[USGS, U.S. Geological Survey; USEPA, U.S. Environmental Protection Agency; C, Celsius; N, nitrogen; P, phosphorus. Phase: W, determination made using whole water; T, total; D, dissolved. Analytical facility, MWRD, Metro Wastewater Reclamation District Laboratory, NWQL, USGS National Water-Quality Laboratory. Preferred analytical method indicates the analytical method currently (2001) in use at the Metro Wastewater Reclamation District Laboratory. Reporting units: stdu, standard pH units; µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; col, colonies per 100 milliliters; na, not applicable; ICP, inductively coupled plasma]

Composite samples

Water-quality property or constituent	Phase	Analytical facility	Analytical facility identifier	USGS parameter code	Preferred analytical method	Reporting units	Preferred analytical method reporting level
Physical properties							
pH	W	MWRD	PHD001	00403	USEPA 150.1	stdu	na
Specific conductance	W	MWRD	CON001	00095	USEPA 120.1	µS/cm	0.10
Hardness, as $CaCO_3$	T	MWRD	HARD001	00900	USEPA 130.2	mg/L	10.00
Residue on evaporation at 105 degrees C	T	MWRD	TSS001	00530	USEPA 160.2	mg/L	1.00
Organics							
Organic carbon	T	MWRD	TOC001	00680	USEPA 415.1	mg/L	1.00
Nutrients							
Ammonia, as N	T	MWRD	NH3A001	00610	USEPA 350.1	mg/L	0.20
Nitrite + nitrate, as N	T	MWRD	NO5001	00630	USEPA 353.2	mg/L	0.02
Ammonia + organic N, as N	T	MWRD	TKNH001	[1]00625	USEPA 351.3	mg/L	0.30
Phosphorus, as P	T	MWRD	TPW001	00665	USEPA 365.4	mg/L	0.03
Orthophosphate, as P	D	MWRD	OP001	00671	USEPA 365.1	mg/L	0.03
Metals							
Copper	D	MWRD	ICPSW007	[2]01040	USEPA 200.7	µg/L	1.00
Copper	T	MWRD	CURFW001	[3]01119	USEPA 220.2	µg/L	1.00
Lead	D	MWRD	ICPSW003	[2]01049	USEPA 200.7	µg/L	10.00
Lead	T	MWRD	PBRFW001	01114	USEPA 239.2	µg/L	10.00
Manganese	D	MWRD	ICPSW005	[4]01056	USEPA 200.7	mg/L	0.02
Manganese	T	MWRD	ICPSW005	[4]00925	USEPA 200.7	mg/L	0.02
Zinc	D	MWRD	ICPSW001	[2]01090	USEPA 200.7	µg/L	0.30
Zinc	T	MWRD	ZNRFW001	[3]01094	USEPA 289.2	µg/L	0.30

Bacteriological samples

Water-quality property or constituent	Phase	Analytical facility	Analytical facility identifier	USGS parameter code	Preferred analytical method	Reporting units	Preferred analytical method reporting level
Escherichia coli	W	MWRD	ECMPN001	50468	USEPA 600/8–78–017, 1978	col	2
Fecal coliform	W	MWRD	FCMPN001	31615	USEPA 600/8–78–017, 1978	col	20

Discrete samples

Water-quality property or constituent	Phase	Analytical facility	Analytical facility identifier	USGS parameter code	Preferred analytical method	Reporting units	Preferred analytical method reporting level
Physical properties							
pH	W	USGS	0068	00403	I–2781–89[5]	stdu	0.1
Specific conductance	W	USGS	0069	00095	I–2781–88[5]	µS/cm	2.6
Hardness, as $CaCO_3$	T	USGS	na	00900	I–1472–87[6]	mg/L	na
Residue on evaporation at 105 degrees C	T	USGS	0169	00530	I–3765–89[5]	mg/L	10.0
Organics							
Organic carbon	D	USGS	2612	00681	O–1103–83[10]	mg/L	0.33
Nutrients							
Ammonia, as N	T	USGS	1976	00608	I–2522–90[6]	mg/L	0.04
Nitrite + nitrite, as N	T	USGS	1975	00631	I–2545–90[6]	mg/L	0.06
Ammonia + organic N, as N	T	USGS	1986	00625	I–4515–91[7]	mg/L	0.10
Phosphorus, as P	T	USGS	1984	00665	I–4610–91[8]	mg/L	0.4
Orthophosphate, as P	D	USGS	1978	00671	I–2606–89[6]	mg/L	0.007
Metals							
Copper	D	USGS	1791	01040	I–2477–92[9]	µg/L	0.23
Lead	D	USGS	1792	01049	I–2477–92[9]	µg/L	0.08
Zinc	D	USGS	1798	01090	I–2477–92[9]	µg/L	1.0

[1]An analytical facility identifier of TKNL001 sometimes used for low-level determinations.

[2]A different analytical facility identifier sometimes used for furnace determinations using the same USEPA methods used for total determinations.

[3]A different analytical facility identifier sometimes used for ICP determinations made using the same USEPA methods used for furnace dissolved determinations.

[4]Manganese results are available only for a subset of all samples.

[5]Fishman and Friedman, 1989.

[6]Fishman, 1993.

[7]Patton and Truitt, 2000.

[8]Patton and Truitt, 1992.

[9]Faires, 1993.

[10]Wershaw and others, 1987.

Discrete Samples

Fifty-two discrete samples were collected to help evaluate the effect that various weighting methods might have on sample compositing. To collect discrete samples, the automatic pumping samplers were operated manually to obtain individual, or discrete, samples through a storm hydrograph. The discrete samples were analyzed for a suite of constituents that did not include determinations for total copper, lead, manganese, and zinc; but otherwise, the suite of constituents was very similar to the composite samples at the NWQL (table 2).

Unlike the composite samples, discrete samples were processed in the field. The steps involved in processing, filtration, bottling, and preservation were performed in accordance with the techniques described in the USGS National Field Manual (U.S. Geological Survey, 1997–2005, chapter A5). Each discrete sample was submitted to the NWQL for analysis, and no physical compositing was done in the field. Rather, the results from individual discrete samples were composited by mathematically using three different weighting techniques based on time, streamflow, and volume using a general equation with the form:

$$WC = \left[\sum C \times WF\right] \div \left[\sum WF\right] \qquad (1)$$

where

WC is weighted concentration,
C is concentration,

and

WF is weighting factor (time, streamflow, or volume).

Quality Assurance and Quality Control

Laboratory QA/QC samples were evaluated as part of this study. QA/QC samples also were collected to characterize the influence that sampling equipment or ambient field conditions may have imparted to samples. Additional QA/QC blank samples that help characterize field conditions and their effects on investigative samples include a series of 14 pairs of samples collected to characterize differences between fixed-point samples and samples integrated across the channel cross section.

Laboratory Quality Assurance and Quality Control

It is standard USGS practice to monitor laboratory performance for purposes of qualifying laboratory results. Laboratory performance in this study was evaluated on the basis of the USGS Standard Reference Sample (SRS) program as well as different types of additional QA/QC samples. The SRS program prepares spiked samples and distributes them to as many as 100 laboratories across the Nation. Results from all laboratories are used to determine a most probable value (MPV), and individual laboratory results are compared to the MPV to determine performance (Woodworth and Connor, 2003).

The NWQL and MWRD SRS program results for chemical analyses used in this study are summarized in table 3. In general, the results indicate that the median relative percent difference (RPD) between laboratory results and the SRS MPV, for both laboratories, had an absolute value less than 1. The RPD for two given values (a and b) is calculated according to the following equation:

$$\text{RPD} = \{(a-b) \div [(a+b) \div 2]\} \times 100 \qquad (2)$$

For example, a laboratory result of 8, when the MPV is 10, results in an RPD of –22.2. The standard deviations for the RPD of reported and most probable values were 9.44 for the NWQL and 34.80 for MWRD. The frequency distribution information in table 3 indicates that the RPDs for MWRD results have an absolute value of 20 percent or less about 80 percent of the time.

Double-blind split (DBS) samples, in which field-matrix water collected under base-flow conditions was split into four individual samples, were submitted to each laboratory in pairs. Results from chemical analyses of the DBS samples had interlaboratory absolute values of RPDs greater than 20 for residue on evaporation at 105°C, ammonia plus organic nitrogen, phosphorus, total copper, and both dissolved and total zinc (table 4). Because the DBS analysis did not determine MPVs,

Table 3. Laboratory performance evaluation data from U.S. Geological Survey Standard Reference Sample program (1997–2002) and split samples.

[MWRD, Metro Wastewater Reclamation District Laboratory; NWQL, USGS National Water-Quality Laboratory; Stddev, standard deviation; n, number of samples. Univariate statistics for U.S. Geological Survey Standard Reference Sample program most probable values and results from Metro Wastewater Reclamation District Laboratory and U.S. Geological Survey National Water-Quality Laboratory]

	Mean	Median	Stddev	Skewness	Minimum	Maximum	n
MWRD	4.39	0.80	34.80	0.72	–160.09	170.07	147
NWQL	–2.55	–0.28	9.44	–3.42	–66.67	12.77	190

Frequency distribution of Metro Wastewater Reclamation District Laboratory relative percent differences

Interval	Frequency	Frequency (percent)	Cumulative frequency (percent
–170 to 50	3	2.041	2.041
–50 to –40	1	0.680	2.721
–40 to –30	2	1.361	4.082
–30 to –20	9	6.122	10.204
–20 to –10	9	6.122	16.327
–10 to 0	44	29.932	46.259
0 to 10	43	29.252	75.510
10 to 20	22	14.966	90.476
20 to 30	1	0.680	91.156
30 to 40	1	0.680	91.837
40 to 50	2	1.361	93.197
50 to 180	10	6.803	100.000
Total	147	100.000	

Table 4. Results from double-blind split samples.

[Samples submitted to the Metro Wastewater Reclamation District Laboratory (MWRD) and the USGS National Water Quality Laboratory (NWQL), and median relative percent difference between Standard Reference Sample (SRS) program most probable values (MPV) and MWRD results. Phase: W, determination made using whole water; T, total; D, dissolved. RPD, relative percent difference; stdu, standard pH units; En, equal-width interval sample and aliquot identifier n (all samples from same batch of water); µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; C, Celsius; µg/L, micrograms per liter; <, less than; na, not applicable]

Property or constitutent	Phase	MWRD				NWQL				Inter-laboratory RPD on mean	Median of historical MWRD SRS RPD
		E1	E2	Mean	RPD	E3	E4	Mean	RPD		
pH, in stdu	W	7.7	7.8	7.75	–1.29	7.981	7.93	7.96	0.64	–2.67	na
Specific conductance, in µS/cm	W	878	869	874	1.03	865.	866.	866	–0.12	0.92	na
Hardness, in mg/L	T	300	263	282	13.14	240	240	240	0	16.09	[1]1.1/13.6
Residue on evaporation at 105 degrees C, in mg/L	T	31	29	30	6.67	19.	21.	20	–10	40.00	na
Ammonia, in mg/L	T	<.2	<.2	<.2	na	.178	.181	.180	–1.67	na	16.47
Nitrite + nitrate, in mg/L	T	5.49	5.47	5.28	0.36	5.301	5.277	5.29	0.45	–0.19	–1.37
Ammonia + organic nitrogen, in mg/L	T	<.3	0.5	0.5	na	1.121	1.105	1.11	1.44	–75.78	–2.63
Phosphorus, in mg/L	T	0.47	0.5	.49	–6.19	.663	.663	.663	0	–30.01	–2.32
Orthophosphate, in mg/L	D	0.58	0.57	.58	1.74	.532	.535	.534	–0.56	8.26	–1.13
Copper, in µg/L	D	3	4	3.5	–28.57	4.33	3.172	3.75	30.87	–6.90	–3.07
Copper, in µg/L	T	7	14	10.5	–66.66	5.128	5.222	5.18	–1.82	67.86	na
Lead, in µg/L	D	<10	<10	<10	na	<1.	<1.	<1.	na	na	2.30
Lead, in µg/L	T	<10	<10	<10	na	2.059	1.822	1.94	12.21	na	na
Zinc, in µg/L	D	43.8	42	42.9	4.20	na	28.865	28.87	na	39.10	9.34
Zinc, in µg/L	T	67.2	40.8	54	48.89	33.68	32.896	33.29	2.36	47.45	na

[1]Results for calcium and magnesium (components of hardness calculation).

it is only possible to indicate that results from the two laboratories, for these constituents, sometimes have an RPD of 20 or more.

Additional QA/QC samples used to evaluate laboratory performance include duplicate and spike samples that were submitted to the MWRD for performance evaluation. Duplicate samples consisted of field-matrix stormwater split into two separate samples; results from duplicate samples indicate that, on an annual basis, about 80 percent of the MWRD results have an absolute value for RPDs of 20 or less (table 5). If it is assumed that one member of each duplicate pair represents a correct value, then the results from the duplicate samples indicate about the same performance as the results from the SRS program.

In addition to duplicate samples, SRS samples were submitted to the MWRD independently of the SRS program and analyzed for ammonia plus organic nitrogen (table 6, spiked samples). The results from these samples indicate an RPD of about –6 percent, indicating that results are close to MPVs.

Blank Samples

Table 6 includes results from an equipment blank, a field blank, and two source blanks. The source blanks are analyses of water used in the equipment and field blanks. The source water also was used to rinse sampler intake lines in between sampling events and generally to rinse all equipment when in the field, as necessary. The equipment blank was collected by pouring source water through a sampler intake line. The field blank was collected by pouring source water directly into sample bottles while in the field. The results from the source blanks indicate that source water contains small amounts of constituents that are inconsequential compared to field values. The results from the field blank indicate that ambient conditions also are likely to introduce only inconsequential amounts of constituents into sample results. The results from the equipment blank suggest that sampler intake lines could introduce as much as 25 mg/L of total zinc into sample results; these results will be discussed in the context of the stormwater sample matrix in the “Summary of Stormwater Quality” section.

Evaluation of Sampling Methods

Fourteen paired-stormwater samples were collected to help evaluate if water obtained from a fixed sampling point in the stream cross section is representative of water in the entire cross section. Each pair of samples consisted of a sample collected using cross-section and depth-integrating methods (Edwards and Glysson, 1999) and a sample collected using the automatic pumping sampler to withdraw water from the fixed-point sampling location. Characteristics of each station and the logistics of collecting a cross-section and depth-integrated sample are such that the time required to collect the sample varied but typically was about 30 minutes. Consequently, cross-section and depth-integrated samples may have some variation related to temporal characteristics that is not present in samples obtained using the pumping samplers.

The results from the 14 paired-stormwater samples (table 7) include RPDs computed using results from cross-section depth-integrated samples and fixed-point samples; a

Table 5. Summary statistics for relative percent differences in duplicate analyses performed at the Metro Wastewater Reclamation District Laboratory.

[RPD, relative percent difference; Stddev, standard deviation; Skew, skewness; n, number of paired samples; Ties, number of paired results with both pair members equal to or less than minimum reporting level. Freq, frequency; Pfreq, frequency as percent; Cpct, cumulative percentage]

	Mean	Median	Stddev	Skew	Minimum	Maximum	n	Ties
RPD 1999–2000	1.09	0.00	31.95	0.03	–135.48	166.10	199	26
RPD 1999	–6.16	–1.37	27.34	–1.68	–112.00	50.00	71	6
RPD 2000	0.64	0.18	27.21	–0.36	–94.74	82.35	56	7
RPD 2001	8.60	0.00	37.77	0.51	–135.48	166.10	72	13

RPD interval	RPD frequency distributions											
	Years											
	1999–2000			1999			2000			2001		
	Freq	Pfreq	Cpct	Freq	Pfreq	Cpct	Freq	Pfreq	Cpct	Freq	Pfreq	Cpct
–140 to –130	1	0.503	0.503	0	0.000	0.000	0	0.000	0.000	1	1.389	1.389
–130 to –120	0	0.000	0.503	0	0.000	0.000	0	0.000	0.000	0	0.000	1.389
–120 to –110	2	1.005	1.508	2	2.817	2.817	0	0.000	0.000	0	0.000	1.389
–110 to –100	0	0.000	1.508	0	0.000	2.817	0	0.000	0.000	0	0.000	1.389
–100 to –90	2	1.005	2.513	0	0.000	2.817	1	1.786	1.786	1	1.389	2.778
–90 to –80	0	0.000	2.513	0	0.000	2.817	0	0.000	1.786	0	0.000	2.778
–80 to –70	1	0.503	3.015	0	0.000	2.817	1	1.786	.571	0	0.000	2.778
–70 to –60	2	1.005	4.020	1	1.408	4.225	1	1.786	5.357	0	0.000	2.778
–60 to –50	3	1.508	5.528	3	4.225	8.451	0	0.000	5.357	0	0.000	2.778
–50 to –40	0	0.000	5.528	0	0.000	8.451	0	0.000	5.357	0	0.000	2.778
–40 to –30	6	3.015	8.543	5	7.042	15.493	1	1.786	7.143	0	0.000	2.778
–30 to –20	3	1.508	10.050	0	0.000	15.493	2	3.571	10.714	1	1.389	4.167
–20 to –10	16	8.040	18.090	7	9.859	25.352	4	7.143	17.857	5	6.944	11.111
–10 to 0	78	39.196	57.286	29	40.845	66.197	18	32.143	50.000	31	43.056	54.167
0 to 10	47	23.618	80.905	11	15.493	81.690	19	33.929	83.929	17	23.611	77.778
10 to 20	9	4.523	85.427	5	7.042	88.732	3	5.357	89.286	1	1.389	79.167
20 to 30	8	4.020	89.447	5	7.042	95.775	2	3.571	92.857	1	1.389	80.556
30 to 40	7	3.518	92.965	2	2.817	98.592	0	0.000	92.857	5	6.944	87.500
40 to 50	3	1.508	94.472	1	1.408	100.000	0	0.000	92.857	2	2.778	90.278
50 to 60	2	1.005	95.477	0	0.000	100.000	2	3.571	96.429	0	0.000	90.278
60 to 70	4	2.010	97.487	0	0.000	100.000	1	1.786	98.214	3	4.167	94.444
70 to 80	1	0.503	97.990	0	0.000	100.000	0	0.000	98.214	1	1.389	95.833
80 to 90	2	1.005	98.995	0	0.000	100.000	1	1.786	100.000	1	1.389	97.222
90 to 100	1	0.503	99.497	0	0.000	100.000	0	0.000	100.000	1	1.389	98.611
100 to 110	0	0.000	99.497	0	0.000	100.000	0	0.000	100.000	0	0.000	98.611
110 to 120	0	0.000	99.497	0	0.000	100.000	0	0.000	100.000	0	0.000	98.611
120 to 130	0	0.000	99.497	0	0.000	100.000	0	0.000	100.000	0	0.000	98.611
130 to 140	0	0.000	99.497	0	0.000	100.000	0	0.000	100.000	0	0.000	98.611
140 to 150	0	0.000	99.497	0	0.000	100.000	0	0.000	100.000	0	0.000	98.611
150 to 160	0	0.000	99.497	0	0.000	100.000	0	0.000	100.000	0	0.000	98.611
160 to 170	1	0.503	100.000	0	0.000	100.000	0	0.000	100.000	1	1.389	100.000
Total	199	100.000		71	100.000		56	100.000		72	100.000	

positive value indicates that values determined from cross-section and depth-integrated samples were larger compared to fixed-point samples. The RPDs were computed collectively for total and dissolved phases and also for just dissolved phases; differences between these two computations may be attributed to determinations made for the total phase.

Table 7 also includes information describing the percentage of RPD computations for the paired-stormwater samples that had an absolute value of 20 percent or less. Information about the number of pairs in which both results were reported as less than the minimum reporting level, referred to as “ties,” is presented in table 6 as well. Ties were not included in RPD computations; however, if it were assumed that ties represent cases with an RPD of (or close to) 0, then including the ties would result in a reduction in the mean RPD.

Table 7 indicates that the RPD central tendency has an absolute value of about 5 or less for Union, Denver, and Tollgate. The mean, and to a lesser extent, the median at Sand

Table 6. Blank and spiked sample results from determinations made at the Metro Wastewater Reclamation District Laboratory.

[Sample type: EB, equipment blank collected by passing certified inorganic blank water through sampler intake line at Tollgate Creek; FB, field blank collected by processing certified inorganic blank water in the field near Sand Creek at mouth; SB, source blanks collected from source of deionized water used to rinse field equipment; S, spikes from USGS Standard Reference Sample Program with a most probable value of 0.66 milligram per liter for ammonia plus organic nitrogen. Phase: W, determination made using whole water; T, total; D, dissolved; stdu, standard pH units; µS/cm, microsiemens per centimeter at 25 degrees Celsius; C, Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; --, no data]

Property or constituent	Phase	Sample type					
		EB	FB	SB	SB	S	S
pH, in stdu	W	7.10	4.80	6.30	5.80	--	--
Specific conductance, in µS/cm	W	25.2	4.00	1.07	2.52	--	--
Hardness, in mg/L	T	<10.0	<10.0	<10.0	<10.0	--	--
Residue on evaporation at 105 degrees C, in mg/L	T	3.00	<1.00	7.00	4.00	--	--
Organic carbon, in mg/L	T	<1.00	<1.00	<1.00	2.00	--	--
Ammonia, in mg/L	T	<0.20	<0.20	<0.20	<0.20	--	--
Nitrite + nitrate, in mg/L	T	<0.02	<0.02	<0.02	--	--	--
Ammonia + organic nitrogen, in mg/L	T	<0.30	--	<0.30	--	0.7	0.7
Phosphorus, in mg/L	T	<0.02	0.04	<0.02	<0.02	--	--
Orthophosphate, in mg/L	D	<0.03	<0.03	<0.03	<0.03	--	--
Copper, in µg/L	D	<1.00	1.00	1.00	<1.00	--	--
Copper, in µg/L	T	1.00	3.00	5.00	2.00	--	--
Lead, in µg/L	D	<10.0	<10.0	<10.0	<10.0	--	--
Lead, in µg/L	T	<10.0	<10.0	<10.0	<10.0	--	--
Manganese, in µg/L	D	--	--	--	<20.0	--	--
Manganese, in µg/L	T	--	--	--	<20.0	--	--
Zinc, in µg/L	D	<0.10	<0.10	0.60	<0.10	--	--
Zinc, in µg/L	T	25.7	6.00	--	1.80	--	--

Table 7. Summary of relative percent differences for pairs of cross-section depth-integrated and fixed-point samples.

[Group indicates that data represent results from all stations (All), South Platte River below Union (Union), South Platte River at Denver (Denver), Tollgate Creek above 6th Avenue (Tollgate), Sand Creek at mouth (Sand Creek), or South Platte River at Henderson (Henderson). Phase indicates total and dissolved determinations for all samples (TD) or just dissolved determinations (D); Pct, percentage of samples with a relative percent difference of 20 or less (absolute value); n, number of paired results with reported values greater than minimum reporting level and, parenthetically, number of samples; Ties, number of paired results with both pair members equal to minimum reporting level]

Group	Phase	Mean	Median	Minimum	Maximum	Standard deviation	Pct	n	Ties
All	TD	1.70	0.00	–183.23	95.91	31.87	62.85	175 (14)	68
All	D	–0.02	–1.24	–183.23	95.65	30.94	73.39	109	41
Union	TD	1.13	–2.22	–40.00	93.33	29.48	73.91	23 (2)	17
Union	D	0.08	–2.22	–40.00	72.27	24.14	80.00	15	9
Denver	TD	–3.09	–5.26	–66.67	53.36	27.27	54.84	31 (5)	10
Denver	D	–5.42	–5.26	–66.67	30.77	22.18	68.42	19	7
Tollgate	TD	–0.54	–0.62	–40.00	54.55	21.67	75.00	24 (2)	17
Tollgate	D	–5.25	–2.18	–40.00	3.08	11.26	92.86	14	11
Sand Creek	TD	19.15	13.70	–22.22	95.91	28.91	61.22	49 (3)	11
Sand Creek	D	16.15	3.02	–13.33	95.65	29.23	73.33	30	7
Henderson	TD	–11.87	–3.97	–183.23	36.36	36.09	57.45	47 (2)	13
Henderson	D	–10.04	–2.93	–183.23	36.36	40.03	64.52	31	7

Creek and Henderson indicate positive and negative biases, respectively. At Henderson, the mean RPD was influenced by a few analyses for total zinc. At most sites, about 75 percent of the paired analyses had RPDs with an absolute value of 20 or less (table 7). In general, the tendency for results that include total determinations to lower the amount of the RPD distribution with an absolute value of 20 or less indicates that departures between cross-section depth-integrated samples were elevated for total determinations compared to dissolved determinations (table 7).

Summary of Stormwater Quality

The results of stormwater sample-collection activities and chemical analyses of stormwater samples are summarized in this section. Descriptions of composite-sample-collection activities characterize sampled storms and describe the number of samples collected. Summary statistics for the results of chemical analyses of composite samples describe results collectively, by station, and by hydrograph classification. Stormwater sample-collection activities and chemical analyses associated with discrete samples also are discussed in this section. In addition, results from composite samples collected in this study are referred to as contemporary and are compared to historical data representing base flow and to numeric standards established by the CDPHE.

Composite and Bacteriological Samples

A summary describing streamflow associated with composite-sample collection is presented in table 8, and hydrographs for each station indicate sampled storms (fig. 2). Table 8 includes data for the streamflow volume, mean streamflow, and duration (length of time) associated with individual composite samples. The data are presented for composite samples from all stations pooled together and for individual stations; a listing of similar, but more detailed, information by sample is included in the Appendix (table A1). The summary in table 8 is further subdivided on the basis of stormwater-runoff hydrograph classification. Samples were classified as associated with the rising or falling portion of the hydrograph, or a hydrograph that represented an entire event. The event hydrograph classification includes both rising and falling portions of the stormwater-runoff hydrograph and may only represent a portion of the stormwater-runoff hydrograph for multiday or peak events. Table 8 also includes results for a few storms that could not be classified due to a lack of streamflow information. Additional details of the classification procedure and example hydrographs from all stations (fig. A1) are presented in the “Hydrograph Classification” section of the Appendix.

A total of 255 composite samples were collected; 13 of the samples, mostly from Tollgate, had no associated streamflow measurements and are characterized as unclassified. About 50 or more samples were collected at each station except Tollgate, which due to the relatively small drainage area is not affected by as many storms as the other four stations and only 35 samples were collected. Overall, and at most stations, samples were most commonly classified as event hydrographs that include rising and falling portions of hydrographs, followed by falling hydrographs and then rising hydrographs; an exception is Tollgate where almost one-third of all samples were unclassified. In most cases, for individual stations, the overall percent difference between mean streamflow associated with composite samples classified as rising, falling, and event were less than 35 percent, and there were not large differences in mean streamflow for different portions of the storm hydrographs. The mean streamflow associated with composite samples at Sand Creek is about eight times the median of measured flow that is sometimes added to Sand Creek described in the “Methods of Study” section.

The results of chemical analyses of composite samples performed at MWRD are summarized in table 9 and figure 3. The results are presented for all stations pooled together, by individual station, and by hydrograph classification. The summary includes the number of samples and the number of missing values for mean streamflow, streamflow volume, and water-quality properties or constituents. For mean streamflow and streamflow volume, the number of missing values indicates the number of samples that have no associated streamflow information. For water-quality properties and constituents, the number of missing values indicates the number of analyses that were not performed. In addition to statistics for values above censoring limits, table 9 also reports the percentage of samples that had censored values, or undetectable concentrations somewhere between zero and the minimum reporting level. The minimum reporting level was not always constant and is summarized with a mean and median. Concentrations for constituents and properties generally had few censored values except for ammonia and dissolved and total lead, which typically had 60 percent or more censored values.

The results in table 9 can be compared to results from equipment, field, and source blanks (table 6) to help determine what effects sampling equipment or ambient conditions may have had on composite results. Results for an equipment blank indicate a total zinc concentration of 25.7 μg/L. Although the concentration in the equipment blank is low compared to most composite-sample results for total zinc, it is possible that total zinc results may be biased somewhat high. Readers also may wish to consider the results of laboratory performance results when reviewing table 9. The results of laboratory performance evaluations indicate that about 80 percent of results can be expected to have an RPD with an absolute value of 20 or less; however, the RPD is likely to be larger than 20 for some results.

The results from chemical analyses of composite samples indicate an important spatial trend. In general and particularly for nutrients, concentration increases downstream in the receiving stream (table 9). For example, the mean concentration of all samples regardless of hydrograph position for nitrite plus nitrate is 0.57 mg/L at Union, 2.09 mg/L at Denver, and 2.17 mg/L at Henderson. This pattern correlates with local contributing drainage area (table 1). Land-cover data (table 1) indicate that the percentage of agricultural land in the local contributing drainage area also increases in downstream direction; the percentage of urban land cover, however, does not. For most water-quality properties and constituents, values measured in the tributary streams are higher compared to values measured in the receiving streams (table 9); however, tributary concentrations do not appear to increase downstream.

Table 8. Streamflow volume, mean streamflow, and duration statistics for composite samples.

[Pooled, all samples for given group; q, mean streamflow in cubic feet per second; v, volume in acre-feet; t, time in decimal days; U, unclassified, in some cases no discharge information for the storm was available and the hydrograph could not be characterized; Stddev, standard deviation, Skew, skewness; Min, minimum; Max, maximum; n, number of samples; na, not applicable]

	All stations												
	Pooled			Rising hydrograph			Falling hydrograph			Event hydrograph			U
	q	v	t	q	v	t	q	v	t	q	v	t	t
Mean	895	806	0.45	1,000	897	0.46	851	753	0.45	865	798	0.45	0.47
Median	533	479	0.44	419	423	0.44	558	469	0.44	591	551	0.43	0.44
Stddev	1,080	965	0.15	1,460	1,190	0.15	970	920	0.17	875	833	0.13	0.17
Skew	2.60	2.24	1.83	2.55	2.24	1.83	2.12	2.15	1.55	1.71	1.78	2.39	1.00
Min	7.00	5.00	0.05	7.00	6.00	0.05	11.0	5.00	0.06	16.00	7.00	0.17	0.22
Max	7,130	6,080	1.00	7,130	6,080	1.00	4,960	4,510	1.00	4,100	3,730	1.00	0.88
n	242	242	255	62	62	62	95	95	95	85	85	85	13
South Platte River below Union Avenue													
Mean	388	364	0.47	309	308	0.46	410	375	0.47	423	393	0.47	na
Median	330	330	0.44	217	237	0.44	351	395	0.44	455	408	0.44	na
Stddev	235	205	0.12	252	223	0.10	201	166	0.15	249	223	0.12	na
Skew	0.59	0.34	3.05	1.17	0.71	2.64	0.15	–0.12	2.90	0.46	0.27	2.70	na
Min	76.0	68.0	0.31	76.0	68	0.39	92.0	83.0	0.31	84.0	121	0.37	na
Max	949	780	1.00	893	747	0.80	721	648	1.00	949	780	0.93	na
n	49	49	49	13	13	13	16	16	16	20	20	20	0
South Platte River at Denver													
Mean	945	835	0.46	999	877	0.41	792	720	0.50	1,080	934	0.45	na
Median	727	609	0.44	735	596	0.43	623	538	0.46	992	780	0.44	na
Stddev	737	638	0.13	890	764	0.11	531	498	0.15	818	691	0.11	na
Skew	1.94	1.65	1.79	1.39	1.16	–2.20	1.42	1.30	2.18	1.96	1.76	2.51	na
Min	201	173	0.05	281	247	0.05	289	215	0.31	201	173	0.28	na
Max	3,908	3,240	0.99	3,370	2,630	0.53	2,275	2,070	0.99	3,910	3,240	0.86	na
n	58	58	59	15	15	15	23	23	23	20	20	20	1
Tollgate Creek above 6th Avenue													
Mean	125	110	0.46	259	211	0.44	95.5	96.8	0.50	85.4	65.1	0.38	0.50
Median	45	44.0	0.44	118	117	0.45	44.0	45.5	0.44	48.5	42.0	0.42	0.47
Stddev	192	159	0.16	326	244	0.04	167	157	0.20	77.3	63.0	0.10	0.18
Skew	2.29	2.00	1.40	0.67	0.51	–0.51	2.47	2.11	1.12	0.8	1.27	–0.85	0.73
Min	7.00	5.00	0.20	7.00	6.00	0.38	11.0	5.00	0.22	16.0	7.00	0.20	0.22
Max	785	583	0.92	785	583	0.47	616	560	0.92	230	207	0.47	0.88
n	25	25	35	5	5	5	12	12	12	8	8	8	10
Sand Creek at mouth													
Mean	380	367	0.45	243	243	0.49	354	348	0.44	498	471	0.44	0.34
Median	185	165	0.43	173	154	0.44	165	142	0.43	342	273	0.43	0.34
Stddev	428	415	0.15	226	233	0.17	486	481	0.15	464	440	0.15	0.05
Skew	2.54	2.07	2.47	1.91	1.37	1.81	2.64	2.14	2.83	1.85	1.45	2.39	0.00
Min	45.0	41.0	0.17	45.0	41.0	0.31	81.0	60.0	0.30	101	91.0	0.17	0.31
Max	2,110	1,930	1.00	924	840	0.99	2,110	1,930	0.99	2,060	1,820	1.00	0.38
n	52	52	54	14	14	14	18	18	18	20	20	20	2
South Platte River at Henderson													
Mean	2,070	1,840	0.43	2,570	2,270	0.48	1,870	1,600	0.38	1,930	1,847	0.47	na
Median	1,590	1,450	0.44	1,730	2,140	0.44	1,430	1,230	0.44	1,630	1,490	0.44	na
Stddev	1,440	1,290	0.19	2,110	1,580	0.22	1,200	1,270	0.18	952	993	0.16	na
Skew	1.60	0.97	1.35	1.03	0.88	1.43	1.20	0.82	0.99	0.63	0.61	2.14	na
Min	394	152	0.06	394	584	0.21	636	152	0.06	735	744	0.33	na
Max	7,130	6,080	1.00	7,130	6,080	1.00	4,960	4,510	1.00	4,100	3,730	0.99	na
n	58	58	58	15	15	15	26	26	26	17	17	17	0

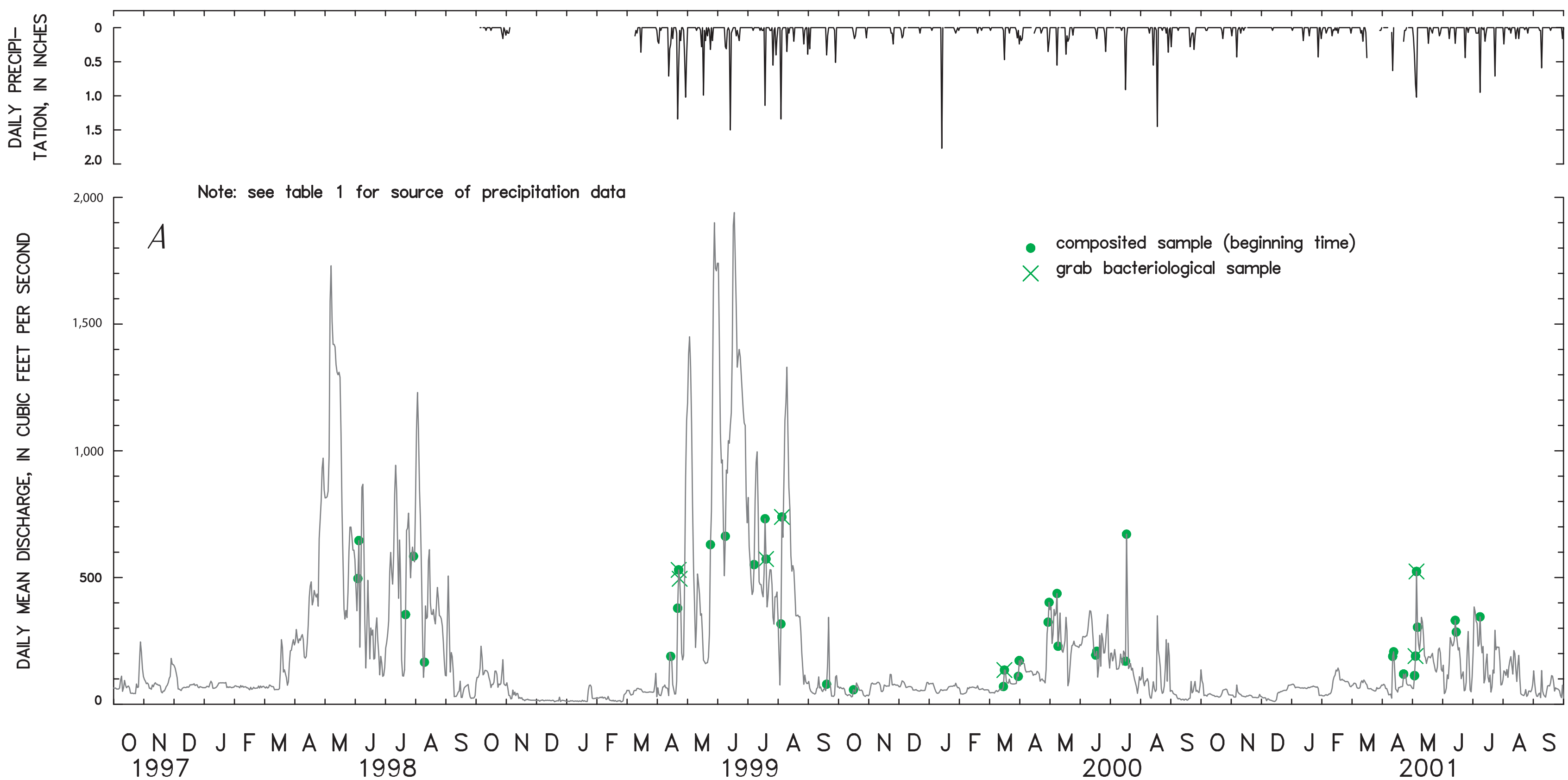

Figure 2. Daily values for streamflow and precipitation at (*A*) South Platte River below Union Avenue, (*B*) South Platte River at Denver, (*C*) Tollgate Creek above 6th Avenue, (*D*) Sand Creek at mouth, and (*E*) South Platte River near Henderson.

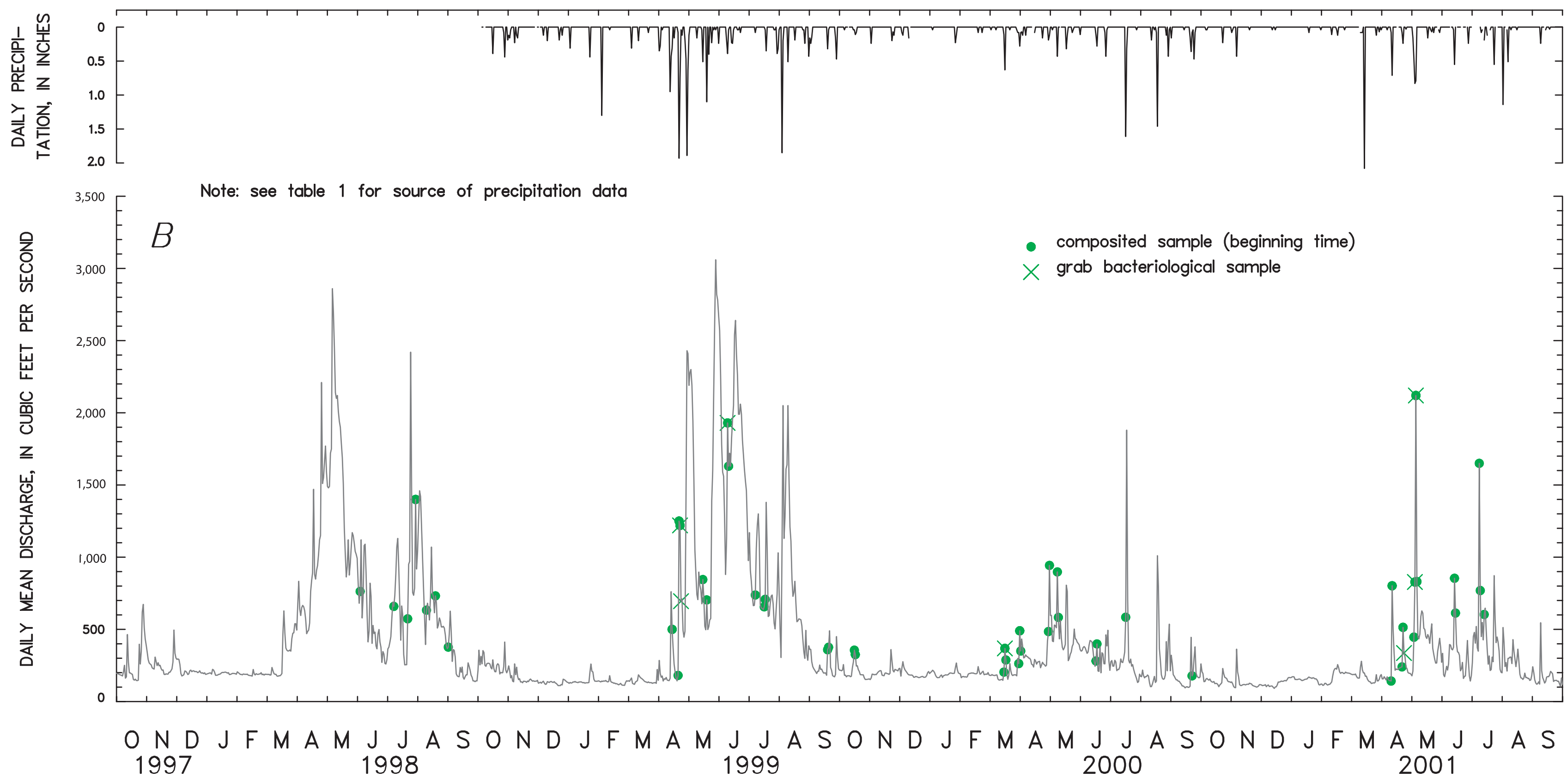

Figure 2. Daily values for streamflow and precipitation at (*A*) South Platte River below Union Avenue, (*B*) South Platte River at Denver, (*C*) Tollgate Creek above 6th Avenue, (*D*) Sand Creek at mouth, and (*E*) South Platte River near Henderson.—Continued

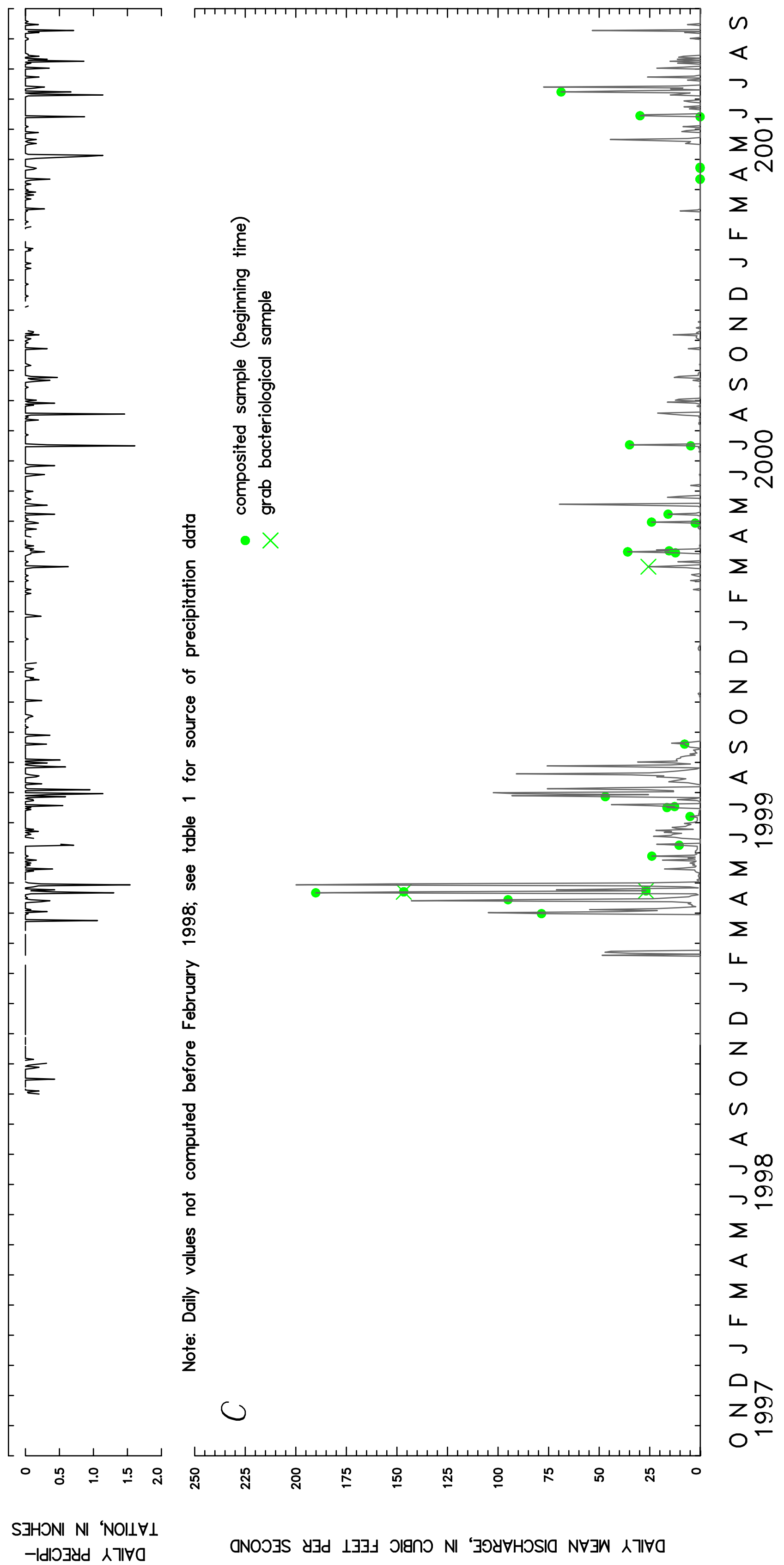

Figure 2. Daily values for streamflow and precipitation at (*A*) South Platte River below Union Avenue, (*B*) South Platte River at Denver, (*C*) Tollgate Creek above 6th Avenue, (*D*) Sand Creek at mouth, and (*E*) South Platte River near Henderson.—Continued

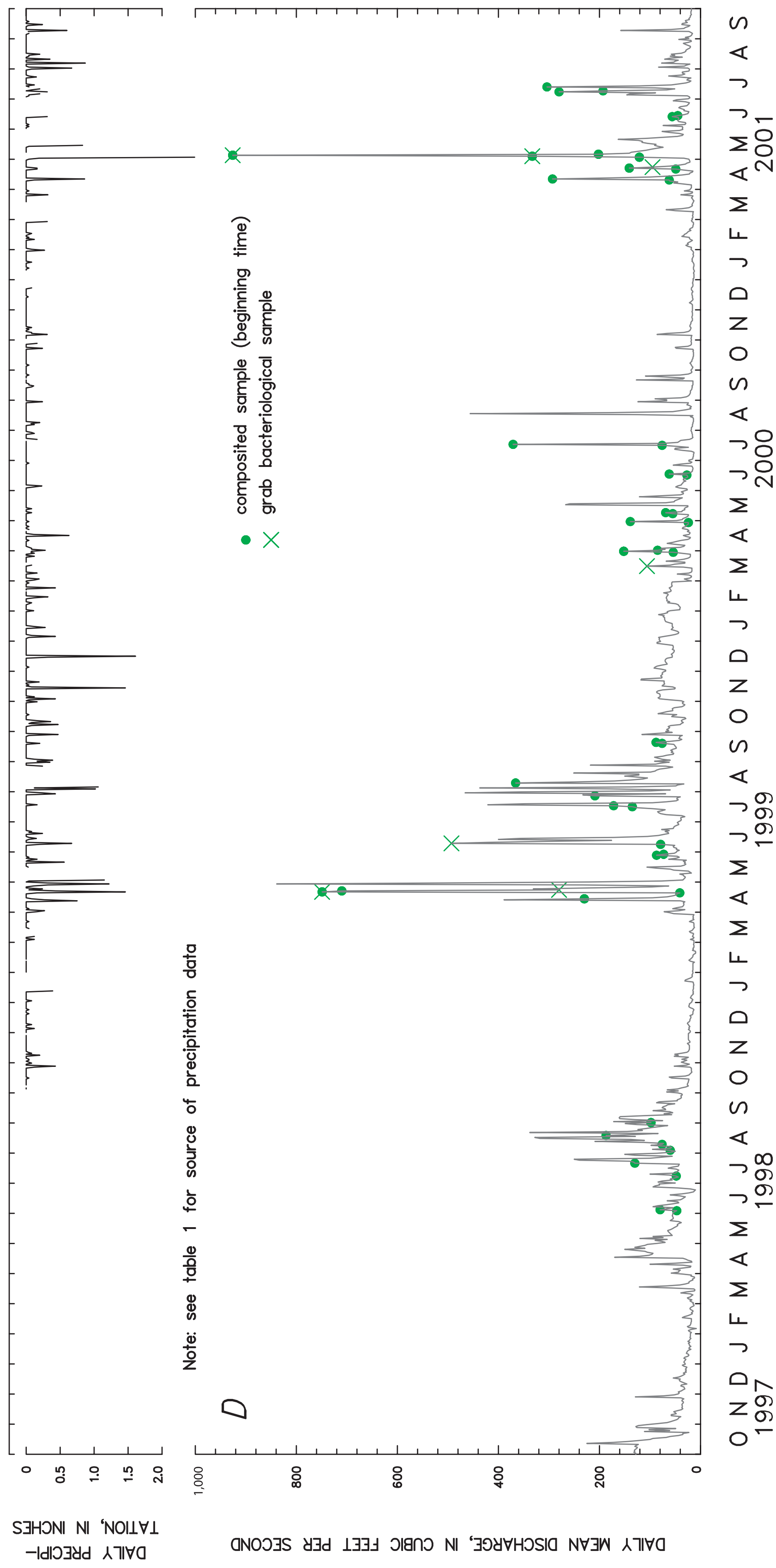

Figure 2. Daily values for streamflow and precipitation at (*A*) South Platte River below Union Avenue, (*B*) South Platte River at Denver, (*C*) Tollgate Creek above 6th Avenue, (*D*) Sand Creek at mouth, and (*E*) South Platte River near Henderson.—Continued

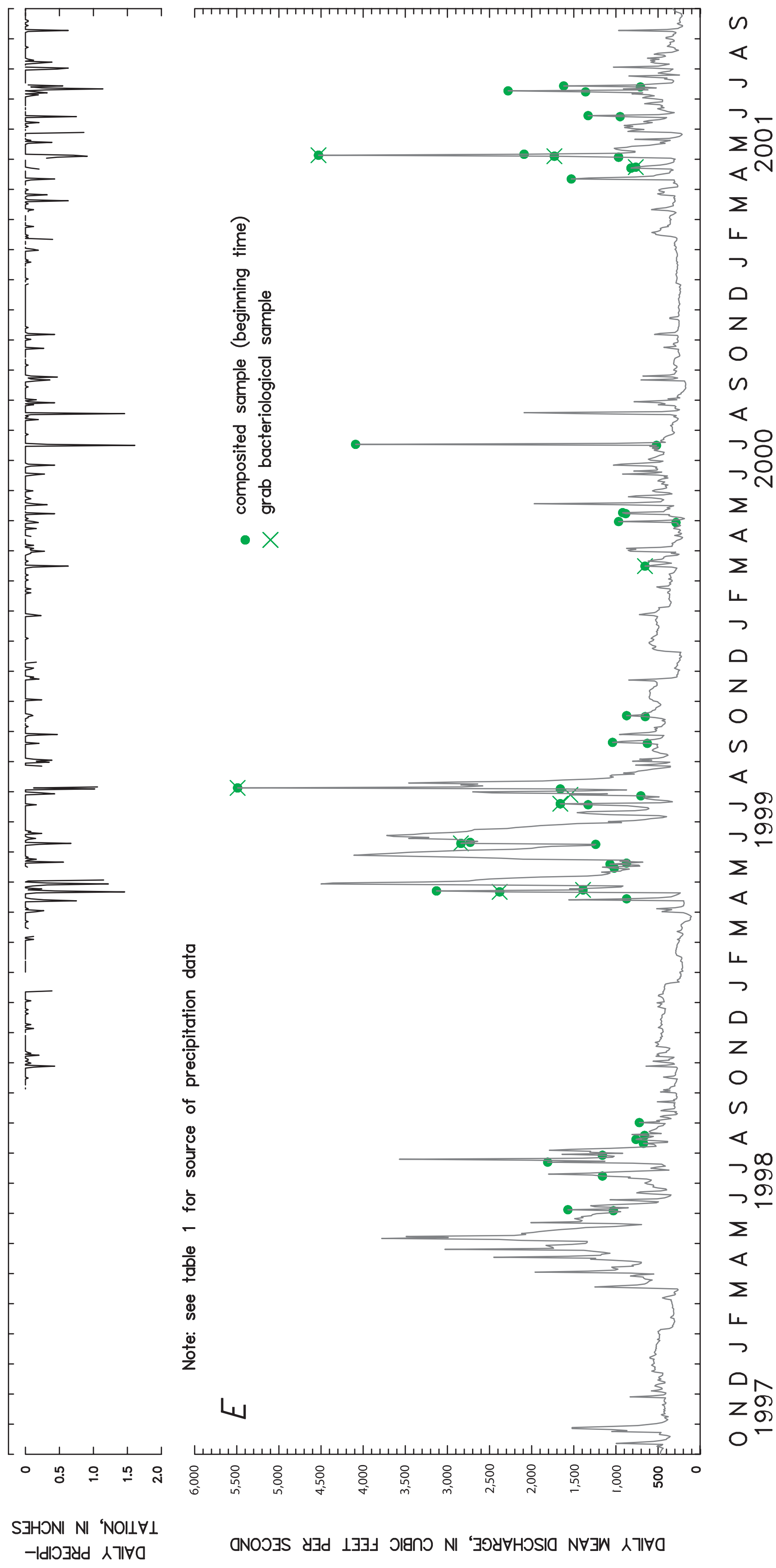

Figure 2. Daily values for streamflow and precipitation at (*A*) South Platte River below Union Avenue, (*B*) South Platte River at Denver, (*C*) Tollgate Creek above 6th Avenue, (*D*) Sand Creek at mouth, and (*E*) South Platte River near Henderson.—Continued

Table 9. Summary statistics for water-quality properties and constituents from composite and bacteriological samples at (A) all stations, (B) South Platte River below Union Avenue, (C) South Platte River at Denver, (D) Tollgate Creek above 6th Avenue, (E) Sand Creek at mouth, and (F) South Platte River at Henderson.

[Phase: W, determination made using whole water; T, total; D, dissolved. Typ: a, all samples regardless of hydrograph position; r, sample from rising limb portion of hydrograph; f, sample from falling limb portion of hydrograph; e, sample from rising and falling limbs of hydrograph; u, unclassified. n, number of samples; M, number of samples with missing values; Pct, percentage of samples below minimum reporting level; Stddev, standard deviation; Skew, skewness; Min, minimum; Max, maximum; ft³/s, cubic feet per second; µS/cm, microsiemens per centimeter at 25 degrees Celsius; C, Celsius; mg/L, milligrams per liter; col, colonies per 100 milliliters; µg/L, micrograms per liter; na, not applicable]

Property or constituent	Phase	Typ	n	M	Pct	Mean	Median	Stddev	Skew	Min	Max	Minimum reporting level	
												Mean	Median
(A) All stations													
Mean discharge, in ft³/s	na	a	242	13	0.00	895	533	1,080	2.60	7.00	7,130	na	na
		r	62	0	0.00	1000	420	1,460	2.59	7.00	7,130	na	na
		f	95	0	0.00	851	558	970	2.12	11.0	4,960	na	na
		e	85	0	0.00	865	591	875	1.71	16.0	4,100	na	na
		u	13	13	na	na	na	na	na	na	na	na	na
Discharge volume, in acre-feet	na	a	242	13	0.00	806	479	965	2.24	5.00	6,080	na	na
		r	62	0	0.00	897	423	1,190	2.24	6.00	6,080	na	na
		f	95	0	0.00	753	469	920	2.15	5.00	4,510	na	na
		e	85	0	0.00	798	551	833	1.78	7.00	3,730	na	na
		u	13	13	na	na	na	na	na	na	na	na	na
pH, in standard pH units	W	a	249	6	0.00	7.41	7.40	0.25	–0.13	6.70	7.90	na	na
		r	61	1	0.00	7.41	7.40	0.21	–0.52	6.80	7.90	na	na
		f	95	2	0.00	7.47	7.50	0.24	–0.11	6.90	7.90	na	na
		e	83	3	0.00	7.33	7.30	0.27	0.13	6.70	7.90	na	na
		u	10	0	0.00	7.42	7.45	0.22	0.11	7.10	7.80	na	na
Specific conductance, in µS/cm	W	a	255	0	0.00	623	578	246	1.24	255	1,940	na	na
		r	62	0	0.00	649	620	295	1.45	260	1,940	na	na
		f	97	0	0.00	613	565	226	1.20	287	1,440	na	na
		e	86	0	0.00	600	539	233	0.91	255	1,320	na	na
		u	10	0	0.00	752	778	161	–0.20	487	951	na	na
Hardness, in mg/L	T	a	255	0	0.00	198	189	63.0	1.72	89	608	na	na
		r	62	0	0.00	203	191	79.3	2.24	100	608	na	na
		f	97	0	0.00	191	182	53.1	1.43	97	451	na	na
		e	86	0	0.00	197	187	61.4	0.92	89	410	na	na
		u	10	0	0.00	241	247	33.0	0.05	190	300	na	na
Residue on evaporation at 105 degrees C, in mg/L	T	a	251	4	0.00	545	330	596	2.53	8.00	3,890	na	na
		r	62	0	0.00	408	219	438	2.20	12.0	2,420	na	na
		f	94	3	0.00	474	257	556	3.32	11.0	3,890	na	na
		e	86	0	0.00	709	445	690	1.98	8.00	3,560	na	na
		u	9	1	0.00	668	322	693	1.10	73.0	2,210	na	na
Organic carbon, in mg/L	T	a	205	50	0.00	12.0	11.0	5.05	1.85	6.00	40.0	na	na
		r	54	8	0.00	12.3	11.5	4.59	0.90	6.00	26.0	na	na
		f	78	19	0.00	10.3	10.0	3.34	1.10	6.00	21.0	na	na
		e	65	21	0.00	13.7	12.0	6.57	1.61	6.00	40.0	na	na
		u	8	2	0.00	11.7	12.0	2.55	0.11	8.00	16.0	na	na
Escherichia coli, in col	W	a	34	0	0.00	2,900	2,000	2,500	0.71	170	7,900	na	na
		r	16	0	0.00	2,850	2,000	2,300	0.80	170	7,900	na	na
		f	18	0	0.00	2,950	2,150	2,730	0.59	330	7,900	na	na
Fecal coliform, in col	W	a	34	0	0.00	5,490	3,300	7,400	2.38	330	35,000	na	na
		r	16	0	0.00	5,050	3,300	5,850	2.06	330	24,000	na	na
		f	18	0	0.00	5,880	3,300	8,710	2.13	330	35,000	na	na
Ammonia, in mg/L	T	a	255	0	62.75	0.89	0.70	0.72	1.39	0.20	3.20	0.26	0.20
		r	62	0	62.90	1.09	0.80	0.93	1.18	0.30	3.20	0.20	0.20
		f	97	0	64.95	0.81	0.70	0.56	1.07	0.20	2.40	0.36	0.20
		e	86	0	58.14	0.83	0.45	0.70	1.18	0.20	2.60	0.20	0.20
		u	10	0	80.00	1.20	1.20	0.85	0.00	0.60	1.80	0.20	0.20
Nitrite + nitrate, in mg/L	T	a	185	70	0.54	1.35	1.04	1.00	1.65	0.05	6.51	0.02	0.02
		r	41	21	2.44	1.63	1.27	1.11	1.18	0.13	4.87	0.02	0.02
		f	69	28	0.00	1.34	1.04	0.86	0.76	0.05	4.03	na	na
		e	69	17	0.00	1.26	0.92	1.07	2.24	0.18	6.51	na	na
		u	6	4	0.00	0.73	0.69	0.10	0.79	0.64	0.90	na	na

Table 9. Summary statistics for water-quality properties and constituents from composite and bacteriological samples at (A) all stations, (B) South Platte River below Union Avenue, (C) South Platte River at Denver, (D) Tollgate Creek above 6th Avenue, (E) Sand Creek at mouth, and (F) South Platte River at Henderson.—Continued

[Phase: W, determination made using whole water; T, total; D, dissolved. Typ: a, all samples regardless of hydrograph position; r, sample from rising limb portion of hydrograph; f, sample from falling limb portion of hydrograph; e, sample from rising and falling limbs of hydrograph; u, unclassified. n, number of samples; M, number of samples with missing values; Pct, percentage of samples below minimum reporting level; Stddev, standard deviation; Skew, skewness; Min, minimum; Max, maximum; ft³/s, cubic feet per second; µS/cm, microsiemens per centimeter at 25 degrees Celsius; C, Celsius; mg/L, milligrams per liter; col, colonies per 100 milliliters; µg/L, micrograms per liter; na, not applicable]

Property or constituent	Phase	Typ	n	M	Pct	Mean	Median	Stddev	Skew	Min	Max	Minimum reporting level	
												Mean	Median
(A) All stations—Continued													
Ammonia + organic nitrogen, in mg/L	T	a	255	0	3.92	2.59	2.00	1.78	1.65	0.30	12.0	1.27	0.30
		r	62	0	4.84	2.71	2.10	1.88	1.52	0.50	9.60	3.53	0.30
		f	97	0	3.09	2.31	1.80	1.66	1.51	0.40	8.40	0.30	0.30
		e	86	0	4.65	2.89	2.65	1.86	1.76	0.30	12.0	0.30	0.30
		u	10	0	0.00	2.07	1.65	1.21	1.40	1.00	5.10	na	na
Phosphorus, in mg/L	T	a	255	0	0.00	0.69	0.57	0.49	1.48	0.03	3.17	na	na
		r	62	0	0.00	0.69	0.54	0.51	1.40	0.04	2.69	na	na
		f	97	0	0.00	0.62	0.49	0.44	1.56	0.03	.54	na	na
		e	86	0	0.00	0.79	0.71	0.53	1.36	0.03	3.17	na	na
		u	10	0	0.00	0.64	0.52	0.44	1.24	0.17	1.70	na	na
Orthophosphate, in mg/L	D	a	248	7	6.85	0.25	0.19	0.17	1.23	0.03	0.80	0.03	0.03
		r	59	3	3.39	0.27	0.22	0.19	1.23	0.05	0.78	0.03	0.03
		f	94	3	5.32	0.23	0.20	0.14	1.11	0.03	0.75	0.03	0.03
		e	85	1	7.06	0.26	0.19	0.18	0.98	0.03	0.80	0.03	0.03
		u	10	0	40.00	0.12	0.12	0.03	0.90	0.10	0.17	0.03	0.03
Copper, in µg/L	D	a	255	0	2.75	7.83	5.00	7.54	2.86	1.00	60.0	1.00	1.00
		r	62	0	3.23	7.67	6.00	7.13	2.59	1.00	44.0	1.00	1.00
		f	97	0	2.06	7.79	5.00	8.61	3.13	1.00	60.0	1.00	1.00
		e	86	0	3.49	7.73	6.00	5.89	1.59	1.00	31.0	1.00	1.00
		u	10	0	0.00	9.90	4.50	11.5	1.75	4.00	40.0	na	na
Copper, µg/L	T	a	253	2	0.40	23.5	16.0	19.8	1.55	1.00	104	1.00	1.00
		r	61	1	0.00	23.5	16.0	19.3	1.24	2.00	84.0	na	na
		f	96	1	1.04	21.3	14.0	18.9	1.68	1.00	86.0	1.00	1.00
		e	86	0	0.00	26.6	21.0	21.2	1.52	3.00	104	na	na
		u	10	0	0.00	18.3	13.0	16.1	1.47	4.00	59.0	na	na
Lead, in µg/L	D	a	255	0	82.7	17.0	14.0	9.58	1.92	1.00	51.0	10.0	10.0
		r	62	0	85.5	17.7	14.0	9.70	1.12	10.0	39.0	10.0	10.0
		f	97	0	86.6	20.1	14.0	13.4	1.45	10.0	51.0	10.0	10.0
		e	86	0	75.6	14.1	14.0	5.20	0.06	1.00	27.0	10.0	10.0
		u	10	0	90.0	31.0	31.0	na	na	31.0	31.0	10.0	10.0
Lead, in µg/L	T	a	251	4	44.6	33.0	25.0	22.4	1.46	10.0	121	10.0	10.0
		r	59	3	50.8	34.5	27.0	22.3	1.47	10.0	110	10.0	10.0
		f	96	1	52.1	32.1	25.0	22.1	1.03	10.0	94.0	10.0	10.0
		e	86	0	30.2	33.4	23.5	23.7	1.60	10.0	121	10.0	10.0
		u	10	0	60.0	27.5	27.5	10.8	0.00	15.0	40.0	10.0	10.0
Manganese, in µg/L	D	a	150	105	6.00	199	120	221	2.88	20.0	1,500	20.0	20.0
		r	35	27	2.86	170	120	133	0.93	20.0	510	20.0	20.0
		f	60	37	6.67	181	115	221	2.72	20.0	1,210	20.0	20.0
		e	49	37	8.16	220	150	198	1.63	20.0	920	20.0	20.0
		u	6	4	0.00	377	125	563	1.23	60.0	1,500	na	na
Manganese, in µg/L	T	a	86	169	0.00	489	370	385	1.93	80.0	2,130	na	na
		r	26	36	0.00	382	355	188	0.53	80.0	790	na	na
		f	33	64	0.00	460	310	411	2.44	100	2,130	na	na
		e	23	63	0.00	653	480	469	0.82	100	1,740	na	na
		u	4	6	0.00	482	330	429	0.64	160	1,110	na	na
Zinc, in µg/L	D	a	254	1	5.91	78.4	49.4	124	7.01	2.20	1,490	16.0	20.0
		r	61	1	4.92	119.9	62.5	216	4.68	6.60	1,490	6.7	0.10
		f	97	0	7.22	62.2	40.5	76.8	3.59	2.20	559	17.2	20.0
		e	86	0	5.81	70.8	54.4	65.38	2.15	6.70	380	20.0	20.0
		u	10	0	0.00	44.9	20.4	49.95	1.01	6.70	146	na	na
Zinc, in µg/L	T	a	253	2	2.37	191.71	140.00	180.68	2.45	8.00	1,500	13.4	20.0
		r	60	2	3.33	247.60	174.50	254.86	2.34	9.20	1,500	10.1	10.1
		f	97	0	2.06	151.61	110.00	129.82	1.71	8.00	739	10.1	10.1
		e	86	0	2.33	204.64	150.00	164.87	1.19	13.8	687	20.0	20.0
		u	10	0	0.00	139.76	107.00	111.89	0.97	22.3	360	na	na

Table 9. Summary statistics for water-quality properties and constituents from composite and bacteriological samples at (A) all stations, (B) South Platte River below Union Avenue, (C) South Platte River at Denver, (D) Tollgate Creek above 6th Avenue, (E) Sand Creek at mouth, and (F) South Platte River at Henderson.—Continued

[Phase: W, determination made using whole water; T, total; D, dissolved. Typ: a, all samples regardless of hydrograph position; r, sample from rising limb portion of hydrograph; f, sample from falling limb portion of hydrograph; e, sample from rising and falling limbs of hydrograph; u, unclassified. n, number of samples; M, number of samples with missing values; Pct, percentage of samples below minimum reporting level; Stddev, standard deviation; Skew, skewness; Min, minimum; Max, maximum; ft^3/s, cubic feet per second; µS/cm, microsiemens per centimeter at 25 degrees Celsius; C, Celsius; mg/L, milligrams per liter; col, colonies per 100 milliliters; µg/L, micrograms per liter; na, not applicable]

Property or constituent	Phase	Typ	n	M	Pct	Mean	Median	Stddev	Skew	Min	Max	Minimum reporting level	
												Mean	Median
(B) South Platte River below Union Avenue (06710247)													
Mean discharge, in ft^3/s	na	a	49	0	0.00	388	330	235	0.59	76.0	949	na	na
		r	13	0	0.00	309	217	252	1.17	76.0	893	na	na
		f	16	0	0.00	409	351	201	0.15	92.0	721	na	na
		e	20	0	0.00	423	455	249	0.46	84.0	949	na	na
		u	0	0	na	na	na	na	na	na	na	na	na
Discharge volume, in acre-feet	na	a	49	0	0.00	364	330	205	0.34	68.0	780	na	na
		r	13	0	0.00	308	237	224	0.71	68.0	747	na	na
		f	16	0	0.00	375	395	166	–0.12	83.0	648	na	na
		e	20	0	0.00	393	408	223	0.27	121	780	na	na
		u	0	0	na	na	na	na	na	na	na	na	na
pH, in standard pH units	W	a	48	1	0.00	7.45	7.50	0.29	–0.52	6.70	7.90	na	na
		r	12	1	0.00	7.39	7.40	0.22	–1.33	6.80	7.70	na	na
		f	16	0	0.00	7.59	7.70	0.29	–0.80	7.00	7.90	na	na
		e	20	0	0.00	7.38	7.40	0.31	–0.39	6.70	7.80	na	na
		u	0	na	na	na	na	na	na	na	na	na	na
Specific conductance, in µS/cm	W	a	49	0	0.00	436	417	121	0.60	255	791	na	na
		r	13	0	0.00	446	441	125	0.09	260	660	na	na
		f	16	0	0.00	424	421	99.6	0.21	287	612	na	na
		e	20	0	0.00	440	406	137	0.81	255	791	na	na
		u	0	na	na	na	na	na	na	na	na	na	na
Hardness, in mg/L	T	a	49	0	0.00	160	156	38.0	0.73	89.0	283	na	na
		r	13	0	0.00	161	160	34.9	0.32	110	236	na	na
		f	16	0	0.00	151	149	27.0	–0.21	97.0	192	na	na
		e	20	0	0.00	166	156	46.9	0.64	89.0	283	na	na
		u	0	na	na	na	na	na	na	na	na	na	na
Residue on evaporation at 105 degrees C, in mg/L	T	a	48	1	0.00	299	185	362	2.02	8.00	1,450	na	na
		r	13	0	0.00	197	120	207	1.56	24.0	772	na	na
		f	15	1	0.00	256	113	328	1.77	11.0	1170	na	na
		e	20	0	0.00	397	272	447	1.53	8.00	1,450	na	na
		u	0	na	na	na	na	na	na	na	na	na	na
Organic carbon, in mg/L	T	a	42	7	0.00	8.93	8.00	2.57	0.69	6.00	15.0	na	na
		r	12	1	0.00	8.83	8.00	2.17	0.64	6.00	13.0	na	na
		f	13	3	0.00	7.31	7.00	1.38	0.55	6.00	10.0	na	na
		e	17	3	0.00	10.2	10.0	2.88	0.04	6.00	15.0	na	na
		u	0	na	na	na	na	na	na	na	na	na	na
Escherichia coli, in col	W	a	7	0	0.00	2,610	3,000	1,500	–0.04	500	4,900	na	na
		r	4	0	0.00	3,370	3,150	1,199	0.42	2,300	4,900	na	na
		f	3	0	0.00	1,600	1,000	1,490	0.34	500	3,300	na	na
Fecal coliform, in col	W	a	7	0	0.00	7,410	4,900	7,980	1.15	500	24,000	na	na
		r	4	0	0.00	928	4,900	9,850	0.74	3,300	24,000	na	na
		f	3	0	0.00	4,930	3,300	5,440	0.27	500	11,000	na	na
Ammonia, in mg/L	T	a	49	0	95.92	0.25	0.25	0.07	0.00	0.20	0.30	0.20	0.20
		r	13	0	100.00	na	na	na	na	na	na	0.20	0.20
		f	16	0	93.75	0.20	0.20	na	na	0.20	0.20	0.20	0.20
		e	20	0	95.00	0.30	0.30	na	na	0.30	0.30	0.20	0.20
		u	0	na	na	na	na	na	na	na	na	na	na
Nitrite + nitrate, in mg/L	T	a	35	14	0.00	0.57	0.54	0.37	1.37	0.05	1.84	na	na
		r	7	6	0.00	0.70	0.54	0.55	1.07	0.13	1.84	na	na
		f	10	6	0.00	0.43	0.38	0.24	0.49	0.05	0.93	na	na
		e	18	2	0.00	0.61	0.57	0.34	0.64	0.18	1.30	na	na
		u	0	na	na	na	na	na	na	na	na	na	na

Table 9. Summary statistics for water-quality properties and constituents from composite and bacteriological samples at (A) all stations, (B) South Platte River below Union Avenue, (C) South Platte River at Denver, (D) Tollgate Creek above 6th Avenue, (E) Sand Creek at mouth, and (F) South Platte River at Henderson.—Continued

[Phase: W, determination made using whole water; T, total; D, dissolved. Typ: a, all samples regardless of hydrograph position; r, sample from rising limb portion of hydrograph; f, sample from falling limb portion of hydrograph; e, sample from rising and falling limbs of hydrograph; u, unclassified. n, number of samples; M, number of samples with missing values; Pct, percentage of samples below minimum reporting level; Stddev, standard deviation; Skew, skewness; Min, minimum; Max, maximum; ft^3/s, cubic feet per second; µS/cm, microsiemens per centimeter at 25 degrees Celsius; C, Celsius; mg/L, milligrams per liter; col, colonies per 100 milliliters; µg/L, micrograms per liter; na, not applicable]

Property or constituent	Phase	Typ	n	M	Pct	Mean	Median	Stddev	Skew	Min	Max	Minimum reporting level	
												Mean	Median
(B) South Platte River below Union Avenue (06710247)—Continued													
Ammonia + organic nitrogen, in mg/L	T	a	49	0	8.16	1.53	1.20	1.23	1.73	0.30	5.80	0.30	0.30
		r	13	0	0.00	1.45	1.30	1.00	1.47	0.50	4.20	na	na
		f	16	0	6.25	0.96	0.80	0.49	1.34	0.50	2.30	0.30	0.30
		e	20	0	15.00	2.11	1.60	1.59	0.91	0.30	5.80	0.30	0.30
		u	0	na	na	na	na	na	na	na	na	na	na
Phosphorus, in mg/L	T	a	49	0	0.00	0.32	0.25	0.35	2.43	0.03	1.73	na	na
		r	13	0	0.00	0.23	0.20	0.19	1.25	0.04	0.73	na	na
		f	16	0	0.00	0.23	0.18	0.21	1.56	0.03	0.84	na	na
		e	20	0	0.00	0.46	0.27	0.47	1.61	0.03	1.73	na	na
		u	0	na	na	na	na	na	na	na	na	na	na
Orthophosphate, in mg/L	D	a	47	2	19.15	0.15	0.11	0.15	2.89	0.03	0.80	0.03	0.03
		r	13	0	15.38	0.13	0.11	0.07	0.87	0.05	0.28	0.03	0.03
		f	15	1	26.67	0.13	0.11	0.09	0.49	0.03	0.29	0.03	0.03
		e	19	1	15.79	0.18	0.11	0.21	1.98	0.05	0.80	0.03	0.03
		u	0	na	na	na	na	na	na	na	na	na	na
Copper, in µg/L	D	a	49	0	6.12	5.22	3.50	5.57	2.78	1.00	31.0	1.00	1.00
		r	13	0	7.69	4.08	3.50	2.47	1.01	1.00	10.0	1.00	1.00
		f	16	0	12.50	5.07	3.00	5.80	1.73	1.00	22.0	1.00	1.00
		e	20	0	0.00	6.00	4.50	6.74	2.55	1.00	31.0	na	na
		u	0	na	na	na	na	na	na	na	na	na	na
Copper, in µg/L	T	a	48	1	0.00	12.6	8.00	16.2	3.87	2.00	103	na	na
		r	12	1	0.00	8.9	6.00	10.4	2.17	2.00	40.0	na	na
		f	16	0	0.00	9.9	7.00	7.78	1.11	3.00	28.0	na	na
		e	20	0	0.00	16.9	10.5	22.4	2.85	3.00	103	na	na
		u	0	na	na	na	na	na	na	na	na	na	na
Lead, in µg/L	D	a	49	0	95.92	18.0	18.0	2.83	0.00	16.0	20.0	10.0	10.0
		r	13	0	100.00	na	na	na	na	na	na	10.0	10.0
		f	16	0	100.00	na	na	na	na	na	na	10.0	10.0
		e	20	0	90.00	18.0	18.0	2.83	0.00	16.0	20.0	10.0	10.0
		u	0	na	na	na	na	na	na	na	na	na	na
Lead, in µg/L	T	a	47	2	74.47	23.6	17.0	17.1	1.46	10.0	67.0	10.0	10.0
		r	11	2	81.82	17.5	17.5	10.6	0.00	10.0	25.0	10.0	10.0
		f	16	0	81.25	17.7	17.0	7.0	0.09	11.0	25.0	10.0	10.0
		e	20	0	65.00	27.9	17.0	21.2	0.86	11.0	67.0	10.0	10.0
		u	0	na	na	na	na	na	na	na	na	na	na
Manganese, in µg/L	D	a	27	22	7.41	98.0	70.0	104	2.92	20.0	530	20.0	20.0
		r	8	5	0.00	70.0	70	30.7	0.05	30.0	120	na	na
		f	11	5	9.09	89.0	65	75.3	1.02	20.0	250	20.0	20.0
		e	8	12	12.50	143	100	174	1.50	30.0	530	20.0	20.0
		u	0	na	na	na	na	na	na	na	na	na	na
Manganese, in µg/L	T	a	17	32	0.00	309	220	195	0.63	100	640	na	na
		r	6	7	0.00	257	220	170	1.10	100	590	na	na
		f	7	9	0.00	286	170	221	0.68	100	640	na	na
		e	4	16	0.00	427	430	180	–0.03	210	640	na	na
		u	0	na	na	na	na	na	na	na	na	na	na
Zinc, in µg/L	D	a	49	0	4.08	28.7	17.7	29.6	1.89	2.20	145	20.0	20.0
		r	13	0	0.00	24.0	17.7	22.2	2.11	6.60	91.8	na	na
		f	16	0	6.25	15.9	9.8	15.9	1.14	2.20	53.0	20.0	20.0
		e	20	0	5.00	42.1	21.1	37.2	1.19	6.70	145	20.0	20.0
		u	0	na	na	na	na	na	na	na	na	na	na
Zinc, in µg/L	T	a	48	1	4.17	59.7	42.2	70.5	4.04	8.00	460	20.0	20.0
		r	12	1	0.00	44.7	39.0	32.3	0.96	9.20	120	na	na
		f	16	0	6.25	38.3	25.0	34.4	1.22	8.00	120	20.0	20.0
		e	20	0	5.00	86.1	60.4	98.1	2.89	13.8	460	20.0	20.0
		u	0	na	na	na	na	na	na	na	na	na	na

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Property or constituent	Phase	Typ	n	M	Pct	Mean	Median	Stddev	Skew	Min	Max	Minimum reporting level	
												Mean	Median
(C) South Platte River at Denver (06714000)													
Mean discharge, in ft^3/s	na	a	58	1	0.00	944	727	737	1.94	201	3,910	na	na
		r	15	0	0.00	999	735	890	1.39	281	3,371	na	na
		f	23	0	0.00	792	623	531	1.42	289	2,270	na	na
		e	20	0	0.00	1,080	992	818	1.96	201	3,910	na	na
		u	1	1	na	na	na	na	na	na	na	na	na
Discharge volume, in acre-feet	na	a	58	1	0.00	834	609	638	1.65	173	3,240	na	na
		r	15	0	0.00	877	596	764	1.16	247	2,630	na	na
		f	23	0	0.00	720	538	498	1.30	215	2,070	na	na
		e	20	0	0.00	934	780	691	1.76	173	3,240	na	na
		u	1	1	na	na	na	na	na	na	na	na	na
pH, in standard pH units	W	a	58	1	0.00	7.36	7.40	0.22	0.06	6.90	7.90	na	na
		r	15	0	0.00	7.41	7.40	0.18	–0.17	7.10	7.70	na	na
		f	24	0	0.00	7.38	7.40	0.21	0.16	7.00	7.80	na	na
		e	19	1	0.00	7.28	7.30	0.26	0.44	6.90	7.90	na	na
		u	0	na	na	na	na	na	na	na	na	na	na
Specific conductance, in µS/cm	W	a	59	0	0.00	565	533	178	0.65	281	1,050	na	na
		r	15	0	0.00	583	642	195	–0.19	281	885	na	na
		f	24	0	0.00	584	539	158	0.95	345	1,020	na	na
		e	20	0	0.00	528	472	191	1.18	314	1,050	na	na
		u	0	na	na	na	na	na	na	na	na	na	na
Hardness, in mg/L	T	a	59	0	0.00	191	187	48.0	0.55	100	333	na	na
		r	15	0	0.00	197	198	60.4	0.32	100	333	na	na
		f	24	0	0.00	189	186	41.3	0.47	127	273	na	na
		e	20	0	0.00	188	179	47.2	0.64	125	303	na	na
		u	0	na	na	na	na	na	na	na	na	na	na
Residue on evaporation at 105 degrees C, in mg/L	T,	a	59	0	0.00	610	418	638	2.60	12.0	3,560	na	na
		r	15	0	0.00	473	414	428	1.47	12.0	1,720	na	na
		f	24	0	0.00	476	383	351	1.03	133.0	1,330	na	na
		e	20	0	0.00	874	496	922	1.68	131.0	3,560	na	na
		u	0	na	na	na	na	na	na	na	na	na	na
Organic carbon, in mg/L	T	a	47	12	0.00	11.9	11.0	5.35	3.15	6.00	40.0	na	na
		r	13	2	0.00	11.7	11.0	2.75	0.61	8.00	17.0	na	na
		f	21	3	0.00	10.4	11.0	2.64	0.12	6.00	16.0	na	na
		e	13	7	0.00	14.5	12.0	8.92	1.69	7.00	40.0	na	na
		u	0	na	na	na	na	na	na	na	na	na	na
Escherichia coli, in col	W	a	7	0	0.00	2,620	1,700	2,260	0.56	490	7,000	na	na
		r	3	0	0.00	3,060	1,700	3,460	0.33	490	7,000	na	na
		f	4	0	0.00	2,300	1,900	2,180	0.17	490	4,900	na	na
Fecal coliform, in col	W	a	7	0	0.00	3,780	3,300	3,690	0.84	490	11,000	na	na
		r	3	0	0.00	5,030	3,300	5,320	0.29	790	11,000	na	na
		f	4	0	0.00	2,850	3,000	2,380	–0.02	490	4,900	na	na
Ammonia, in mg/L	T	a	59	0	59.32	0.47	0.40	0.25	1.30	0.20	1.20	0.20	0.20
		r	15	0	60.00	0.47	0.40	0.23	1.05	0.30	0.90	0.20	0.20
		f	24	0	79.17	0.48	0.40	0.26	0.17	0.20	0.80	0.20	0.20
		e	20	0	35.00	0.47	0.40	0.28	1.44	0.20	1.20	0.20	0.20
		u	0	na	na	na	na	na	na	na	na	na	na
Nitrite + nitrate, in mg/L	T	a	43	16	0.00	2.09	1.86	1.14	1.68	0.71	6.51	na	na
		r	11	4	0.00	2.62	2.38	1.12	0.48	0.96	4.87	na	na
		f	17	7	0.00	1.85	1.78	0.69	0.13	0.72	3.10	na	na
		e	15	5	0.00	1.98	1.45	1.47	1.96	0.71	6.51	na	na
		u	0	na	na	na	na	na	na	na	na	na	na

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Property or constituent	Phase	Typ	n	M	Pct	Mean	Median	Stddev	Skew	Min	Max	Minimum reporting level	
												Mean	Median
(C) South Platte River at Denver (06714000)—Continued													
Ammonia + organic nitrogen, in mg/L	T	a	59	0	5.08	3.00	2.40	2.12	1.94	0.40	12.0	0.30	0.30
		r	15	0	13.33	3.38	2.90	1.88	1.37	1.70	8.40	0.30	0.30
		f	24	0	4.17	2.80	1.90	2.02	1.19	0.40	7.40	0.30	0.30
		e	20	0	0.00	2.99	2.55	2.44	2.42	0.80	12.0	na	na
		u	0	na	na	na	na	na	na	na	na	na	na
Phosphorus, in mg/L	T	a	59	0	0.00	0.81	0.64	0.61	1.90	0.14	3.17	na	na
		r	15	0	0.00	0.83	0.79	0.59	1.85	0.14	2.69	na	na
		f	24	0	0.00	0.72	0.51	0.56	1.73	0.21	2.54	na	na
		e	20	0	0.00	0.88	0.70	0.70	1.73	0.14	3.17	na	na
		u	0	na	na	na	na	na	na	na	na	na	na
Orthophosphate, in mg/L	D	a	58	1	0.00	0.23	0.20	0.11	1.09	0.08	0.55	na	na
		r	14	1	0.00	0.28	0.27	0.11	0.50	0.10	0.50	na	na
		f	24	0	0.00	0.21	0.19	0.09	1.19	0.08	0.47	na	na
		e	20	0	0.00	0.24	0.19	0.13	1.09	0.09	0.55	na	na
		u	0	na	na	na	na	na	na	na	na	na	na
Copper, in µg/L	D	a	59	0	3.39	7.93	5.00	8.86	3.86	2.00	60.0	1.00	1.00
		r	15	0	0.00	8.40	6.00	6.40	1.42	2.00	26.0	na	na
		f	24	0	0.00	7.33	4.00	12.0	3.55	2.00	60.0	na	na
		e	20	0	10.00	8.33	7.00	5.27	1.28	3.00	23.0	1.00	1.00
		u	0	na	na	na	na	na	na	na	na	na	na
Copper, in µg/L	T	a	59	0	0.00	28.3	24.0	21.1	1.29	1.00	104	na	na
		r	15	0	0.00	31.3	27.0	19.0	0.67	7.00	74.0	na	na
		f	24	0	0.00	22.7	15.5	20.3	1.37	1.00	77.0	na	na
		e	20	0	0.00	32.6	25.5	22.9	1.46	8.00	104	na	na
		u	0	na	na	na	na	na	na	na	na	na	na
Lead, in µg/L	D	a	59	0	81.36	19.0	14.0	12.3	1.33	10.0	47.0	10.0	10.0
		r	15	0	80.00	23.3	20.0	14.3	0.22	11.0	39.0	10.0	10.0
		f	24	0	91.67	29.5	29.5	24.7	0.00	12.0	47.0	10.0	10.0
		e	20	0	70.00	13.3	13.5	2.6	0.04	10.0	17.0	10.0	10.0
		u	0	na	na	na	na	na	na	na	na	na	na
Lead, in µg/L	T	a	59	0	27.12	34.8	30.0	24.0	1.67	10.0	121	10.0	10.0
		r	15	0	26.67	33.5	30.0	18.7	0.96	15.0	75.0	10.0	10.0
		f	24	0	41.67	27.0	26.5	14.2	0.64	10.0	60.0	10.0	10.0
		e	20	0	10.00	41.7	30.5	31.0	1.18	10.0	121	10.0	10.0
		u	0	na	na	na	na	na	na	na	na	na	na
Manganese, in µg/L	D	a	34	25	11.76	165	100	181	2.12	20.0	840	20.0	20.0
		r	8	7	0.00	187	100	169	0.79	50.0	510	na	na
		f	14	10	14.29	142	75.0	223	2.51	30.0	840	20.0	20.0
		e	12	8	16.67	175	140	144	0.96	20.0	500	20.0	20.0
		u	0	na	na	na	na	na	na	na	na	na	na
Manganese, in µg/L	T	a	21	38	0.00	405	310	250	1.45	150	1,120	na	na
		r	6	9	0.00	377	325	171	0.96	240	700	na	na
		f	9	15	0.00	327	290	140	0.72	170	570	na	na
		e	6	14	0.00	552	445	390	0.38	150	1,120	na	na
		u	0	na	na	na	na	na	na	na	na	na	na
Zinc, in µg/L	D	a	59	0	8.47	57.4	41.4	51.9	2.07	10.6	275	16.0	20.0
		r	15	0	0.00	71.5	70.0	49.5	0.97	20.0	180	na	na
		f	24	0	12.50	52.2	32.2	65.1	2.35	12.3	275	13.4	20.0
		e	20	0	10.00	51.7	47.5	33.9	0.54	10.6	125	20.0	20.0
		u	0	na	na	na	na	na	na	na	na	na	na
Zinc, in µg/L	T	a	59	0	1.69	173	132	136	1.58	27.8	672	0.30	0.30
		r	15	0	0.00	195	140	154	1.12	40.0	544	na	na
		f	24	0	4.17	131	97.0	109	1.69	27.8	469	0.30	0.30
		e	20	0	0.00	206	150	144	1.58	55.9	672	na	na
		u	0	na	na	na	na	na	na	na	na	na	na

Table 9. Summary statistics for water-quality properties and constituents from composite and bacteriological samples at (A) all stations, (B) South Platte River below Union Avenue, (C) South Platte River at Denver, (D) Tollgate Creek above 6th Avenue, (E) Sand Creek at mouth, and (F) South Platte River at Henderson.—Continued

[Phase: W, determination made using whole water; T, total; D, dissolved. Typ: a, all samples regardless of hydrograph position; r, sample from rising limb portion of hydrograph; f, sample from falling limb portion of hydrograph; e, sample from rising and falling limbs of hydrograph; u, unclassified. n, number of samples; M, number of samples with missing values; Pct, percentage of samples below minimum reporting level; Stddev, standard deviation; Skew, skewness; Min, minimum; Max, maximum; ft³/s, cubic feet per second; µS/cm, microsiemens per centimeter at 25 degrees Celsius; C, Celsius; mg/L, milligrams per liter; col, colonies per 100 milliliters; µg/L, micrograms per liter; na, not applicable]

Property or constituent	Phase	Typ	n	M	Pct	Mean	Median	Stddev	Skew	Min	Max	Minimum reporting level	
												Mean	Median
(D) Tollgate Creek above 6th Avenue (394329104490101)													
Mean discharge, in ft³/s	na	a	25	10	0.00	125	45.0	192	2.29	7.00	785	na	na
		r	5	0	0.00	259	118	326	0.67	7.00	785	na	na
		f	12	0	0.00	95.5	44.0	167	2.47	11.0	616	na	na
		e	8	0	0.00	85.4	48.5	77.3	0.77	16.0	230	na	na
		u	10	10	na	na	na	na	na	na	na	na	na
Discharge volume, in acre-feet	na	a	25	10	0.00	109	44.0	159	2.00	5.00	583	na	na
		r	5	0	0.00	211	117	244	0.51	6.00	583	na	na
		f	12	0	0.00	96.8	45.5	157	2.11	5.00	560	na	na
		e	8	0	0.00	65.1	42.0	63.0	1.27	7.00	207	na	na
		u	10	10	na	na	na	na	na	na	na	na	na
pH, in standard pH units	W	a	34	1	0.00	7.46	7.50	0.23	–0.28	7.00	7.80	na	na
		r	5	0	0.00	7.58	7.60	0.08	0.25	7.50	7.70	na	na
		f	13	0	0.00	7.53	7.50	0.21	–0.18	7.20	7.80	na	na
		e	8	1	0.00	7.30	7.20	0.28	0.42	7.00	7.70	na	na
		u	8	0	0.00	7.43	7.45	0.23	0.12	7.10	7.80	na	na
Specific conductance, in µS/cm	W	a	35	0	0.00	873	811	315	1.09	316	1,940	na	na
		r	5	0	0.00	1,130	1,060	528	0.43	578	1,940	na	na
		f	13	0	0.00	828	742	293	0.57	316	1,440	na	na
		e	9	0	0.00	874	888	276	–0.25	396	1,310	na	na
		u	8	0	0.00	780	834	168	–0.58	487	951	na	na
Hardness, in mg/L	T	a	35	0	0.00	268	252	90.4	1.58	94.0	608	na	na
		r	5	0	0.00	340	257	156	0.89	236	608	na	na
		f	13	0	0.00	245	232	74.6	1.43	154	451	na	na
		e	9	0	0.00	276	289	95.0	–0.41	94.0	410	na	na
		u	8	0	0.00	251	252	28.3	0.00	202	300	na	na
Residue on evaporation at 105 degrees C, in mg/L	T	a	34	1	0.00	762	389	901	1.99	73.0	3,890	na	na
		r	5	0	0.00	423	196	356	0.31	130	868	na	na
		f	13	0	0.00	625	241	1,000	2.59	97.0	3,890	na	na
		e	9	0	0.00	1,160	692	1,020	0.83	149	3,310	na	na
		u	7	1	0.00	750	322	765	0.82	73.0	2,210	na	na
Organic carbon, in mg/L	T	a	28	7	0.00	13.7	12.0	5.02	1.08	8.00	27.0	na	na
		r	4	1	0.00	14.5	14.5	5.69	0.00	8.00	21.0	na	na
		f	11	2	0.00	12.1	12.0	3.39	1.41	8.00	21.0	na	na
		e	7	2	0.00	18.5	20.0	5.91	0.16	12.0	27.0	na	na
		u	6	2	0.00	10.7	11.5	1.75	–0.51	8.00	12.0	na	na
Escherichia coli, in col	W	a	3	0	0.00	1,460	900	1,640	0.30	170	3,300	na	na
		r	1	0	0.00	170	170	na	na	170	170	na	na
		f	2	0	0.00	2,100	2,100	1,700	0	900	3,300	na	na
Fecal coliform, in col	W	a	3	0	0.00	1,550	900	1,530	0.35	460	3,300	na	na
		r	1	0	0.00	460	460	na	na	460	460	na	na
		f	2	0	0.00	2,100	2,100	1,700	0	900	3,300	na	na
Ammonia, in mg/L	T	a	35	0	80.00	0.50	0.30	0.57	1.61	0.20	1.80	0.20	0.20
		r	5	0	80.00	0.30	0.30	na	na	0.30	0.30	0.20	0.20
		f	13	0	84.62	0.30	0.30	0.00	0.00	0.30	0.30	0.20	0.20
		e	9	0	66.67	0.27	0.30	0.06	–0.38	0.20	0.30	0.20	0.20
		u	8	0	87.50	1.80	1.80	na	na	1.80	1.80	0.20	0.20
Nitrite + nitrate, in mg/L	T	a	28	7	0.00	0.62	0.57	0.20	1.60	0.42	1.31	na	na
		r	4	1	0.00	0.70	0.55	0.41	0.69	0.42	1.31	na	na
		f	10	3	0.00	0.57	0.50	0.18	0.88	0.42	0.94	na	na
		e	8	1	0.00	0.55	0.51	0.10	0.78	0.42	0.74	na	na
		u	6	2	0.00	0.73	0.69	0.10	0.79	0.64	0.90	na	na

Table 9. Summary statistics for water-quality properties and constituents from composite and bacteriological samples at (A) all stations, (B) South Platte River below Union Avenue, (C) South Platte River at Denver, (D) Tollgate Creek above 6th Avenue, (E) Sand Creek at mouth, and (F) South Platte River at Henderson.—Continued

[Phase: W, determination made using whole water; T, total; D, dissolved. Typ: a, all samples regardless of hydrograph position; r, sample from rising limb portion of hydrograph; f, sample from falling limb portion of hydrograph; e, sample from rising and falling limbs of hydrograph; u, unclassified. n, number of samples; M, number of samples with missing values; Pct, percentage of samples below minimum reporting level; Stddev, standard deviation; Skew, skewness; Min, minimum; Max, maximum; ft³/s, cubic feet per second; µS/cm, microsiemens per centimeter at 25 degrees Celsius; C, Celsius; mg/L, milligrams per liter; col, colonies per 100 milliliters; µg/L, micrograms per liter; na, not applicable]

Property or constituent	Phase	Typ	n	M	Pct	Mean	Median	Stddev	Skew	Min	Max	Minimum reporting level	
												Mean	Median
(D) Tollgate Creek above 6th Avenue (394329104490101)—Continued													
Ammonia + organic nitrogen, in mg/L	T	a	35	0	0.00	2.17	1.80	1.31	1.29	0.50	6.00	na	na
		r	5	0	0.00	2.28	1.90	1.13	–0.04	0.80	3.60	na	na
		f	13	0	0.00	1.75	1.70	0.82	1.03	0.90	3.80	na	na
		e	9	0	0.00	3.10	2.60	1.95	0.23	0.50	6.00	na	na
		u	8	0	0.00	1.75	1.55	0.66	0.28	1.00	2.70	na	na
Phosphorus, in mg/L	T	a	35	0	0.00	0.64	0.48	0.44	1.57	0.17	1.94	na	na
		r	5	0	0.00	0.61	0.43	0.36	0.45	0.30	1.13	na	na
		f	13	0	0.00	0.46	0.41	0.19	0.61	0.19	0.85	na	na
		e	9	0	0.00	0.91	0.88	0.61	0.58	0.23	1.94	na	na
		u	8	0	0.00	0.63	0.52	0.47	1.27	0.17	1.70	na	na
Orthophosphate, in mg/L	D	a	35	0	20.00	0.13	0.11	0.10	2.25	0.03	0.47	0.03	0.03
		r	5	0	0.00	0.16	0.11	0.14	1.03	0.08	0.40	na	na
		f	13	0	7.69	0.12	0.12	0.05	0.23	0.04	0.21	0.03	0.03
		e	9	0	22.22	0.15	0.09	0.15	1.31	0.03	0.47	0.03	0.03
		u	8	0	50.00	0.12	0.12	0.01	0.00	0.10	0.13	0.03	0.03
Copper, in µg/L	D	a	35	0	0.00	6.97	4.00	7.23	2.81	1.00	40.0	na	na
		r	5	0	0.00	5.60	5.00	2.70	0.64	3.00	10.0	na	na
		f	13	0	0.00	5.31	4.00	4.42	0.77	1.00	14.0	na	na
		e	9	0	0.00	7.11	4.00	5.40	0.44	2.00	15.0	na	na
		u	8	0	0.00	10.4	4.50	12.8	1.50	4.00	40.0	na	na
Copper, in µg/L	T	a	35	0	0.00	19.7	14.0	15.9	1.40	4.00	66.0	na	na
		r	5	0	0.00	17.4	14.0	10.0	0.16	7.00	28.0	na	na
		f	13	0	0.00	15.8	10.0	13.4	1.83	7.00	54.0	na	na
		e	9	0	0.00	27.7	28.0	19.5	0.53	6.00	66.0	na	na
		u	8	0	0.00	18.6	13.0	17.4	1.42	4.00	59.0	na	na
Lead, in µg/L	D	a	35	0	91.43	18.0	13.0	11.4	0.35	10.0	31.0	10.0	10.0
		r	5	0	100.00	na	na	na	na	na	na	10.0	10.0
		f	13	0	92.31	13.0	13.0	na	na	13.0	13.0	10.0	10.0
		e	9	0	88.89	10.0	10.0	na	na	10.0	10.0	10.0	10.0
		u	8	0	87.50	31.0	31.0	na	na	31.0	31.0	10.0	10.0
Lead, in µg/L	T	a	35	0	60.00	26.4	23.0	13.7	1.02	14.0	54.0	10.0	10.0
		r	5	0	60.00	23.5	23.5	0.71	0.00	23.0	24.0	10.0	10.0
		f	13	0	69.23	24.7	15.5	19.5	0.75	14.0	54.0	10.0	10.0
		e	9	0	44.44	29.0	28.0	15.2	0.68	15.0	54.0	10.0	10.0
		u	8	0	62.50	26.0	23.0	12.8	0.22	15.0	40.0	10.0	10.0
Manganese, in µg/L	D	a	20	15	0.00	333	150	375	1.66	50.0	1,500	na	na
		r	3	2	0.00	300	310	155	–0.06	140	450	na	na
		f	8	5	0.00	242	105	292	0.93	50.0	730	na	na
		e	5	4	0.00	404	340	317	0.65	150	920	na	na
		u	4	4	0.00	452	125	700	0.74	60	1,500	na	na
Manganese, in µg/L	T	a	9	26	0.00	802	420	676	0.86	160	2,130	na	na
		r	2	3	0.00	605	605	262	0.00	420	790	na	na
		f	3	10	0.00	943	360	1030	0.38	340	2,130	na	na
		e	2	7	0.00	1,310	1,315	474	0.00	980	1,650	na	na
		u	2	6	0.00	275	275	163	0.00	160	390	na	na
Zinc, in µg/L	D	a	35	0	5.71	38.9	24.5	34.4	1.29	6.00	146	20.0	20.0
		r	5	0	20.00	40.8	40.8	23.2	0.00	13.8	68.0	20.0	20.0
		f	13	0	7.69	34.5	25.5	27.3	0.45	6.00	80.0	20.0	20.0
		e	9	0	0.00	46.5	26.7	37.3	0.74	13.3	112	na	na
		u	8	0	0.00	36.1	14.9	48.1	1.42	6.70	146	na	na
Zinc, in µg/L	T	a	35	0	2.86	119	90.0	89.0	1.13	22.3	350	20.0	20.0
		r	5	0	20.00	116	119	66.6	–0.05	44.6	180	20.0	20.0
		f	13	0	0.00	91.7	77.2	79.4	1.75	24.0	320	na	na
		e	9	0	0.00	166	170	102	0.36	54.0	350	na	na
		u	8	0	0.00	115	97.0	91.6	1.18	22.3	320	na	na

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[Phase: W, determination made using whole water; T, total; D, dissolved. Typ: a, all samples regardless of hydrograph position; r, sample from rising limb portion of hydrograph; f, sample from falling limb portion of hydrograph; e, sample from rising and falling limbs of hydrograph; u, unclassified. n, number of samples; M, number of samples with missing values; Pct, percentage of samples below minimum reporting level; Stddev, standard deviation; Skew, skewness; Min, minimum; Max, maximum; ft³/s, cubic feet per second; µS/cm, microsiemens per centimeter at 25 degrees Celsius; C, Celsius; mg/L, milligrams per liter; col, colonies per 100 milliliters; µg/L, micrograms per liter; na, not applicable]

Property or constituent	Phase	Typ	n	M	Pct	Mean	Median	Stddev	Skew	Min	Max	Minimum reporting level	
												Mean	Median
(E) Sand Creek at mouth (394839104570300)													
Mean discharge, in ft³/s	na	a	52	2	0.00	380	185	427	2.54	45.0	2,110	na	na
		r	14	0	0.00	243	173	223	1.91	45.0	924	na	na
		f	18	0	0.00	354	165	486	2.64	81.0	2,110	na	na
		e	20	0	0.00	498	342	464	1.85	101	2,060	na	na
		u	2	2	na	na	na	na	na	na	na	na	na
Discharge volume, in acre-feet	na	a	52	2	0.00	367	165	415	2.07	41.0	1,930	na	na
		r	14	0	0.00	242	154	233	1.37	41.0	840	na	na
		f	18	0	0.00	348	142	481	2.14	60.0	1,930	na	na
		e	20	0	0.00	471	273	440	1.45	91.0	1,820	na	na
		u	2	2	na	na	na	na	na	na	na	na	na
pH, in standard pH units	W	a	52	2	0.00	7.50	7.50	0.24	–0.08	7.00	7.90	na	na
		r	14	0	0.00	7.53	7.50	0.19	0.25	7.20	7.90	na	na
		f	17	1	0.00	7.57	7.60	0.23	–0.28	7.10	7.90	na	na
		e	19	1	0.00	7.42	7.40	0.26	0.20	7.00	7.90	na	na
		u	2	0	0.00	7.40	7.40	0.28	0.00	7.20	7.60	na	na
Specific conductance, in µS/cm	W	a	54	0	0.00	758	761	214	–0.08	318	1,200	na	na
		r	14	0	0.00	854	883	188	–1.15	354	1,080	na	na
		f	18	0	0.00	775	785	239	0.24	404	1,200	na	na
		e	20	0	0.00	688	713	197	–0.14	318	1,060	na	na
		u	2	0	0.00	636	636	41.0	0.00	607	665	na	na
Hardness, in mg/L	T	a	54	0	0.00	228	221	48.8	–0.07	123	317	na	na
		r	14	0	0.00	241	239	55.5	–0.29	123	317	na	na
		f	18	0	0.00	226	235	44.4	–0.44	131	293	na	na
		e	20	0	0.00	223	217	50.5	0.11	141	303	na	na
		u	2	0	0.00	202	202	17.0	0.00	190	214	na	na
Residue on evaporation at 105 degrees C, in mg/L	T	a	54	0	0.00	472	251	432	1.36	69.0	1,720	na	na
		r	14	0	0.00	248	166	238	1.97	69.0	970	na	na
		f	18	0	0.00	385	237	414	1.95	73.0	1,660	na	na
		e	20	0	0.00	717	635	463	0.62	71.0	1,720	na	na
		u	2	0	0.00	379	379	340	0.00	139	620	na	na
Organic carbon, in mg/L	T	a	43	11	0.00	14.2	13.0	5.65	0.77	6.00	30.0	na	na
		r	12	2	0.00	14.7	13.0	5.77	0.42	7.00	26.0	na	na
		f	14	4	0.00	12.3	11.0	4.48	0.48	6.00	20.0	na	na
		e	15	5	0.00	15.5	15.0	6.70	0.65	8.00	30.0	na	na
		u	2	0	0.00	15.0	15.0	1.41	0.00	14.0	16.0	na	na
Escherichia coli, in col	W	a	7	0	0.00	2,010	1,700	1,610	0.75	490	5,000	na	na
		r	4	0	0.00	2,000	1,700	887	0.64	1,300	3,300	na	na
		f	3	0	0.00	2,030	600	2,570	0.38	490	5,000	na	na
Fecal coliform, in col	W	a	7	0	0.00	6,700	1,300	12,600	1.56	490	35,000	na	na
		r	4	0	0.00	2,700	2,300	1,743	0.23	1,300	4,900	na	na
		f	31	0	0.00	2,030	600	19,900	0.38	490	35,000	na	na
Ammonia, in mg/L	T	a	54	0	90.74	0.76	0.60	0.38	0.38	0.40	1.30	0.40	0.20
		r	14	0	92.86	1.30	1.30	na	na	1.30	1.30	0.20	0.20
		f	18	0	94.44	0.50	0.50	na	na	0.50	0.50	0.78	0.20
		e	20	0	90.00	0.70	0.70	0.42	0.00	0.40	1.00	0.20	0.20
		u	2	0	50.00	0.60	0.60	na	na	0.60	0.60	0.20	0.20
Nitrite + nitrate, in mg/L	T	a	38	16	0.00	0.93	0.92	0.30	0.76	0.47	1.78	na	na
		r	9	5	0.00	1.08	1.07	0.11	–0.45	0.86	1.24	na	na
		f	13	5	0.00	0.91	0.89	0.31	1.09	0.48	1.72	na	na
		e	16	4	0.00	0.87	0.82	0.35	1.09	0.47	1.78	na	na
		u	0	na	na	na	na	na	na	na	na	na	na

Table 9. Summary statistics for water-quality properties and constituents from composite and bacteriological samples at (A) all stations, (B) South Platte River below Union Avenue, (C) South Platte River at Denver, (D) Tollgate Creek above 6th Avenue, (E) Sand Creek at mouth, and (F) South Platte River at Henderson.—Continued

[Phase: W, determination made using whole water; T, total; D, dissolved. Typ: a, all samples regardless of hydrograph position; r, sample from rising limb portion of hydrograph; f, sample from falling limb portion of hydrograph; e, sample from rising and falling limbs of hydrograph; u, unclassified. n, number of samples; M, number of samples with missing values; Pct, percentage of samples below minimum reporting level; Stddev, standard deviation; Skew, skewness; Min, minimum; Max, maximum; ft³/s, cubic feet per second; µS/cm, microsiemens per centimeter at 25 degrees Celsius; C, Celsius; mg/L, milligrams per liter; col, colonies per 100 milliliters; µg/L, micrograms per liter; na, not applicable]

Property or constituent	Phase	Typ	n	M	Pct	Mean	Median	Stddev	Skew	Min	Max	Minimum reporting level Mean	Minimum reporting level Median
(E) Sand Creek at mouth (394839104570300)—Continued													
Ammonia + organic nitrogen, in mg/L	T	a	54	0	5.56	2.32	2.00	1.40	1.59	0.40	7.70	0.30	0.30
		r	14	0	7.14	1.82	1.90	0.68	0.62	0.90	3.40	0.30	0.30
		f	18	0	5.56	2.09	2.00	1.31	0.99	0.40	5.10	0.30	0.30
		e	20	0	5.00	2.77	2.30	1.65	1.45	0.80	7.70	0.30	0.30
		u	2	0	0.00	3.35	3.35	2.47	0.00	1.60	5.10	na	na
Phosphorus, in mg/L	T	a	54	0	0.00	0.61	0.53	0.31	0.81	0.23	1.40	na	na
		r	14	0	0.00	0.49	0.43	0.19	0.54	0.23	0.83	na	na
		f	18	0	0.00	0.54	0.47	0.30	1.41	0.26	1.40	na	na
		e	20	0	0.00	0.75	0.73	0.33	0.08	0.23	1.36	na	na
		u	2	0	0.00	0.69	0.69	0.39	0.00	0.42	0.97	na	na
Orthophosphate, in mg/L	D	a	52	2	0.00	0.19	0.17	0.10	1.61	0.04	0.60	na	na
		r	13	1	0.00	0.18	0.17	0.05	0.95	0.13	0.29	na	na
		f	17	1	0.00	0.18	0.17	0.09	1.51	0.04	0.47	na	na
		e	20	0	0.00	0.22	0.18	0.14	1.00	0.04	0.60	na	na
		u	2	0	0.00	0.14	0.14	0.04	0.00	0.11	0.17	na	na
Copper, in µg/L	D	a	54	0	1.85	7.77	6.00	6.79	2.12	1.00	35.0	1.00	1.00
		r	14	0	0.00	5.64	4.50	3.69	0.58	1.00	12.0	na	na
		f	18	0	0.00	9.50	6.50	9.75	1.52	1.00	35.0	na	na
		e	20	0	5.00	7.68	6.00	5.03	0.94	3.00	20.0	1.00	1.00
		u	2	0	0.00	8.00	8.00	5.66	0.00	4.00	12.0	na	na
Copper, in µg/L	T	a	54	0	0.00	18.8	14.0	14.5	1.81	3.00	73.0	na	na
		r	14	0	0.00	12.5	10.0	6.2	0.89	3.00	25.0	na	na
		f	18	0	0.00	15.7	12.5	10.5	1.69	5.00	48.0	na	na
		e	20	0	0.00	26.3	23.0	18.8	1.01	6.00	73.0	na	na
		u	2	0	0.00	17.0	17.0	14.1	0.00	7.00	27.0	na	na
Lead, in µg/L	D	a	54	0	79.63	17.5	14.0	11.6	2.13	10.0	51.0	10.0	10.0
		r	14	0	92.86	13.0	13.0	na	na	13.0	13.0	10.0	10.0
		f	18	0	83.33	25.0	14.0	22.6	0.37	10.0	51.0	10.0	10.0
		e	20	0	65.00	15.0	14.0	3.70	0.17	11.0	20.0	10.0	10.0
		u	2	0	100.00	na	na	na	na	na	na	10.0	10.0
Lead, in µg/L	T	a	54	0	48.15	26.6	22.0	14.7	0.95	10.0	61.0	10.0	10.0
		r	14	0	78.57	16.7	18.0	5.13	–0.24	11.0	21.0	10.0	10.0
		f	18	0	61.11	22.7	16.0	13.5	0.87	10.0	49.0	10.0	10.0
		e	20	0	15.00	29.7	23.0	16.1	0.70	11.0	61.0	10.0	10.0
		u	2	0	50.00	32.0	32.0	na	na	32.0	32.0	10.0	10.0
Manganese, in µg/L	D	a	35	19	2.86	237	155	233	2.39	20.0	1,210	20.0	20.0
		r	9	5	0.00	168	170	103	–0.14	20.0	290	na	na
		f	11	7	0.00	273	140	331	1.99	60.0	1,210	na	na
		e	13	7	7.69	260	205	215	1.00	30.0	770	20.0	20.0
		u	2	0	0.00	225	225	219	0.00	70.0	380	na	na
Manganese, in µg/L	T	a	20	34	0.00	507	405	406	1.51	80.0	1,740	na	na
		r	7	7	0.00	361	370	160	–0.34	80.0	590	na	na
		f	6	12	0.00	340	265	194	0.71	150	680	na	na
		e	5	15	0.00	838	660	612	0.29	100	1,740	na	na
		u	2	0	0.00	690	690	594	0.00	270	1,110	na	na
Zinc, in µg/L	D	a	53	1	3.77	184	120	228	3.88	22.0	1,490	10.0	10.0
		r	13	1	7.69	367	227	388	1.93	64.1	1,490	0.10	0.10
		f	18	0	0.00	128	102	125	2.26	26.0	559	na	na
		e	20	0	5.00	132	104	92.3	1.16	22.0	380	20.0	20.0
		u	2	0	0.00	80.0	80.0	56.6	0.00	40.0	120	na	na
Zinc, in µg/L	T	a	53	1	3.77	350	300	253	1.94	70.0	1,500	10.1	10.1
		r	13	1	7.69	539	480	351	1.54	160	1,500	0.30	0.30
		f	18	0	0.00	234	200	162	1.59	84.0	739	na	na
		e	20	0	5.00	354	347	193	0.25	70.0	687	20.0	20.0
		u	2	0	0.00	235	235	177	0.00	110	360	na	na

Table 9. Summary statistics for water-quality properties and constituents from composite and bacteriological samples at (A) all stations, (B) South Platte River below Union Avenue, (C) South Platte River at Denver, (D) Tollgate Creek above 6th Avenue, (E) Sand Creek at mouth, and (F) South Platte River at Henderson.—Continued

[Phase: W, determination made using whole water; T, total; D, dissolved. Typ: a, all samples regardless of hydrograph position; r, sample from rising limb portion of hydrograph; f, sample from falling limb portion of hydrograph; e, sample from rising and falling limbs of hydrograph; u, unclassified. n, number of samples; M, number of samples with missing values; Pct, percentage of samples below minimum reporting level; Stddev, standard deviation; Skew, skewness; Min, minimum; Max, maximum; ft³/s, cubic feet per second; µS/cm, microsiemens per centimeter at 25 degrees Celsius; C, Celsius; mg/L, milligrams per liter; col, colonies per 100 milliliters; µg/L, micrograms per liter; na, not applicable]

Property or constituent	Phase	Typ	n	M	Pct	Mean	Median	Stddev	Skew	Min	Max	Minimum reporting level Mean	Minimum reporting level Median
(F) South Platte River at Henderson (07720500)													
Mean discharge, in ft³/s	na	a	58	0	0.00	2,070	1,590	1,440	1.60	394	7,130	na	na
		r	15	0	0.00	2,570	1,730	2,110	1.03	394	7,130	na	na
		f	26	0	0.00	1,870	14,230	1,200	1.20	636	4,960	na	na
		e	17	0	0.00	1,930	1,630	952	0.63	735	4,100	na	na
		u	0	0	na	na	na	na	na	na	na	na	na
Discharge volume, in acre-feet	na	a	58	0	0.00	1,840	1,450	1,290	0.97	152	6,080	na	na
		r	15	0	0.00	2,270	2,140	1,580	0.88	584	6,080	na	na
		f	26	0	0.00	1,600	1,220	1,280	0.82	152	4,510	na	na
		e	17	0	0.00	1,850	1,490	992	0.61	744	3,730	na	na
		u	0	na	na	na	na	na	na	na	na	na	na
pH, in standard pH units	W	a	57	1	0.00	7.31	7.30	0.22	-0.15	6.80	7.70	na	na
		r	15	0	0.00	7.28	7.30	0.19	-0.49	6.90	7.60	na	na
		f	25	1	0.00	7.38	7.40	0.22	-0.15	6.90	7.70	na	na
		e	17	0	0.00	7.24	7.20	0.22	-0.09	6.80	7.60	na	na
		u	0	na	na	na	na	na	na	na	na	na	na
Specific conductance, in µS/cm	W	a	58	0	0.00	562	530	172	1.47	277	1,320	na	na
		r	15	0	0.00	540	518	184	0.43	277	861	na	na
		f	26	0	0.00	536	521	122	0.21	302	784	na	na
		e	17	0	0.00	620	590	218	1.76	349	1,320	na	na
		u	0	na	na	na	na	na	na	na	na	na	na
Hardness, in mg/L	T	a	58	0	0.00	167	164	30.5	0.38	119	238	na	na
		r	15	0	0.00	162	156	36.7	0.46	119	226	na	na
		f	26	0	0.00	165	162	27.3	0.56	120	233	na	na
		e	17	0	0.00	172	173	30.4	0.10	123	238	na	na
		u	0	na	na	na	na	na	na	na	na	na	na
Residue on evaporation at 105 degrees C, in mg/L	T	a	56	2	0.00	628	492	556	1.65	58.0	2,580	na	na
		r	15	0	0.00	669	626	621	1.39	58.0	2,420	na	na
		f	24	2	0.00	594	402	587	1.78	80.0	2,580	na	na
		e	17	0	0.00	638	591	477	1.26	166	2,030	na	na
		u	0	na	na	na	na	na	na	na	na	na	na
Organic carbon, in mg/L	T	a	45	13	0.00	11.6	11.0	4.54	1.79	1.70	30.0	na	na
		r	13	2	0.00	13.4	13.0	4.59	0.38	7.00	23.0	na	na
		f	19	7	0.00	9.53	9.00	2.39	0.88	7.00	15.0	na	na
		e	13	4	0.00	12.8	12.0	5.83	1.81	7.00	30.0	na	na
		u	0	na	na	na	na	na	na	na	na	na	na
Escherichia coli, in col	W	a	10	0	0.00	4,350	4,900	3,310	–0.13	170	7,900	na	na
		r	4	0	0.00	3,670	3,300	3,440	0.17	170	7,900	na	na
		f	6	0	0.00	4,800	5,950	3,470	–0.34	330	7,900	na	na
Fecal coliform, in col	W	a	10	0	0.00	5,680	4,100	5,650	0.76	330	17,000	na	na
		r	4	0	0.00	4,360	4,600	3,670	–0.06	330	7,900	na	na
		f	6	0	0.00	6,550	4,100	6,870	0.48	330	17,000	na	na
Ammonia, in mg/L	T	a	58	0	1.72	1.15	0.90	0.78	0.94	0.20	3.20	0.20	0.20
		r	15	0	0.00	1.37	1.00	1.02	0.71	0.30	3.20	na	na
		f	26	0	3.85	0.96	0.90	0.57	0.80	0.20	2.40	0.20	0.20
		e	17	0	0.00	1.25	1.00	0.78	0.33	0.20	2.60	na	na
		u	0	na	na	na	na	na	na	na	na	na	na
Nitrite + nitrate, in mg/L	T	a	41	17	2.44	2.16	1.96	0.81	0.87	1.04	4.55	0.20	0.20
		r	10	5	10.00	2.12	1.87	1.02	1.33	1.20	4.55	0.20	0.20
		f	19	7	0.00	2.05	1.92	0.74	0.83	1.04	4.03	na	na
		e	12	5	0.00	2.36	2.39	0.78	–0.08	1.34	3.36	na	na
		u	0	na	na	na	na	na	na	na	na	na	na

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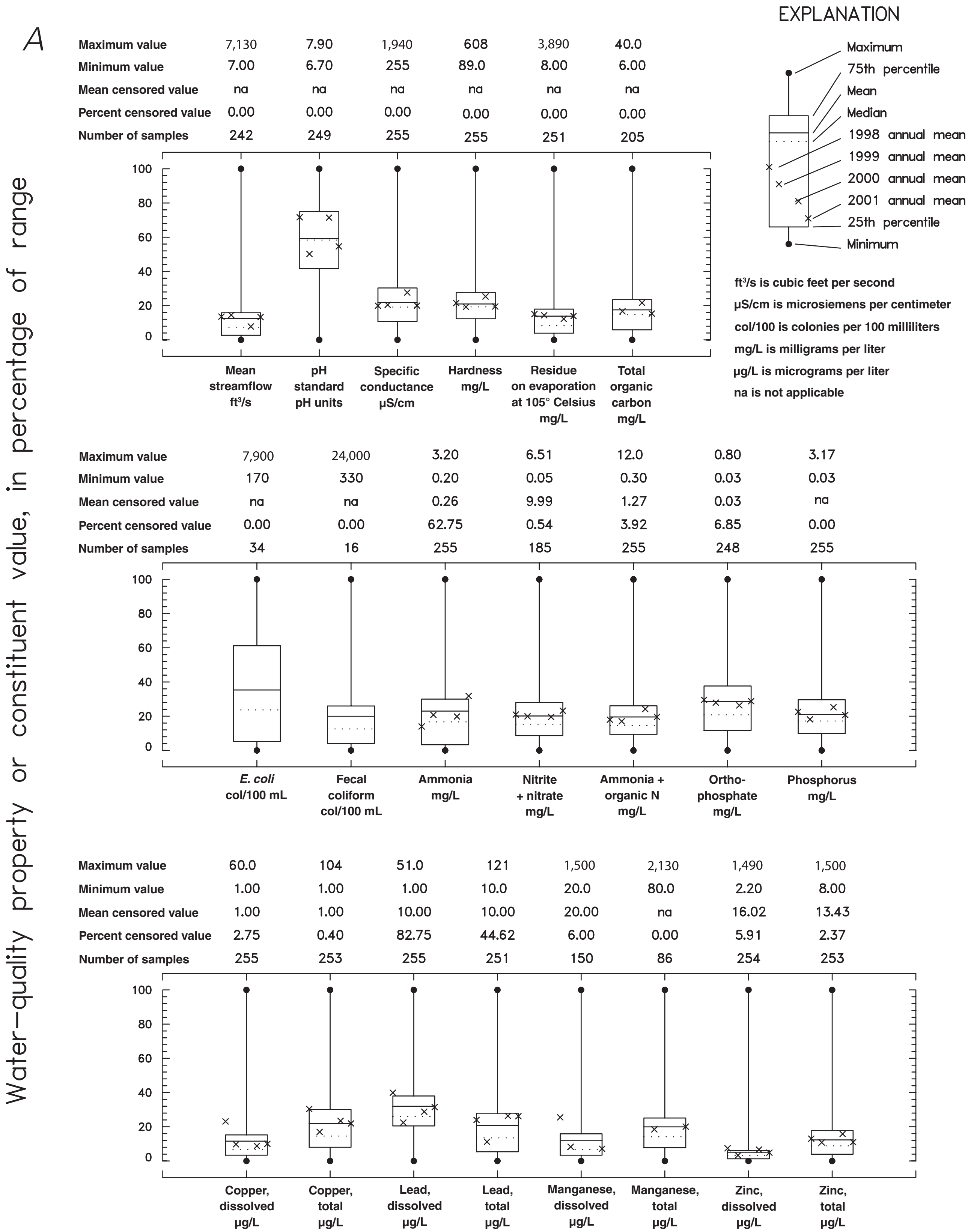
[Phase: W, determination made using whole water; T, total; D, dissolved. Typ: a, all samples regardless of hydrograph position; r, sample from rising limb portion of hydrograph; f, sample from falling limb portion of hydrograph; e, sample from rising and falling limbs of hydrograph; u, unclassified. n, number of samples; M, number of samples with missing values; Pct, percentage of samples below minimum reporting level; Stddev, standard deviation; Skew, skewness; Min, minimum; Max, maximum; ft³/s, cubic feet per second; µS/cm, microsiemens per centimeter at 25 degrees Celsius; C, Celsius; mg/L, milligrams per liter; col, colonies per 100 milliliters; µg/L, micrograms per liter; na, not applicable]

Property or constituent	Phase	Typ	n	M	Pct	Mean	Median	Stddev	Skew	Min	Max	Minimum reporting level	
												Mean	Median
(F) South Platte River at Henderson (07720500)—Continued													
Ammonia + organic nitrogen, in mg/L	T	a	58	0	0.00	3.49	3.10	1.80	1.00	0.50	9.60	na	na
		r	15	0	0.00	4.12	4.10	2.29	0.67	1.10	9.60	na	na
		f	26	0	0.00	3.08	2.50	1.73	1.06	0.50	8.40	na	na
		e	17	0	0.00	3.57	3.40	1.30	0.63	1.80	6.40	na	na
		u	0	na	na	na	na	na	na	na	na	na	na
Phosphorus, in mg/L	T	a	58	0	0.00	1.00	0.95	0.41	0.62	0.36	2.20	na	na
		r	15	0	0.00	1.16	1.18	0.46	0.25	0.42	2.20	na	na
		f	26	0	0.00	0.89	0.83	0.39	0.72	0.36	1.89	na	na
		e	17	0	0.00	1.03	0.94	0.35	0.88	0.57	1.89	na	na
		u	0	na	na	na	na	na	na	na	na	na	na
Orthophosphate, in mg/L	D	a	56	2	1.79	0.43	0.38	0.16	0.64	0.18	0.78	0.03	0.03
		r	14	1	0.00	0.50	0.50	0.20	0.08	0.22	0.78	na	na
		f	25	1	0.00	0.38	0.35	0.12	1.23	0.18	0.75	na	na
		e	17	0	5.88	0.45	0.50	0.15	0.06	0.20	0.76	0.03	0.03
		u	0	na	na	na	na	na	na	na	na	na	na
Copper, in µg/L	D	a	58	0	1.72	10.4	9.00	7.74	1.68	1.00	44.0	1.00	1.00
		r	15	0	6.67	12.7	12.5	10.9	1.43	1.00	44.0	1.00	1.00
		f	26	0	0.00	9.73	9.00	6.33	0.86	1.00	26.0	na	na
		e	17	0	0.00	9.53	8.00	6.60	1.12	2.00	27.0	na	na
		u	0	na	na	na	na	na	na	na	na	na	na
Copper, in µg/L	T	a	57	1	1.75	34.8	32.5	21.1	0.91	9.00	86.0	1.00	1.00
		r	15	0	0.00	39.6	36.0	20.9	0.69	14.00	84.0	na	na
		f	25	1	4.00	34.7	31.0	22.5	0.93	9.00	86.0	1.00	1.00
		e	17	0	0.00	30.8	24.0	19.6	0.94	12.00	72.0	na	na
		u	0	na	na	na	na	na	na	na	na	na	na
Lead, in µg/L	D	a	58	0	70.69	15.0	14.0	6.62	0.19	1.00	27.0	10.0	10.00
		r	15	0	66.67	15.2	14.0	6.98	0.80	10.0	27.0	10.0	10.0
		f	26	0	73.08	16.3	14.0	4.50	0.22	12.0	22.0	10.0	10.0
		e	17	0	70.59	13.0	12.0	9.41	0.24	1.00	27.0	10.0	10.0
		u	0	na	na	na	na	na	na	na	na	na	na
Lead, in µg/L	T	a	56	2	25.00	40.4	34.0	26.4	0.76	10.0	110	10.0	10.0
		r	14	1	21.43	45.4	44.0	26.8	0.96	10.0	110	10.0	10.0
		f	25	1	28.00	43.8	36.0	27.3	0.25	10.0	94.0	10.0	10.0
		e	17	0	23.53	31.5	22.0	24.5	1.35	13.0	89.0	10.0	10.0
		u	0	na	na	na	na	na	na	na	na	na	na
Manganese, in µg/L	D	a	34	24	5.88	186	155	124	1.03	20.0	540	20.0	20.0
		r	7	8	14.29	220	215	143	0.38	30.0	460	20.0	20.0
		f	16	10	6.25	175	150	113	0.56	20.0	400	20.0	20.0
		e	11	6	0.00	183	150	137	1.48	50.0	540	na	na
		u	0	na	na	na	na	na	na	na	na	na	na
Manganese, in µg/L	T	a	19	39	0.00	575	470	353	0.97	160.0	1,470	na	na
		r	5	10	0.00	478	470	178	0.28	270.0	740	na	na
		f	8	18	0.00	669	570	403	0.73	250.0	1,470	na	na
		e	6	11	0.00	530	345	412	0.60	160.0	1,200	na	na
		u	0	na	na	na	na	na	na	na	na	na	na
Zinc, in µg/L	D	a	58	0	6.90	66.8	53.3	42.3	1.03	11.6	172	15.02	20.0
		r	15	0	6.67	71.3	66.2	37.6	0.48	11.6	143	0.10	0.10
		f	26	0	7.69	64.3	53.0	43.5	1.09	15.0	172	20.00	20.0
		e	17	0	5.88	66.7	52.2	46.7	1.13	17.6	170	20.00	20.0
		u	0	na	na	na	na	na	na	na	na	na	na
Zinc, in µg/L	T	a	58	0	0.00	217	192	130	1.19	49.5	687	na	na
		r	15	0	0.00	265	250	161	1.08	66.8	687	na	na
		f	26	0	0.00	208	192	115	1.25	49.5	550	na	na
		e	17	0	0.00	188	131	118	0.35	50.0	380	na	na
		u	0	na	na	na	na	na	na	na	na	na	na

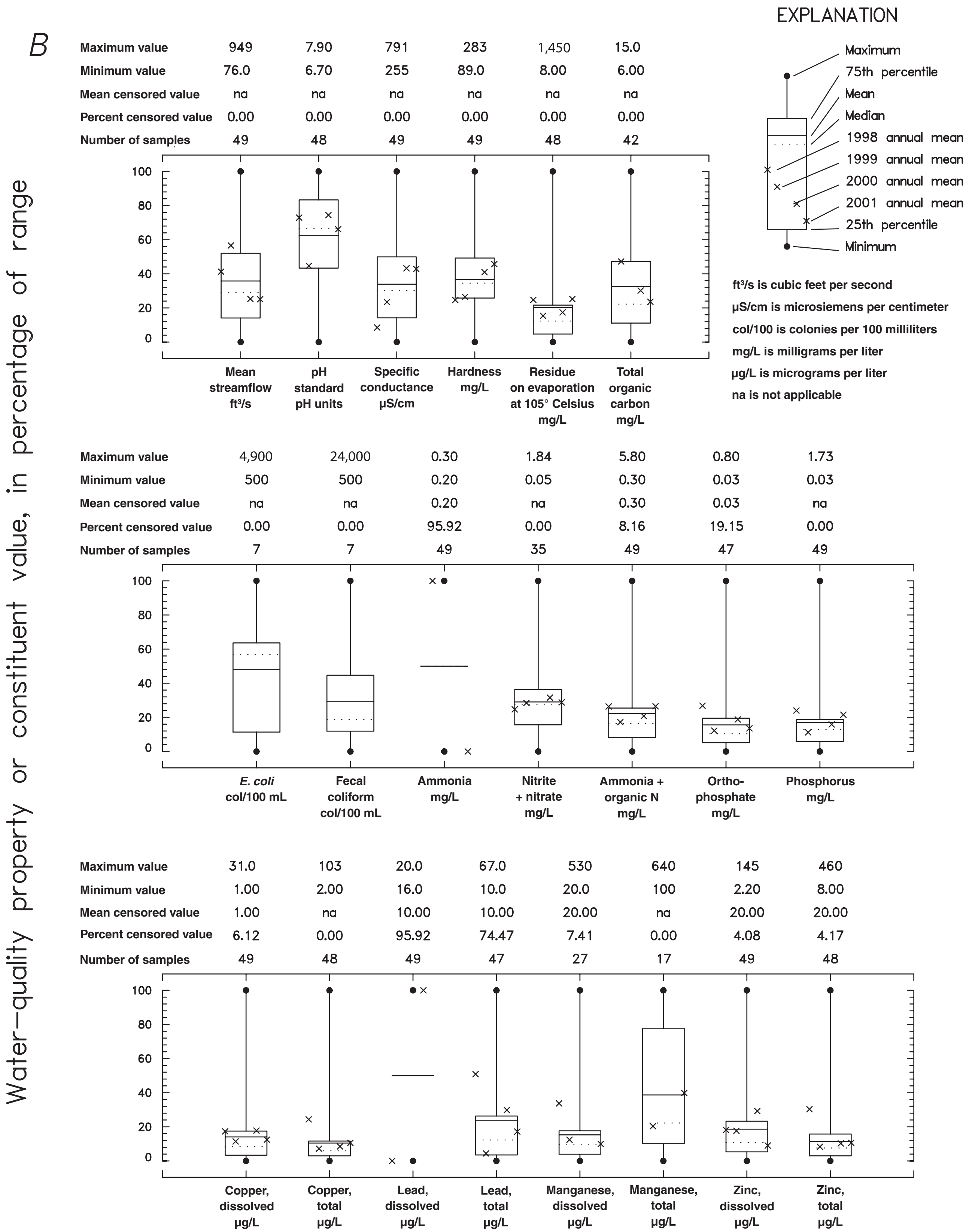


	Mean streamflow ft³/s	pH standard pH units	Specific conductance µS/cm	Hardness mg/L	Residue on evaporation at 105° Celsius mg/L	Total organic carbon mg/L
Maximum value	7,130	7.90	1,940	608	3,890	40.0
Minimum value	7.00	6.70	255	89.0	8.00	6.00
Mean censored value	na	na	na	na	na	na
Percent censored value	0.00	0.00	0.00	0.00	0.00	0.00
Number of samples	242	249	255	255	251	205

	E. coli col/100 mL	Fecal coliform col/100 mL	Ammonia mg/L	Nitrite + nitrate mg/L	Ammonia + organic N mg/L	Ortho-phosphate mg/L	Phosphorus mg/L
Maximum value	7,900	24,000	3.20	6.51	12.0	0.80	3.17
Minimum value	170	330	0.20	0.05	0.30	0.03	0.03
Mean censored value	na	na	0.26	9.99	1.27	0.03	na
Percent censored value	0.00	0.00	62.75	0.54	3.92	6.85	0.00
Number of samples	34	16	255	185	255	248	255

	Copper, dissolved µg/L	Copper, total µg/L	Lead, dissolved µg/L	Lead, total µg/L	Manganese, dissolved µg/L	Manganese, total µg/L	Zinc, dissolved µg/L	Zinc, total µg/L
Maximum value	60.0	104	51.0	121	1,500	2,130	1,490	1,500
Minimum value	1.00	1.00	1.00	10.0	20.0	80.0	2.20	8.00
Mean censored value	1.00	1.00	10.00	10.00	20.00	na	16.02	13.43
Percent censored value	2.75	0.40	82.75	44.62	6.00	0.00	5.91	2.37
Number of samples	255	253	255	251	150	86	254	253

Figure 3. Distribution of water-quality properties and constituents at (*A*) all stations, (*B*) South Platte River below Union Avenue, (*C*) South Platte River at Denver, (*D*) Tollgate Creek above 6th Avenue, (*E*) Sand Creek at mouth, and (*F*) South Platte River at Henderson.



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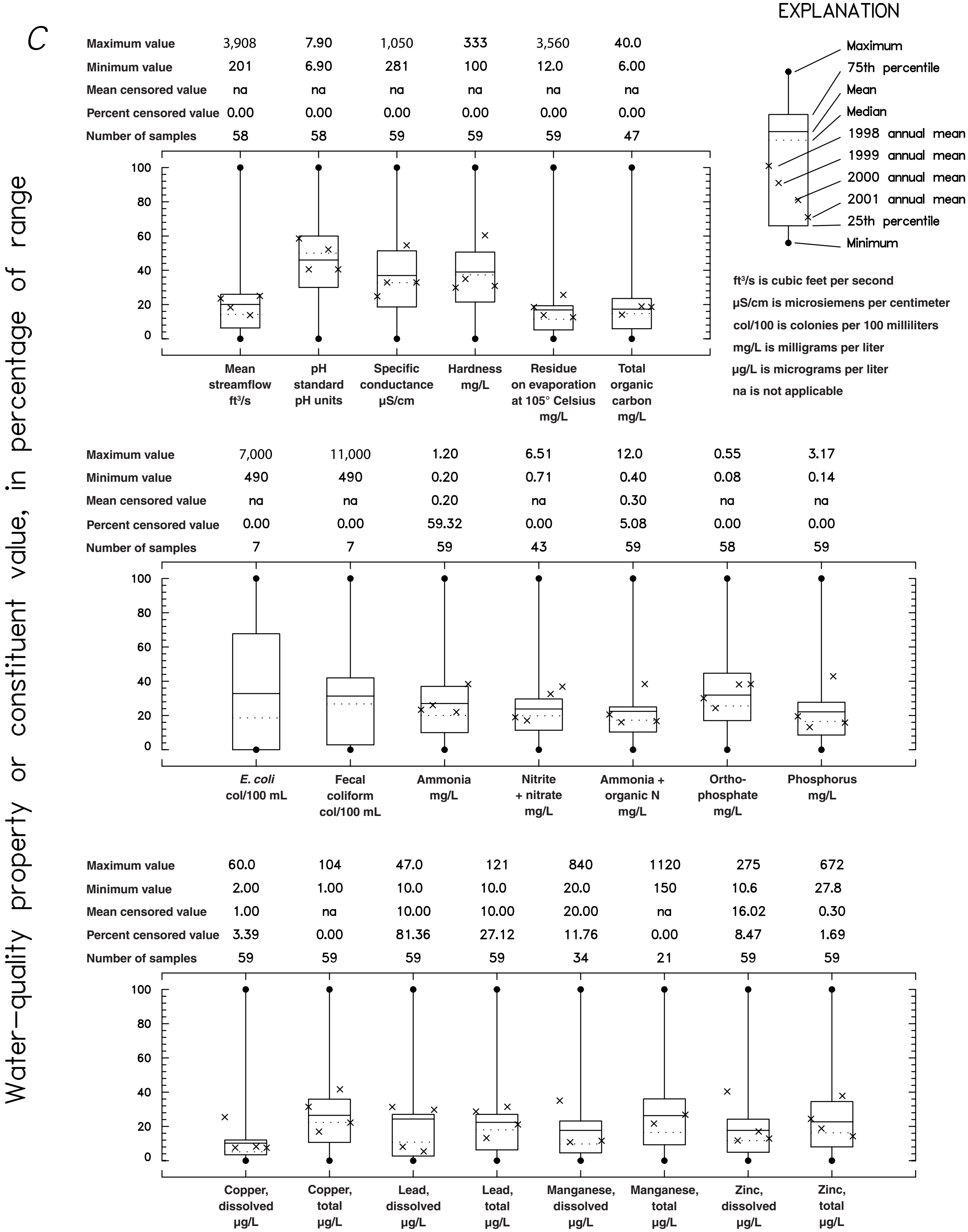

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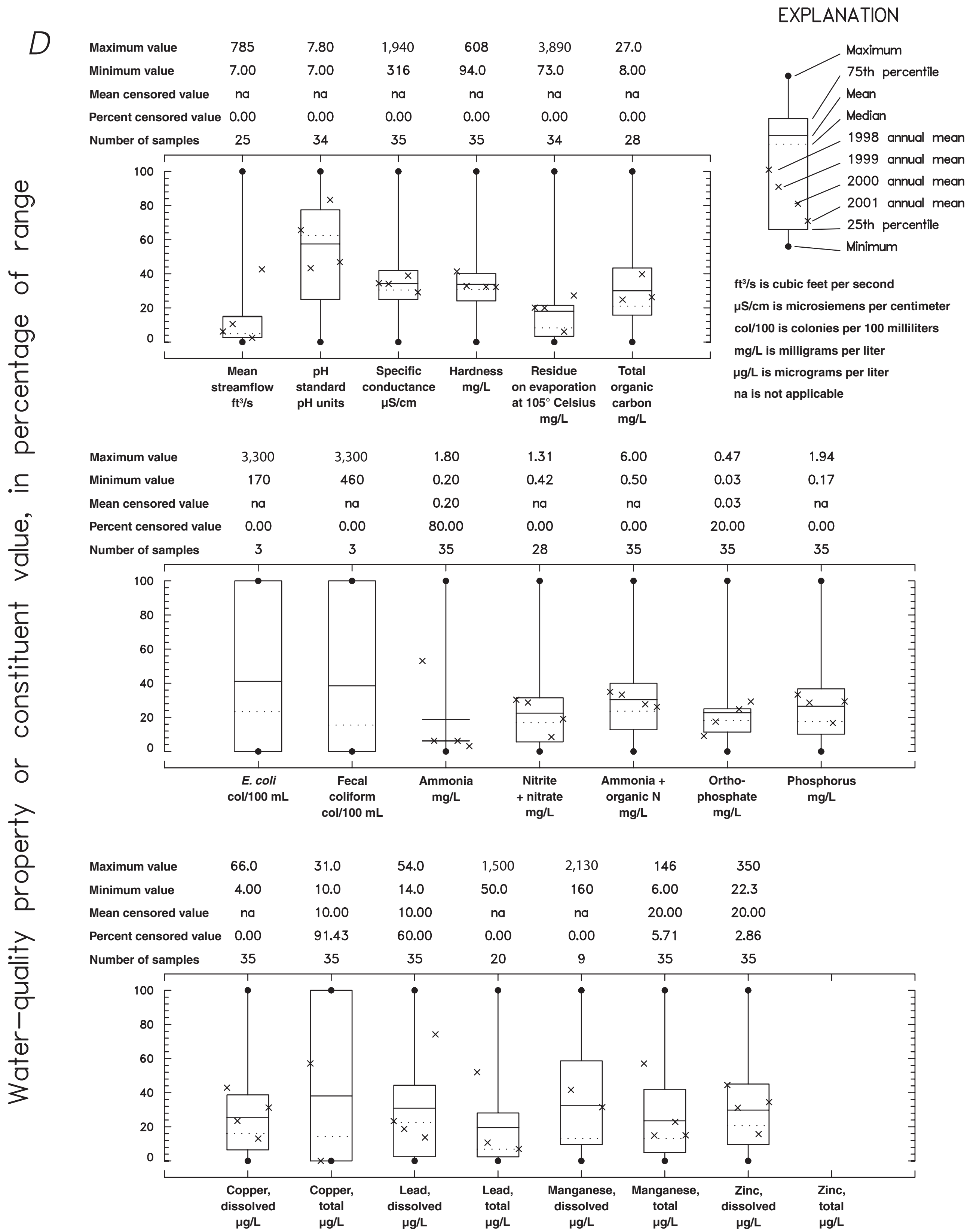

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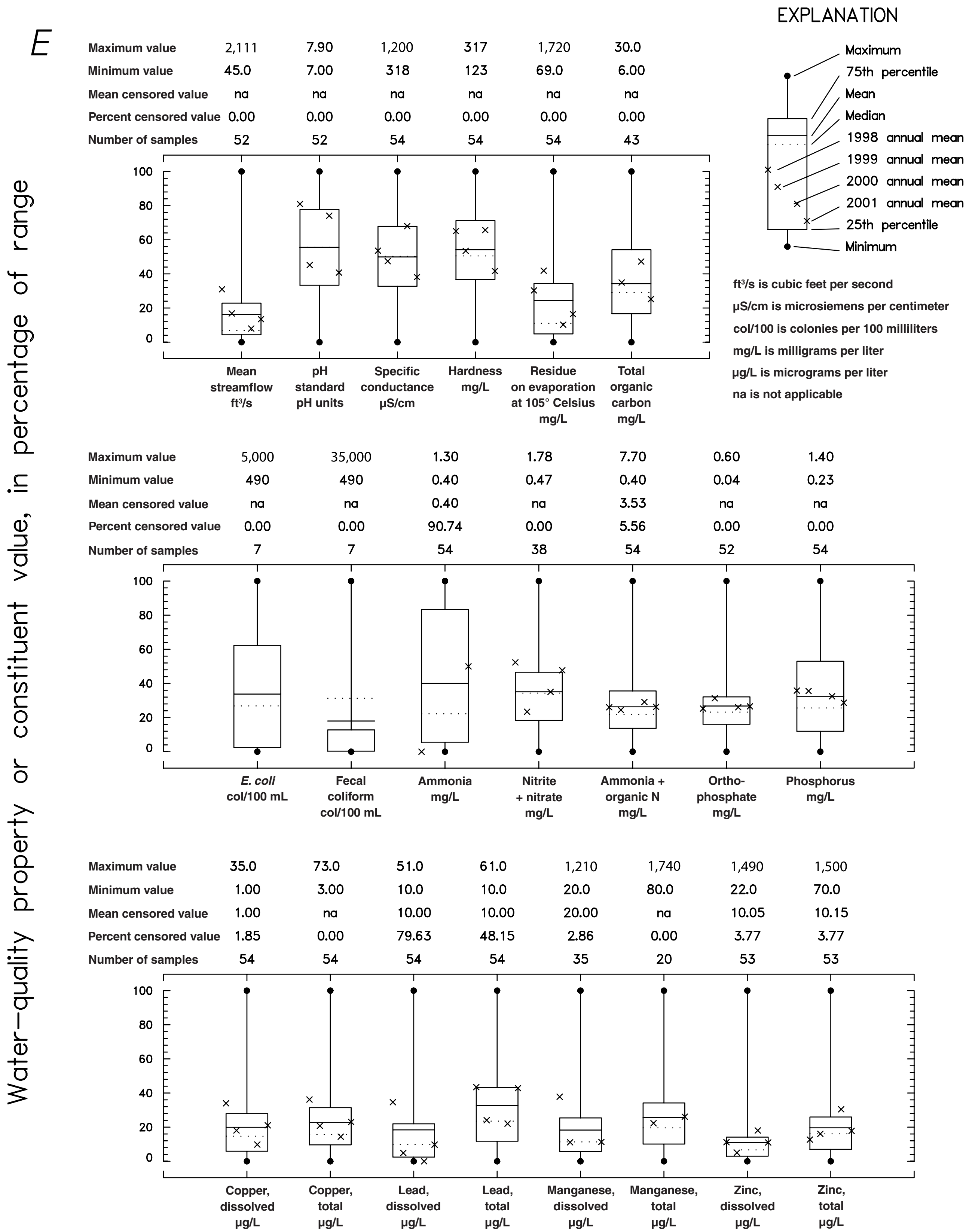

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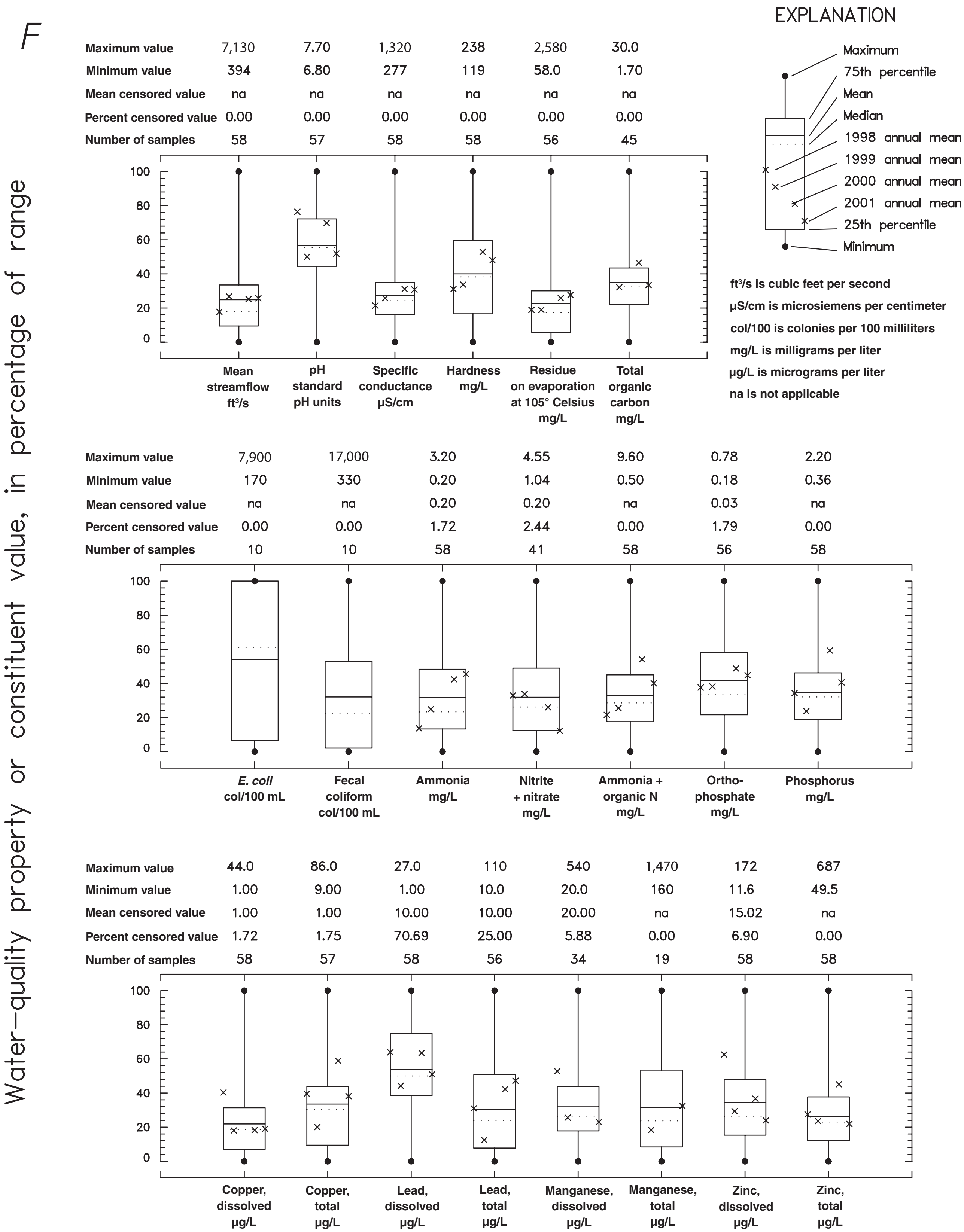

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Discrete Samples

Fifty-two discrete samples were collected during three storms, one at Denver and two at Sand Creek. Hydrographs for each storm were about 7 hours long, and two of the storms had very distinct peaks, whereas one storm had multiple peaks; storm hydrographs are shown in the Appendix (fig. A2). The discrete samples were collected to provide a basis for comparison of time-weighted results to alternative weighting methods. Summaries of results from various weighting methods are presented in table 10, and actual analytical results as well as overall weighted values are in the Appendix (table A2, fig. A2).

Three weighting methods, referred to as "time," "discharge," and "volume," were evaluated to determine the effects of different weighting methods. All weighting computations were made using the general form of equation 2 given in the "Methods of Study" section. Time-weighted results were computed on the basis of the amount of hydrograph time associated with each sample. If sampling intervals are fixed, then time-weighted results are simply the average of all values; however, in the discrete sampling activities presented here, time intervals were not fixed and the hydrograph time associated with each discrete sample was computed on the basis of subdivision methods described by Rantz and others (1982, chapter 15). Discharge-weighted results were computed

Table 10. Summary of relative percent differences and correlations between various weighting methods for analytical determinations of discrete samples.

[All determinations made at USGS National Water-Quality Laboratory. RPD: 1, relative percent difference between time- and discharge-weighted concentrations; 2, relative percent difference between discharge- and volume-weighted concentrations; 3, relative percent difference between time- and volume-weighted concentrations. Stddev, standard deviation; Pct, percentage of samples with a relative percent difference of 20 or less (absolute value); Np, number of water-quality property and constituent pairs in relative percent difference calculation. Phase: W, determination made using whole water; T, total; D, dissolved. Corr, Pearson correlation coefficient; n, number of discrete storm samples; µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; C, Celsius; µg/L, micrograms per liter; na, not applicable]

Relative percent differences from discrete sampling events								
RPD	Mean	Median	Stddev	Skewness	Minimum	Maximum	Pct	Np
All storms								
1	–3.84	–0.98	10.10	–1.12	–35.47	11.72	93.31	52
2	–0.45	–0.34	6.30	0.65	–16.69	24.76	98.01	52
3	3.40	1.33	8.15	1.20	–13.87	31.52	94.23	52
Storm 1, South Platte River at Denver (06710400), July 24, 2001								
1	–8.29	–6.45	12.50	–0.60	–35.47	7.88	88.23	17
2	–2.27	–2.16	4.78	–0.45	–13.57	3.96	100.00	17
3	6.04	1.53	10.63	0.72	–13.87	31.52	88.23	17
Storm 2, Sand Creek at mouth (394839104570300) , August 6, 2001								
1	–2.34	–1.24	4.84	–1.30	–15.58	2.69	100.00	17
2	1.63	0.21	8.65	0.49	–16.69	24.76	94.12	17
3	3.97	1.74	6.00	2.02	–1.12	23.28	94.12	17
Storm 3, Sand Creek at mouth (394839104570300) , August 16, 2001								
1	–1.04	1.88	10.33	–1.01	–25.24	11.72	88.89	18
2	–0.69	0.36	4.43	–0.85	–11.55	3.77	100.00	18
3	0.36	–0.35	6.50	0.62	–12.95	15.06	100.00	18

Correlation coefficients between time- and volume-weighted concentrations from discrete samples collected during three storms									
Property or constituent	Phase	All storms		Storm number (described above)					
				1		2		3	
		Corr	n	Corr	n	Corr	n	Corr	n
All properties and constituents	na	0.68	39	0.96	13	0.94	12	0.96	14
Specific conductance, in µS/cm	W	0.01	39	0.76	13	0.74	12	0.94	14
Hardness, in mg/L	W	0.04	39	0.76	13	0.75	12	0.94	14
Residue at 105 degrees C, in mg/L	T	0.87	39	0.94	13	0.97	12	0.96	14
Organic carbon, in mg/L	T	0.64	26	na	13	0.75	12	0.92	14
Ammonia, in mg/L	T	0.62	39	0.83	13	0.80	12	0.92	14
Nitrite + nitrate, in mg/L	T	0.40	39	0.71	13	0.75	12	0.93	14
Ammonia + organic nitrogen, in mg/L	T	0.22	39	0.77	13	0.73	12	0.88	14
Phosphorus, in mg/L	T	–0.01	39	0.71	13	0.28	12	0.91	14
Orthophosphate, in mg/L	D	0.34	39	0.76	13	0.73	12	0.94	14
Copper, µg/L	D	0.04	39	0.63	13	0.61	12	0.94	14
Lead, µg/L	D	0.22	39	0.64	13	0.71	12	0.92	14
Zinc, µg/L	D	–0.16	39	0.72	13	0.33	12	0.94	14

on the basis of discharge at the time of sample collection. Volume-weighted computations were made on the basis of the product of the subdivided time and streamflow at the time of sample collection. With fixed sampling intervals, the discharge- and volume-weighting methods used in this study are equivalent.

On the basis of the mean and standard deviation for RPDs calculated between time- and volume-weighted results computed in this study, differences between the two weighting methods are consistently small, typically having RPDs with a value of about 1; the RPD was less than 20 in 85 percent of all cases (table 10). In addition, Pearson's correlation coefficients (Pearson, 1901) for time- and volume-weighted results indicate that intrastorm correlations generally were strong and had a mean correlation coefficient of about 0.8. Although relations within a given storm appeared to be strong, relations between storms were much weaker and fit an intuitive model that concentrations from one storm likely are not strong or accurate indicators of concentrations in another storm, regardless of the weighting method. In addition, the central tendency (median) for the RPD typically has a value of about 1, indicating good agreement between the various weighting methods for data collected as part of this study.

The results from discrete samples also indicate that composited values tend to "smooth" results because the composite value represents a weighted mean of values that typically vary through storm hydrographs. For example, the volume-weighted value for specific conductance during the July 23, 2001, storm at Denver was 276 μS/cm at 25°C; however, specific-conductance values from discrete samples through the storm ranged from 200 to 618 μS/cm at 25°C (table A2). In this case, the larger values, which were measured near the beginning and end of storm runoff, indicate that the stormwater generally was more dilute than base flow.

Comparison to Historical Results and Numeric Standards

Results from chemical analyses of composite stormwater samples were compared to available historical data that were screened to represent base flow and to numeric standards established by the CDPHE for segments 14, 15, and 16A of the South Platte River. The results of these comparisons are described in this section.

Historical Results

Historical data, consisting of results obtained before this study began, are available from the USGS National Water Information System (NWIS) for Union, Denver, Sand Creek, and Henderson. The historical NWIS data do not include any data reflecting composited stormwater. Streamflow-screening criteria that eliminated samples collected at streamflows considered elevated compared to base flow (table 11) were implemented before preparing the summary statistics for the historical data. The resultant data, summarized in table 10, represent stable base-flow conditions and indicate that base-flow concentrations for some water-quality properties and constituents were different than concentrations in stormwater runoff.

Differences between concentrations from composite samples and historical samples were determined on the basis of results from all stations pooled together and for individual stations. It is important to note that different stations have varying amounts of historical results. For example, of the water-quality properties and constituents evaluated in this study, only streamflow and specific conductance were available at Union. In addition, most nutrient data are from Henderson, and the historical data include no results for total concentrations of copper, lead, or zinc.

Historical base-flow results from all stations (table 11A) for specific conductance, hardness, ammonia, nitrite plus nitrate, ammonia plus organic nitrogen, phosphorus, and orthophosphate were elevated compared to results from composite samples (table 9A); mean differences for some nutrients were sometimes two or more times different, and the mean difference for specific conductance was about 20 percent. Historical base-flow results from all stations for total organic carbon as well as dissolved copper, lead, and zinc are all low compared to concentrations from composite samples; mean differences for lead and zinc were two or more times different (tables 9 and 11).

Numeric Standards

Results from chemical analyses of composite samples were compared to numeric standards for pH, *Escherichia coli*, fecal coliform, nitrite plus nitrate, dissolved copper, lead, manganese, and zinc, and total manganese (Colorado Department of Public Health and Environment, 2001, 2002). All standards do not apply to all stations. For example, dissolved manganese and nitrite plus nitrate standards for Tollgate or Sand Creek do not exist. The numeric standards for pH, *Escherichia coli*, fecal coliform, nitrite plus nitrate, and dissolved manganese are fixed values and are not designated as either acute or chronic. The numeric standards for dissolved copper, lead, manganese, and zinc are each calculated according to equations provided by the CDPHE (Colorado Department of Public Health and Environment, 2001, 2002); in this study, acute values were used. The calculations for these values, often referred to as "table-value standards," are based on a hardness value; in this study, the hardness associated with the composite sample was used in the calculation. The general form of the equation is an exponentiation using a linear function of the natural log of hardness.

A summary of results from composite samples and bacteriological samples that did not meet or were elevated compared to numeric standards is presented in table 12

Table 11. Summary statistics for historical (before water year 1998) water-quality properties and constituents from (A) all stations, (B) South Platte River below Union Avenue, (C) South Platte River at Denver, (D) Sand Creek at mouth, and (E) South Platte River at Henderson.

[Samples with streamflow values greater than 250 ft^3/s at Union, 400 ft^3/s at Denver, 35 ft^3/s at Sand Creek, and 650 ft^3/s at Henderson were not included in this summary. Phase: W, determination made using whole water; T, total; D, dissolved; n, number of samples, M, number of samples with missing values; Pct, percentage of samples below minimum reporting level; Stddev, standard deviation; Skew, skewness; Min, minimum; Max, maximum; ft^3/s, cubic feet per second; stdu, standard pH units; µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; C, Celsius; µg/L, micrograms per liter; na, not applicable]

Property or constituent	Phase	n	M	Pct	Mean	Median	Stddev	Skew	Min	Max	Minimum reporting level	
											Mean	Median
(A) All stations												
Instantaneous discharge, in ft^3/s	na	255	0	0.00	200	173	148	0.98	5.10	640	na	na
pH, in stdu	W	109	146	0.00	7.58	7.60	0.31	–0.64	6.80	8.20	na	na
Specific conductance, in µS/cm	W	174	81	0.00	1,010	962	365	1.15	436	2,310	na	na
Hardness, in mg/L	T	102	153	0.00	217	220	33.0	–0.33	110	310	na	na
Residue on evaporation at 105 degrees C, in mg/L	T	0	na	na	na	na	na	na	na	na	na	na
Organic carbon, in mg/L	T	5	250	0.00	9.24	9.60	0.84	–0.32	8.10	10.0	na	na
Ammonia, in mg/L	T	29	226	0.00	6.93	5.90	5.18	0.94	0.05	20.0	na	na
Nitrite + nitrate, in mg/L	T	12	243	0.00	3.60	4.05	1.57	–0.66	0.15	5.60	na	na
Ammonia + organic nitrogen, in mg/L	T	116	139	0.86	4.51	3.80	4.10	2.40	0.42	28.0	0.20	0.20
Phosphorus, in mg/L	T	114	141	0.00	1.64	1.50	0.90	0.83	0.27	4.70	na	na
Orthophosphate, in mg/L	D	115	140	0.87	1.34	1.20	0.74	0.66	0.16	3.70	0.01	0.01
Copper, in µg/L	D	32	223	0.00	3.75	3.00	1.41	1.09	1.00	8.00	na	na
Copper, in µg/L	T	0	na	na	na	na	na	na	na	na	na	na
Lead, in µg/L	D	32	223	90.62	1.00	1.00	0.00	0.00	1.00	1.00	1.83	1.00
Lead, in µg/L	T	0	na	na	na	na	na	na	na	na	na	na
Zinc, in µg/L	D	32	223	0.00	23.03	21.00	7.05	0.93	13.00	44.00	na	na
Zinc, in µg/L	T	0	na	na	na	na	na	na	na	na	na	na
(B) South Platte River below Union Avenue (06710247)												
Instantaneous discharge, in ft^3/s	na	18	0	0.00	65.7	62.0	47.3	0.59	5.10	174	na	na
pH, in stdu	W	0	na	na	na	na	na	na	na	na	na	na
Specific conductance, in µS/cm	W	16	2	0.00	685	604	225	0.80	436	1,170	na	na
Hardness, in mg/L	T	0	na	na	na	na	na	na	na	na	na	na
Residue on evaporation at 105 degrees C, in mg/L	T	0	na	na	na	na	na	na	na	na	na	na
Organic carbon, in mg/L	T	0	na	na	na	na	na	na	na	na	na	na
Ammonia, in mg/L	T	0	na	na	na	na	na	na	na	na	na	na
Nitrite + nitrate, in mg/L	T	0	na	na	na	na	na	na	na	na	na	na
Ammonia + organic nitrogen, in mg/L	T	0	na	na	na	na	na	na	na	na	na	na
Phosphorus, in mg/L	T	0	na	na	na	na	na	na	na	na	na	na
Orthophosphate, in mg/L	D	0	na	na	na	na	na	na	na	na	na	na
Copper, in µg/L	D	0	na	na	na	na	na	na	na	na	na	na
Copper, in µg/L	T	0	na	na	na	na	na	na	na	na	na	na
Lead, in µg/L	D	0	na	na	na	na	na	na	na	na	na	na
Lead, in µg/L	T	0	na	na	na	na	na	na	na	na	na	na
Zinc, in µg/L	D	0	na	na	na	na	na	na	na	na	na	na
Zinc, in µg/L	T	0	na	na	na	na	na	na	na	na	na	na
(C) South Platte River at Denver (0671400)												
Instantaneous discharge, in ft^3/s	na	95	0	0.00	186	169	87.0	0.74	42.0	394	na	na
pH, in stdu	W	37	58	0.00	7.71	7.80	0.36	–1.36	6.80	8.20	na	na
Specific conductance, in µS/cm	W	49	46	0.00	831	814	178	0.06	509	1,170	na	na
Hardness, in mg/L	T	35	60	0.00	226	230	39.2	–0.11	150	310	na	na
Residue on evaporation at 105 degrees C, in mg/L	T	0	na	na	na	na	na	na	na	na	na	na
Organic carbon, in mg/L	T	1	94	0.00	8.10	8.10	na	na	8.10	8.10	na	na
Ammonia, in mg/L	T	0	na	na	na	na	na	na	na	na	na	na
Nitrite + nitrate, in mg/L	T	0	na	na	na	na	na	na	na	na	na	na
Ammonia + organic nitrogen, in mg/L	T	43	52	0.00	1.51	1.20	1.38	4.19	0.42	9.30	na	na
Phosphorus, in mg/L	T	43	52	0.00	0.90	0.93	0.41	0.23	0.27	1.80	na	na
Orthophosphate, in mg/L	D	43	52	0.00	0.71	0.75	0.34	0.03	0.16	1.30	na	na
Copper, in µg/L	D	7	88	0.00	3.57	3.00	1.51	1.62	3.00	7.00	na	na
Copper, in µg/L	T	0	na	na	na	na	na	na	na	na	na	na
Lead, in µg/L	D	0	na	na	na	na	na	na	na	na	na	na
Lead, in µg/L	T	0	na	na	na	na	na	na	na	na	na	na
Zinc, in µg/L	D	7	88	0.00	21.9	20.0	6.96	0.67	13.0	35.0	na	na
Zinc, in µg/L	T	0	na	na	na	na	na	na	na	na	na	na

Table 11. Summary statistics for historical (before water year 1998) water-quality properties and constituents from (A) all stations, (B) South Platte River below Union Avenue, (C) South Platte River at Denver, (D) Sand Creek at mouth, and (E) South Platte River at Henderson.—Continued

[Samples with streamflow values greater than 250 ft³/s at Union, 400 ft³/s at Denver, 35 ft³/s at Sand Creek, and 650 ft³/s at Henderson were not included in this summary. Phase: W, determination made using whole water; T, total; D, dissolved; n, number of samples, M, number of samples with missing values; Pct, percentage of samples below minimum reporting level; Stddev, standard deviation; Skew, skewness; Min, minimum; Max, maximum; ft³/s, cubic feet per second; stdu, standard pH units; µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; C, Celsius; µg/L, micrograms per liter; na, not applicable]

Property or constituent	Phase	n	M	Pct	Mean	Median	Stddev	Skew	Min	Max	Minimum reporting level	
											Mean	Median
(D) Sand Creek at mouth (394839104570300)												
Instantaneous discharge, in ft³/s	na	34	0	0.00	21.3	21.0	4.97	0.57	12.0	34.0	na	na
pH, in stdu	W	0	na	na	na	na	na	na	na	na	na	na
Specific conductance, in µS/cm	W	33	1	0.00	1,620	1,650	300	–0.23	910	2,310	na	na
Hardness, in mg/L	T	0	na	na	na	na	na	na	na	na	na	na
Residue on evaporation at 105 degrees C, in mg/L	T	0	na	na	na	na	na	na	na	na	na	na
Organic carbon, in mg/L	T	0	na	na	na	na	na	na	na	na	na	na
Ammonia, in mg/L	T	0	na	na	na	na	na	na	na	na	na	na
Nitrite + nitrate, in mg/L	T	0	na	na	na	na	na	na	na	na	na	na
Ammonia + organic nitrogen, in mg/L	T	2	32	0.00	1.65	1.65	0.92	0.00	1.00	2.30	na	na
Phosphorus, in mg/L	T	2	32	0.00	0.62	0.62	0.39	0.00	0.34	0.89	na	na
Orthophosphate, in mg/L	D	2	32	0.00	0.46	0.46	0.33	0.00	0.23	0.69	na	na
Copper, in µg/L	D	0	na	na	na	na	na	na	na	na	na	na
Copper, in µg/L	T	0	na	na	na	na	na	na	na	na	na	na
Lead, in µg/L	D	0	na	na	na	na	na	na	na	na	na	na
Lead, in µg/L	T	0	na	na	na	na	na	na	na	na	na	na
Zinc, in µg/L	D	0	na	na	na	na	na	na	na	na	na	na
Zinc, in µg/L	T	0	na	na	na	na	na	na	na	na	na	na
(E) South Platte River at Henderson (06720500)												
Instantaneous discharge, in ft³/s	na	108	0	0.00	290	259	153	0.74	44.0	640	na	na
pH, in stdu	W	72	36	0.00	7.51	7.60	0.27	–0.54	6.90	7.90	na	na
Specific conductance, in µS/cm	W	76	32	0.00	929	957	156	–0.50	449	1,220	na	na
Hardness, in mg/L	T	67	41	0.00	213	220	28.5	–1.07	110	260	na	na
Residue on evaporation at 105 degrees C, in mg/L	T	0	na	na	na	na	na	na	na	na	na	na
Organic carbon, in mg/L	T	4	104	0.00	9.52	9.75	0.64	–0.60	8.60	10.0	na	na
Ammonia, in mg/L	T	29	79	0.00	6.93	5.90	5.18	0.94	0.05	20.0	na	na
Nitrite + nitrate, in mg/L	T	12	96	0.00	3.60	4.05	1.57	–0.66	0.15	5.60	na	na
Ammonia + organic nitrogen, in mg/L	T	70	38	0.00	6.43	5.35	4.13	2.69	1.80	28.0	na	na
Phosphorus, in mg/L	T	69	39	0.00	2.13	2.00	0.79	0.99	0.87	4.70	na	na
Orthophosphate, in mg/L	D	69	39	0.00	1.76	1.70	0.62	0.86	0.74	3.70	na	na
Copper, in µg/L	D	25	83	0.00	3.80	3.00	1.41	0.85	1.00	8.00	na	na
Copper, in µg/L	T	0	na	na	na	na	na	na	na	na	na	na
Lead, in µg/L	D	3	105	0.00	1.00	1.00	0.00	0.00	1.00	1.00	na	na
Lead, in µg/L	T	0	na	na	na	na	na	na	na	na	na	na
Zinc, in µg/L	D	25	83	0.00	23.4	22.0	7.18	0.94	13.0	44.0	na	na
Zinc, in µg/L	T	0	na	na	na	na	na	na	na	na	na	na

for all stations pooled together and for individual stations. Exception frequency and magnitude are described in absolute numbers and also as a fraction of the total number of samples with analyses. Exceptions also are characterized as multiple of the actual standard, for magnitude.

The results for all stations pooled together (table 12A) indicate that no exceptions to standards were observed for pH, nitrite plus nitrate, dissolved lead, and total manganese. Fewer bacteriological samples were collected than composite samples (34 bacteriological and 255 composite); however, 100 percent of the bacteriological samples did not meet numeric standards for *Escherichia coli* and fecal coliform. Generally less than 10 percent of the composite samples had exceptions for dissolved copper, dissolved manganese, and dissolved zinc; the exceptions were at Denver where dissolved manganese did not meet the numeric standard in about 27 percent of samples, Sand Creek where dissolved zinc did not meet the numeric standard in about 20 percent of the samples, and at Henderson where dissolved copper did not meet numeric standards in about 12 percent of the samples.

Table 12. Summary of composite and bacteriological sample results not meeting numeric standards for (A) all stations, (B) South Platte River below Union Avenue, (C) South Platte River at Denver, (D) Tollgate Creek above 6th Avenue, (E) Sand Creek at mouth, and (F) South Platte River at Henderson.

[Phase: W, determination made using whole water; T, total; D, dissolved. Typ indicates statistics for: std, numeric standard; dif, difference between composite-stormwater results and numeric standard; pdf, dif divided by numeric standard. n, number of samples; M, number of missing values; Pctc, percentage of determination with concentrations below minimum reporting level; E, number of samples that did not meet numeric standard; Pcte, percentage of determinations with values greater than minimum reporting level that did not meet numeric standard; Stddev, standard deviation; Min, minimum, Max, maximum; col, colonies per 100 milliliters; mg/L, milligrams per liter; µg/L, micrograms per liter]

Property or constituent	Phase	Typ	n	M	Pctc	E	Pcte	Mean	Median	Stddev	Skewness	Min	Max
(A) All stations													
pH, in standard pH units	W	std	249	6	0.00	0	0.00	No exceptions to standard.					
		dif						The pH standard specifies pH should be in the range of 6.5					
		pdf						to 9.0.					
Escherichia coli, in col	W	std	34	0	0.00	34	100.00	126	126	0	0.00	126	126.00
		dif						4,540	2,670	6,680	2.94	44.0	34,900
		pdf						36.0	21.2	53.0	2.94	0.35	277
Fecal coliform, in col	W	std	34	0	0.00	34	100.00	200	200	0	0.00	200	200
		dif						5,290	3,100	7,400	2.38	130	34,800
		pdf						26.4	15.5	37.0	2.38	0.65	174
Nitrite + nitrate, in mg/L	T	std	185	70	0.54	0	0.00	No exceptions to standards.					
		dif						The nitrite plus nitrate standards specify that nitrite plus					
		pdf						nitrate should not exceed 10.5 (segments 14 and 16A) or 11 (segment 15).					
Copper, in µg/L	D	std	255	0	2.75	15	6.05	22.1	21.2	4.74	0.47	15.8	32.1
		dif						7.03	3.93	9.36	1.92	0.17	34.5
		pdf						0.30	0.15	0.39	1.81	0.01	1.4
Lead, in µg/L	D	std	255	0	82.75	0	0.00	No exceptions to standard.					
		dif						The dissolved lead standard is specified as a table-value					
		pdf						standard.					
Manganese, in µg/L	D	std	150	105	6.00	12	8.51	225	190	81.7	1.57	190	400
		dif						189	130	185	1.16	20.0	650
		pdf						0.96	0.00	1.00	1.15	0.11	3.42
Manganese, in µg/L	T	std	86	169	0.00	0	0.00	No exceptions to standard.					
		dif						The total manganese standard is specified as a table-value					
		pdf						standard.					
Zinc, in µg/L	D	std	254	1	5.91	15	6.28	224	225	42.8	–0.15	151	299
		dif						173.0	66.8	311	2.47	2.32	1,220
		pdf						0.68	0.27	1.14	2.36	0.01	4.45
(B) South Platte River below Union Avenue (06710247)													
pH, in standard pH units	W	std	48	1	0.00	0	0.00	No exceptions to standard.					
		dif						The pH standard specifies pH should be in the range of 6.5					
		pdf						to 9.0.					
Escherichia coli, in col	W	std	7	0	0.00	7	100.00	126	126	0	0.00	126	126
		dif						5,340	3,170	4,690	0.58	374	12,900
		pdf						42.4	25.2	37.2	0.58	2.97	102
Fecal coliform, in col	W	std	7	0	0.00	7	100.00	200	200	0	0.00	200	200
		dif						7,210	4,700	7,990	1.15	300	23,800
		pdf						36.1	23.5	39.9	1.15	1.50	119
Nitrite + nitrate, in mg/L	T	std	35	14	0.00	0	0.00	No exceptions to standard.					
		dif						The nitrite plus nitrate standard specifies that nitrite plus					
		pdf						nitrate should not exceed 11.					
Copper, in µg/L	D	std	49	0	6.12	2	4.35	22.7	22.7	4.69	0.00	19.4	26.0
		dif						3.74	3.74	1.68	0.00	2.56	4.93
		pdf						0.16	0.16	0.04	0.00	0.13	0.19
Lead, in µg/L	D	std	49	0	95.92	0	0.00	No exceptions to standard.					
		dif						The dissolved lead standard is specified as a table-value					
		pdf						standard.					
Manganese, in µg/L	D	std	27	22	7.41	2	8.00	190	190	0.00	0.00	190	190
		dif						200	200	198	0.00	60.0	340
		pdf						1.05	1.05	1.04	0.00	0.32	1.79
Manganese, in µg/L	T	std	17	32	0.00	0	0.00	No exceptions to standard.					
		dif						The total manganese standard is specified as a table-value					
		pdf						standard.					
Zinc, in µg/L	D	std	49	0	4.08	0	0.00	No exceptions to standard.					
		dif						The dissolved zinc standard is specified as a table-value					
		pdf						standard.					

Table 12. Summary of composite and bacteriological sample results not meeting numeric standards for (A) all stations, (B) South Platte River below Union Avenue, (C) South Platte River at Denver, (D) Tollgate Creek above 6th Avenue, (E) Sand Creek at mouth, and (F) South Platte River at Henderson.—Continued

[Phase: W, determination made using whole water; T, total; D, dissolved. Typ indicates statistics for: std, numeric standard; dif, difference between composite-stormwater results and numeric standard; pdf, dif divided by numeric standard. n, number of samples; M, number of missing values; Pctc, percentage of determination with concentrations below minimum reporting level; E, number of samples that did not meet numeric standard; Pcte, percentage of determinations with values greater than minimum reporting level that did not meet numeric standard; Stddev, standard deviation; Min, minimum, Max, maximum; col, colonies per 100 milliliters; mg/L, milligrams per liter; µg/L, micrograms per liter]

Property or constituent	Phase	Typ	n	M	Pctc	E	Pcte	Mean	Median	Stddev	Skew-ness	Min	Max
(C) South Platte River at Denver (06714000)													
pH, in standard pH units	W	std	58	1	0.00	0	0.00	No exceptions to standard.					
		dif						The pH standard specifies pH should be in the range of 6.5 to 9.0.					
		pdf											
Escherichia coli, in col	W	std	7	0	0.00	7	100.00	126	126	0	0.00	126	126
		dif						2,500	1,570	2,560	0.56	364	6,870
		pdf						19.8	12.5	20.3	0.56	2.89	54.6
Fecal coliform, in col	W	std	7	0	0.00	7	100.00	200	200	0	0.00	200	200
		dif						3,580	3,100	3,690	0.84	290	10,800
		pdf						17.9	15.5	18.5	0.84	1.45	54
Nitrite + nitrate, in mg/L	T	std	43	16	0.00	0	0.00	No exceptions to standard.					
		dif						The nitrite plus nitrate standard specify that nitrite plus nitrate should not exceed 11.					
		pdf											
Copper, in µg/L	D	std	59	0	3.39	2	3.51	25.0	25.0	0.61	0.00	24.6	25.5
		dif						18.0	18.0	23.4	0.00	1.40	34.5
		pdf						0.71	0.71	0.92	0.00	0.06	1.36
Lead, in µg/L	D	std	59	0	81.36	0	0.00	No exceptions to standard.					
		dif						The dissolved lead standard is specified as a table-value standard.					
		pdf											
Manganese, in µg/L	D	std	34	25	11.76	8	26.67	190	190	0	0.00	190	190
		dif						209	140	213	0.92	20.0	650
		pdf						1.10	0.74	1.12	0.92	0.11	3.42
Manganese, in µg/L	T	std	21	38	0.00	0	0.00	No exceptions to standard.					
		dif						The total manganese standard is specified as a table-value standard.					
		pdf											
Zinc, in µg/L	D	std	59	0	8.47	2	3.70	185	185	32.3	0.00	162	208
		dif						42.2	42.2	34.8	0.00	17.6	66.8
		pdf						0.21	0.21	0.15	0.00	0.11	0.32
(D) Tollgate Creek at 6th Avenue (394329104490101)													
pH, in standard pH units	W	std	34	1	0.00	0	0.00	No exceptions to standard.					
		dif						The pH standard specifies pH should be in the range of 6.5 to 9.0.					
		pdf											
Escherichia coli, in col	W	std	3	0	0.00	3	100.00	126	126	0	0.00	126	126
		dif						1,330	774	1,640	0.30	44.0	3,170
		pdf						10.6	6.14	13.0	0.30	0.35	25.2
Fecal coliform, in col	W	std	3	0	0.00	3	100.00	200	200	0	0.00	200	200
		dif						1,350	700	1,530	0.35	260	3,100
		pdf						6.77	3.50	7.64	0.35	1.30	15.5
Copper, in µg/L	D	std	35	0	0.00	1	2.86	32.1	32.1	0.00	0.00	32.1	32.1
		dif						7.89	7.89	0.00	0.00	7.89	7.89
		pdf						0.25	0.25	0.00	0.00	0.25	0.25
Lead, in µg/L	D	std	35	0	91.43	0	0.00	No exceptions to standard.					
		dif						The dissolved lead standard is specified as a table-value standard.					
		pdf											
Manganese, in µg/L	T	std	9	26	0.00	0	0.00	No exceptions to standard.					
		dif						The total manganese standard is specified as a table-value standard.					
		pdf											
Zinc, in µg/L	D	std	35	0	5.71	0	0.00	No exceptions to standard.					
		dif						The dissolved zinc standard is specified as a table-value standard.					
		pdf											

Table 12. Summary of composite and bacteriological sample results not meeting numeric standards for (A) all stations, (B) South Platte River below Union Avenue, (C) South Platte River at Denver, (D) Tollgate Creek above 6th Avenue, (E) Sand Creek at mouth, and (F) South Platte River at Henderson.—Continued

[Phase: W, determination made using whole water; T, total; D, dissolved. Typ indicates statistics for: std, numeric standard; dif, difference between composite-stormwater results and numeric standard; pdf, dif divided by numeric standard. n, number of samples; M, number of missing values; Pctc, percentage of determination with concentrations below minimum reporting level; E, number of samples that did not meet numeric standard; Pcte, percentage of determinations with values greater than minimum reporting level that did not meet numeric standard; Stddev, standard deviation; Min, minimum, Max, maximum; col, colonies per 100 milliliters; mg/L, milligrams per liter; µg/L, micrograms per liter]

Property or constituent	Phase	Typ	n	M	Pctc	E	Pcte	Mean	Median	Stddev	Skew-ness	Min	Max
(E) Sand Creek at mouth (394839104570300)													
pH, in standard pH units	W	std	52	2	0.00	0	0.00	No exceptions to pH standards.					
		dif						The pH standard specifies pH should be in the range of 6.5 to 9.0.					
		pdf											
Escherichia coli, in col	W	std	7	0	0.00	7	100.00	126	126	0.00	0.00	126	126
		dif						6,170	1,570	12,690	1.60	364	34,900
		pdf						49.0	12.5	101	1.60	2.89	277
Fecal coliform, in col	W	std	7	0	0.00	7	100.00	200	200	0.00	0.00	200	200
		dif						6,500	1,100	12,600	1.57	290	34,800
		pdf						32.5	5.50	62.9	1.57	1.45	174
Copper, in µg/L	D	std	54	0	1.85	3	5.66	24.7	26.1	4.19	–0.28	20.0	28.1
		dif						4.58	3.93	2.04	0.29	2.94	6.87
		pdf						0.18	0.15	0.06	0.38	0.15	0.24
Lead, in µg/L	D	std	54	0	79.63	0	0.00	No exceptions to dissolved lead standard.					
		dif						The dissolved lead standard is specified as a table-value standard.					
		pdf											
Manganese, in µg/L	T	std	20	34	0.00	0	0.00	No exceptions to total manganese standard.					
		dif						The total manganese standard is specified as a table-value standard.					
		pdf											
Zinc, in µg/L	D	std	53	1	3.77	11	21.57	243.6	238	29.4	0.33	197	299
		dif						226.3	81.1	351.3	1.95	2.32	1,220
		pdf						0.87	0.37	1.29	1.84	0.01	4.45
(F) South Platte River at Henderson (06720500)													
pH, in standard pH units	W	std	57	1	0.00	0	0.00	No exceptions to pH standard.					
		dif						The pH standard specifies pH should be in the range of 6.5 to 9.0.					
		pdf											
Escherichia coli, in col	W	std	10	0	0.00	10	100.00	126	126	0.00	0.00	126	126
		dif						5,220	4,774	5,180	0.88	44.0	16,900
		pdf						41.5	39.0	41.1	0.88	0.35	133
Fecal coliform, in col	W	std	10	0	0.00	10	100.00	200	200	0.00	0.00	200	200
		dif						5,480	3,900	5,650	0.76	130	16,800
		pdf						27.4	19.5	28.3	0.76	0.65	84.0
Nitrite + nitrate, in mg/L	T	std	41	17	2.44	0	0.00	No exceptions to nitrite and nitrate standards.					
		dif						The nitrite and nitrate standards specify that nitrite + nitrate should not exceed 11.					
		pdf											
Copper, in µg/L	D	std	58	0	1.72	7	12.28	18.5	17.8	2.17	0.15	15.8	21.2
		dif						5.77	2.42	7.91	1.32	0.17	22.8
		pdf						0.28	0.15	0.37	1.29	0.01	1.08
Lead, in µg/L	D	std	58	0	70.69	0	0.00	No exceptions to dissolved lead standard.					
		dif						The dissolved lead standard is specified as a table-value standard.					
		pdf											
Manganese, in µg/L	D	std	34	24	5.80	2	6.25	400	400	0.00	0.00	400	400
		dif						100	100	56.6	0.00	60.0	140
		pdf						0.25	0.25	0.14	0.00	0.15	0.35
Manganese, in µg/L	T	std	19	39	0.00	0	0.00	No exceptions to total manganese standard.					
		dif						The total manganese standard is specified as a table-value standard.					
		pdf											
Zinc, in µg/L	D	std	58	0	6.90	2	3.70	158	158.2	9.98	0.00	151	165
		dif						10.8	10.8	8.57	0.00	4.77	17.0
		pdf						0.07	0.07	0.06	0.00	0.03	0.11

Evaluation of Stormwater Quality

Results from chemical analyses of composite samples are evaluated in this section by using a preliminary examination of annual means and two statistical methods. The goal of the evaluations is to establish criteria that may be compared with results from future sampling.

Annual Means

Composite samples collected as part of this study describe the quality of stormwater runoff during a 4-year period. It can be desirable to evaluate data collected over a period of several years to determine if the data describe trends; identification of simple monotonic trends, in which values tend to show upward or downward changes through time, is a common goal of such evaluations. In addition, it is important to determine the presence or absence of stationarity (that is, the absence of trends) before pursuing additional statistical evaluations. If data are not stationary, then adjustments, such as developing trend-free regression residuals, are typically made as a precursor to additional analyses.

Data from composite samples collected as part of this study were evaluated to determine if trend testing was appropriate. The data were found to have considerable annual ranges (table A3) that were interpreted as seasonal variations that occur on an annual cycle; these seasonal patterns essentially are local trends that cannot be readily explained by data collected as part of this study. Rather than contrive explanations for the seasonal variations, we aggregated the data into annual means for further evaluation.

A visual scan of the annual means, which are shown in figure 3, indicates no obvious monotonic trends for most water-quality properties and constituents at all five stations. There are, however, some exceptions that may indicate monotonic trends. Annual means for specific conductance and hardness at Union, orthophosphate at Tollgate, and specific conductance and ammonia at Henderson all indicate a consistent increase, or upward monotonic trend, through the data-collection period. In addition, total organic carbon at Union, organic nitrogen plus ammonia at Tollgate, and total phosphorus at Sand Creek all indicate a consistent decrease, or downward monotonic trend.

Tolerance Intervals

Tolerance intervals specifying lower and upper bounds that contain a specified portion of a given distribution, referred to as "coverage," can be defined on the basis of samples from the distribution. Typically, tolerance intervals are reported for a specified coverage with an associated confidence. A symmetrical, two-sided, 99-percent coverage tolerance interval with 95-percent confidence, for example, is a 95-percent confident estimate of an interval that contains 99 percent, from the 0.5 percentile to the 99.5 percentile, of the entire population. Because such a tolerance interval covers 99 percent of the distribution, only 1 sample out of 100 would be expected to fall outside the defined interval. If 2 samples out of 100 were to fall outside of the defined interval, that would be some indication, at 95-percent confidence, that there has been a change in the distribution. Two-sided tolerance intervals for a specified percent coverage at 95-percent confidence were computed in this study to establish a baseline for future comparisons. In all cases, except those using nonparametric computations described in the "Computations" section, the specified coverage was 99 percent.

Computations

A brief description of the methods used to compute tolerance intervals in this study is presented here. Computations were complicated by the presence of censored data, multiple censoring levels, and data that did not meet normality criteria. More detailed descriptions of the methods used are in publications by Hahn and Meeker (1991), Gibbons (1994), and the U.S. Environmental Protection Agency (1989, 1992).

For trend-free data that have no censored values and are normally distributed, conventional statistical methods can be used to compute a tolerance interval on the basis of the number of samples, mean, and standard deviation. Tolerance intervals were not calculated for water-quality properties and constituents that indicated monotonic trends as discussed in the "Annual Means" section of this report. In addition, some data from this study have censored values, and the percentage of censored data (table 9) was used to determine tolerance-interval computation methods. If less than 60 percent of the data was censored, then maximum likelihood estimation (MLE) methods utilizing Cohen's adjustment (Hahn and Meeker, 1991; Gibbons, 1994) were used to compute tolerance intervals. If 60 percent or more of the data were censored, then parametric methods were deemed as inappropriate and nonparametric methods were used to compute tolerance intervals.

Before MLE methods were implemented, data with multiple censoring levels were recensored to the most elevated censoring level. Following recensoring, MLE methods were used to estimate the characteristics of the distribution below the censoring level and to make an estimate of the mean and standard deviation, which are used in the conventional tolerance-interval computation. Nonparametric methods used in this study set the lower and upper tolerance-interval bounds to minima and maxima and then compute a new coverage.

Data were evaluated for normality on the basis of skewness by using methods described by Fisher and Potter (1989) that define normality on the basis of skewness and the number of samples. Data that did not meet normality criteria were modified with a natural log transform and then compared to normality criteria again. Tolerance intervals for transformed data that did not meet normality criteria were calculated using nonparametric methods.

Computed Tolerance Intervals

The results of tolerance-interval computations are listed in table 13 by station. About 53 percent, or most, of the computations were made by using conventional methods with no adjustments; about 23 percent of the computations were made using Cohen's adjustment, and the remaining 24 percent were made using nonparametric methods. The use of nonparametric methods effected a decrease, from 99 percent, to the specified coverage; because the number of samples is generally on the order of about 50, specified coverages were usually 90 percent or larger. For bacteriological data at Tollgate, however, the specified coverage dropped to about 37 percent.

Minima and maxima and the number of samples are included in table 13 for comparison purposes. It is important to note that the specified coverages for tolerance intervals computed with nonparametric methods (about 37 to 95 percent) have upper and lower bounds that are closer to the central tendency (elevated compared to minimum and lowered compared to maximum) than those from parametric methods (99 percent). As additional data become available, they can be compared to tolerance intervals computed in this study. For example, repeated stormwater results for specific conductance at Denver (table 13B) at a level above the upper tolerance-interval bound (1,400 µS/cm at 25°C) would indicate a change in the distribution of stormwater specific conductance.

Regression Relations

Tolerance intervals are useful for identifying changes near the extremes of a given distribution. If, for example, new samples indicate values that are elevated compared to the upper bound of the tolerance interval, then the tolerance interval would be an effective means to quantify that a new population is being sampled.

Tolerance intervals, however, may not quantify changes that cause a given water-quality constituent to have a new distribution that is "within" the existing distribution (intradistribution). For example, if a best-management practice caused a reduction in elevated concentrations for a water-quality constituent, that would create a new distribution for the given constituent that has a reduced maximum and the new maximum would be within any previously defined tolerance interval. If, however, the given constituent had a linear relation with another constituent that was not affected by the best-management practice, then the nature of the regression would change, and that change could be used to help identify intradistribution changes.

Relations among water-quality properties and constituents were evaluated to identify any linear regressions that could be useful in quantifying future intradistribution changes. Linear regressions and correlation coefficients were calculated for all possible pairs and then, for regressions, screened on the basis of 95-percent significance, and the magnitude of the coefficient of determination, a statistic commonly referred to as "r squared (r^2)" was calculated. In addition, each regression pair was evaluated using three different transform scenarios: (1) no transform, (2) a natural log transform on one variable, and (3) a natural log transform on both variables; the regression with the largest r^2 value was selected. If an r^2 value was 0.65 or greater for any one of the five stations and was 95-percent significant, the regression is referred to as "screened" because it met screening criteria. When a screened regression was identified for any station in the network, additional 95-percent significant regressions, using the transform with the highest r^2 value, for all remaining stations were included and referred to as "associated." In addition, the correlation coefficient, which may be used as a surrogate for r^2 (r^2 is the square of the correlation coefficient) is shown for all possible pairs of water-quality properties and constituents in table A4.

The screened (bold) and associated 95-percent significant regressions are presented in table 14. The screened regressions include 26 pairs (out of a possible 231) of water-quality properties and constituents. Table 14 includes 95-percent confidence bounds on the slope to enable computation of 95-percent confidence bounds for regression-predicted values. Only a few of the screened regressions have r^2 values greater than 0.8, and these relatively strong regressions typically occur only at a few stations rather than at all stations. For example, total lead with total manganese at Henderson and total copper with total manganese at Henderson have relatively strong regressions. Other examples of relatively strong regressions (r^2 greater than 0.8) at only one station involve residue on evaporation at 105°C with total manganese and with total lead. Only one pair, total manganese with total zinc, had relatively strong regressions at several stations (Union, Denver, and Henderson). In general, relatively strong regressions, for a given pair, do not consistently occur at all stations, indicating that the system is not spatially consistent and that the system is heterogeneous.

Another important characteristic of the reported regressions is that for regressions such as mean streamflow with specific conductance, which intuitively would be expected to have a strong inverse (negative slope) regression due to the addition of large amounts of dilute (low specific conductance) water (precipitation), the Pearson correlation coefficient is not very strong (median correlation coefficient of –0.543 [between –0.526 and –0.559], table A4). One possible explanation for this is that the regression of mean streamflow with specific conductance in a receiving stream such as the South Platte River is dependent on conditions in several contributing tributaries. Consequently, rather than a simple model in which an inverse relation between mean streamflow and specific conductance is based largely on a uniform source of relatively dilute precipitation, the model becomes more complex due to mixing introduced by contributions from tributaries with unique mean streamflow and specific conductances.

Table 13. Tolerance intervals computed for physical properties and constituents at 99-percent coverage with 95-percent confidence at (A) South Platte River below Union Avenue, (B), South Platte River at Denver, (C) Tollgate Creek above 6th Avenue, (D) Sand Creek at mouth, and (F) South Platte River at Henderson.

[Phase: W, determination made using whole water; T, total; D, dissolved. I, transform indicator: 0, not applicable, 1, natural log transform; 2, no transform. Type indicates amount of censored values and method used to calculate tolerance intervals: 1, no censored values and regular computation; 2, less than 90-percent censored values and computed using Cohen's adjustment for censored values; 4, greater than 90-percent censored values and nonparametric computation; 5, normal distribution assumptions not met, nonparametric computation. n, number of samples; ft³/s, cubic feet per second; µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; C, Celsius; col, colonies per 100 milliliters; µg/L, micrograms per liter; na, not applicable]

Property or constituent	Phase	I	Type	n	Maximum	Upper bound tolerance interval	Minimum	Lower bound tolerance interval	Non-paramet-ric cover-age
(A) South Platte River below Union Avenue (06710247)									
Mean discharge, in ft³/s	na	1	1	49	949	2,770	76.0	36.41	na
Discharge volume, in acre-feet	na	2	1	49	780	1,010	68.0	68.0	na
pH, in standard units	W	2	1	48	7.90	8.36	6.70	6.54	na
Specific conductance, in µS/cm	W	1	1	49	791	na	255	na	na
Hardness, in mg/L	T	1	1	49	283	na	89.0	na	na
Residue on evaporation at 105 degrees C, in mg/L	T	1	1	48	1,450	6,650	8.00	3.97	na
Organic carbon, in mg/L	T	1	1	42	15.0	na	6.00	na	na
Escherichia coli, in col	W	2	1	7	4,900	10,500	500	500	na
Fecal coliform, in col	W	1	1	7	4,000	2,420,000	500	8.17	na
Ammonia, in mg/L	T	0	4	49	0.30	0.30	0.20	0.20	94.10
Nitrite + nitrate, in mg/L	T	0	5	35	1.84	1.84	0.05	0.05	91.80
Ammonia + organic nitrogen, in mg/L	T	1	2	49	5.80	13.6	0.30	0.08	na
Phosphorus, in mg/L	T	1	1	49	1.73	4.27	0.03	0.01	na
Orthophosphate, in mg/L	D	0	5	47	0.80	0.80	0.03	0.03	93.80
Copper, in µg/L	D	1	2	49	31.0	61.9	1.00	0.17	na
Copper, µg/L	T	0	5	48	103	103	2.00	2.00	93.90
Lead, in µg/L	D	0	4	49	20.0	20.0	16.0	16.0	94.10
Lead, in µg/L	T	0	5	47	67.0	67.0	10.0	10.0	93.80
Manganese, in µg/L	D	1	2	27	530	1,150	20.0	3.49	na
Manganese, in µg/L	T	1	1	17	640	2,700	100	24.0	na
Zinc, in µg/L	D	0	5	49	145	145	2.20	2.20	94.10
Zinc, in µg/L	T	1	2	48	460	590	8.00	2.61	na
(B) South Platte River at Denver (06714000)									
Mean discharge, in ft³/s	na	1	1	58	3,908	6,100	201	92.2	na
Discharge volume, in acre-feet	na	1	1	58	3,240	5,520	173	78.5	na
pH, in standard pH units	W	2	1	58	7.90	8.04	6.90	6.68	na
Specific conductance, in µS/cm	W	1	1	59	1,050	1,400	281	207.8	na
Hardness, in mg/L	T	1	1	59	333	399	100	85.7	na
Residue on evaporation at 105 degrees C, in mg/L	T	0	5	59	3,560	3,560	12.0	12.0	95.10
Organic carbon, in mg/L	T	0	5	47	40.0	40.0	6.00	6.00	93.80
Escherichia coli, in col	W	1	1	7 7,000	694,000	490	3.56	na	
Fecal coliform, in col	W	1	1	7	1,000	922,000	490	5.84	na
Ammonia, in mg/L	T	0	5	59	1.20	1.20	0.20	0.20	95.10
Nitrite + nitrate, in mg/L	T	1	1	43	6.51	8.86	0.71	0.39	na
Ammonia + organic nitrogen, in mg/L	T	1	2	59	12.0	26.26	0.40	0.18	na
Phosphorus, in mg/L	T	1	1	59	3.17	5.33	0.14	0.08	na
Orthophosphate, in mg/L	D	1	1	58	0.55	0.88	0.08	0.05	na
Copper, in µg/L	D	0	5	59	60.0	60.0	2.00	2.00	95.10
Copper, in µg/L	T	0	5	59	104	104	1.00	1.00	95.10
Lead, in µg/L	D	0	5	59	47.0	47.0	10.0	10.0	95.10
Lead, in µg/L	T	1	2	59	121	308	10.0	1.13	na
Manganese, in µg/L	D	1	2	34	840	3,330	20.0	2.10	na
Manganese, in µg/L	T	1	1	21	1,120	2,340	150	52.6	na
Zinc, in µg/L	D	1	2	59	275	484	10.6	2.99	na
Zinc, in µg/L	T	1	2	59	672	3,520	27.8	4.10	na

Table 13. Tolerance intervals computed for physical properties and constituents at 99-percent coverage with 95-percent confidence at (A) South Platte River below Union Avenue, (B), South Platte River at Denver, (C) Tollgate Creek above 6th Avenue, (D) Sand Creek at mouth, and (F) South Platte River at Henderson.—Continued

[Phase: W, determination made using whole water; T, total; D, dissolved. I, transform indicator: 0, not applicable, 1, natural log transform; 2, no transform. Type indicates amount of censored values and method used to calculate tolerance intervals: 1, no censored values and regular computation; 2, less than 90-percent censored values and computed using Cohen's adjustment for censored values; 4, greater than 90-percent censored values and nonparametric computation; 5, normal distribution assumptions not met, nonparametric computation. n, number of samples; ft³/s, cubic feet per second; µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; C, Celsius; col, colonies per 100 milliliters; µg/L, micrograms per liter; na, not applicable]

Property or constituent	Phase	I	Type	n	Maximum	Upper bound tolerance interval	Minimum	Lower bound tolerance interval	Non-paramet-ric cover-age
(C) Tollgate Creek above 6th Avenue (394329104490101)									
Mean discharge, in ft³/s	na	1	1	25	785	3,810	7.00	0.88	na
Discharge volume, in acre-feet	na	1	1	25	583	4,550	5.00	0.53	na
pH, in standard pH units	W	2	1	34	7.80	8.22	7.00	6.70	na
Specific conductance, in µS/cm	W	1	1	35	1,940	2,660	316	252.8	na
Hardness, in mg/L	T	1	1	35	608	725	94.0	89.4	na
Residue on evaporation at 105 degrees C, in mg/L	T	1	1	34 3,890	132,000	73.0	15.1	na	
Organic carbon, in mg/L	T	1	1	28	27.0	39.6	8.00	4.22	na
Escherichia coli, in col	W	0	5	3 3,300	3,300	170	170	36.80	
Fecal coliform, in col	W	0	5	3	3,300	3,300	460	460	36.80
Ammonia, in mg/L	T	0	5	35	1.80	1.80	0.20	0.20	91.80
Nitrite + nitrate, in mg/L	T	0	5	28	1.31	1.31	0.42	0.42	89.90
Ammonia + organic nitrogen, in mg/L	T	1	1	35	6.00	na	0.50	na	na
Phosphorus, in mg/L	T	1	1	35	1.94	3.88	0.17	0.07	na
Orthophosphate, in mg/L	D	1	2	35	0.47	na	0.03	na	na
Copper, in µg/L	D	1	1	35	40.0	71.6	1.00	0.34	na
Copper, in µg/L	T	1	1	35	66.0	160	4.00	1.44	na
Lead, in µg/L	T	1	2	35	54.0	261	14.0	0.25	na
Manganese, in µg/L	D	1	1	20	1,500	8,040	50.00	4.99	na
Manganese, in µg/L	T	1	1	9	2,130	28,800	160	12.1	na
Zinc, in µg/L	D	1	2	35	146	480	6.00	1.35	na
Zinc, in µg/L	T	1	2	35	350	1,170	22.3	6.59	na
(D) Sand Creek at mouth (394839104570300)									
Mean discharge, in ft³/s	na	0	5	52	2,110	2,110	45.0	45.0	94.50
Discharge volume, in acre-feet	na	1	1	52	1,930	4,410	41.0	11.8	na
pH, in standard pH units	W	2	1	52	7.90	8.25	7.00	6.75	na
Specific conductance, in µS/cm	W	2	1	54	1,200	1,420	318	93.4	na
Hardness, in mg/L	T	2	1	54	317	380	123	76.5	na
Residue on evaporation at 105 degrees C, in mg/L	T	1	1	54	1,720	5,090	69.0	20.2	na
Organic carbon, in mg/L	T	1	1	43	30	45.7	6.00	3.81	na
Escherichia coli, in col	W	1	1	7	5,000	5,010,000	490	0.99	na
Fecal coliform, in col	W	1	1	7	5,000	118,000	490	19.3	na
Ammonia, in mg/L	T	0	4	54	1.30	1.30	0.40	0.40	94.60
Nitrite + nitrate, in mg/L	T	1	1	38	1.78	2.50	0.47	0.32	na
Ammonia + organic nitrogen, in mg/L	T	1	2	54	7.70	17.9	0.40	0.17	na
Phosphorus, in mg/L	T	1	1	54	1.40	na	0.23	na	na
Orthophosphate, in mg/L	D	1	1	52	0.60	0.87	0.04	0.03	na
Copper, in µg/L	D	1	2	54	35.0	67.7	1.00	0.46	na
Copper, in µg/L	T	1	1	54	73.0	120	3.00	1.88	na
Lead, in µg/L	D	0	5	54	51.0	51.0	10.0	10.0	94.60
Lead, in µg/L	T	1	2	54	61.0	213	10.0	0.56	na
Manganese, in µg/L	D	1	2	35	1,210	3,640	20.0	6.42	na
Manganese, in µg/L	T	1	1	20	1,740	6,460	80.0	22.8	na
Zinc, in µg/L	D	1	2	53	1,490	2,480	22.0	4.98	na
Zinc, in µg/L	T	1	2	53	1,500	5,030	70.0	11.7	na

Table 13. Tolerance intervals computed for physical properties and constituents at 99-percent coverage with 95-percent confidence at (A) South Platte River below Union Avenue, (B), South Platte River at Denver, (C) Tollgate Creek above 6th Avenue, (D) Sand Creek at mouth, and (F) South Platte River at Henderson.—Continued

[Phase: W, determination made using whole water; T, total; D, dissolved. I, transform indicator: 0, not applicable, 1, natural log transform; 2, no transform. Type indicates amount of censored values and method used to calculate tolerance intervals: 1, no censored values and regular computation; 2, less than 90-percent censored values and computed using Cohen's adjustment for censored values; 4, greater than 90-percent censored values and nonparametric computation; 5, normal distribution assumptions not met, nonparametric computation. n, number of samples; ft^3/s, cubic feet per second; µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; C, Celsius; col, colonies per 100 milliliters; µg/L, micrograms per liter; na, not applicable]

Property or constituent	Phase	I	Type	n	Maximum	Upper bound tolerance interval	Minimum	Lower bound tolerance interval	Non-parametric coverage
(E) South Platte River at Henderson (06720500)									
Mean discharge, in ft^3/s	na	1	1	58	7,130	12,120	394	234	na
Discharge volume, in acre-feet	na	0	5	58	6,077	6,077	152	152	95.00
pH, in standard pH units	W	2	1	57	7.70	7.99	6.80	6.63	na
Specific conductance, in µS/cm	W	1	1	58	1,320	na	277	na	na
Hardness, in mg/L	T	1	1	58	238	286	119	94.2	na
Residue on evaporation at 105 degrees C, in mg/L	T	1	1	56	2,580	7,230	58.0	25.9	na
Organic carbon, in mg/L	T	0	5	45	30.0	30.0	1.70	1.70	93.60
Escherichia coli, in col	W	2	1	10	7,900	19,000	170.0	170	na
Fecal coliform, in col	W	1	1	10	7,000	1,690,000	330.0	4.86	na
Ammonia, in mg/L	T	1	2	58	3.20	9.16	0.20	0.08	na
Nitrite + nitrate, in mg/L	T	1	2	41	4.55	10.1	1.04	0.36	na
Ammonia + organic nitrogen, in mg/L	T	0	5	58	9.60	na	0.50	na	na
Phosphorus, in mg/L	T	1	1	58	2.20	3.47	0.36	0.25	na
Orthophosphate, in mg/L	D	1	2	56	0.78	1.89	0.18	0.08	na
Copper, in µg/L	D	0	5	58	44.0	44.0	1.00	1.00	95.00
Copper, in µg/L	T	1	2	57	86.0	297.8	9.00	2.50	na
Lead, in µg/L	D	0	5	58	27.0	27.0	10.0	10.0	95.00
Lead, in µg/L	T	1	2	56	110	467	10.0	0.93	na
Manganese, in µg/L	D	0	5	34	540	540	20.0	20.0	91.60
Manganese, in µg/L	T	1	1	19	1,470	4,340	160	53.7	na
Zinc, in µg/L	D	1	2	58	172	415	11.6	5.44	na
Zinc, in µg/L	T	1	1	58	687	1,260	49.5	26.0	na

Table 14. Results of linear regression analyses.

[Group indicates that data represent results from all stations (All), South Platte River below Union Avenue (SPRU), South Platte River at Denver (SPRD), Tollgate Creek above 6th Avenue (TGC6), Sand Creek at mouth (SCRM), or South Platte River at Henderson (SPRH); T indicates transform: 1, no transform; 2, natural log transform for dependent variable; 3, natural log transform for both variables; Dependent and Independent describe regression variables. n, number of values used in regression; M, number of missing values; r^2, coefficient of determination (commonly referred to as r-squared). Slope, slope of the linear regression line; Intercept, y-axis intercept of the linear regression line; Confidence bounds, lower and upper bounds for slope that define 95-percent confidence intervals. Regressions with r^2 values greater than 0.65 are shown in bold print]

Group	T	Water-quality property or constituent		n	M	r^2	Slope	Intercept	Confidence bounds	
		Dependent	Independent						Lower	Upper
All	3	Mean streamflow	Specific conductance	242	13	0.279	–1.792	17.515	–2.157	–1.426
SPRU	**3**	**Mean streamflow**	**Specific conductance**	**49**	**0**	**0.667**	**–2.041**	**18.086**	**–2.463**	**–1.617**
SPRD	**3**	**Mean streamflow**	**Specific conductance**	**58**	**1**	**0.705**	**–1.805**	**17.972**	**–2.117**	**–1.492**
SCRM	3	Mean streamflow	Specific conductance	52	2	0.370	–1.652	16.421	–2.264	–1.039
SPRH	3	Mean streamflow	Specific conductance	58	0	0.430	–1.449	16.548	–1.895	–1.002
SPRU	**2**	**Mean streamflow**	**Nitrite + nitrate**	**35**	**14**	**0.679**	**–1.544**	**6.734**	**–1.920**	**–1.167**
SPRD	**3**	**Mean streamflow**	**Nitrite + nitrate**	**42**	**17**	**0.605**	**–1.003**	**7.142**	**–1.262**	**–0.744**
SCRM	3	Mean streamflow	Nitrite + nitrate	38	16	0.291	–1.408	5.382	–2.150	–0.665
SPRH	3	Mean streamflow	Nitrite + nitrate	40	18	0.585	–1.279	8.364	–1.632	–0.925
All	3	Specific conductance	Hardness	255	0	0.583	0.979	1.230	0.876	1.081
SPRU	3	Specific conductance	Hardness	49	0	0.460	0.796	2.021	0.543	1.049
SPRD	3	Specific conductance	Hardness	59	0	0.591	0.956	1.298	0.745	1.166
TGC6	1	Specific conductance	Hardness	35	0	0.373	2.132	301.726	1.152	3.110
SCRM	3	Specific conductance	Hardness	54	0	0.437	0.906	1.690	0.619	1.192
SPRH	**2**	**Specific conductance**	**Hardness**	**58**	**0**	**0.721**	**0.008**	**4.958**	**0.006**	**0.009**

Table 14. Results of linear regression analyses.—Continued

[Group indicates that data represent results from all stations (All), South Platte River below Union Avenue (SPRU), South Platte River at Denver (SPRD), Tollgate Creek above 6th Avenue (TGC6), Sand Creek at mouth (SCRM), or South Platte River at Henderson (SPRH); T indicates transform: 1, no transform; 2, natural log transform for dependent variable; 3, natural log transform for both variables; Dependent and Independent describe regression variables. n, number of values used in regression; M, number of missing values; r^2, coefficient of determination (commonly referred to as r-squared). Slope, slope of the linear regression line; Intercept, y-axis intercept of the linear regression line; Confidence bounds, lower and upper bounds for slope that define 95-percent confidence intervals. Regressions with r^2 values greater than 0.65 are shown in bold print]

Group	T	Water-quality property or constituent		n	M	r^2	Slope	Intercept	Confidence bounds	
		Dependent	Independent						Lower	Upper
All	3	Residue at 105 C	Total phosphorus	251	4	0.532	0.948	6.403	0.836	1.058
SPRU	3	Residue at 105 C	Total phosphorus	48	1	0.565	0.939	6.529	0.694	1.182
SPRD	3	Residue at 105 C	Total phosphorus	59	0	0.541	1.032	6.462	0.780	1.284
TGC6	**3**	**Residue at 105 C**	**Total phosphorus**	**34**	**1**	**0.655**	**1.352**	**6.982**	**0.998**	**1.705**
SCRM	3	Residue at 105 C	Total phosphorus	54	0	0.531	1.327	6.582	0.980	1.674
SPRH	3	Residue at 105 C	Total phosphorus	56	2	0.352	1.344	6.138	0.846	1.840
All	3	Residue at 105 C	Total copper	248	7	0.521	0.901	3.244	0.792	1.010
SPRU	3	Residue at 105 C	Total copper	47	2	0.530	1.050	2.815	0.753	1.346
SPRD	2	Residue at 105 C	Total copper	59	0	0.540	0.034	5.045	0.025	0.041
TGC6	**3**	**Residue at 105 C**	**Total copper**	**34**	**1**	**0.663**	**1.159**	**2.935**	**0.860**	**1.456**
SCRM	2	Residue at 105 C	Total copper	54	0	0.409	0.039	5.030	0.026	0.052
SPRH	3	Residue at 105 C	Total copper	54	4	0.480	1.038	2.534	0.737	1.338
All	**3**	**Residue at 105 C**	**Total manganese**	**86**	**169**	**0.760**	**1.311**	**–2.099**	**1.151**	**1.470**
SPRU	**2**	**Residue at 105 C**	**Total manganese**	**17**	**32**	**0.742**	**0.005**	**3.776**	**0.003**	**0.006**
SPRD	**3**	**Residue at 105 C**	**Total manganese**	**21**	**38**	**0.813**	**1.383**	**–2.418**	**1.064**	**1.702**
SCRM	**2**	**Residue at 105 C**	**Total manganese**	**20**	**34**	**0.718**	**0.002**	**4.520**	**0.001**	**0.002**
SPRH	**3**	**Residue at 105 C**	**Total manganese**	**19**	**39**	**0.792**	**1.546**	**–3.471**	**1.140**	**1.951**
All	3	Residue at 105 C	Total lead	137	118	0.374	0.774	3.830	0.603	0.944
SPRU	3	Residue at 105 C	Total lead	12	37	0.430	0.800	4.000	0.151	1.447
SPRD	3	Residue at 105 C	Total lead	43	16	0.584	1.001	2.943	0.734	1.266
TGC6	**1**	**Residue at 105 C**	**Total lead**	**14**	**21**	**0.913**	**75.322**	**–597.058**	**60.661**	**89.982**
SCRM	3	Residue at 105 C	Total lead	28	26	0.307	0.677	4.259	0.267	1.087
SPRH	3	Residue at 105 C	Total lead	40	18	0.448	0.821	3.394	0.521	1.119
All	3	Residue at 105 C	Total zinc	243	12	0.295	0.582	3.000	0.467	0.695
SPRU	3	Residue at 105 C	Total zinc	45	4	0.502	0.937	1.659	0.650	1.224
SPRD	2	Residue at 105 C	Total zinc	58	1	0.518	0.005	5.097	0.003	0.006
TGC6	**2**	**Residue at 105 C**	**Total zinc**	**33**	**2**	**0.702**	**0.010**	**4.994**	**0.007**	**0.011**
SPRH	2	Residue at 105 C	Total zinc	56	2	0.335	0.004	5.198	0.002	0.005
All	1	**Ammonia + organic N**	Total phosphorus	245	10	0.682	2.964	0.483	2.708	3.220
SPRU	1	Ammonia + organic N	Total phosphorus	45	4	0.605	2.667	0.634	2.003	3.330
SPRD	**3**	**Ammonia + organic N**	**Total phosphorus**	**56**	**3**	**0.688**	**0.797**	**1.215**	**0.651**	**0.943**
TGC6	1	Ammonia + organic N	Total phosphorus	35	0	0.395	1.863	0.987	1.045	2.680
SCRM	3	Ammonia + organic N	Total phosphorus	51	3	0.412	0.733	1.125	0.481	0.984
SPRH	3	Ammonia + organic N	Total phosphorus	58	0	0.456	0.872	1.187	0.617	1.127
All	3	Ammonia + organic N	Total manganese	86	169	0.391	0.528	–2.355	0.385	0.671
SPRU	**3**	**Ammonia + organic N**	**Total manganese**	**17**	**32**	**0.682**	**0.755**	**–3.821**	**0.471**	**1.039**
SPRD	**3**	**Ammonia + organic N**	**Total manganese**	**21**	**38**	**0.658**	**0.605**	**–2.773**	**0.395**	**0.813**
SCRM	3	Ammonia + organic N	Total manganese	20	34	0.639	0.505	–2.324	0.317	0.693
All	3	Ammonia + organic N	Total zinc	239	16	0.267	0.362	–1.010	0.285	0.438
SPRU	1	Ammonia + organic N	Total zinc	43	6	0.326	0.010	0.961	0.005	0.014
SPRD	**1**	**Ammonia + organic N**	**Total zinc**	**56**	**3**	**0.659**	**0.013**	**0.748**	**0.010**	**0.015**
TGC6	1	Ammonia + organic N	Total zinc	34	1	0.253	0.007	1.254	0.002	0.012
SPRH	1	Ammonia + organic N	Total zinc	58	0	0.128	0.005	2.422	0.001	0.008
SPRU	**2**	**Orthophosphate**	**Total manganese**	**15**	**34**	**0.658**	**0.003**	**–2.993**	**0.001**	**0.003**
SPRD	3	Orthophosphate	Total manganese	21	38	0.270	0.338	–3.404	0.070	0.604
SPRH	3	Orthophosphate	Total manganese	18	40	0.414	–0.352	1.333	–0.573	–0.130

Table 14. Results of linear regression analyses.—Continued

[Group indicates that data represent results from all stations (All), South Platte River below Union Avenue (SPRU), South Platte River at Denver (SPRD), Tollgate Creek above 6th Avenue (TGC6), Sand Creek at mouth (SCRM), or South Platte River at Henderson (SPRH); T indicates transform: 1, no transform; 2, natural log transform for dependent variable; 3, natural log transform for both variables; Dependent and Independent describe regression variables. n, number of values used in regression; M, number of missing values; r^2, coefficient of determination (commonly referred to as r-squared). Slope, slope of the linear regression line; Intercept, y-axis intercept of the linear regression line; Confidence bounds, lower and upper bounds for slope that define 95-percent confidence intervals. Regressions with r^2 values greater than 0.65 are shown in bold print]

Group	T	Water-quality property or constituent		n	M	r^2	Slope	Intercept	Confidence bounds	
		Dependent	Independent						Lower	Upper
All	1	Total phosphorus	Total copper	252	3	0.643	0.020	0.219	0.018	0.021
SPRU	**3**	**Total phosphorus**	**Total copper**	**48**	**1**	**0.658**	**0.954**	**–3.609**	**0.750**	**1.158**
SPRD	2	Total phosphorus	Total copper	59	0	0.604	0.025	–1.168	0.019	0.030
TGC6	1	Total phosphorus	Total copper	35	0	0.638	0.022	0.199	0.016	0.028
SCRM	1	Total phosphorus	Total copper	54	0	0.619	0.017	0.299	0.012	0.020
SPRH	1	Total phosphorus	Total copper	56	2	0.435	0.013	0.547	0.008	0.016
All	3	Total phosphorus	Total manganese	86	169	0.550	0.797	–5.349	0.640	0.953
SPRU	**2**	**Total phosphorus**	**Total manganese**	**17**	**32**	**0.758**	**0.004**	**–2.688**	**0.002**	**0.005**
SPRD	**3**	**Total phosphorus**	**Total manganese**	**21**	**38**	**0.797**	**0.685**	**–4.582**	**0.519**	**0.851**
SCRM	**1**	**Total phosphorus**	**Total manganese**	**20**	**34**	**0.711**	**0.001**	**0.268**	**0.000**	**0.000**
SPRH	1	Total phosphorus	Total manganese	19	39	0.562	0.001	0.707	0.000	0.001
All	3	Total phosphorus	Total zinc	247	8	0.489	0.580	–3.423	0.505	0.654
SPRU	**3**	**Total phosphorus**	**Total zinc**	**46**	**3**	**0.755**	**0.960**	**–5.077**	**0.794**	**1.126**
SPRD	**1**	**Total phosphorus**	**Total zinc**	**58**	**1**	**0.710**	**0.004**	**0.152**	**0.003**	**0.004**
TGC6	**1**	**Total phosphorus**	**Total zinc**	**34**	**1**	**0.684**	**0.004**	**0.150**	**0.003**	**0.005**
SPRH	1	Total phosphorus	Total zinc	58	0	0.247	0.002	0.666	0.000	0.002
All	3	Dissolved copper	Dissolved manganese	140	115	0.546	0.650	–1.290	0.549	0.749
SPRU	2	Dissolved copper	Dissolved manganese	30	29	0.769	0.719	–1.376	0.566	0.870
TGC6	**3**	**Dissolved copper**	**Dissolved manganese**	**20**	**15**	**0.661**	**0.748**	**–2.310**	**0.483**	**1.013**
SCRM	3	Dissolved copper	Dissolved manganese	34	20	0.586	0.567	–0.929	0.395	0.737
SPRH	**3**	**Dissolved copper**	**Dissolved manganese**	**32**	**26**	**0.717**	**0.767**	**–1.589**	**0.587**	**0.946**
All	1	Dissolved copper	Dissolved lead	44	211	0.577	0.803	4.314	0.589	1.017
SPRD	**2**	**Dissolved copper**	**Dissolved lead**	**11**	**48**	**0.721**	**0.039**	**2.024**	**0.020**	**0.057**
SCRM	1	Dissolved copper	Dissolved lead	11	43	0.554	0.417	8.042	0.134	0.699
SPRH	2	Dissolved copper	Dissolved lead	17	41	0.615	0.043	2.150	0.024	0.061
SPRU	2	Dissolved copper	Dissolved zinc	44	5	0.280	0.016	0.859	0.007	0.023
SPRD	**2**	**Dissolved copper**	**Dissolved zinc**	**52**	**7**	**0.680**	**0.011**	**1.166**	**0.009**	**0.013**
TGC6	2	Dissolved copper	Dissolved zinc	33	2	0.642	0.019	0.866	0.013	0.024
SPRH	3	Dissolved copper	Dissolved zinc	54	4	0.634	1.015	–1.992	0.800	1.229
All	**3**	**Total copper**	**Total manganese**	**85**	**170**	**0.707**	**0.948**	**–2.795**	**0.814**	**1.081**
SPRU	**2**	**Total copper**	**Total manganese**	**17**	**32**	**0.671**	**0.003**	**1.331**	**0.001**	**0.004**
SPRD	**3**	**Total copper**	**Total manganese**	**21**	**38**	**0.772**	**1.021**	**–3.016**	**0.754**	**1.287**
SCRM	**2**	**Total copper**	**Total manganese**	**20**	**34**	**0.748**	**0.001**	**2.019**	**0.001**	**0.001**
SPRH	**3**	**Total copper**	**Total manganese**	**18**	**40**	**0.896**	**1.106**	**–3.458**	**0.906**	**1.306**
All	**3**	**Total copper**	**Total lead**	**139**	**116**	**0.726**	**0.805**	**0.697**	**0.721**	**0.889**
SPRU	2	Total copper	Total lead	12	37	0.646	0.034	2.265	0.016	0.052
SPRD	3	Total copper	Total lead	43	16	0.635	0.784	0.732	0.597	0.971
TGC6	**2**	**Total copper**	**Total lead**	**14**	**21**	**0.703**	**0.029**	**2.665**	**0.016**	**0.040**
SCRM	**2**	**Total copper**	**Total lead**	**28**	**26**	**0.824**	**0.033**	**2.284**	**0.026**	**0.039**
SPRH	**1**	**Total copper**	**Total lead**	**42**	**16**	**0.823**	**0.715**	**10.278**	**0.608**	**0.820**
All	1	Total copper	Total zinc	245	10	0.241	0.054	13.598	0.041	0.065
SPRU	3	Total copper	Total zinc	46	3	0.644	0.784	–0.748	0.607	0.961
SPRD	**1**	**Total copper**	**Total zinc**	**58**	**1**	**0.828**	**0.140**	**4.324**	**0.123**	**0.157**
TGC6	**3**	**Total copper**	**Total zinc**	**34**	**1**	**0.849**	**0.910**	**–1.406**	**0.772**	**1.048**
SPRH	**3**	**Total copper**	**Total zinc**	**56**	**2**	**0.700**	**0.825**	**–0.916**	**0.677**	**0.972**

Table 14. Results of linear regression analyses.—Continued

[Group indicates that data represent results from all stations (All), South Platte River below Union Avenue (SPRU), South Platte River at Denver (SPRD), Tollgate Creek above 6th Avenue (TGC6), Sand Creek at mouth (SCRM), or South Platte River at Henderson (SPRH); T indicates transform: 1, no transform; 2, natural log transform for dependent variable; 3, natural log transform for both variables; Dependent and Independent describe regression variables. n, number of values used in regression; M, number of missing values; r^2, coefficient of determination (commonly referred to as r-squared). Slope, slope of the linear regression line; Intercept, y-axis intercept of the linear regression line; Confidence bounds, lower and upper bounds for slope that define 95-percent confidence intervals. Regressions with r^2 values greater than 0.65 are shown in bold print]

Group	T	Water-quality property or constituent		n	M	r^2	Slope	Intercept	Confidence bounds	
		Dependent	Independent						Lower	Upper
All	3	Dissolved manganese	Dissolved zinc	133	122	0.432	0.552	2.761	0.442	0.660
SPRU	3	Dissolved manganese	Dissolved zinc	25	24	0.607	0.699	2.378	0.456	0.941
SPRD	**3**	**Dissolved manganese**	**Dissolved zinc**	**28**	**31**	**0.752**	**0.884**	**1.361**	**0.679**	**1.088**
TGC6	**2**	**Dissolved manganese**	**Dissolved zinc**	**18**	**17**	**0.785**	**0.023**	**4.263**	**0.016**	**0.028**
SPRH	**3**	**Dissolved manganese**	**Dissolved zinc**	**30**	**28**	**0.798**	**0.947**	**1.243**	**0.762**	**1.131**
All	3	Dissolved manganese	Total zinc	136	119	0.218	0.475	2.586	0.321	0.628
SPRU	**1**	**Dissolved manganese**	**Total zinc**	**24**	**25**	**0.833**	**1.069**	**28.825**	**0.857**	**1.280**
TGC6	2	Dissolved manganese	Total zinc	19	16	0.250	0.005	4.572	0.000	0.009
SPRH	1	Dissolved manganese	Total zinc	32	26	0.143	0.366	116.497	0.031	0.701
All	3	Total manganese	Total zinc	85	170	0.467	0.504	3.572	0.386	0.620
SPRU	**1**	**Total manganese**	**Total zinc**	**16**	**33**	**0.900**	**4.769**	**57.409**	**3.860**	**5.677**
SPRD	**1**	**Total manganese**	**Total zinc**	**21**	**38**	**0.902**	**2.813**	**71.051**	**2.367**	**3.259**
SPRH	**1**	**Total manganese**	**Total zinc**	**19**	**39**	**0.970**	**2.645**	**87.417**	**2.405**	**2.883**
All	3	Total lead	Total manganese	47	208	0.517	0.806	–1.725	0.572	1.039
SPRD	**2**	**Total lead**	**Total manganese**	**17**	**42**	**0.707**	**0.002**	**2.237**	**0.001**	**0.002**
SPRH	**3**	**Total lead**	**Total manganese**	**13**	**45**	**0.824**	**1.288**	**–4.495**	**0.893**	**1.682**
All	1	Total lead	Total zinc	138	117	0.300	0.082	13.820	0.061	0.103
SPRU	**2**	**Total lead**	**Total zinc**	**12**	**37**	**0.653**	**0.004**	**2.443**	**0.002**	**0.006**
SPRD	2	Total lead	Total zinc	43	16	0.492	0.003	2.746	0.002	0.003
TGC6	2	Total lead	Total zinc	14	21	0.893	0.005	2.204	0.003	0.006
SPRH	3	Total lead	Total zinc	42	16	0.525	0.947	–1.577	0.658	1.234

Summary

The quality of stormwater runoff is of interest to many management and regulatory agencies as well as academia, scientists, recreational stream users, and the general public. The basic character of stormwater runoff is of general interest to all, whereas more detailed information concerning spatial and temporal variations may be of interest to management and regulatory agencies. In response to these interests, the U.S. Geological Survey, in cooperation with the Urban Drainage and Flood Control District, systematically collects stormwater during wet weather from a monitoring network of five stations in and around metropolitan Denver, Colorado. This report describes the quality of stormwater sampled from water year 1998 and through water year 2001 in a network of five stations in and around metropolitan Denver. The network includes three stations known as Union, Denver, and Henderson on the principal, or receiving, stream draining the area, the South Platte River. The network also includes stations on two tributary streams: Sand Creek, which is tributary to the South Platte River, and Tollgate Creek, which is tributary to Sand Creek. Sampling was facilitated using refrigerated automatic pumping samplers that were used to collect composite and discrete investigative samples. Time-weighted composite stormwater samples were collected by compositing individual aliquots of stormwater that were obtained at fixed time increments during, typically, 12-hour intervals; bacteriological samples were collected manually from streams during some storms. Discrete samples of stormwater also were collected during a few storms; the discrete samples were submitted for chemical analyses individually and were not composited. Various types of quality-assurance and quality-control samples also were collected to help evaluate laboratory performance, to evaluate relations between fixed point and cross-section depth-integrated samples, and to document field and equipment conditions that could potentially affect results.

Composite samples were submitted to the Metro Wastewater Reclamation District Laboratory for analysis of physical properties, organic carbon, nutrients, and dissolved and total copper, lead, manganese, and zinc. Bacteriological samples were submitted to the Metro Wastewater Reclamation District Laboratory for determination of *Escherichia coli* and fecal coliform. Discrete samples were submitted to the U.S. Geological Survey National Water Quality Laboratory for analysis of a similar suite of water-quality properties and constituents that did not include total copper, lead, manganese, and zinc. Quality-control and quality-assurance results for laboratory performance indicate that results from the National Water Quality Laboratory are consistently close to most probable values determined on the basis of results from as many as 100 laboratories across the country. The performance results for the Metro Wastewater Reclamation District Laboratory indicate mean results that are close to most probable values; however, in as many as 20 percent of samples, results may vary from the most probable value by a relative percent difference of about 20 or more. Other quality-control and quality-assurance results indicate that samples collected from the fixed point locations used by pumping samplers are similar to, but not always the same as, samples collected using methods that integrate vertically and horizontally in the channel cross section.

A total of 255 composite stormwater samples were collected at the five stations. Streamflow information associated with the composite samples indicates that most samples were collected for hydrographs with "event" classifications; however, some samples also represented hydrographs classified as "falling" or "rising." In most cases, differences were not large between mean streamflow values associated with the different hydrograph classifications for individual stations and storms. Results from chemical analyses of composite samples indicate that concentrations for many water-quality properties and constituents tend to increase in downstream order along the receiving stream, the South Platte River. Although land-cover data indicate that the percentage of land classified as agricultural increases with local contributing drainage area along the South Platte River, the percentage of urban land cover does not.

A comparison of composite-sample results to historical data that represent base-flow conditions indicates that concentrations for specific conductance, hardness, ammonia, nitrite plus nitrate, ammonia plus organic nitrogen, phosphorus, and orthophosphate were high in base-flow samples compared to results from composite samples of stormwater. Historical concentrations in base flow for organic carbon and dissolved copper, lead, and zinc were low compared to results from composite samples.

A comparison of composite-sample results to numeric standards associated with use classifications established by the Colorado Department of Public Health and Environment indicates that biological indicators such as fecal coliform consistently exceed numeric standards. The results from composite samples indicate for pH, nitrite plus nitrate, dissolved lead, and total manganese were always met; however, standards for dissolved copper, dissolved manganese, and dissolved zinc locally were not met in about 10 percent or more samples.

A total of 52 discrete samples were collected during three storms to provide a basis for comparison of time-weighted results to alternative weighting methods. The results indicate that, within storms, time-weighted concentrations have a strong correlation with volume-weighted concentrations and that the central tendency for relative percent differences typically had a low value of about 1. The results from discrete samples also indicate that composited values tend to "smooth" results.

Evaluation of the composite-sample results indicate that data for each station are, for the most part, stationary, although annual means do indicate monotonic trends for the following water-quality properties and constituents: specific conductance and hardness at Union, orthophosphate at Tollgate, and specific conductance and ammonia at Henderson (upward monotonic trends), and total organic carbon at Union, ammonia plus organic nitrogen at Tollgate, and total phosphorus at Sand Creek (downward monotonic trends).

Tolerance intervals were computed to provide a basis for comparison with future samples. In general, it was possible to compute 95-percent confident two-sided tolerance intervals with 99-percent coverage. Linear regression also was used to help provide a basis for determining intradistribution changes that would not be detected using tolerance intervals. When linear regressions for all possible pairs (231) of water-quality properties and constituents were screened to remove relations that did not have 95-percent significance and a r^2 value of at least 0.65, about 26 pairs remained. At some stations, regressions for total manganese with total lead and copper, and residue on evaporation at 105°C with total manganese and total lead, were relatively strong. The screened regressions also indicate that regression relations differ considerably from station to station and are not spatially consistent. The regression results, together with correlation coefficients for all pairs of water-quality properties and constituents, indicate that the system represented by the five stations is heterogeneous.

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Appendix

The following abbreviations are used in some tables and figures in the Appendix.

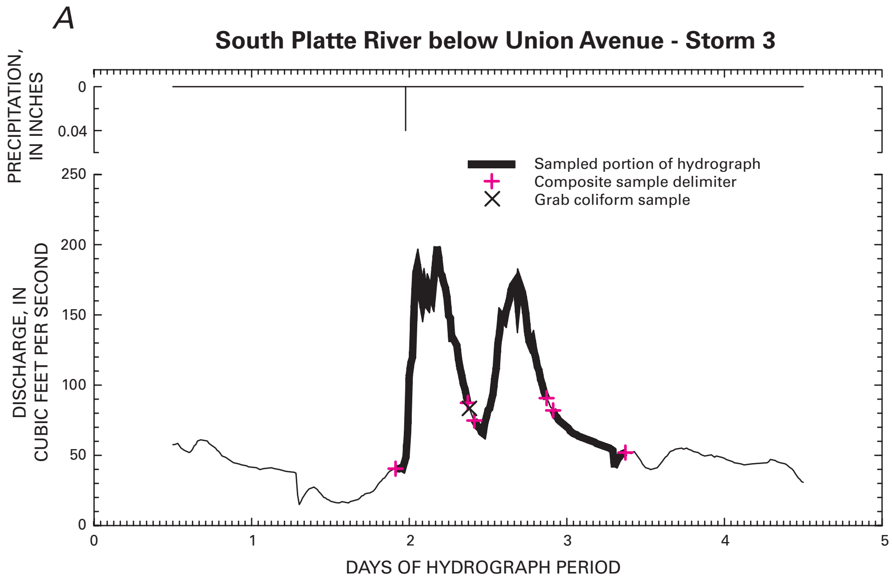
Abbreviation	Water-quality property or constituent	Phase	Reporting units
ph	pH	Whole water	Standard pH units
sc	Specific conductance	Dissolved	μS/cm
hdn	Hardness, as $CaCO_3$	Total	mg/L
tss	Residue on evaporation at 105 degrees Celsius	Total	mg/L
toc	Organic carbon	Total	mg/L
nh3	Ammonia	Total	mg/L
no23	Nitrite + nitrate	Total	mg/L
tn	Ammonia + organic nitrogen	Total	mg/L
tpo4	Phosphorus	Total	mg/L
opo4	Orthophosphate	Dissolved	mg/L
cud	Copper	Dissolved	μg/L
cut	Copper	Total	μg/L
pbd	Lead	Dissolved	μg/L
pbt	Lead	Total	μg/L
mnd	Manganese	Dissolved	mg/L
mnt	Manganese	Total	mg/L
znd	Zinc	Dissolved	μg/L
znt	Zinc	Total	μg/L
ecol	*Escherichia coli*	Whole water	Colonies per 100 milliliters
tcol	Fecal coliform	Whole water	Colonies per 100 milliliters

Hydrograph Classification

The portion of the storm hydrograph associated with each composite sample was classified as “rising,” “falling,” “event,” or “unclassified.” Examples for rising, falling, and event classifications are in figure A1. Samples classified as rising or falling are associated with the rising or falling limb of a storm hydrograph. Samples classified as event are associated with both a rising and falling portion of a storm hydrograph. In some cases, mostly at Tollgate, streamflow data were not available and samples were categorized as unclassified.

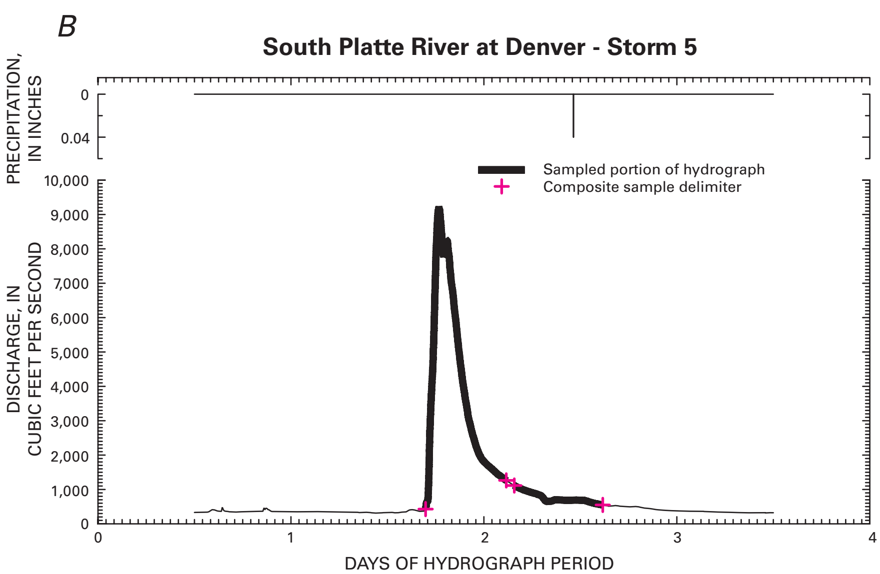
The hydrographs in figure A1 include some hydrographs from outside the study period and indicate examples of each classification. The hydrographs provide readers with a sense for storm hydrographs from the different stations. Additional information that characterizes storm hydrographs sampled as part of this study in terms of peak streamflow and runoff volumes are in table 8 and table A1. Summer storm hydrographs commonly originate from convective storm cells and have very steep rising limbs, steep falling limbs, and a duration that may be 12 hours or less (fig. A1*B*). Spring storm hydrographs sometimes originate from snowfall that accumulates as wet snow over a period of hours and then melts over a period of a day or more. Spring storm hydrographs typically have multiple peaks and a duration of days (fig. A1*D*).

At Union, storm-runoff peaks typically are between 300 and 400 ft^3/s; in the example shown (fig. A1*A*), samples 1 and 2 were classified as event, and sample 3 was classified as falling. At Denver, storm hydrograph peaks commonly are thousands of cubic feet per second; in the example shown (fig. A1*B*), sample 1 was classified as event, and sample 2 was classified as falling (table A1). At Tollgate, storm hydrograph peaks are typically about 100 ft^3/s; in the example shown (fig. A1*C*), samples 1, 2, and 3 were classified as event, rising, and falling, and sample 4 also was classified as falling (table A1). The Sand Creek hydrograph in figure A1*D* is from a spring snowstorm and has multiple peaks; sample 1 was classified as rising, samples 2 and 3 were classified as event, and samples 4 and 5 were classified as falling. At Henderson, storm-runoff peaks are typically thousands of cubic feet per second; in the example shown (fig. A1*E*), sample 1 was classified as event, and samples 2 and 3 were classified as falling.



		Precipitation depth (inches)	Computed mean runoff (cubic feet per second)	Computed runoff volume (acre-feet)	Classification
Hydrograph	06022002 1200 0606 1200	0.20	64	507	na
Sample 1	06032002 2155 0604 0855	na	131	119	Event
Sample 2	06042002 0955 0604 2055	na	122	111	Event
Sample 3	06042002 2155 0605 0855	na	61	56	Falling

* Discharge record from U.S. Geological Survey
* Precipitation record from Urban Drainage and Flood Control District gage at Union
* na is not applicable

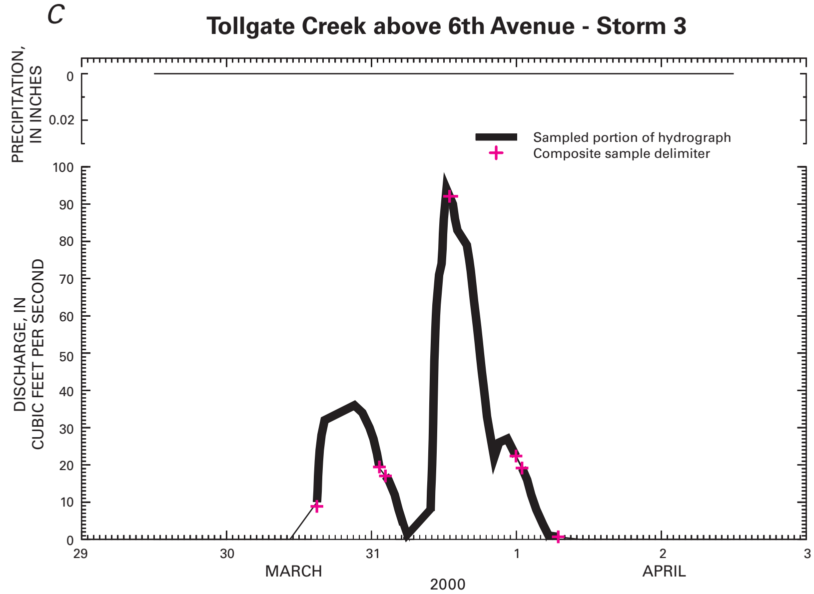


		Precipitation depth (inches)	Computed mean runoff (cubic feet per second)	Computed runoff volume (acre-feet)	Classification
Hydrograph	07072001 1200 0710 1200	0.08	1116	6636	na
Sample 1	07082001 1645 0709 0247	na	3908	3240	Event
Sample 2	07092001 0347 0709 1447	na	1941	1765	Falling

* Discharge record from Colorado Division of Water Resources
* Precipitation record from Urban Drainage and Flood Control District gage at Cherry Creek at Champa
* na is not applicable

Figure A1. Example storm hydrographs at (*A*) South Platte River below Union Avenue, (*B*) South Platte River at Denver, (*C*) Tollgate Creek above 6th Avenue, (*D*) Sand Creek at mouth, and (*E*) South Platte River at Henderson.

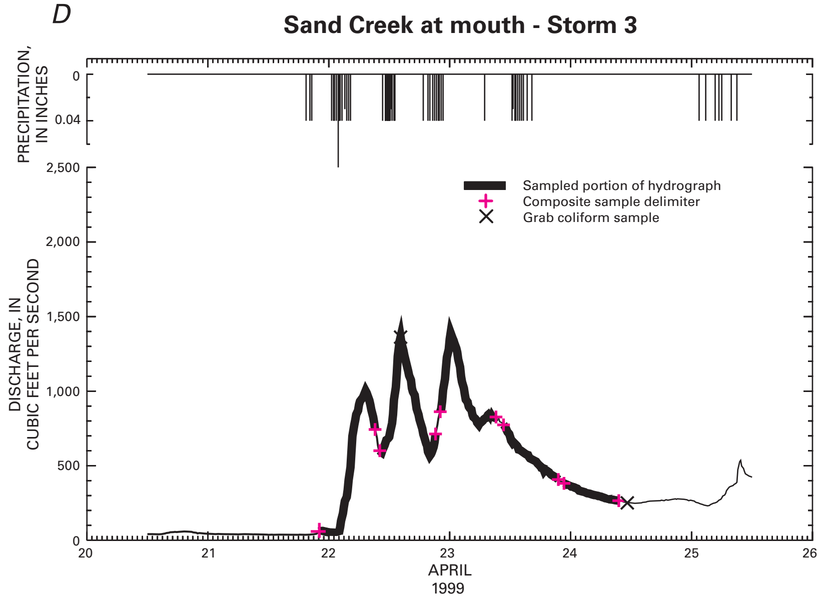
C



		Precipitation depth (inches)	Computed mean runoff (cubic feet per second)	Computed runoff volume (acre-feet)	Classification
Hydrograph period	03292000 1200 04022000 1200	0.00	19	147	na
Sample 1	03302000 1458 03312000 0119	no	31	27	Event
Sample 2	03312000 0219 03312000 1300	no	25	22	Rising
Sample 3	03312000 1256 03312000 2356	no	45	41	Falling
Sample 4	04012000 0056 04012000 0656	no	11	5	Falling

- Discharge record from Urban Drainage and Flood Control District Alert system
- Precipitation record from Urban Drainage and Flood Control District gage at 6th Avenue and Sable
- na is not applicable

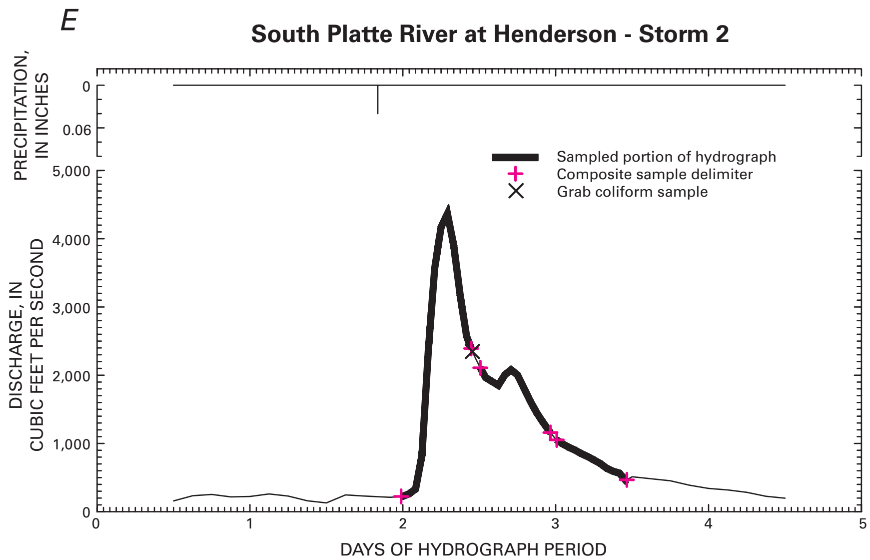
D



		Precipitation depth (inches)	Computed mean runoff (cubic feet per second)	Computed runoff volume (acre-feet)	Classification
Hydrograph period	04221999 1200 04251999 1200	2.33	394	3905	na
Sample 1	04211999 2213 04221999 0913	no	454	415	Rising
Sample 2	04221999 1013 04221999 2113	no	870	795	Event
Sample 3	04221999 2213 04231999 0915	no	986	901	Event
Sample 4	04231999 1037 04231999 2137	no	558	502	Falling
Sample 5	04231999 2237 04241999 0937	no	314	282	Falling

- Discharge record from U.S. Geological Survey
- Precipitation record from Urban Drainage and Flood Control District gage at Brighton Road and I-270
- na is not applicable

Figure A1. Example storm hydrographs at (*A*) South Platte River below Union Avenue, (*B*) South Platte River at Denver, (*C*) Tollgate Creek above 6th Avenue, (*D*) Sand Creek at mouth, and (*E*) South Platte River at Henderson.—Continued



		Precipitation depth (inches)	Computed mean runoff (cubic feet per second)	Computed runoff volume (acre-feet)	Classification
Hydrograph	05222002 1200 0526 1200	1.26	783	6209	na
Sample 1	05232002 2344 0524 1044	na	2385	2168	Event
Sample 2	05242002 1210 0524 2310	na	1774	1613	Falling
Sample 3	05252002 0010 0525 1110	na	766	697	Falling

* Discharge record from Colorado Division of Water Resources
* Precipitation record from Urban Drainage and Flood Control District gage at Henderson
* na is not applicable

Figure A1. Example storm hydrographs at (*A*) South Platte River below Union Avenue, (*B*) South Platte River at Denver, (*C*) Tollgate Creek above 6th Avenue, (*D*) Sand Creek at mouth, and (*E*) South Platte River at Henderson.—Continued

Table A1. Composite-stormwater-sample streamflow characteristics.

[Site indicates sampling station. SPRU, South Platte River below Union Avenue; SPRD, South Platte River at Denver; TGC6, Tollgate Creek at 6th Avenue; SCRM, Sand Creek at mouth; SPRH, South Platte River at Henderson. Lab id, Metro Wastewater Reclamation District Laboratory sample identifier; Date, date in mmddyy (month, day, year); Time, time in hhmm (hours, minutes); Day%, fractional portion of day that sample represents. Type indicates portion of hydrograph represented: r--, rising; f--, falling; e-- event; u--, unclassified; ft³/s, cubic feet per second; acre-ft, acre-feet; na, not available]

Site	Lab id	Beginning		Ending		Day%	Type	Mean streamflow (ft³/s)	Streamflow volume (acre-ft)
		Date	Time	Date	Time				
SPRU	360517	060498	1843	060598	1002	0.64	e--	554	704
SPRU	360518	060598	1410	060698	1414	1.00	f--	236	469
SPRU	364270	072298	1729	072398	0529	0.48	e--	531	527
SPRU	365004	073098	1652	073198	0352	0.42	f--	529	483
SPRU	366193	081098	1700	081198	1220	0.80	r--	330	527
SPRU	386913	041599	1230	041599	2130	0.37	e--	304	226
SPRU	387545	042299	1430	042399	0230	0.48	e--	513	509
SPRU	387546	042299	0230	042299	1330	0.45	r--	303	277
SPRU	387627	042399	0922	042399	2022	0.46	e--	591	540
SPRU	387628	042399	2122	042499	0822	0.45	f--	509	465
SPRU	390720	052599	0940	052599	2027	0.44	f--	676	597
SPRU	392149	060999	2123	061099	0723	0.41	e--	949	780
SPRU	394711	070899	1536	070999	0233	0.43	r--	735	757
SPRU	395680	072099	0446	072099	1246	0.31	f--	710	473
SPRU	397230	080499	1647	080599	0305	0.43	r--	893	747
SPRU	397341	080599	0405	080599	1505	0.47	f--	721	648
SPRU	401341	091999	1522	092099	0455	0.53	e--	112	125
SPRU	403720	101699	1135	101699	2230	0.45	r--	76	68
SPRU	416167	031500	1356	031600	1214	0.93	e--	84	155
SPRU	416243	031600	1339	031700	0039	0.43	e--	197	179
SPRU	417324	033000	1321	033100	0013	0.44	r--	130	116
SPRU	417325	033100	0113	033100	1130	0.42	e--	146	124
SPRU	417399	033100	1232	033100	2232	0.41	e--	201	166
SPRU	417400	033100	2332	040100	1032	0.44	f--	147	134
SPRU	419873	042900	2302	043000	0953	0.42	e--	458	410
SPRU	419874	043000	1053	043000	2153	0.44	f--	359	326
SPRU	420646	050800	1330	050900	0023	0.44	e--	452	407
SPRU	420647	050900	0123	050900	1123	0.41	f--	277	229
SPRU	423916	061600	1816	061700	0433	0.41	r--	217	185
SPRU	423917	061700	0523	061700	1633	0.45	e--	237	219
SPRU	426632	071600	2009	071700	0709	0.46	e--	724	658
SPRU	426707	071700	0809	071700	1909	0.47	e--	523	475
SPRU	450264	041101	1234	041101	2334	0.45	e--	363	330
SPRU	450265	041201	0034	041201	1134	0.44	f--	225	205
SPRU	451107	042201	0055	042301	1134	0.43	r--	117	335
SPRU	451193	042201	1234	042201	2215	0.41	e--	151	121
SPRU	451194	042201	2315	042301	1015	0.45	f--	92	83
SPRU	452203	050301	0541	050301	1547	0.40	r--	103	86
SPRU	452286	050301	1647	050401	0245	0.39	r--	167	138
SPRU	452287	050401	0345	050401	1445	0.44	r--	203	184
SPRU	452361	050401	1527	050501	0227	0.44	r--	261	237
SPRU	452362	050501	0327	050501	1427	0.45	r--	482	438
SPRU	452449	050501	1710	050601	0410	0.45	f--	588	534
SPRU	452450	050601	0510	050601	1610	0.46	f--	344	313
SPRU	452454	050601	1706	050701	0406	0.46	f--	296	269
SPRU	455853	061301	1435	061401	0135	0.43	e--	485	441
SPRU	455854	061401	0235	061401	1335	0.44	f--	328	298
SPRU	457963	070801	1736	070901	0436	0.44	f--	516	469
SPRD	360522	060498	1350	060498	2152	0.31	r--	895	596
SPRD	363045	070898	2341	070998	1435	0.61	f--	738	915
SPRD	364271	072298	1728	072398	0528	0.48	e--	1,132	1,122

Table A1. Composite-stormwater-sample streamflow characteristics.—Continued

[Site indicates sampling station. SPRU, South Platte River below Union Avenue; SPRD, South Platte River at Denver; TGC6, Tollgate Creek at 6th Avenue; SCRM, Sand Creek at mouth; SPRH, South Platte River at Henderson. Lab id, Metro Wastewater Reclamation District Laboratory sample identifier; Date, date in mmddyy (month, day, year); Time, time in hhmm (hours, minutes); Day%, fractional portion of day that sample represents. Type indicates portion of hydrograph represented: r--, rising; f--, falling; e-- event; u--, unclassified; ft^3/s, cubic feet per second; acre-ft, acre-feet; na, not available]

Site	Lab id	Beginning		Ending		Day%	Type	Mean streamflow (ft^3/s)	Streamflow volume (acre-ft)
		Date	Time	Date	Time				
SPRD	365008	073098	1627	073198	0523	0.53	r--	2,218	2,218
SPRD	366343	081098	1717	081198	0019	0.28	e--	1,148	676
SPRD	366732	081598	1727	081598	0327	0.40	u--	na	na
SPRD	367036	081998	2204	082098	0742	0.38	e--	997	788
SPRD	368289	090198	0611	090198	1811	0.50	e--	385	382
SPRD	386914	041599	0920	041599	2020	0.46	e--	527	474
SPRD	386915	041599	2120	041699	0920	0.49	f--	391	387
SPRD	387442	042199	2108	042299	0908	0.50	r--	735	728
SPRD	387547	042299	1010	042299	2110	0.47	e--	1,369	1,251
SPRD	387548	042299	2210	042399	1010	0.50	f--	1,264	1,253
SPRD	387630	042399	1020	042399	2120	0.46	f--	1,159	1,059
SPRD	387631	042399	2220	042499	1020	0.49	f--	719	713
SPRD	389787	051699	1553	051799	0252	0.42	e--	988	888
SPRD	390295	052099	1535	052199	0147	0.39	e--	908	773
SPRD	392189	061099	1523	061199	0201	0.44	e--	2,021	1,785
SPRD	392190	061199	0301	061199	1400	0.47	f--	1,646	1,505
SPRD	394712	070899	1538	070999	0213	0.43	r--	877	774
SPRD	395419	071799	1929	071899	0629	0.44	e--	647	591
SPRD	395420	071899	0729	071899	0629	0.94	f--	757	352
SPRD	401345	091999	1525	092099	0126	0.40	e--	612	512
SPRD	401346	092099	0226	092099	1326	0.45	f--	406	371
SPRD	403718	101699	1203	101699	1303	0.05	r--	471	431
SPRD	403719	101799	0003	101799	1103	0.46	f--	352	322
SPRD	416169	031500	1350	031600	0019	0.42	e--	208	180
SPRD	416170	031600	0119	031600	1219	0.45	r--	321	291
SPRD	416241	031600	1334	031700	0334	0.56	f--	442	511
SPRD	416242	031700	0234	031700	1134	0.36	f--	289	215
SPRD	417326	033000	1326	033100	0004	0.44	r--	281	247
SPRD	417327	033100	0104	033100	1204	0.46	r--	446	405
SPRD	417401	033100	1341	040100	0016	0.43	f--	538	471
SPRD	417402	040100	0116	040100	1216	0.46	f--	346	314
SPRD	419871	042900	2303	043000	1027	0.46	e--	1,087	1,024
SPRD	419872	043000	1027	043000	2127	0.45	f--	661	601
SPRD	420644	050800	1334	050900	0012	0.43	e--	1,187	1,043
SPRD	420645	050900	0112	050900	0112	0.99	f--	592	538
SPRD	426633	071600	1849	071700	0415	0.39	r--	3,371	2,628
SPRD	432739	092100	1938	092200	0606	0.44	e--	201	173
SPRD	450258	041001	1806	041101	0444	0.42	r--	348	306
SPRD	450259	041101	0534	041101	1634	0.45	r--	950	863
SPRD	450263	041101	1903	041201	0602	0.46	f--	793	719
SPRD	451106	042101	2058	042201	0706	0.42	r--	371	311
SPRD	451186	042201	0806	042201	1906	0.47	f--	417	379
SPRD	451187	042201	2006	042301	0706	0.46	f--	362	329
SPRD	452202	050301	0412	050301	1414	0.42	r--	445	369
SPRD	452284	050301	1514	050401	0014	0.37	e--	528	393
SPRD	452285	050401	0144	050401	1344	0.48	e--	622	617
SPRD	452355	050401	1436	050501	0136	0.43	r--	1,179	1,071
SPRD	452356	050501	0236	050501	1336	0.44	r--	2,077	1,917
SPRD	452443	050501	1436	050601	0136	0.43	f--	2,275	2,068
SPRD	452444	050601	0236	050601	1336	0.44	f--	897	815
SPRD	452455	050601	1436	050701	0136	0.43	f--	617	560

Table A1. Composite-stormwater-sample streamflow characteristics.—Continued

[Site indicates sampling station. SPRU, South Platte River below Union Avenue; SPRD, South Platte River at Denver; TGC6, Tollgate Creek at 6th Avenue; SCRM, Sand Creek at mouth; SPRH, South Platte River at Henderson. Lab id, Metro Wastewater Reclamation District Laboratory sample identifier; Date, date in mmddyy (month, day, year); Time, time in hhmm (hours, minutes); Day%, fractional portion of day that sample represents. Type indicates portion of hydrograph represented: r--, rising; f--, falling; e-- event; u--, unclassified; ft^3/s, cubic feet per second; acre-ft, acre-feet; na, not available]

Site	Lab id	Beginning		Ending		Day%	Type	Mean streamflow (ft^3/s)	Streamflow volume (acre-ft)
		Date	Time	Date	Time				
SPRD	455752	061301	1414	061401	0051	0.41	e--	1,530	1,342
SPRD	455855	061401	0451	061401	1251	0.31	f--	623	412
SPRD	457962	070801	1645	070901	0247	0.39	e--	3,908	3,240
SPRD	458060	070901	0347	070901	1447	0.44	f--	1,941	1,765
SPRD	458524	071301	1535	071401	1200	0.86	e--	1,568	1,425
TGC6	363044	070898	1132	070898	2332	0.49	u--	na	na
TGC6	363046	070998	1743	071098	0443	0.43	u--	na	na
TGC6	364274	072298	1911	072398	0711	0.50	f--	55	54
TGC6	365575	080498	1606	080598	1345	0.88	u--	na	na
TGC6	368295	090198	0734	090198	1834	0.45	u--	na	na
TGC6	385703	040199	1943	040299	0743	0.47	r--	118	117
TGC6	386917	041599	0930	041599	1830	0.37	e--	110	82
TGC6	387566	042299	1508	042399	0208	0.45	e--	230	207
TGC6	387567	042399	0308	042499	0108	0.91	f--	126	229
TGC6	387636	042399	1340	042499	0040	0.43	f--	82	75
TGC6	387637	042499	0140	042499	1140	0.40	f--	22	18
TGC6	391070	052999	1537	053099	0137	0.39	e--	53	44
TGC6	392150	060999	2125	061099	1125	0.57	f--	43	50
TGC6	394710	070899	1535	070899	2035	0.20	e--	16	7
TGC6	395422	071799	1800	071899	0700	0.55	u--	na	na
TGC6	395423	071899	0755	071899	1335	0.22	u--	na	na
TGC6	396613	072899	1714	072999	0414	0.45	u--	na	na
TGC6	401340	091999	1523	092099	0223	0.44	u--	na	na
TGC6	417328	033000	1458	033100	0119	0.42	e--	31	27
TGC6	417329	033100	0219	033100	1300	0.45	r--	25	22
TGC6	417403	033100	1256	033100	2356	0.44	f--	45	41
TGC6	417404	040100	0056	040100	0656	0.22	f--	11	5
TGC6	419869	042900	2303	043000	1003	0.46	e--	44	40
TGC6	419870	043000	1103	043000	0903	0.92	f--	12	8
TGC6	420643	050800	1547	050900	0347	0.47	e--	31	31
TGC6	426629	071600	2057	071700	0757	0.42	r--	7	6
TGC6	426708	071700	0857	071700	1957	0.43	f--	30	27
TGC6	450260	041001	0010	041101	1110	0.46	r--	358	326
TGC6	450268	041101	1210	041101	2110	0.38	r--	785	583
TGC6	450269	041101	2242	041201	0942	0.44	f--	616	560
TGC6	451197	042201	1324	042301	0024	0.44	u--	na	na
TGC6	451198	042301	0124	042301	1304	0.49	u--	na	na
TGC6	455753	061301	1442	061401	0142	0.43	f--	71	65
TGC6	455856	061401	0242	061401	1342	0.44	f--	33	30
TGC6	457965	070801	1640	070801	2240	0.24	e--	168	83
SCRM	360520	060498	1322	060598	1320	0.99	r--	308	610
SCRM	360521	060598	1530	060698	1547	0.99	f--	535	1,070
SCRM	363043	070998	1859	071098	0559	0.42	f--	2,111	1,930
SCRM	364273	072298	1803	072398	0504	0.46	e--	2,059	1,822
SCRM	365574	080498	1605	080598	0405	0.50	r--	362	359
SCRM	366345	081098	1720	081198	0113	0.32	e--	200	130
SCRM	367038	081998	2204	082098	0650	0.33	e--	370	264
SCRM	368292	090198	0858	090198	1958	0.43	e--	101	91
SCRM	368297	090198	2058	090298	0458	0.30	f--	120	78
SCRM	386919	041599	0920	041599	2020	0.46	e--	258	232
SCRM	386920	041599	1928	041699	0320	0.32	f--	136	88

Table A1. Composite-stormwater-sample streamflow characteristics.—Continued

[Site indicates sampling station. SPRU, South Platte River below Union Avenue; SPRD, South Platte River at Denver; TGC6, Tollgate Creek at 6th Avenue; SCRM, Sand Creek at mouth; SPRH, South Platte River at Henderson. Lab id, Metro Wastewater Reclamation District Laboratory sample identifier; Date, date in mmddyy (month, day, year); Time, time in hhmm (hours, minutes); Day%, fractional portion of day that sample represents. Type indicates portion of hydrograph represented: r--, rising; f--, falling; e-- event; u--, unclassified; ft^3/s, cubic feet per second; acre-ft, acre-feet; na, not available]

Site	Lab id	Beginning		Ending		Day%	Type	Mean streamflow (ft^3/s)	Streamflow volume (acre-ft)
		Date	Time	Date	Time				
SCRM	387446	042199	2213	042299	0913	0.46	r--	454	415
SCRM	387563	042299	1013	042299	2113	0.46	e--	870	795
SCRM	387564	042299	2213	042399	0915	0.46	e--	986	901
SCRM	387633	042399	1037	042399	2137	0.45	f--	558	502
SCRM	387634	042399	2237	042499	0937	0.44	e--	314	282
SCRM	391071	052999	1456	053099	0134	0.42	e--	144	125
SCRM	391072	053099	0234	053099	1134	0.36	f--	81	60
SCRM	395424	071799	1757	071899	0401	0.42	e--	182	149
SCRM	395425	071899	0501	071899	1501	0.43	f--	176	145
SCRM	396614	072899	1812	072999	0457	0.41	e--	625	551
SCRM	397668	081099	1639	081199	0305	0.43	e--	888	756
SCRM	401343	091999	1524	092099	0148	0.40	e--	120	104
SCRM	401344	092099	0248	092099	1048	0.31	f--	93	62
SCRM	417330	033000	1503	033100	0129	0.42	r--	110	95
SCRM	417331	033100	0129	033100	1329	0.49	r--	144	143
SCRM	417405	033100	1350	040100	0050	0.42	f--	329	299
SCRM	417407	040100	0150	040100	1250	0.43	f--	154	140
SCRM	419877	042900	2304	043000	0930	0.42	e--	221	191
SCRM	419878	043000	1030	043000	2130	0.45	f--	178	161
SCRM	420641	050800	1348	050800	2349	0.40	r--	200	166
SCRM	420642	050900	0049	050900	1149	0.43	f--	135	123
SCRM	423920	061600	1818	061700	0458	0.41	r--	120	106
SCRM	423921	061700	0558	061700	0637	1.00	e--	152	134
SCRM	426628	071600	1916	071700	2337	0.17	e--	463	1084
SCRM	426709	071700	0637	071700	1737	0.44	f--	306	278
SCRM	450255	041001	1805	041101	1200	0.75	r--	90	80
SCRM	450257	041101	0552	041101	1352	0.31	r--	166	110
SCRM	451109	042101	2321	042301	1000	0.45	f--	110	97
SCRM	451189	042201	1121	042201	2221	0.46	r--	186	169
SCRM	451190	042201	2321	042201	1021	0.45	r--	45	41
SCRM	452132	050301	0410	050301	1417	0.42	r--	117	98
SCRM	452290	050301	1650	050401	0250	0.38	e--	134	111
SCRM	452291	050401	0350	050401	1450	0.43	r--	181	165
SCRM	452357	050401	1550	050501	0250	0.43	e--	614	558
SCRM	452358	050501	0350	050501	1450	0.43	r--	924	840
SCRM	452445	050501	1550	050601	0250	0.43	f--	883	803
SCRM	452446	050601	0350	050601	1450	0.43	f--	185	169
SCRM	452453	050601	1550	050701	0250	0.43	f--	144	131
SCRM	455755	061301	1446	061401	0046	0.38	u--	na	na
SCRM	455858	061401	0446	061401	1246	0.31	u--	na	na
SCRM	457966	070801	1643	070901	0334	0.43	e--	685	614
SCRM	458059	070901	0434	070901	1534	0.45	f--	133	121
SCRM	458525	071301	1534	071401	0232	0.44	e--	577	523
SPRH	360519	060498	1108	060598	1100	1.00	r--	1,331	2,640
SPRH	360523	060598	1606	060698	1609	1.00	f--	1,384	2,745
SPRH	363042	070998	1803	071098	0203	0.33	r--	1,557	1,037
SPRH	364272	072398	0045	072398	0745	0.27	f--	2,591	3,412
SPRH	365013	073098	2113	073198	1313	0.67	e--	2,519	3,412
SPRH	366344	081198	0142	081198	0312	0.06	f--	1,229	152
SPRH	366733	081598	2145	081698	0215	0.18	f--	1,693	629

Table A1. Composite-stormwater-sample streamflow characteristics.—Continued

[Site indicates sampling station. SPRU, South Platte River below Union Avenue; SPRD, South Platte River at Denver; TGC6, Tollgate Creek at 6th Avenue; SCRM, Sand Creek at mouth; SPRH, South Platte River at Henderson. Lab id, Metro Wastewater Reclamation District Laboratory sample identifier; Date, date in mmddyy (month, day, year); Time, time in hhmm (hours, minutes); Day%, fractional portion of day that sample represents. Type indicates portion of hydrograph represented: r--, rising; f--, falling; e-- event; u--, unclassified; ft³/s, cubic feet per second; acre-ft, acre-feet; na, not available]

Site	Lab id	Beginning		Ending		Day%	Type	Mean streamflow (ft^3/s)	Streamflow volume (acre-ft)
		Date	Time	Date	Time				
SPRH	367037	081998	2204	082098	0644	0.33	e--	1,094	780
SPRH	368294	090198	1120	090198	1350	0.08	f--	903	196
SPRH	386916	041599	0920	041699	0920	0.99	e--	735	1,458
SPRH	387443	042299	0230	042299	1230	0.40	r--	1,728	1,446
SPRH	387574	042299	1415	042299	2345	0.38	e--	2,649	2,093
SPRH	387575	042399	0015	042399	1430	0.58	e--	2,812	3,311
SPRH	387639	042399	1450	042499	0150	0.42	f--	2,631	2,404
SPRH	387640	042499	0250	042499	1250	0.39	e--	1,850	1,519
SPRH	389788	051699	1928	051799	0628	0.44	e--	1,483	1,333
SPRH	390296	052099	1940	052199	0640	0.43	f--	2,261	2,067
SPRH	390298	052199	0740	052199	1240	0.19	f--	728	304
SPRH	392147	060999	2130	061099	0830	0.44	r--	2,442	2,195
SPRH	392148	061099	0930	061099	2030	0.45	r--	2,659	2,389
SPRH	392187	061099	2229	061199	0929	0.44	e--	3,215	2,939
SPRH	392188	061199	1029	061199	1510	0.20	f--	2,371	918
SPRH	395558	071999	1932	072099	0632	0.44	e--	2,844	2,599
SPRH	395681	072099	0732	072099	1832	0.45	f--	1,470	1,344
SPRH	395682	072099	1943	072199	0043	0.18	f--	807	338
SPRH	396599	072899	2224	072999	0924	0.45	e--	1,627	1,487
SPRH	397235	080499	1905	080599	0605	0.46	r--	6,763	6,077
SPRH	397342	080599	0705	080599	1805	0.47	f--	4,953	4,451
SPRH	397343	080599	1905	080699	0605	0.46	f--	3,009	2,704
SPRH	401347	091999	1947	092099	0547	0.39	e--	1,182	970
SPRH	401348	092099	0647	092099	1447	0.31	f--	844	562
SPRH	403721	101699	1439	101799	0139	0.43	r--	881	805
SPRH	403722	101799	0239	101799	1039	0.31	f--	793	528
SPRH	416240	031600	1604	031700	0304	0.46	e--	818	744
SPRH	419875	042900	0504	043000	1004	0.21	r--	394	945
SPRH	419876	043000	1104	043000	2204	0.47	f--	741	674
SPRH	420639	050800	1413	050900	0113	0.45	r--	1,325	1,204
SPRH	420640	050900	0213	050900	1313	0.46	f--	991	901
SPRH	426631	071600	2330	071700	0630	0.27	r--	7,130	4,124
SPRH	426711	071700	0730	071700	1830	0.45	f--	3,275	2,976
SPRH	450266	041101	1716	041201	0416	0.45	f--	2,707	2,460
SPRH	451112	042201	0346	042201	1406	0.44	r--	684	584
SPRH	451199	042201	1546	042301	0246	0.43	e--	1,145	1,040
SPRH	451200	042301	0346	042301	1446	0.44	f--	636	578
SPRH	452131	050301	0409	050301	1500	0.46	r--	916	821
SPRH	452288	050301	1608	050401	0008	0.33	e--	1,304	862
SPRH	452289	050401	0408	050401	1508	0.46	e--	1,323	1,203
SPRH	452359	050401	1608	050501	1508	0.96	r--	4,191	3,809
SPRH	452360	050501	0408	050501	1508	0.46	r--	4,191	3,809
SPRH	452447	050501	1608	050601	0308	0.45	f--	4,961	4,509
SPRH	452448	050601	0408	050601	1508	0.46	f--	2,006	1,823
SPRH	452452	050601	1608	050701	0308	0.45	f--	1,349	1,226
SPRH	455754	061301	1625	061401	0325	0.44	r--	2,356	2,141
SPRH	455857	061401	0725	061401	1525	0.33	f--	1,046	691
SPRH	457967	070801	1649	070901	0349	0.43	e--	4,104	3,730
SPRH	458061	070901	0449	070901	1549	0.43	f--	1,876	1,705
SPRH	458526	071301	1830	071401	0516	0.44	e--	2,149	1,911
SPRH	458593	071401	0716	071401	1816	0.46	f--	1,346	1,224

Table A2. Results from discrete samples collected during storms and computed time, discharge, and volume-weighted concentrations, with relative percent differences.

[Samples collected with pumping samplers; Analytical determination made at USGS National Water-Quality Laboratory; na, missing value (isolated missing values were replaced with an average of the preceding and following values for weighting computations); values greater than –999 and less than 0 are censored; Laboratory estimated values included in weighting computations; Weighting method—Time: (summation of interval × concentration) / sampling period time, where interval is the sum of the midpoint between sample time preceding and following sample times—Discharge: (summation of discharge × concentration) / summation of discharge—Volume: (summation of interval × discharge × concentration) / (summation of interval × discharge); RPD, relative percent difference: 1, time and discharge; 2, time and volume; 3, discharge and volume; na, not applicable; ft^3/s, cubic feet per second; µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; $NO_2 + NO_3$, nitrite plus nitrate; --, no data; µg/L, micrograms per liter]

	Weighting method			RPD1	RPD2	RPD3				
	Time	Discharge	Volume							
Station number 06714000										
Date (yyyymmdd)	na	na	na	na	na	na	**20010723**	**20010723**	**20010723**	**20010723**
Time (hhmm)	na	na	na	na	na	na	**1620**	**1635**	**1650**	**1705**
Decimal julian day	na	na	na	na	na	na	**204.6806**	**204.6910**	**204.7014**	**204.7118**
00065 Gage height (feet)	6.071	6.378	6.357	–4.938	–4.606	0.332	4.430	5.410	5.680	6.200
00061 Discharge, instantaneous (ft^3/s)	2,133.753	2,481.889	2,444.278	–15.085	–13.566	1.527	835.000	1,360.000	1,710.000	2,250.000
00403 pH, whole water, laboratory (standard units)	7.313	7.197	7.271	1.600	0.570	–1.029	7.500	7.200	7.000	7.100
Field conductivity (µS/cm)	273.896	271.414	267.787	0.910	2.255	1.345	657.000	383.000	209.000	202.000
90095 Specific conductance (µS/cm)	283.217	276.281	276.510	2.479	2.397	–0.083	618.000	363.000	200.000	216.000
00900 Hardness, total (mg/L as CaO_3)	80.685	77.665	77.549	3.814	3.963	0.149	190.000	na	54.000	59.000
00915 Calcium, dissolved (mg/L as Ca)	24.611	23.701	23.675	3.765	3.876	0.112	57.100	na	16.800	18.200
00925 Magnesium, dissolved (mg/L as Mg)	4.622	4.474	4.444	3.245	3.914	0.669	11.400	na	2.980	3.360
00530 Residue, total (mg/L)	656.449	606.703	697.142	7.877	–6.013	–13.873	212.000	588.000	622.000	414.000
00608 Nitrogen, ammonia (mg/L as N)	0.564	0.678	0.612	–18.424	–8.282	10.181	0.410	0.784	0.823	0.764
00625 Nitrogen, ammonia + organic (mg/L as N)	1.146	1.306	1.197	–13.052	–4.404	8.661	1.100	1.500	1.400	1.500
00631 $NO_2 + NO_3$, dissolved (mg/L as N)	1.035	1.137	1.057	–9.398	–2.071	7.331	1.830	1.190	0.933	1.080
00671 Phosphorus, orthophosphate (mg/L as P)	0.161	0.172	0.164	–6.446	–1.821	4.626	0.216	0.136	0.189	0.195
00665 Phosphorus, total (mg/L as P)	0.181	0.206	0.187	–13.196	–3.493	9.715	0.219	0.208	0.193	0.220
00681 Carbon, organic, dissolved (mg/L as C)	--	--	--	--	--	--	--	--	--	--
01040 Copper, dissolved (µg/L as Cu)	2.501	3.034	2.555	–19.264	–2.155	17.127	4.200	4.100	4.200	4.100
01049 Lead, dissolved (µg/L as Pb)	0.185	0.264	0.192	–35.474	–4.070	31.518	0.190	0.410	0.540	0.520
01090 Zinc, dissolved (µg/L as Zn)	5.832	7.840	6.138	–29.386	–5.119	24.359	11.000	12.000	12.000	11.000

Table A2. Results from discrete samples collected during storms and computed time, discharge, and volume-weighted concentrations, with relative percent differences.—Continued

[Samples collected with pumping samplers; Analytical determination made at USGS National Water-Quality Laboratory; na, missing value (isolated missing values were replaced with an average of the preceding and following values for weighting computations); values greater than –999 and less than 0 are censored; Laboratory estimated values included in weighting computations; Weighting method—Time: (summation of interval × concentration) / sampling period time, where interval is the sum of the midpoint between sample time preceding and following sample times—Discharge: (summation of discharge × concentration) / summation of discharge—Volume: (summation of interval × discharge × concentration) / (summation of interval × discharge); RPD, relative percent difference: 1, time and discharge; 2, time and volume; 3, discharge and volume; na, not applicable; ft^3/s, cubic feet per second; µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; $NO_2 + NO_3$, nitrite plus nitrate; --, no data; µg/L, micrograms per liter]

	Weighting method			RPD1	RPD2	RPD3			
	Time	Discharge	Volume						
Station number 06714000									
Date (yyyymmdd)	**20010723**	**20010723**	**20010723**	**20010723**	**20010723**	**20010723**	**20010723**	**20010723**	**20010724**
Time (hhmm)	**1720**	**1735**	**1805**	**1835**	**1935**	**2035**	**2135**	**2235**	**15**
Decimal julian day	**204.7222**	**204.7326**	**204.7535**	**204.7743**	**204.8160**	**204.8576**	**204.8993**	**204.9410**	**205.0104**
00065 Gage height (feet)	6.630	7.000	7.210	7.080	6.810	6.180	5.560	5.360	5.150
00061 Discharge, instantaneous (ft^3/s)	2,680.000	3,210.000	3,440.000	3,230.000	2,960.000	2,130.000	1,560.000	1,350.000	1,190.000
00403 pH, whole water, laboratory (standard units)	6.800	7.100	7.300	7.000	7.400	7.300	7.500	7.500	7.400
Field conductivity (µS/cm)	207.000	279.000	250.000	262.000	294.000	261.000	229.000	255.000	343.000
90095 Specific conductance (µS/cm)	219.000	267.000	273.000	251.000	320.000	255.000	248.000	275.000	361.000
00900 Hardness, total (mg/L as CaO_3)	55.000	72.000	75.000	68.000	89.000	71.000	70.000	79.000	110.000
00915 Calcium, dissolved (mg/L as Ca)	16.900	22.000	22.900	20.800	27.000	21.800	21.600	24.400	32.700
00925 Magnesium, dissolved (mg/L as Mg)	3.170	4.200	4.310	3.940	5.110	3.990	3.960	4.490	6.310
00530 Residue, total (mg/L)	116.000	428.000	860.000	588.000	848.000	1,510.000	336.000	500.000	412.000
00608 Nitrogen, ammonia (mg/L as N)	0.876	0.803	0.756	0.756	0.611	0.479	0.363	0.475	0.320
00625 Nitrogen, ammonia + organic (mg/L as N)	1.800	1.500	1.300	1.200	1.200	1.100	0.990	0.980	0.810
00631 $NO_2 + NO_3$, dissolved (mg/L as N)	1.280	1.270	1.350	1.310	0.873	0.749	0.834	0.947	1.190
00671 Phosphorus, orthophosphate (mg/L as P)	0.236	0.084	0.226	0.209	0.138	0.140	0.127	0.164	0.164
00665 Phosphorus, total (mg/L as P)	0.274	0.261	0.230	0.215	0.145	0.149	0.155	0.163	0.167
00681 Carbon, organic, dissolved (mg/L as C)	--	--	--	--	--	--	--	--	--
01040 Copper, dissolved (µg/L as Cu)	4.400	3.300	2.800	2.600	2.200	1.800	1.900	2.000	2.300
01049 Lead, dissolved (µg/L as Pb)	0.500	0.290	0.180	0.190	0.120	0.110	0.130	0.140	0.070
01090 Zinc, dissolved (µg/L as Zn)	13.000	9.000	7.000	7.000	5.000	3.000	4.000	4.000	4.000

Table A2. Results from discrete samples collected during storms and computed time, discharge, and volume-weighted concentrations, with relative percent differences.—Continued

[Samples collected with pumping samplers; Analytical determination made at USGS National Water-Quality Laboratory; na, missing value (isolated missing values were replaced with an average of the preceding and following values for weighting computations); values greater than –999 and less than 0 are censored; Laboratory estimated values included in weighting computations; Weighting method—Time: (summation of interval × concentration) / sampling period time, where interval is the sum of the midpoint between sample time preceding and following sample times—Discharge: (summation of discharge × concentration) / summation of discharge—Volume: (summation of interval × discharge × concentration) / (summation of interval × discharge); RPD, relative percent difference: 1, time and discharge; 2, time and volume; 3, discharge and volume; na, not applicable; ft^3/s, cubic feet per second; µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; $NO_2 + NO_3$, nitrite plus nitrate; --, no data; µg/L, micrograms per liter]

	Weighting method			RPD1	RPD2	RPD3				
	Time	Discharge	Volume							
Station number 39483910457030										
Date (yyyymmdd)	na	na	na	na	na	na	**20010806**	**20010806**	**20010806**	**20010806**
Time (hhmm)	na	na	na	na	na	na	**1630**	**1700**	**1730**	**1800**
Decimal julian day	na	na	na	na	na	na	**218.6875**	**218.7083**	**218.7292**	**218.7500**
00065 Gage height (feet)	4.516	4.572	4.572	–1.235	–1.233	0.002	4.11	4.66	4.66	4.53
00061 Discharge, instantaneous (ft^3/s)	217.853	242.262	241.297	–10.610	–10.212	0.399	69.0	275	280	215
00403 pH, whole water, laboratory (standard units)	7.490	7.485	7.475	0.063	0.205	0.142	8.20	7.50	7.40	7.20
Field conductivity (µS/cm)	--	--	--	--	--	--	--	--	--	--
90095 Specific conductance (µS/cm)	571.873	564.011	554.304	1.384	3.120	1.736	1,370	974	402	348
00900 Hardness, total (mg/L as CaO_3)	136.050	132.876	130.742	2.360	3.979	1.619	350	240	83.0	78.0
00915 Calcium, dissolved (mg/L as Ca)	40.596	39.517	38.999	2.694	4.013	1.320	103	69.6	24.7	23.4
00925 Magnesium, dissolved (mg/L as Mg)	8.444	8.303	8.128	1.680	3.807	2.128	23.1	15.7	5.17	4.70
00530 Residue, total (mg/L)	350.140	409.287	413.882	–15.577	–16.686	–1.117	23.0	336	518	316
00608 Nitrogen, ammonia (mg/L as N)	0.380	0.402	0.388	–5.543	–1.971	3.573	0.38	0.43	0.57	0.55
00625 Nitrogen, ammonia + organic (mg/L as N)	0.899	0.938	0.913	–4.338	–1.566	2.772	0.95	1.00	1.20	1.10
00631 $NO_2 + NO_3$, dissolved (mg/L as N)	0.863	0.879	0.874	–1.791	–1.207	0.584	0.72	0.84	0.96	0.88
00671 Phosphorus, orthophosphate (mg/L as P)	0.131	0.138	0.132	–5.192	–0.732	4.461	0.18	0.19	0.16	0.16
00665 Phosphorus, total (mg/L as P)	0.171	0.171	0.154	–0.192	10.416	10.608	0.93	0.21	0.18	0.18
00681 Carbon, organic, dissolved (mg/L as C)	8.528	8.634	8.524	–1.246	0.045	1.291	6.90	11.0	11.0	9.20
01040 Copper, dissolved (µg/L as Cu)	2.759	2.779	2.677	–0.733	3.000	3.733	6.40	3.90	2.90	2.50
01049 Lead, dissolved (µg/L as Pb)	0.200	0.197	0.156	1.502	24.763	23.283	2.17	0.14	0.16	0.28
01090 Zinc, dissolved (µg/L as Zn)	13.737	14.164	12.695	–3.058	7.888	10.940	71.0	13.0	15.0	18.0

Table A2. Results from discrete samples collected during storms and computed time, discharge, and volume-weighted concentrations, with relative percent differences.—Continued

[Samples collected with pumping samplers; Analytical determination made at USGS National Water-Quality Laboratory; na, missing value (isolated missing values were replaced with an average of the preceding and following values for weighting computations); values greater than –999 and less than 0 are censored; Laboratory estimated values included in weighting computations; Weighting method—Time: (summation of interval × concentration) / sampling period time, where interval is the sum of the midpoint between sample time preceding and following sample times—Discharge: (summation of discharge × concentration) / summation of discharge—Volume: (summation of interval × discharge × concentration) / (summation of interval × discharge); RPD, relative percent difference: 1, time and discharge; 2, time and volume; 3, discharge and volume; na, not applicable; ft^3/s, cubic feet per second; µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; $NO_2 + NO_3$, nitrite plus nitrate; --, no data; µg/L, micrograms per liter]

	Weighting method			RPD1	RPD2	RPD3		
	Time	Discharge	Volume					
Station number 39483910457030								
Date (yyyymmdd)	**20010806**	**20010806**	**20010806**	**20010806**	**20010806**	**20010806**	**20010806**	**20010806**
Time (hhmm)	**1830**	**1900**	**1930**	**2000**	**2100**	**2200**	**2300**	**2310**
Decimal julian day	**218.7708**	**218.7917**	**218.8125**	**218.8333**	**218.8750**	**218.9167**	**218.9583**	**218.9653**
00065 Gage height (feet)	4.50	4.70	4.75	4.68	4.48	4.30	4.33	4.33
00061 Discharge, instantaneous (ft^3/s)	202	306	327	285	190	136	139	141
00403 pH, whole water, laboratory (standard units)	7.30	7.50	7.60	7.50	7.50	7.50	7.50	7.60
Field conductivity (µS/cm)	--	--	--	--	--	--	--	--
90095 Specific conductance (µS/cm)	396	477	636	448	622	559	505	503
00900 Hardness, total (mg/L as CaO_3)	88.0	110	150	100	160	130	120	120
00915 Calcium, dissolved (mg/L as Ca)	26.5	32.8	44.7	30.9	47.3	39.3	36.6	35.0
00925 Magnesium, dissolved (mg/L as Mg)	5.39	6.91	9.35	6.29	9.45	7.89	7.31	7.02
00530 Residue, total (mg/L)	230	356	812	700	314	109	136	206
00608 Nitrogen, ammonia (mg/L as N)	0.58	0.47	0.28	0.26	0.31	0.29	0.30	0.30
00625 Nitrogen, ammonia + organic (mg/L as N)	1.20	1.00	0.87	0.68	0.78	0.77	0.76	0.77
00631 $NO_2 + NO_3$, dissolved (mg/L as N)	0.84	0.79	1.05	0.84	0.84	0.84	0.88	0.89
00671 Phosphorus, orthophosphate (mg/L as P)	0.18	0.14	0.10	0.11	0.09	0.11	0.12	0.12
00665 Phosphorus, total (mg/L as P)	0.19	0.16	0.11	0.12	0.10	0.11	0.13	0.12
00681 Carbon, organic, dissolved (mg/L as C)	8.50	7.40	7.40	6.70	8.50	8.40	8.90	9.10
01040 Copper, dissolved (µg/L as Cu)	2.70	2.70	2.50	1.90	2.60	2.50	2.50	2.50
01049 Lead, dissolved (µg/L as Pb)	0.26	0.19	0.12	0.09	0.05	0.05	0.07	0.07
01090 Zinc, dissolved (µg/L as Zn)	19.0	16.0	12.0	8.00	8.00	8.00	8.00	8.00

Table A2. Results from discrete samples collected during storms and computed time, discharge, and volume-weighted concentrations, with relative percent differences.—Continued

[Samples collected with pumping samplers; Analytical determination made at USGS National Water-Quality Laboratory; na, missing value (isolated missing values were replaced with an average of the preceding and following values for weighting computations); values greater than –999 and less than 0 are censored; Laboratory estimated values included in weighting computations; Weighting method—Time: (summation of interval × concentration) / sampling period time, where interval is the sum of the midpoint between sample time preceding and following sample times—Discharge: (summation of discharge × concentration) / summation of discharge—Volume: (summation of interval × discharge × concentration) / (summation of interval × discharge); RPD, relative percent difference: 1, time and discharge; 2, time and volume; 3, discharge and volume; na, not applicable; ft³/s, cubic feet per second; µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; NO_2+ NO_3, nitrite plus nitrate; --, no data; µg/L, micrograms per liter]

	Weighting method			RPD1	RPD2	RPD3				
	Time	Discharge	Volume							
Station number 39483910457030										
Date (yyyymmdd)	na	na	na	na	na	na	**20010815**	**20010815**	**20010815**	**20010815**
Time (hhmm)	na	na	na	na	na	na	**1450**	**1505**	**1520**	**1535**
Decimal julian day	na	na	na	na	na	na	**227.6181**	**227.6285**	**227.6389**	**227.6493**
00065 Gage height (feet)	4.176	4.285	4.223	–2.574	–1.120	1.454	3.94	4.12	4.43	4.47
00061 Discharge, instantaneous (ft³/s)	96.959	124.971	108.842	–25.243	–11.548	13.796	49.0	81.0	149	179
00403 pH, whole water, laboratory (standard units)	7.470	7.460	7.457	0.133	0.168	0.035	7.90	7.90	7.90	7.50
Field conductivity (µS/cm)	721.920	669.984	695.853	7.463	3.677	–3.788	na	1,140	1,090	767
90095 Specific conductance (µS/cm)	715.160	666.851	690.663	6.991	3.485	–3.508	1,120	1,120	1,070	758
00900 Hardness, total (mg/L as CaO_3)	190.720	177.821	183.913	7.000	3.634	–3.368	320	310	300	210
00915 Calcium, dissolved (mg/L as Ca)	58.134	54.008	56.007	7.359	3.726	–3.635	96.6	94.6	91.3	62.5
00925 Magnesium, dissolved (mg/L as Mg)	11.405	10.601	10.984	7.308	3.766	–3.544	19.2	18.7	18.5	12.3
00530 Residue, total (mg/L)	216.518	192.540	219.202	11.723	–1.232	–12.951	20.0	59.0	136	328
00608 Nitrogen, ammonia (mg/L as N)	0.499	0.533	0.519	–6.480	–3.785	2.697	0.22	0.19	0.11	0.31
00625 Nitrogen, ammonia + organic (mg/L as N)	1.992	2.253	2.124	–12.314	–6.436	5.890	1.00	1.10	1.40	2.70
00631 NO_2 + NO_3, dissolved (mg/L as N)	1.173	1.165	1.166	0.673	0.543	–0.130	1.35	1.36	1.33	1.18
00671 Phosphorus, orthophosphate (mg/L as P)	0.226	0.219	0.221	3.087	2.523	–0.564	0.39	0.38	0.29	0.20
00665 Phosphorus, total (mg/L as P)	0.618	0.668	0.646	–7.892	–4.491	3.404	0.48	0.57	0.71	0.96
00681 Carbon, organic, dissolved (mg/L as C)	8.380	8.587	8.502	–2.443	–1.443	1.000	7.40	7.20	7.50	8.40
01040 Copper, dissolved (µg/L as Cu)	4.712	4.506	4.664	4.479	1.017	–3.463	5.30	5.50	5.10	4.90
01049 Lead, dissolved (µg/L as Pb)	0.173	0.215	0.185	–21.963	–6.965	15.055	0.09	0.09	0.09	0.14
01090 Zinc, dissolved (µg/L as Zn)	13.680	13.145	13.396	3.987	2.095	–1.892	19.0	12.0	13.0	12.0

Table A2. Results from discrete samples collected during storms and computed time, discharge, and volume-weighted concentrations, with relative percent differences.—Continued

[Samples collected with pumping samplers; Analytical determination made at USGS National Water-Quality Laboratory; na, missing value (isolated missing values were replaced with an average of the preceding and following values for weighting computations); values greater than –999 and less than 0 are censored; Laboratory estimated values included in weighting computations; Weighting method—Time: (summation of interval × concentration) / sampling period time, where interval is the sum of the midpoint between sample time preceding and following sample times—Discharge: (summation of discharge × concentration) / summation of discharge—Volume: (summation of interval × discharge × concentration) / (summation of interval × discharge); RPD, relative percent difference: 1, time and discharge; 2, time and volume; 3, discharge and volume; na, not applicable; ft³/s, cubic feet per second; µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; NO_2+ NO_3, nitrite plus nitrate; --, no data; µg/L, micrograms per liter]

	Weighting method			RPD1	RPD2	RPD3				
	Time	Discharge	Volume							
Station number 39483910457030										
Date (yyyymmdd)	**20010815**	**20010815**	**20010815**	**20010815**	**20010815**	**20010815**	**20010815**	**20010815**	**20010815**	**20010815**
Time (hhmm)	**1550**	**1605**	**1620**	**1635**	**1650**	**1705**	**1720**	**1805**	**1905**	**2105**
Decimal julian day	**227.6597**	**227.6701**	**227.6806**	**227.6910**	**227.7014**	**227.7118**	**227.7222**	**227.7535**	**227.7951**	**227.8785**
00065 Gage height (feet)	4.43	4.37	4.32	4.28	4.24	4.20	4.17	4.15	4.11	4.01
00061 Discharge, instantaneous (ft³/s)	168	150	134	122	111	101	92.0	87.0	80.0	59.0
00403 pH, whole water, laboratory (standard units)	7.300	7.30	7.30	7.40	7.20	7.30	7.40	7.40	7.50	7.50
Field conductivity (µS/cm)	510	516	503	395	406	487	577	688	795	833
90095 Specific conductance (µS/cm)	515	524	508	400	413	490	579	682	784	818
00900 Hardness, total (mg/L as CaO_3)	130	140	130	98.0	100	120	150	180	210	220
00915 Calcium, dissolved (mg/L as Ca)	40.2	41.4	39.6	29.8	30.8	37.9	44.7	55.3	64.6	66.6
00925 Magnesium, dissolved (mg/L as Mg)	7.81	8.03	7.67	5.73	5.88	7.24	8.61	10.7	12.7	13.2
00530 Residue, total (mg/L)	258	202	182	96.0	186	144	104	312	316	154
00608 Nitrogen, ammonia (mg/L as N)	0.72	0.74	0.70	0.64	0.66	0.78	0.81	0.59	0.43	0.32
00625 Nitrogen, ammonia + organic (mg/L as N)	3.20	2.80	2.30	2.60	2.20	2.40	2.30	2.00	1.90	1.40
00631 NO_2 + NO_3, dissolved (mg/L as N)	1.11	1.16	1.14	1.06	1.04	1.07	1.09	1.17	1.18	1.21
00671 Phosphorus, orthophosphate (mg/L as P)	0.18	0.18	0.18	0.15	0.17	0.21	0.22	0.27	0.21	0.22
00665 Phosphorus, total (mg/L as P)	0.80	0.73	0.60	0.60	0.56	0.56	0.56	0.53	0.71	0.48
00681 Carbon, organic, dissolved (mg/L as C)	9.50	10.0	10.0	8.30	8.80	6.90	9.20	8.80	8.00	8.00
01040 Copper, dissolved (µg/L as Cu)	4.80	4.20	3.70	3.50	3.90	3.70	3.90	5.90	4.90	4.50
01049 Lead, dissolved (µg/L as Pb)	0.15	0.17	0.18	0.60	0.61	0.22	0.19	0.20	0.09	0.10
01090 Zinc, dissolved (µg/L as Zn)	12.0	13.0	12.0	13.0	14.0	13.0	14.0	15.0	13.0	15.0

Table A3. Summary statistics for water-quality properties and constituents by water year for (A) all stations, (B) South Platte River below Union Avenue, (C) South Platte River at Denver, (D) Tollgate Creek above 6th Avenue, (E) Sand Creek at mouth, and (F) South Platte River at Henderson.

[Variables, abbreviations used for water-quality properties and constituents as defined at the beginning of the Appendix; n, number of samples; M, number of samples with missing values; Pct, percentage of samples below minimum reporting level; Stddev, standard deviation; Skew, skewness; na, not applicable]

Variable	Water year	n	M	Pct	Mean	Median	Stddev	Skew	Minimum	Maximum	Minimum reporting level	
											Mean	Median
(A) All stations												
mq	1998	31	5	0.00	975	895	743	0.69	55.0	2,590	na	na
mq	1999	80	4	0.00	1,040	732	1,138	2.37	16.0	6,760	na	na
mq	2000	56	0	0.00	563	257	1,096	4.38	7.00	7,130	na	na
mq	2001	75	4	0.00	955	588	1,100	1.91	33.0	4,960	na	na
qv	1998	31	5	0.00	994	629	969	1.26	54.0	3412	na	na
qv	1999	80	4	0.00	916	576	1,038	2.39	7.00	6077	na	na
qv	2000	56	0	0.00	484	217	744	3.16	5.00	4124	na	na
qv	2001	75	4	0.00	850	523	989	1.94	30.0	4509	na	na
ph	1998	30	6	0.00	7.56	7.60	0.25	–0.08	7.10	7.90	na	na
ph	1999	84	0	0.00	7.30	7.30	0.24	–0.14	6.70	7.80	na	na
ph	2000	56	0	0.00	7.56	7.60	0.21	–0.54	7.00	7.90	na	na
ph	2001	79	0	0.00	7.36	7.40	0.21	–0.18	6.90	7.80	na	na
sc	1998	36	0	0.00	590	525	251	1.24	255	1,440	na	na
sc	1999	84	0	0.00	600	538	261	1.88	260	1,940	na	na
sc	2000	56	0	0.00	720	742	277	0.43	316	1,320	na	na
sc	2001	79	0	0.00	592	561	180	0.43	281	1,060	na	na
hdn	1998	36	0	0.00	200	192	75.3	1.27	89.0	451	na	na
hdn	1999	84	0	0.00	188	177	74.3	2.53	94.0	608	na	na
hdn	2000	56	0	0.00	220	222	51.3	0.16	131	333	na	na
hdn	2001	79	0	0.00	190	185	46.4	0.79	100	347	na	na
tss	1998	36	0	0.00	591	509	498	1.20	8.00	2,210	na	na
tss	1999	80	4	0.00	565	404	484	1.28	12.0	2,030	na	na
tss	2000	56	0	0.00	483	261	568	3.14	22.0	3,560	na	na
tss	2001	79	0	0.00	547	241	747	2.62	52.0	3,890	na	na
nh3	1998	36	0	58.33	0.62	0.50	0.41	1.36	0.20	1.80	0.67	0.20
nh3	1999	84	0	64.29	0.82	0.75	0.68	1.55	0.20	3.10	0.20	0.20
nh3	2000	56	0	66.07	0.79	0.40	0.77	1.69	0.20	2.90	0.20	0.20
nh3	2001	79	0	60.76	1.15	1.00	0.78	0.76	0.20	3.20	0.20	0.20
no23	1998	36	0	0.00	1.40	1.30	0.79	0.52	0.33	3.07	na	na
no23	1999	84	0	0.00	1.34	1.03	0.94	1.14	0.05	4.55	na	na
no23	2000	56	0	1.79	1.31	0.93	1.15	2.15	0.27	6.51	9.99	9.99
no23	2001	9	70	0.00	1.55	1.12	1.36	1.50	0.55	4.87	na	na
opo4	1998	29	7	13.79	0.26	0.19	0.16	0.84	0.06	0.61	0.03	0.03
opo4	1999	84	0	8.33	0.24	0.20	0.17	1.19	0.03	0.77	0.03	0.03
opo4	2000	56	0	5.36	0.23	0.16	0.18	1.48	0.03	0.80	0.03	0.03
opo4	2001	79	0	3.80	0.25	0.21	0.16	1.13	0.04	0.78	0.03	0.03

Table A3. Summary statistics for water-quality properties and constituents by water year for (A) all stations, (B) South Platte River below Union Avenue, (C) South Platte River at Denver, (D) Tollgate Creek above 6th Avenue, (E) Sand Creek at mouth, and (F) South Platte River at Henderson.—Continued

[Variables, abbreviations used for water-quality properties and constituents as defined at the beginning of the Appendix; n, number of samples; M, number of samples with missing values; Pct, percentage of samples below minimum reporting level; Stddev, standard deviation; Skew, skewness; na, not applicable]

Variable	Water year	n	M	Pct	Mean	Median	Stddev	Skew	Minimum	Maximum	Minimum reporting level	
											Mean	Median
(A) All stations—Continued												
tpo4	1998	36	0	0.00	0.74	0.59	0.50	0.46	0.05	1.70	na	na
tpo4	1999	84	0	0.00	0.60	0.53	0.36	0.87	0.04	1.83	na	na
tpo4	2000	56	0	0.00	0.82	0.67	0.68	1.49	0.03	3.17	na	na
tpo4	2001	79	0	0.00	0.68	0.51	0.44	0.89	0.03	1.94	na	na
tkn	1998	36	0	8.33	2.40	2.10	1.52	0.96	0.50	6.70	0.30	0.30
tkn	1999	84	0	7.14	2.29	1.95	1.45	1.16	0.30	7.70	0.30	0.30
tkn	2000	56	0	1.79	3.13	2.30	2.43	1.53	0.50	12.0	9.99	9.99
tkn	2001	79	0	0.00	2.59	2.00	1.57	1.15	0.50	8.40	na	na
toc	1998	0	na	na	na	na	na	na	na	na	na	na
toc	1999	70	14	0.00	11.6	11.0	3.97	1.76	7.00	27.0	na	na
toc	2000	56	0	0.00	13.3	13.0	5.17	0.39	6.00	26.0	na	na
toc	2001	79	0	0.00	11.2	10.0	5.66	2.68	6.00	40.0	na	na
cud	1998	36	0	0.00	14.6	12.0	12.1	2.03	1.00	60.0	na	na
cud	1999	84	0	2.38	6.76	5.00	4.89	1.26	1.00	23.0	1.00	1.00
cud	2000	56	0	5.36	6.19	4.00	6.22	2.25	1.00	31.0	1.00	1.00
cud	2001	79	0	2.53	6.91	4.00	6.27	2.19	1.00	35.0	1.00	1.00
pbt	1999	81	3	41.98	22.4	21.0	9.97	0.69	10.0	48.0	10.0	10.0
pbt	2000	56	0	53.57	39.2	27.5	28.8	1.40	11.0	121	10.0	10.0
pbt	2001	78	1	46.15	39.0	30.5	25.2	0.79	10.0	97.0	10.0	10.0
mnd	1998	36	0	0.00	397	315	333	1.42	20.0	1,500	na	na
mnd	1999	35	49	0.00	142	120	100	1.75	30.0	460	na	na
mnd	2000	0	na	na	na	na	na	na	na	na	na	na
mnd	2001	79	0	11.39	125	100	102	1.57	20.0	510	20.0	20.0
mnt	1998	0	na	na	na	na	na	na	na	na	na	na
mnt	1999	7	77	0.00	458	400	275	0.82	210	980	na	na
mnt	2000	0	na	na	na	na	na	na	na	na	na	na
mnt	2001	79	0	0.00	491	370	394	1.92	80.00	2,130	na	na
znd	1998	35	1	2.86	112	98.0	83.8	1.09	6.60	380	20.0	20.0
znd	1999	84	0	3.57	51.3	38.8	42.0	2.08	2.20	254	6.73	0.10
znd	2000	56	0	0.00	101	50.7	208	5.46	3.40	1,490	na	na
znd	2001	79	0	13.92	74.6	37.1	109	3.01	2.50	580	18.19	20.0
znt	1998	35	1	5.71	202	170	124	0.47	20.0	470	20.0	20.0
znt	1999	83	1	3.61	169	132	140	1.56	9.20	687	6.87	0.30
znt	2000	56	0	0.00	243	170	265	2.27	8.0	1,500	na	na
znt	2001	79	0	1.27	172	120	155	1.34	8.90	640	20.0	20.0

Table A3. Summary statistics for water-quality properties and constituents by water year for (A) all stations, (B) South Platte River below Union Avenue, (C) South Platte River at Denver, (D) Tollgate Creek above 6th Avenue, (E) Sand Creek at mouth, and (F) South Platte River at Henderson.—Continued

[Variables, abbreviations used for water-quality properties and constituents as defined at the beginning of the Appendix; n, number of samples; M, number of samples with missing values; Pct, percentage of samples below minimum reporting level; Stddev, standard deviation; Skew, skewness; na, not applicable]

Variable	Water year	n	M	Pct	Mean	Median	Stddev	Skew	Minimum	Maximum	Minimum reporting level	
											Mean	Median
(B) South Platte River below Union Avenue (06710247)												
mq	1998	5	0	0.00	436	529	143	–0.40	236	554	na	na
mq	1999	14	0	0.00	570	633	281	–0.39	76.0	949	na	na
mq	2000	14	0	0.00	296	227	183	0.87	84.0	724	na	na
mq	2001	16	0	0.00	295	278	158	0.35	92.0	588	na	na
qv	1998	5	0	0.00	542	527	94.2	0.87	469	704	na	na
qv	1999	14	0	0.00	491	524	235	–0.46	68.0	780	na	na
qv	2000	14	0	0.00	270	202	162	0.99	116	658	na	na
qv	2001	16	0	0.00	280	283	140	0.19	83.0	534	na	na
ph	1998	4	1	0.00	7.57	7.55	0.32	0.03	7.30	7.90	na	na
ph	1999	14	0	0.00	7.24	7.20	0.33	0.13	6.70	7.80	na	na
ph	2000	14	0	0.00	7.59	7.65	0.22	–0.49	7.20	7.90	na	na
ph	2001	16	0	0.00	7.49	7.50	0.21	–0.48	7.00	7.80	na	na
sc	1998	5	0	0.00	300	305	30.7	–0.38	255	330	na	na
sc	1999	14	0	0.00	380	354	114	0.90	260	660	na	na
sc	2000	14	0	0.00	486	420	133	0.82	316	791	na	na
sc	2001	16	0	0.00	484	482	77.4	0.05	362	612	na	na
hdn	1998	5	0	0.00	136	125	52.4	0.81	89.0	226	na	na
hdn	1999	14	0	0.00	140	134	36.6	1.15	97.0	236	na	na
hdn	2000	14	0	0.00	168	160	25.2	1.29	145	234	na	na
hdn	2001	16	0	0.00	177	178	34.9	1.52	143	283	na	na
tss	1998	5	0	0.00	364	32.0	621	0.96	8.00	1,450	na	na
tss	1999	13	1	0.00	229	201	101	0.12	74.0	402	na	na
tss	2000	14	0	0.00	258	165	325	2.11	22.0	1,280	na	na
tss	2001	16	0	0.00	371	148	443	1.23	52.0	1,440	na	na
nh3	1998	5	0	100.00	na	na	na	na	na	na	0.20	0.20
nh3	1999	14	0	92.86	0.30	0.30	na	na	0.30	0.30	0.20	0.20
nh3	2000	14	0	100.00	na	na	na	na	na	na	0.20	0.20
nh3	2001	16	0	93.75	0.20	0.20	na	na	0.20	0.20	0.20	0.20
no23	1998	5	0	0.00	0.49	0.51	0.14	–0.09	0.33	0.64	na	na
no23	1999	14	0	0.00	0.56	0.45	0.50	1.23	0.05	1.84	na	na
no23	2000	14	0	0.00	0.62	0.55	0.31	0.61	0.27	1.30	na	na
no23	2001	2	14	0.00	0.56	0.56	0.02	0.00	0.55	0.58	na	na
opo4	1998	3	2	0.00	0.24	0.06	0.31	0.38	0.06	0.59	na	na
opo4	1999	14	0	28.57	0.12	0.11	0.05	0.53	0.07	0.21	0.03	0.03
opo4	2000	14	0	21.43	0.17	0.11	0.22	2.16	0.03	0.80	0.03	0.03
opo4	2001	16	0	12.50	0.13	0.10	0.09	0.66	0.05	0.29	0.03	0.03

Table A3. Summary statistics for water-quality properties and constituents by water year for (A) all stations, (B) South Platte River below Union Avenue, (C) South Platte River at Denver, (D) Tollgate Creek above 6th Avenue, (E) Sand Creek at mouth, and (F) South Platte River at Henderson.—Continued

[Variables, abbreviations used for water-quality properties and constituents as defined at the beginning of the Appendix; n, number of samples; M, number of samples with missing values; Pct, percentage of samples below minimum reporting level; Stddev, standard deviation; Skew, skewness; na, not applicable]

Variable	Water year	n	M	Pct	Mean	Median	Stddev	Skew	Minimum	Maximum	Minimum reporting level	
											Mean	Median
(B) South Platte River below Union Avenue (06710247)—Continued												
tpo4	1998	5	0	0.00	0.44	0.10	0.63	0.92	0.05	1.53	na	na
tpo4	1999	14	0	0.00	0.22	0.23	0.10	–0.42	0.04	0.36	na	na
tpo4	2000	14	0	0.00	0.30	0.25	0.28	1.40	0.03	1.06	na	na
tpo4	2001	16	0	0.00	0.40	0.22	0.43	1.87	0.03	1.73	na	na
tkn	1998	5	0	20.00	1.75	0.95	1.92	0.71	0.50	4.60	0.30	0.30
tkn	1999	14	0	21.43	1.25	0.90	1.10	1.64	0.30	4.20	0.30	0.30
tkn	2000	14	0	0.00	1.44	1.10	1.12	1.32	0.50	4.40	na	na
tkn	2001	16	0	0.00	1.76	1.40	1.30	1.90	0.50	5.80	na	na
toc	1998	0	na	na	na	na	na	na	na	na	na	na
toc	1999	12	2	0.00	10.2	10.0	1.82	–0.17	7.00	13.0	na	na
toc	2000	14	0	0.00	8.71	8.00	3.15	0.85	6.00	15.0	na	na
toc	2001	16	0	0.00	8.12	7.50	2.22	1.33	6.00	14.0	na	na
cud	1998	5	0	0.00	6.20	6.00	4.15	0.14	1.00	12.0	na	na
cud	1999	14	0	0.00	4.43	4.50	2.59	0.84	1.00	11.0	na	na
cud	2000	14	0	14.29	6.33	3.00	8.57	1.92	1.00	31.0	1.00	1.00
cud	2001	16	0	6.25	4.73	3.00	5.32	2.26	1.00	22.0	1.00	1.00
pbt	1998	5	0	60.00	39.0	39.0	39.6	0.00	11.0	67.0	10.0	10.0
pbt	1999	13	1	84.62	12.5	12.5	3.54	0.00	10.0	15.0	10.0	10.0
pbt	2000	14	0	78.57	27.0	22.0	19.0	0.24	11.0	48.0	10.0	10.0
pbt	2001	15	1	66.67	19.8	17.0	4.82	0.23	15.0	25.0	10.0	10.0
mnd	1998	5	0	0.00	192	70.0	206	0.73	50.0	530	na	na
mnd	1999	6	8	0.00	83.3	85.0	32.0	–0.43	30.0	120	na	na
mnd	2000	0	na	na	na	na	na	na	na	na	na	na
mnd	2001	16	0	12.50	70.7	60.0	47.4	1.00	20.0	190	20.0	20.0
mnt	1998	0	na	na	na	na	na	na	na	na	na	na
mnt	1999	1	13	0.00	210	210	na	na	210.0	210	na	na
mnt	2000	0	na	na	na	na	na	na	na	na	na	na
mnt	2001	16	0	0.00	315	225	200	0.55	100.0	640	na	na
znd	1998	5	0	0.00	28.1	7.50	32.3	0.66	6.60	80.0	na	na
znd	1999	14	0	0.00	27.4	18.0	22.3	1.63	2.20	91.6	na	na
znd	2000	14	0	0.00	43.9	24.0	41.7	0.96	3.40	145	na	na
znd	2001	16	0	12.50	15.0	14.4	9.97	0.92	2.50	40.6	20.0	20.0
znt	1998	5	0	20.00	145	50.0	211	0.71	20.0	460	20.0	20.0
znt	1999	13	1	0.00	43.5	40.0	25.9	0.73	9.20	101	na	na
znt	2000	14	0	0.00	54.4	48.2	44.1	1.37	8.00	178	na	na
znt	2001	16	0	6.25	55.9	42.5	40.3	0.50	8.90	120	20.0	20.0

Table A3. Summary statistics for water-quality properties and constituents by water year for (A) all stations, (B) South Platte River below Union Avenue, (C) South Platte River at Denver, (D) Tollgate Creek above 6th Avenue, (E) Sand Creek at mouth, and (F) South Platte River at Henderson.—Continued

[Variables, abbreviations used for water-quality properties and constituents as defined at the beginning of the Appendix; n, number of samples; M, number of samples with missing values; Pct, percentage of samples below minimum reporting level; Stddev, standard deviation; Skew, skewness; na, not applicable]

Variable	Water year	n	M	Pct	Mean	Median	Stddev	Skew	Minimum	Maximum	Minimum reporting level	
											Mean	Median
(C) South Platte River at Denver (06714000)												
mq	1998	7	1	0.00	1,073	997	569	0.88	385	2,218	na	na
mq	1999	18	0	0.00	880	746	459	0.92	352	2,021	na	na
mq	2000	14	0	0.00	712	444	822	2.36	201	3,371	na	na
mq	2001	19	0	0.00	1,129	793	913	1.50	348	3,908	na	na
qv	1998	7	1	0.00	956	788	603	1.13	382	2,218	na	na
qv	1999	18	0	0.00	787	720	428	0.82	322	1,785	na	na
qv	2000	14	0	0.00	617	438	642	2.13	173	2,628	na	na
qv	2001	19	0	0.00	994	719	791	1.27	306	3,240	na	na
ph	1998	7	1	0.00	7.49	7.50	0.28	0.01	7.10	7.90	na	na
ph	1999	18	0	0.00	7.31	7.35	0.16	–0.32	7.00	7.50	na	na
ph	2000	14	0	0.00	7.42	7.45	0.22	–0.13	7.00	7.80	na	na
ph	2001	19	0	0.00	7.31	7.30	0.23	–0.17	6.90	7.70	na	na
sc	1998	8	0	0.00	471	472	92.0	0.14	339	614	na	na
sc	1999	18	0	0.00	533	523	138	0.38	321	841	na	na
sc	2000	14	0	0.00	700	742	218	–0.05	348	1,050	na	na
sc	2001	19	0	0.00	534	542	162	0.24	281	885	na	na
hdn	1998	8	0	0.00	169	160	26.4	0.35	144	209	na	na
hdn	1999	18	0	0.00	181	185	38.2	0.07	125	255	na	na
hdn	2000	14	0	0.00	240	237	45.7	0.27	165	333	na	na
hdn	2001	19	0	0.00	172	163	40.6	0.19	100	250	na	na
tss	1998	8	0	0.00	668	595	494	0.62	67.0	1,600	na	na
tss	1999	18	0	0.00	502	428	372	0.91	12.0	1,450	na	na
tss	2000	14	0	0.00	921	487	895	1.76	212	3,560	na	na
tss	2001	19	0	0.00	457	307	629	3.06	118	2,910	na	na
nh3	1998	8	0	62.50	0.43	0.30	0.32	0.34	0.20	0.80	0.20	0.20
nh3	1999	18	0	72.22	0.46	0.30	0.26	0.82	0.30	0.90	0.20	0.20
nh3	2000	14	0	28.57	0.42	0.40	0.19	1.47	0.20	0.90	0.20	0.20
nh3	2001	19	0	68.42	0.58	0.50	0.34	0.76	0.30	1.20	0.20	0.20
no23	1998	8	0	0.00	1.81	1.82	0.62	0.24	0.96	2.84	na	na
no23	1999	18	0	0.00	1.70	1.62	0.77	0.70	0.71	3.58	na	na
no23	2000	14	0	0.00	2.60	2.39	1.43	1.28	0.97	6.51	na	na
no23	2001	3	16	0.00	2.85	2.28	1.81	0.28	1.39	4.87	na	na
opo4	1998	7	1	0.00	0.22	0.17	0.09	0.89	0.16	0.38	na	na
opo4	1999	18	0	0.00	0.19	0.16	0.11	0.86	0.08	0.47	na	na
opo4	2000	14	0	0.00	0.26	0.22	0.12	1.24	0.14	0.55	na	na
opo4	2001	19	0	0.00	0.26	0.23	0.10	1.20	0.14	0.54	na	na

Table A3. Summary statistics for water-quality properties and constituents by water year for (A) all stations, (B) South Platte River below Union Avenue, (C) South Platte River at Denver, (D) Tollgate Creek above 6th Avenue, (E) Sand Creek at mouth, and (F) South Platte River at Henderson.—Continued

[Variables, abbreviations used for water-quality properties and constituents as defined at the beginning of the Appendix; n, number of samples; M, number of samples with missing values; Pct, percentage of samples below minimum reporting level; Stddev, standard deviation; Skew, skewness; na, not applicable]

Variable	Water year	n	M	Pct	Mean	Median	Stddev	Skew	Minimum	Maximum	Minimum reporting level	
											Mean	Median
(C) South Platte River at Denver (06714000)—Continued												
tpo4	1998	8	0	0.00	0.73	0.64	0.51	0.38	0.21	1.60	na	na
tpo4	1999	18	0	0.00	0.54	0.49	0.34	0.93	0.14	1.38	na	na
tpo4	2000	14	0	0.00	1.44	1.00	0.82	0.89	0.70	3.17	na	na
tpo4	2001	19	0	0.00	0.62	0.51	0.29	1.31	0.28	1.48	na	na
tkn	1998	8	0	12.50	2.79	1.70	2.14	0.71	0.80	6.70	0.30	0.30
tkn	1999	18	0	11.11	2.26	2.00	1.22	0.84	0.40	4.90	0.30	0.30
tkn	2000	14	0	0.00	4.85	3.25	2.94	0.98	1.20	12.0	na	na
tkn	2001	19	0	0.00	2.34	1.90	1.06	1.08	1.20	4.80	na	na
toc	1998	0	na	na	na	na	na	na	na	na	na	na
toc	1999	14	4	0.00	10.7	11.0	2.72	0.32	7.00	16.0	na	na
toc	2000	14	0	0.00	12.4	12.0	4.26	0.59	6.00	22.0	na	na
toc	2001	19	0	0.00	12.3	10.0	7.30	2.80	7.00	40.0	na	na
cud	1998	8	0	0.00	16.7	11.0	18.0	1.64	4.00	60.0	na	na
cud	1999	18	0	5.56	6.41	4.00	5.12	2.01	2.00	23.0	1.00	1.00
cud	2000	14	0	7.14	6.77	5.00	5.61	1.78	2.00	23.0	1.00	1.00
cud	2001	19	0	0.00	6.37	4.00	5.77	2.24	2.00	26.0	na	na
pbt	1998	8	0	25.00	41.8	40.5	15.8	–0.44	15.0	60.0	10.0	10.0
pbt	1999	18	0	33.33	24.6	25.5	9.22	–0.21	10.0	39.0	10.0	10.0
pbt	2000	14	0	28.57	44.9	34.0	33.6	1.06	15.0	121	10.0	10.0
pbt	2001	19	0	21.05	33.4	28.0	25.6	1.30	10.0	97.0	10.0	10.0
mnd	1998	8	0	0.00	307	260	263	0.82	30.0	840	na	na
mnd	1999	7	11	0.00	108	110	58.7	0.38	40.0	210	na	na
mnd	2000	0	na	na	na	na	na	na	na	na	na	na
mnd	2001	19	0	21.05	115	70.0	124	2.14	20.0	510	20.0	20.0
mnt	1998	0	na	na	na	na	na	na	na	na	na	na
mnt	1999	2	16	0.00	360	360	98.9	0.00	290	430	na	na
mnt	2000	0	na	na	na	na	na	na	na	na	na	na
mnt	2001	19	0	0.00	410	310	262	1.35	150	1,120	na	na
znd	1998	8	0	0.00	117	98.0	78.4	0.80	28.0	275	na	na
znd	1999	18	0	5.56	41.6	36.0	22.0	0.31	10.6	80.8	0.10	0.10
znd	2000	14	0	0.00	55.6	47.2	47.9	1.63	14.1	195	na	na
znd	2001	19	0	21.05	44.7	29.3	43.4	1.66	12.7	170	20.0	20.0
znt	1998	8	0	0.00	185	160	111	0.14	40.0	330	na	na
znt	1999	18	0	5.56	148	135	123	2.03	51.0	544	0.30	0.30
znt	2000	14	0	0.00	271	227	172	0.91	92.0	672	na	na
znt	2001	19	0	0.00	119	90.0	88.0	1.17	27.8	310	na	na

Table A3. Summary statistics for water-quality properties and constituents by water year for (A) all stations, (B) South Platte River below Union Avenue, (C) South Platte River at Denver, (D) Tollgate Creek above 6th Avenue, (E) Sand Creek at mouth, and (F) South Platte River at Henderson.—Continued

[Variables, abbreviations used for water-quality properties and constituents as defined at the beginning of the Appendix; n, number of samples; M, number of samples with missing values; Pct, percentage of samples below minimum reporting level; Stddev, standard deviation; Skew, skewness; na, not applicable]

Variable	Water year	n	M	Pct	Mean	Median	Stddev	Skew	Minimum	Maximum	Minimum reporting level	
											Mean	Median
(D) Tollgate Creek above 6th Avenue (394329104490101)												
mq	1998	1	4	0.00	55.0	55.0	na	na	55.0	55.0	na	na
mq	1999	9	4	0.00	88.8	82.0	66.9	0.77	16.0	230	na	na
mq	2000	9	0	0.00	26.2	30.0	13.8	–0.04	7.00	45.0	na	na
mq	2001	6	2	0.00	338	263	306	0.33	33.0	785	na	na
qv	1998	1	4	0.00	54.0	54.0	na	na	54.0	54.0	na	na
qv	1999	9	4	0.00	92.1	75.0	78.8	0.65	7.00	229	na	na
qv	2000	9	0	0.00	23.0	27.0	13.9	–0.11	5.00	41.0	na	na
qv	2001	6	2	0.00	274	204	252	0.23	30.0	583	na	na
ph	1998	4	1	0.00	7.53	7.50	0.26	0.05	7.30	7.80	na	na
ph	1999	13	0	0.00	7.35	7.40	0.21	–0.11	7.00	7.60	na	na
ph	2000	9	0	0.00	7.67	7.70	0.14	–0.65	7.40	7.80	na	na
ph	2001	8	0	0.00	7.38	7.50	0.21	–0.58	7.00	7.60	na	na
sc	1998	5	0	0.00	875	745	352	0.63	583	1,440	na	na
sc	1999	13	0	0.00	870	858	407	1.18	316	1,940	na	na
sc	2000	9	0	0.00	947	880	249	0.19	578	1,300	na	na
sc	2001	8	0	0.00	789	756	204	–0.49	396	1,060	na	na
hdn	1998	5	0	0.00	306	252	99.8	0.43	218	451	na	na
hdn	1999	13	0	0.00	263	232	130	1.29	94.0	608	na	na
hdn	2000	9	0	0.00	260	253	24.4	0.17	224	300	na	na
hdn	2001	8	0	0.00	259	255	53.0	0.11	180	347	na	na
tss	1998	5	0	0.00	841	692	794	0.88	235	2,210	na	na
tss	1999	12	1	0.00	837	655	588	0.44	170	1,880	na	na
tss	2000	9	0	0.00	303	228	255	1.22	97.0	868	na	na
tss	2001	8	0	0.00	1114	281	1,555	0.93	73.0	3,890	na	na
nh3	1998	5	0	60.00	1.05	1.05	1.06	0.00	0.30	1.80	0.20	0.20
nh3	1999	13	0	92.31	0.30	0.30	na	na	0.30	0.30	0.20	0.20
nh3	2000	9	0	77.78	0.30	0.30	0.00	0.00	0.30	0.30	0.20	0.20
nh3	2001	8	0	75.00	0.25	0.25	0.07	0.00	0.20	0.30	0.20	0.20
no23	1998	5	0	0.00	0.69	0.71	0.19	–0.12	0.42	0.94	na	na
no23	1999	13	0	0.00	0.68	0.62	0.24	1.31	0.42	1.31	na	na
no23	2000	9	0	0.00	0.50	0.50	0.07	0.71	0.42	0.64	na	na
no23	2001	1	7	0.00	0.59	0.59	na	na	0.59	0.59	na	na
opo4	1998	5	0	80.00	0.07	0.07	na	na	0.07	0.07	0.03	0.03
opo4	1999	13	0	23.08	0.11	0.10	0.05	0.24	0.03	0.19	0.03	0.03
opo4	2000	9	0	0.00	0.14	0.09	0.10	1.76	0.08	0.40	na	na
opo4	2001	8	0	0.00	0.16	0.12	0.13	1.43	0.04	0.47	na	na

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[Variables, abbreviations used for water-quality properties and constituents as defined at the beginning of the Appendix; n, number of samples; M, number of samples with missing values; Pct, percentage of samples below minimum reporting level; Stddev, standard deviation; Skew, skewness; na, not applicable]

Variable	Water year	n	M	Pct	Mean	Median	Stddev	Skew	Minimum	Maximum	Minimum reporting level	
											Mean	Median
(D) Tollgate Creek above 6th Avenue (394329104490101)—Continued												
tpo4	1998	5	0	0.00	0.76	0.58	0.57	0.69	0.23	1.70	na	na
tpo4	1999	13	0	0.00	0.68	0.61	0.43	1.31	0.19	1.83	na	na
tpo4	2000	9	0	0.00	0.47	0.43	0.19	0.63	0.27	0.82	na	na
tpo4	2001	8	0	0.00	0.69	0.41	0.59	1.07	0.17	1.94	na	na
tkn	1998	5	0	0.00	2.42	2.30	0.95	0.19	1.20	3.80	na	na
tkn	1999	13	0	0.00	2.33	2.20	1.61	0.94	0.50	6.00	na	na
tkn	2000	9	0	0.00	2.02	1.80	0.91	0.66	0.90	3.60	na	na
tkn	2001	8	0	0.00	1.94	1.70	1.50	1.56	0.80	5.50	na	na
toc	1998	0	na	na	na	na	na	na	na	na	na	na
toc	1999	11	2	0.00	12.7	12.0	4.94	2.09	9.00	27.0	na	na
toc	2000	9	0	0.00	15.5	14.0	5.25	0.22	8.00	24.0	na	na
toc	2001	8	0	0.00	13.0	12.0	4.93	0.62	8.00	21.0	na	na
cud	1998	5	0	0.00	16.8	14.0	13.6	0.81	4.00	40.0	na	na
cud	1999	13	0	0.00	5.62	4.00	4.93	1.32	1.00	17.0	na	na
cud	2000	9	0	0.00	5.56	4.00	3.21	0.56	2.00	11.0	na	na
cud	2001	8	0	0.00	4.62	4.00	3.66	1.32	1.00	13.0	na	na
pbt	1998	5	0	40.00	23.3	16.0	14.4	0.38	14.0	40.0	10.0	10.0
pbt	1999	13	0	53.85	21.5	21.0	6.1	0.09	15.0	29.0	10.0	10.0
pbt	2000	9	0	77.78	19.5	19.5	6.3	0.00	15.0	24.0	10.0	10.0
pbt	2001	8	0	62.50	43.6	54.0	17.9	–0.38	23.0	54.0	10.0	10.0
mnd	1998	5	0	0.00	804	730	478	0.15	170	1,500	na	na
mnd	1999	7	6	0.00	205	150	174	0.64	50.0	460	na	na
mnd	2000	0	na	na	na	na	na	na	na	na	na	na
mnd	2001	8	0	0.00	151	115	111	0.76	50.0	340	na	na
mnt	1998	0	na	na	na	na	na	na	na	na	na	na
mnt	1999	1	12	0.00	980	980	na	na	980	980	na	na
mnt	2000	0	na	na	na	na	na	na	na	na	na	na
mnt	2001	8	0	0.00	780	405	718	0.88	160	2,130	na	na
znd	1998	5	0	0.00	85.9	80.0	46.2	–0.03	23.5	146	na	na
znd	1999	13	0	7.69	26.9	22.2	20.0	0.94	6.00	67.0	20.0	20.0
znd	2000	9	0	0.00	38.0	31.0	23.7	0.15	11.0	68.0	na	na
znd	2001	8	0	12.50	27.0	13.8	33.4	1.39	6.10	100	20.0	20.0
znt	1998	5	0	0.00	168	170	93.9	0.62	90.0	320	na	na
znt	1999	13	0	7.69	124	105	72.3	0.45	24.0	250	20.0	20.0
znt	2000	9	0	0.00	73.7	74.4	40.1	1.06	30.0	165	na	na
znt	2001	8	0	0.00	135	62.7	132.4	0.67	22.3	350	na	na

Table A3. Summary statistics for water-quality properties and constituents by water year for (A) all stations, (B) South Platte River below Union Avenue, (C) South Platte River at Denver, (D) Tollgate Creek above 6th Avenue, (E) Sand Creek at mouth, and (F) South Platte River at Henderson.—Continued

[Variables, abbreviations used for water-quality properties and constituents as defined at the beginning of the Appendix; n, number of samples; M, number of samples with missing values; Pct, percentage of samples below minimum reporting level; Stddev, standard deviation; Skew, skewness; na, not applicable]

Variable	Water year	n	M	Pct	Mean	Median	Stddev	Skew	Minimum	Maximum	Minimum reporting level	
											Mean	Median
(E) Sand Creek at mouth (394839104570300)												
mq	1998	9	0	0.00	685	362	805	1.04	101	2,111	na	na
mq	1999	15	0	0.00	392	258	317	0.68	81	986	na	na
mq	2000	12	0	0.00	209	166	105	1.14	110	463	na	na
mq	2001	16	2	0.00	323	173	301	0.91	45	924	na	na
qv	1998	9	0	0.00	706	359	733	0.70	78.0	1,930	na	na
qv	1999	15	0	0.00	344	232	290	0.66	60.0	901	na	na
qv	2000	12	0	0.00	243	152	272	2.41	95.0	1,084	na	na
qv	2001	16	2	0.00	289	148	275	0.91	41.0	840	na	na
ph	1998	7	2	0.00	7.73	7.80	0.23	–0.66	7.40	7.90	na	na
ph	1999	15	0	0.00	7.41	7.40	0.21	0.17	7.10	7.70	na	na
ph	2000	12	0	0.00	7.67	7.65	0.13	–0.11	7.40	7.90	na	na
ph	2001	18	0	0.00	7.37	7.40	0.18	–0.42	7.00	7.60	na	na
sc	1998	9	0	0.00	790	752	171	–0.17	499	1,006	na	na
sc	1999	15	0	0.00	736	763	212	–0.06	422	1,060	na	na
sc	2000	12	0	0.00	917	892	198	–0.30	506	1,200	na	na
sc	2001	18	0	0.00	654	667	190	–0.18	318	964	na	na
hdn	1998	9	0	0.00	249	245	44.0	0.34	202	316	na	na
hdn	1999	15	0	0.00	226	236	55.2	–0.24	131	303	na	na
hdn	2000	12	0	0.00	250	241	39.4	0.43	195	317	na	na
hdn	2001	18	0	0.00	203	202	42.1	–0.10	123	268	na	na
tss	1998	9	0	0.00	569	604	344	0.33	149	1,190	na	na
tss	1999	15	0	0.00	760	596	569	0.54	149	1,720	na	na
tss	2000	12	0	0.00	237	212	154	1.33	71.0	626	na	na
tss	2001	18	0	0.00	340	180	329	1.25	69.0	1,120	na	na
nh3	1998	9	0	88.89	0.40	0.40	na	na	0.40	0.40	1.42	0.20
nh3	1999	15	0	100.00	na	na	na	na	na	na	0.20	0.20
nh3	2000	12	0	100.00	na	na	na	na	na	na	0.20	0.20
nh3	2001	18	0	77.78	0.85	0.80	0.37	0.18	0.50	1.30	0.20	0.20
no23	1998	9	0	0.00	1.16	1.14	0.42	0.21	0.57	1.78	na	na
no23	1999	15	0	0.00	0.78	0.80	0.21	0.08	0.47	1.15	na	na
no23	2000	12	0	0.00	0.93	0.94	0.20	–0.62	0.48	1.24	na	na
no23	2001	2	16	0.00	1.10	1.10	0.04	0.00	1.07	1.12	na	na
opo4	1998	7	2	0.00	0.18	0.17	0.03	0.40	0.14	0.24	na	na
opo4	1999	15	0	0.00	0.22	0.19	0.13	0.56	0.04	0.47	na	na
opo4	2000	12	0	0.00	0.19	0.14	0.14	1.97	0.08	0.60	na	na
opo4	2001	18	0	0.00	0.19	0.17	0.07	0.36	0.04	0.35	na	na

Table A3. Summary statistics for water-quality properties and constituents by water year for (A) all stations, (B) South Platte River below Union Avenue, (C) South Platte River at Denver, (D) Tollgate Creek above 6th Avenue, (E) Sand Creek at mouth, and (F) South Platte River at Henderson.—Continued

[Variables, abbreviations used for water-quality properties and constituents as defined at the beginning of the Appendix; n, number of samples; M, number of samples with missing values; Pct, percentage of samples below minimum reporting level; Stddev, standard deviation; Skew, skewness; na, not applicable]

Variable	Water year	n	M	Pct	Mean	Median	Stddev	Skew	Minimum	Maximum	Minimum reporting level	
											Mean	Median
(E) Sand Creek at mouth (394839104570300)—Continued												
tpo4	1998	9	0	0.00	0.65	0.45	0.45	0.72	0.26	1.40	na	na
tpo4	1999	15	0	0.00	0.65	0.57	0.29	0.54	0.30	1.21	na	na
tpo4	2000	12	0	0.00	0.61	0.62	0.25	0.12	0.23	1.01	na	na
tpo4	2001	18	0	0.00	0.57	0.44	0.28	0.78	0.23	1.19	na	na
tkn	1998	9	0	11.11	2.30	2.05	1.37	0.58	0.80	4.80	0.30	0.30
tkn	1999	15	0	6.67	2.19	1.65	1.84	1.82	0.40	7.70	0.30	0.30
tkn	2000	12	0	8.33	2.53	2.30	1.15	1.55	1.30	5.60	9.99	9.99
tkn	2001	18	0	0.00	2.32	1.95	1.26	1.04	0.80	5.10	na	na
toc	1998	0	na	na	na	na	na	na	na	na	na	na
toc	1999	13	2	0.00	14.3	12.0	5.53	0.75	9.00	26.0	na	na
toc	2000	12	0	0.00	17.3	17.5	4.16	0.21	10.0	26.0	na	na
toc	2001	18	0	0.00	12.0	10.0	5.85	1.61	6.00	30.0	na	na
cud	1998	9	0	0.00	12.5	11.0	7.37	1.31	5.00	30.0	na	na
cud	1999	15	0	6.67	7.14	5.50	4.79	1.30	3.00	20.0	1.00	1.00
cud	2000	12	0	0.00	4.33	3.00	3.37	0.97	1.00	12.0	na	na
cud	2001	18	0	0.00	8.17	5.50	8.35	2.07	3.00	35.0	na	na
pbt	1998	9	0	33.33	32.1	25.0	18.0	0.42	17.0	59.0	10.0	10.0
pbt	1999	15	0	26.67	22.2	16.0	13.5	0.93	10.0	48.0	10.0	10.0
pbt	2000	12	0	66.67	21.2	22.0	7.8	–0.21	11.0	30.0	10.0	10.0
pbt	2001	18	0	61.11	31.8	25.0	15.9	0.74	16.0	61.0	10.0	10.0
mnd	1998	9	0	0.00	470	330	326	1.23	170	1,210	na	na
mnd	1999	8	7	0.00	152	135	98.5	0.57	30.0	330	na	na
mnd	2000	0	na	na	na	na	na	na	na	na	na	na
mnd	2001	18	0	5.56	154	120	116	0.92	20.0	410	20.0	20.0
mnt	1998	0	na	na	na	na	na	na	na	na	na	na
mnt	1999	2	13	0.00	450	450	296	0.00	240	660	na	na
mnt	2000	0	na	na	na	na	na	na	na	na	na	na
mnt	2001	18	0	0.00	513	405	422	1.46	80.0	1,740	na	na
znd	1998	8	1	12.50	186	175	116	0.23	26.0	380	20.0	20.0
znd	1999	15	0	6.67	95.4	92.7	60.8	1.18	22.0	254	0.10	0.10
znd	2000	12	0	0.00	286	142	402	2.18	41.4	1,490	na	na
znd	2001	18	0	0.00	183	120	164	1.27	34.4	580	na	na
znt	1998	8	1	12.50	251	230	103	–0.06	90.0	400	20.0	20.0
znt	1999	15	0	6.67	299	268	207	0.51	70.0	687	0.30	0.30
znt	2000	12	0	0.00	505	385	379	1.33	103	1,500	na	na
znt	2001	18	0	0.00	324	280	186	0.38	85.5	640	na	na

Table A3. Summary statistics for water-quality properties and constituents by water year for (A) all stations, (B) South Platte River below Union Avenue, (C) South Platte River at Denver, (D) Tollgate Creek above 6th Avenue, (E) Sand Creek at mouth, and (F) South Platte River at Henderson.—Continued

[Variables, abbreviations used for water-quality properties and constituents as defined at the beginning of the Appendix; n, number of samples; M, number of samples with missing values; Pct, percentage of samples below minimum reporting level; Stddev, standard deviation; Skew, skewness; na, not applicable]

Variable	Water year	n	M	Pct	Mean	Median	Stddev	Skew	Minimum	Maximum	Minimum reporting level	
											Mean	Median
(F) South Platte River at Henderson (06720500)												
mq	1998	9	0	0.00	1589	1384	595	0.68	903	2,591	na	na
mq	1999	24	0	0.00	2197	2055	1416	1.46	728	6,763	na	na
mq	2000	7	0	0.00	2096	991	2412	1.20	394	7,130	na	na
mq	2001	18	0	0.00	2127	1612	1358	0.80	636	4,961	na	na
qv	1998	9	0	0.00	1667	1037	1365	0.18	152	3,412	na	na
qv	1999	24	0	0.00	1926	1503	1348	1.27	304	6,077	na	na
qv	2000	7	0	0.00	1652	945	1348	0.87	674	4,124	na	na
qv	2001	18	0	0.00	1895	1465	1264	0.77	578	4,509	na	na
ph	1998	8	1	0.00	7.49	7.50	0.19	–0.18	7.20	7.70	na	na
ph	1999	24	0	0.00	7.25	7.30	0.25	0.02	6.80	7.70	na	na
ph	2000	7	0	0.00	7.43	7.40	0.17	–0.03	7.20	7.60	na	na
ph	2001	18	0	0.00	7.27	7.30	0.15	–0.53	6.90	7.50	na	na
sc	1998	9	0	0.00	500	502	67.7	0.23	416	604	na	na
sc	1999	24	0	0.00	546	536	146	–0.05	277	804	na	na
sc	2000	7	0	0.00	601	504	331	1.32	322	1,320	na	na
sc	2001	18	0	0.00	598	569	158	0.11	302	861	na	na
hdn	1998	9	0	0.00	156	159	22.0	–0.12	124	190	na	na
hdn	1999	24	0	0.00	159	158	29.3	0.32	119	222	na	na
hdn	2000	7	0	0.00	181	165	36.6	0.19	131	238	na	na
hdn	2001	18	0	0.00	176	170	30.4	0.23	127	233	na	na
tss	1998	9	0	0.00	534	452	403	0.48	58.0	1,310	na	na
tss	1999	22	2	0.00	535	383	474	1.54	106	2,030	na	na
tss	2000	7	0	0.00	709	705	275	0.09	329	1,140	na	na
tss	2001	18	0	0.00	754	556	764	1.21	105	2,580	na	na
nh3	1998	9	0	0.00	0.61	0.70	0.26	–0.18	0.30	0.90	na	na
nh3	1999	24	0	4.17	0.95	0.90	0.72	1.26	0.20	3.10	0.20	0.20
nh3	2000	7	0	0.00	1.47	1.10	0.94	0.50	0.60	2.90	na	na
nh3	2001	18	0	0.00	1.57	1.50	0.74	0.42	0.40	3.20	na	na
no23	1998	9	0	0.00	2.20	1.96	0.63	0.01	1.32	3.07	na	na
no23	1999	24	0	0.00	2.23	2.05	0.91	0.87	1.15	4.55	na	na
no23	2000	7	0	14.29	1.95	2.00	0.71	0.27	1.04	3.10	9.99	9.99
no23	2001	1	17	0.00	1.47	1.47	na	na	1.47	1.47	na	na
opo4	1998	7	2	0.00	0.41	0.42	0.14	–0.13	0.18	0.61	na	na
opo4	1999	24	0	0.00	0.41	0.35	0.17	0.76	0.20	0.77	na	na
opo4	2000	7	0	0.00	0.47	0.37	0.17	0.50	0.31	0.76	na	na
opo4	2001	18	0	5.56	0.45	0.41	0.15	0.68	0.27	0.78	0.03	0.03

Table A3. Summary statistics for water-quality properties and constituents by water year for (A) all stations, (B) South Platte River below Union Avenue, (C) South Platte River at Denver, (D) Tollgate Creek above 6th Avenue, (E) Sand Creek at mouth, and (F) South Platte River at Henderson.—Continued

[Variables, abbreviations used for water-quality properties and constituents as defined at the beginning of the Appendix; n, number of samples; M, number of samples with missing values; Pct, percentage of samples below minimum reporting level; Stddev, standard deviation; Skew, skewness; na, not applicable]

Variable	Water year	n	M	Pct	Mean	Median	Stddev	Skew	Minimum	Maximum	Minimum reporting level Mean	Minimum reporting level Median
(F) South Platte River at Henderson (06720500)—Continued												
tpo4	1998	9	0	0.00	0.99	1.02	0.42	0.12	0.42	1.70	na	na
tpo4	1999	24	0	0.00	0.80	0.80	0.31	0.51	0.36	1.56	na	na
tpo4	2000	7	0	0.00	1.45	1.45	0.46	0.40	0.92	2.20	na	na
tpo4	2001	18	0	0.00	1.11	1.09	0.33	0.60	0.68	1.89	na	na
tkn	1998	9	0	0.00	2.47	2.40	1.40	0.83	0.80	5.50	na	na
tkn	1999	24	0	0.00	2.83	2.75	1.22	0.53	0.50	5.90	na	na
tkn	2000	7	0	0.00	5.43	5.50	2.49	0.20	1.80	9.60	na	na
tkn	2001	18	0	0.00	4.15	4.35	1.61	0.67	1.80	8.40	na	na
toc	1998	0	na	na	na	na	na	na	na	na	na	na
toc	1999	20	4	0.00	10.8	11.5	3.11	0.17	7.00	16.0	na	na
toc	2000	7	0	0.00	14.8	14.0	4.71	0.31	8.00	23.0	na	na
toc	2001	18	0	0.00	11.1	10.0	5.42	2.34	7.00	30.0	na	na
cud	1998	9	0	0.00	18.3	15.0	11.3	1.07	4.00	44.0	na	na
cud	1999	24	0	0.00	8.75	8.00	5.32	0.30	1.00	20.0	na	na
cud	2000	7	0	0.00	8.86	4.00	9.28	0.90	3.00	26.0	na	na
cud	2001	18	0	5.56	9.18	9.00	5.48	0.93	1.00	24.0	1.00	1.00
pbt	1998	9	0	22.22	41.0	40.0	26.2	0.24	10.0	83.0	10.0	10.0
pbt	1999	22	2	27.27	22.4	21.0	9.44	0.45	10.0	40.0	10.0	10.0
pbt	2000	7	0	0.00	52.2	53.0	30.6	0.68	21.0	110	na	na
pbt	2001	18	0	33.33	57.1	63.5	26.8	–0.39	10.00	94.0	10.0	10.0
mnd	1998	9	0	0.00	294	280	162	–0.10	20.0	540	na	na
mnd	1999	7	17	0.00	152	130	44.9	0.56	110	230	na	na
mnd	2000	0	na	na	na	na	na	na	na	na	na	na
mnd	2001	18	0	11.11	139	135	83.8	0.45	20.0	320	20.0	20.0
mnt	1998	0	na	na	na	na	na	na	na	na	na	na
mnt	1999	1	23	0.00	400	400	na	na	400	400	na	na
mnt	2000	0	na	na	na	na	na	na	na	na	na	na
mnt	2001	18	0	0.00	584	505	361	0.89	160	1,470	na	na
znd	1998	9	0	0.00	111	103	47.1	–0.48	18.8	170	na	na
znd	1999	24	0	0.00	58.6	49.8	35.5	1.42	16.6	168	na	na
znd	2000	7	0	0.00	70.4	49.7	52.2	0.91	27.7	172	na	na
znd	2001	18	0	22.22	49.9	50.0	24.5	0.16	11.6	100	15.0	20.0
znt	1998	9	0	0.00	224	150	127	0.68	80.0	470	na	na
znt	1999	24	0	0.00	199	186	93.1	0.14	50.0	355	na	na
znt	2000	7	0	0.00	337	236	188	0.80	182	687	na	na
znt	2001	18	0	0.00	188	180	133	1.03	49.5	550	na	na

Table A4. Correlation among water-quality properties and constituents, by station.

[Variables, abbreviations used for water-quality properties and constituents as defined at the beginning of the Appendix; R, Pearson correlation coefficient; n, number of pairs used in calculation; na, not applicable]

Variables		All stations		Union		Denver		Henderson		Tollgate		Sand Creek	
		R	n	R	n	R	n	R	n	R	n	R	n
mq	qv	0.956	242	0.939	49	0.986	58	0.906	58	0.978	25	0.948	52
mq	ph	–0.365	237	–0.443	48	–0.291	57	–0.400	57	–0.085	25	–0.169	50
mq	sc	–0.397	242	–0.776	49	–0.684	58	–0.559	58	–0.112	25	–0.526	52
mq	hdn	–0.411	242	–0.499	49	–0.544	58	–0.568	58	–0.016	25	–0.439	52
mq	tss	0.296	239	0.379	48	0.385	58	0.429	56	0.023	25	0.608	52
mq	nh3	–0.040	92	1.000	2	0.154	23	–0.386	57	–0.816	6	–0.572	4
mq	no23	0.125	175	–0.706	35	–0.527	42	–0.615	40	0.111	20	–0.421	38
mq	opo4	0.354	224	0.366	38	0.196	57	–0.324	55	0.026	24	0.113	50
mq	tpo4	0.339	242	0.203	49	0.052	58	0.094	58	0.185	25	0.737	52
mq	tkn	0.245	232	0.268	45	0.038	55	–0.066	58	–0.173	25	0.527	49
mq	toc	–0.026	197	0.170	42	0.099	47	0.045	45	–0.249	22	–0.138	41
mq	cud	0.299	235	0.314	46	0.019	56	0.309	57	–0.186	25	0.435	51
mq	cut	0.475	239	0.297	48	0.242	58	0.432	56	0.022	25	0.700	52
mq	pbd	–0.089	43	1.000	2	–0.205	11	–0.252	17	1.000	2	0.698	11
mq	pbt	0.525	133	0.229	12	0.521	42	0.510	42	–0.009	10	0.590	27
mq	mnd	0.084	132	0.391	25	–0.032	29	–0.021	32	–0.188	14	0.581	32
mq	mnt	0.297	82	0.751	17	0.646	21	0.519	19	–0.418	7	0.600	18
mq	znd	–0.042	226	0.273	47	0.113	53	0.345	54	–0.237	23	–0.240	49
mq	znt	0.142	234	0.224	46	0.120	57	0.475	58	0.057	24	–0.236	49
qv	ph	–0.333	237	–0.485	48	–0.307	57	–0.304	57	–0.063	25	–0.079	50
qv	sc	–0.389	242	–0.814	49	–0.684	58	–0.534	58	–0.111	25	–0.479	52
qv	hdn	–0.410	242	–0.526	49	–0.549	58	–0.571	58	–0.034	25	–0.397	52
qv	tss	0.276	239	0.329	48	0.373	58	0.395	56	–0.028	25	0.524	52
qv	nh3	–0.021	92	1.000	2	0.186	23	–0.358	57	–0.283	6	–0.570	4
qv	no23	0.111	175	–0.682	35	–0.556	42	–0.622	40	0.080	20	–0.339	38
qv	opo4	0.342	224	0.370	38	0.164	57	–0.334	55	–0.014	24	0.241	50
qv	tpo4	0.341	242	0.186	49	0.079	58	0.107	58	0.090	25	0.682	52
qv	tkn	0.239	232	0.279	45	0.060	55	–0.089	58	–0.224	25	0.503	49
qv	toc	–0.017	197	0.176	42	0.105	47	0.084	45	–0.314	22	–0.123	41
qv	cud	0.316	235	0.315	46	0.069	56	0.337	57	–0.242	25	0.400	51
qv	cut	0.473	239	0.295	48	0.256	58	0.436	56	–0.059	25	0.638	52
qv	pbd	–0.067	43	1.000	2	–0.107	11	–0.276	17	1.000	2	0.709	11
qv	pbt	0.488	133	0.340	12	0.504	42	0.436	42	–0.125	10	0.545	27
qv	mnd	0.118	132	0.321	25	0.043	29	0.122	32	–0.233	14	0.576	32
qv	mnt	0.293	82	0.730	17	0.645	21	0.523	19	–0.488	7	0.599	18
qv	znd	–0.037	226	0.238	47	0.163	53	0.396	54	–0.300	23	–0.259	49
qv	znt	0.121	234	0.241	46	0.117	57	0.388	58	–0.019	24	–0.252	49
ph	sc	0.275	249	0.257	48	0.070	58	0.219	57	0.281	34	0.505	52
ph	hdn	0.262	249	0.290	48	0.188	58	0.349	57	0.049	34	0.375	52
ph	tss	–0.320	245	–0.070	47	–0.203	58	–0.210	55	–0.654	33	–0.502	52
ph	nh3	0.033	93	–1.000	2	–0.424	23	0.179	56	–0.141	7	–0.363	5
ph	no23	–0.127	178	0.158	34	–0.061	42	0.318	39	–0.119	27	0.204	36
ph	opo4	–0.194	226	0.036	37	–0.237	57	0.252	54	–0.274	28	–0.240	50
ph	tpo4	–0.216	249	–0.015	48	–0.085	58	0.154	57	–0.580	34	–0.371	52
ph	tkn	–0.199	240	–0.147	44	–0.084	55	0.188	57	–0.518	34	–0.248	50
ph	toc	–0.090	205	–0.343	42	–0.220	47	0.067	45	–0.230	28	0.002	43
ph	cud	–0.134	242	–0.179	45	–0.023	56	–0.004	56	–0.257	34	–0.131	51
ph	cut	–0.257	246	0.008	47	–0.163	58	–0.003	55	–0.593	34	–0.318	52
ph	pbd	0.056	41	–1.000	2	–0.094	10	0.140	16	0.050	3	0.102	10
ph	pbt	–0.135	136	0.328	12	–0.165	42	–0.042	41	–0.473	14	–0.234	27
ph	mnd	0.104	135	0.278	24	0.113	29	0.494	31	–0.091	19	0.106	32
ph	mnt	–0.494	86	–0.452	17	–0.618	21	–0.172	19	–0.707	9	–0.673	20
ph	znd	0.086	233	–0.130	46	0.114	53	–0.056	53	–0.263	32	0.122	49
ph	znt	–0.048	241	0.042	45	–0.133	57	–0.100	57	–0.583	33	0.031	49

Table A4. Correlation among water-quality properties and constituents, by station.—Continued

[Variables, abbreviations used for water-quality properties and constituents as defined at the beginning of the Appendix; R, Pearson correlation coefficient; n, number of pairs used in calculation; na, not applicable]

Variables		All stations		Union		Denver		Henderson		Tollgate		Sand Creek	
		R	n	R	n	R	n	R	n	R	n	R	n
sc	hdn	0.767	255	0.643	49	0.736	59	0.833	58	0.611	35	0.645	54
sc	tss	–0.167	251	–0.229	48	–0.169	59	–0.188	56	–0.409	34	–0.536	54
sc	nh3	0.228	95	–1.000	2	–0.073	24	0.694	57	–0.219	7	–0.242	5
sc	no23	0.124	184	0.741	35	0.685	43	0.691	40	0.463	28	0.389	38
sc	opo4	–0.061	231	–0.321	38	0.175	58	0.651	55	–0.331	28	–0.177	52
sc	tpo4	–0.001	255	–0.061	49	0.162	59	0.298	58	–0.295	35	–0.450	54
sc	tkn	0.003	245	–0.133	45	0.076	56	0.392	58	–0.050	35	–0.358	51
sc	toc	0.292	205	0.034	42	–0.071	47	0.081	45	0.134	28	0.375	43
sc	cud	–0.137	248	–0.171	46	–0.039	57	–0.320	57	–0.182	35	–0.281	53
sc	cut	–0.178	252	–0.180	48	0.035	59	–0.299	56	–0.264	35	–0.457	54
sc	pbd	–0.036	44	–1.000	2	–0.027	11	0.149	17	–0.703	3	–0.153	11
sc	pbt	–0.282	139	–0.234	12	–0.286	43	–0.281	42	–0.361	14	–0.446	28
sc	mnd	0.171	141	–0.375	25	–0.046	30	–0.127	32	0.076	20	–0.097	34
sc	mnt	–0.214	86	–0.670	17	–0.376	21	–0.402	19	–0.549	9	–0.585	20
sc	znd	0.254	239	–0.102	47	–0.034	54	–0.301	54	–0.023	33	0.386	51
sc	znt	0.197	247	–0.147	46	0.092	58	–0.384	58	–0.241	34	0.371	51
hdn	tss	0.078	251	0.312	48	0.274	59	–0.173	56	–0.023	34	–0.349	54
hdn	nh3	–0.010	95	–1.000	2	–0.046	24	0.668	57	–0.154	7	0.092	5
hdn	no23	0.054	184	0.584	35	0.538	43	0.749	40	0.635	28	0.511	38
hdn	opo4	–0.169	231	0.259	38	0.112	58	0.522	55	–0.212	28	–0.270	52
hdn	tpo4	0.130	255	0.303	49	0.573	59	0.394	58	–0.048	35	–0.197	54
hdn	tkn	0.183	245	0.348	45	0.521	56	0.485	58	0.432	35	–0.105	51
hdn	toc	0.231	205	0.035	42	0.005	47	0.138	45	–0.176	28	0.278	43
hdn	cud	–0.036	248	0.175	46	0.063	57	–0.323	57	0.087	35	–0.158	53
hdn	cut	0.013	252	0.313	48	0.430	59	–0.127	56	–0.027	35	–0.114	54
hdn	pbd	0.093	44	–1.000	2	0.034	11	0.408	17	–0.342	3	–0.067	11
hdn	pbt	–0.013	139	0.771	12	0.198	43	0.030	42	0.076	14	–0.085	28
hdn	mnd	0.334	141	0.202	25	0.133	30	–0.104	32	0.268	20	0.197	34
hdn	mnt	0.196	86	–0.002	17	0.003	21	–0.147	19	0.123	9	0.038	20
hdn	znd	0.199	239	0.168	47	0.042	54	–0.316	54	0.182	33	0.235	51
hdn	znt	0.281	247	0.344	46	0.532	58	–0.260	58	0.061	34	0.398	51
tss	nh3	–0.128	94	1.000	2	0.009	24	–0.112	56	0.145	7	–0.293	5
tss	no23	–0.041	180	–0.117	34	–0.244	43	–0.298	38	–0.030	27	–0.452	38
tss	opo4	0.174	229	0.765	38	0.118	58	–0.187	53	0.543	28	0.154	52
tss	tpo4	0.661	251	0.685	48	0.771	59	0.548	56	0.742	34	0.667	54
tss	tkn	0.509	241	0.627	44	0.718	56	0.304	56	0.498	34	0.443	51
tss	toc	0.256	201	0.243	41	0.292	47	0.278	43	0.367	27	–0.031	43
tss	cud	0.349	244	0.654	45	0.325	57	0.274	55	0.357	34	0.310	53
tss	cut	0.672	248	0.756	47	0.768	59	0.609	54	0.838	34	0.584	54
tss	pbd	0.079	44	–1.000	2	–0.077	11	0.079	17	0.768	3	0.275	11
tss	pbt	0.552	137	0.661	12	0.803	43	0.533	40	0.955	14	0.434	28
tss	mnd	0.274	141	0.627	25	0.166	30	0.199	32	0.176	20	0.298	34
tss	mnt	0.831	86	0.759	17	0.722	21	0.809	19	0.986	9	0.926	20
tss	znd	–0.002	235	0.442	46	0.179	54	0.342	52	0.547	32	–0.243	51
tss	znt	0.318	243	0.760	45	0.756	58	0.545	56	0.856	33	–0.164	51
nh3	no23	0.299	65	na	0	0.641	19	0.453	39	0.028	5	na	0
nh3	opo4	0.671	91	na	0	0.375	24	0.657	54	–0.943	6	0.223	5
nh3	tpo4	0.253	95	1.000	2	–0.057	24	0.467	57	0.471	7	–0.553	5
nh3	tkn	0.383	95	–1.000	2	–0.139	24	0.676	57	–0.227	7	–0.569	5
nh3	toc	–0.052	73	1.000	2	–0.278	19	0.215	44	–0.098	4	–0.868	4
nh3	cud	–0.104	93	1.000	2	–0.365	23	–0.335	56	0.913	7	–0.730	5
nh3	cut	–0.041	93	na	0	0.082	24	–0.067	55	0.387	7	–0.434	5
nh3	pbd	–0.100	24	na	0	–0.305	4	–0.210	17	1.000	2	na	0
nh3	pbt	0.080	71	na	0	0.141	21	0.098	41	0.084	5	0.395	4

Table A4. Correlation among water-quality properties and constituents, by station.—Continued

[Variables, abbreviations used for water-quality properties and constituents as defined at the beginning of the Appendix; R, Pearson correlation coefficient; n, number of pairs used in calculation; na, not applicable]

Variables		All stations		Union		Denver		Henderson		Tollgate		Sand Creek	
		R	n	R	n	R	n	R	n	R	n	R	n
nh3	mnd	–0.111	51	1.000	2	–0.648	8	–0.371	32	0.915	5	–0.731	4
nh3	mnt	–0.286	32	na	0	0.671	6	–0.264	19	1.000	2	–0.170	4
nh3	znd	–0.156	86	1.000	2	–0.246	21	–0.380	53	0.739	5	0.414	5
nh3	znt	–0.109	94	1.000	2	0.040	24	–0.171	57	0.352	6	0.205	5
no23	opo4	0.568	163	–0.042	26	0.622	42	0.626	38	–0.103	21	–0.016	36
no23	tpo4	0.324	184	0.119	35	0.063	43	0.111	40	–0.089	28	–0.494	38
no23	tkn	0.240	174	–0.025	31	–0.021	40	0.035	40	0.154	28	–0.344	35
no23	toc	–0.063	134	0.157	28	–0.151	31	0.129	27	–0.288	21	0.212	27
no23	cud	0.073	179	–0.086	33	–0.078	41	–0.312	40	0.168	28	–0.023	37
no23	cut	0.202	182	–0.009	34	–0.008	43	–0.378	39	0.033	28	–0.260	38
no23	pbd	–0.011	39	–1.000	2	–0.080	10	0.258	14	0.905	3	0.005	10
no23	pbt	–0.020	101	0.609	8	–0.289	31	–0.342	30	–0.011	11	–0.218	21
no23	mnd	–0.013	80	0.109	13	0.075	18	0.079	17	0.193	13	0.171	19
no23	mnt	–0.102	16	–0.566	3	–0.459	5	–1.000	2	1.000	2	–0.824	4
no23	znd	–0.014	179	–0.066	35	–0.056	42	–0.265	40	0.233	27	0.288	35
no23	znt	0.088	177	0.095	33	0.043	42	–0.288	40	0.088	27	0.105	35
opo4	tpo4	0.470	231	0.817	38	0.144	58	0.323	55	0.490	28	0.272	52
opo4	tkn	0.435	224	0.788	36	0.078	56	0.451	55	0.332	28	0.132	49
opo4	toc	0.060	193	–0.013	34	0.099	47	0.314	44	0.452	25	–0.082	43
opo4	cud	0.190	225	0.747	36	–0.001	56	–0.146	54	0.256	28	–0.030	51
opo4	cut	0.306	228	0.740	37	0.165	58	–0.243	53	0.542	28	–0.063	52
opo4	pbd	–0.131	43	1.000	2	–0.151	11	–0.224	17	1.000	2	–0.393	11
opo4	pbt	0.204	133	0.820	11	0.206	43	–0.085	40	0.553	11	–0.226	28
opo4	mnd	0.041	128	0.762	22	–0.008	29	–0.062	29	–0.031	16	–0.194	32
opo4	mnt	0.109	83	0.858	15	0.481	21	–0.586	18	0.677	9	–0.137	20
opo4	znd	–0.006	218	0.673	38	0.039	53	–0.142	51	0.551	26	–0.062	50
opo4	znt	0.092	226	0.756	37	0.164	57	–0.253	55	0.496	27	–0.121	50
tpo4	tkn	0.826	245	0.778	45	0.900	56	0.768	58	0.628	35	0.712	51
tpo4	toc	0.338	205	0.390	42	0.323	47	0.580	45	0.486	28	0.092	43
tpo4	cud	0.381	248	0.437	46	0.370	57	0.131	57	0.461	35	0.308	53
tpo4	cut	0.802	252	0.725	48	0.853	59	0.660	56	0.798	35	0.787	54
tpo4	pbd	0.232	44	–1.000	2	0.232	11	0.131	17	0.971	3	0.399	11
tpo4	pbt	0.604	139	0.593	12	0.598	43	0.602	42	0.621	14	0.726	28
tpo4	mnd	0.365	141	0.849	25	0.418	30	0.327	32	0.318	20	0.401	34
tpo4	mnt	0.682	86	0.828	17	0.859	21	0.749	19	0.619	9	0.843	20
tpo4	znd	0.062	239	0.545	47	0.288	54	0.227	54	0.456	33	–0.137	51
tpo4	znt	0.445	247	0.770	46	0.843	58	0.497	58	0.827	34	0.073	51
tkn	toc	0.303	198	0.472	39	0.345	45	0.452	45	0.275	28	0.134	41
tkn	cud	0.268	238	0.425	42	0.431	54	–0.137	57	0.315	35	0.176	50
tkn	cut	0.651	242	0.559	44	0.826	56	0.431	56	0.493	35	0.460	51
tkn	pbd	0.216	44	–1.000	2	0.461	11	–0.006	17	–0.721	3	0.384	11
tkn	pbt	0.505	138	0.521	11	0.563	43	0.496	42	0.243	14	0.336	28
tkn	mnd	0.274	135	0.654	23	0.558	28	–0.017	32	0.245	20	0.300	32
tkn	mnt	0.495	86	0.741	17	0.716	21	0.317	19	0.433	9	0.680	20
tkn	znd	0.036	230	0.520	43	0.252	52	–0.107	54	0.393	33	–0.098	48
tkn	znt	0.374	239	0.571	43	0.812	56	0.358	58	0.502	34	0.031	48
toc	cud	–0.057	198	0.195	39	0.100	45	–0.117	44	–0.099	28	–0.305	42
toc	cut	0.209	203	0.111	41	0.286	47	0.217	44	0.571	28	–0.038	43
toc	pbd	–0.005	26	na	0	0.682	6	–0.254	12	na	0	–0.236	6
toc	pbt	0.121	106	–0.302	10	0.229	33	0.193	32	0.271	10	–0.004	21
toc	mnd	0.249	93	0.080	18	0.645	19	0.112	20	0.260	13	–0.043	23
toc	mnt	0.314	79	0.536	16	0.050	19	0.148	18	0.945	8	0.232	18
toc	znd	0.223	192	0.281	40	0.157	42	–0.005	41	0.274	27	0.161	42
toc	znt	0.380	201	0.238	40	0.283	46	0.219	45	0.537	28	0.360	42

Table A4. Correlation among water-quality properties and constituents, by station.—Continued

[Variables, abbreviations used for water-quality properties and constituents as defined at the beginning of the Appendix; R, Pearson correlation coefficient; n, number of pairs used in calculation; na, not applicable]

Variables		All stations		Union		Denver		Henderson		Tollgate		Sand Creek	
		R	n	R	n	R	n	R	n	R	n	R	n
cud	cut	0.433	245	0.527	45	0.342	57	0.338	55	0.541	35	0.362	53
cud	pbd	0.760	44	1.000	2	0.870	11	0.734	17	0.986	3	0.744	11
cud	pbt	0.270	136	0.489	12	0.248	41	0.250	42	0.224	14	0.351	27
cud	mnd	0.697	140	0.446	24	0.910	30	0.834	32	0.925	20	0.637	34
cud	mnt	0.163	84	0.386	16	0.308	21	0.359	18	0.288	9	–0.073	20
cud	znd	0.206	233	0.649	44	0.869	52	0.824	54	0.837	33	–0.042	50
cud	znt	0.177	240	0.476	43	0.317	56	0.270	57	0.473	34	–0.153	50
cut	pbd	0.183	44	–1.000	2	0.161	11	0.202	17	0.938	3	0.334	11
cut	pbt	0.835	139	0.901	12	0.740	43	0.907	42	0.892	14	0.935	28
cut	mnd	0.413	139	0.869	25	0.420	30	0.368	30	0.501	20	0.551	34
cut	mnt	0.831	85	0.800	17	0.883	21	0.959	18	0.944	9	0.931	20
cut	znd	0.051	236	0.502	46	0.330	54	0.388	52	0.663	33	–0.145	51
cut	znt	0.491	245	0.952	46	0.910	58	0.846	56	0.966	34	0.066	51
pbd	pbt	0.196	42	–1.000	2	0.279	11	0.227	16	0.762	3	0.317	10
pbd	mnd	0.710	31	na	0	0.889	9	0.770	11	0.993	3	0.929	7
pbd	mnt	–0.055	8	na	0	0.189	3	–0.012	4	na	0	na	0
pbd	znd	0.421	42	1.000	2	0.764	11	0.699	17	0.993	3	–0.033	9
pbd	znt	0.006	42	–1.000	2	0.185	11	0.134	17	0.841	3	–0.374	9
pbt	mnd	0.115	80	0.866	7	0.225	23	0.078	23	0.013	9	0.506	18
pbt	mnt	0.642	47	0.322	5	0.897	17	0.904	13	0.948	4	0.968	8
pbt	znd	0.132	130	0.519	11	0.224	40	0.287	39	0.571	13	–0.098	27
pbt	znt	0.548	138	0.909	12	0.697	43	0.744	42	0.923	14	0.240	27
mnd	mnt	0.387	77	0.680	15	0.191	17	0.360	17	0.363	9	0.492	19
mnd	znd	0.396	133	0.831	25	0.929	28	0.918	30	0.916	18	0.215	32
mnd	znt	0.338	136	0.913	24	0.445	29	0.378	32	0.457	19	0.157	32
mnt	znd	0.026	75	0.698	15	0.506	17	0.556	15	0.868	8	–0.288	20
mnt	znt	0.599	85	0.949	16	0.950	21	0.985	19	0.942	9	0.367	20
znd	znt	0.716	237	0.498	45	0.284	54	0.377	54	0.613	33	0.791	51

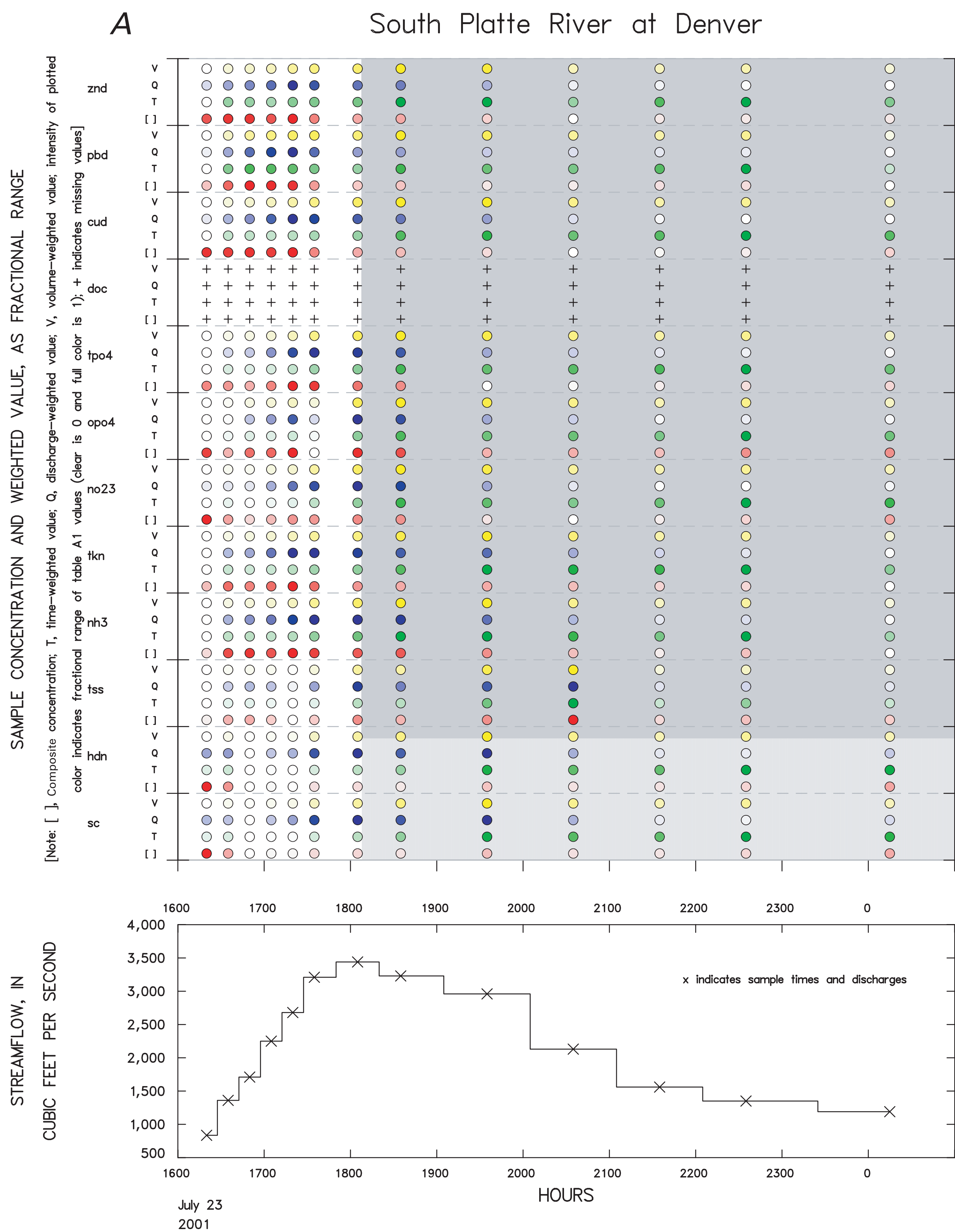

Figure A2. Results from discrete sampling events (*A*) July 24, 2001, at South Platte River at Denver, (*B*) August 6, 2001, at Sand Creek at mouth, and (*C*) August 16, 2001, at Sand Creek at mouth. Abbreviations for variables used for water-quality properties and constituents are at the beginning of the Appendix.

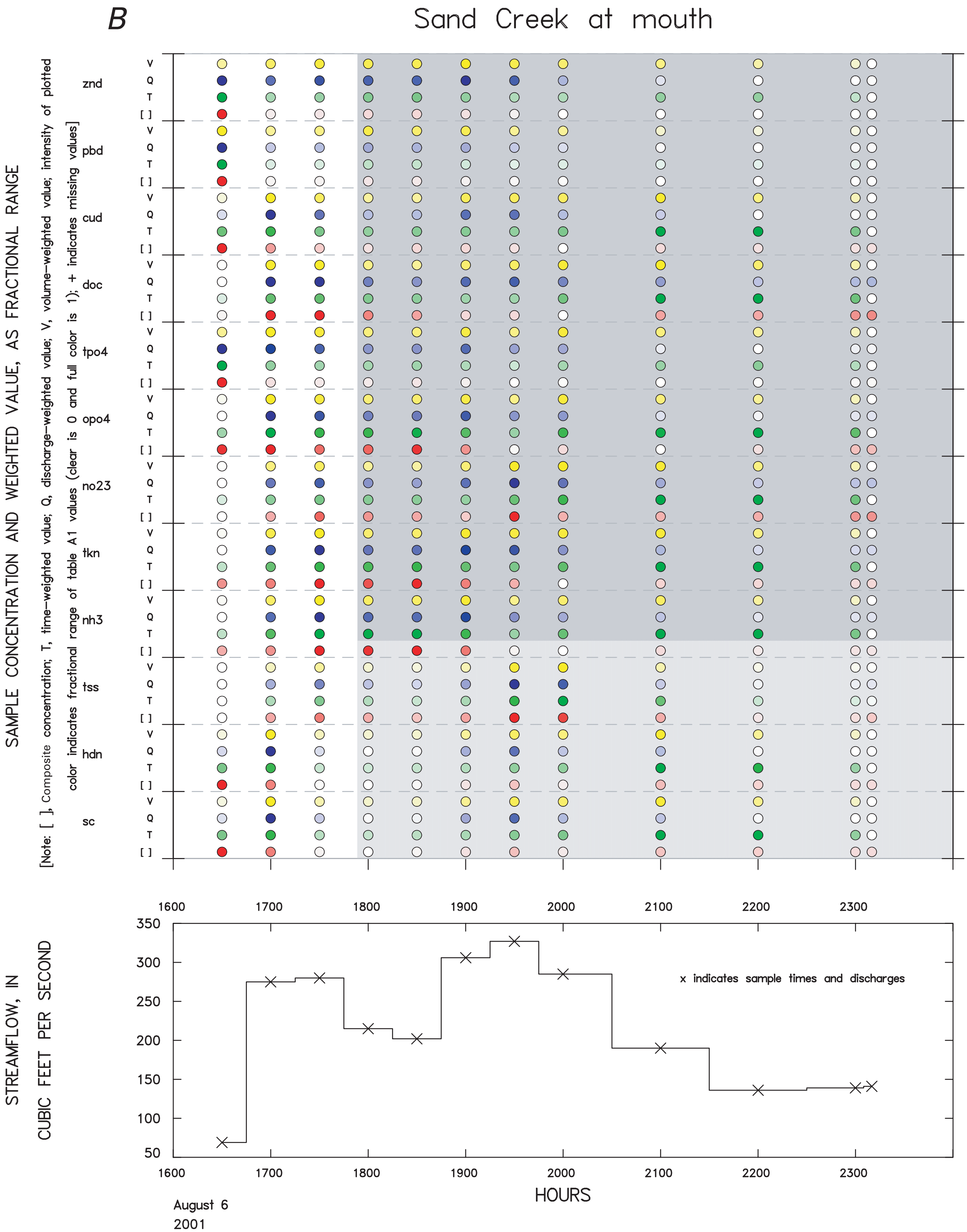

Figure A2. Results from discrete sampling events (*A*) July 24, 2001, at South Platte River at Denver, (*B*) August 6, 2001, at Sand Creek at mouth, and (*C*) August 16, 2001, at Sand Creek at mouth. Abbreviations for variables used for water-quality properties and constituents are at the beginning of the Appendix.—Continued

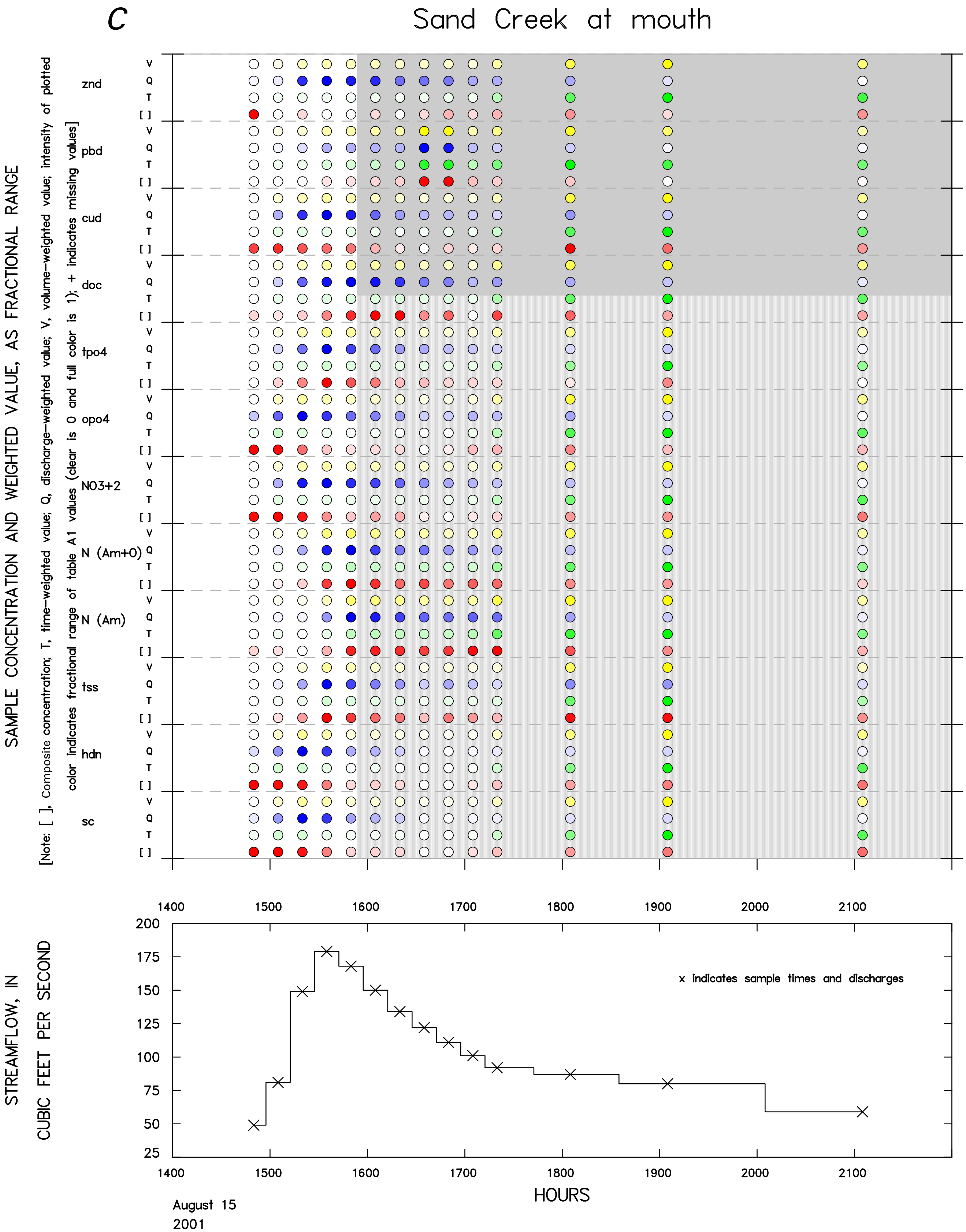

Figure A2. Results from discrete sampling events (*A*) July 24, 2001, at South Platte River at Denver, (*B*) August 6, 2001, at Sand Creek at mouth, and (*C*) August 16, 2001, at Sand Creek at mouth. Abbreviations for variables used for water-quality properties and constituents are at the beginning of the Appendix.—Continued